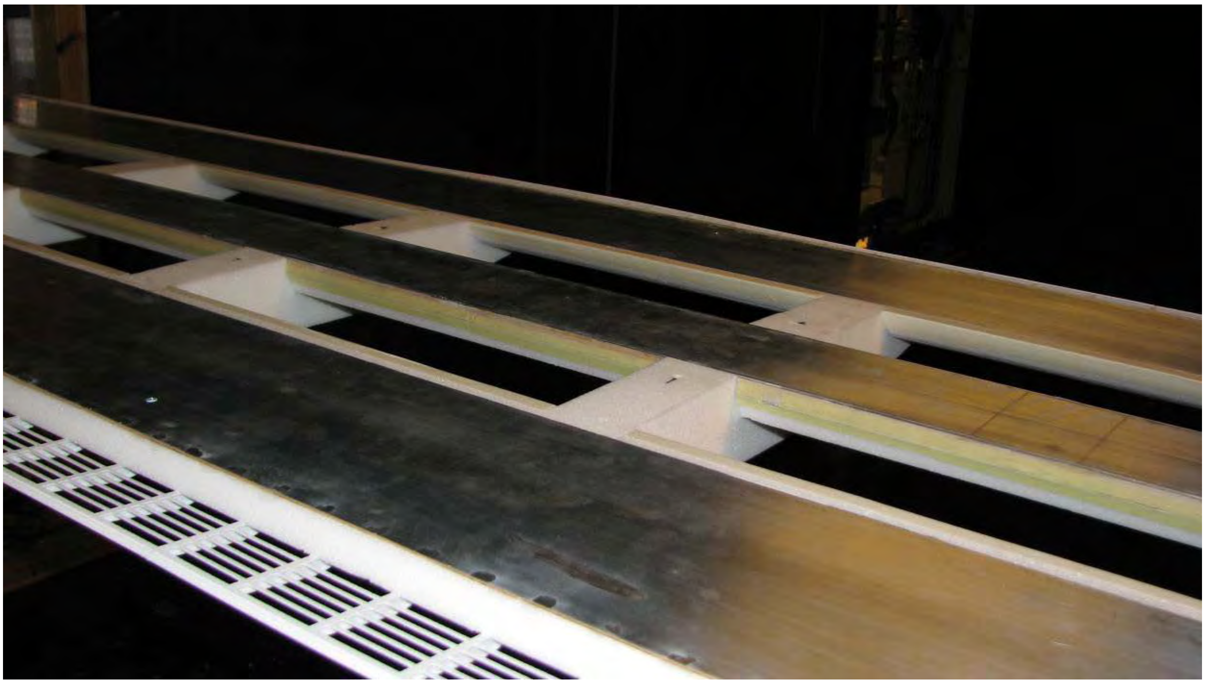

EUROLINK S.C.P.A

Sub-test D4 Section Model Tests for the Messina Strait Bridge (Erection Stage)

FORCE 110-26444.03 Rev. A/2011-02-25

Project No. and Title of Report:

FORCE 110-26444.03
Sub-test D4 Section Model Tests for the Messina Strait Bridge (Erection Stage)

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	Approved by:

1	Final Report	PSS/SVL	SGE		
A	Draft Report (PDF version)	PSS/SVL	SGE	CRS	2011-01-17
Revision	**Description**	**By**	**Checked**	**Approved**	**Date**

Keywords:
Suspension Bridge.
Section Model Tests.
Static Load Coefficients.
Aerodynamic Admittance.
Aerodynamic Flutter Derivatives.
Erection Stage.

Classification:

☐ **Open**

☐ **Internal**

■ **Confidential**

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APPENDICES:

1. Introduction

FORCE Technology was commissioned by EUROLINK S.C.P.A to conduct an investigation of the wind effects on the bridge deck of the Messina Strait Bridge. COWI A/S acted as the Client's representative. The present section model tests are referred to as Sub-test D4.

The Messina Strait Crossing is a suspension bridge with a main span of 3300 m. The deck is 3666 m long, including the two suspension side spans, and approximately 60 m wide. The structure is composed of three box sections - two lateral ones for the roadway deck and a central one for the railway tracks. The deck's roadway section has three 3.75 m wide lanes in each direction. The railway section has two tracks and two lateral pedestrian sidewalks.

The height of the two towers is 399 m to allow for a navigation clearance with a minimum height of 65 m. The bridge's suspension system consists of two pairs of steel cables each with a diameter of 1.24 m and the total length between the anchor blocks is 5300 m.

The present report describes the section model tests performed to assess the static load coefficients, the aerodynamic admittance and the aerodynamic flutter derivatives for the bridge deck in the erection stage condition.

The section model tests were performed on a 1:80-scale section model of the bridge deck in FORCE Technology's 2.6 m wide boundary-layer wind tunnel. The tests were conducted at FORCE Technology in October and November 2010.

The work was performed according to the Agreement between FORCE Technology and Eurolink S.c.p.A. dated 2010-06-21 (with reference to FORCE Technology's quotation 110-26444 dated 2010-05-21).

2. Summary and Conclusions

This report presents the results of the wind-tunnel tests conducted to establish aerodynamic data for the erection stage configuration of the bridge girder for the Messina Strait Bridge. A 2.55 m long section model built at a geometric scale of 1:80 for previous investigations was modified for the present tests. The model was tested in smooth flow and in turbulent flow in FORCE Technology's 2.6 m wide Boundary-Layer Wind Tunnel.

The following aerodynamic parameters were established for the present configuration (referred to as C5/63° in the corresponding in-service stage configuration):

1) Static force coefficients in smooth and turbulent flow
2) Aerodynamic admittance in turbulent flow
3) Aerodynamic flutter derivatives in smooth and turbulent flow

The tests listed above were conducted for the erection stage configuration.

The static wind load coefficients and their variations with angle of wind incidence were established from –10° to +10° in steps of 0.5°. The aerodynamic admittance and the flutter derivatives were determined for angles of wind incidence from -6° to +6° in steps of 2°.

The main findings are summarised in the following.

Static Tests

The static force coefficients at 0° and their variations with angle of wind incidence (first derivatives) are shown in Table 2.1. Figure 6.2 show plots of the determined coefficients, with the drag and lift coefficients, C_d and C_l, being fixed in a wind coordinate system, and C_x and C_z being body fixed coefficients, see Section 6.

		Erection stage smooth	Erection stage turbulent
C_d	(0°)	0.050	0.049
C_l	(0°)	-0.101	-0.114
C_m	(0°)	0.003	-0.001
$\frac{dC_d}{d\alpha}$	(-1° to +1°)	0.02	0.06
$\frac{dC_l}{d\alpha}$	(-1° to +1°)	2.78	2.62
$\frac{dC_m}{d\alpha}$	(-1° to +1°)	0.33	0.31

Table 2.1. Static aerodynamic force coefficients and their slopes
(based on a deck width of B= 60.4 m).

Aerodynamic Admittance Tests

The aerodynamic admittance was determined for the erection stage deck section configuration in turbulent flow. The results are presented in Section 7.2.

Aerodynamic Flutter Derivatives

Finally, the aerodynamic flutter derivatives were determined for the erection stage deck section configuration in smooth and turbulent flow. The results of these tests are presented in Section 8.2.

3. Model Design

3.1 Prototype Structure

The Messina Strait Crossing comprises a suspended main span of 3300 m. The total length of the bridge is 3666 m. The bridge deck comprises three closed box girders and the overall deck width is approximately 60 m.

An elevation of the prototype structure is shown in Figure 3.1.

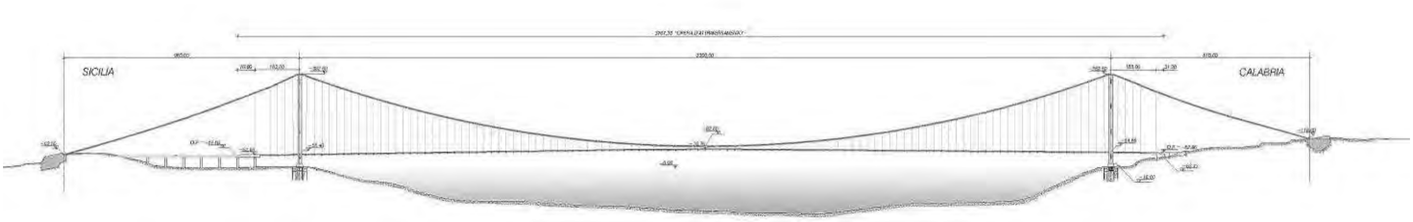


Figure 3.1 Elevation of the Messina Strait Crossing.

Figure 3.2 shows the cross section of the prototype bridge deck and its main dimensions in the erection stage configuration.

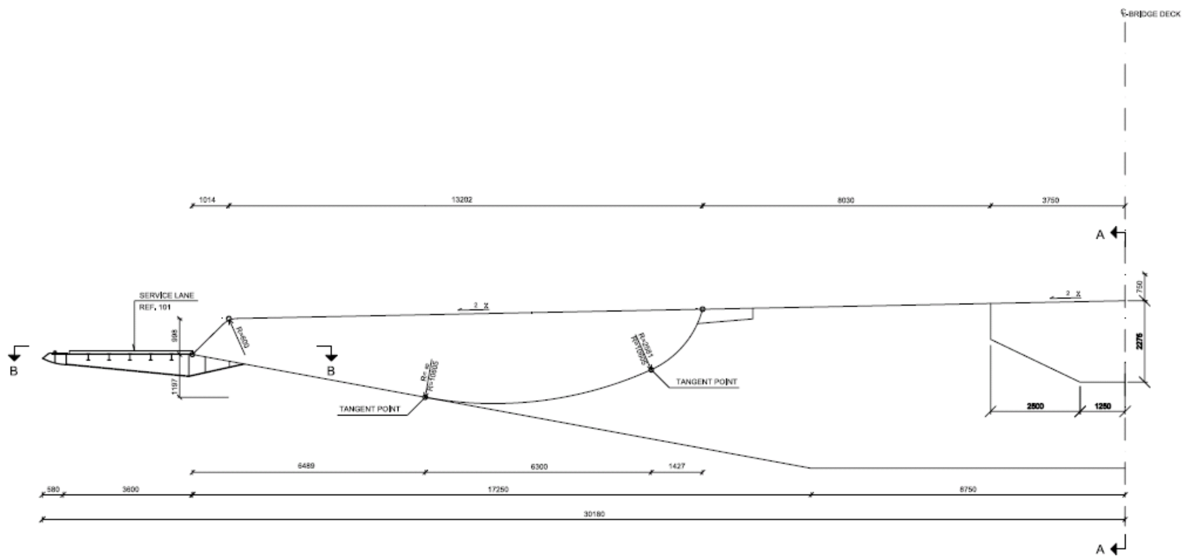


Figure 3.2. Cross-section of prototype bridge deck – erection stage.

3.2 Scaling Parameters

A combination of geometrical, mass and stiffness considerations resulted in the selection of a 1:80 geometrical scale for the section model of the Messina Strait Bridge deck, see [1].

3.3 Section Model Design

The 1:80 geometrical scale section model of the bridge deck was built with the properly scaled outer shape of the prototype structure.

Configuration C5 was fitted with slanted panels on the rail girder. The panels were given an angle with horizontal of 63°, see the following figure.

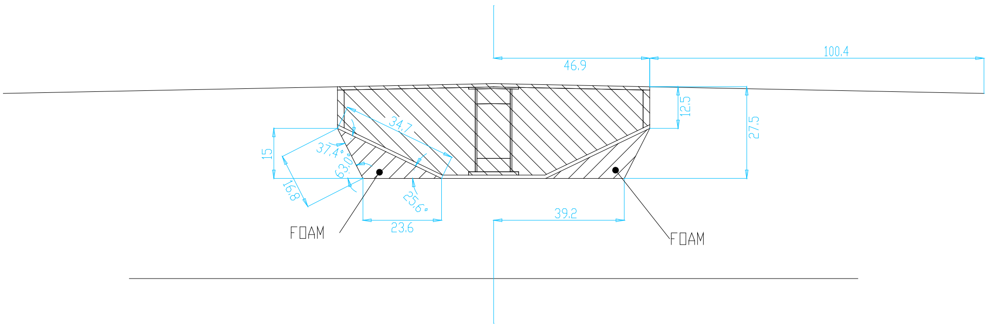


Figure 3.3. Modified railway girder configuration – 63° rail girder edge: C5/63°.

Further, a 80 mm tall gutter plate on the edge of the road girder, see Figure 3.4, was simulated by a 1 mm by 1 mm trip mounted this location on the model.

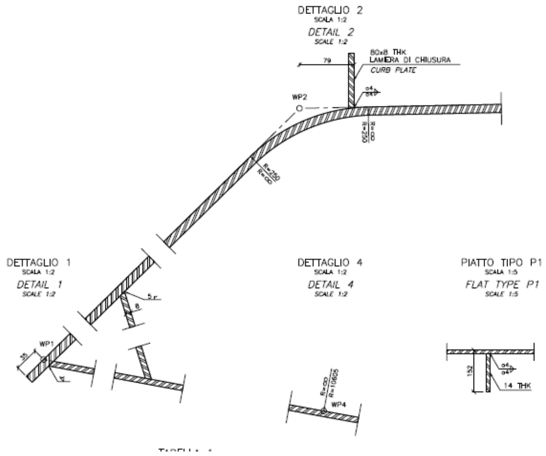


Figure 3.4. Gutter plate on road girder.

The following figures show photographs of the model.

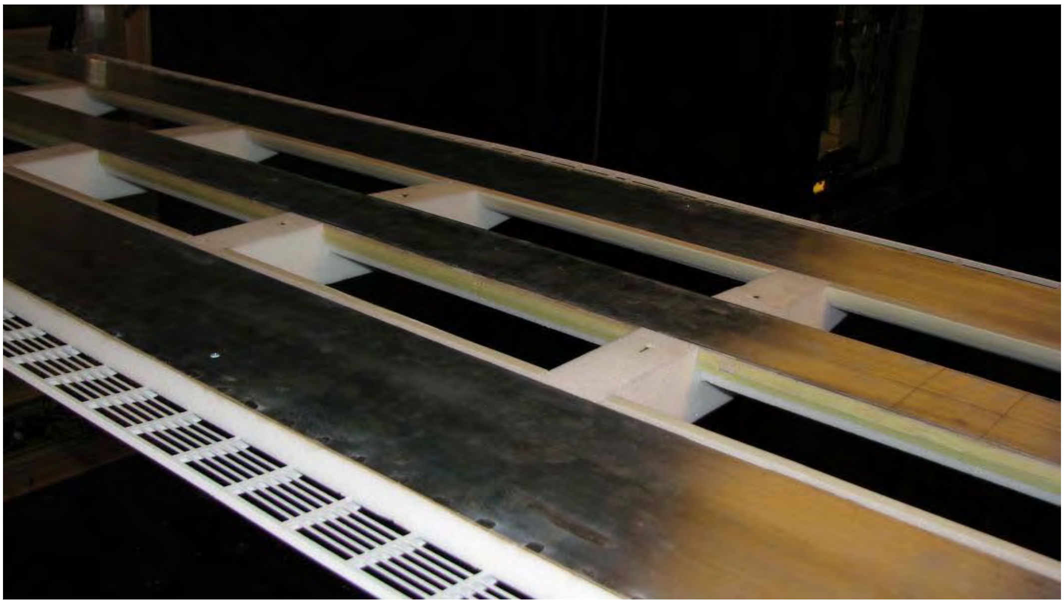


Figure 3.5. Model in erection stage configuration.

Figure 3.6. Model in erection stage configuration – view from below.

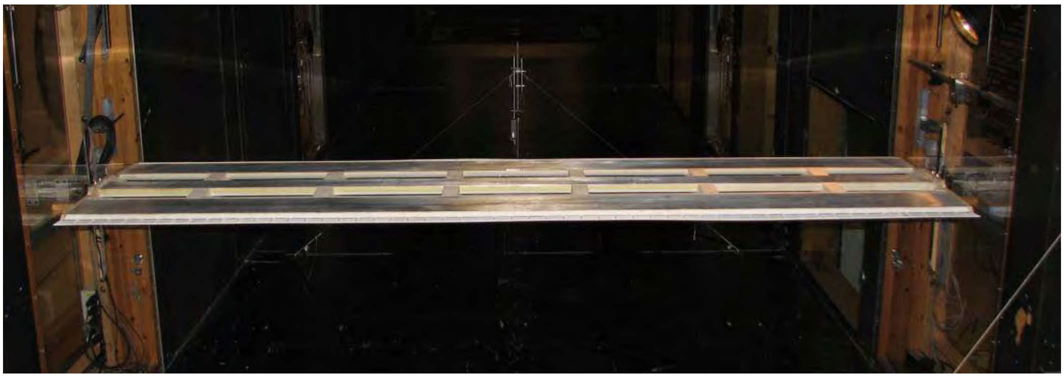


Figure 3.7. Model in erection stage configuration installed in wind tunnel.

4. Wind Tunnel and Flow Conditions

The section model tests were conducted in FORCE Technology's 2.6 m wide x 1.8 m high x 21 m long Boundary-Layer Wind Tunnel II. The model was placed 14.5 m downstream of the inlet at the mid height of the wind tunnel. The ceiling of the wind tunnel was adjusted so that it was horizontal throughout the length of the wind tunnel.

The wind-tunnel tests were performed in smooth flow and turbulent flow.

The smooth flow condition corresponds to an empty tunnel (i.e., without exposure upwind of the model). The smooth flow condition has a turbulence intensity ($I_{u,\,w}$) of approximately 0.5%.

For all tests, the turbulent exposure was obtained by three spires mounted 1.1 m from the wind tunnel inlet. The spires were 1.8 m high with a tapered width: 0.32 m at the floor to 0.18 m at the wind tunnel ceiling. The turbulent exposure is shown in Figure 4.1.

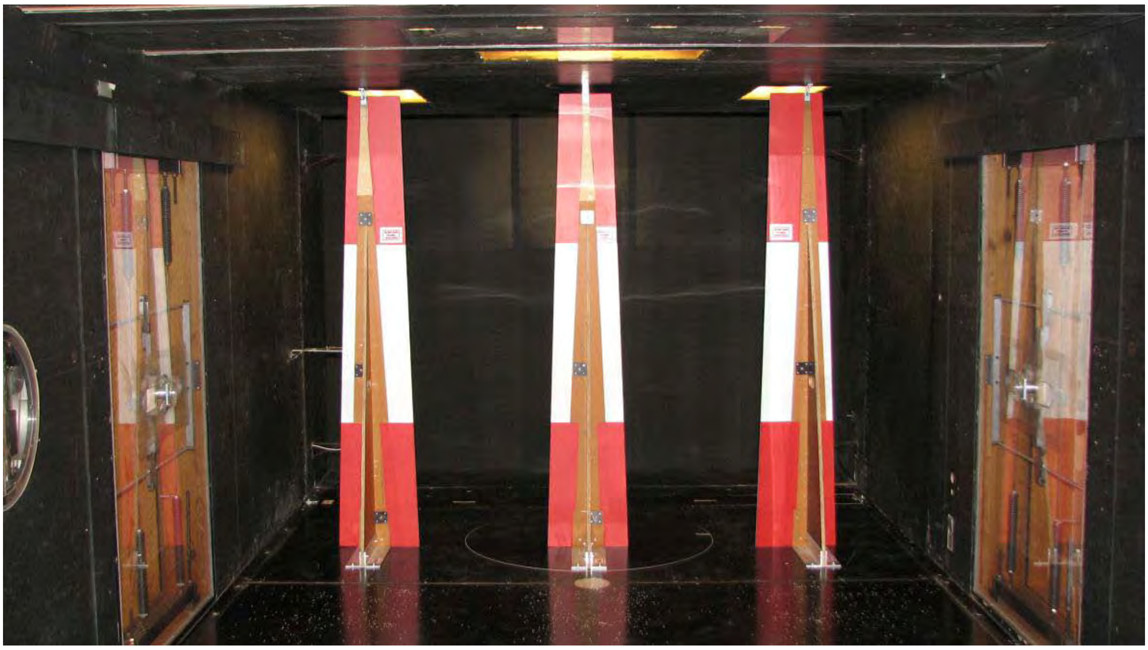


Figure 4.1. Turbulence generating spires in the wind tunnel up-wind of the model.

The static tests were conducted in the normal position in the wind tunnel, i.e., 14.5 m from the wind tunnel inlet. On the other hand, the aerodynamic derivatives and admittance tests were conducted 3.9 m upwind from the normal section model position. Thus, due to the different distance from the spires, the turbulent flow conditions were slightly different for the two test positions. The turbulent flow conditions are described in the two following sections.

The spectral density of the velocity fluctuations can be expressed by the von Kármán formulation:

$$\frac{f \cdot S_u(f)}{\sigma_u^2} = \frac{4 \cdot f \cdot L_u / U}{\left[1 + 70.8 \cdot \left(f \cdot L_u / U\right)^2\right]^{5/6}}$$

$$\frac{f \cdot S_{v,w}(f)}{\sigma_{v,w}^2} = \frac{4 \cdot f \cdot L_{v,w} / U \cdot \left[1 + 755.2 \cdot \left(f \cdot L_{v,w} / U\right)^2\right]}{\left[1 + 283.2 \cdot \left(f \cdot L_{v,w} / U\right)^2\right]^{11/6}}$$

where:

U = Mean wind speed

$\sigma_{u,v,w}$ = Standard deviation of turbulence component in along-wind (u), horizontal across-wind (v) and vertical across-wind (w) direction, respectively.

f = Frequency.

$S_{u\ v,w}$ = Spectral ordinate of the along-wind turbulence component.

$L_{u,v,w}$ =Turbulent length scale associated with the given spectrum.

4.1 Static Tests

The three-spire exposure resulted in turbulence intensities of approximately 7.5% for I_u and 7.4% for I_w.

The spectral density function (SDF) of the velocity fluctuation was derived from a long time series recorded at centre position (wind-tunnel centre line), see Figure 4.2 and

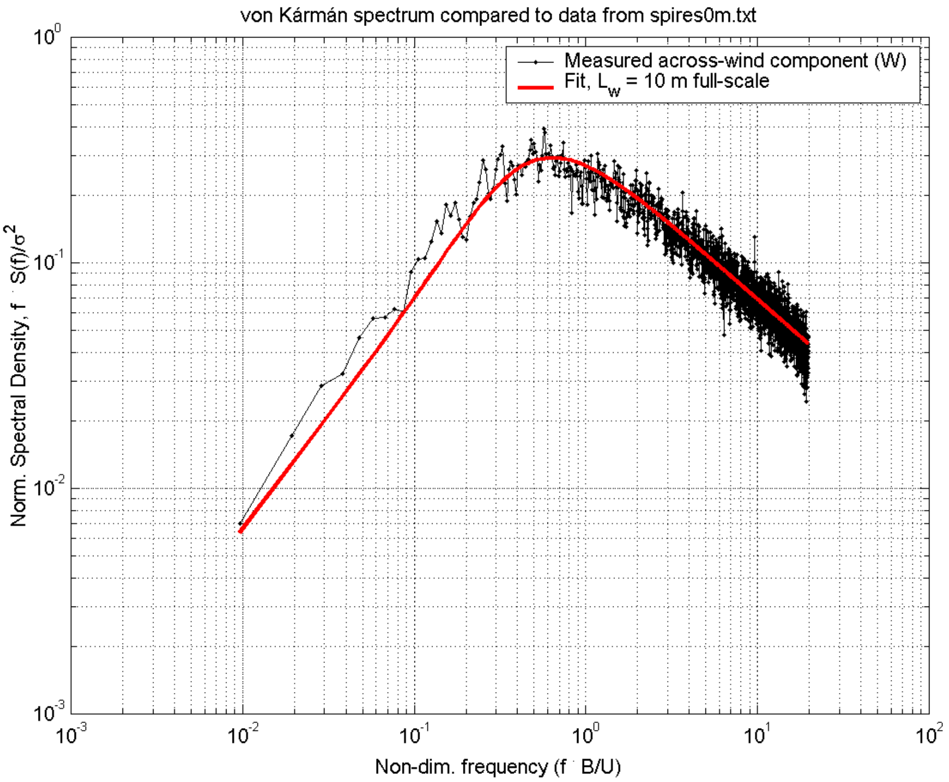


Figure 4.3.

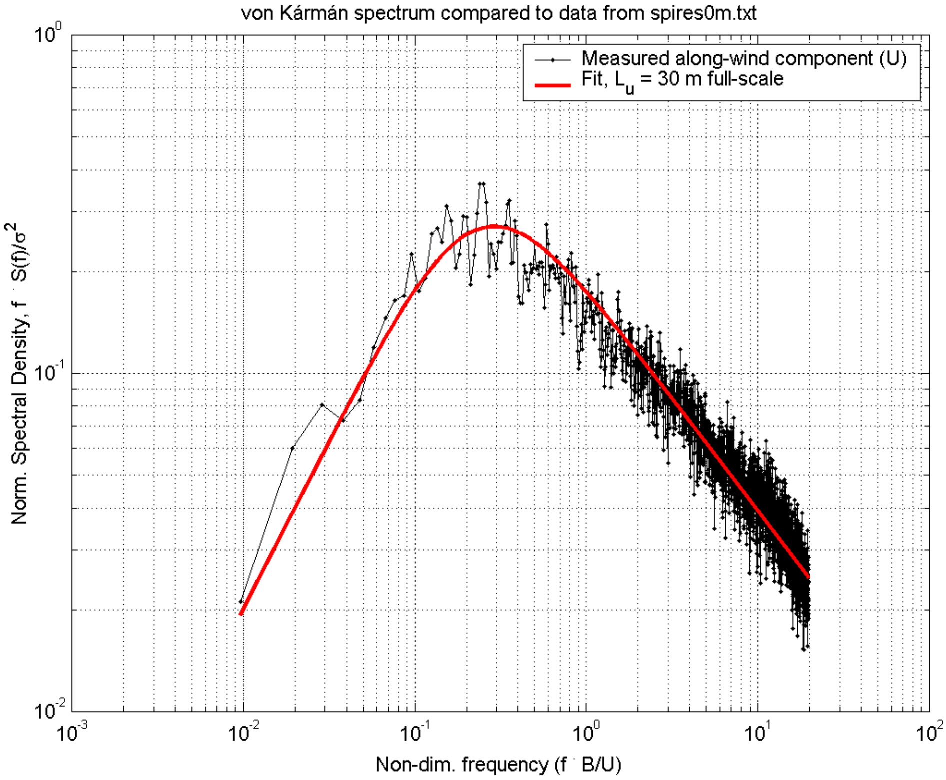


Figure 4.2 U-Component Spectra at Bridge Location (and wind tunnel centre line).

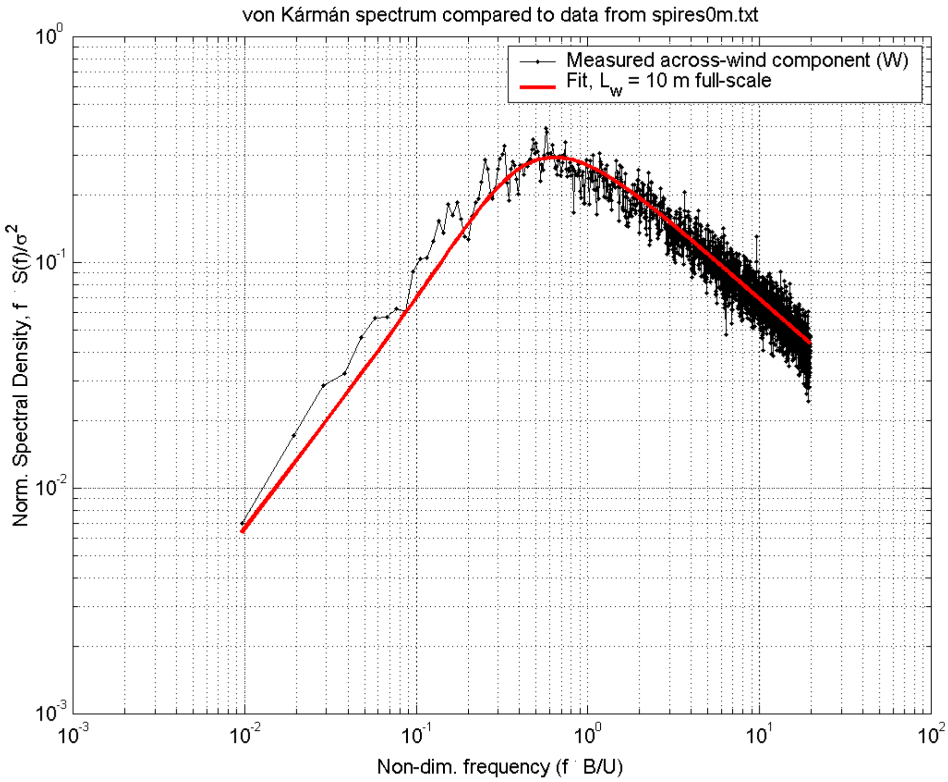


Figure 4.3 W-Component Spectra at Bridge Location (and wind tunnel centre line).

In extension to the spectra, the root coherence was measured. The results are presented in Appendix C.

4.2 Aerodynamic Flutter Derivative and Admittance Tests

The thee-spire exposure resulted in turbulence intensities of approximately 8.2% for I_u and 9.2% for I_w.

The spectral density function (SDF) of the velocity fluctuation was derived from a long time series recorded at centre position (wind-tunnel centre line), see Figure 4.4 and Figure 4.5.

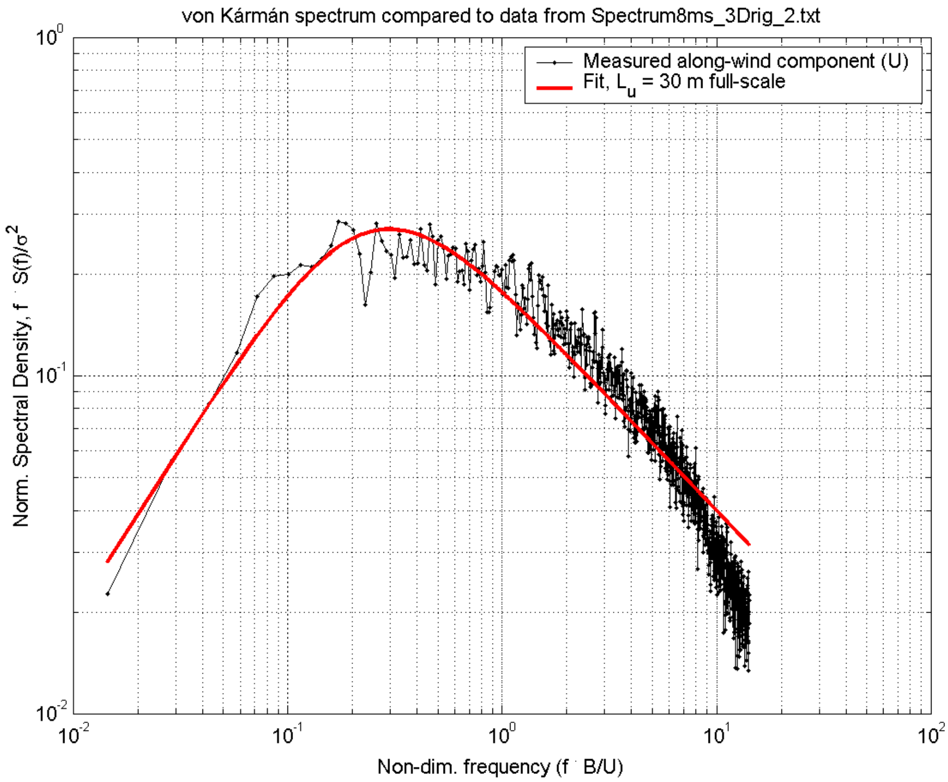


Figure 4.4 U-Component Spectra at Bridge Location (and wind tunnel centre line).

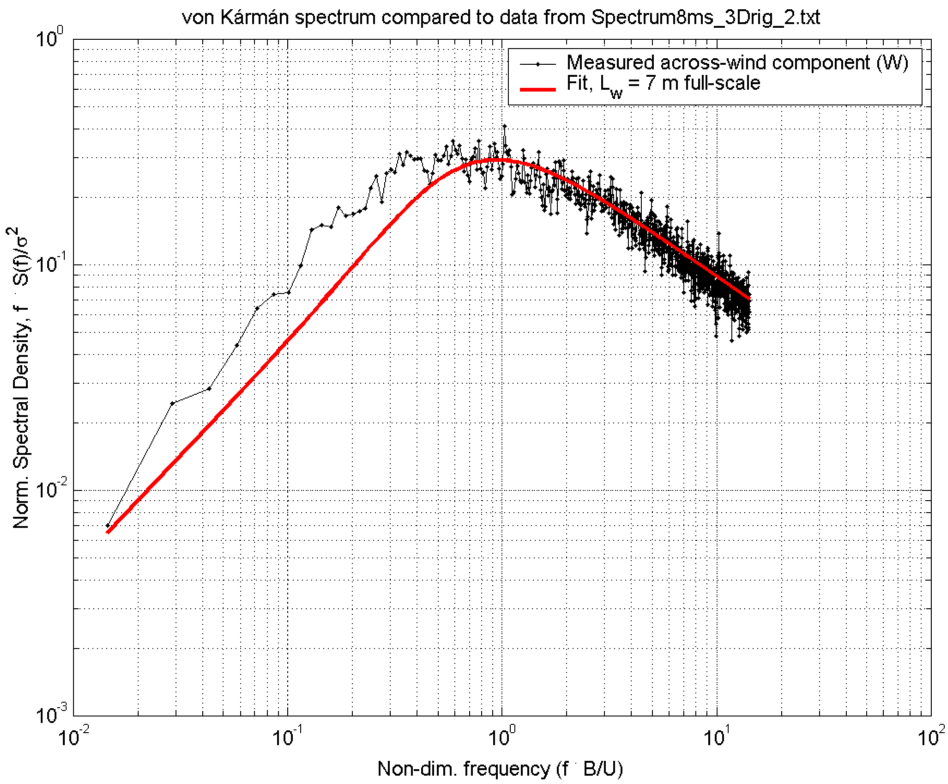


Figure 4.5 W-Component Spectra at Bridge Location (and wind tunnel centre line).

5. Wind-Tunnel Test Programme

The test programme consisted of static and dynamic section model tests, the objective being to determine the static wind loads, aerodynamic admittance and the aerodynamic derivatives.

The detailed test programme is outlined in Table 5.1.

#	Test	Angles	Configuration	Flow
1	Static tests	-10° to +10°, Δ=0.5°	Erection	Smooth
2	Static tests	-10° to +10°, Δ=0.5°	Erection	Turbulent
3	Aerodynamic admittance	-6° to +6°, Δ=2°	Erection	Turbulent
4	Aerodynamic derivatives	-6° to +6°, Δ=2°	Erection	Smooth
5	Aerodynamic derivatives	-6° to +6°, Δ=2°	Erection	Turbulent

Table 5.1. Test programme for section model tests.

6. Static Tests

6.1 Static Force Coefficients Definition

The static aerodynamic force coefficients for the deck of the Messina Strait Bridge were determined based on wind-tunnel tests on a 1:80 geometrical scale model of a section of the deck in smooth and turbulent flow.

A typical force coefficient is defined as follows:

$$C_{x,z,l,d} = \frac{\overline{F}_{x,z,l,d}}{\overline{q}\,BL} \tag{6.1a}$$

$$C_m = \frac{\overline{M}}{\overline{q}\,B^2 L} \tag{6.1b}$$

Where:

C	=	Aerodynamic coefficient
$\overline{F}$	=	Time-averaged (mean) aerodynamic force
$\overline{M}$	=	Mean overturning moment (torque)
B	=	The bridge deck width (60.4 m in the present case)
L	=	The model span length
$\overline{q}$	=	The mean wind velocity pressure[1] at deck level; $\overline{q} = \frac{1}{2}\rho\overline{V^2}$ where:
ρ	=	Air density [kg/m^3]
$\overline{V}$	=	Mean wind velocity at deck level in [m/s]

The subscripts x, z, l, d and m refer to the x and z body-force components, lift, drag and overturning moment, respectively.

The procedure for the determination of the static coefficients consists of mounting the 2.55 m long section model of the bridge in a static rig equipped with two 3-component force balances. The force balances measure the vertical, lateral and torsional reactions at the extremities of the model. The reactions are combined to obtain: $\overline{F_l}, \overline{F_d}$ and $\overline{M}$, respectively.

These quantities are subsequently normalized according to the equations above. This procedure is repeated for several angles of attack of the model (from –10° to +10° in increments of 0.5°, measured from the horizontal plane).

[1] The mean velocity pressure is measured directly (by micro manometers), consequently the value of the air density and the mean wind velocity are not determined explicitly.

The rate of change (or slope) of the coefficients with angle of attack α in radians is evaluated from these tests in the vicinity of zero degrees (between –1° and +1° - and not between -0.5° and +0.5°).

The drag and lift coefficients, C_d and C_l, are defined in the global coordinate system in relation to the wind. The body force coefficients, C_x and C_z, defined in the local coordinate system, are linked to the drag and lift coefficients by the following relationships:

$$C_x(\alpha) = C_d(\alpha)\cos\alpha - C_l(\alpha)\sin\alpha \quad (6.2a)$$

$$C_z(\alpha) = C_d(\alpha)\sin\alpha + C_l(\alpha)\cos\alpha \quad (6.2b)$$

A bridge deck width, B, of 60.4 m (full-scale) was used in the determination of the coefficients. The centre of measurement of the forces and moment was set at the shear centre of the section, 1.33 m (in full-scale) above the bottom plate of the railway girder.

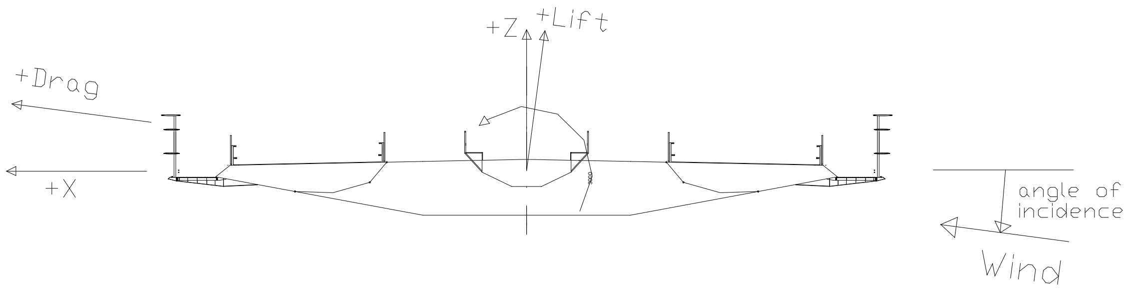


Figure 6.1. Sign convention for the static section model tests.

6.2 Results

The present tests were conducted at model-scale wind speeds of typically about 12 m/s. Figure 6.2 present the variations of the coefficients with angle of wind incidence, α, for the bridge deck.

A summary of the main static coefficients is given in Table 2.1 of Section 2. The rate of change (slope) of the coefficients around 0° was calculated based on the values at –1° and +1°, see also the table in Section 2.

The measured coefficients have been corrected for the effect of blockage according to ESDU[2]. The blockage correction was in the order of 2-7% depending on the deck inclination.

[2] Engineering Sciences Data Unit Item 80024:" Blockage correction for bluff bodies in confined flows", Nov. 1980.

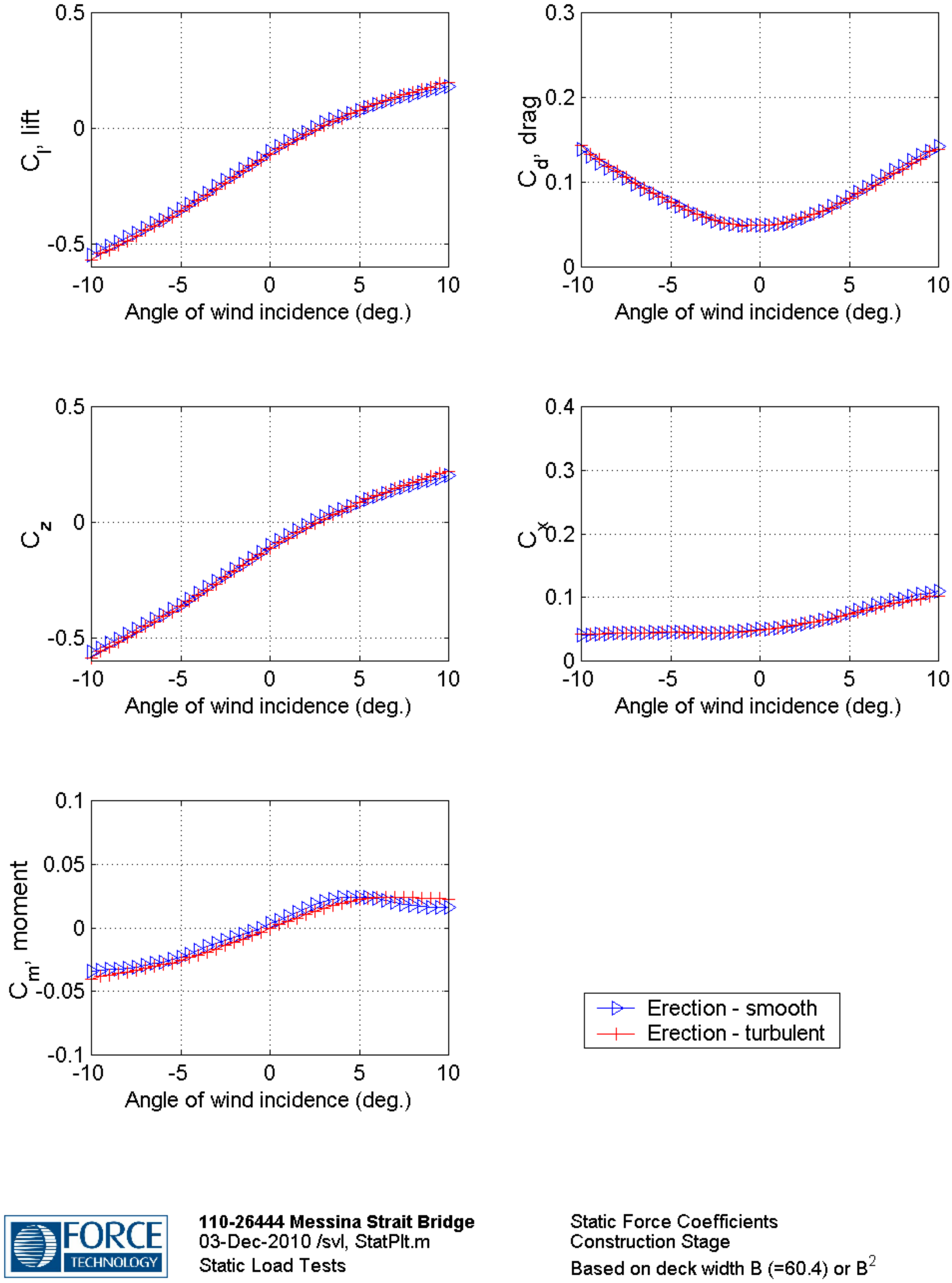


Figure 6.2. Variations of the static force coefficients – C5/63° erection stage.

	Erection stage smooth			Erection stage turbulent		
α [°]	C_d	C_l	C_m	C_d	C_l	C_m
-10.0	0.139	-0.547	-0.034	0.143	-0.570	-0.040
-9.5	0.130	-0.528	-0.033	0.133	-0.541	-0.038
-9.0	0.123	-0.508	-0.033	0.126	-0.525	-0.037
-8.5	0.117	-0.491	-0.032	0.119	-0.504	-0.036
-8.0	0.110	-0.472	-0.032	0.113	-0.486	-0.035
-7.5	0.105	-0.454	-0.031	0.106	-0.465	-0.033
-7.0	0.098	-0.431	-0.030	0.099	-0.440	-0.032
-6.5	0.091	-0.410	-0.028	0.093	-0.422	-0.031
-6.0	0.087	-0.395	-0.027	0.087	-0.400	-0.029
-5.5	0.081	-0.372	-0.025	0.082	-0.382	-0.028
-5.0	0.076	-0.351	-0.023	0.076	-0.359	-0.026
-4.5	0.072	-0.329	-0.020	0.071	-0.335	-0.023
-4.0	0.066	-0.302	-0.017	0.067	-0.311	-0.021
-3.5	0.062	-0.279	-0.015	0.063	-0.289	-0.019
-3.0	0.057	-0.253	-0.012	0.058	-0.263	-0.017
-2.5	0.054	-0.226	-0.010	0.055	-0.237	-0.014
-2.0	0.052	-0.203	-0.008	0.052	-0.210	-0.011
-1.5	0.050	-0.178	-0.005	0.051	-0.186	-0.009
-1.0	0.049	-0.155	-0.003	0.049	-0.160	-0.006
-0.5	0.050	-0.129	0.000	0.049	-0.138	-0.004
0.0	0.050	-0.101	0.003	0.049	-0.114	-0.001
0.5	0.049	-0.079	0.006	0.050	-0.088	0.003
1.0	0.050	-0.058	0.009	0.051	-0.068	0.005
1.5	0.052	-0.035	0.012	0.053	-0.046	0.008
2.0	0.054	-0.016	0.015	0.056	-0.027	0.011
2.5	0.058	0.004	0.018	0.059	-0.008	0.013
3.0	0.062	0.024	0.021	0.062	0.011	0.015
3.5	0.066	0.037	0.022	0.066	0.028	0.017
4.0	0.072	0.052	0.024	0.069	0.043	0.019
4.5	0.077	0.064	0.024	0.076	0.062	0.021
5.0	0.083	0.077	0.024	0.081	0.079	0.022
5.5	0.088	0.090	0.024	0.087	0.094	0.023
6.0	0.094	0.102	0.023	0.092	0.106	0.024
6.5	0.101	0.114	0.022	0.097	0.119	0.024
7.0	0.108	0.125	0.020	0.104	0.134	0.024
7.5	0.114	0.136	0.019	0.111	0.147	0.024
8.0	0.119	0.144	0.018	0.115	0.157	0.024
8.5	0.126	0.155	0.017	0.122	0.169	0.023
9.0	0.132	0.163	0.016	0.127	0.178	0.023
9.5	0.137	0.170	0.016	0.136	0.192	0.023
10.0	0.143	0.180	0.016	0.139	0.196	0.023

Table 6.1. The static force coefficients with angle of incidence.

7. Aerodynamic Admittance Tests

7.1 Theory

Based on the quasi-steady formulation of the buffeting wind forces on a bridge deck, it is possible to measure the efficiency of a deck cross-section to extract energy from the turbulence. This quantity is generally called the aerodynamic admittance, and is expressed in the frequency domain. The main idea is to measure the forces acting on a restrained section model while exposed to a turbulent wind field. From these measurements the spectra of the wind forces may be evaluated. To determine the aerodynamic admittance it is further necessary to evaluate the co-coherence of the turbulent wind field. To evaluate the co-coherence of the turbulent wind field, simultaneous wind measurements with in varied distances have to be performed.

The theory described in the following refers to a coordinate system and quantities as defined in the figure below.

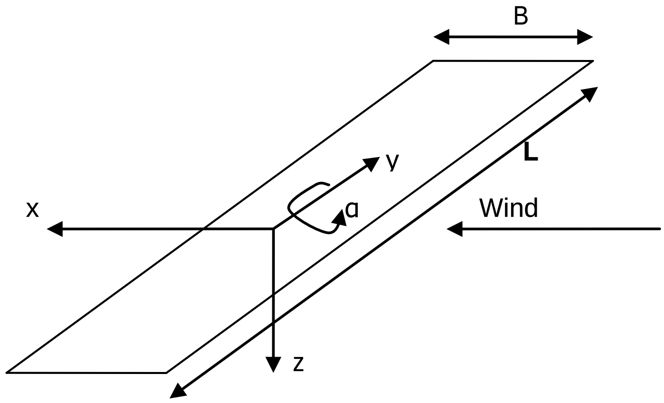


Figure 7.1 Coordinate system and section model quantities.

For details, refer to ref. [7].

7.2 Results

Execution of the admittance tests were undertaken in the 3D rig at approximately 8 m/s model-scale wind speed.

The admittance tests were performed for the erection stage configuration. The tests were repeated for angles of incidence -6°, -4°, -2°, 0°, 2°, 4° and 6°. All results are included in Appendix V.

8. Aerodynamic Flutter Derivatives

The aerodynamic derivatives represent the motion-induced forces acting on an oscillating bridge deck immersed in a fluid in motion. They can best be described as a representation of the aerodynamic damping and the aerodynamic stiffness provided by the wind for a given deck geometry.

The current project includes determination of 3-DOF (Degrees Of Freedom) flutter derivatives. Historically FORCE Technology has determined 2-DOF flutter derivates using the free vibrating techniques combined with system design identification techniques. To determine 3-DOF flutter derivatives, FORCE has developed a forced oscillation rig, or simply 3D-rig and appertaining dedicated analysis software.

The forced motion techniques have a number of advantages compared to the widely used free vibration techniques. Using the forced motion rig, it is possible to measure the response through or all the way to the flutter instability, whereas the system identification techniques used in connection with free vibration techniques typically capitulates before the flutter limit has been reached. Further and very importantly the forced motion rig allows for determination of flutter derivatives in turbulent flows, whereas this is difficult using free vibration techniques in combination with system identification techniques.

The results produced by the new rig and the new analysis software have been tested on known bridge sections. The results have been compared width 2-DOF flutter derivatives derived through free vibration test and system design identification techniques. The results showed very fine agreement.

8.1 Analysis

The equation of motion for a section doing forced motions are:

$$m\left(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}\right) = mg - m_{a,z}\ddot{h} - 2m\omega_{h,0}\zeta_h\dot{h} + FZ_{external}(\omega_h, t) + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + mz_G\ddot{p} + mx_G\ddot{h} = -I_{a,y}\ddot{\alpha} - 2I_y\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + MY_{external}(\omega_\alpha, t) + M_{ad} + M_{ae} + M_b$$

$$m\left(\ddot{p} + z_G\ddot{\alpha} - x_G\dot{\alpha}^2\right) = -m_{a,x}\ddot{p} - 2m\omega_{p,0}\zeta_p\dot{p} + FX_{external}(\omega_p, t) + D_{ad} + D_{ae} + D_b$$

where:

h	:	Vertical displacement, displacement along z-axis, positive downwards. [m]
α	:	Rotation around y-axis, nose up is positive, [rad.]
p	:	Horizontal displacement, displacement along the x-axis, positive in direction of wind, [m]
m	:	Mass per unit length, [kg/m]
I_y	:	Moment of inertia per unit length around y-axis, [m²·kg/m]
$m_{a,z}$	:	Added mass in horizontal direction, [kg/m]
$m_{a,x}$	:	Added mass in vertical direction, [kg/m]
$I_{a,y}$	:	Added moment of inertia per unit length around y-axis, [m²·kg/m]
X_G	:	X-coordinate for centre of gravity, [m]
Z_G	:	Z-coordinate for centre of gravity, [m]
ω_h	:	Forced circular frequency for vertical motion, [Hz]
$\omega_{h,0}$	:	Natural circular frequency for vertical motion, [Hz]
ζ_h	:	Damping ratio-to-critical for vertical motion, [-]
ω_α	:	Forced circular frequency for rotation around y axis, [Hz]
$\omega_{\alpha,0}$	:	Natural circular frequency for rotation around y axis, [Hz]

ζ_α	:	Damping ratio-to-critical for rotation around y axis, [-]
ω_α	:	Forced circular frequency for horizontal motion along x-axis [Hz]
$\omega_{\alpha,0}$	:	Natural circular frequency for horizontal motion along x-axis [Hz]
ζ_p	:	Damping ratio-to-critical for horizontal motion along x-axis, [-]
$FZ_{External}$	:	Force from rig per meter section, [N/m]
$MY_{External}$	:	Moment from rig per meter section, [Nm/m]
$FX_{External}$	:	Force from rig per meter section, [N/m]
L_{ad}	:	aero dynamic lift, [N/m]
L_{ae}	:	aeroelastic lift, [N/m]
L_b	:	buffeting lift, [N/m]
M_{ad}	:	aero dynamic pitch moment, [Nm/m]
M_{ae}	:	aeroelastic pitch moment, [Nm/m]
M_b	:	buffeting pitch moment, [Nm/m]
D_{ad}	:	aero dynamic drag, [N/m]
D_{ae}	:	aeroelastic drag, [N/m]
D_b	:	buffeting drag, [N/m]

The flutter derivatives are related to a motion, where the vertical, torsional and horizontal vibrations, are coupled. The self excited forces, drag D_{ae}, lift L_{ae} and moment M_{ae} acting on bridge decks are commonly expressed through the use of aerodynamic derivatives P^*_{1-6}, H^*_{1-6}, A^*_{1-6} following Scanlan's original definition:

$$L_{ae} = ½\rho U^2 (2B)\left(K^2 H_4^* \frac{h}{B} + K^2 H_3^* \alpha + K^2 H_6^* \frac{p}{B} + KH_1^* \frac{\dot{h}}{U} + KH_2^* \frac{B\dot{\alpha}}{U} + KH_5^* \frac{\dot{p}}{U} \right)$$

$$M_{ae} = ½\rho U^2 (2B^2)\left(K^2 A_4^* \frac{h}{B} + K^2 A_3^* \alpha + K^2 A_6^* \frac{p}{B} + KA_1^* \frac{\dot{h}}{U} + KA_2^* \frac{B\dot{\alpha}}{U} + KA_5^* \frac{\dot{p}}{U} \right)$$

$$D_{ae} = ½\rho U^2 (2B)\left(K^2 P_6^* \frac{h}{B} + K^2 P_3^* \alpha + K^2 P_4^* \frac{p}{B} + KP_5^* \frac{\dot{h}}{U} + KP_2^* \frac{B\dot{\alpha}}{U} + KP_1^* \frac{\dot{p}}{U} \right)$$

where:

B	:	Deck width, [m]
ρ	:	Air density, [kg/m^3]
U	:	Mean velocity of incoming wind, [m/s]
K	:	Reduced frequency, $K = \frac{\omega B}{U}$
H_i^*	:	Flutter derivatives for vertical force, i = 1-6
A_i^*	:	Flutter derivatives for moment around y-axis, i = 1-6
P_i^*	:	Flutter derivatives for horizontal force, i = 1-6

For details, refer to ref. [7].

8.2 Results

The flutter tests were performed for the erection stage configuration. The tests were performed in smooth flow as well as in turbulent flow. Further the tests were repeated for angles of incidence -6°, -4°, -2°, 0°, 2°, 4° and 6°. All results are included in Appendix D through Q.

Appendices R and S contain comparisons of the flutter derivatives for the different angle of incidence for the different flow types.

9. References

[1] “Section Model Tests for the Messina Strait Crossing, Italy”
FORCE 2005011 rev. 3.1, 2005-04-18

[2] “Stability Tests for Modified Deck for the Messina Strait Crossing, Italy”
FORCE 2005263 rev. A, 2005-12-22

[3] “Static section model tests the Messina Strait Bridge”
FORCE 109-28238 rev. 1, 2010-01-13

[4] “Sub-Test 1 Section Model Tests for the Messina Strait Bridge”
FORCE 110-25465 rev. 1, 2010-06-25

[5] “Indicative Vortex-Shedding Tests, Static & Stability Tests for the Messina Strait Bridge”
FORCE 110-26444.02 rev. 1, 2010-12-07

[6] “Additional Static & Stability Tests for the Messina Strait Bridge”
FORCE 110-26444.02a rev. 1.1, 2011-01-17

[7] “Sub-test D4 Section Model Tests the Messina Strait Bridge”
FORCE 110-26444.01 rev. A, 2011-01-18.

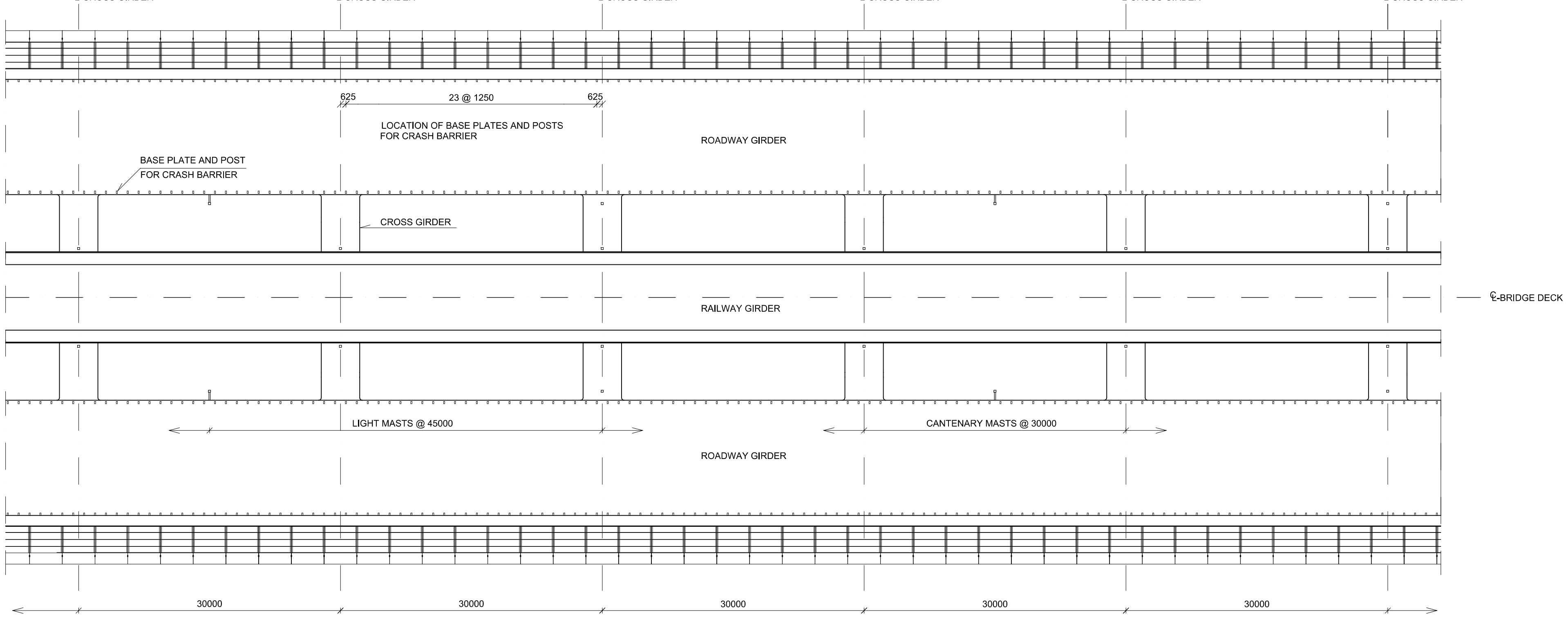
APPENDIX A

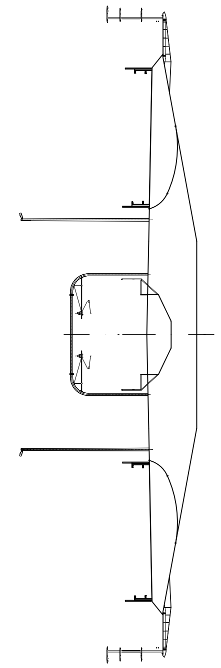
Drawings

NOTE GENERALI

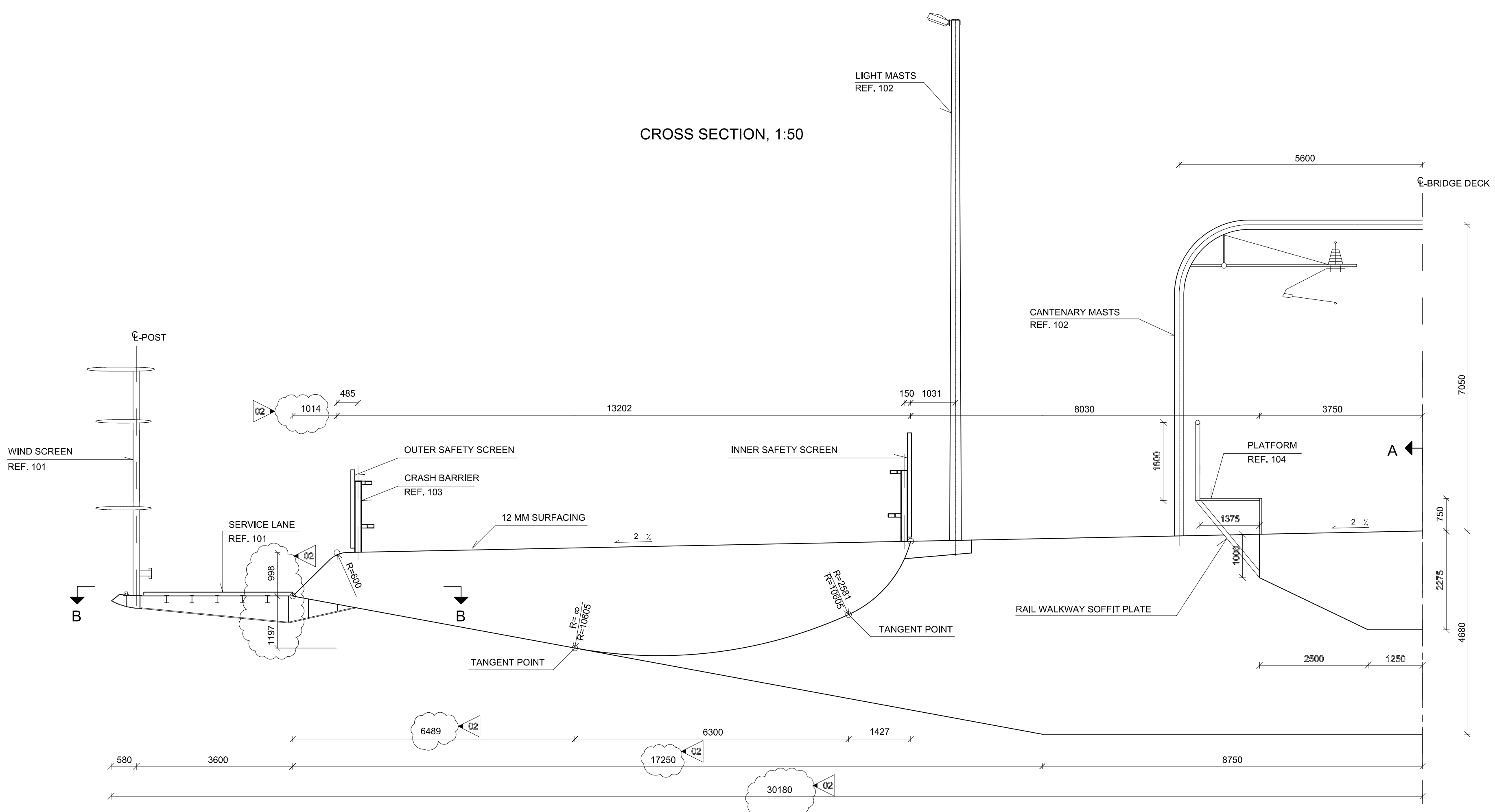
DIMENSIONS:
ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE STATED.

PLAN, 1:250

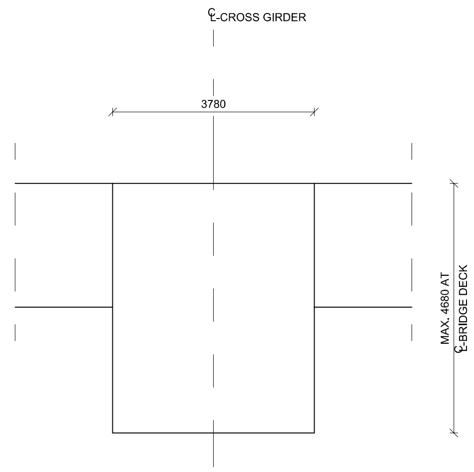




CROSS SECTION, 1:50



SECTION A-A, 1:50



Rev.	Date	Description	Designed	Checked	Approved
02	2010/06/11	ROADWAY GIRDER	LSJ	HPO	ALN
01	2010/05/06	TITLE BAR UPDATED	HEAE	HPO	ALN

STRETTO DI MESSINA
BRIDGE OVER THE MESSINA STRAIT

Project no.	
Designed	HEAE
Checked	HPO
Approved	ALN / LSJ
Scale	-
Date	2010/04/20
Document no.	100
Rev.	02

Description
DECK SECTION FOR WIND TUNNEL TEST

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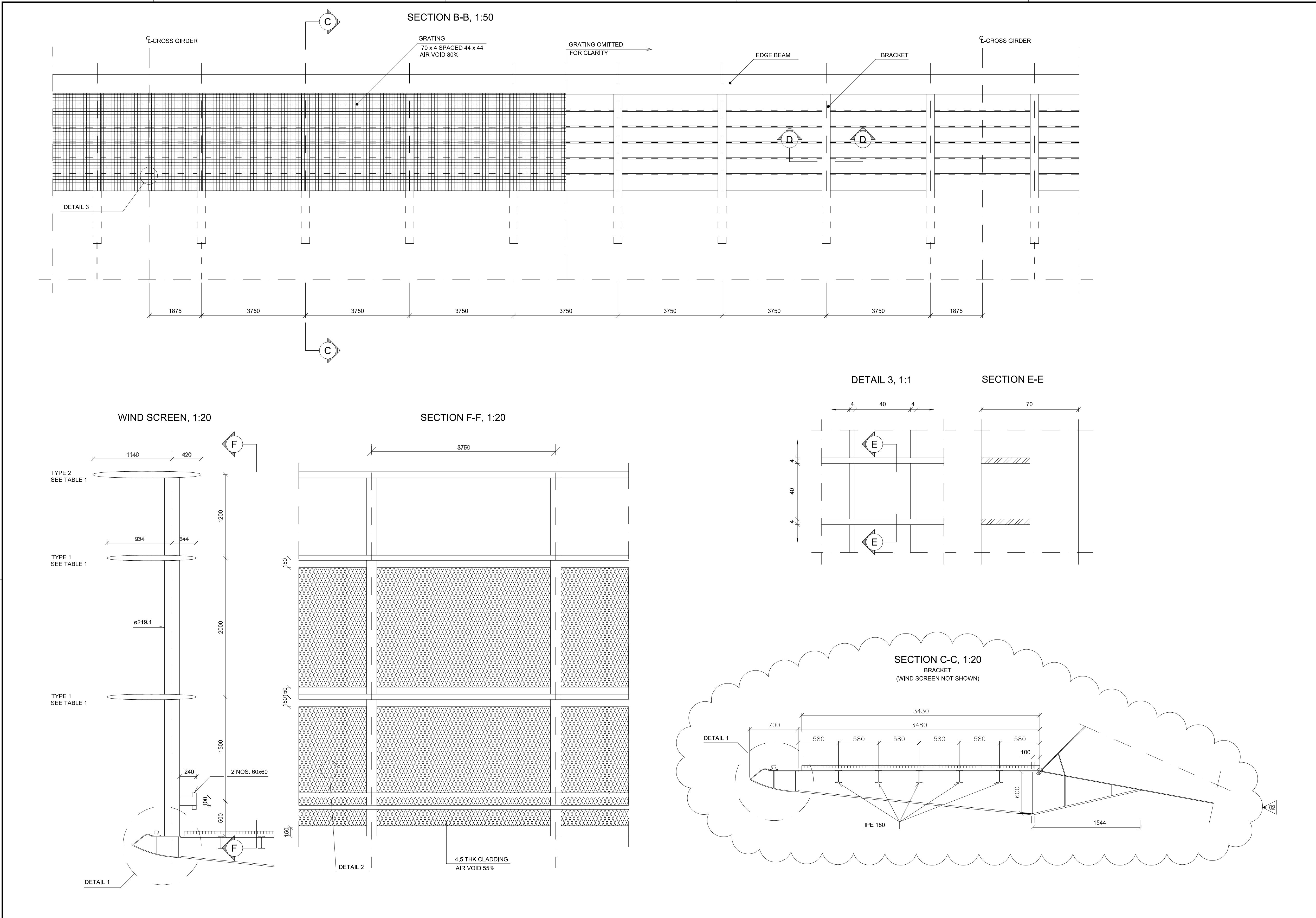

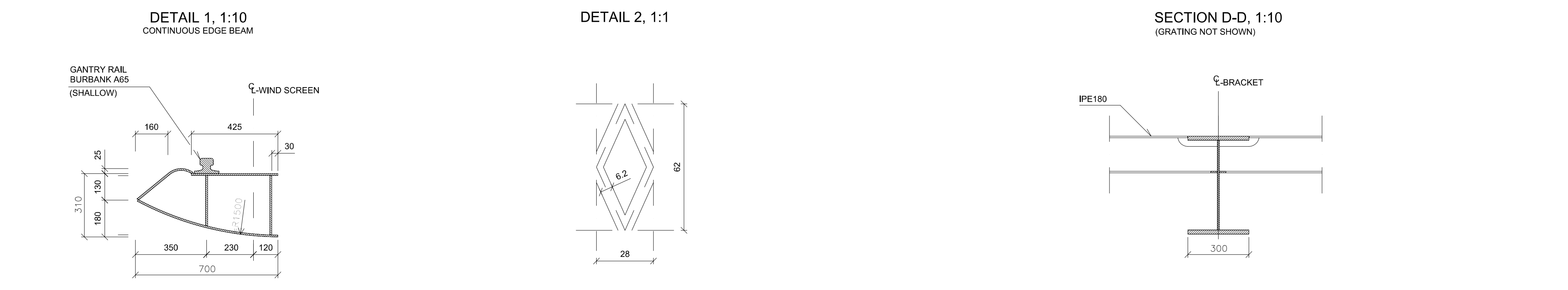

TABLE 1

TYPE 1		TYPE 2	
X (mm)	Y (mm)	X (mm)	Y (mm)
0	0	0	0
16	12	20	14
32	16	39	19
64	21	78	25
96	24	117	30
128	27	156	33
192	31	234	38
256	34	312	41
383	37	468	45
511	38	624	47
639	38	780	47

NOTE GENERALI

DIMENSIONS:

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Rev.	Date	Description	Designed	Checked	Approved
02	2010/06/11	ROADWAY GIRDER	LSJ	HPO	ALN
01	2010/05/06	TITLE BAR UPDATED	HEAE	HPO	ALN

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BRIDGE OVER THE MESSINA STRAIT

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Scale -
Date 2010/04/20

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Rev. 02

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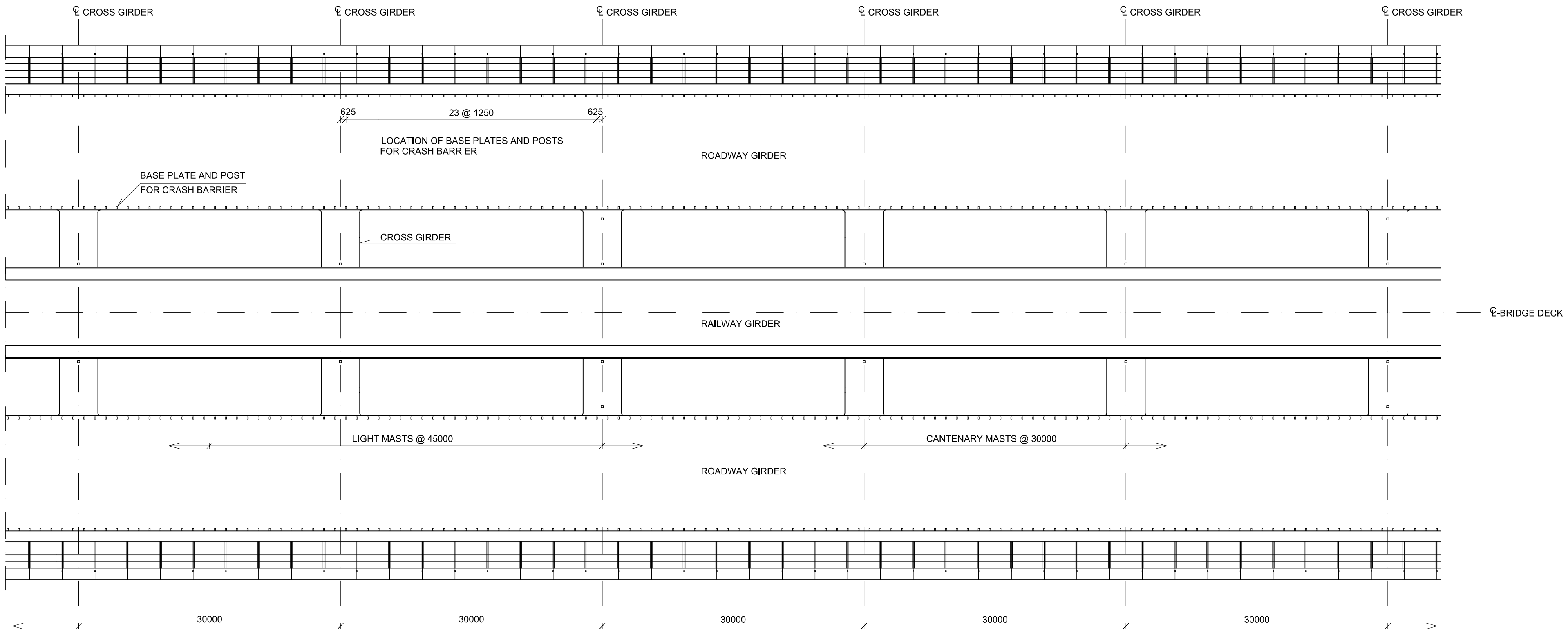
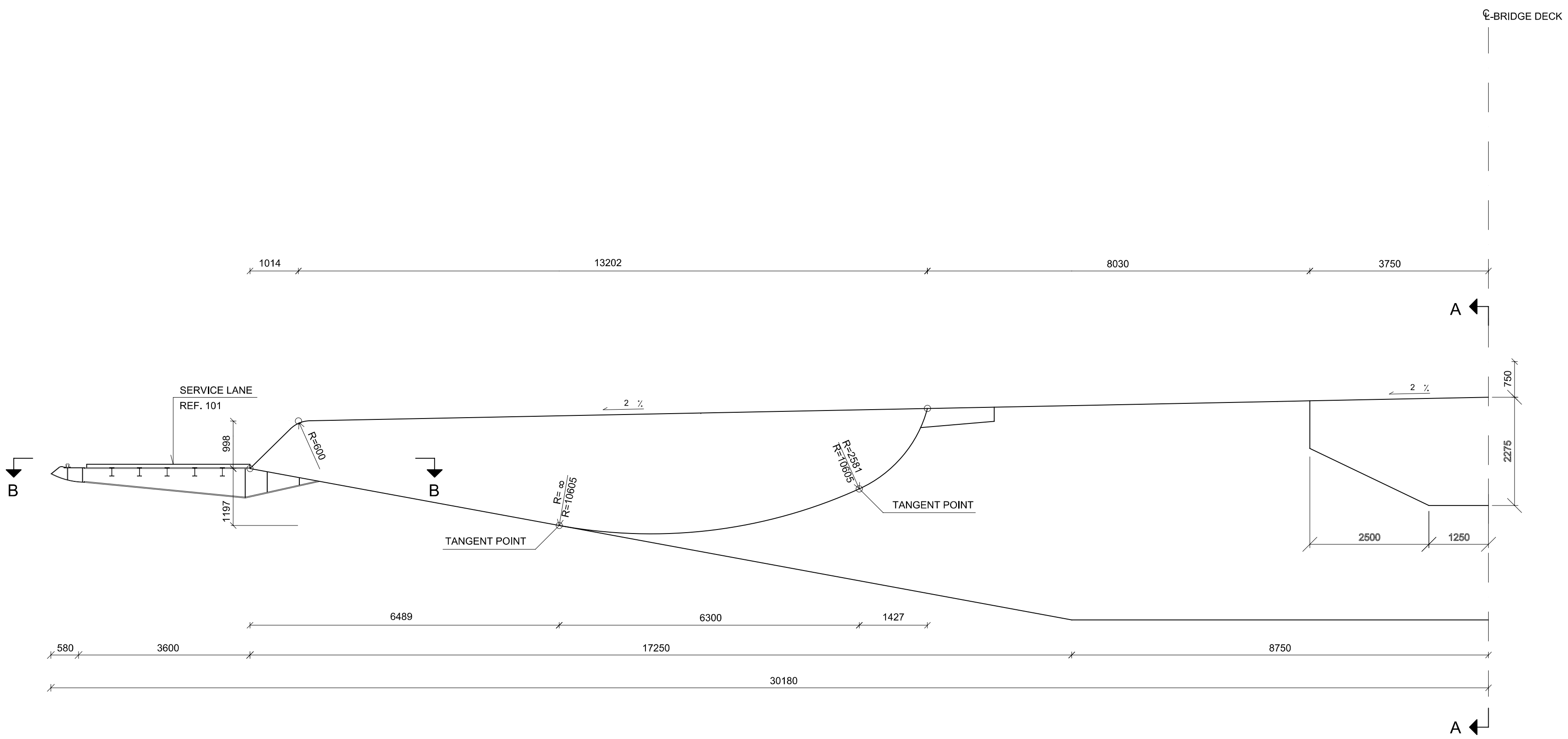
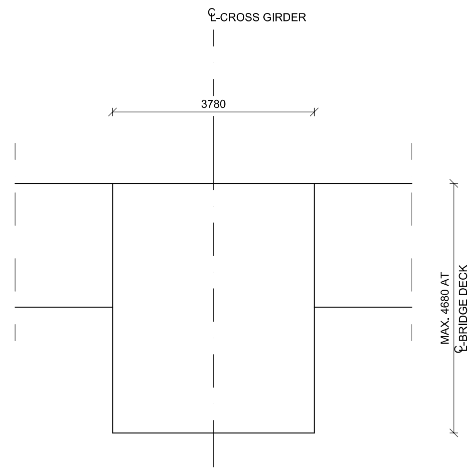
PLAN, 1:250



CROSS SECTION, 1:50



SECTION A-A, 1:50



Rev.	Date	Description	Designed	Checked	Approved

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Designed	HEAE
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Date	2010/04/20

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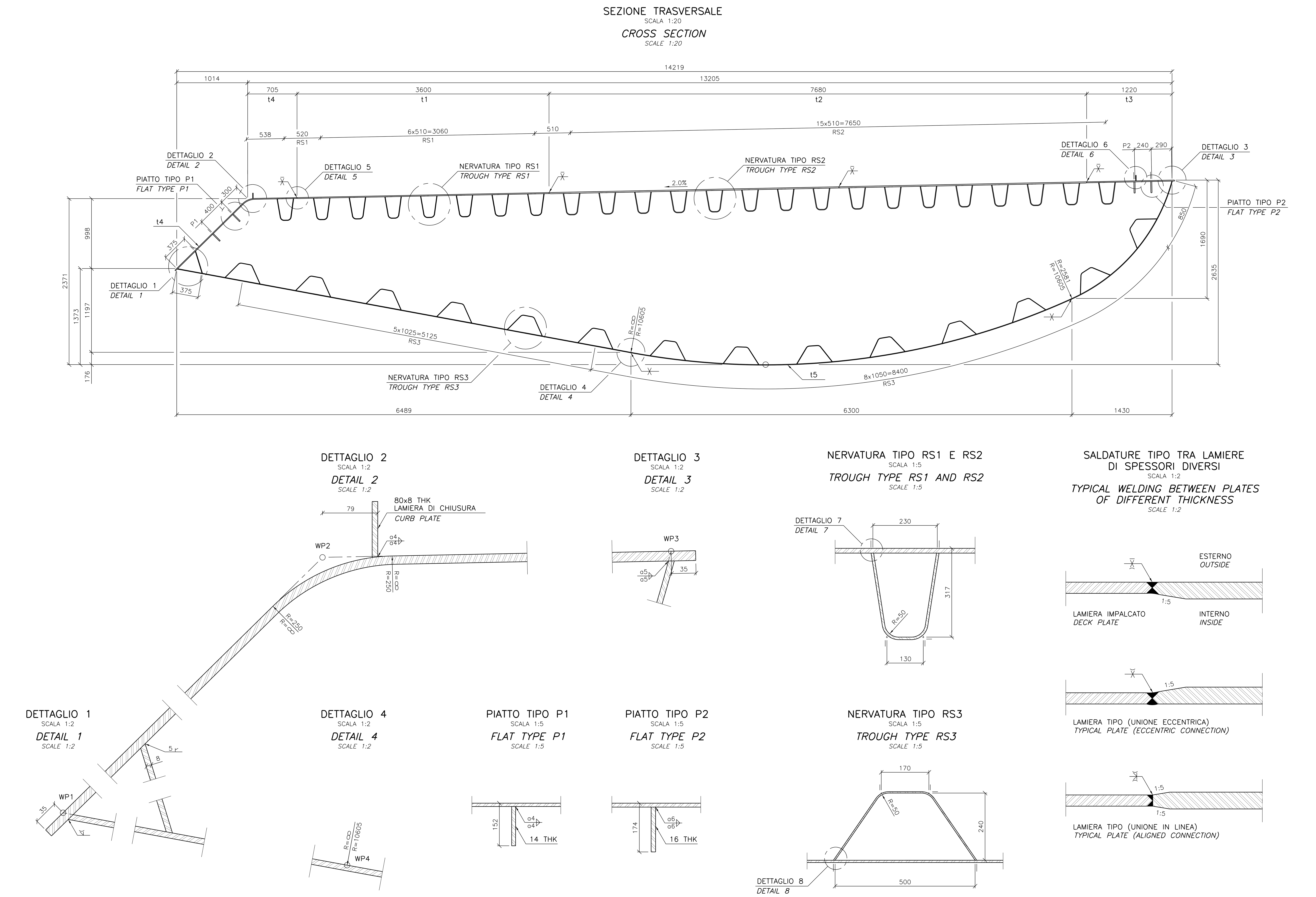

TABELLA 1
SPESSORE LAMIERE E CLASSI ACCIAIO
TABLE 1
PLATE THICKNESS AND STEEL GRADE

	CASSONE STRADALE TIPO *ROADWAY GIRDER TYPE*	CS1	CS2	CS3	CS6	CS8
t1	LAMIERE CORSIA DI EMERGENZA *EMERGENCY LANE*	14	14	14	14	14
t2	LAMIERE CORSIA DI MARCIA NORMALE E DI SORPASSO *INNER AND OUTER LANE*	17	17	17	17	17
t3	LAMIERE D'IMPALCATO INTERNA *INNER DECK PLATE*	14	14	14	14	14
t4	LAMIERE DI BORDO ED ESTERNA *EDGE PLATE AND OUTER DECK PLATE*	12	12	12	12	12
t5	PIATTABANDA INFERIORE *BOTTOM PLATE*	8	9	9	9	12
RS1	NERVATURA TIPO RS1 *TROUGH TYPE RS1*	7	7	7	7	7
RS2	NERVATURA TIPO RS2 *TROUGH TYPE RS2*	9	9	9	9	9
RS3	NERVATURA TIPO RS3 *TROUGH TYPE RS3*	5	5	5	5	6
	CLASSE ACCIAIO *STEEL GRADE*	S355	S420	S460	S460	S460

NOTE GENERALI

NOTE:
DIMENSIONI: TUTTE LE DIMENSIONI SONO IN MILLIMETRI, SALVO OVE DIVERSAMENTE INDICATO.

MATERIALI: CLASSE ACCIAIO SECONDO TABELLA 1.

LEGENDA:
- ACCIAIO
- PAVIMENTAZIONE
- ○ PUNTO DI RIFERIMENTO

ELABORATI DI RIFERIMENTO:
CG1000PSXDPSV000000000001 NOTE GENERALI

NOTES:
DIMENSIONS: DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE NOTED.

MATERIALS: STEEL GRADE ACCORDING TO TABLE 1.

LEGENDS:
- *STEEL*
- *PAVEMENT*
- ○ *WORKING POINT*

REFERENCES:
CG1000PSXDPSV000000000001 GENERAL NOTES

QUESTO ELABORATO GRAFICO VA LETTO INSIEME A:
THIS DRAWING TO BE READ IN CONJUNCTION WITH:
CG1000PAXDPSVI3CS00D00001
CG1000PBXDPSVI3CS00000001
CG1000PBXDPSVI3CS00000002

Preliminary
02-09-2010

Stretto di Messina
Concessionaria per la progettazione, realizzazione e gestione del collegamento stabile tra la Sicilia e il Continente
Organismo di Diritto pubblico
(Legge n° 1158 del 17 dicembre 1971, modificata dal D.Lgs. n° 114 del 24 aprile 2003)

Eurolink

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

EUROLINK S.C.p.A.
IMPREGILO S.p.A. (Mandataria)
SOCIETA' ITALIANA PER CONDOTTE D'ACQUA S.p.A. (Mandante)
COOPERATIVA MURATORI E CEMENTISTI - C.M.C. di Ravenna Soc. Coop. a.r.l. (Mandante)
SACYR S.A.U. (Mandante)
ISHIKAWAJIMA - HARIMA HEAVY INDUSTRIES CO. Ltd. (Mandante)
A.C.I. S.C.P.A. - CONSORZIO STABILE (Mandante)

IL PROGETTISTA PROJECT MANAGER (Ing. E.M. Veje) COWI	INTEGRAZIONE PRESTAZIONI SPECIALISTICHE (Dott. Ing..............)	IL CONTRAENTE GENERALE PROJECT MANAGER (Ing. P.P. Marcheselli)	STRETTO DI MESSINA
DATA____________	DATA____________	DATA____________	DATA____________

OPERA DI ATTRAVERSAMENTO
SOVRASTRUTTURE
IMPALCATO SOSPESO
IMPALCATO STRADALE – CAMPATA CENTRALE E LATERALI
SEZIONE

CODICE C G 1 0 0 0 P W X D P S V I 3 C S 0 0 0 0 0 0 0 1 A SCALA: VARIE

REV.	DATA	DESCRIZIONE	REDATTO	VERIFICATO	APPROVATO
			LHU/HEAE	HPO	HPO/LSJ

NOME DEL FILE: CG1000-PWXDPSV-I3CS000000-01.DWG revisione interna: A-01

NOTE GENERALI

DIMENSIONS:
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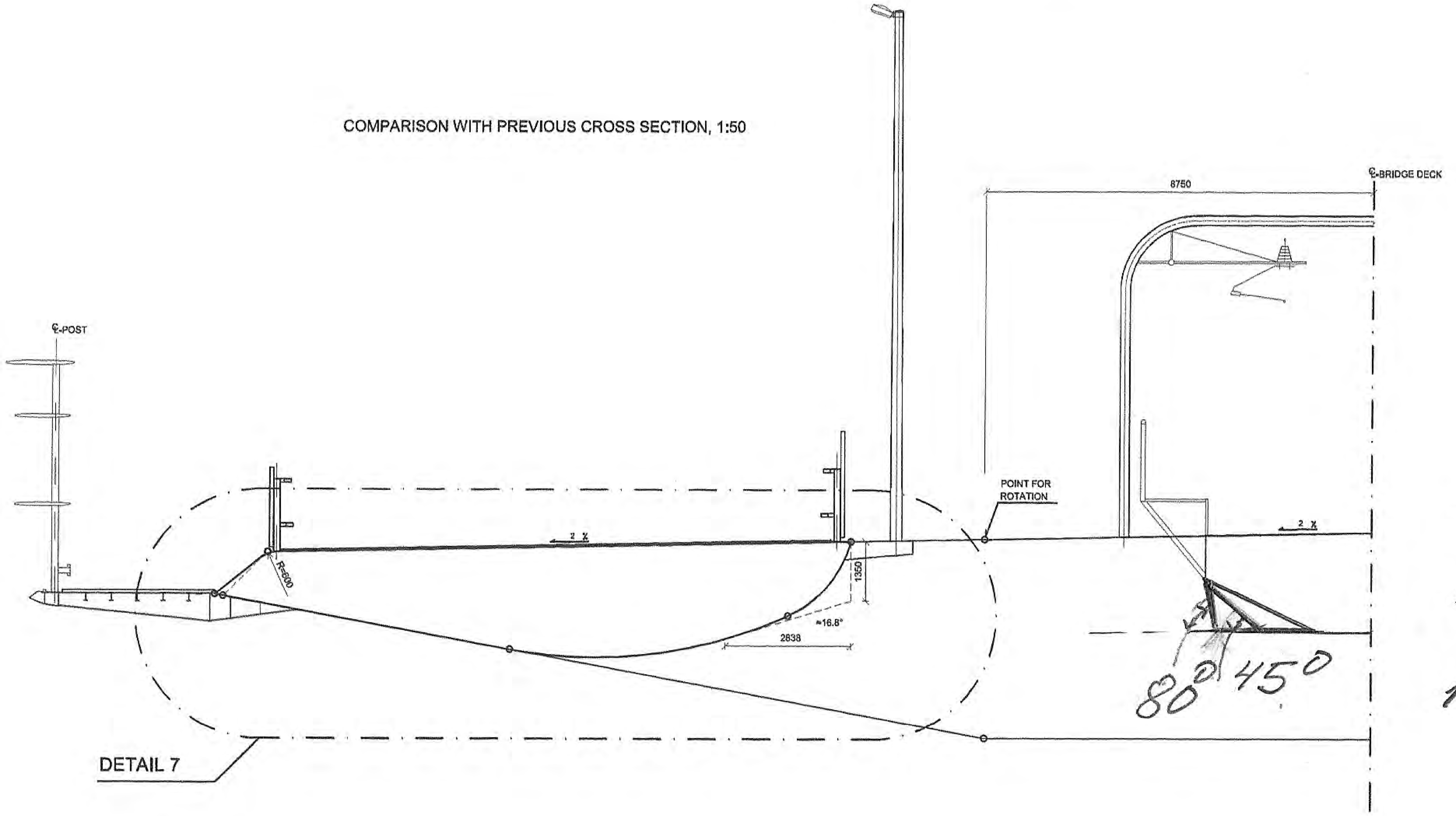
LEGEND:

- ——— LAYOUT OF CROSS SECTION FOR PROGETTO DEFINITIVO
- – – – LAYOUT OF CROSS SECTION BY ROTATION OF ROADWAY GIRDER AND PART OF CROSS GIRDER (LAYOUT AS IN TENDER DESIGN) AT ROTATION POINT. LAYOUT ROTATED 4%

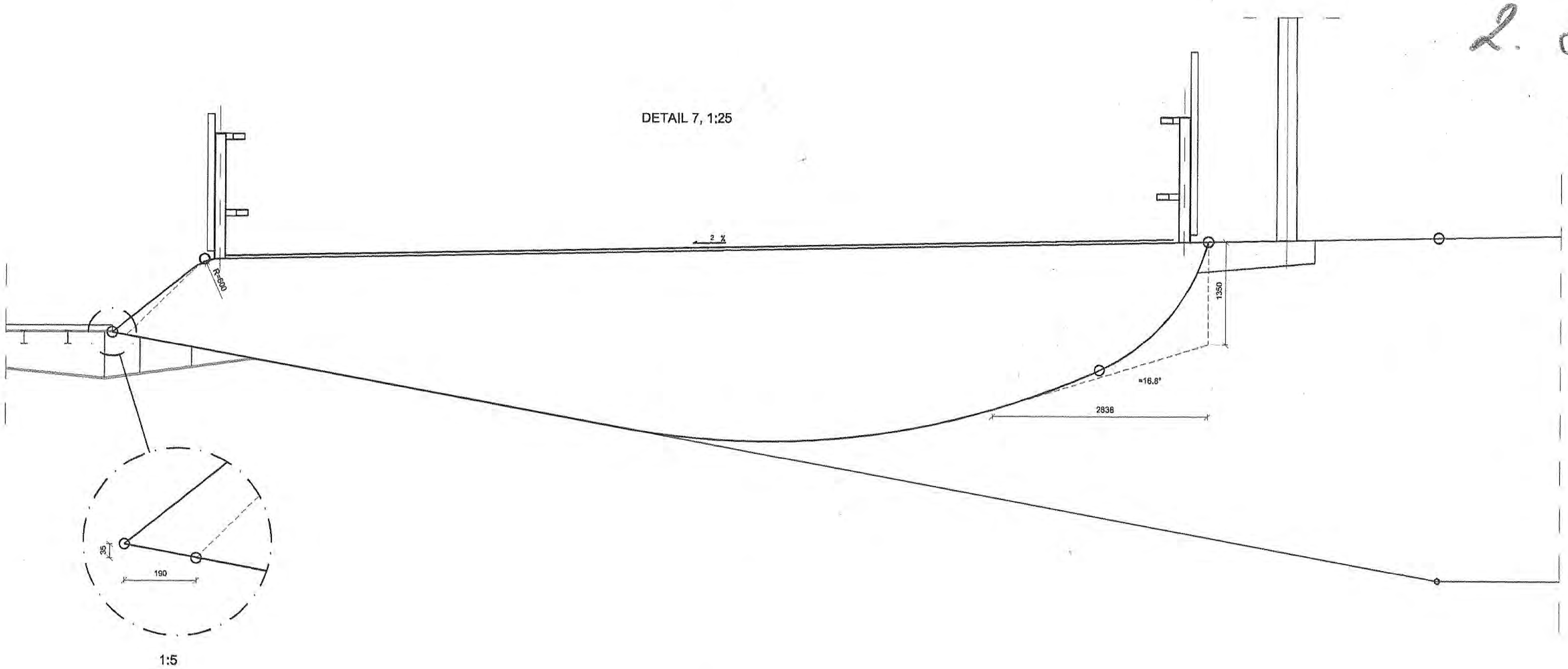
COMPARISON WITH PREVIOUS CROSS SECTION, 1:50



9-Aug-2010 / ALN

modifications
railway box girder
1. Sloping side panels
80° with horizontal
2. Sloping side panels
45° with horizontal

DETAIL 7, 1:25



Rev.	Date	Description	Designed	Checked	Approved

STRETTO DI MESSINA
BRIDGE OVER THE MESSINA STRAIT

Description
DECK SECTION FOR WIND TUNNEL TEST

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Designed	HEAE
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Date	2010/05/06
Document no.	107
Rev.	00

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APPENDIX B

The Boundary-Layer Wind Tunnel II

Wind Tunnel II

FORCE Technology's 2.6 m wide x 1.8 m high x 21 m long Boundary-Layer Wind Tunnel II is used for variety of studies. This wind tunnel has maximum wind speed of 24 m/s when empty. The ceiling of the wind tunnel was adjusted so that it was horizontal throughout the length of the wind tunnel. A principle sketch of this wind tunnel is given in Figure 9.1.

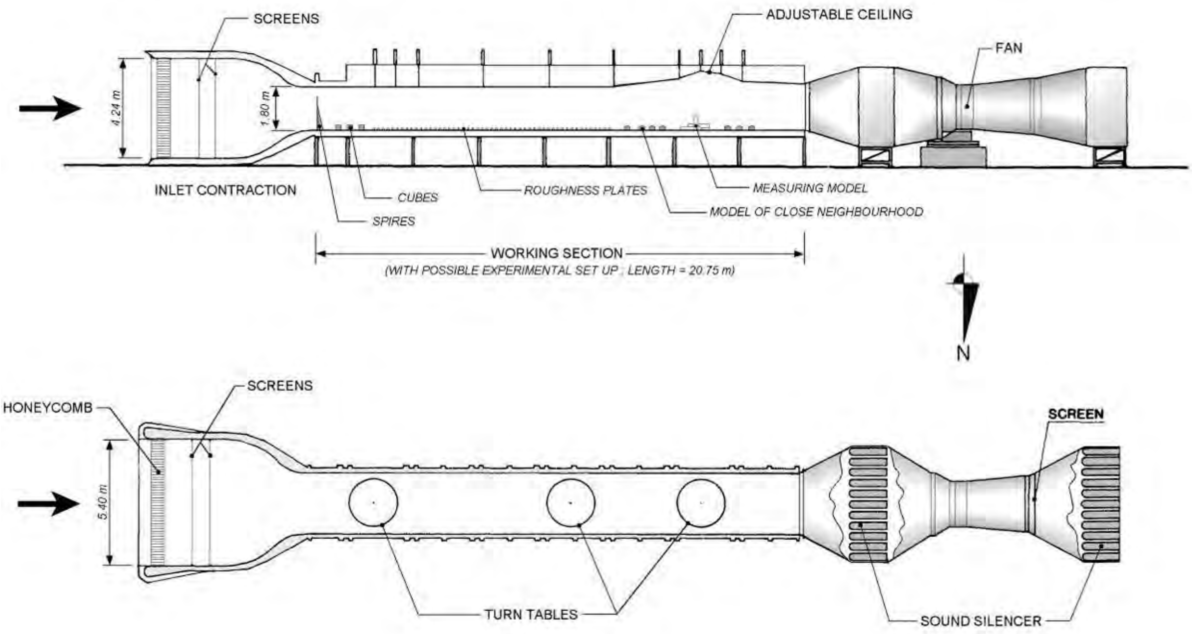


Figure 9.1. FORCE Technology's Boundary-Layer Wind Tunnel II.

Figure B.1. View along BLWT in Flow Direction.

The tunnel consists of an inlet section, a working section and a fan section. The air is sucked through the wind tunnel and returned through the building in which the wind tunnel is situated. In the inlet section, the air passes through a honeycomb, two fine-meshed nets and a contraction. Thus, a flow with uniform velocity and very little turbulence can be obtained. The working section has the following principal dimensions:

Length	=	20.8 m
Width	=	2.6 m
Height	=	1.8 - 2.3 m (adjustable).

The long working section is necessary to build up a natural boundary-layer wind profile.

Appendix C

Coherence Tests

Introduction

This Appendix documents the coherence measurements performed for the Messina Bridge – Sub-Test D4. The measurements were conducted at the position where the section model was mounted during the admittance (and static) tests.

The flow conditions were documented by means of Cobra probe anemometry.

Coherence Measurements

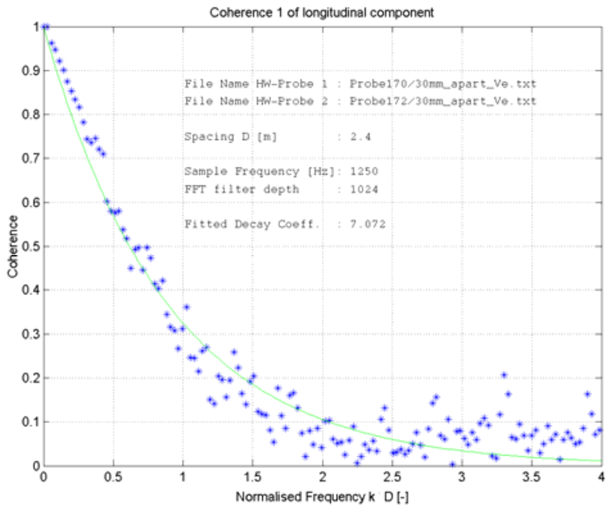
Flow coherence was calculated both for the longitudinal (u) and vertical (w) components at the centre of at the position of the section model during admittance (and static) tests. For comparison of the results, the frequency axis of the coherence graphs is normalised with the mean wind speed $\bar{U}$ and the distance D. Using the wave number $k=2\pi f/\bar{U}$ the normalised frequency axis is expressed as $k \cdot D$.

The characteristics of coherence measurements are commonly presented in form of decay coefficients, a_{ii}, as used in the exponential equation below:

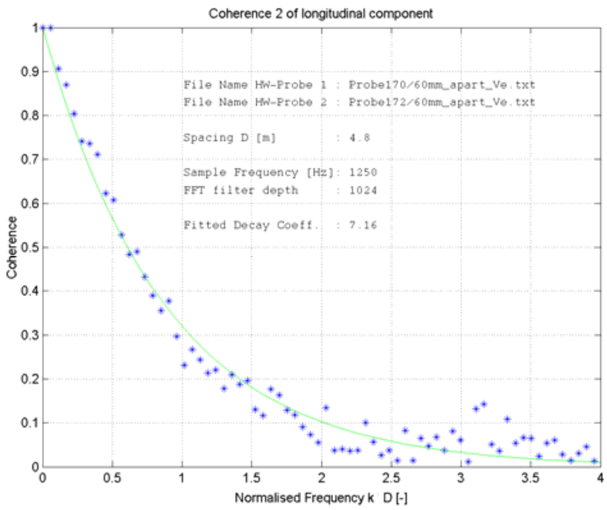
$$\gamma\{D\} = e^{-a_{ii}\frac{f \cdot D}{\bar{U}}}$$

In the graphs with the calculated coherences the above approximation is shown for a best fit and the value of the fitted decay coefficients are given in the graphs and summarized in a table.

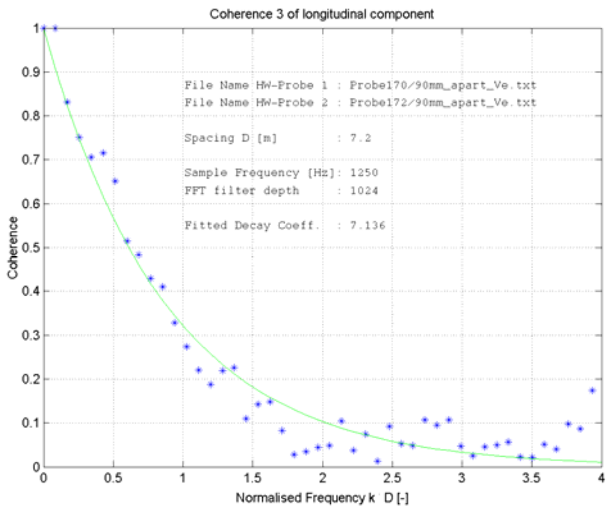
Measurements at Position for Aerodynamic Admittance Tests



Coherence of longitudinal flow component, measured at the bridge deck centre and 30 mm aside (2.4m full-scale).



Coherence of longitudinal flow component, measured at the bridge deck centre 60 mm aside (4.8m full-scale).



Coherence of longitudinal flow component, measured at the bridge deck centre and 90 mm aside (7.2m full-scale).

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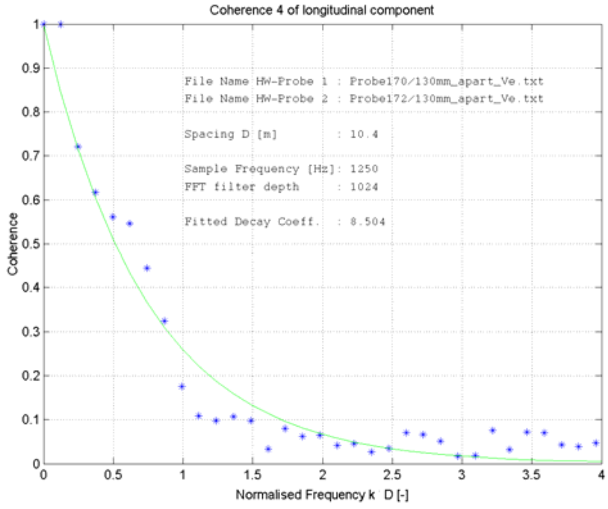
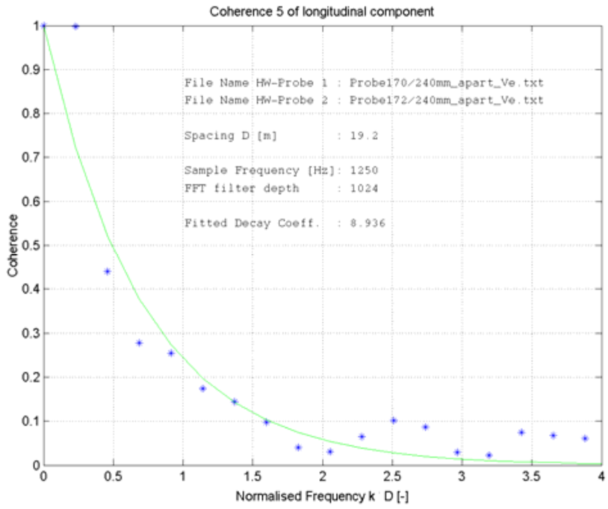
<td>
</td>
<td>Coherence of longitudinal flow component, measured at the bridge deck centre and 130 mm aside (10.4m full-scale).</td>
</tr>
<tr>
<td>
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<td>Coherence of longitudinal flow component, measured at the bridge deck centre and 240 mm aside (19.2m full-scale).</td>
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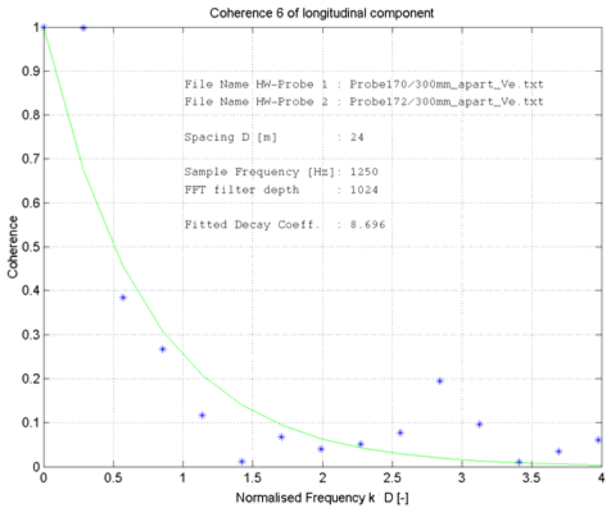
<tr>
<td>
</td>
<td>Coherence of longitudinal flow component, measured at the bridge deck centre and 300 mm aside (24m full-scale).</td>
</tr>
</table>

<table>
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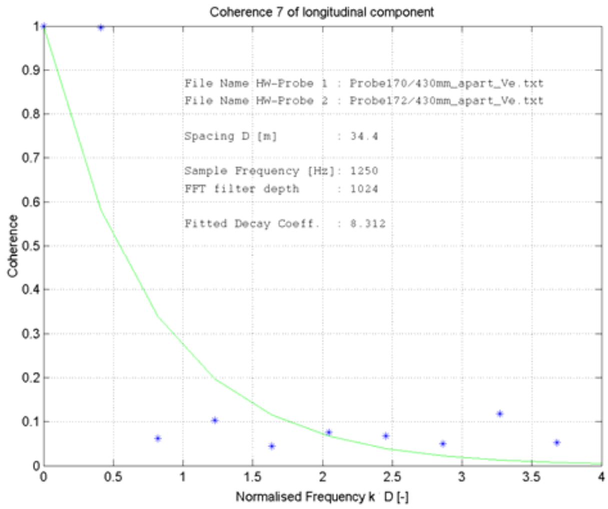
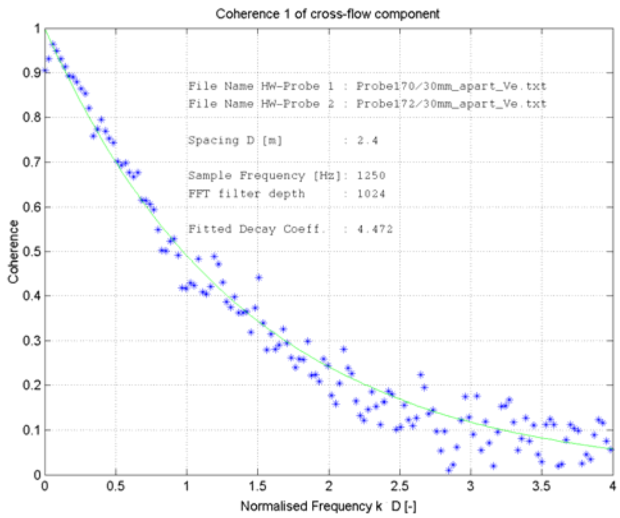
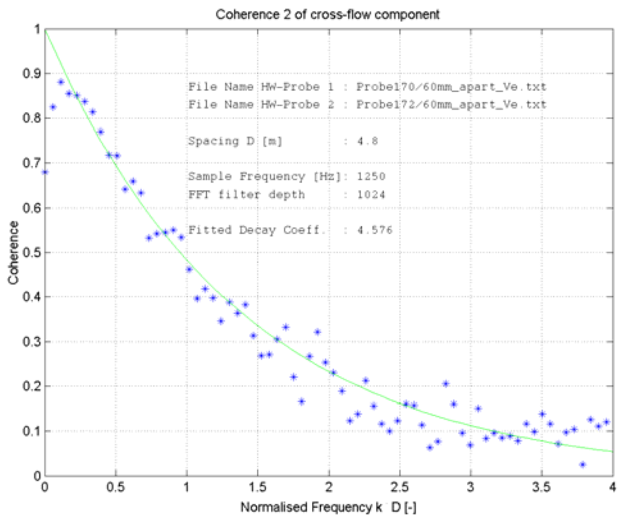
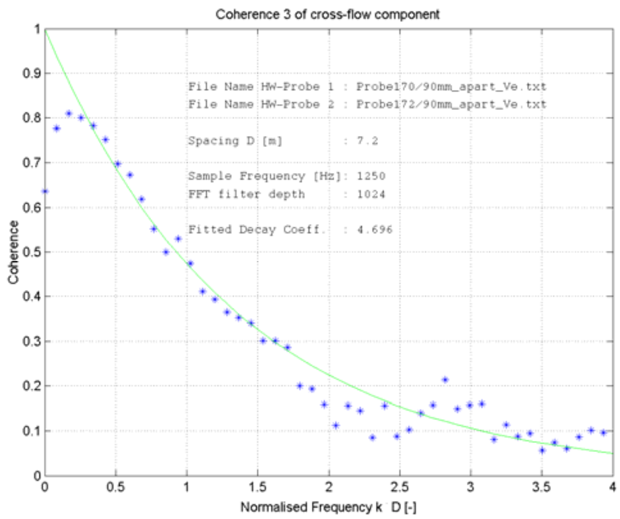
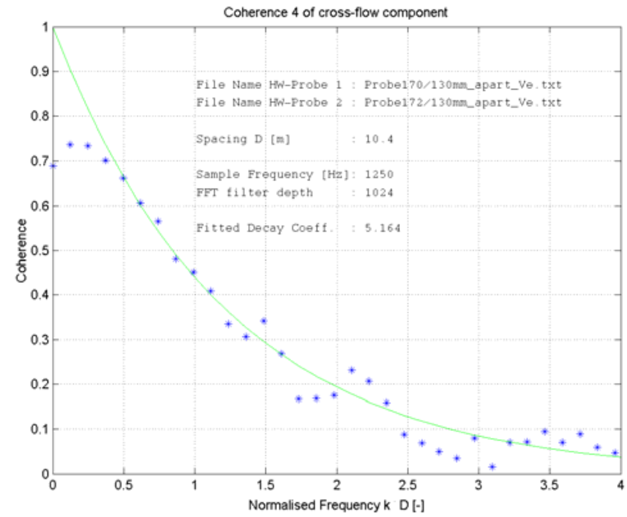
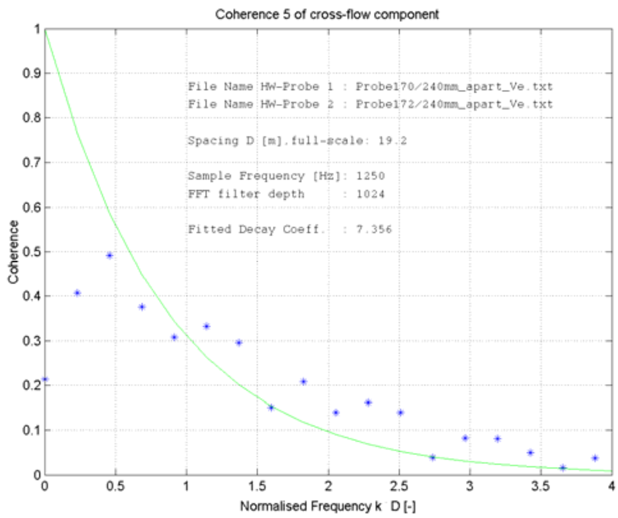
<td>
</td>
<td>Coherence of longitudinal flow component, measured at the bridge deck centre and 430 mm aside (34.4m full-scale).</td>
</tr>
</table>

Figure C.1 Flow coherence along the section model position.

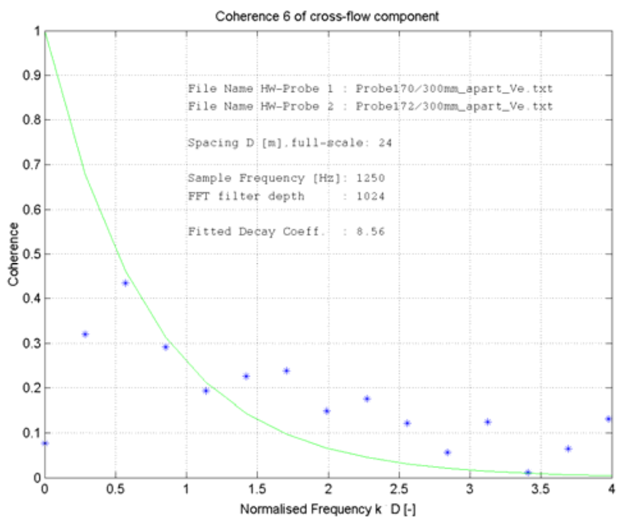
	Coherence of across wind flow component, measured at the bridge deck centre and 30 mm aside (2.4m full-scale).
	Coherence of across wind flow component, measured at the bridge deck centre 60 mm aside (4.8m full-scale).
	Coherence of across wind flow component, measured at the bridge deck centre and 90 mm aside (7.2m full-scale).



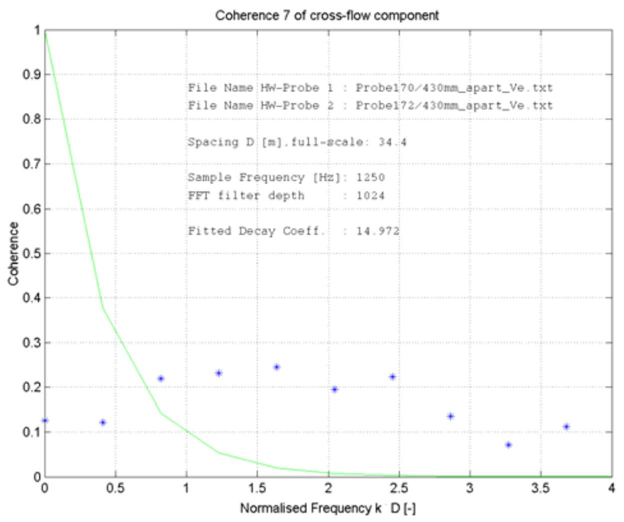
Coherence of across wind flow component, measured at the bridge deck centre and 130 mm aside (10.4m full-scale).



Coherence of across wind flow component, measured at the bridge deck centre and 240 mm aside (19.2m full-scale).



Coherence of across wind flow component, measured at the bridge deck centre and 300 mm aside (24m full-scale).



Coherence of across wind flow component, measured at the bridge deck centre and 430 mm aside (34.4m full-scale).

Figure C.2 Flow coherence along the section model position.

Spacing D [m]	Fitted Decay Coefficient for Longitudinal Flow Component	Fitted Decay Coefficient for Across Wind Flow Component
2.4	7.072	4.472
4.8	7.16	4.576
7.2	7.136	4.696
10.4	8.504	5.164
19.2	8.936	7.356
24	8.696	8.56
34.4	8.312	14.972

Table C.1 Fitted Decay Coefficients.

Appendix D

3D Flutter Tests

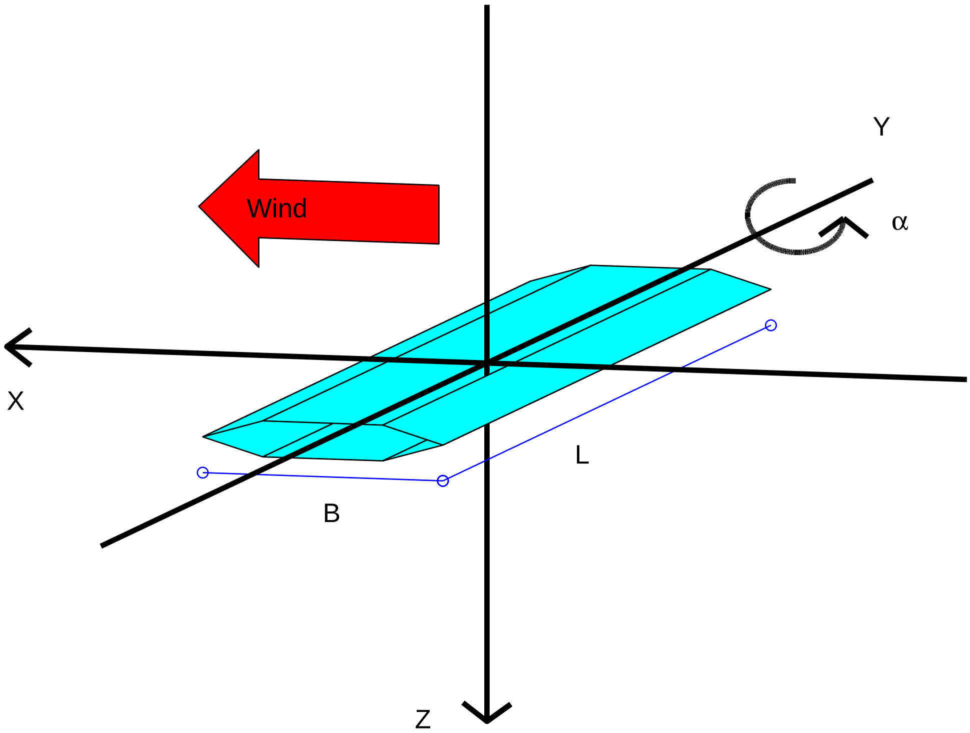
Flutter derivatives, Smooth flow, Angle of incidence = −6 deg.

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^oC	28.0
Relative humidity	ϕ	%	28
Barometric pressure	p	mmBar	1019.0

Table D.1: Project Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2\,m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2\,m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2\,m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h	: Vertical displacement, displacement along z-axis, [m]
α	: Rotation around y-axis, nose up is positive, [rad]
p	: Horizontal displacement, displacement along the x-axis, [m]
m	: Mass per unit length, [kg/m]
I_y	: Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$	: Added mass in vertical direction, [kg/m]
$m_{a,x}$	: Added mass in horizontal direction, [kg/m]
$I_{a,y}$	: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G	: X-coordinate for centre of gravity, [m]
Z_G	: Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$	: Natural circular frequency for vertical motion, [/s]
ζ_h	: Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$	: Natural circular frequency for rotation around y axis, [/s]
ζ_α	: Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$	: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p	: Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$	: Force from rig per meter section, [N/m]
$M_{Y,external}$	: Moment from rig per meter section, [Nm/m]
$F_{X,external}$	: Force from rig per meter section, [N/m]

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Formula D.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.385
Added mass in horizontal	$m_{a,x}$	kg/m	0.552
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.140
Horizontal centre of gravity	x_G	m	0.000
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.041
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.043
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.007

Table D.2: Mechanical Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula D.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

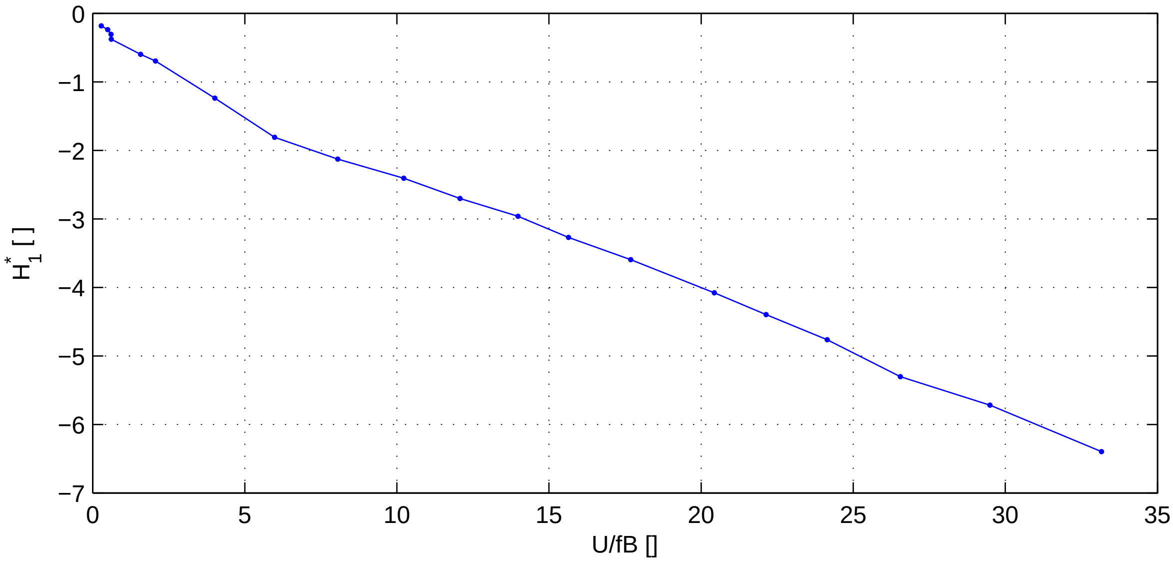

Figure D.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
0.86	25.13	4.00	22.12	0.28	−0.18
1.48	25.13	4.00	12.82	0.49	−0.24
1.83	25.13	4.00	10.39	0.60	−0.31
1.84	25.13	4.00	10.33	0.61	−0.38
4.77	25.13	4.00	3.98	1.58	−0.60
6.23	25.13	4.00	3.04	2.06	−0.70
12.13	25.13	4.00	1.56	4.02	−1.24
18.05	25.13	4.00	1.05	5.98	−1.81
20.07	20.74	3.30	0.78	8.05	−2.13
20.08	16.34	2.60	0.61	10.22	−2.41
20.05	13.82	2.20	0.52	12.07	−2.70
20.05	11.93	1.90	0.45	13.98	−2.96
20.06	10.68	1.70	0.40	15.64	−3.27
20.03	9.43	1.50	0.36	17.69	−3.60
20.05	8.17	1.30	0.31	20.44	−4.08
20.05	7.54	1.20	0.28	22.14	−4.40
20.05	6.91	1.10	0.26	24.15	−4.76
20.05	6.28	1.00	0.24	26.55	−5.30
20.04	5.66	0.90	0.21	29.49	−5.72
20.03	5.03	0.80	0.19	33.16	−6.40

Table D.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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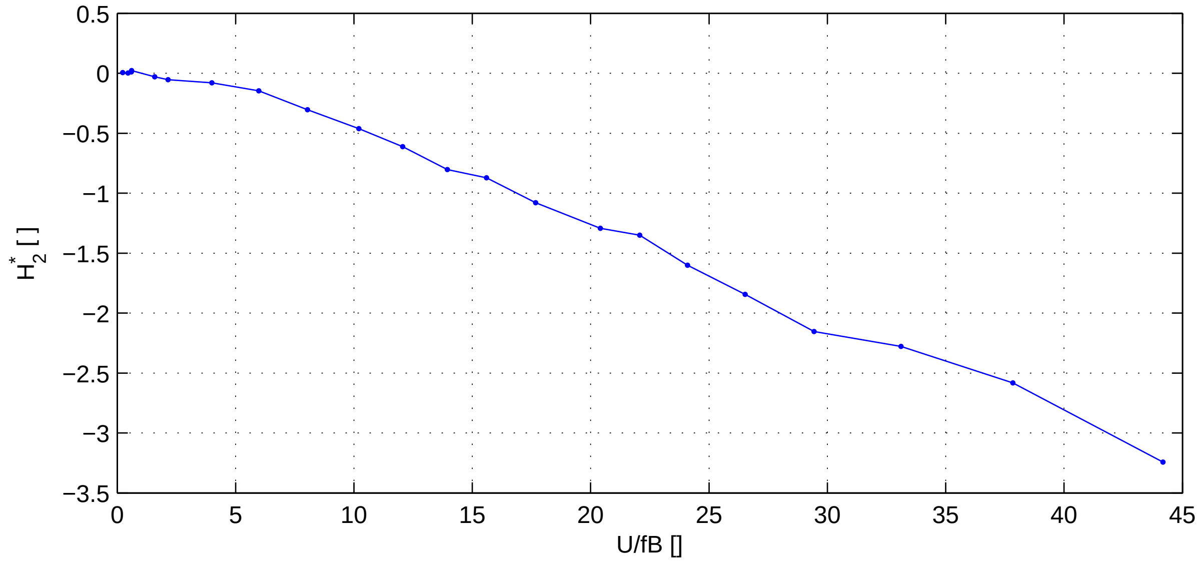

Figure D.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
0.69	25.13	4.00	27.40	0.23	0.00
1.37	25.13	4.00	13.87	0.45	0.00
1.82	25.13	4.00	10.45	0.60	0.01
1.84	25.13	4.00	10.33	0.61	0.02
4.77	25.13	4.00	3.98	1.58	−0.03
6.49	25.13	4.00	2.92	2.15	−0.05
12.07	25.13	4.00	1.57	4.00	−0.08
18.07	25.13	4.00	1.05	5.98	−0.15
20.03	20.74	3.30	0.78	8.04	−0.31
20.04	16.34	2.60	0.62	10.20	−0.46
20.02	13.82	2.20	0.52	12.05	−0.61
20.01	11.93	1.90	0.45	13.95	−0.80
20.02	10.68	1.70	0.40	15.60	−0.87
20.02	9.43	1.50	0.36	17.67	−1.08
20.02	8.17	1.30	0.31	20.41	−1.29
20.00	7.54	1.20	0.28	22.08	−1.35
20.01	6.91	1.10	0.26	24.09	−1.60
20.02	6.28	1.00	0.24	26.52	−1.84
20.00	5.66	0.90	0.21	29.44	−2.15
20.00	5.03	0.80	0.19	33.11	−2.28
20.00	4.40	0.70	0.17	37.84	−2.58
20.01	3.77	0.60	0.14	44.17	−3.24

Table D.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

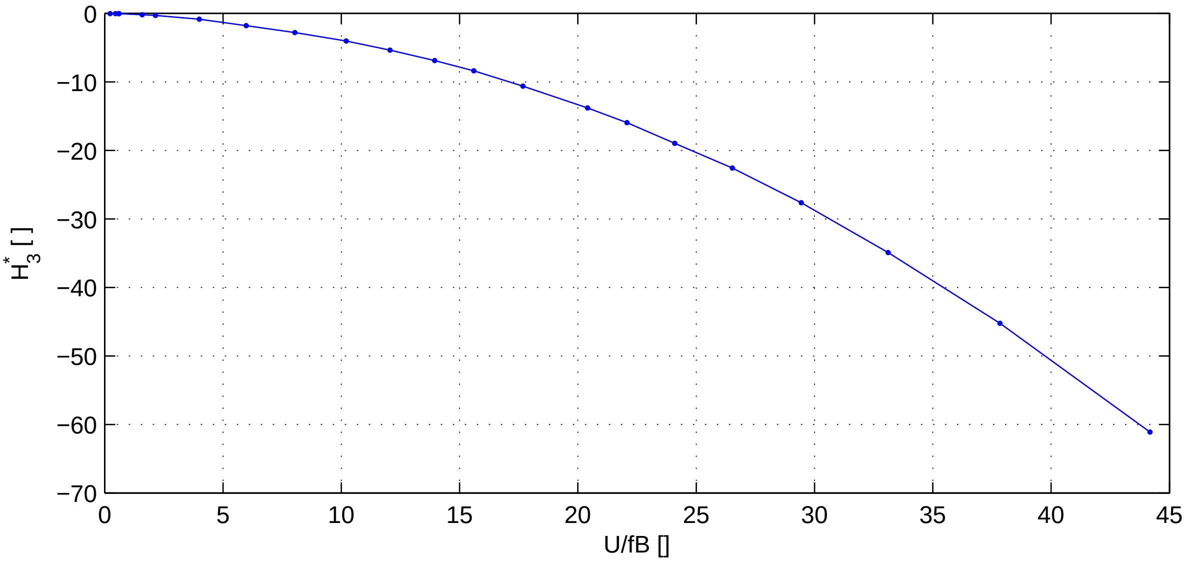

Figure D.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
0.69	25.13	4.00	27.40	0.23	−0.05
1.37	25.13	4.00	13.87	0.45	−0.05
1.82	25.13	4.00	10.45	0.60	−0.05
1.84	25.13	4.00	10.33	0.61	−0.06
4.77	25.13	4.00	3.98	1.58	−0.21
6.49	25.13	4.00	2.92	2.15	−0.30
12.07	25.13	4.00	1.57	4.00	−0.86
18.07	25.13	4.00	1.05	5.98	−1.81
20.03	20.74	3.30	0.78	8.04	−2.82
20.04	16.34	2.60	0.62	10.20	−4.05
20.02	13.82	2.20	0.52	12.05	−5.36
20.01	11.93	1.90	0.45	13.95	−6.89
20.02	10.68	1.70	0.40	15.60	−8.40
20.02	9.43	1.50	0.36	17.67	−10.62
20.02	8.17	1.30	0.31	20.41	−13.82
20.00	7.54	1.20	0.28	22.08	−15.97
20.01	6.91	1.10	0.26	24.09	−18.97
20.02	6.28	1.00	0.24	26.52	−22.59
20.00	5.66	0.90	0.21	29.44	−27.66
20.00	5.03	0.80	0.19	33.11	−34.93
20.00	4.40	0.70	0.17	37.84	−45.24
20.01	3.77	0.60	0.14	44.17	−61.12

Table D.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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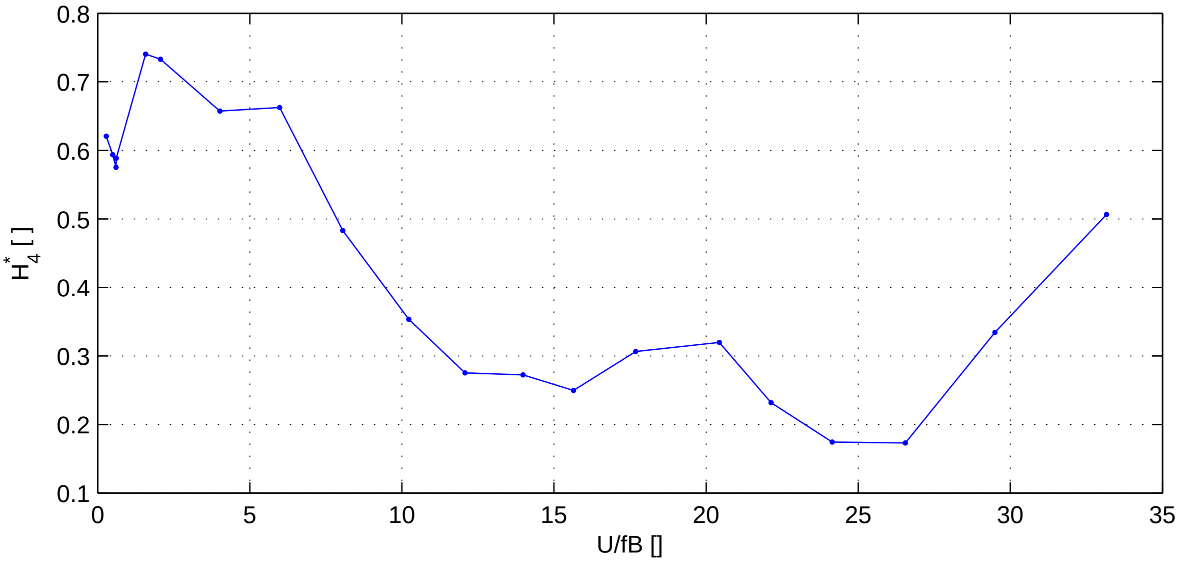

Figure D.4: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_4^*
0.86	25.13	4.00	22.12	0.28	0.62
1.48	25.13	4.00	12.82	0.49	0.59
1.83	25.13	4.00	10.39	0.60	0.58
1.84	25.13	4.00	10.33	0.61	0.59
4.77	25.13	4.00	3.98	1.58	0.74
6.23	25.13	4.00	3.04	2.06	0.73
12.13	25.13	4.00	1.56	4.02	0.66
18.05	25.13	4.00	1.05	5.98	0.66
20.07	20.74	3.30	0.78	8.05	0.48
20.08	16.34	2.60	0.61	10.22	0.35
20.05	13.82	2.20	0.52	12.07	0.28
20.05	11.93	1.90	0.45	13.98	0.27
20.06	10.68	1.70	0.40	15.64	0.25
20.03	9.43	1.50	0.36	17.69	0.31
20.05	8.17	1.30	0.31	20.44	0.32
20.05	7.54	1.20	0.28	22.14	0.23
20.05	6.91	1.10	0.26	24.15	0.17
20.05	6.28	1.00	0.24	26.55	0.17
20.04	5.66	0.90	0.21	29.49	0.33
20.03	5.03	0.80	0.19	33.16	0.51

Table D.6: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

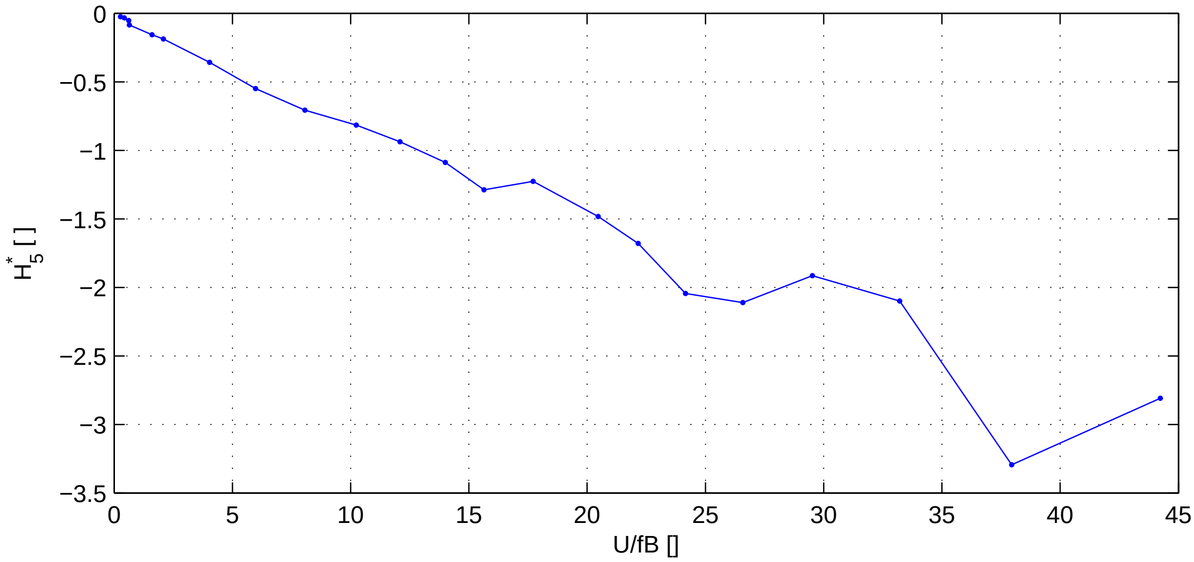

Figure D.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
0.80	25.13	4.00	23.65	0.27	−0.03
1.29	25.13	4.00	14.72	0.43	−0.03
1.85	25.13	4.00	10.25	0.61	−0.05
1.95	25.13	4.00	9.73	0.65	−0.08
4.84	25.13	4.00	3.92	1.60	−0.16
6.28	25.13	4.00	3.02	2.08	−0.19
12.18	25.13	4.00	1.56	4.03	−0.36
18.07	25.13	4.00	1.05	5.98	−0.55
20.10	20.74	3.30	0.78	8.07	−0.71
20.10	16.34	2.60	0.61	10.24	−0.82
20.08	13.82	2.20	0.52	12.09	−0.94
20.08	11.93	1.90	0.45	14.00	−1.09
20.06	10.68	1.70	0.40	15.64	−1.29
20.07	9.43	1.50	0.35	17.71	−1.23
20.08	8.17	1.30	0.31	20.46	−1.48
20.07	7.54	1.20	0.28	22.16	−1.68
20.07	6.91	1.10	0.26	24.16	−2.04
20.07	6.28	1.00	0.24	26.58	−2.11
20.06	5.66	0.90	0.21	29.52	−1.92
20.06	5.03	0.80	0.19	33.22	−2.10
20.05	4.40	0.70	0.17	37.95	−3.29
20.04	3.77	0.60	0.14	44.23	−2.81

Table D.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

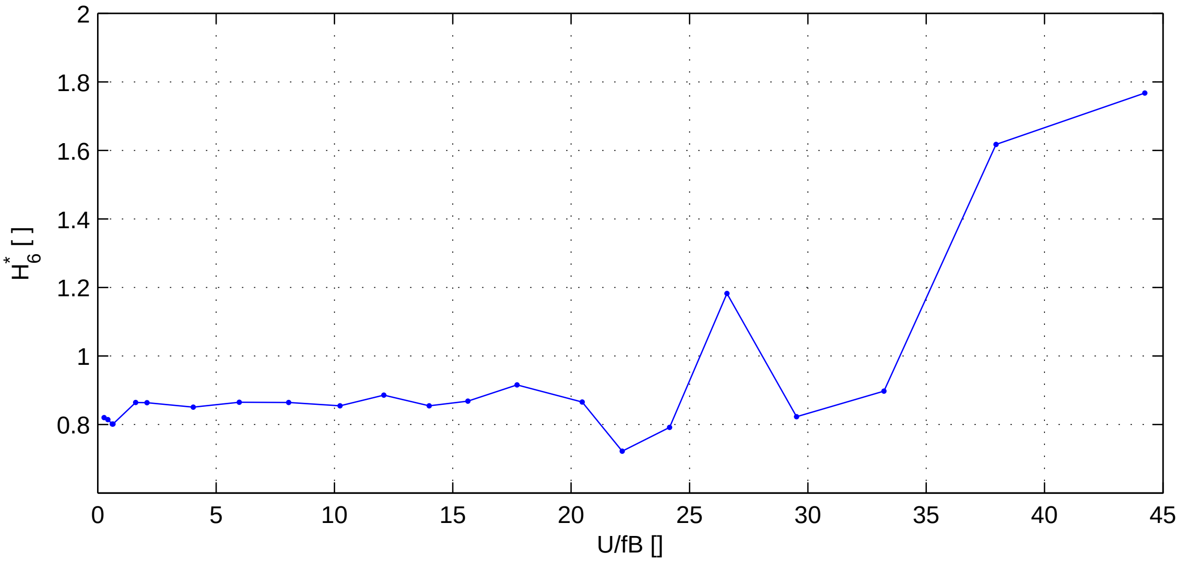

Figure D.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
0.80	25.13	4.00	23.65	0.27	0.82
1.29	25.13	4.00	14.72	0.43	0.81
1.85	25.13	4.00	10.25	0.61	0.80
1.95	25.13	4.00	9.73	0.65	0.80
4.84	25.13	4.00	3.92	1.60	0.86
6.28	25.13	4.00	3.02	2.08	0.86
12.18	25.13	4.00	1.56	4.03	0.85
18.07	25.13	4.00	1.05	5.98	0.86
20.10	20.74	3.30	0.78	8.07	0.86
20.10	16.34	2.60	0.61	10.24	0.85
20.08	13.82	2.20	0.52	12.09	0.89
20.08	11.93	1.90	0.45	14.00	0.85
20.06	10.68	1.70	0.40	15.64	0.87
20.07	9.43	1.50	0.35	17.71	0.92
20.08	8.17	1.30	0.31	20.46	0.87
20.07	7.54	1.20	0.28	22.16	0.72
20.07	6.91	1.10	0.26	24.16	0.79
20.07	6.28	1.00	0.24	26.58	1.18
20.06	5.66	0.90	0.21	29.52	0.82
20.06	5.03	0.80	0.19	33.22	0.90
20.05	4.40	0.70	0.17	37.95	1.62
20.04	3.77	0.60	0.14	44.23	1.77

Table D.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

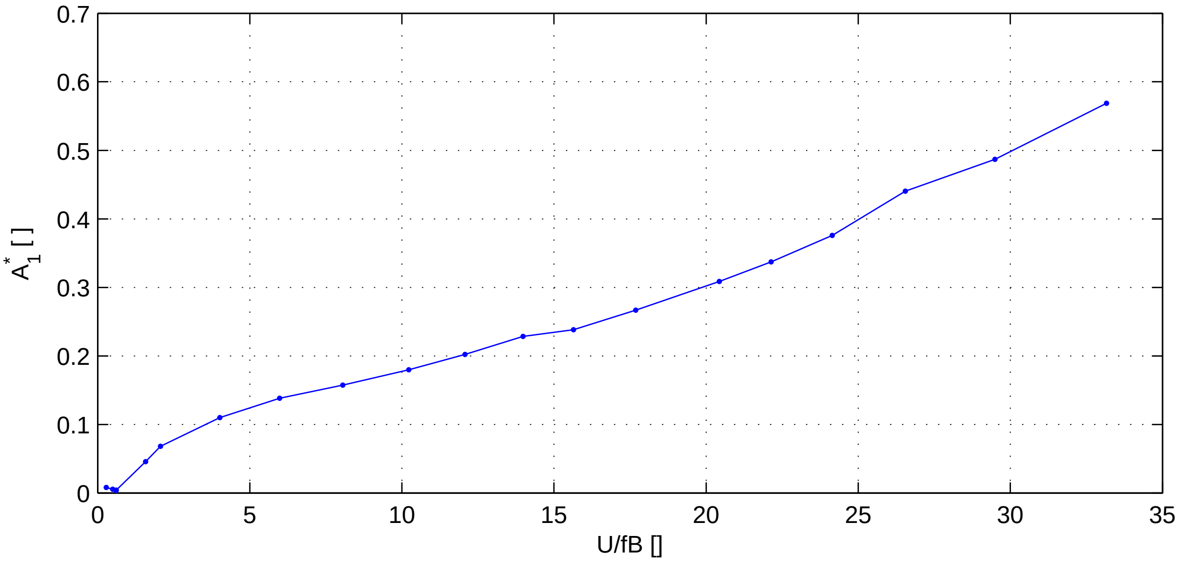

Figure D.7: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_1^*
0.86	25.13	4.00	22.12	0.28	0.01
1.48	25.13	4.00	12.82	0.49	0.01
1.83	25.13	4.00	10.39	0.60	0.00
1.84	25.13	4.00	10.33	0.61	0.00
4.77	25.13	4.00	3.98	1.58	0.05
6.23	25.13	4.00	3.04	2.06	0.07
12.13	25.13	4.00	1.56	4.02	0.11
18.05	25.13	4.00	1.05	5.98	0.14
20.07	20.74	3.30	0.78	8.05	0.16
20.08	16.34	2.60	0.61	10.22	0.18
20.05	13.82	2.20	0.52	12.07	0.20
20.05	11.93	1.90	0.45	13.98	0.23
20.06	10.68	1.70	0.40	15.64	0.24
20.03	9.43	1.50	0.36	17.69	0.27
20.05	8.17	1.30	0.31	20.44	0.31
20.05	7.54	1.20	0.28	22.14	0.34
20.05	6.91	1.10	0.26	24.15	0.38
20.05	6.28	1.00	0.24	26.55	0.44
20.04	5.66	0.90	0.21	29.49	0.49
20.03	5.03	0.80	0.19	33.16	0.57

Table D.9: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

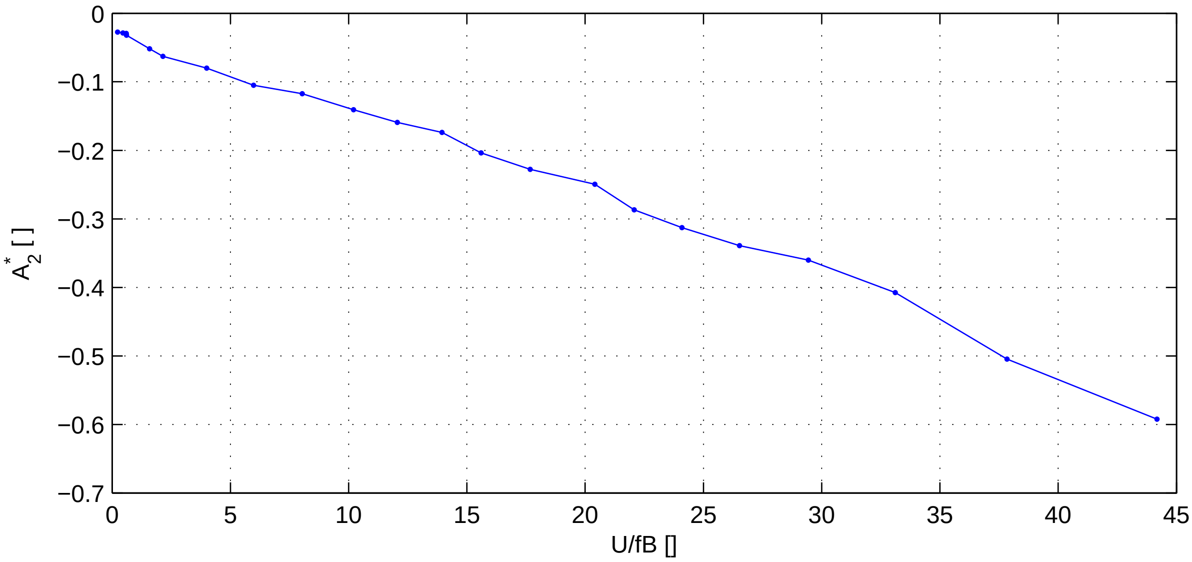

Figure D.8: A^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_2
0.69	25.13	4.00	27.40	0.23	−0.03
1.37	25.13	4.00	13.87	0.45	−0.03
1.82	25.13	4.00	10.45	0.60	−0.03
1.84	25.13	4.00	10.33	0.61	−0.03
4.77	25.13	4.00	3.98	1.58	−0.05
6.49	25.13	4.00	2.92	2.15	−0.06
12.07	25.13	4.00	1.57	4.00	−0.08
18.07	25.13	4.00	1.05	5.98	−0.11
20.03	20.74	3.30	0.78	8.04	−0.12
20.04	16.34	2.60	0.62	10.20	−0.14
20.02	13.82	2.20	0.52	12.05	−0.16
20.01	11.93	1.90	0.45	13.95	−0.17
20.02	10.68	1.70	0.40	15.60	−0.20
20.02	9.43	1.50	0.36	17.67	−0.23
20.02	8.17	1.30	0.31	20.41	−0.25
20.00	7.54	1.20	0.28	22.08	−0.29
20.01	6.91	1.10	0.26	24.09	−0.31
20.02	6.28	1.00	0.24	26.52	−0.34
20.00	5.66	0.90	0.21	29.44	−0.36
20.00	5.03	0.80	0.19	33.11	−0.41
20.00	4.40	0.70	0.17	37.84	−0.50
20.01	3.77	0.60	0.14	44.17	−0.59

Table D.10: A^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

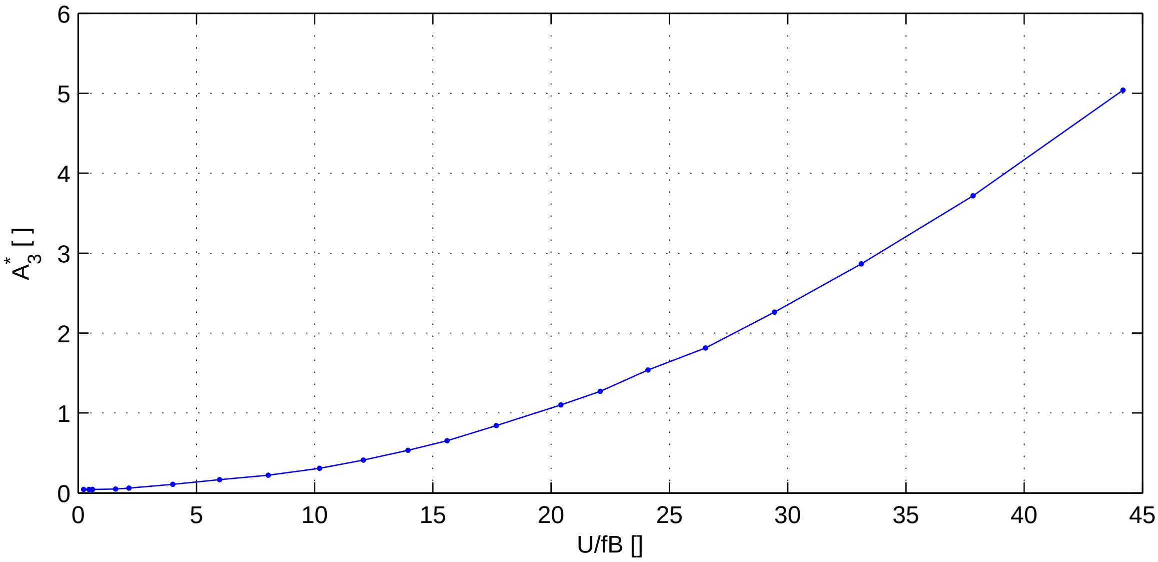

Figure D.9: A^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_3
0.69	25.13	4.00	27.40	0.23	0.04
1.37	25.13	4.00	13.87	0.45	0.04
1.82	25.13	4.00	10.45	0.60	0.04
1.84	25.13	4.00	10.33	0.61	0.04
4.77	25.13	4.00	3.98	1.58	0.05
6.49	25.13	4.00	2.92	2.15	0.06
12.07	25.13	4.00	1.57	4.00	0.11
18.07	25.13	4.00	1.05	5.98	0.16
20.03	20.74	3.30	0.78	8.04	0.22
20.04	16.34	2.60	0.62	10.20	0.31
20.02	13.82	2.20	0.52	12.05	0.41
20.01	11.93	1.90	0.45	13.95	0.53
20.02	10.68	1.70	0.40	15.60	0.65
20.02	9.43	1.50	0.36	17.67	0.84
20.02	8.17	1.30	0.31	20.41	1.10
20.00	7.54	1.20	0.28	22.08	1.27
20.01	6.91	1.10	0.26	24.09	1.54
20.02	6.28	1.00	0.24	26.52	1.81
20.00	5.66	0.90	0.21	29.44	2.26
20.00	5.03	0.80	0.19	33.11	2.86
20.00	4.40	0.70	0.17	37.84	3.72
20.01	3.77	0.60	0.14	44.17	5.04

Table D.11: A^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

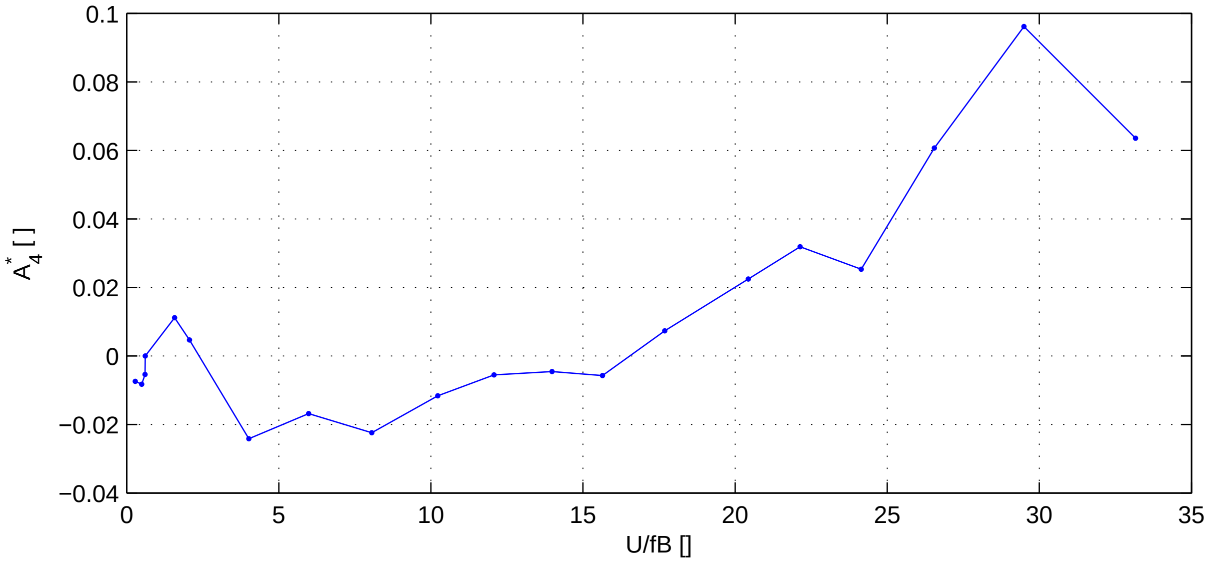

Figure D.10: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_4^*
0.86	25.13	4.00	22.12	0.28	−0.01
1.48	25.13	4.00	12.82	0.49	−0.01
1.83	25.13	4.00	10.39	0.60	−0.01
1.84	25.13	4.00	10.33	0.61	−0.00
4.77	25.13	4.00	3.98	1.58	0.01
6.23	25.13	4.00	3.04	2.06	0.00
12.13	25.13	4.00	1.56	4.02	−0.02
18.05	25.13	4.00	1.05	5.98	−0.02
20.07	20.74	3.30	0.78	8.05	−0.02
20.08	16.34	2.60	0.61	10.22	−0.01
20.05	13.82	2.20	0.52	12.07	−0.01
20.05	11.93	1.90	0.45	13.98	−0.00
20.06	10.68	1.70	0.40	15.64	−0.01
20.03	9.43	1.50	0.36	17.69	0.01
20.05	8.17	1.30	0.31	20.44	0.02
20.05	7.54	1.20	0.28	22.14	0.03
20.05	6.91	1.10	0.26	24.15	0.03
20.05	6.28	1.00	0.24	26.55	0.06
20.04	5.66	0.90	0.21	29.49	0.10
20.03	5.03	0.80	0.19	33.16	0.06

Table D.12: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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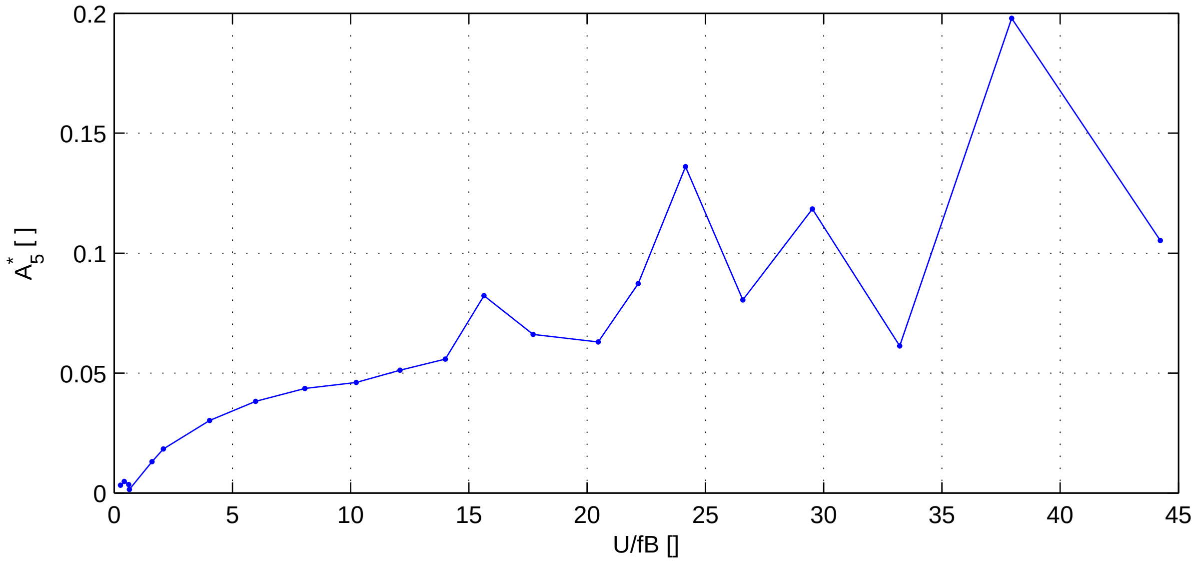

Figure D.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
0.80	25.13	4.00	23.65	0.27	0.00
1.29	25.13	4.00	14.72	0.43	0.00
1.85	25.13	4.00	10.25	0.61	0.00
1.95	25.13	4.00	9.73	0.65	0.00
4.84	25.13	4.00	3.92	1.60	0.01
6.28	25.13	4.00	3.02	2.08	0.02
12.18	25.13	4.00	1.56	4.03	0.03
18.07	25.13	4.00	1.05	5.98	0.04
20.10	20.74	3.30	0.78	8.07	0.04
20.10	16.34	2.60	0.61	10.24	0.05
20.08	13.82	2.20	0.52	12.09	0.05
20.08	11.93	1.90	0.45	14.00	0.06
20.06	10.68	1.70	0.40	15.64	0.08
20.07	9.43	1.50	0.35	17.71	0.07
20.08	8.17	1.30	0.31	20.46	0.06
20.07	7.54	1.20	0.28	22.16	0.09
20.07	6.91	1.10	0.26	24.16	0.14
20.07	6.28	1.00	0.24	26.58	0.08
20.06	5.66	0.90	0.21	29.52	0.12
20.06	5.03	0.80	0.19	33.22	0.06
20.05	4.40	0.70	0.17	37.95	0.20
20.04	3.77	0.60	0.14	44.23	0.11

Table D.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

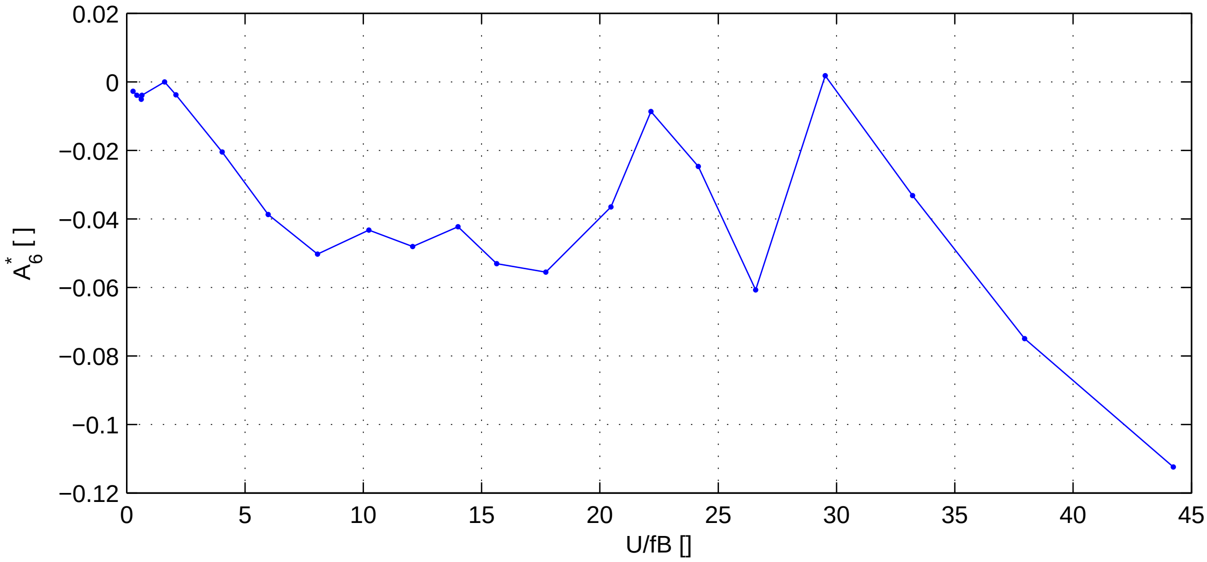

Figure D.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
0.80	25.13	4.00	23.65	0.27	−0.00
1.29	25.13	4.00	14.72	0.43	−0.00
1.85	25.13	4.00	10.25	0.61	−0.01
1.95	25.13	4.00	9.73	0.65	−0.00
4.84	25.13	4.00	3.92	1.60	−0.00
6.28	25.13	4.00	3.02	2.08	−0.00
12.18	25.13	4.00	1.56	4.03	−0.02
18.07	25.13	4.00	1.05	5.98	−0.04
20.10	20.74	3.30	0.78	8.07	−0.05
20.10	16.34	2.60	0.61	10.24	−0.04
20.08	13.82	2.20	0.52	12.09	−0.05
20.08	11.93	1.90	0.45	14.00	−0.04
20.06	10.68	1.70	0.40	15.64	−0.05
20.07	9.43	1.50	0.35	17.71	−0.06
20.08	8.17	1.30	0.31	20.46	−0.04
20.07	7.54	1.20	0.28	22.16	−0.01
20.07	6.91	1.10	0.26	24.16	−0.02
20.07	6.28	1.00	0.24	26.58	−0.06
20.06	5.66	0.90	0.21	29.52	0.00
20.06	5.03	0.80	0.19	33.22	−0.03
20.05	4.40	0.70	0.17	37.95	−0.07
20.04	3.77	0.60	0.14	44.23	−0.11

Table D.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

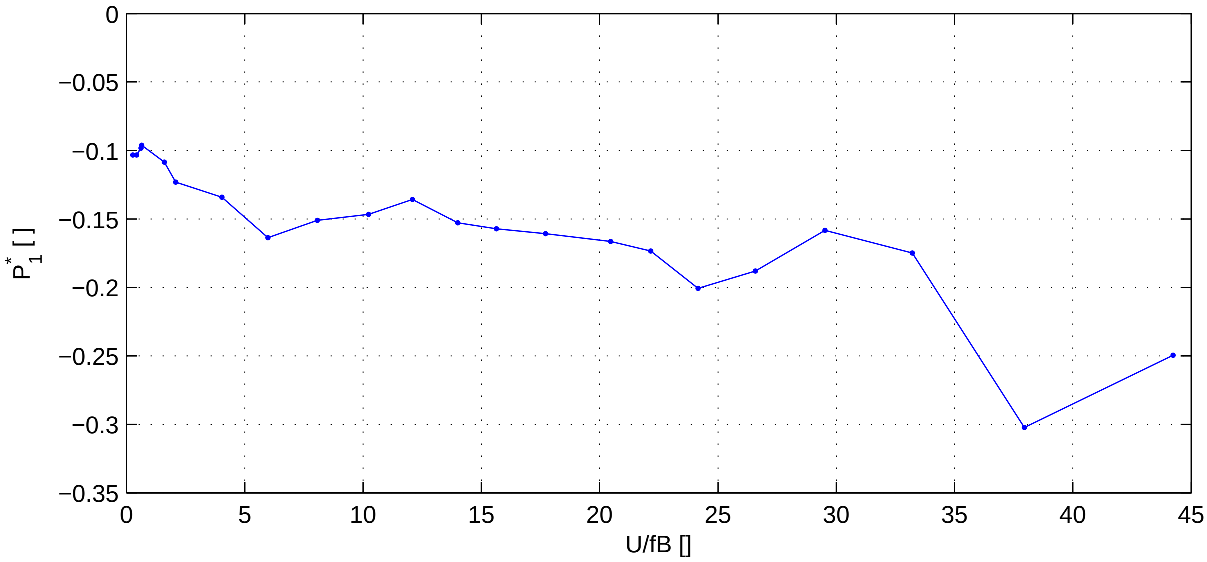

Figure D.13: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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U m/s	Omega rad/s	f /s	K	U/fB	P_1^*
0.80	25.13	4.00	23.65	0.27	−0.10
1.29	25.13	4.00	14.72	0.43	−0.10
1.85	25.13	4.00	10.25	0.61	−0.10
1.95	25.13	4.00	9.73	0.65	−0.10
4.84	25.13	4.00	3.92	1.60	−0.11
6.28	25.13	4.00	3.02	2.08	−0.12
12.18	25.13	4.00	1.56	4.03	−0.13
18.07	25.13	4.00	1.05	5.98	−0.16
20.10	20.74	3.30	0.78	8.07	−0.15
20.10	16.34	2.60	0.61	10.24	−0.15
20.08	13.82	2.20	0.52	12.09	−0.14
20.08	11.93	1.90	0.45	14.00	−0.15
20.06	10.68	1.70	0.40	15.64	−0.16
20.07	9.43	1.50	0.35	17.71	−0.16
20.08	8.17	1.30	0.31	20.46	−0.17
20.07	7.54	1.20	0.28	22.16	−0.17
20.07	6.91	1.10	0.26	24.16	−0.20
20.07	6.28	1.00	0.24	26.58	−0.19
20.06	5.66	0.90	0.21	29.52	−0.16
20.06	5.03	0.80	0.19	33.22	−0.17
20.05	4.40	0.70	0.17	37.95	−0.30
20.04	3.77	0.60	0.14	44.23	−0.25

Table D.15: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

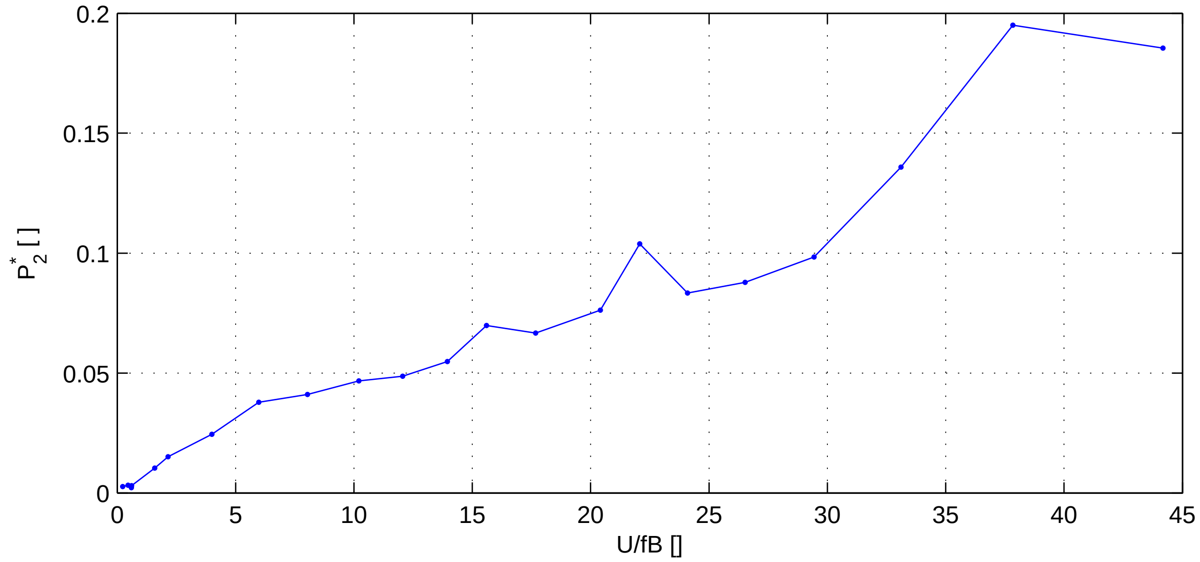

Figure D.14: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_2
0.69	25.13	4.00	27.40	0.23	0.00
1.37	25.13	4.00	13.87	0.45	0.00
1.82	25.13	4.00	10.45	0.60	0.00
1.84	25.13	4.00	10.33	0.61	0.00
4.77	25.13	4.00	3.98	1.58	0.01
6.49	25.13	4.00	2.92	2.15	0.02
12.07	25.13	4.00	1.57	4.00	0.02
18.07	25.13	4.00	1.05	5.98	0.04
20.03	20.74	3.30	0.78	8.04	0.04
20.04	16.34	2.60	0.62	10.20	0.05
20.02	13.82	2.20	0.52	12.05	0.05
20.01	11.93	1.90	0.45	13.95	0.05
20.02	10.68	1.70	0.40	15.60	0.07
20.02	9.43	1.50	0.36	17.67	0.07
20.02	8.17	1.30	0.31	20.41	0.08
20.00	7.54	1.20	0.28	22.08	0.10
20.01	6.91	1.10	0.26	24.09	0.08
20.02	6.28	1.00	0.24	26.52	0.09
20.00	5.66	0.90	0.21	29.44	0.10
20.00	5.03	0.80	0.19	33.11	0.14
20.00	4.40	0.70	0.17	37.84	0.20
20.01	3.77	0.60	0.14	44.17	0.19

Table D.16: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

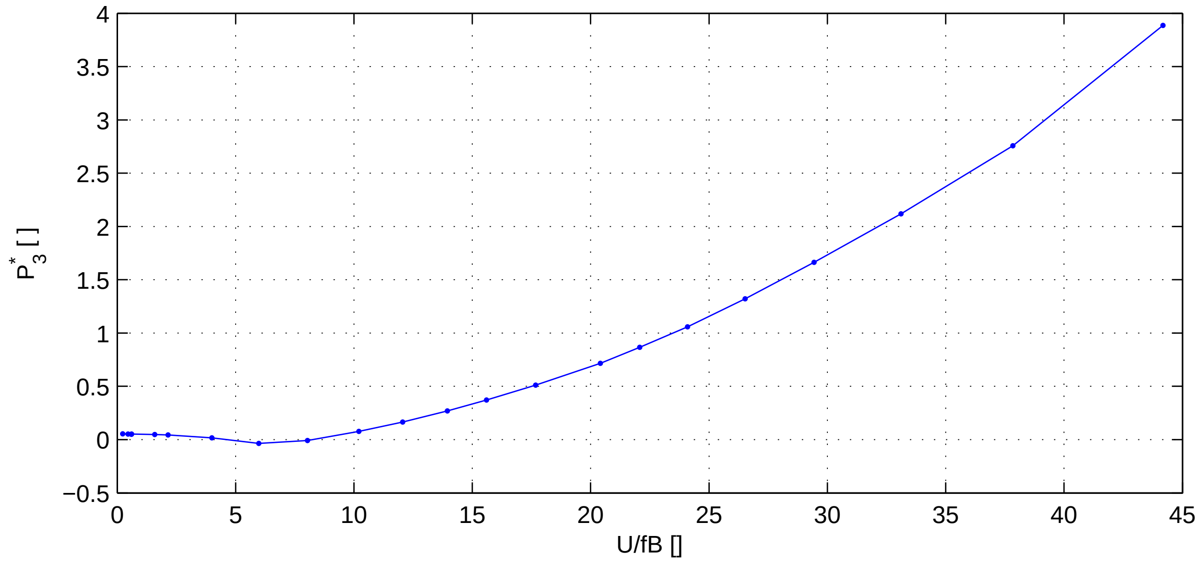

Figure D.15: P_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_3^*
0.69	25.13	4.00	27.40	0.23	0.05
1.37	25.13	4.00	13.87	0.45	0.05
1.82	25.13	4.00	10.45	0.60	0.05
1.84	25.13	4.00	10.33	0.61	0.05
4.77	25.13	4.00	3.98	1.58	0.05
6.49	25.13	4.00	2.92	2.15	0.04
12.07	25.13	4.00	1.57	4.00	0.02
18.07	25.13	4.00	1.05	5.98	−0.04
20.03	20.74	3.30	0.78	8.04	−0.01
20.04	16.34	2.60	0.62	10.20	0.08
20.02	13.82	2.20	0.52	12.05	0.17
20.01	11.93	1.90	0.45	13.95	0.27
20.02	10.68	1.70	0.40	15.60	0.37
20.02	9.43	1.50	0.36	17.67	0.51
20.02	8.17	1.30	0.31	20.41	0.72
20.00	7.54	1.20	0.28	22.08	0.87
20.01	6.91	1.10	0.26	24.09	1.06
20.02	6.28	1.00	0.24	26.52	1.32
20.00	5.66	0.90	0.21	29.44	1.66
20.00	5.03	0.80	0.19	33.11	2.12
20.00	4.40	0.70	0.17	37.84	2.76
20.01	3.77	0.60	0.14	44.17	3.89

Table D.17: P_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

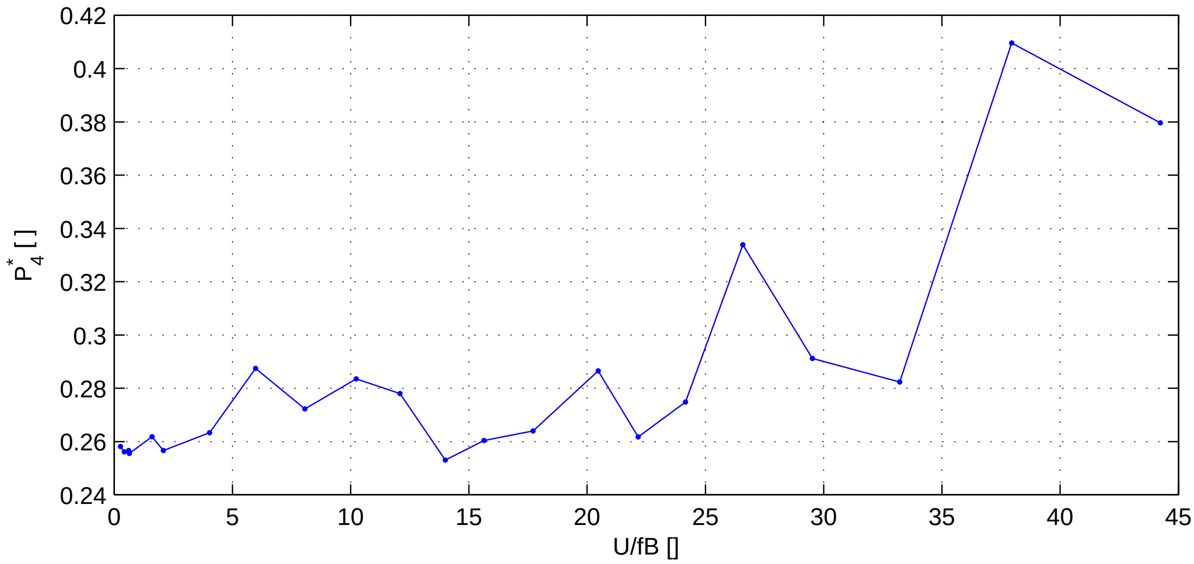

Figure D.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
0.80	25.13	4.00	23.65	0.27	0.26
1.29	25.13	4.00	14.72	0.43	0.26
1.85	25.13	4.00	10.25	0.61	0.26
1.95	25.13	4.00	9.73	0.65	0.26
4.84	25.13	4.00	3.92	1.60	0.26
6.28	25.13	4.00	3.02	2.08	0.26
12.18	25.13	4.00	1.56	4.03	0.26
18.07	25.13	4.00	1.05	5.98	0.29
20.10	20.74	3.30	0.78	8.07	0.27
20.10	16.34	2.60	0.61	10.24	0.28
20.08	13.82	2.20	0.52	12.09	0.28
20.08	11.93	1.90	0.45	14.00	0.25
20.06	10.68	1.70	0.40	15.64	0.26
20.07	9.43	1.50	0.35	17.71	0.26
20.08	8.17	1.30	0.31	20.46	0.29
20.07	7.54	1.20	0.28	22.16	0.26
20.07	6.91	1.10	0.26	24.16	0.27
20.07	6.28	1.00	0.24	26.58	0.33
20.06	5.66	0.90	0.21	29.52	0.29
20.06	5.03	0.80	0.19	33.22	0.28
20.05	4.40	0.70	0.17	37.95	0.41
20.04	3.77	0.60	0.14	44.23	0.38

Table D.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

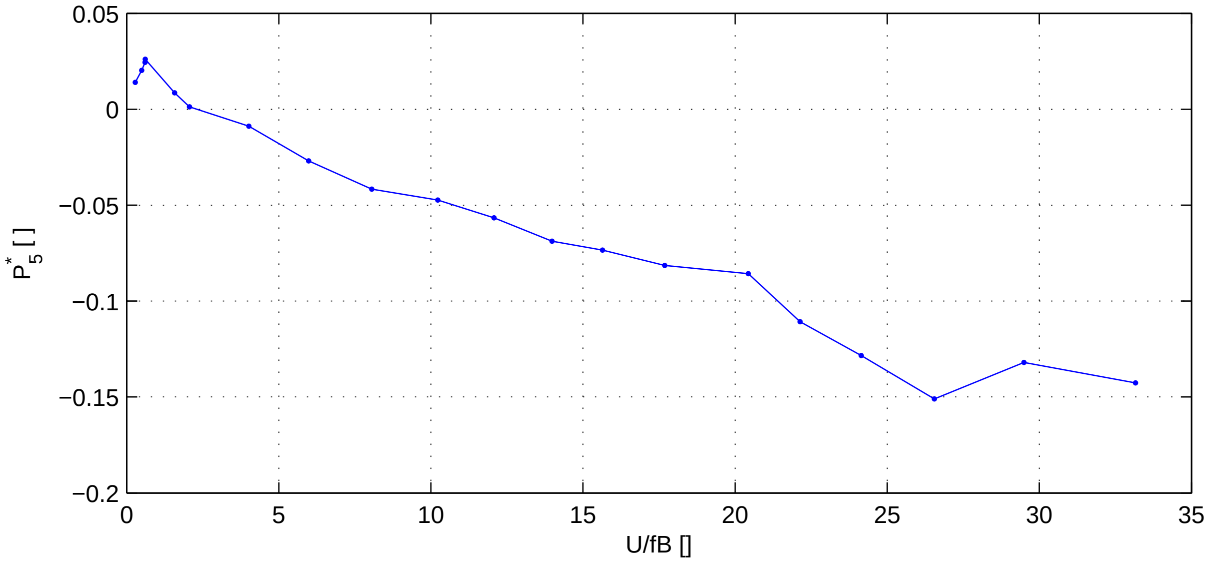

Figure D.17: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_5
0.86	25.13	4.00	22.12	0.28	0.01
1.48	25.13	4.00	12.82	0.49	0.02
1.83	25.13	4.00	10.39	0.60	0.02
1.84	25.13	4.00	10.33	0.61	0.03
4.77	25.13	4.00	3.98	1.58	0.01
6.23	25.13	4.00	3.04	2.06	0.00
12.13	25.13	4.00	1.56	4.02	−0.01
18.05	25.13	4.00	1.05	5.98	−0.03
20.07	20.74	3.30	0.78	8.05	−0.04
20.08	16.34	2.60	0.61	10.22	−0.05
20.05	13.82	2.20	0.52	12.07	−0.06
20.05	11.93	1.90	0.45	13.98	−0.07
20.06	10.68	1.70	0.40	15.64	−0.07
20.03	9.43	1.50	0.36	17.69	−0.08
20.05	8.17	1.30	0.31	20.44	−0.09
20.05	7.54	1.20	0.28	22.14	−0.11
20.05	6.91	1.10	0.26	24.15	−0.13
20.05	6.28	1.00	0.24	26.55	−0.15
20.04	5.66	0.90	0.21	29.49	−0.13
20.03	5.03	0.80	0.19	33.16	−0.14

Table D.19: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:06:19

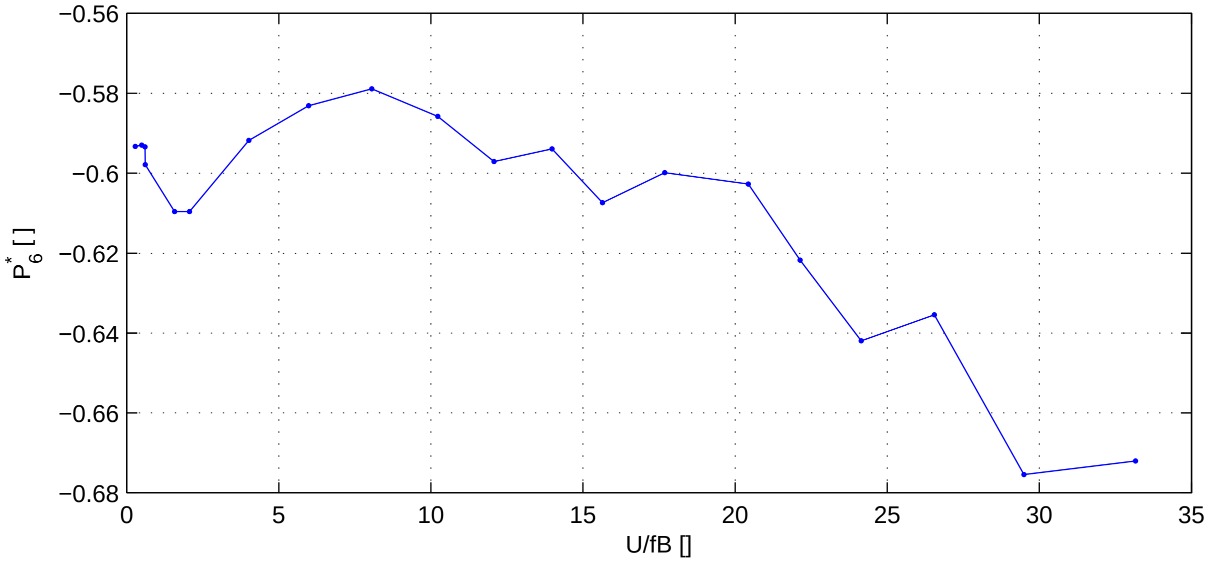

Figure D.18: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_6^*
0.86	25.13	4.00	22.12	0.28	−0.59
1.48	25.13	4.00	12.82	0.49	−0.59
1.83	25.13	4.00	10.39	0.60	−0.59
1.84	25.13	4.00	10.33	0.61	−0.60
4.77	25.13	4.00	3.98	1.58	−0.61
6.23	25.13	4.00	3.04	2.06	−0.61
12.13	25.13	4.00	1.56	4.02	−0.59
18.05	25.13	4.00	1.05	5.98	−0.58
20.07	20.74	3.30	0.78	8.05	−0.58
20.08	16.34	2.60	0.61	10.22	−0.59
20.05	13.82	2.20	0.52	12.07	−0.60
20.05	11.93	1.90	0.45	13.98	−0.59
20.06	10.68	1.70	0.40	15.64	−0.61
20.03	9.43	1.50	0.36	17.69	−0.60
20.05	8.17	1.30	0.31	20.44	−0.60
20.05	7.54	1.20	0.28	22.14	−0.62
20.05	6.91	1.10	0.26	24.15	−0.64
20.05	6.28	1.00	0.24	26.55	−0.64
20.04	5.66	0.90	0.21	29.49	−0.68
20.03	5.03	0.80	0.19	33.16	−0.67

Table D.20: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\,(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\,(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\,(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

Formula D.3: Equation of Motion (Stretto di Messina. Ref. [5].)

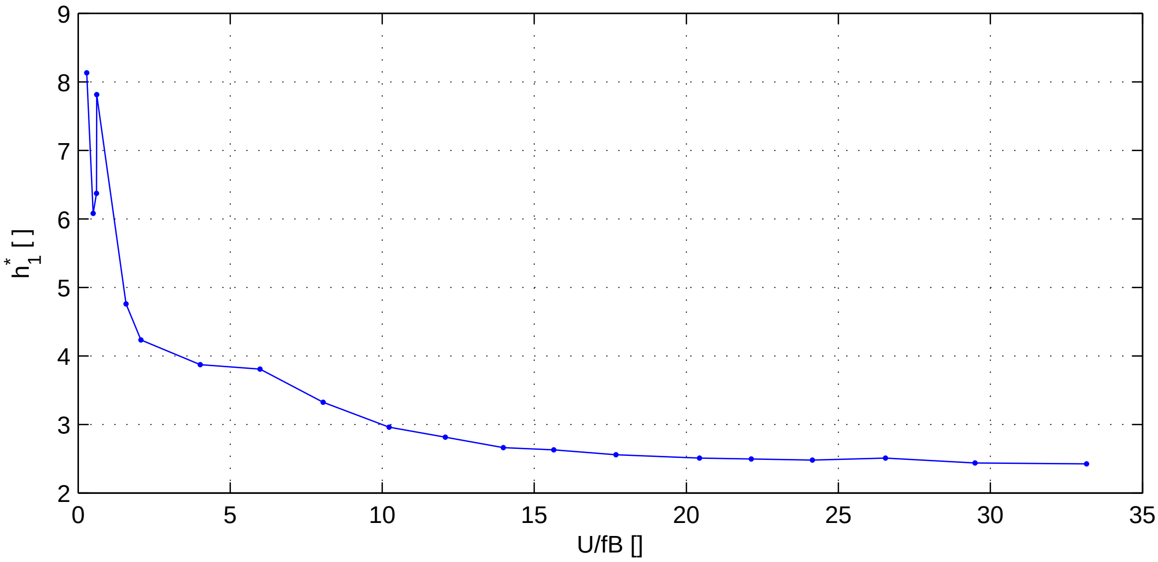

Figure D.19: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_1^*
0.86	25.13	4.00	22.12	0.28	8.13
1.48	25.13	4.00	12.82	0.49	6.08
1.83	25.13	4.00	10.39	0.60	6.37
1.84	25.13	4.00	10.33	0.61	7.81
4.77	25.13	4.00	3.98	1.58	4.76
6.23	25.13	4.00	3.04	2.06	4.23
12.13	25.13	4.00	1.56	4.02	3.87
18.05	25.13	4.00	1.05	5.98	3.81
20.07	20.74	3.30	0.78	8.05	3.32
20.08	16.34	2.60	0.61	10.22	2.96
20.05	13.82	2.20	0.52	12.07	2.81
20.05	11.93	1.90	0.45	13.98	2.66
20.06	10.68	1.70	0.40	15.64	2.63
20.03	9.43	1.50	0.36	17.69	2.56
20.05	8.17	1.30	0.31	20.44	2.51
20.05	7.54	1.20	0.28	22.14	2.50
20.05	6.91	1.10	0.26	24.15	2.48
20.05	6.28	1.00	0.24	26.55	2.51
20.04	5.66	0.90	0.21	29.49	2.44
20.03	5.03	0.80	0.19	33.16	2.42

Table D.21: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

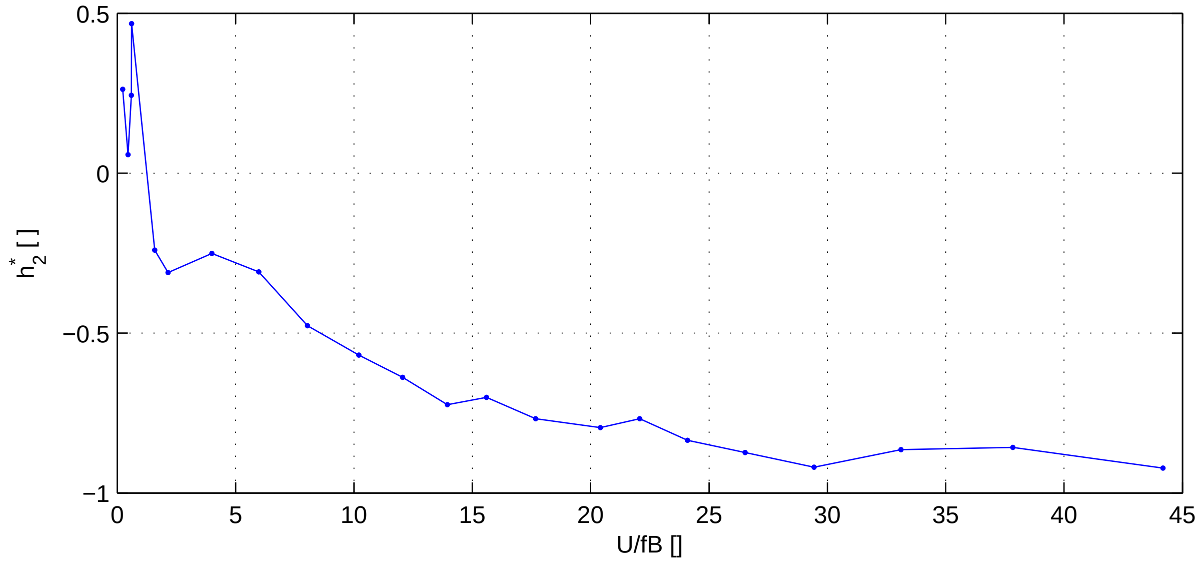

Figure D.20: h^*_2 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_2
0.69	25.13	4.00	27.40	0.23	0.26
1.37	25.13	4.00	13.87	0.45	0.06
1.82	25.13	4.00	10.45	0.60	0.24
1.84	25.13	4.00	10.33	0.61	0.47
4.77	25.13	4.00	3.98	1.58	−0.24
6.49	25.13	4.00	2.92	2.15	−0.31
12.07	25.13	4.00	1.57	4.00	−0.25
18.07	25.13	4.00	1.05	5.98	−0.31
20.03	20.74	3.30	0.78	8.04	−0.48
20.04	16.34	2.60	0.62	10.20	−0.57
20.02	13.82	2.20	0.52	12.05	−0.64
20.01	11.93	1.90	0.45	13.95	−0.72
20.02	10.68	1.70	0.40	15.60	−0.70
20.02	9.43	1.50	0.36	17.67	−0.77
20.02	8.17	1.30	0.31	20.41	−0.80
20.00	7.54	1.20	0.28	22.08	−0.77
20.01	6.91	1.10	0.26	24.09	−0.84
20.02	6.28	1.00	0.24	26.52	−0.87
20.00	5.66	0.90	0.21	29.44	−0.92
20.00	5.03	0.80	0.19	33.11	−0.86
20.00	4.40	0.70	0.17	37.84	−0.86
20.01	3.77	0.60	0.14	44.17	−0.92

Table D.22: h^*_2 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

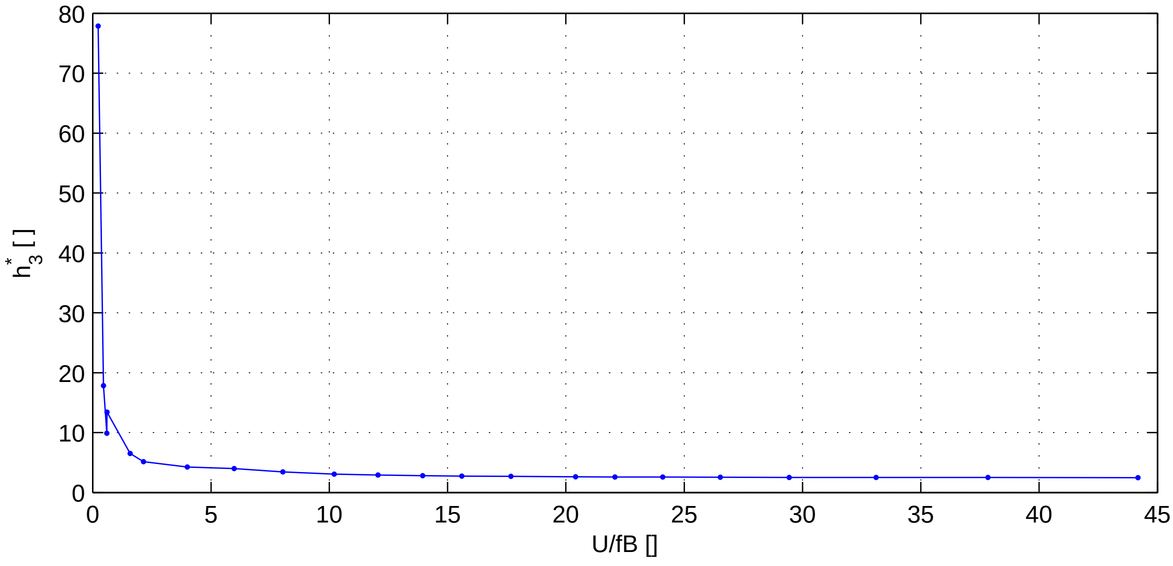

Figure D.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
0.69	25.13	4.00	27.40	0.23	77.86
1.37	25.13	4.00	13.87	0.45	17.81
1.82	25.13	4.00	10.45	0.60	9.89
1.84	25.13	4.00	10.33	0.61	13.40
4.77	25.13	4.00	3.98	1.58	6.51
6.49	25.13	4.00	2.92	2.15	5.13
12.07	25.13	4.00	1.57	4.00	4.26
18.07	25.13	4.00	1.05	5.98	3.99
20.03	20.74	3.30	0.78	8.04	3.44
20.04	16.34	2.60	0.62	10.20	3.07
20.02	13.82	2.20	0.52	12.05	2.92
20.01	11.93	1.90	0.45	13.95	2.80
20.02	10.68	1.70	0.40	15.60	2.72
20.02	9.43	1.50	0.36	17.67	2.68
20.02	8.17	1.30	0.31	20.41	2.62
20.00	7.54	1.20	0.28	22.08	2.59
20.01	6.91	1.10	0.26	24.09	2.58
20.02	6.28	1.00	0.24	26.52	2.54
20.00	5.66	0.90	0.21	29.44	2.52
20.00	5.03	0.80	0.19	33.11	2.52
20.00	4.40	0.70	0.17	37.84	2.49
20.01	3.77	0.60	0.14	44.17	2.47

Table D.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

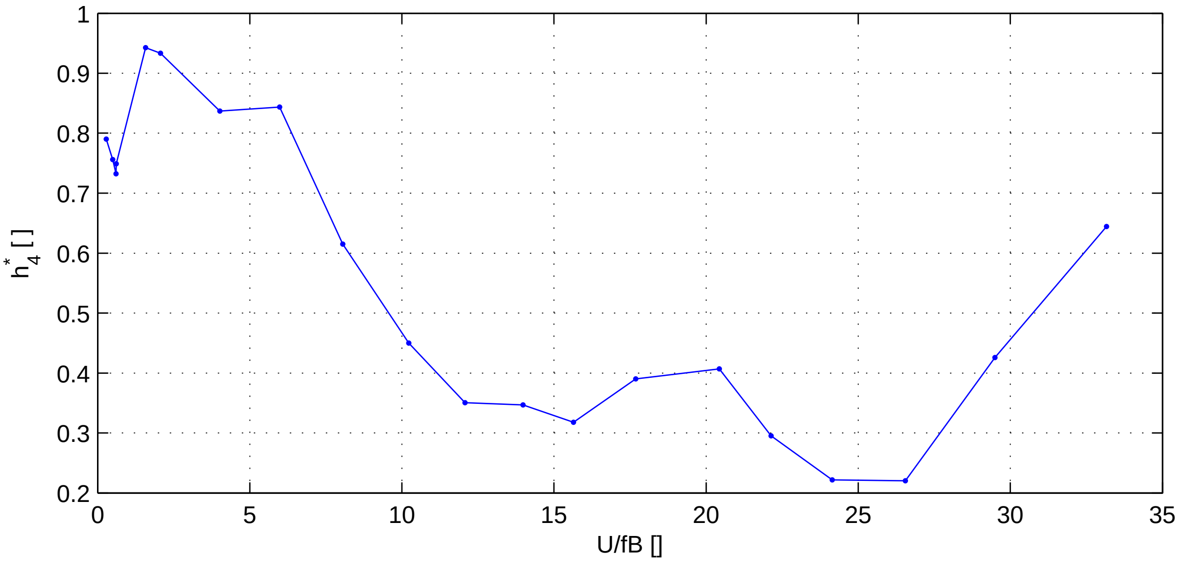

Figure D.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
0.86	25.13	4.00	22.12	0.28	0.79
1.48	25.13	4.00	12.82	0.49	0.76
1.83	25.13	4.00	10.39	0.60	0.73
1.84	25.13	4.00	10.33	0.61	0.75
4.77	25.13	4.00	3.98	1.58	0.94
6.23	25.13	4.00	3.04	2.06	0.93
12.13	25.13	4.00	1.56	4.02	0.84
18.05	25.13	4.00	1.05	5.98	0.84
20.07	20.74	3.30	0.78	8.05	0.62
20.08	16.34	2.60	0.61	10.22	0.45
20.05	13.82	2.20	0.52	12.07	0.35
20.05	11.93	1.90	0.45	13.98	0.35
20.06	10.68	1.70	0.40	15.64	0.32
20.03	9.43	1.50	0.36	17.69	0.39
20.05	8.17	1.30	0.31	20.44	0.41
20.05	7.54	1.20	0.28	22.14	0.30
20.05	6.91	1.10	0.26	24.15	0.22
20.05	6.28	1.00	0.24	26.55	0.22
20.04	5.66	0.90	0.21	29.49	0.43
20.03	5.03	0.80	0.19	33.16	0.64

Table D.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

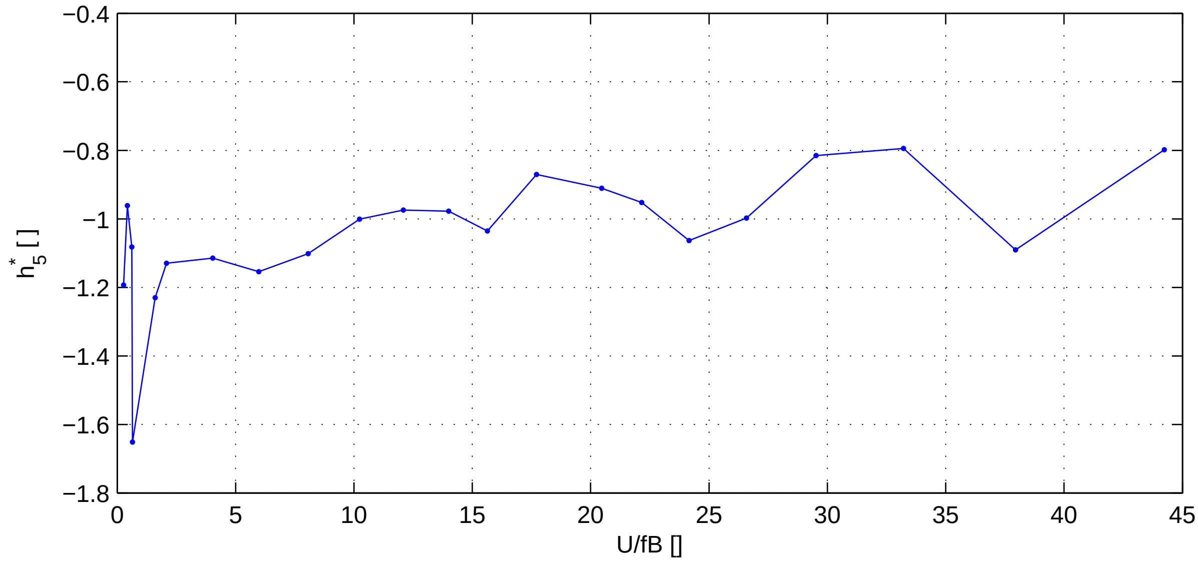

Figure D.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
0.80	25.13	4.00	23.65	0.27	−1.19
1.29	25.13	4.00	14.72	0.43	−0.96
1.85	25.13	4.00	10.25	0.61	−1.08
1.95	25.13	4.00	9.73	0.65	−1.65
4.84	25.13	4.00	3.92	1.60	−1.23
6.28	25.13	4.00	3.02	2.08	−1.13
12.18	25.13	4.00	1.56	4.03	−1.11
18.07	25.13	4.00	1.05	5.98	−1.15
20.10	20.74	3.30	0.78	8.07	−1.10
20.10	16.34	2.60	0.61	10.24	−1.00
20.08	13.82	2.20	0.52	12.09	−0.97
20.08	11.93	1.90	0.45	14.00	−0.98
20.06	10.68	1.70	0.40	15.64	−1.04
20.07	9.43	1.50	0.35	17.71	−0.87
20.08	8.17	1.30	0.31	20.46	−0.91
20.07	7.54	1.20	0.28	22.16	−0.95
20.07	6.91	1.10	0.26	24.16	−1.06
20.07	6.28	1.00	0.24	26.58	−1.00
20.06	5.66	0.90	0.21	29.52	−0.82
20.06	5.03	0.80	0.19	33.22	−0.79
20.05	4.40	0.70	0.17	37.95	−1.09
20.04	3.77	0.60	0.14	44.23	−0.80

Table D.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

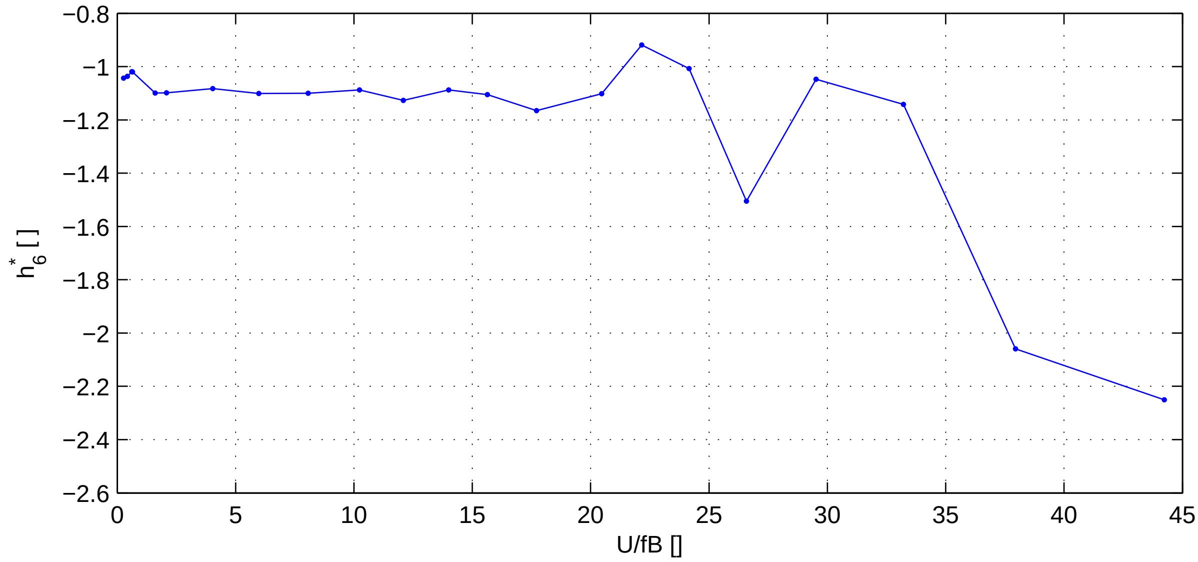

Figure D.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
0.80	25.13	4.00	23.65	0.27	−1.04
1.29	25.13	4.00	14.72	0.43	−1.04
1.85	25.13	4.00	10.25	0.61	−1.02
1.95	25.13	4.00	9.73	0.65	−1.02
4.84	25.13	4.00	3.92	1.60	−1.10
6.28	25.13	4.00	3.02	2.08	−1.10
12.18	25.13	4.00	1.56	4.03	−1.08
18.07	25.13	4.00	1.05	5.98	−1.10
20.10	20.74	3.30	0.78	8.07	−1.10
20.10	16.34	2.60	0.61	10.24	−1.09
20.08	13.82	2.20	0.52	12.09	−1.13
20.08	11.93	1.90	0.45	14.00	−1.09
20.06	10.68	1.70	0.40	15.64	−1.11
20.07	9.43	1.50	0.35	17.71	−1.17
20.08	8.17	1.30	0.31	20.46	−1.10
20.07	7.54	1.20	0.28	22.16	−0.92
20.07	6.91	1.10	0.26	24.16	−1.01
20.07	6.28	1.00	0.24	26.58	−1.51
20.06	5.66	0.90	0.21	29.52	−1.05
20.06	5.03	0.80	0.19	33.22	−1.14
20.05	4.40	0.70	0.17	37.95	−2.06
20.04	3.77	0.60	0.14	44.23	−2.25

Table D.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

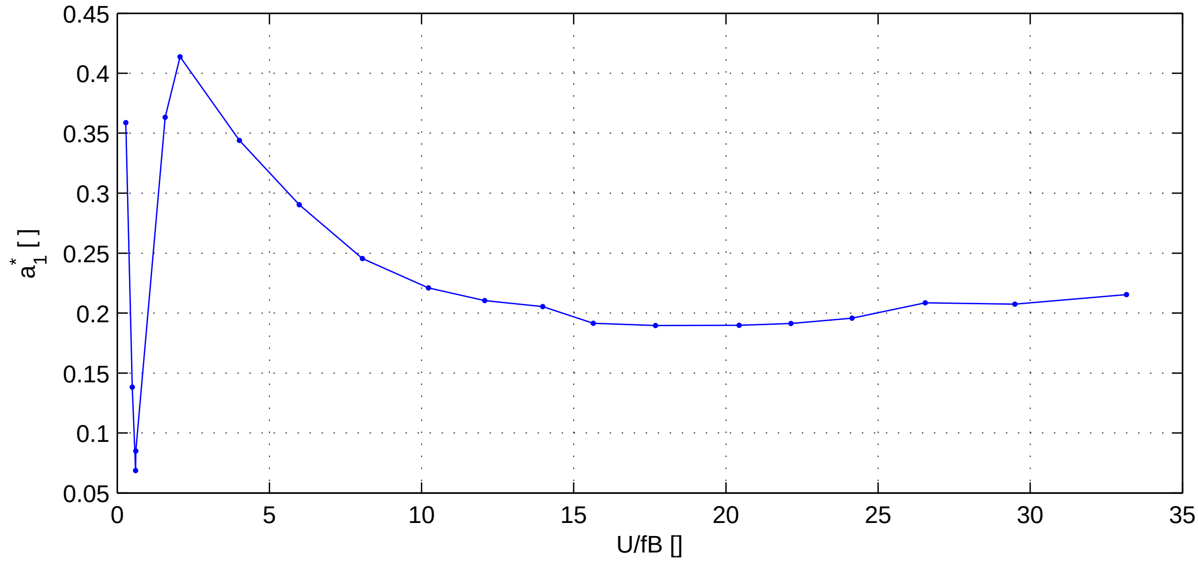

Figure D.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
0.86	25.13	4.00	22.12	0.28	0.36
1.48	25.13	4.00	12.82	0.49	0.14
1.83	25.13	4.00	10.39	0.60	0.07
1.84	25.13	4.00	10.33	0.61	0.08
4.77	25.13	4.00	3.98	1.58	0.36
6.23	25.13	4.00	3.04	2.06	0.41
12.13	25.13	4.00	1.56	4.02	0.34
18.05	25.13	4.00	1.05	5.98	0.29
20.07	20.74	3.30	0.78	8.05	0.25
20.08	16.34	2.60	0.61	10.22	0.22
20.05	13.82	2.20	0.52	12.07	0.21
20.05	11.93	1.90	0.45	13.98	0.21
20.06	10.68	1.70	0.40	15.64	0.19
20.03	9.43	1.50	0.36	17.69	0.19
20.05	8.17	1.30	0.31	20.44	0.19
20.05	7.54	1.20	0.28	22.14	0.19
20.05	6.91	1.10	0.26	24.15	0.20
20.05	6.28	1.00	0.24	26.55	0.21
20.04	5.66	0.90	0.21	29.49	0.21
20.03	5.03	0.80	0.19	33.16	0.22

Table D.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

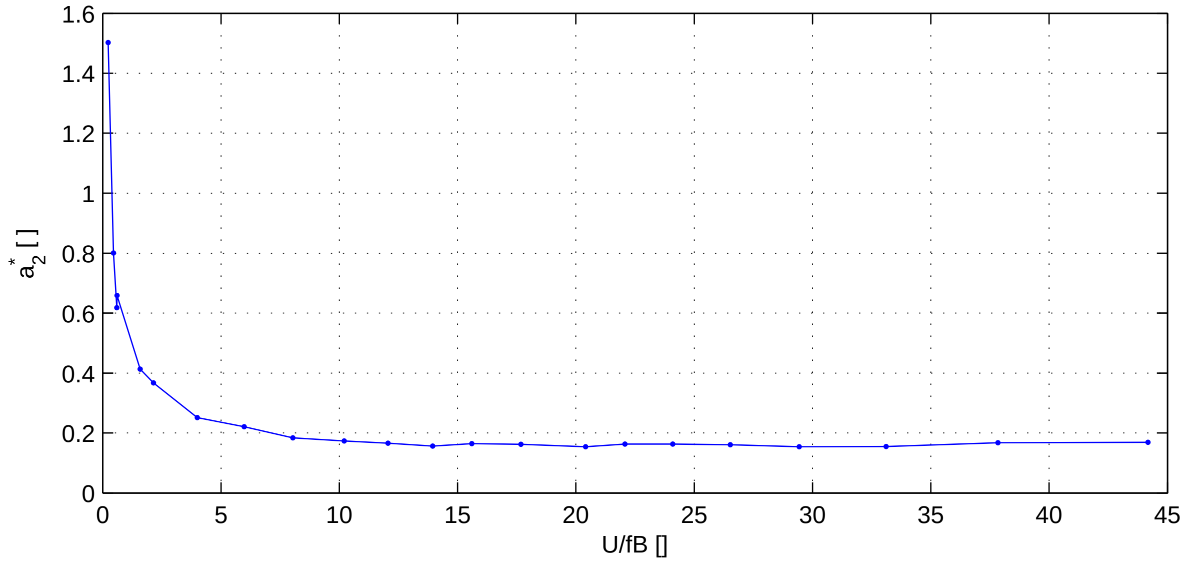

Figure D.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
0.69	25.13	4.00	27.40	0.23	1.50
1.37	25.13	4.00	13.87	0.45	0.80
1.82	25.13	4.00	10.45	0.60	0.62
1.84	25.13	4.00	10.33	0.61	0.66
4.77	25.13	4.00	3.98	1.58	0.41
6.49	25.13	4.00	2.92	2.15	0.37
12.07	25.13	4.00	1.57	4.00	0.25
18.07	25.13	4.00	1.05	5.98	0.22
20.03	20.74	3.30	0.78	8.04	0.18
20.04	16.34	2.60	0.62	10.20	0.17
20.02	13.82	2.20	0.52	12.05	0.17
20.01	11.93	1.90	0.45	13.95	0.16
20.02	10.68	1.70	0.40	15.60	0.16
20.02	9.43	1.50	0.36	17.67	0.16
20.02	8.17	1.30	0.31	20.41	0.15
20.00	7.54	1.20	0.28	22.08	0.16
20.01	6.91	1.10	0.26	24.09	0.16
20.02	6.28	1.00	0.24	26.52	0.16
20.00	5.66	0.90	0.21	29.44	0.15
20.00	5.03	0.80	0.19	33.11	0.15
20.00	4.40	0.70	0.17	37.84	0.17
20.01	3.77	0.60	0.14	44.17	0.17

Table D.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

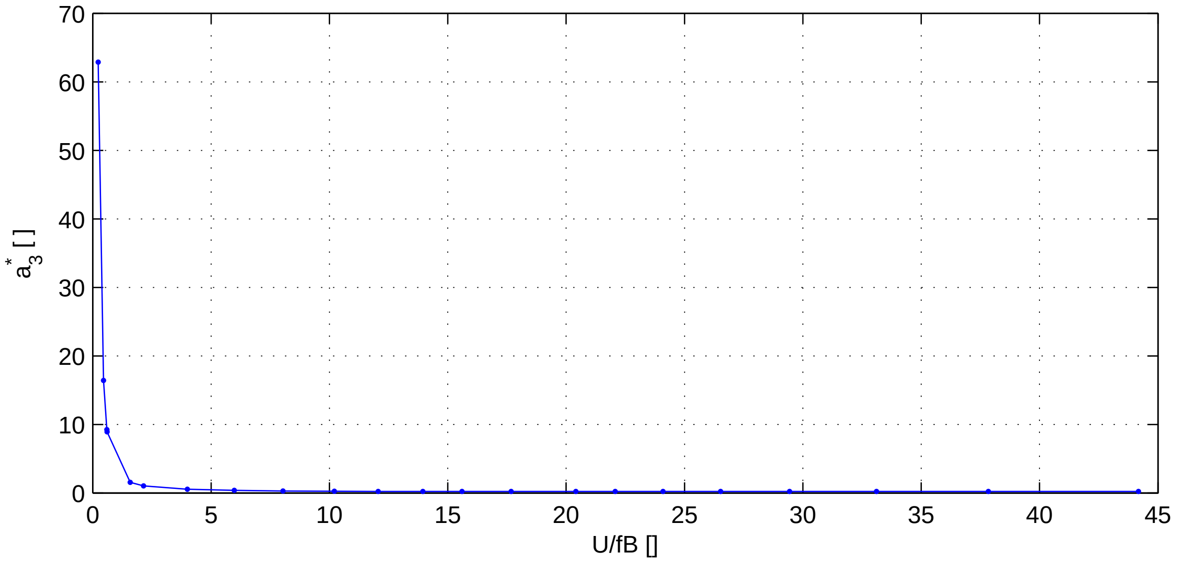

Figure D.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
0.69	25.13	4.00	27.40	0.23	62.89
1.37	25.13	4.00	13.87	0.45	16.41
1.82	25.13	4.00	10.45	0.60	9.24
1.84	25.13	4.00	10.33	0.61	8.91
4.77	25.13	4.00	3.98	1.58	1.54
6.49	25.13	4.00	2.92	2.15	1.03
12.07	25.13	4.00	1.57	4.00	0.53
18.07	25.13	4.00	1.05	5.98	0.36
20.03	20.74	3.30	0.78	8.04	0.27
20.04	16.34	2.60	0.62	10.20	0.23
20.02	13.82	2.20	0.52	12.05	0.22
20.01	11.93	1.90	0.45	13.95	0.22
20.02	10.68	1.70	0.40	15.60	0.21
20.02	9.43	1.50	0.36	17.67	0.21
20.02	8.17	1.30	0.31	20.41	0.21
20.00	7.54	1.20	0.28	22.08	0.21
20.01	6.91	1.10	0.26	24.09	0.21
20.02	6.28	1.00	0.24	26.52	0.20
20.00	5.66	0.90	0.21	29.44	0.21
20.00	5.03	0.80	0.19	33.11	0.21
20.00	4.40	0.70	0.17	37.84	0.20
20.01	3.77	0.60	0.14	44.17	0.20

Table D.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:06:19

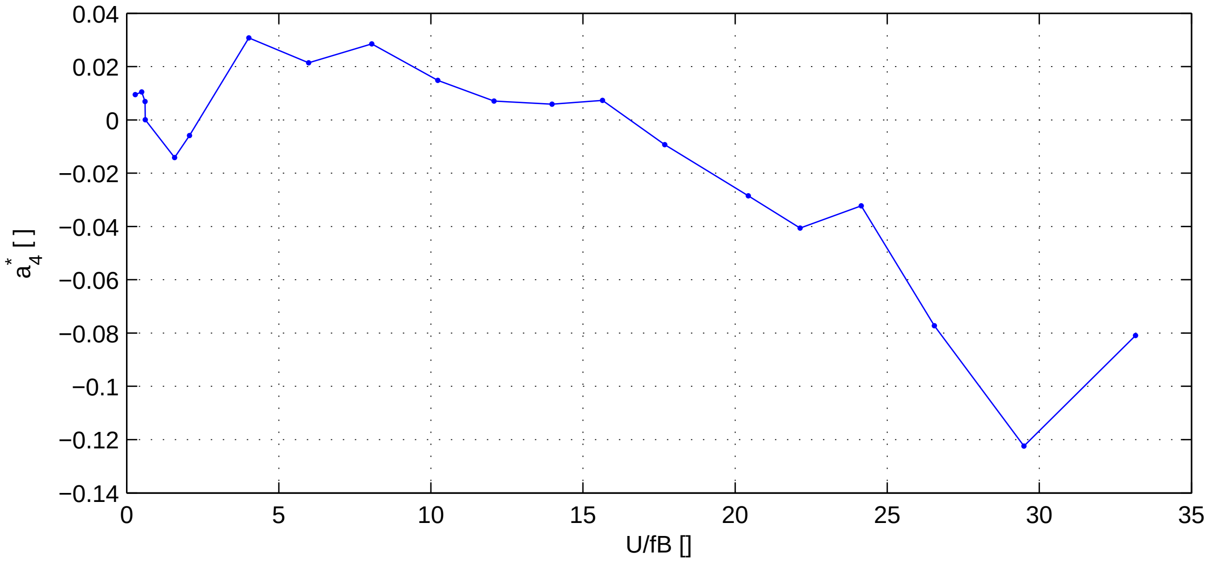

Figure D.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
0.86	25.13	4.00	22.12	0.28	0.01
1.48	25.13	4.00	12.82	0.49	0.01
1.83	25.13	4.00	10.39	0.60	0.01
1.84	25.13	4.00	10.33	0.61	0.00
4.77	25.13	4.00	3.98	1.58	−0.01
6.23	25.13	4.00	3.04	2.06	−0.01
12.13	25.13	4.00	1.56	4.02	0.03
18.05	25.13	4.00	1.05	5.98	0.02
20.07	20.74	3.30	0.78	8.05	0.03
20.08	16.34	2.60	0.61	10.22	0.01
20.05	13.82	2.20	0.52	12.07	0.01
20.05	11.93	1.90	0.45	13.98	0.01
20.06	10.68	1.70	0.40	15.64	0.01
20.03	9.43	1.50	0.36	17.69	−0.01
20.05	8.17	1.30	0.31	20.44	−0.03
20.05	7.54	1.20	0.28	22.14	−0.04
20.05	6.91	1.10	0.26	24.15	−0.03
20.05	6.28	1.00	0.24	26.55	−0.08
20.04	5.66	0.90	0.21	29.49	−0.12
20.03	5.03	0.80	0.19	33.16	−0.08

Table D.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

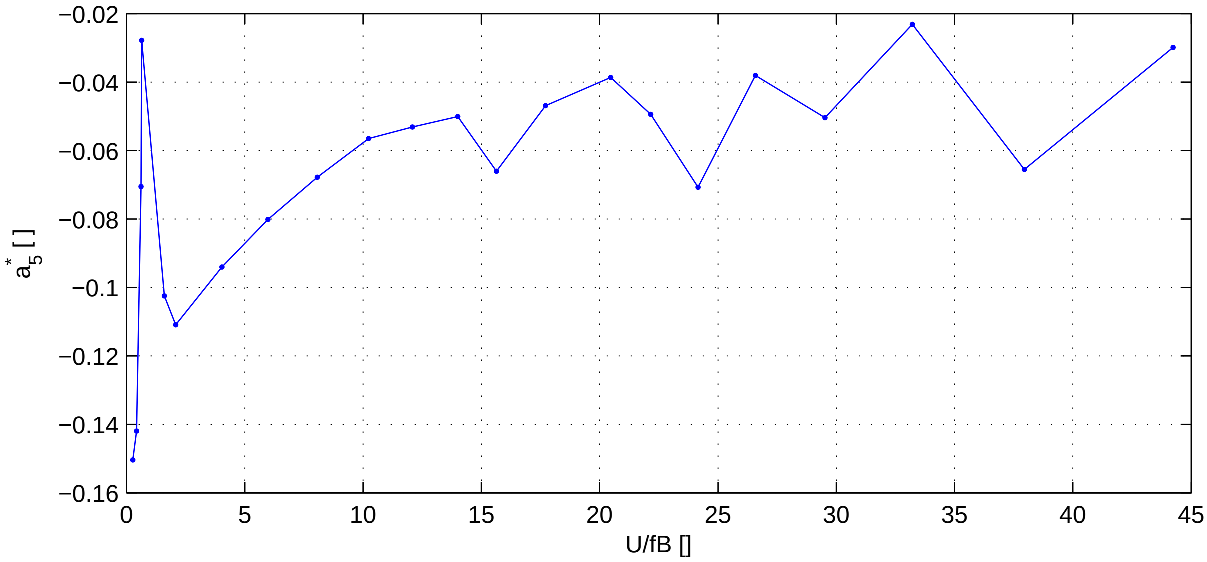

Figure D.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
0.80	25.13	4.00	23.65	0.27	−0.15
1.29	25.13	4.00	14.72	0.43	−0.14
1.85	25.13	4.00	10.25	0.61	−0.07
1.95	25.13	4.00	9.73	0.65	−0.03
4.84	25.13	4.00	3.92	1.60	−0.10
6.28	25.13	4.00	3.02	2.08	−0.11
12.18	25.13	4.00	1.56	4.03	−0.09
18.07	25.13	4.00	1.05	5.98	−0.08
20.10	20.74	3.30	0.78	8.07	−0.07
20.10	16.34	2.60	0.61	10.24	−0.06
20.08	13.82	2.20	0.52	12.09	−0.05
20.08	11.93	1.90	0.45	14.00	−0.05
20.06	10.68	1.70	0.40	15.64	−0.07
20.07	9.43	1.50	0.35	17.71	−0.05
20.08	8.17	1.30	0.31	20.46	−0.04
20.07	7.54	1.20	0.28	22.16	−0.05
20.07	6.91	1.10	0.26	24.16	−0.07
20.07	6.28	1.00	0.24	26.58	−0.04
20.06	5.66	0.90	0.21	29.52	−0.05
20.06	5.03	0.80	0.19	33.22	−0.02
20.05	4.40	0.70	0.17	37.95	−0.07
20.04	3.77	0.60	0.14	44.23	−0.03

Table D.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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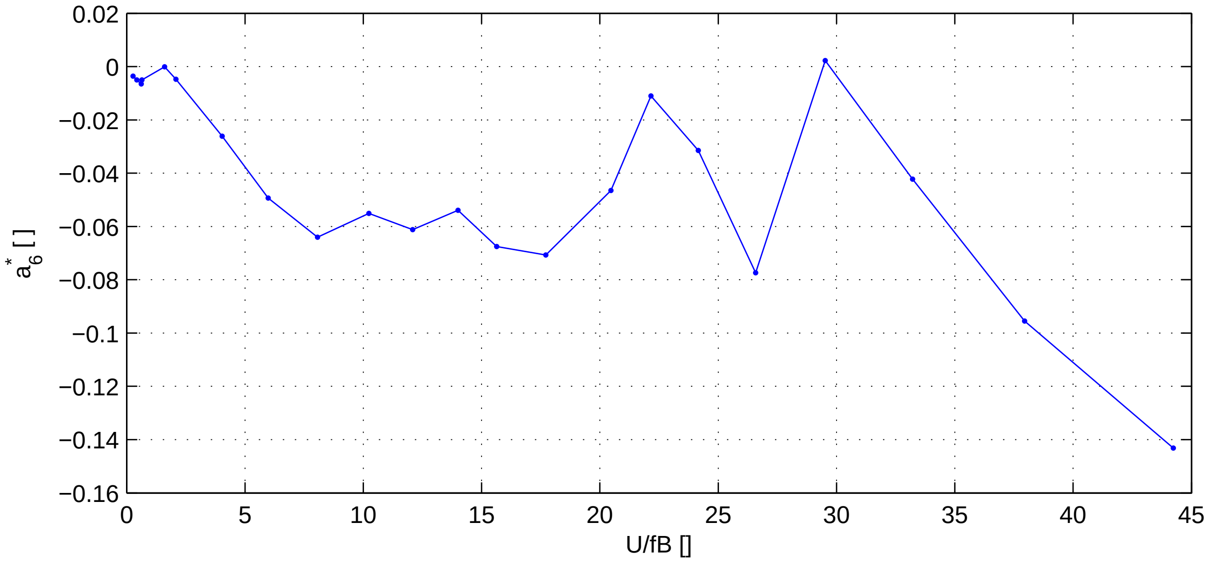

Figure D.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
0.80	25.13	4.00	23.65	0.27	−0.00
1.29	25.13	4.00	14.72	0.43	−0.00
1.85	25.13	4.00	10.25	0.61	−0.01
1.95	25.13	4.00	9.73	0.65	−0.00
4.84	25.13	4.00	3.92	1.60	−0.00
6.28	25.13	4.00	3.02	2.08	−0.00
12.18	25.13	4.00	1.56	4.03	−0.03
18.07	25.13	4.00	1.05	5.98	−0.05
20.10	20.74	3.30	0.78	8.07	−0.06
20.10	16.34	2.60	0.61	10.24	−0.06
20.08	13.82	2.20	0.52	12.09	−0.06
20.08	11.93	1.90	0.45	14.00	−0.05
20.06	10.68	1.70	0.40	15.64	−0.07
20.07	9.43	1.50	0.35	17.71	−0.07
20.08	8.17	1.30	0.31	20.46	−0.05
20.07	7.54	1.20	0.28	22.16	−0.01
20.07	6.91	1.10	0.26	24.16	−0.03
20.07	6.28	1.00	0.24	26.58	−0.08
20.06	5.66	0.90	0.21	29.52	0.00
20.06	5.03	0.80	0.19	33.22	−0.04
20.05	4.40	0.70	0.17	37.95	−0.10
20.04	3.77	0.60	0.14	44.23	−0.14

Table D.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

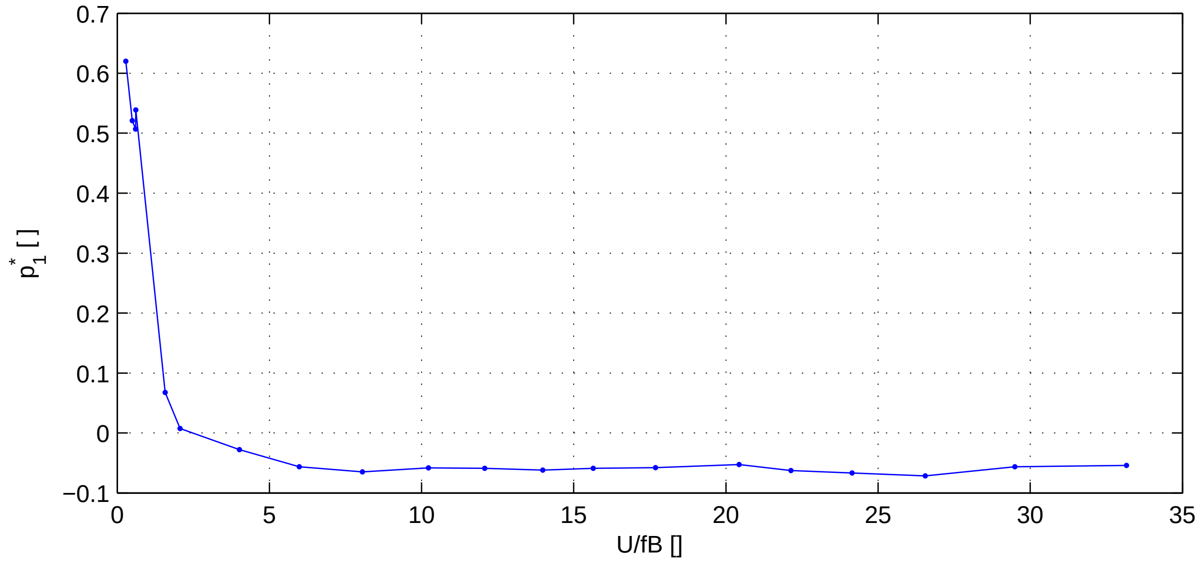

Figure D.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
0.86	25.13	4.00	22.12	0.28	0.62
1.48	25.13	4.00	12.82	0.49	0.52
1.83	25.13	4.00	10.39	0.60	0.51
1.84	25.13	4.00	10.33	0.61	0.54
4.77	25.13	4.00	3.98	1.58	0.07
6.23	25.13	4.00	3.04	2.06	0.01
12.13	25.13	4.00	1.56	4.02	−0.03
18.05	25.13	4.00	1.05	5.98	−0.06
20.07	20.74	3.30	0.78	8.05	−0.07
20.08	16.34	2.60	0.61	10.22	−0.06
20.05	13.82	2.20	0.52	12.07	−0.06
20.05	11.93	1.90	0.45	13.98	−0.06
20.06	10.68	1.70	0.40	15.64	−0.06
20.03	9.43	1.50	0.36	17.69	−0.06
20.05	8.17	1.30	0.31	20.44	−0.05
20.05	7.54	1.20	0.28	22.14	−0.06
20.05	6.91	1.10	0.26	24.15	−0.07
20.05	6.28	1.00	0.24	26.55	−0.07
20.04	5.66	0.90	0.21	29.49	−0.06
20.03	5.03	0.80	0.19	33.16	−0.05

Table D.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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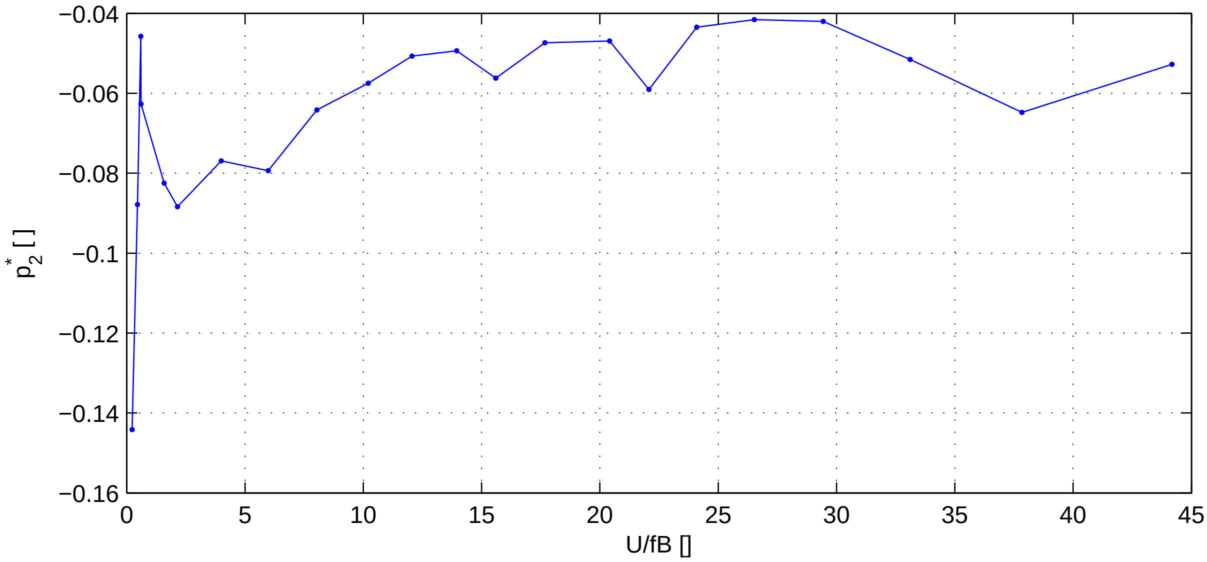

Figure D.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
0.69	25.13	4.00	27.40	0.23	−0.14
1.37	25.13	4.00	13.87	0.45	−0.09
1.82	25.13	4.00	10.45	0.60	−0.05
1.84	25.13	4.00	10.33	0.61	−0.06
4.77	25.13	4.00	3.98	1.58	−0.08
6.49	25.13	4.00	2.92	2.15	−0.09
12.07	25.13	4.00	1.57	4.00	−0.08
18.07	25.13	4.00	1.05	5.98	−0.08
20.03	20.74	3.30	0.78	8.04	−0.06
20.04	16.34	2.60	0.62	10.20	−0.06
20.02	13.82	2.20	0.52	12.05	−0.05
20.01	11.93	1.90	0.45	13.95	−0.05
20.02	10.68	1.70	0.40	15.60	−0.06
20.02	9.43	1.50	0.36	17.67	−0.05
20.02	8.17	1.30	0.31	20.41	−0.05
20.00	7.54	1.20	0.28	22.08	−0.06
20.01	6.91	1.10	0.26	24.09	−0.04
20.02	6.28	1.00	0.24	26.52	−0.04
20.00	5.66	0.90	0.21	29.44	−0.04
20.00	5.03	0.80	0.19	33.11	−0.05
20.00	4.40	0.70	0.17	37.84	−0.06
20.01	3.77	0.60	0.14	44.17	−0.05

Table D.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

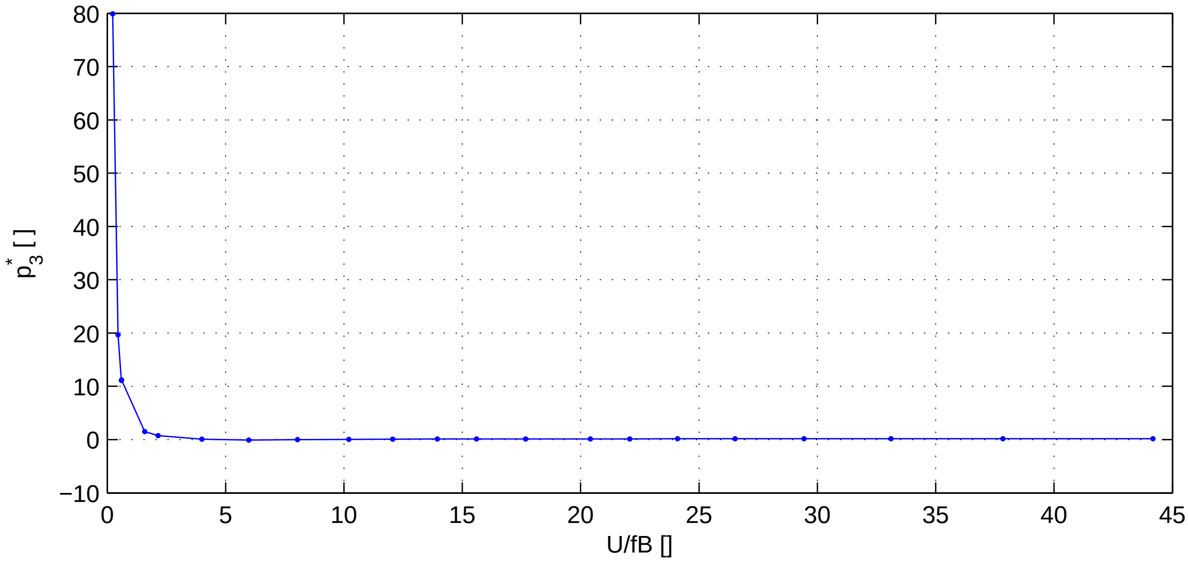

Figure D.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
0.69	25.13	4.00	27.40	0.23	79.88
1.37	25.13	4.00	13.87	0.45	19.65
1.82	25.13	4.00	10.45	0.60	11.11
1.84	25.13	4.00	10.33	0.61	11.18
4.77	25.13	4.00	3.98	1.58	1.51
6.49	25.13	4.00	2.92	2.15	0.74
12.07	25.13	4.00	1.57	4.00	0.08
18.07	25.13	4.00	1.05	5.98	−0.08
20.03	20.74	3.30	0.78	8.04	−0.01
20.04	16.34	2.60	0.62	10.20	0.06
20.02	13.82	2.20	0.52	12.05	0.09
20.01	11.93	1.90	0.45	13.95	0.11
20.02	10.68	1.70	0.40	15.60	0.12
20.02	9.43	1.50	0.36	17.67	0.13
20.02	8.17	1.30	0.31	20.41	0.14
20.00	7.54	1.20	0.28	22.08	0.14
20.01	6.91	1.10	0.26	24.09	0.14
20.02	6.28	1.00	0.24	26.52	0.15
20.00	5.66	0.90	0.21	29.44	0.15
20.00	5.03	0.80	0.19	33.11	0.15
20.00	4.40	0.70	0.17	37.84	0.15
20.01	3.77	0.60	0.14	44.17	0.16

Table D.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

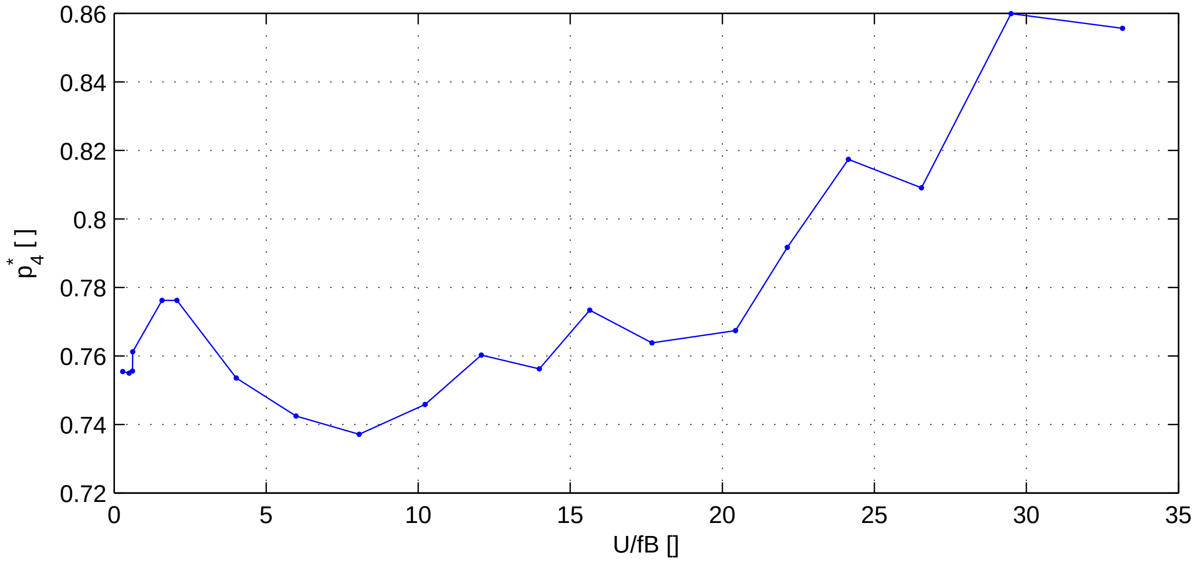

Figure D.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
0.86	25.13	4.00	22.12	0.28	0.76
1.48	25.13	4.00	12.82	0.49	0.75
1.83	25.13	4.00	10.39	0.60	0.76
1.84	25.13	4.00	10.33	0.61	0.76
4.77	25.13	4.00	3.98	1.58	0.78
6.23	25.13	4.00	3.04	2.06	0.78
12.13	25.13	4.00	1.56	4.02	0.75
18.05	25.13	4.00	1.05	5.98	0.74
20.07	20.74	3.30	0.78	8.05	0.74
20.08	16.34	2.60	0.61	10.22	0.75
20.05	13.82	2.20	0.52	12.07	0.76
20.05	11.93	1.90	0.45	13.98	0.76
20.06	10.68	1.70	0.40	15.64	0.77
20.03	9.43	1.50	0.36	17.69	0.76
20.05	8.17	1.30	0.31	20.44	0.77
20.05	7.54	1.20	0.28	22.14	0.79
20.05	6.91	1.10	0.26	24.15	0.82
20.05	6.28	1.00	0.24	26.55	0.81
20.04	5.66	0.90	0.21	29.49	0.86
20.03	5.03	0.80	0.19	33.16	0.86

Table D.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

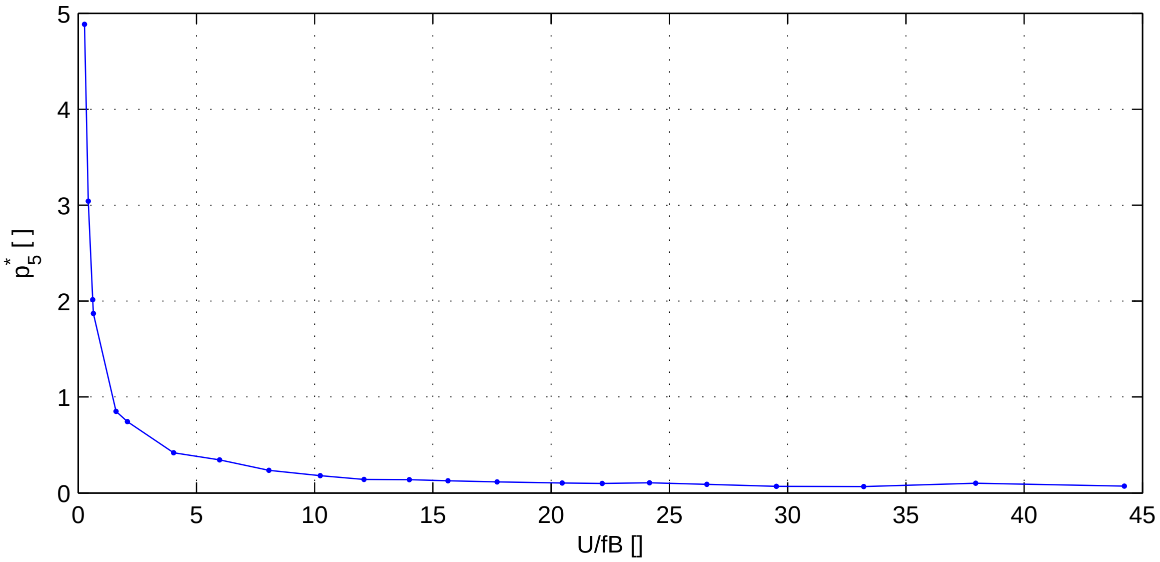

Figure D.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
0.80	25.13	4.00	23.65	0.27	4.88
1.29	25.13	4.00	14.72	0.43	3.04
1.85	25.13	4.00	10.25	0.61	2.01
1.95	25.13	4.00	9.73	0.65	1.87
4.84	25.13	4.00	3.92	1.60	0.85
6.28	25.13	4.00	3.02	2.08	0.74
12.18	25.13	4.00	1.56	4.03	0.42
18.07	25.13	4.00	1.05	5.98	0.34
20.10	20.74	3.30	0.78	8.07	0.24
20.10	16.34	2.60	0.61	10.24	0.18
20.08	13.82	2.20	0.52	12.09	0.14
20.08	11.93	1.90	0.45	14.00	0.14
20.06	10.68	1.70	0.40	15.64	0.13
20.07	9.43	1.50	0.35	17.71	0.11
20.08	8.17	1.30	0.31	20.46	0.10
20.07	7.54	1.20	0.28	22.16	0.10
20.07	6.91	1.10	0.26	24.16	0.10
20.07	6.28	1.00	0.24	26.58	0.09
20.06	5.66	0.90	0.21	29.52	0.07
20.06	5.03	0.80	0.19	33.22	0.07
20.05	4.40	0.70	0.17	37.95	0.10
20.04	3.77	0.60	0.14	44.23	0.07

Table D.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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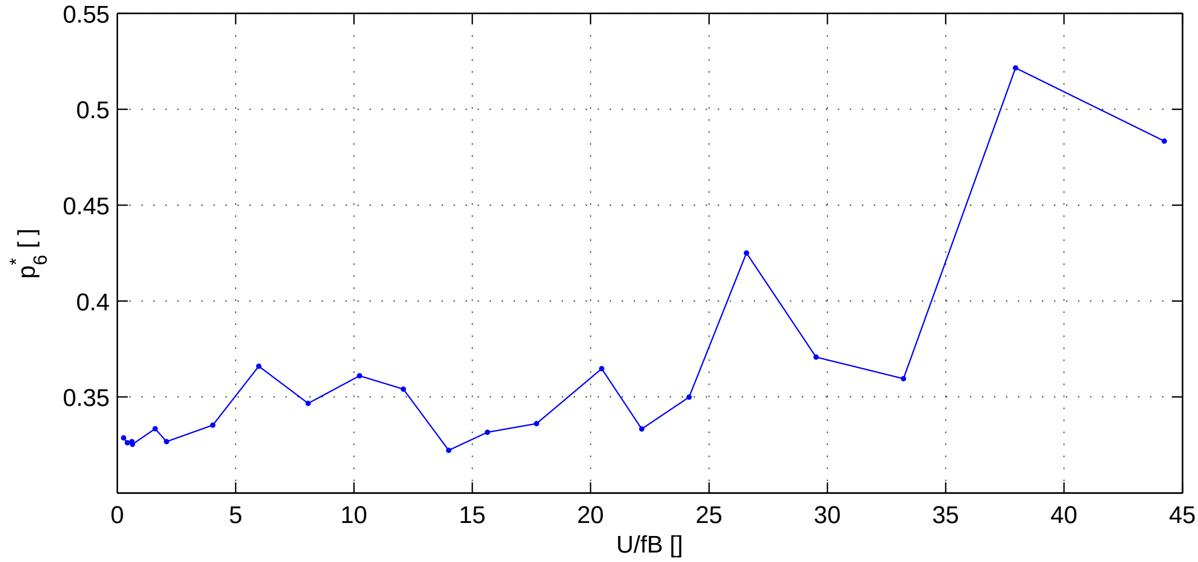


Figure D.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
0.80	25.13	4.00	23.65	0.27	0.33
1.29	25.13	4.00	14.72	0.43	0.33
1.85	25.13	4.00	10.25	0.61	0.33
1.95	25.13	4.00	9.73	0.65	0.33
4.84	25.13	4.00	3.92	1.60	0.33
6.28	25.13	4.00	3.02	2.08	0.33
12.18	25.13	4.00	1.56	4.03	0.34
18.07	25.13	4.00	1.05	5.98	0.37
20.10	20.74	3.30	0.78	8.07	0.35
20.10	16.34	2.60	0.61	10.24	0.36
20.08	13.82	2.20	0.52	12.09	0.35
20.08	11.93	1.90	0.45	14.00	0.32
20.06	10.68	1.70	0.40	15.64	0.33
20.07	9.43	1.50	0.35	17.71	0.34
20.08	8.17	1.30	0.31	20.46	0.36
20.07	7.54	1.20	0.28	22.16	0.33
20.07	6.91	1.10	0.26	24.16	0.35
20.07	6.28	1.00	0.24	26.58	0.43
20.06	5.66	0.90	0.21	29.52	0.37
20.06	5.03	0.80	0.19	33.22	0.36
20.05	4.40	0.70	0.17	37.95	0.52
20.04	3.77	0.60	0.14	44.23	0.48

Table D.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

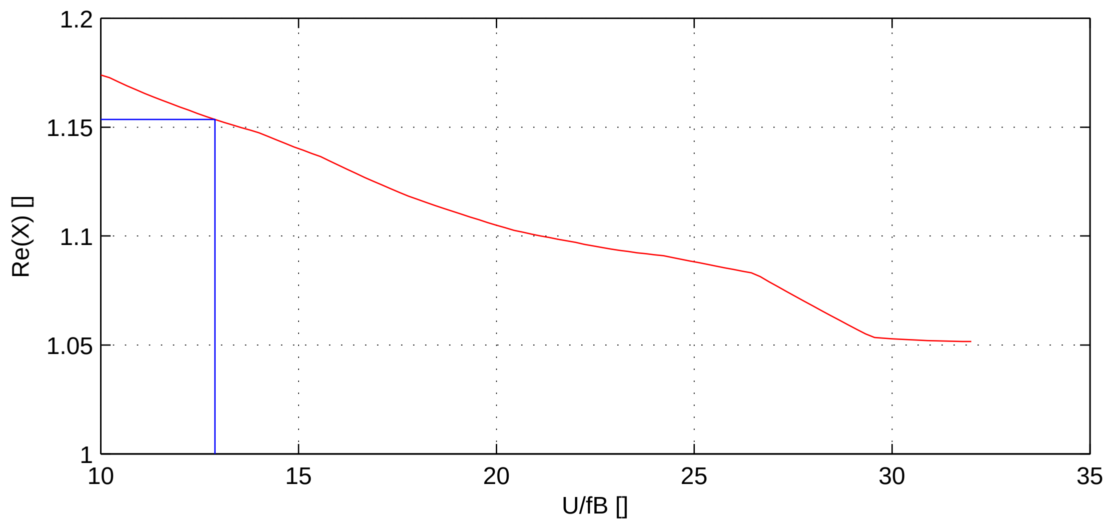


Figure D.37: Real part of the solution to stability equantion

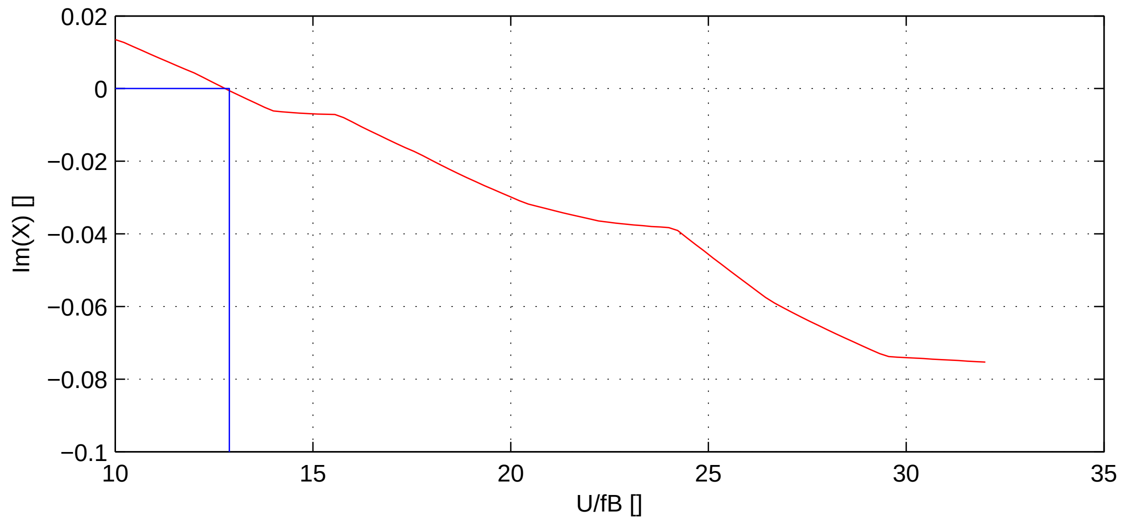


Figure D.38: Imaginary part of the solution to stability equantion

V_{Crit} = 12.9

f_{Crit} = 0.0746 Hz

U_{Crit} = 58.1 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.

[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.

[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.

[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.

[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix E

3D Flutter Tests

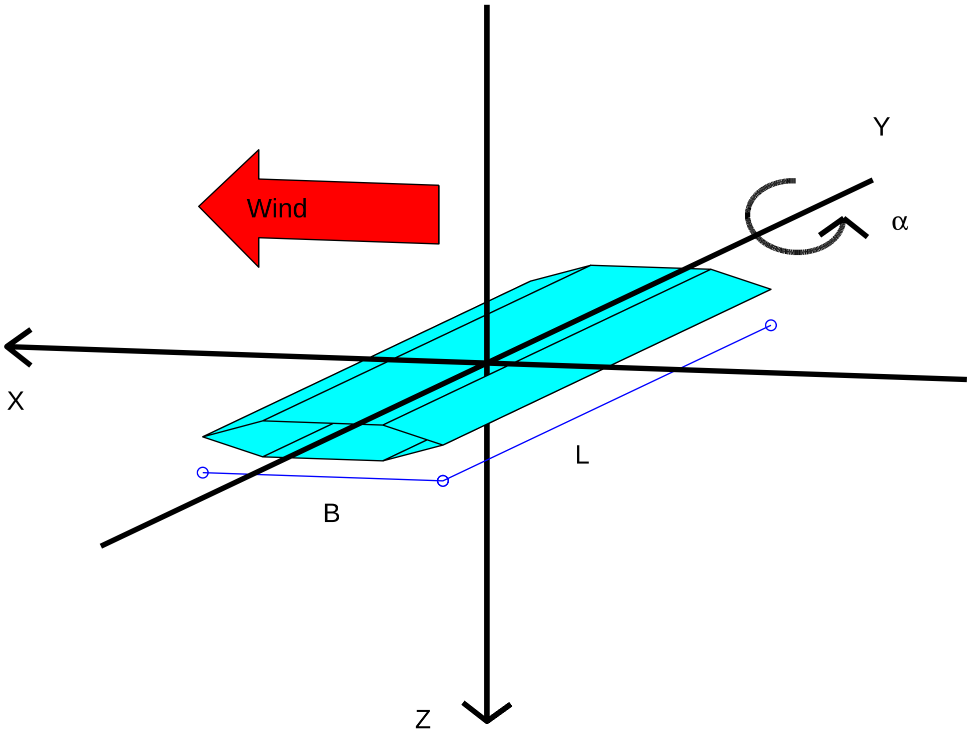
Flutter derivatives, Smooth flow, Angle of incidence = −4 deg.

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^{o}C	28.0
Relative humidity	ϕ	%	28
Barometric pressure	p	mmBar	1019.0

Table E.1: Project Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2\,m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha} m\,g - 2\,m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2\,m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h : Vertical displacement, displacement along z-axis, [m]
α : Rotation around y-axis, nose up is positive, [rad]
p : Horizontal displacement, displacement along the x-axis, [m]
m : Mass per unit length, [kg/m]
I_y : Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$: Added mass in vertical direction, [kg/m]
$m_{a,x}$: Added mass in horizontal direction, [kg/m]
$I_{a,y}$: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G : X-coordinate for centre of gravity, [m]
Z_G : Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$: Natural circular frequency for vertical motion, [/s]
ζ_h : Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$: Natural circular frequency for rotation around y axis, [/s]
ζ_α : Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p : Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$: Force from rig per meter section, [N/m]
$M_{Y,external}$: Moment from rig per meter section, [Nm/m]
$F_{X,external}$: Force from rig per meter section, [N/m]

Formula E.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.406
Added mass in horizontal	$m_{a,x}$	kg/m	0.547
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.141
Horizontal centre of gravity	x_G	m	−0.000
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.019
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.037
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.011

Table E.2: Mechanical Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = mg - m_{a,z}\ddot{h} - 2m\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m z_G\ddot{p} + m x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}mg - 2m\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b: buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b: buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b: buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\rho U^2 B C_z$$

$$M_{ad} = 1/2\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\rho U^2 B C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + KH_1^*\frac{\dot{h}}{U} + KH_2^*\frac{B\dot{\alpha}}{U} + KH_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + KA_1^*\frac{\dot{h}}{U} + KA_2^*\frac{B\dot{\alpha}}{U} + KA_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + KP_5^*\frac{\dot{h}}{U} + KP_2^*\frac{B\dot{\alpha}}{U} + KP_1^*\frac{\dot{p}}{U})$$

Formula E.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

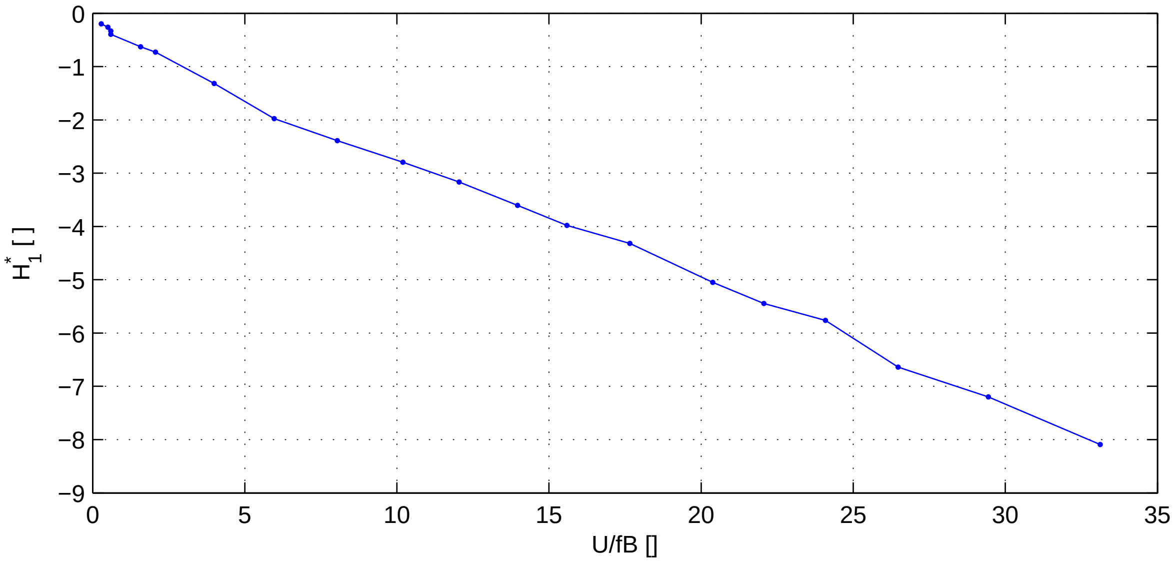


Figure E.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
0.85	25.13	4.00	22.40	0.28	−0.20
1.51	25.13	4.00	12.54	0.50	−0.26
1.79	25.13	4.00	10.60	0.59	−0.33
1.81	25.13	4.00	10.50	0.60	−0.40
4.75	25.13	4.00	3.99	1.57	−0.63
6.22	25.13	4.00	3.05	2.06	−0.73
12.05	25.13	4.00	1.57	3.99	−1.32
18.01	25.13	4.00	1.05	5.96	−1.98
20.03	20.74	3.30	0.78	8.04	−2.39
20.02	16.34	2.60	0.62	10.20	−2.79
20.01	13.82	2.20	0.52	12.05	−3.16
20.02	11.93	1.90	0.45	13.96	−3.60
20.01	10.69	1.70	0.40	15.59	−3.98
20.00	9.43	1.50	0.36	17.66	−4.32
20.00	8.17	1.30	0.31	20.38	−5.05
20.00	7.54	1.20	0.28	22.06	−5.45
20.00	6.91	1.10	0.26	24.08	−5.76
19.99	6.28	1.00	0.24	26.48	−6.64
20.01	5.66	0.90	0.21	29.44	−7.20
20.00	5.03	0.80	0.19	33.12	−8.09

Table E.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

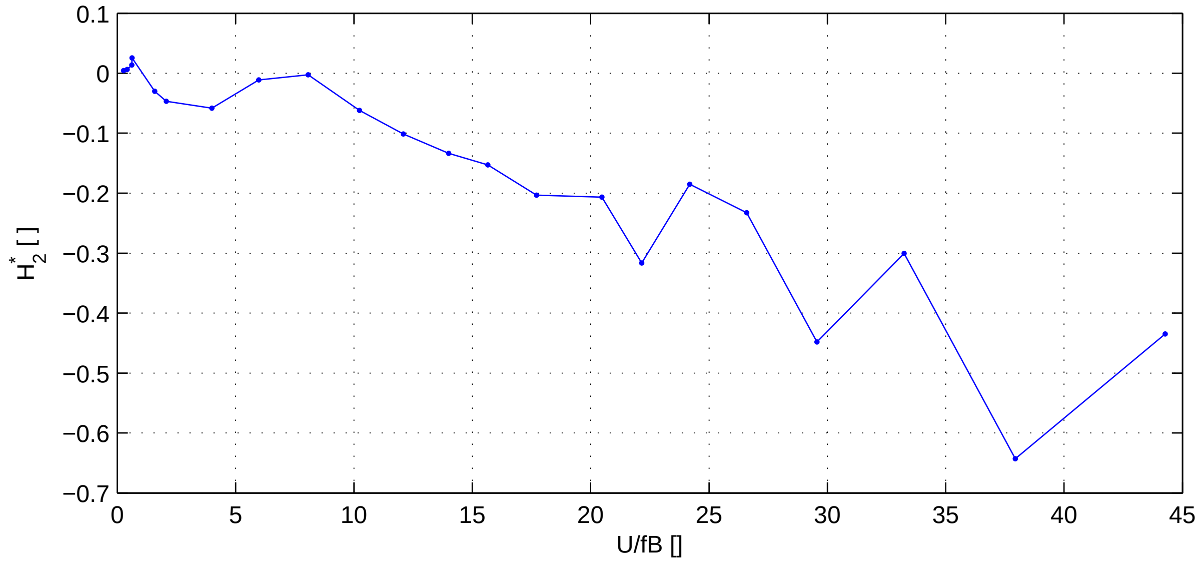


Figure E.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
0.81	25.13	4.00	23.35	0.27	0.00
1.26	25.13	4.00	15.03	0.42	0.01
1.86	25.13	4.00	10.21	0.62	0.01
1.89	25.13	4.00	10.06	0.62	0.03
4.79	25.13	4.00	3.97	1.58	−0.03
6.26	25.13	4.00	3.03	2.07	−0.05
12.07	25.13	4.00	1.57	4.00	−0.06
18.06	25.13	4.00	1.05	5.98	−0.01
20.09	20.74	3.30	0.78	8.06	−0.00
20.09	16.34	2.60	0.61	10.23	−0.06
20.08	13.82	2.20	0.52	12.09	−0.10
20.09	11.93	1.90	0.45	14.01	−0.13
20.10	10.69	1.70	0.40	15.65	−0.15
20.06	9.43	1.50	0.35	17.71	−0.20
20.09	8.17	1.30	0.31	20.48	−0.21
20.07	7.54	1.20	0.28	22.15	−0.32
20.09	6.91	1.10	0.26	24.19	−0.19
20.08	6.28	1.00	0.24	26.59	−0.23
20.09	5.66	0.90	0.21	29.56	−0.45
20.08	5.03	0.80	0.19	33.24	−0.30
20.05	4.40	0.70	0.17	37.94	−0.64
20.06	3.77	0.60	0.14	44.28	−0.43

Table E.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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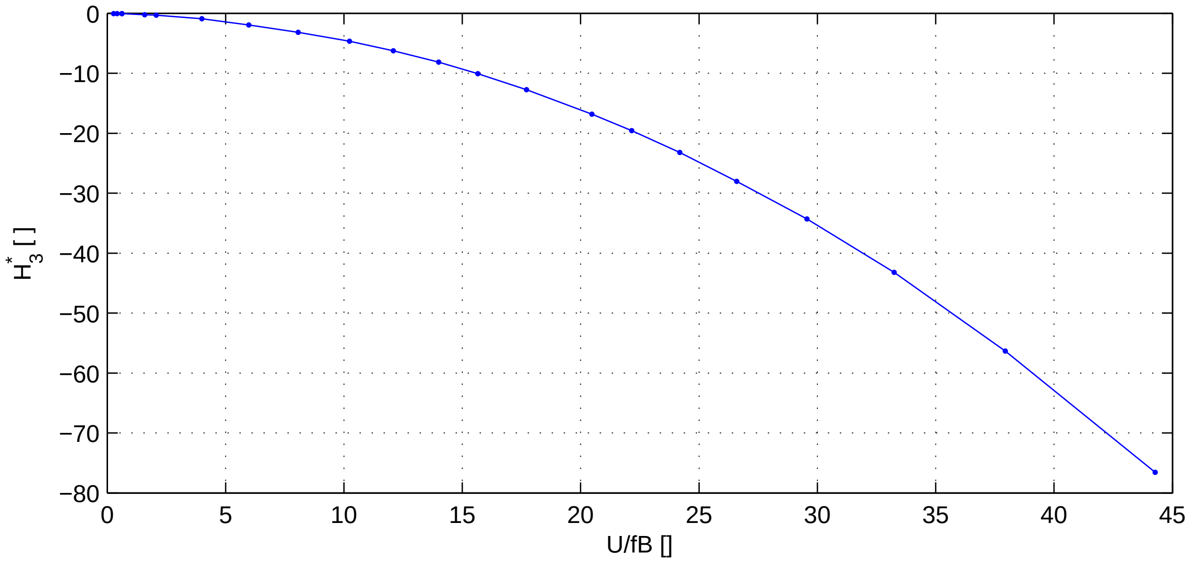

Figure E.3: H^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_3
0.81	25.13	4.00	23.35	0.27	−0.05
1.26	25.13	4.00	15.03	0.42	−0.05
1.86	25.13	4.00	10.21	0.62	−0.05
1.89	25.13	4.00	10.06	0.62	−0.07
4.79	25.13	4.00	3.97	1.58	−0.23
6.26	25.13	4.00	3.03	2.07	−0.31
12.07	25.13	4.00	1.57	4.00	−0.91
18.06	25.13	4.00	1.05	5.98	−1.94
20.09	20.74	3.30	0.78	8.06	−3.16
20.09	16.34	2.60	0.61	10.23	−4.65
20.08	13.82	2.20	0.52	12.09	−6.25
20.09	11.93	1.90	0.45	14.01	−8.15
20.10	10.69	1.70	0.40	15.65	−10.07
20.06	9.43	1.50	0.35	17.71	−12.75
20.09	8.17	1.30	0.31	20.48	−16.84
20.07	7.54	1.20	0.28	22.15	−19.56
20.09	6.91	1.10	0.26	24.19	−23.20
20.08	6.28	1.00	0.24	26.59	−28.04
20.09	5.66	0.90	0.21	29.56	−34.30
20.08	5.03	0.80	0.19	33.24	−43.22
20.05	4.40	0.70	0.17	37.94	−56.36
20.06	3.77	0.60	0.14	44.28	−76.56

Table E.5: H^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

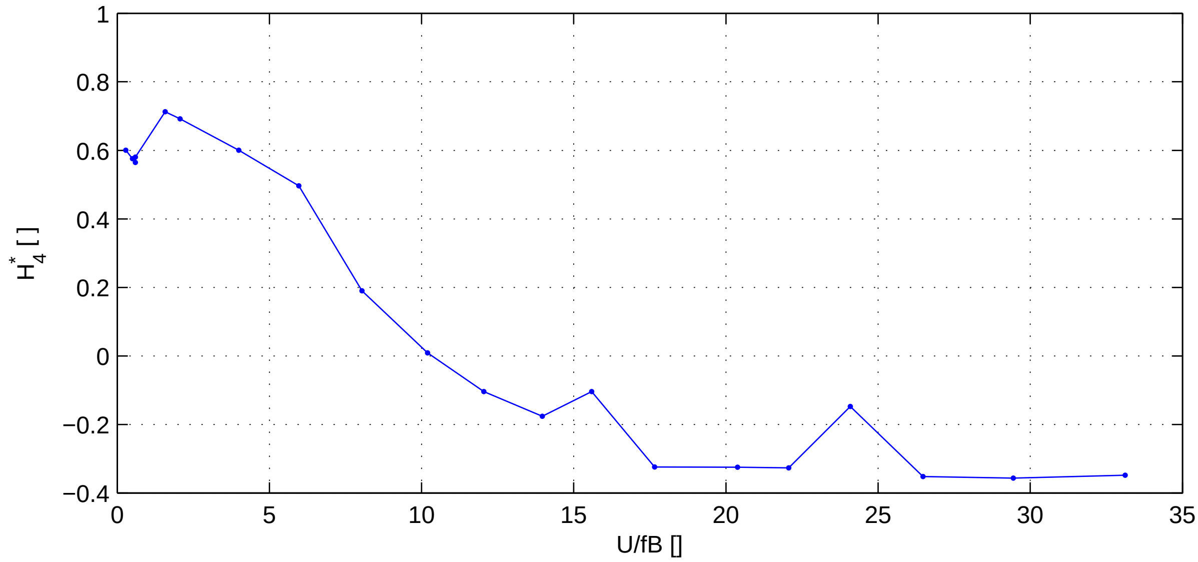

Figure E.4: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_4^*
0.85	25.13	4.00	22.40	0.28	0.60
1.51	25.13	4.00	12.54	0.50	0.58
1.79	25.13	4.00	10.60	0.59	0.56
1.81	25.13	4.00	10.50	0.60	0.58
4.75	25.13	4.00	3.99	1.57	0.71
6.22	25.13	4.00	3.05	2.06	0.69
12.05	25.13	4.00	1.57	3.99	0.60
18.01	25.13	4.00	1.05	5.96	0.50
20.03	20.74	3.30	0.78	8.04	0.19
20.02	16.34	2.60	0.62	10.20	0.01
20.01	13.82	2.20	0.52	12.05	−0.10
20.02	11.93	1.90	0.45	13.96	−0.18
20.01	10.69	1.70	0.40	15.59	−0.10
20.00	9.43	1.50	0.36	17.66	−0.32
20.00	8.17	1.30	0.31	20.38	−0.32
20.00	7.54	1.20	0.28	22.06	−0.33
20.00	6.91	1.10	0.26	24.08	−0.15
19.99	6.28	1.00	0.24	26.48	−0.35
20.01	5.66	0.90	0.21	29.44	−0.36
20.00	5.03	0.80	0.19	33.12	−0.35

Table E.6: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

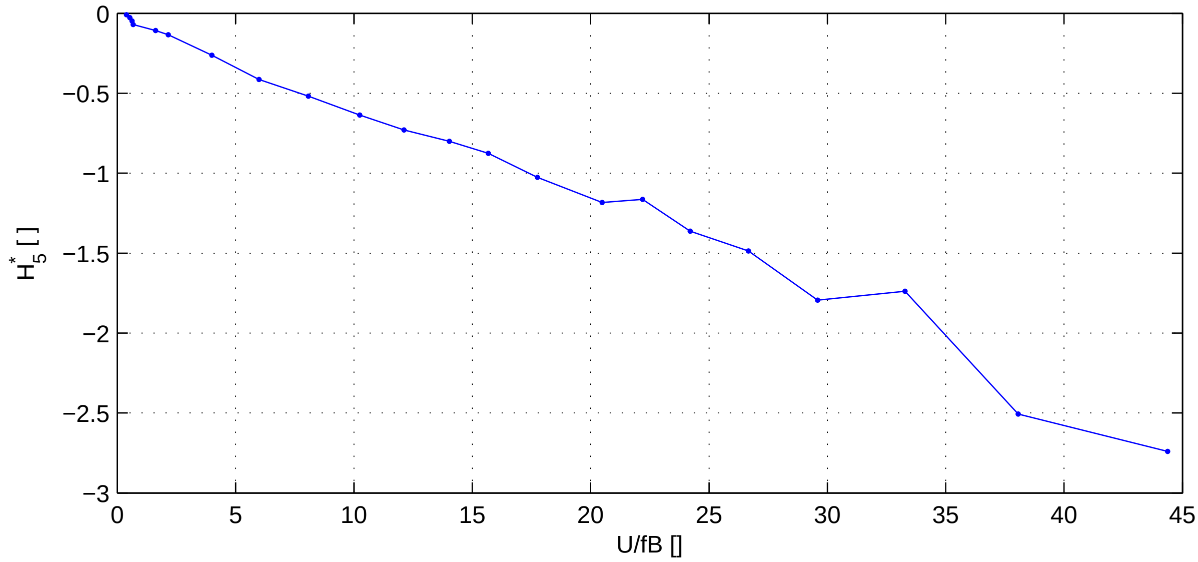

Figure E.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
1.18	25.13	4.00	16.02	0.39	−0.01
1.60	25.13	4.00	11.89	0.53	−0.03
1.89	25.13	4.00	10.01	0.63	−0.05
2.02	25.13	4.00	9.38	0.67	−0.07
4.89	25.13	4.00	3.88	1.62	−0.11
6.50	25.13	4.00	2.92	2.15	−0.13
12.08	25.13	4.00	1.57	4.00	−0.26
18.09	25.13	4.00	1.05	5.99	−0.41
20.11	20.74	3.30	0.78	8.07	−0.52
20.12	16.34	2.60	0.61	10.24	−0.64
20.12	13.82	2.20	0.52	12.11	−0.73
20.12	11.93	1.90	0.45	14.03	−0.80
20.11	10.68	1.70	0.40	15.67	−0.88
20.11	9.43	1.50	0.35	17.75	−1.03
20.10	8.17	1.30	0.31	20.48	−1.18
20.10	7.54	1.20	0.28	22.19	−1.16
20.10	6.91	1.10	0.26	24.20	−1.36
20.12	6.28	1.00	0.24	26.67	−1.49
20.11	5.66	0.90	0.21	29.59	−1.79
20.10	5.03	0.80	0.19	33.28	−1.74
20.11	4.40	0.70	0.17	38.06	−2.51
20.10	3.77	0.60	0.14	44.38	−2.74

Table E.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

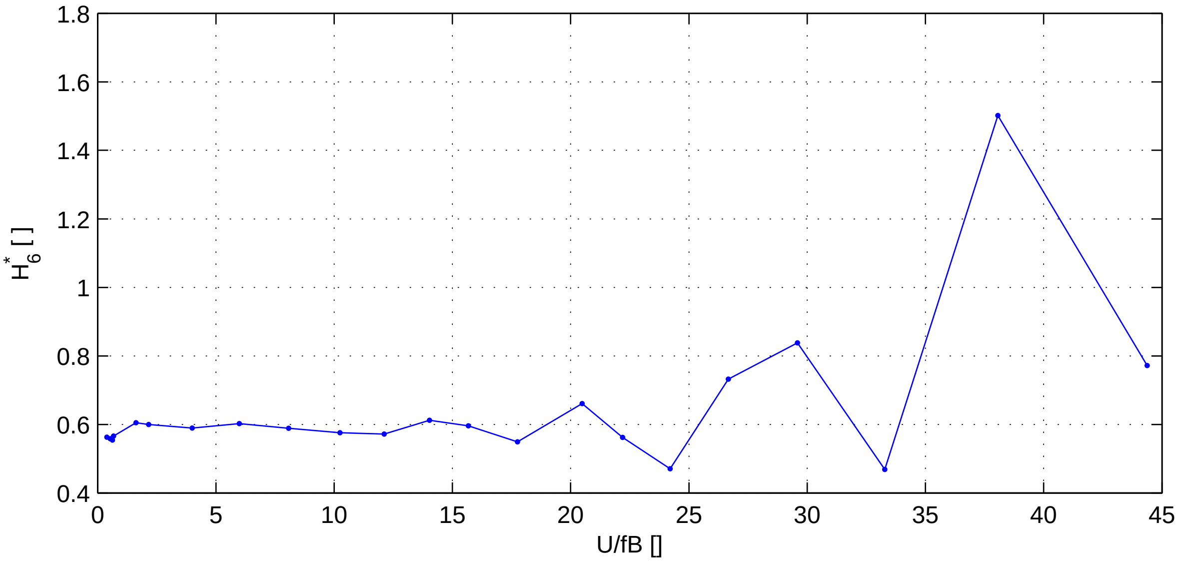

Figure E.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
1.18	25.13	4.00	16.02	0.39	0.56
1.60	25.13	4.00	11.89	0.53	0.56
1.89	25.13	4.00	10.01	0.63	0.55
2.02	25.13	4.00	9.38	0.67	0.57
4.89	25.13	4.00	3.88	1.62	0.60
6.50	25.13	4.00	2.92	2.15	0.60
12.08	25.13	4.00	1.57	4.00	0.59
18.09	25.13	4.00	1.05	5.99	0.60
20.11	20.74	3.30	0.78	8.07	0.59
20.12	16.34	2.60	0.61	10.24	0.58
20.12	13.82	2.20	0.52	12.11	0.57
20.12	11.93	1.90	0.45	14.03	0.61
20.11	10.68	1.70	0.40	15.67	0.60
20.11	9.43	1.50	0.35	17.75	0.55
20.10	8.17	1.30	0.31	20.48	0.66
20.10	7.54	1.20	0.28	22.19	0.56
20.10	6.91	1.10	0.26	24.20	0.47
20.12	6.28	1.00	0.24	26.67	0.73
20.11	5.66	0.90	0.21	29.59	0.84
20.10	5.03	0.80	0.19	33.28	0.47
20.11	4.40	0.70	0.17	38.06	1.50
20.10	3.77	0.60	0.14	44.38	0.77

Table E.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

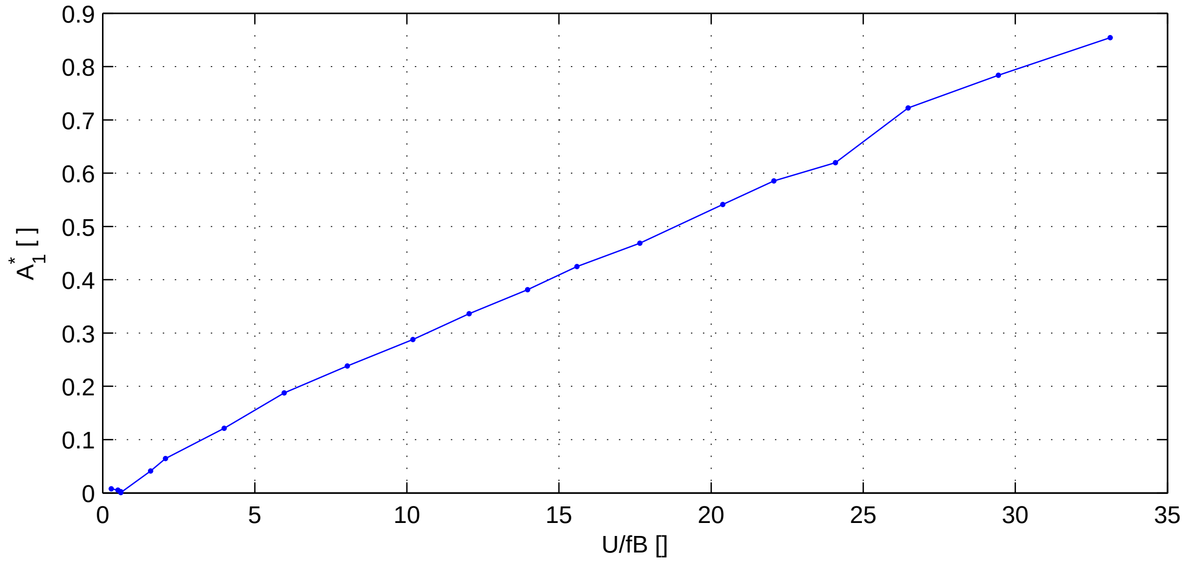

Figure E.7: A^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_1
0.85	25.13	4.00	22.40	0.28	0.01
1.51	25.13	4.00	12.54	0.50	0.01
1.79	25.13	4.00	10.60	0.59	0.00
1.81	25.13	4.00	10.50	0.60	0.00
4.75	25.13	4.00	3.99	1.57	0.04
6.22	25.13	4.00	3.05	2.06	0.06
12.05	25.13	4.00	1.57	3.99	0.12
18.01	25.13	4.00	1.05	5.96	0.19
20.03	20.74	3.30	0.78	8.04	0.24
20.02	16.34	2.60	0.62	10.20	0.29
20.01	13.82	2.20	0.52	12.05	0.34
20.02	11.93	1.90	0.45	13.96	0.38
20.01	10.69	1.70	0.40	15.59	0.42
20.00	9.43	1.50	0.36	17.66	0.47
20.00	8.17	1.30	0.31	20.38	0.54
20.00	7.54	1.20	0.28	22.06	0.59
20.00	6.91	1.10	0.26	24.08	0.62
19.99	6.28	1.00	0.24	26.48	0.72
20.01	5.66	0.90	0.21	29.44	0.78
20.00	5.03	0.80	0.19	33.12	0.85

Table E.9: A^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

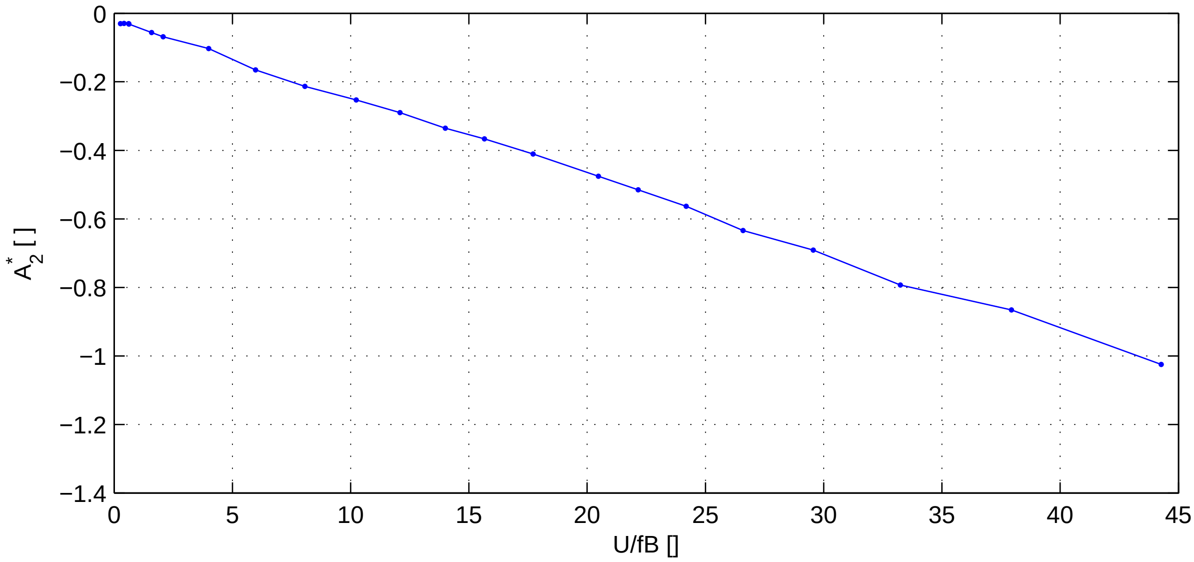

Figure E.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
0.81	25.13	4.00	23.35	0.27	−0.03
1.26	25.13	4.00	15.03	0.42	−0.03
1.86	25.13	4.00	10.21	0.62	−0.03
1.89	25.13	4.00	10.06	0.62	−0.03
4.79	25.13	4.00	3.97	1.58	−0.06
6.26	25.13	4.00	3.03	2.07	−0.07
12.07	25.13	4.00	1.57	4.00	−0.10
18.06	25.13	4.00	1.05	5.98	−0.17
20.09	20.74	3.30	0.78	8.06	−0.21
20.09	16.34	2.60	0.61	10.23	−0.25
20.08	13.82	2.20	0.52	12.09	−0.29
20.09	11.93	1.90	0.45	14.01	−0.34
20.10	10.69	1.70	0.40	15.65	−0.37
20.06	9.43	1.50	0.35	17.71	−0.41
20.09	8.17	1.30	0.31	20.48	−0.48
20.07	7.54	1.20	0.28	22.15	−0.52
20.09	6.91	1.10	0.26	24.19	−0.56
20.08	6.28	1.00	0.24	26.59	−0.63
20.09	5.66	0.90	0.21	29.56	−0.69
20.08	5.03	0.80	0.19	33.24	−0.79
20.05	4.40	0.70	0.17	37.94	−0.87
20.06	3.77	0.60	0.14	44.28	−1.03

Table E.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

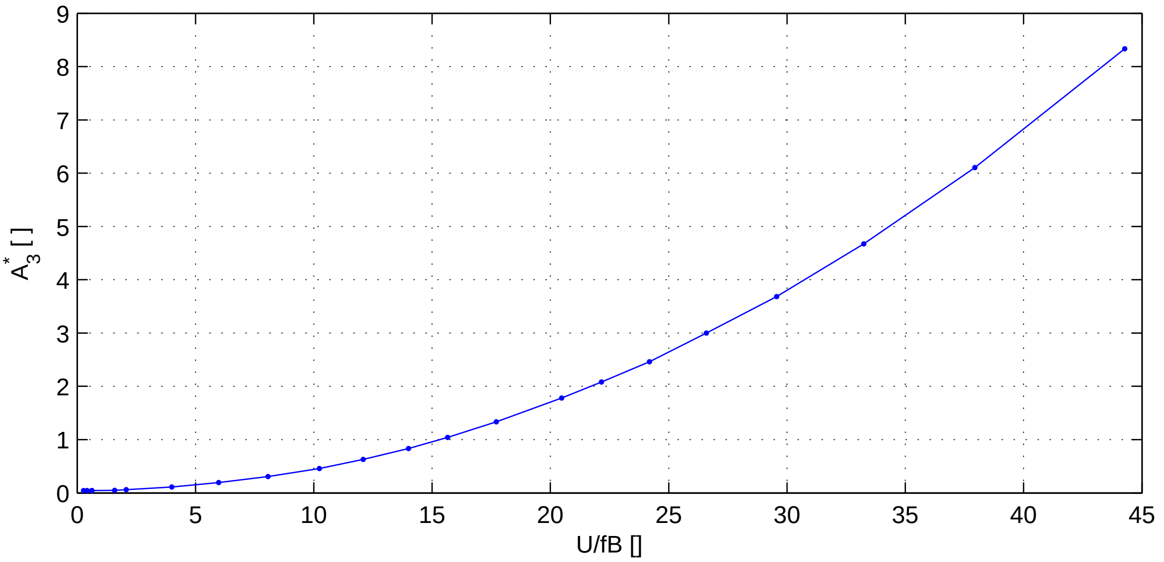

Figure E.9: A^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_3
0.81	25.13	4.00	23.35	0.27	0.05
1.26	25.13	4.00	15.03	0.42	0.04
1.86	25.13	4.00	10.21	0.62	0.04
1.89	25.13	4.00	10.06	0.62	0.04
4.79	25.13	4.00	3.97	1.58	0.05
6.26	25.13	4.00	3.03	2.07	0.06
12.07	25.13	4.00	1.57	4.00	0.11
18.06	25.13	4.00	1.05	5.98	0.19
20.09	20.74	3.30	0.78	8.06	0.31
20.09	16.34	2.60	0.61	10.23	0.46
20.08	13.82	2.20	0.52	12.09	0.63
20.09	11.93	1.90	0.45	14.01	0.83
20.10	10.69	1.70	0.40	15.65	1.04
20.06	9.43	1.50	0.35	17.71	1.34
20.09	8.17	1.30	0.31	20.48	1.78
20.07	7.54	1.20	0.28	22.15	2.08
20.09	6.91	1.10	0.26	24.19	2.46
20.08	6.28	1.00	0.24	26.59	3.00
20.09	5.66	0.90	0.21	29.56	3.68
20.08	5.03	0.80	0.19	33.24	4.67
20.05	4.40	0.70	0.17	37.94	6.11
20.06	3.77	0.60	0.14	44.28	8.33

Table E.11: A^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

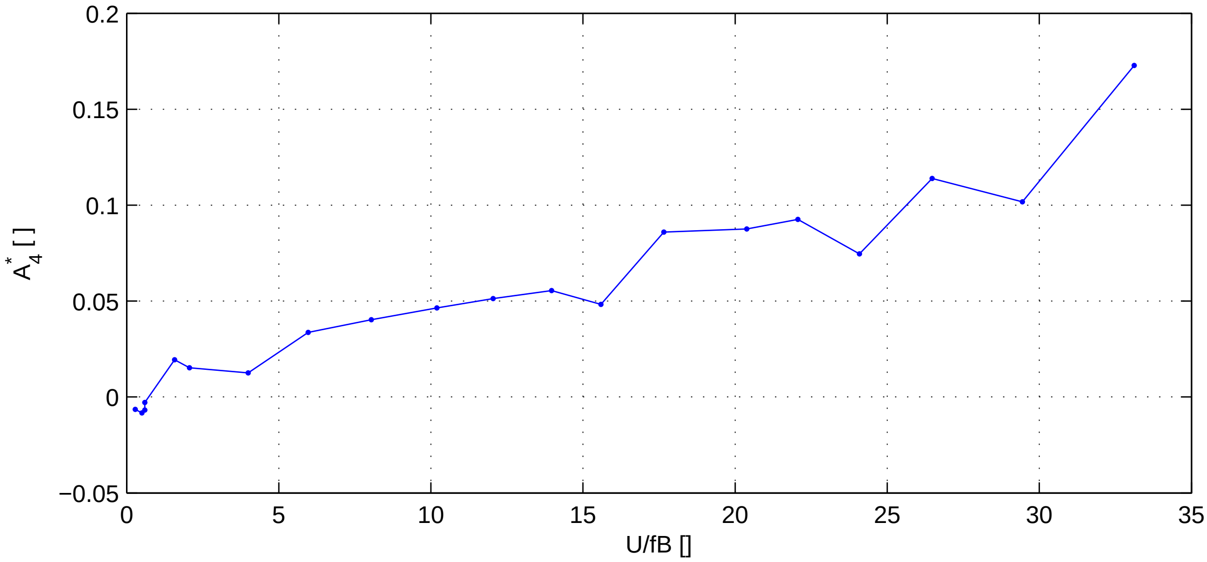

Figure E.10: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_4^*
0.85	25.13	4.00	22.40	0.28	−0.01
1.51	25.13	4.00	12.54	0.50	−0.01
1.79	25.13	4.00	10.60	0.59	−0.01
1.81	25.13	4.00	10.50	0.60	−0.00
4.75	25.13	4.00	3.99	1.57	0.02
6.22	25.13	4.00	3.05	2.06	0.02
12.05	25.13	4.00	1.57	3.99	0.01
18.01	25.13	4.00	1.05	5.96	0.03
20.03	20.74	3.30	0.78	8.04	0.04
20.02	16.34	2.60	0.62	10.20	0.05
20.01	13.82	2.20	0.52	12.05	0.05
20.02	11.93	1.90	0.45	13.96	0.06
20.01	10.69	1.70	0.40	15.59	0.05
20.00	9.43	1.50	0.36	17.66	0.09
20.00	8.17	1.30	0.31	20.38	0.09
20.00	7.54	1.20	0.28	22.06	0.09
20.00	6.91	1.10	0.26	24.08	0.07
19.99	6.28	1.00	0.24	26.48	0.11
20.01	5.66	0.90	0.21	29.44	0.10
20.00	5.03	0.80	0.19	33.12	0.17

Table E.12: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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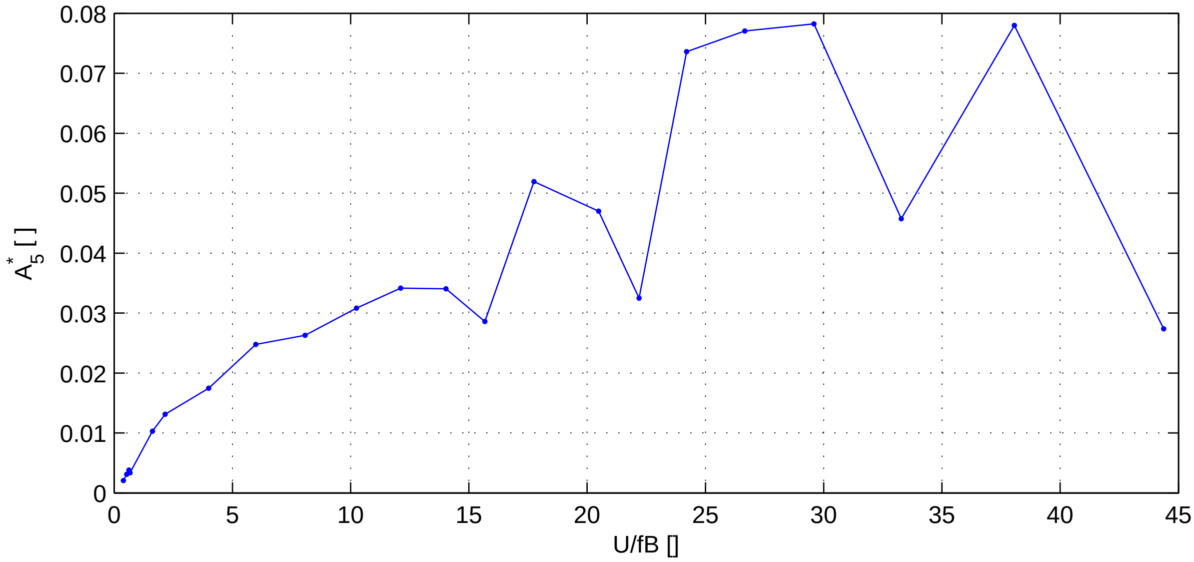

Figure E.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
1.18	25.13	4.00	16.02	0.39	0.00
1.60	25.13	4.00	11.89	0.53	0.00
1.89	25.13	4.00	10.01	0.63	0.00
2.02	25.13	4.00	9.38	0.67	0.00
4.89	25.13	4.00	3.88	1.62	0.01
6.50	25.13	4.00	2.92	2.15	0.01
12.08	25.13	4.00	1.57	4.00	0.02
18.09	25.13	4.00	1.05	5.99	0.02
20.11	20.74	3.30	0.78	8.07	0.03
20.12	16.34	2.60	0.61	10.24	0.03
20.12	13.82	2.20	0.52	12.11	0.03
20.12	11.93	1.90	0.45	14.03	0.03
20.11	10.68	1.70	0.40	15.67	0.03
20.11	9.43	1.50	0.35	17.75	0.05
20.10	8.17	1.30	0.31	20.48	0.05
20.10	7.54	1.20	0.28	22.19	0.03
20.10	6.91	1.10	0.26	24.20	0.07
20.12	6.28	1.00	0.24	26.67	0.08
20.11	5.66	0.90	0.21	29.59	0.08
20.10	5.03	0.80	0.19	33.28	0.05
20.11	4.40	0.70	0.17	38.06	0.08
20.10	3.77	0.60	0.14	44.38	0.03

Table E.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

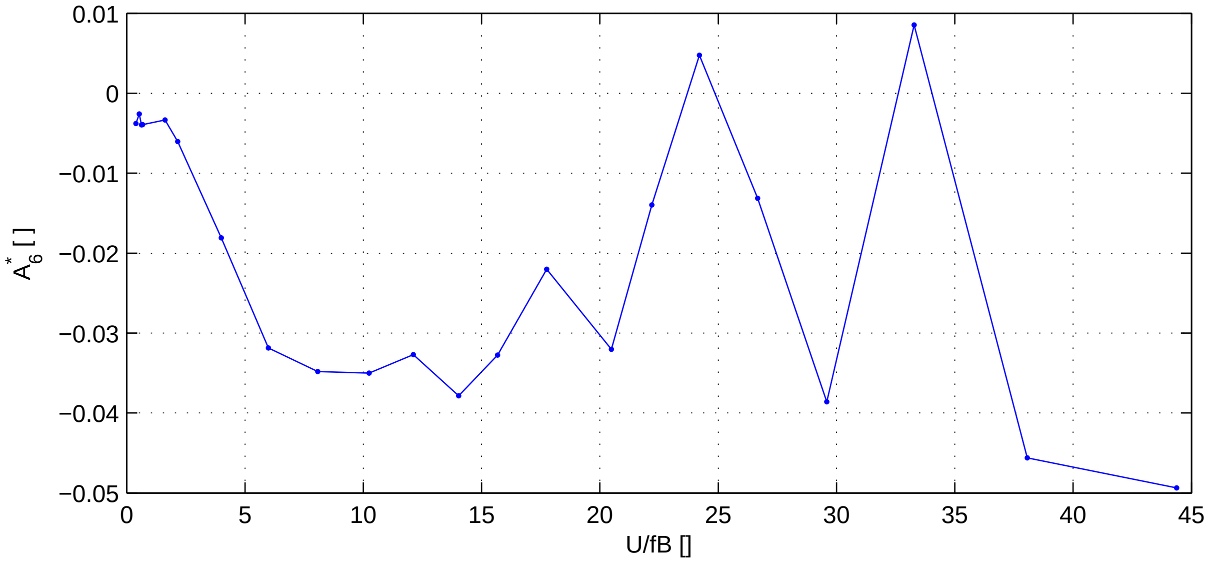

Figure E.12: A^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_6
1.18	25.13	4.00	16.02	0.39	−0.00
1.60	25.13	4.00	11.89	0.53	−0.00
1.89	25.13	4.00	10.01	0.63	−0.00
2.02	25.13	4.00	9.38	0.67	−0.00
4.89	25.13	4.00	3.88	1.62	−0.00
6.50	25.13	4.00	2.92	2.15	−0.01
12.08	25.13	4.00	1.57	4.00	−0.02
18.09	25.13	4.00	1.05	5.99	−0.03
20.11	20.74	3.30	0.78	8.07	−0.03
20.12	16.34	2.60	0.61	10.24	−0.04
20.12	13.82	2.20	0.52	12.11	−0.03
20.12	11.93	1.90	0.45	14.03	−0.04
20.11	10.68	1.70	0.40	15.67	−0.03
20.11	9.43	1.50	0.35	17.75	−0.02
20.10	8.17	1.30	0.31	20.48	−0.03
20.10	7.54	1.20	0.28	22.19	−0.01
20.10	6.91	1.10	0.26	24.20	0.00
20.12	6.28	1.00	0.24	26.67	−0.01
20.11	5.66	0.90	0.21	29.59	−0.04
20.10	5.03	0.80	0.19	33.28	0.01
20.11	4.40	0.70	0.17	38.06	−0.05
20.10	3.77	0.60	0.14	44.38	−0.05

Table E.14: A^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

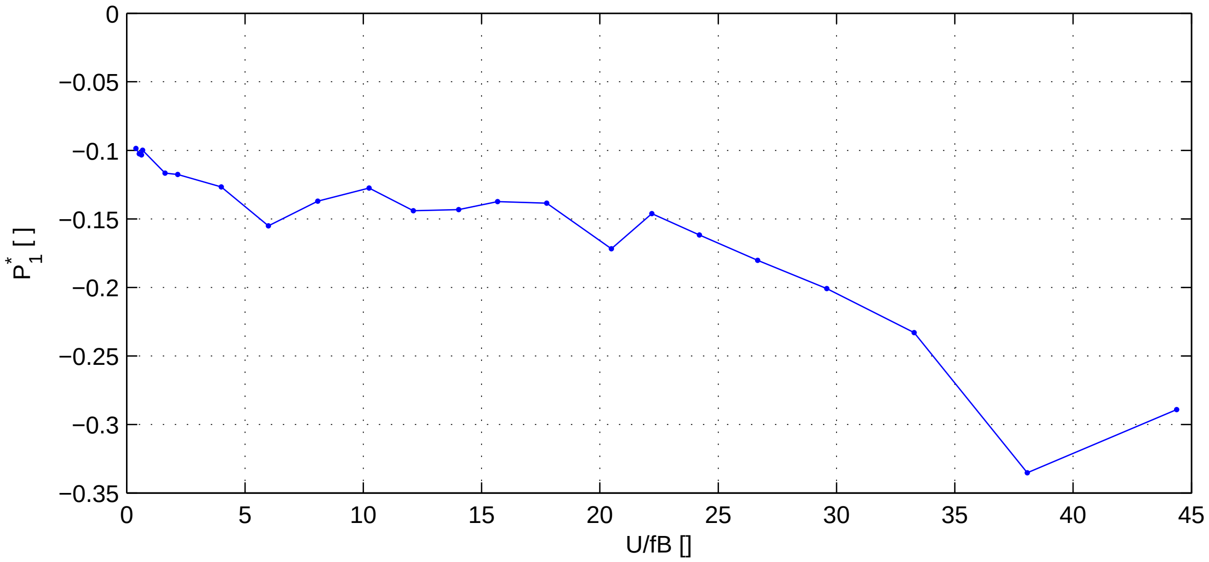

Figure E.13: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_1^*
1.18	25.13	4.00	16.02	0.39	−0.10
1.60	25.13	4.00	11.89	0.53	−0.10
1.89	25.13	4.00	10.01	0.63	−0.10
2.02	25.13	4.00	9.38	0.67	−0.10
4.89	25.13	4.00	3.88	1.62	−0.12
6.50	25.13	4.00	2.92	2.15	−0.12
12.08	25.13	4.00	1.57	4.00	−0.13
18.09	25.13	4.00	1.05	5.99	−0.16
20.11	20.74	3.30	0.78	8.07	−0.14
20.12	16.34	2.60	0.61	10.24	−0.13
20.12	13.82	2.20	0.52	12.11	−0.14
20.12	11.93	1.90	0.45	14.03	−0.14
20.11	10.68	1.70	0.40	15.67	−0.14
20.11	9.43	1.50	0.35	17.75	−0.14
20.10	8.17	1.30	0.31	20.48	−0.17
20.10	7.54	1.20	0.28	22.19	−0.15
20.10	6.91	1.10	0.26	24.20	−0.16
20.12	6.28	1.00	0.24	26.67	−0.18
20.11	5.66	0.90	0.21	29.59	−0.20
20.10	5.03	0.80	0.19	33.28	−0.23
20.11	4.40	0.70	0.17	38.06	−0.34
20.10	3.77	0.60	0.14	44.38	−0.29

Table E.15: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

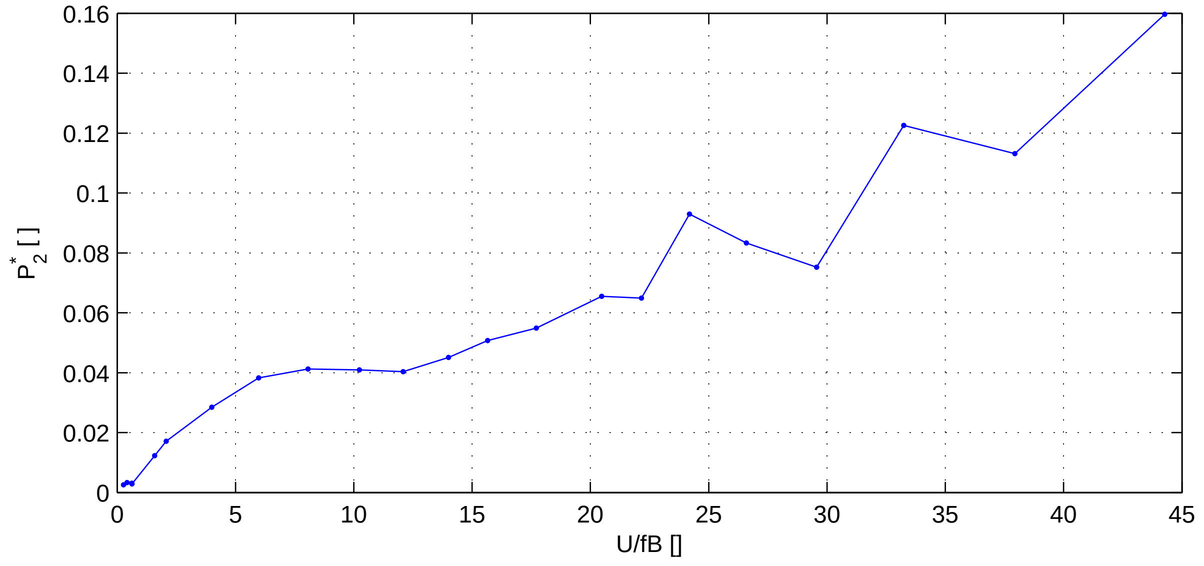

Figure E.14: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_2
0.81	25.13	4.00	23.35	0.27	0.00
1.26	25.13	4.00	15.03	0.42	0.00
1.86	25.13	4.00	10.21	0.62	0.00
1.89	25.13	4.00	10.06	0.62	0.00
4.79	25.13	4.00	3.97	1.58	0.01
6.26	25.13	4.00	3.03	2.07	0.02
12.07	25.13	4.00	1.57	4.00	0.03
18.06	25.13	4.00	1.05	5.98	0.04
20.09	20.74	3.30	0.78	8.06	0.04
20.09	16.34	2.60	0.61	10.23	0.04
20.08	13.82	2.20	0.52	12.09	0.04
20.09	11.93	1.90	0.45	14.01	0.05
20.10	10.69	1.70	0.40	15.65	0.05
20.06	9.43	1.50	0.35	17.71	0.05
20.09	8.17	1.30	0.31	20.48	0.07
20.07	7.54	1.20	0.28	22.15	0.06
20.09	6.91	1.10	0.26	24.19	0.09
20.08	6.28	1.00	0.24	26.59	0.08
20.09	5.66	0.90	0.21	29.56	0.08
20.08	5.03	0.80	0.19	33.24	0.12
20.05	4.40	0.70	0.17	37.94	0.11
20.06	3.77	0.60	0.14	44.28	0.16

Table E.16: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

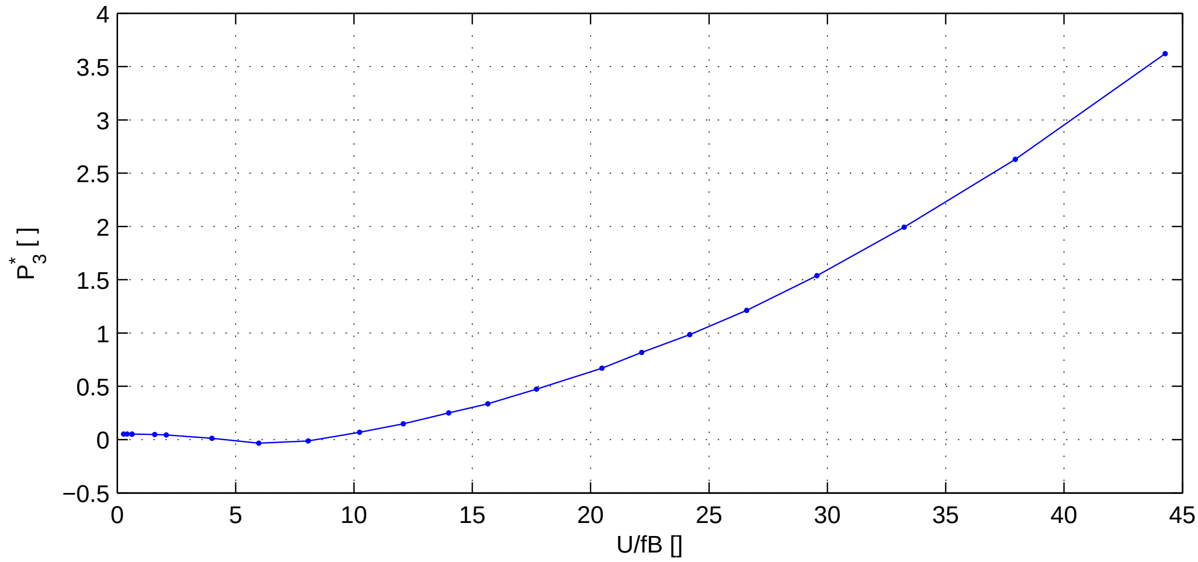

Figure E.15: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_3
0.81	25.13	4.00	23.35	0.27	0.05
1.26	25.13	4.00	15.03	0.42	0.05
1.86	25.13	4.00	10.21	0.62	0.05
1.89	25.13	4.00	10.06	0.62	0.05
4.79	25.13	4.00	3.97	1.58	0.05
6.26	25.13	4.00	3.03	2.07	0.04
12.07	25.13	4.00	1.57	4.00	0.01
18.06	25.13	4.00	1.05	5.98	−0.03
20.09	20.74	3.30	0.78	8.06	−0.01
20.09	16.34	2.60	0.61	10.23	0.07
20.08	13.82	2.20	0.52	12.09	0.15
20.09	11.93	1.90	0.45	14.01	0.25
20.10	10.69	1.70	0.40	15.65	0.34
20.06	9.43	1.50	0.35	17.71	0.47
20.09	8.17	1.30	0.31	20.48	0.67
20.07	7.54	1.20	0.28	22.15	0.82
20.09	6.91	1.10	0.26	24.19	0.98
20.08	6.28	1.00	0.24	26.59	1.21
20.09	5.66	0.90	0.21	29.56	1.54
20.08	5.03	0.80	0.19	33.24	1.99
20.05	4.40	0.70	0.17	37.94	2.63
20.06	3.77	0.60	0.14	44.28	3.62

Table E.17: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

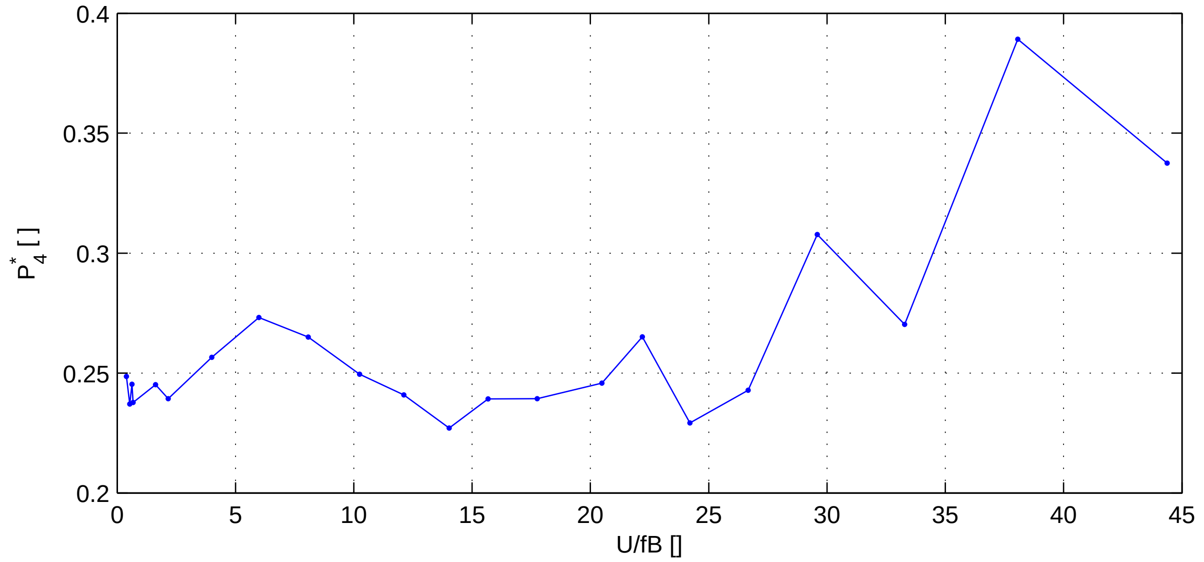

Figure E.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
1.18	25.13	4.00	16.02	0.39	0.25
1.60	25.13	4.00	11.89	0.53	0.24
1.89	25.13	4.00	10.01	0.63	0.25
2.02	25.13	4.00	9.38	0.67	0.24
4.89	25.13	4.00	3.88	1.62	0.25
6.50	25.13	4.00	2.92	2.15	0.24
12.08	25.13	4.00	1.57	4.00	0.26
18.09	25.13	4.00	1.05	5.99	0.27
20.11	20.74	3.30	0.78	8.07	0.26
20.12	16.34	2.60	0.61	10.24	0.25
20.12	13.82	2.20	0.52	12.11	0.24
20.12	11.93	1.90	0.45	14.03	0.23
20.11	10.68	1.70	0.40	15.67	0.24
20.11	9.43	1.50	0.35	17.75	0.24
20.10	8.17	1.30	0.31	20.48	0.25
20.10	7.54	1.20	0.28	22.19	0.27
20.10	6.91	1.10	0.26	24.20	0.23
20.12	6.28	1.00	0.24	26.67	0.24
20.11	5.66	0.90	0.21	29.59	0.31
20.10	5.03	0.80	0.19	33.28	0.27
20.11	4.40	0.70	0.17	38.06	0.39
20.10	3.77	0.60	0.14	44.38	0.34

Table E.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

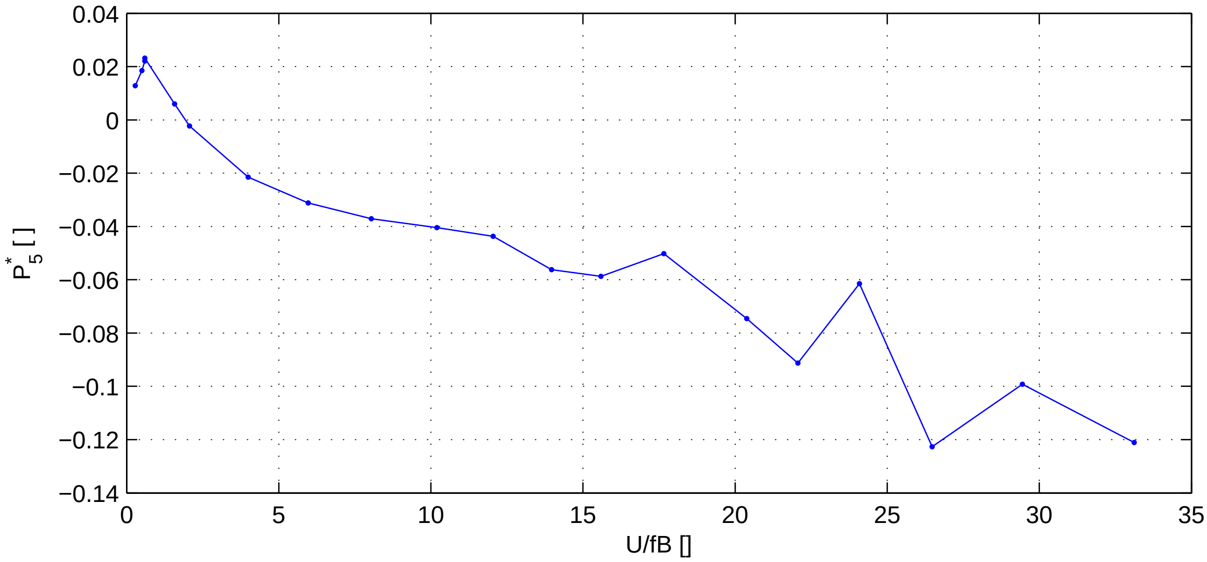

Figure E.17: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_5
0.85	25.13	4.00	22.40	0.28	0.01
1.51	25.13	4.00	12.54	0.50	0.02
1.79	25.13	4.00	10.60	0.59	0.02
1.81	25.13	4.00	10.50	0.60	0.02
4.75	25.13	4.00	3.99	1.57	0.01
6.22	25.13	4.00	3.05	2.06	−0.00
12.05	25.13	4.00	1.57	3.99	−0.02
18.01	25.13	4.00	1.05	5.96	−0.03
20.03	20.74	3.30	0.78	8.04	−0.04
20.02	16.34	2.60	0.62	10.20	−0.04
20.01	13.82	2.20	0.52	12.05	−0.04
20.02	11.93	1.90	0.45	13.96	−0.06
20.01	10.69	1.70	0.40	15.59	−0.06
20.00	9.43	1.50	0.36	17.66	−0.05
20.00	8.17	1.30	0.31	20.38	−0.07
20.00	7.54	1.20	0.28	22.06	−0.09
20.00	6.91	1.10	0.26	24.08	−0.06
19.99	6.28	1.00	0.24	26.48	−0.12
20.01	5.66	0.90	0.21	29.44	−0.10
20.00	5.03	0.80	0.19	33.12	−0.12

Table E.19: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:08:43

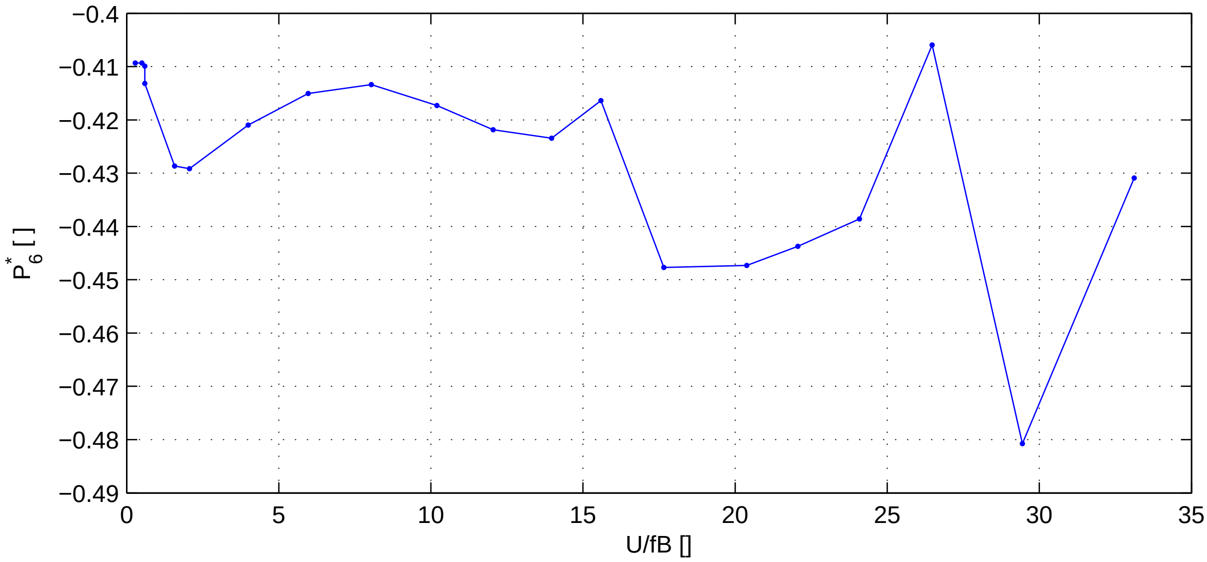

Figure E.18: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_6
0.85	25.13	4.00	22.40	0.28	−0.41
1.51	25.13	4.00	12.54	0.50	−0.41
1.79	25.13	4.00	10.60	0.59	−0.41
1.81	25.13	4.00	10.50	0.60	−0.41
4.75	25.13	4.00	3.99	1.57	−0.43
6.22	25.13	4.00	3.05	2.06	−0.43
12.05	25.13	4.00	1.57	3.99	−0.42
18.01	25.13	4.00	1.05	5.96	−0.42
20.03	20.74	3.30	0.78	8.04	−0.41
20.02	16.34	2.60	0.62	10.20	−0.42
20.01	13.82	2.20	0.52	12.05	−0.42
20.02	11.93	1.90	0.45	13.96	−0.42
20.01	10.69	1.70	0.40	15.59	−0.42
20.00	9.43	1.50	0.36	17.66	−0.45
20.00	8.17	1.30	0.31	20.38	−0.45
20.00	7.54	1.20	0.28	22.06	−0.44
20.00	6.91	1.10	0.26	24.08	−0.44
19.99	6.28	1.00	0.24	26.48	−0.41
20.01	5.66	0.90	0.21	29.44	−0.48
20.00	5.03	0.80	0.19	33.12	−0.43

Table E.20: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = mg - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\,(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\,(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\,(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

Formula E.3: Equation of Motion (Stretto di Messina. Ref. [5].)

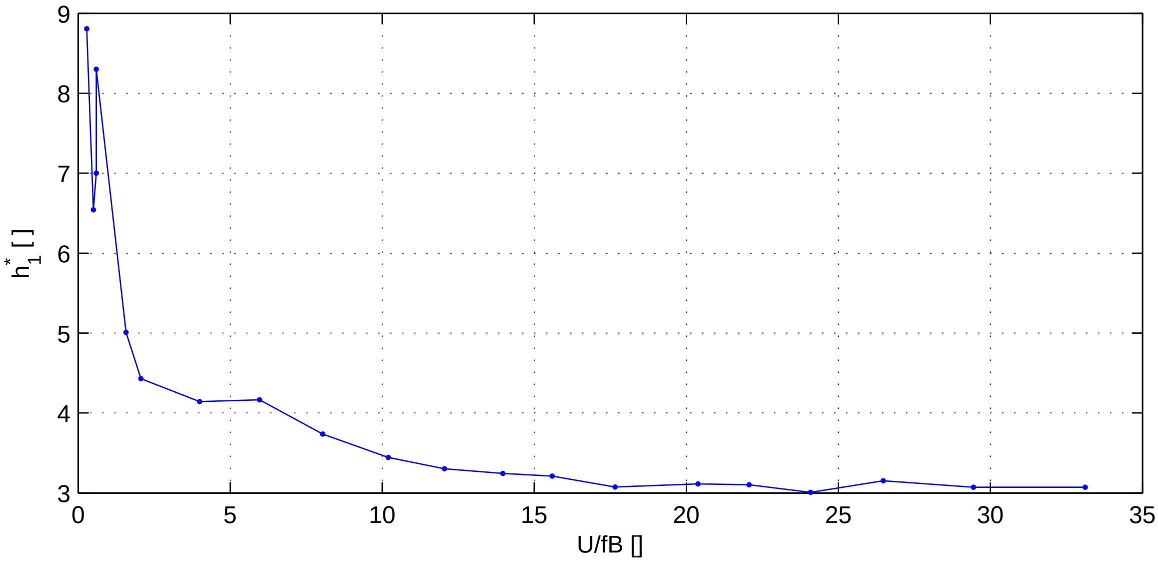

Figure E.19: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_1^*
0.85	25.13	4.00	22.40	0.28	8.81
1.51	25.13	4.00	12.54	0.50	6.54
1.79	25.13	4.00	10.60	0.59	7.00
1.81	25.13	4.00	10.50	0.60	8.30
4.75	25.13	4.00	3.99	1.57	5.01
6.22	25.13	4.00	3.05	2.06	4.43
12.05	25.13	4.00	1.57	3.99	4.14
18.01	25.13	4.00	1.05	5.96	4.17
20.03	20.74	3.30	0.78	8.04	3.74
20.02	16.34	2.60	0.62	10.20	3.44
20.01	13.82	2.20	0.52	12.05	3.30
20.02	11.93	1.90	0.45	13.96	3.24
20.01	10.69	1.70	0.40	15.59	3.21
20.00	9.43	1.50	0.36	17.66	3.07
20.00	8.17	1.30	0.31	20.38	3.11
20.00	7.54	1.20	0.28	22.06	3.10
20.00	6.91	1.10	0.26	24.08	3.01
19.99	6.28	1.00	0.24	26.48	3.15
20.01	5.66	0.90	0.21	29.44	3.07
20.00	5.03	0.80	0.19	33.12	3.07

Table E.21: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

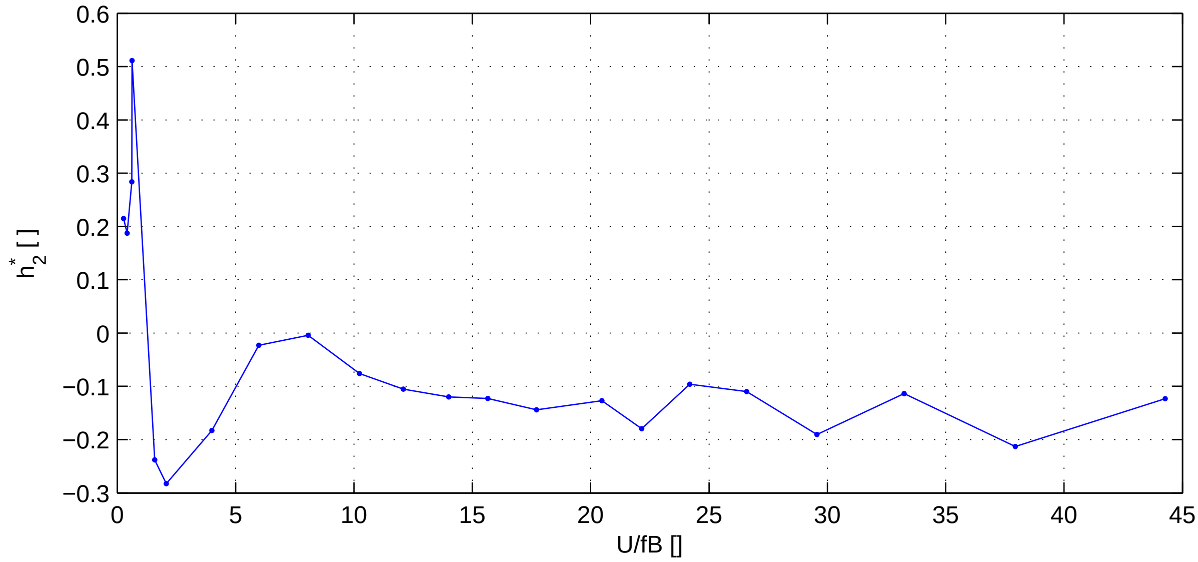

Figure E.20: h^*_2 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_2
0.81	25.13	4.00	23.35	0.27	0.22
1.26	25.13	4.00	15.03	0.42	0.19
1.86	25.13	4.00	10.21	0.62	0.28
1.89	25.13	4.00	10.06	0.62	0.51
4.79	25.13	4.00	3.97	1.58	−0.24
6.26	25.13	4.00	3.03	2.07	−0.28
12.07	25.13	4.00	1.57	4.00	−0.18
18.06	25.13	4.00	1.05	5.98	−0.02
20.09	20.74	3.30	0.78	8.06	−0.00
20.09	16.34	2.60	0.61	10.23	−0.08
20.08	13.82	2.20	0.52	12.09	−0.11
20.09	11.93	1.90	0.45	14.01	−0.12
20.10	10.69	1.70	0.40	15.65	−0.12
20.06	9.43	1.50	0.35	17.71	−0.14
20.09	8.17	1.30	0.31	20.48	−0.13
20.07	7.54	1.20	0.28	22.15	−0.18
20.09	6.91	1.10	0.26	24.19	−0.10
20.08	6.28	1.00	0.24	26.59	−0.11
20.09	5.66	0.90	0.21	29.56	−0.19
20.08	5.03	0.80	0.19	33.24	−0.11
20.05	4.40	0.70	0.17	37.94	−0.21
20.06	3.77	0.60	0.14	44.28	−0.12

Table E.22: h^*_2 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

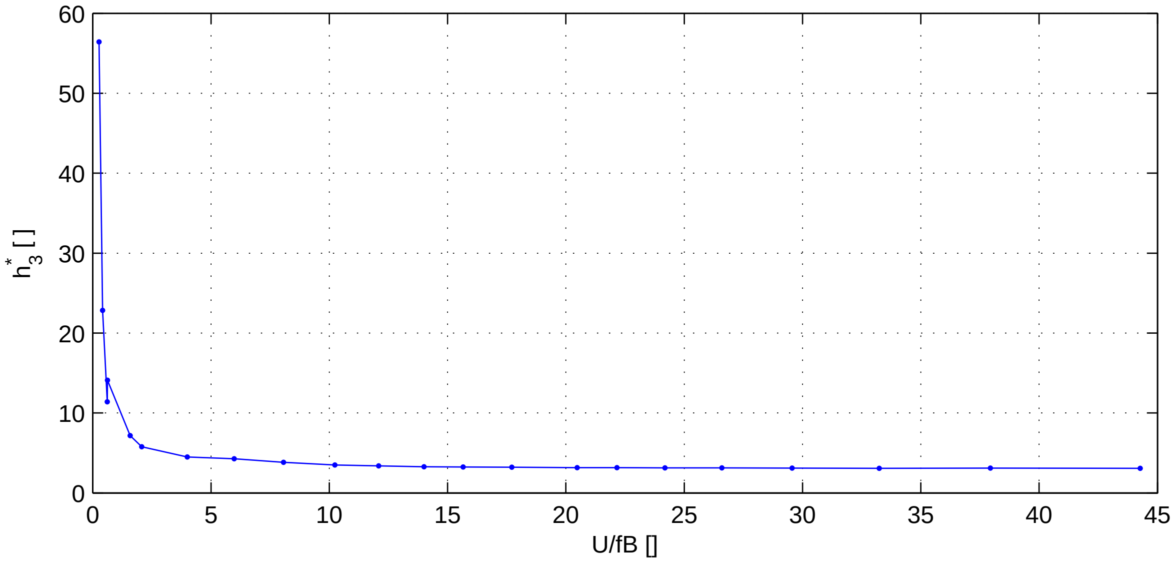

Figure E.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
0.81	25.13	4.00	23.35	0.27	56.41
1.26	25.13	4.00	15.03	0.42	22.84
1.86	25.13	4.00	10.21	0.62	11.38
1.89	25.13	4.00	10.06	0.62	14.08
4.79	25.13	4.00	3.97	1.58	7.16
6.26	25.13	4.00	3.03	2.07	5.78
12.07	25.13	4.00	1.57	4.00	4.49
18.06	25.13	4.00	1.05	5.98	4.27
20.09	20.74	3.30	0.78	8.06	3.83
20.09	16.34	2.60	0.61	10.23	3.51
20.08	13.82	2.20	0.52	12.09	3.38
20.09	11.93	1.90	0.45	14.01	3.28
20.10	10.69	1.70	0.40	15.65	3.25
20.06	9.43	1.50	0.35	17.71	3.21
20.09	8.17	1.30	0.31	20.48	3.17
20.07	7.54	1.20	0.28	22.15	3.15
20.09	6.91	1.10	0.26	24.19	3.13
20.08	6.28	1.00	0.24	26.59	3.13
20.09	5.66	0.90	0.21	29.56	3.10
20.08	5.03	0.80	0.19	33.24	3.09
20.05	4.40	0.70	0.17	37.94	3.09
20.06	3.77	0.60	0.14	44.28	3.08

Table E.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

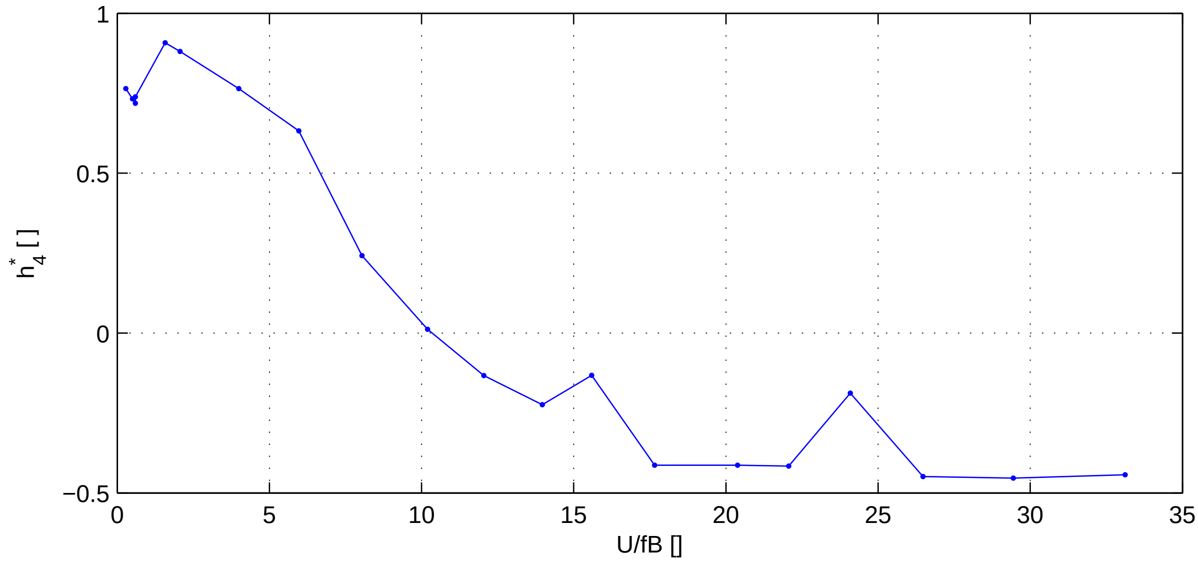

Figure E.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
0.85	25.13	4.00	22.40	0.28	0.76
1.51	25.13	4.00	12.54	0.50	0.73
1.79	25.13	4.00	10.60	0.59	0.72
1.81	25.13	4.00	10.50	0.60	0.74
4.75	25.13	4.00	3.99	1.57	0.91
6.22	25.13	4.00	3.05	2.06	0.88
12.05	25.13	4.00	1.57	3.99	0.76
18.01	25.13	4.00	1.05	5.96	0.63
20.03	20.74	3.30	0.78	8.04	0.24
20.02	16.34	2.60	0.62	10.20	0.01
20.01	13.82	2.20	0.52	12.05	−0.13
20.02	11.93	1.90	0.45	13.96	−0.22
20.01	10.69	1.70	0.40	15.59	−0.13
20.00	9.43	1.50	0.36	17.66	−0.41
20.00	8.17	1.30	0.31	20.38	−0.41
20.00	7.54	1.20	0.28	22.06	−0.42
20.00	6.91	1.10	0.26	24.08	−0.19
19.99	6.28	1.00	0.24	26.48	−0.45
20.01	5.66	0.90	0.21	29.44	−0.45
20.00	5.03	0.80	0.19	33.12	−0.44

Table E.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

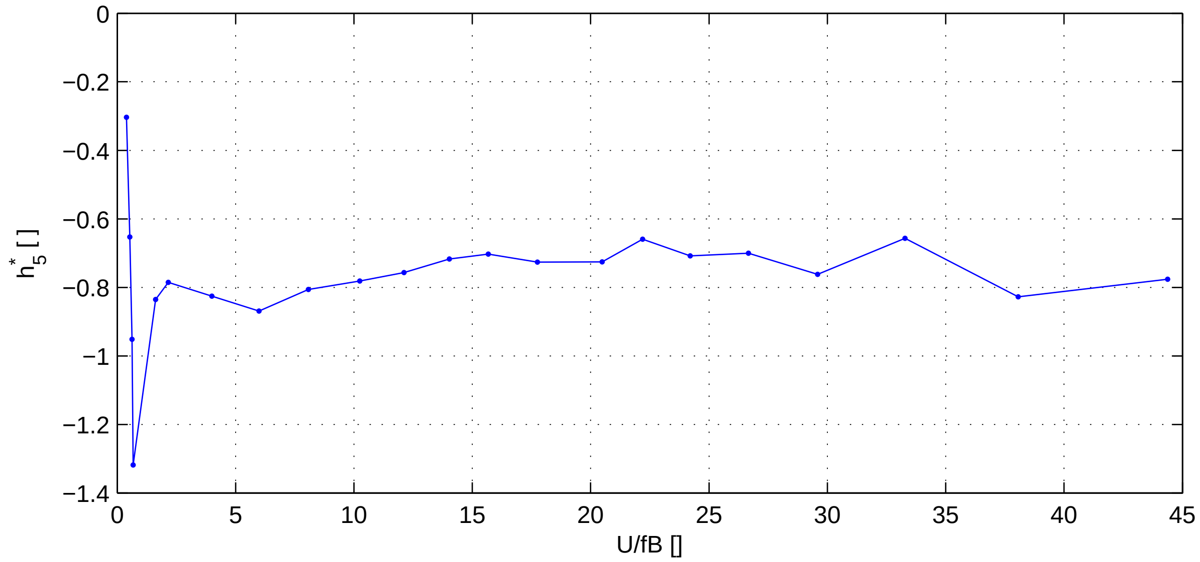

Figure E.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
1.18	25.13	4.00	16.02	0.39	−0.30
1.60	25.13	4.00	11.89	0.53	−0.65
1.89	25.13	4.00	10.01	0.63	−0.95
2.02	25.13	4.00	9.38	0.67	−1.32
4.89	25.13	4.00	3.88	1.62	−0.84
6.50	25.13	4.00	2.92	2.15	−0.79
12.08	25.13	4.00	1.57	4.00	−0.83
18.09	25.13	4.00	1.05	5.99	−0.87
20.11	20.74	3.30	0.78	8.07	−0.81
20.12	16.34	2.60	0.61	10.24	−0.78
20.12	13.82	2.20	0.52	12.11	−0.76
20.12	11.93	1.90	0.45	14.03	−0.72
20.11	10.68	1.70	0.40	15.67	−0.70
20.11	9.43	1.50	0.35	17.75	−0.73
20.10	8.17	1.30	0.31	20.48	−0.73
20.10	7.54	1.20	0.28	22.19	−0.66
20.10	6.91	1.10	0.26	24.20	−0.71
20.12	6.28	1.00	0.24	26.67	−0.70
20.11	5.66	0.90	0.21	29.59	−0.76
20.10	5.03	0.80	0.19	33.28	−0.66
20.11	4.40	0.70	0.17	38.06	−0.83
20.10	3.77	0.60	0.14	44.38	−0.78

Table E.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

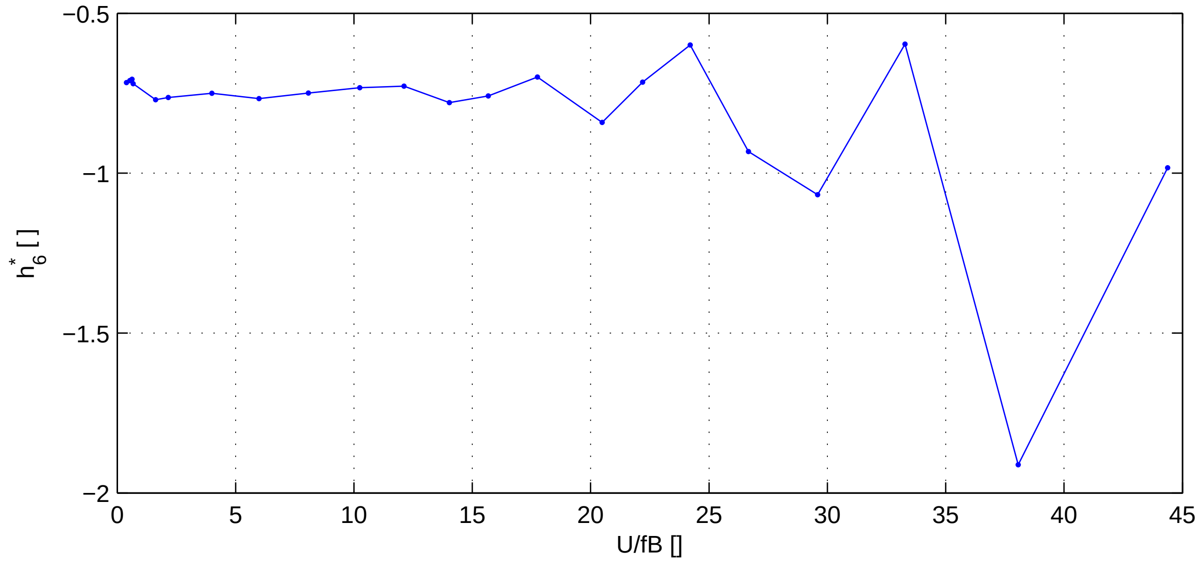

Figure E.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
1.18	25.13	4.00	16.02	0.39	−0.72
1.60	25.13	4.00	11.89	0.53	−0.71
1.89	25.13	4.00	10.01	0.63	−0.71
2.02	25.13	4.00	9.38	0.67	−0.72
4.89	25.13	4.00	3.88	1.62	−0.77
6.50	25.13	4.00	2.92	2.15	−0.76
12.08	25.13	4.00	1.57	4.00	−0.75
18.09	25.13	4.00	1.05	5.99	−0.77
20.11	20.74	3.30	0.78	8.07	−0.75
20.12	16.34	2.60	0.61	10.24	−0.73
20.12	13.82	2.20	0.52	12.11	−0.73
20.12	11.93	1.90	0.45	14.03	−0.78
20.11	10.68	1.70	0.40	15.67	−0.76
20.11	9.43	1.50	0.35	17.75	−0.70
20.10	8.17	1.30	0.31	20.48	−0.84
20.10	7.54	1.20	0.28	22.19	−0.72
20.10	6.91	1.10	0.26	24.20	−0.60
20.12	6.28	1.00	0.24	26.67	−0.93
20.11	5.66	0.90	0.21	29.59	−1.07
20.10	5.03	0.80	0.19	33.28	−0.60
20.11	4.40	0.70	0.17	38.06	−1.91
20.10	3.77	0.60	0.14	44.38	−0.98

Table E.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

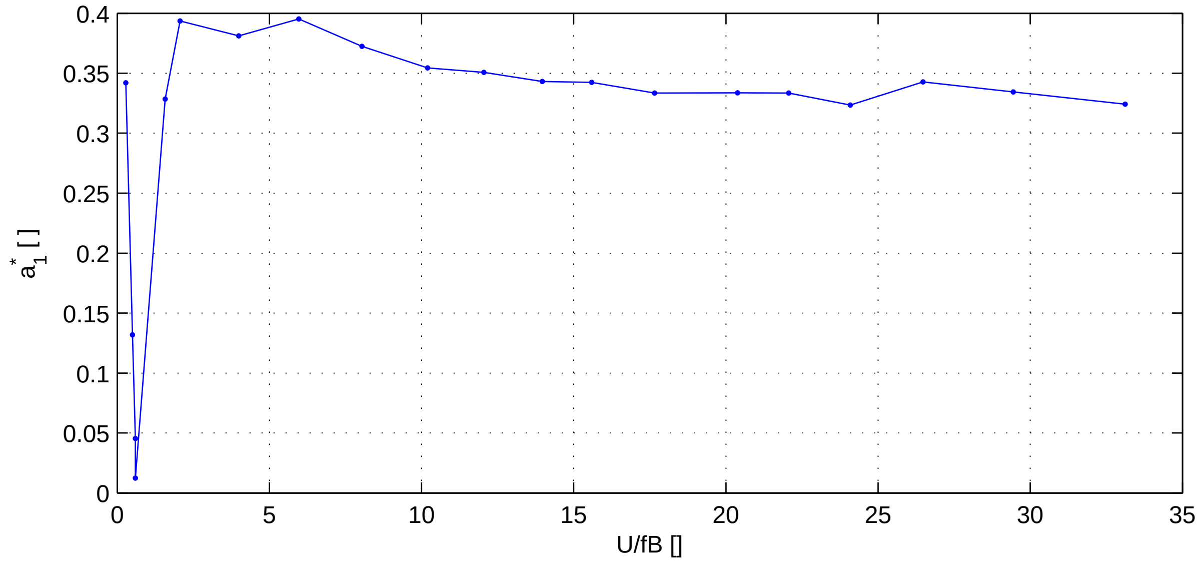

Figure E.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
0.85	25.13	4.00	22.40	0.28	0.34
1.51	25.13	4.00	12.54	0.50	0.13
1.79	25.13	4.00	10.60	0.59	0.05
1.81	25.13	4.00	10.50	0.60	0.01
4.75	25.13	4.00	3.99	1.57	0.33
6.22	25.13	4.00	3.05	2.06	0.39
12.05	25.13	4.00	1.57	3.99	0.38
18.01	25.13	4.00	1.05	5.96	0.40
20.03	20.74	3.30	0.78	8.04	0.37
20.02	16.34	2.60	0.62	10.20	0.35
20.01	13.82	2.20	0.52	12.05	0.35
20.02	11.93	1.90	0.45	13.96	0.34
20.01	10.69	1.70	0.40	15.59	0.34
20.00	9.43	1.50	0.36	17.66	0.33
20.00	8.17	1.30	0.31	20.38	0.33
20.00	7.54	1.20	0.28	22.06	0.33
20.00	6.91	1.10	0.26	24.08	0.32
19.99	6.28	1.00	0.24	26.48	0.34
20.01	5.66	0.90	0.21	29.44	0.33
20.00	5.03	0.80	0.19	33.12	0.32

Table E.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

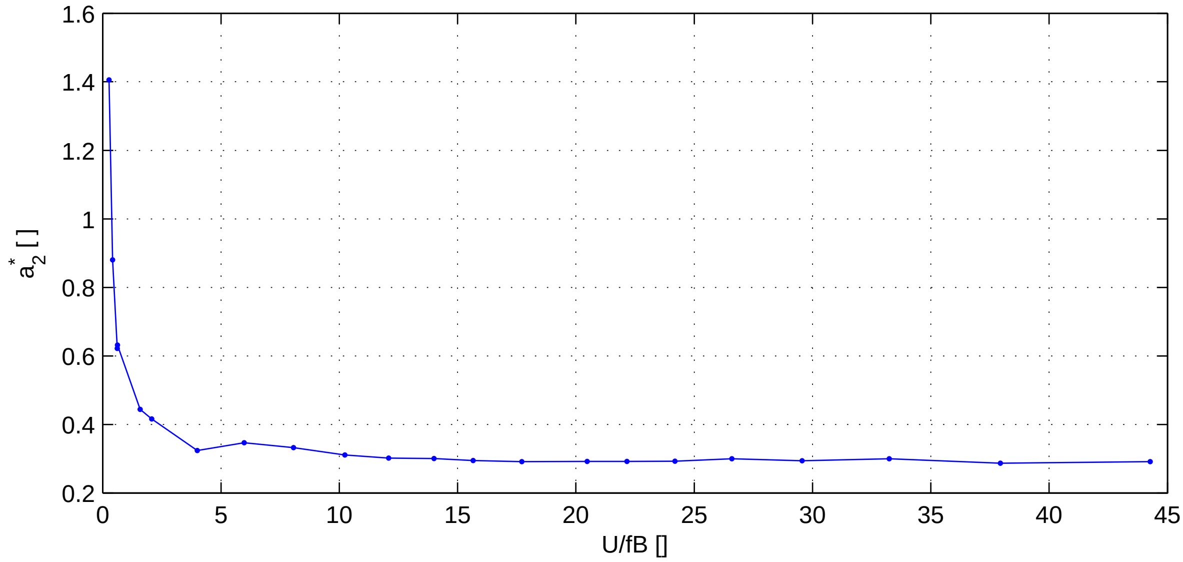

Figure E.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
0.81	25.13	4.00	23.35	0.27	1.41
1.26	25.13	4.00	15.03	0.42	0.88
1.86	25.13	4.00	10.21	0.62	0.62
1.89	25.13	4.00	10.06	0.62	0.63
4.79	25.13	4.00	3.97	1.58	0.44
6.26	25.13	4.00	3.03	2.07	0.42
12.07	25.13	4.00	1.57	4.00	0.32
18.06	25.13	4.00	1.05	5.98	0.35
20.09	20.74	3.30	0.78	8.06	0.33
20.09	16.34	2.60	0.61	10.23	0.31
20.08	13.82	2.20	0.52	12.09	0.30
20.09	11.93	1.90	0.45	14.01	0.30
20.10	10.69	1.70	0.40	15.65	0.29
20.06	9.43	1.50	0.35	17.71	0.29
20.09	8.17	1.30	0.31	20.48	0.29
20.07	7.54	1.20	0.28	22.15	0.29
20.09	6.91	1.10	0.26	24.19	0.29
20.08	6.28	1.00	0.24	26.59	0.30
20.09	5.66	0.90	0.21	29.56	0.29
20.08	5.03	0.80	0.19	33.24	0.30
20.05	4.40	0.70	0.17	37.94	0.29
20.06	3.77	0.60	0.14	44.28	0.29

Table E.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

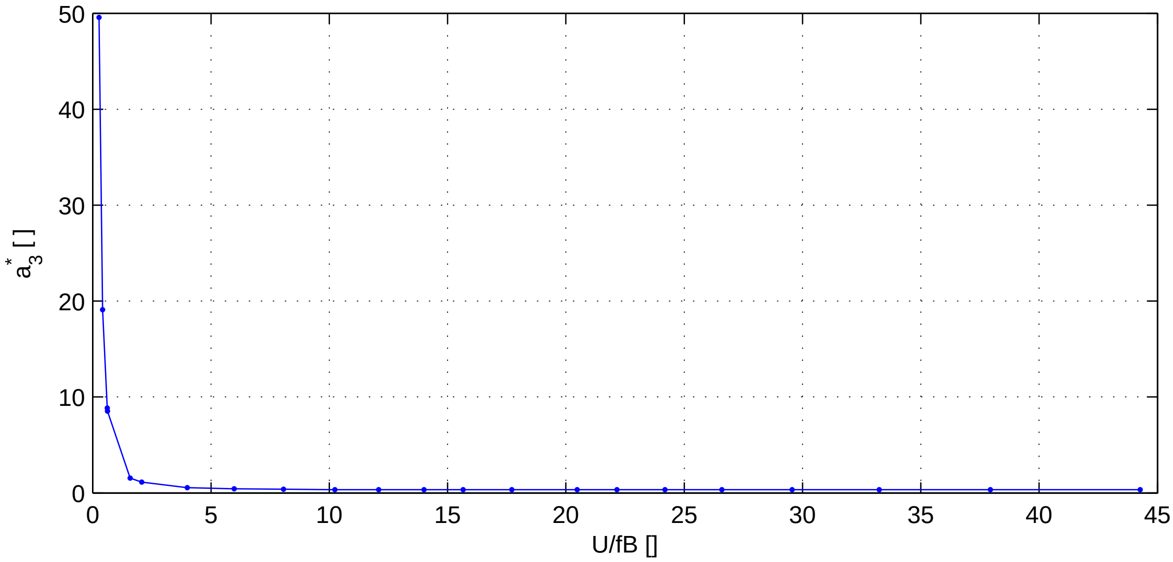

Figure E.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
0.81	25.13	4.00	23.35	0.27	49.58
1.26	25.13	4.00	15.03	0.42	19.10
1.86	25.13	4.00	10.21	0.62	8.85
1.89	25.13	4.00	10.06	0.62	8.53
4.79	25.13	4.00	3.97	1.58	1.54
6.26	25.13	4.00	3.03	2.07	1.13
12.07	25.13	4.00	1.57	4.00	0.55
18.06	25.13	4.00	1.05	5.98	0.43
20.09	20.74	3.30	0.78	8.06	0.37
20.09	16.34	2.60	0.61	10.23	0.35
20.08	13.82	2.20	0.52	12.09	0.34
20.09	11.93	1.90	0.45	14.01	0.34
20.10	10.69	1.70	0.40	15.65	0.34
20.06	9.43	1.50	0.35	17.71	0.34
20.09	8.17	1.30	0.31	20.48	0.34
20.07	7.54	1.20	0.28	22.15	0.33
20.09	6.91	1.10	0.26	24.19	0.33
20.08	6.28	1.00	0.24	26.59	0.33
20.09	5.66	0.90	0.21	29.56	0.33
20.08	5.03	0.80	0.19	33.24	0.33
20.05	4.40	0.70	0.17	37.94	0.33
20.06	3.77	0.60	0.14	44.28	0.34

Table E.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:08:43

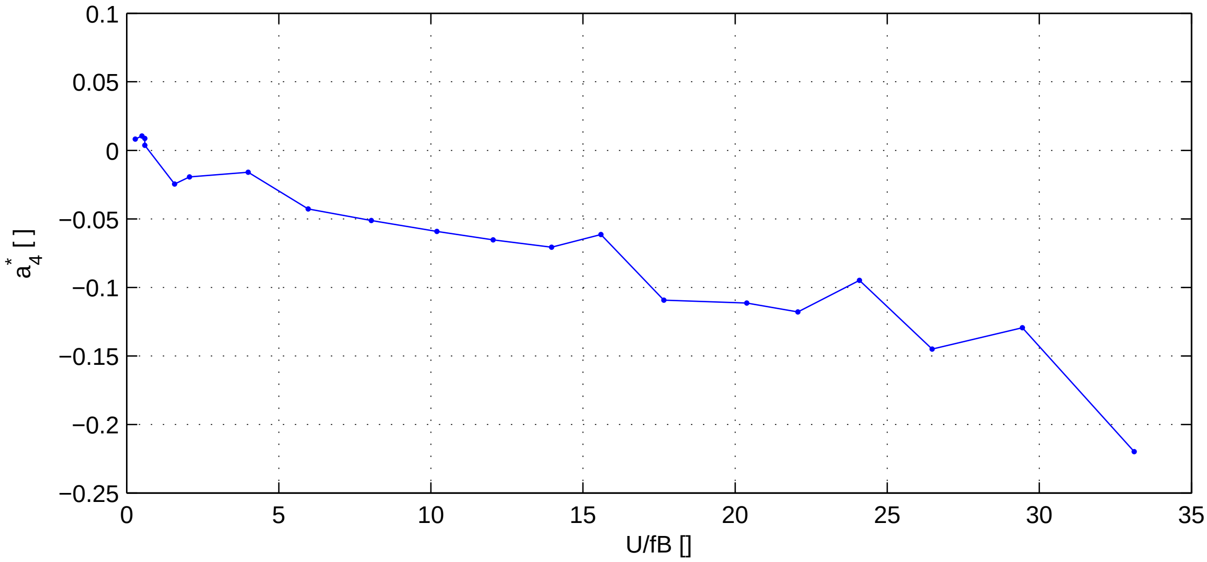

Figure E.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
0.85	25.13	4.00	22.40	0.28	0.01
1.51	25.13	4.00	12.54	0.50	0.01
1.79	25.13	4.00	10.60	0.59	0.01
1.81	25.13	4.00	10.50	0.60	0.00
4.75	25.13	4.00	3.99	1.57	−0.02
6.22	25.13	4.00	3.05	2.06	−0.02
12.05	25.13	4.00	1.57	3.99	−0.02
18.01	25.13	4.00	1.05	5.96	−0.04
20.03	20.74	3.30	0.78	8.04	−0.05
20.02	16.34	2.60	0.62	10.20	−0.06
20.01	13.82	2.20	0.52	12.05	−0.07
20.02	11.93	1.90	0.45	13.96	−0.07
20.01	10.69	1.70	0.40	15.59	−0.06
20.00	9.43	1.50	0.36	17.66	−0.11
20.00	8.17	1.30	0.31	20.38	−0.11
20.00	7.54	1.20	0.28	22.06	−0.12
20.00	6.91	1.10	0.26	24.08	−0.09
19.99	6.28	1.00	0.24	26.48	−0.15
20.01	5.66	0.90	0.21	29.44	−0.13
20.00	5.03	0.80	0.19	33.12	−0.22

Table E.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

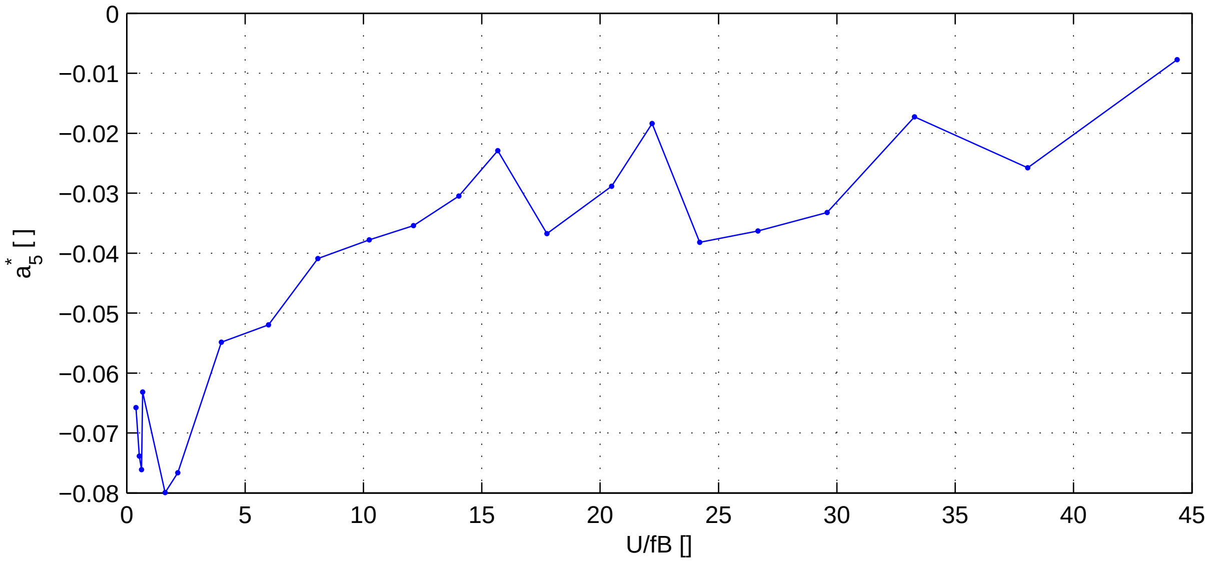

Figure E.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
1.18	25.13	4.00	16.02	0.39	−0.07
1.60	25.13	4.00	11.89	0.53	−0.07
1.89	25.13	4.00	10.01	0.63	−0.08
2.02	25.13	4.00	9.38	0.67	−0.06
4.89	25.13	4.00	3.88	1.62	−0.08
6.50	25.13	4.00	2.92	2.15	−0.08
12.08	25.13	4.00	1.57	4.00	−0.05
18.09	25.13	4.00	1.05	5.99	−0.05
20.11	20.74	3.30	0.78	8.07	−0.04
20.12	16.34	2.60	0.61	10.24	−0.04
20.12	13.82	2.20	0.52	12.11	−0.04
20.12	11.93	1.90	0.45	14.03	−0.03
20.11	10.68	1.70	0.40	15.67	−0.02
20.11	9.43	1.50	0.35	17.75	−0.04
20.10	8.17	1.30	0.31	20.48	−0.03
20.10	7.54	1.20	0.28	22.19	−0.02
20.10	6.91	1.10	0.26	24.20	−0.04
20.12	6.28	1.00	0.24	26.67	−0.04
20.11	5.66	0.90	0.21	29.59	−0.03
20.10	5.03	0.80	0.19	33.28	−0.02
20.11	4.40	0.70	0.17	38.06	−0.03
20.10	3.77	0.60	0.14	44.38	−0.01

Table E.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

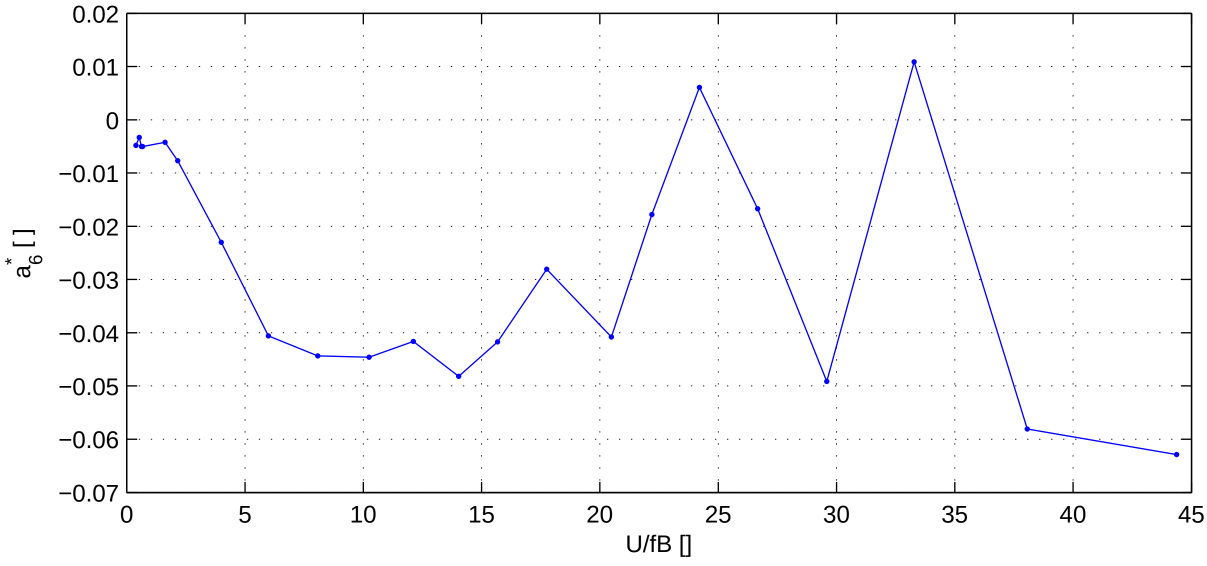

Figure E.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
1.18	25.13	4.00	16.02	0.39	−0.00
1.60	25.13	4.00	11.89	0.53	−0.00
1.89	25.13	4.00	10.01	0.63	−0.01
2.02	25.13	4.00	9.38	0.67	−0.01
4.89	25.13	4.00	3.88	1.62	−0.00
6.50	25.13	4.00	2.92	2.15	−0.01
12.08	25.13	4.00	1.57	4.00	−0.02
18.09	25.13	4.00	1.05	5.99	−0.04
20.11	20.74	3.30	0.78	8.07	−0.04
20.12	16.34	2.60	0.61	10.24	−0.04
20.12	13.82	2.20	0.52	12.11	−0.04
20.12	11.93	1.90	0.45	14.03	−0.05
20.11	10.68	1.70	0.40	15.67	−0.04
20.11	9.43	1.50	0.35	17.75	−0.03
20.10	8.17	1.30	0.31	20.48	−0.04
20.10	7.54	1.20	0.28	22.19	−0.02
20.10	6.91	1.10	0.26	24.20	0.01
20.12	6.28	1.00	0.24	26.67	−0.02
20.11	5.66	0.90	0.21	29.59	−0.05
20.10	5.03	0.80	0.19	33.28	0.01
20.11	4.40	0.70	0.17	38.06	−0.06
20.10	3.77	0.60	0.14	44.38	−0.06

Table E.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

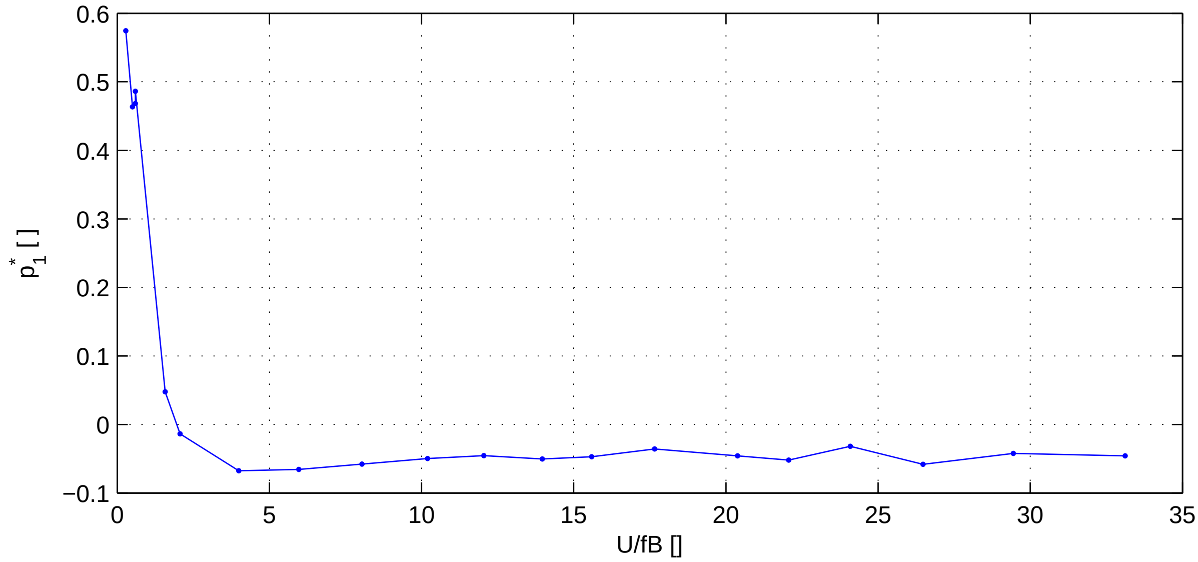

Figure E.31: p^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p^*_1
0.85	25.13	4.00	22.40	0.28	0.57
1.51	25.13	4.00	12.54	0.50	0.46
1.79	25.13	4.00	10.60	0.59	0.47
1.81	25.13	4.00	10.50	0.60	0.49
4.75	25.13	4.00	3.99	1.57	0.05
6.22	25.13	4.00	3.05	2.06	−0.01
12.05	25.13	4.00	1.57	3.99	−0.07
18.01	25.13	4.00	1.05	5.96	−0.07
20.03	20.74	3.30	0.78	8.04	−0.06
20.02	16.34	2.60	0.62	10.20	−0.05
20.01	13.82	2.20	0.52	12.05	−0.05
20.02	11.93	1.90	0.45	13.96	−0.05
20.01	10.69	1.70	0.40	15.59	−0.05
20.00	9.43	1.50	0.36	17.66	−0.04
20.00	8.17	1.30	0.31	20.38	−0.05
20.00	7.54	1.20	0.28	22.06	−0.05
20.00	6.91	1.10	0.26	24.08	−0.03
19.99	6.28	1.00	0.24	26.48	−0.06
20.01	5.66	0.90	0.21	29.44	−0.04
20.00	5.03	0.80	0.19	33.12	−0.05

Table E.33: p^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

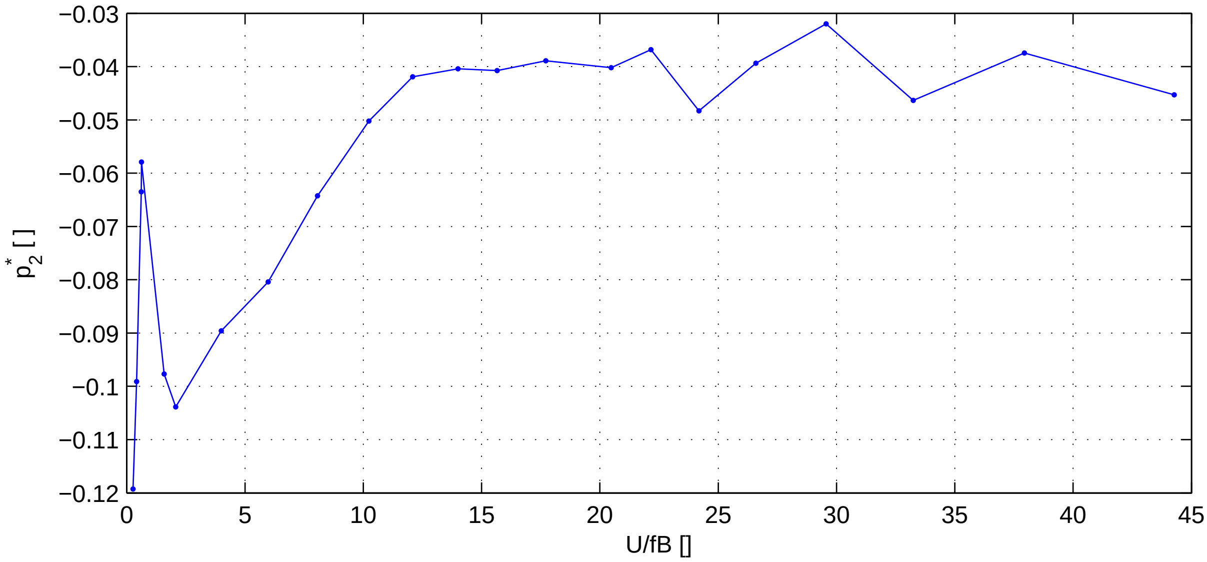

Figure E.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
0.81	25.13	4.00	23.35	0.27	−0.12
1.26	25.13	4.00	15.03	0.42	−0.10
1.86	25.13	4.00	10.21	0.62	−0.06
1.89	25.13	4.00	10.06	0.62	−0.06
4.79	25.13	4.00	3.97	1.58	−0.10
6.26	25.13	4.00	3.03	2.07	−0.10
12.07	25.13	4.00	1.57	4.00	−0.09
18.06	25.13	4.00	1.05	5.98	−0.08
20.09	20.74	3.30	0.78	8.06	−0.06
20.09	16.34	2.60	0.61	10.23	−0.05
20.08	13.82	2.20	0.52	12.09	−0.04
20.09	11.93	1.90	0.45	14.01	−0.04
20.10	10.69	1.70	0.40	15.65	−0.04
20.06	9.43	1.50	0.35	17.71	−0.04
20.09	8.17	1.30	0.31	20.48	−0.04
20.07	7.54	1.20	0.28	22.15	−0.04
20.09	6.91	1.10	0.26	24.19	−0.05
20.08	6.28	1.00	0.24	26.59	−0.04
20.09	5.66	0.90	0.21	29.56	−0.03
20.08	5.03	0.80	0.19	33.24	−0.05
20.05	4.40	0.70	0.17	37.94	−0.04
20.06	3.77	0.60	0.14	44.28	−0.05

Table E.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

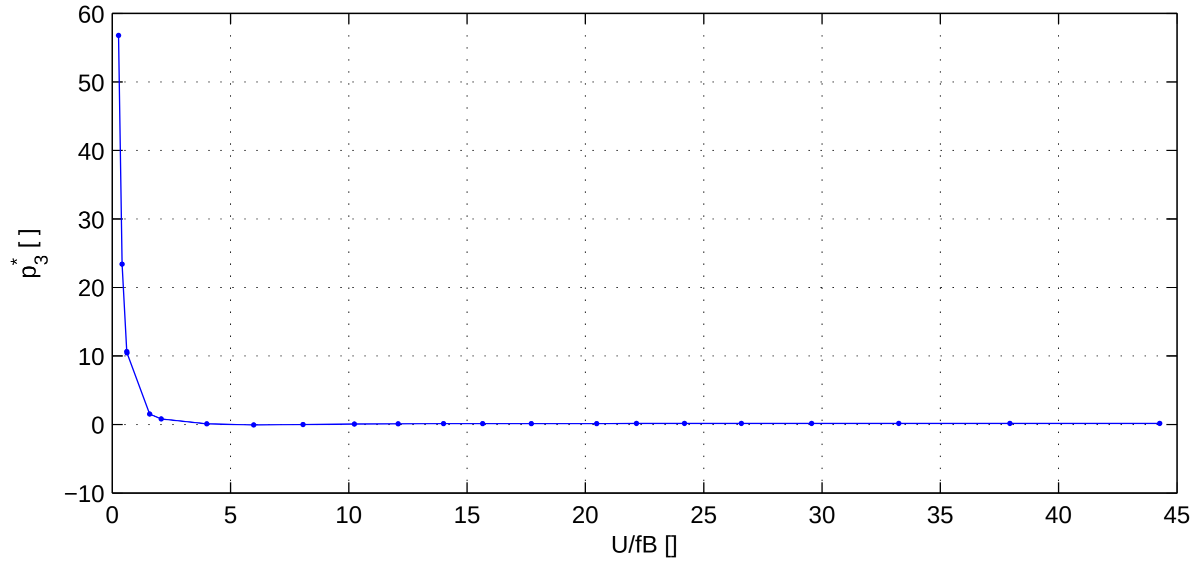

Figure E.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
0.81	25.13	4.00	23.35	0.27	56.77
1.26	25.13	4.00	15.03	0.42	23.40
1.86	25.13	4.00	10.21	0.62	10.63
1.89	25.13	4.00	10.06	0.62	10.43
4.79	25.13	4.00	3.97	1.58	1.52
6.26	25.13	4.00	3.03	2.07	0.80
12.07	25.13	4.00	1.57	4.00	0.07
18.06	25.13	4.00	1.05	5.98	−0.07
20.09	20.74	3.30	0.78	8.06	−0.01
20.09	16.34	2.60	0.61	10.23	0.05
20.08	13.82	2.20	0.52	12.09	0.08
20.09	11.93	1.90	0.45	14.01	0.10
20.10	10.69	1.70	0.40	15.65	0.11
20.06	9.43	1.50	0.35	17.71	0.12
20.09	8.17	1.30	0.31	20.48	0.13
20.07	7.54	1.20	0.28	22.15	0.13
20.09	6.91	1.10	0.26	24.19	0.13
20.08	6.28	1.00	0.24	26.59	0.14
20.09	5.66	0.90	0.21	29.56	0.14
20.08	5.03	0.80	0.19	33.24	0.14
20.05	4.40	0.70	0.17	37.94	0.14
20.06	3.77	0.60	0.14	44.28	0.15

Table E.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

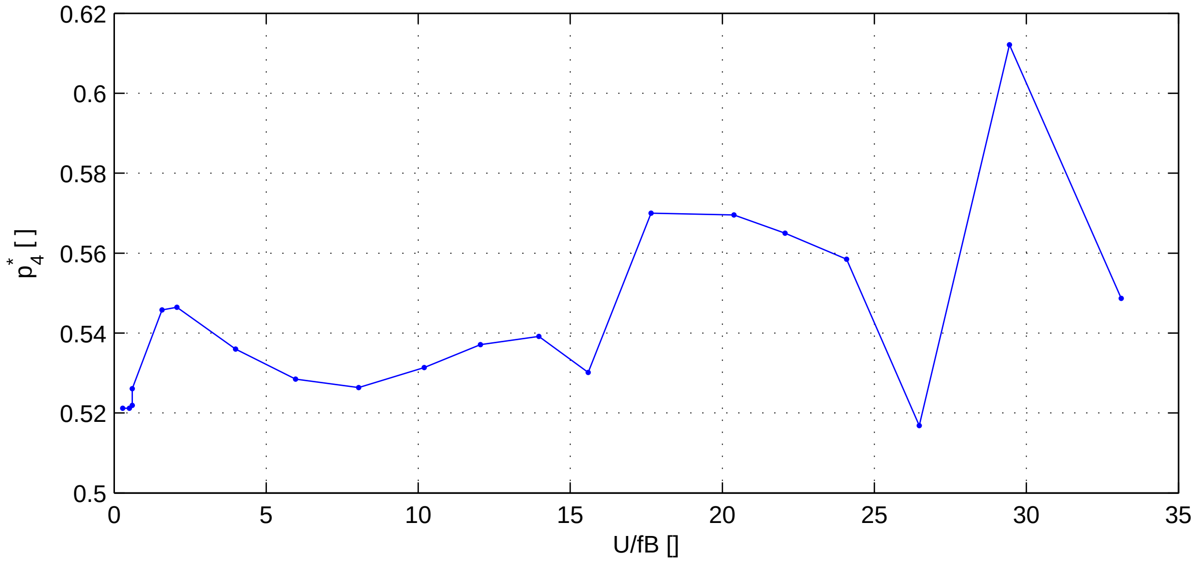

Figure E.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
0.85	25.13	4.00	22.40	0.28	0.52
1.51	25.13	4.00	12.54	0.50	0.52
1.79	25.13	4.00	10.60	0.59	0.52
1.81	25.13	4.00	10.50	0.60	0.53
4.75	25.13	4.00	3.99	1.57	0.55
6.22	25.13	4.00	3.05	2.06	0.55
12.05	25.13	4.00	1.57	3.99	0.54
18.01	25.13	4.00	1.05	5.96	0.53
20.03	20.74	3.30	0.78	8.04	0.53
20.02	16.34	2.60	0.62	10.20	0.53
20.01	13.82	2.20	0.52	12.05	0.54
20.02	11.93	1.90	0.45	13.96	0.54
20.01	10.69	1.70	0.40	15.59	0.53
20.00	9.43	1.50	0.36	17.66	0.57
20.00	8.17	1.30	0.31	20.38	0.57
20.00	7.54	1.20	0.28	22.06	0.56
20.00	6.91	1.10	0.26	24.08	0.56
19.99	6.28	1.00	0.24	26.48	0.52
20.01	5.66	0.90	0.21	29.44	0.61
20.00	5.03	0.80	0.19	33.12	0.55

Table E.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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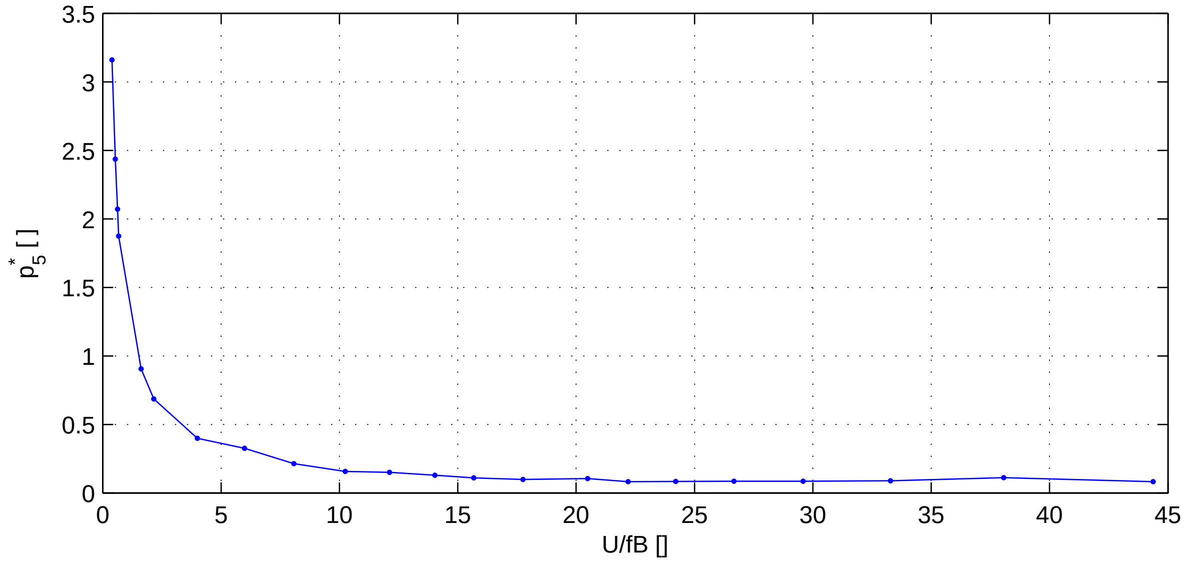


Figure E.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
1.18	25.13	4.00	16.02	0.39	3.16
1.60	25.13	4.00	11.89	0.53	2.44
1.89	25.13	4.00	10.01	0.63	2.07
2.02	25.13	4.00	9.38	0.67	1.87
4.89	25.13	4.00	3.88	1.62	0.91
6.50	25.13	4.00	2.92	2.15	0.69
12.08	25.13	4.00	1.57	4.00	0.40
18.09	25.13	4.00	1.05	5.99	0.33
20.11	20.74	3.30	0.78	8.07	0.21
20.12	16.34	2.60	0.61	10.24	0.16
20.12	13.82	2.20	0.52	12.11	0.15
20.12	11.93	1.90	0.45	14.03	0.13
20.11	10.68	1.70	0.40	15.67	0.11
20.11	9.43	1.50	0.35	17.75	0.10
20.10	8.17	1.30	0.31	20.48	0.11
20.10	7.54	1.20	0.28	22.19	0.08
20.10	6.91	1.10	0.26	24.20	0.08
20.12	6.28	1.00	0.24	26.67	0.08
20.11	5.66	0.90	0.21	29.59	0.09
20.10	5.03	0.80	0.19	33.28	0.09
20.11	4.40	0.70	0.17	38.06	0.11
20.10	3.77	0.60	0.14	44.38	0.08

Table E.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

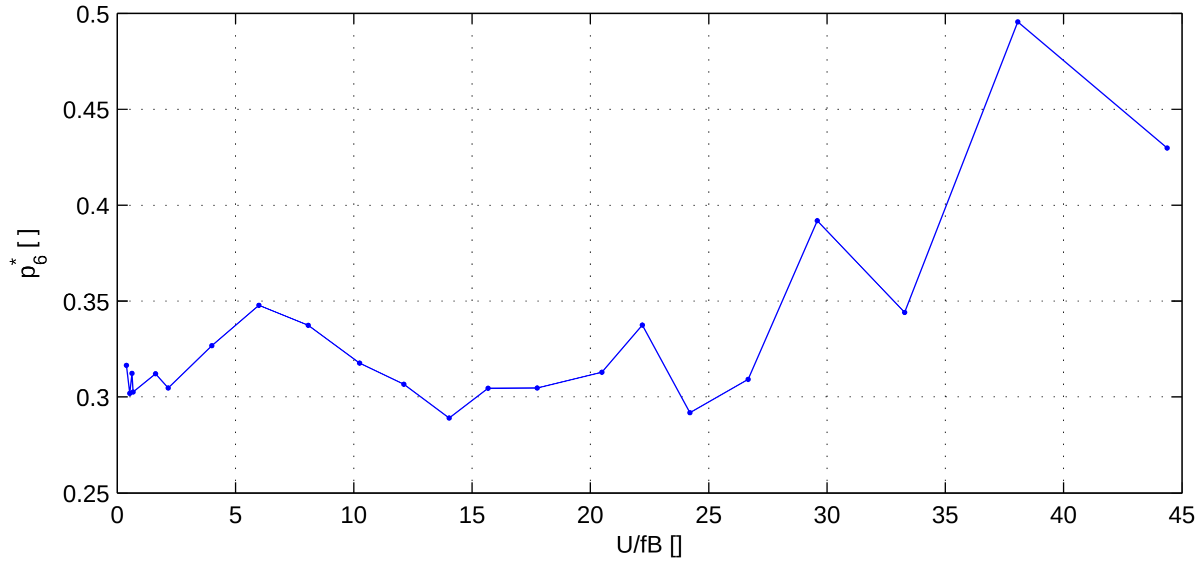


Figure E.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
1.18	25.13	4.00	16.02	0.39	0.32
1.60	25.13	4.00	11.89	0.53	0.30
1.89	25.13	4.00	10.01	0.63	0.31
2.02	25.13	4.00	9.38	0.67	0.30
4.89	25.13	4.00	3.88	1.62	0.31
6.50	25.13	4.00	2.92	2.15	0.30
12.08	25.13	4.00	1.57	4.00	0.33
18.09	25.13	4.00	1.05	5.99	0.35
20.11	20.74	3.30	0.78	8.07	0.34
20.12	16.34	2.60	0.61	10.24	0.32
20.12	13.82	2.20	0.52	12.11	0.31
20.12	11.93	1.90	0.45	14.03	0.29
20.11	10.68	1.70	0.40	15.67	0.30
20.11	9.43	1.50	0.35	17.75	0.30
20.10	8.17	1.30	0.31	20.48	0.31
20.10	7.54	1.20	0.28	22.19	0.34
20.10	6.91	1.10	0.26	24.20	0.29
20.12	6.28	1.00	0.24	26.67	0.31
20.11	5.66	0.90	0.21	29.59	0.39
20.10	5.03	0.80	0.19	33.28	0.34
20.11	4.40	0.70	0.17	38.06	0.50
20.10	3.77	0.60	0.14	44.38	0.43

Table E.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

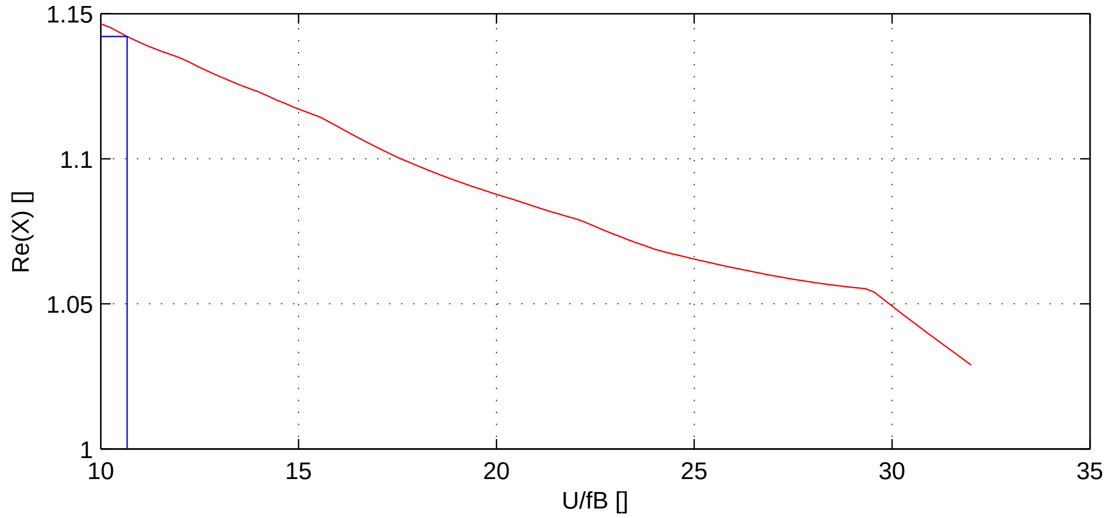


Figure E.37: Real part of the solution to stability equantion

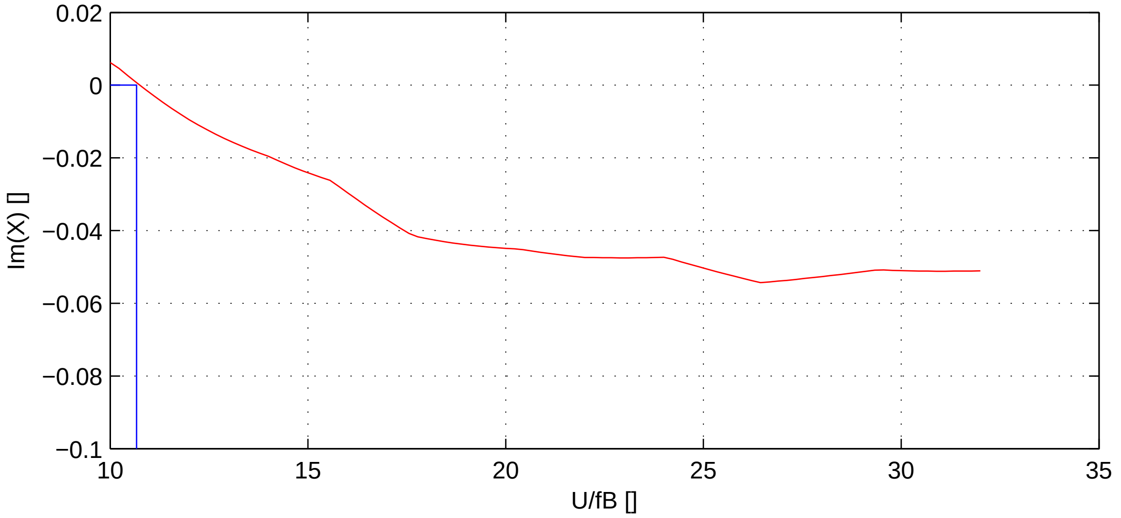


Figure E.38: Imaginary part of the solution to stability equantion

V_{Crit} = 10.7

f_{Crit} = 0.0739 Hz

U_{Crit} = 47.6 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.
[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.
[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.
[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.
[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix F

3D Flutter Tests

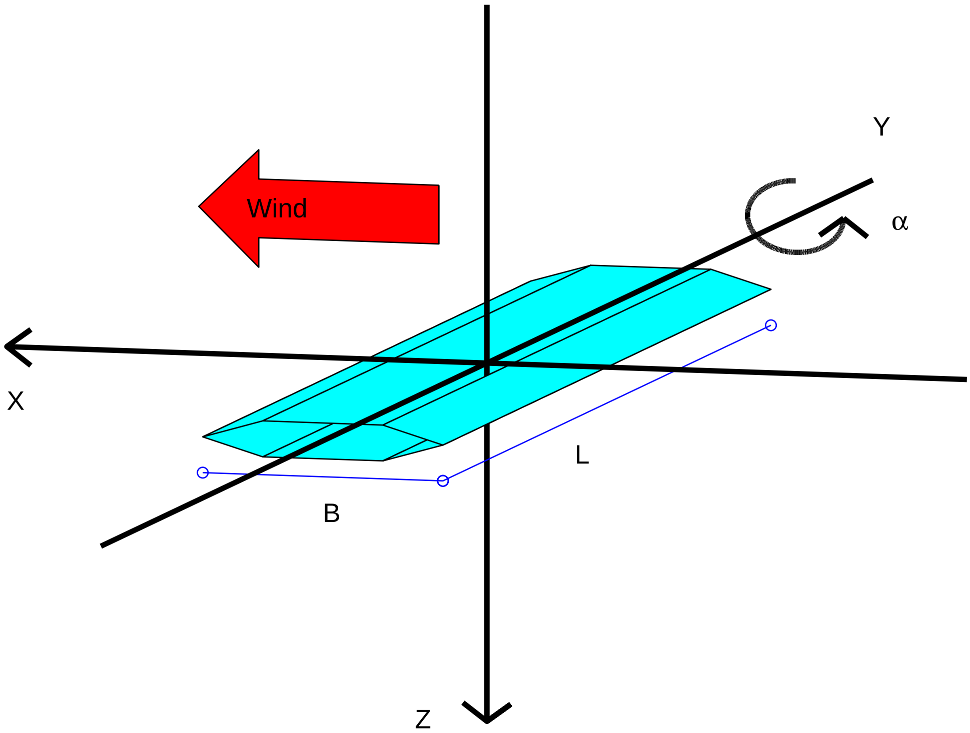
Flutter derivatives, Smooth flow, Angle of incidence = −2 deg.

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^{o}C	28.0
Relative humidity	ϕ	%	28
Barometric pressure	p	mmBar	1019.0

Table F.1: Project Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2\,m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$
$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha} m\,g - 2\,m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$
$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2\,m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h	: Vertical displacement, displacement along z-axis, [m]
α	: Rotation around y-axis, nose up is positive, [rad]
p	: Horizontal displacement, displacement along the x-axis, [m]
m	: Mass per unit length, [kg/m]
I_y	: Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$	: Added mass in vertical direction, [kg/m]
$m_{a,x}$	: Added mass in horizontal direction, [kg/m]
$I_{a,y}$	: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G	: X-coordinate for centre of gravity, [m]
Z_G	: Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$	: Natural circular frequency for vertical motion, [/s]
ζ_h	: Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$	: Natural circular frequency for rotation around y axis, [/s]
ζ_α	: Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$	: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p	: Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$	: Force from rig per meter section, [N/m]
$M_{Y,external}$	: Moment from rig per meter section, [Nm/m]
$F_{X,external}$	: Force from rig per meter section, [N/m]

Formula F.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.380
Added mass in horizontal	$m_{a,x}$	kg/m	0.545
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.142
Horizontal centre of gravity	x_G	m	−0.000
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.039
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.042
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.010

Table F.2: Mechanical Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2\,m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2\,m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2\,m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula F.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

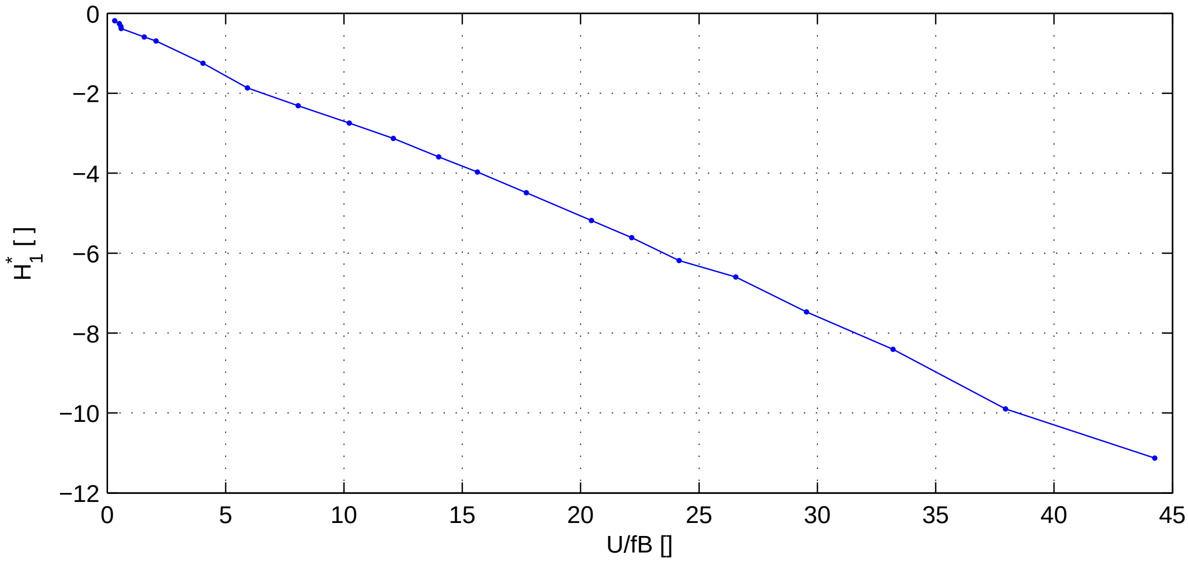


Figure F.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
0.95	25.13	4.00	20.01	0.31	−0.19
1.56	25.13	4.00	12.17	0.52	−0.26
1.75	25.13	4.00	10.83	0.58	−0.33
1.77	25.13	4.00	10.74	0.59	−0.38
4.74	25.13	4.00	4.01	1.57	−0.60
6.21	25.08	3.99	3.05	2.06	−0.69
12.18	25.08	3.99	1.55	4.04	−1.25
17.90	25.13	4.00	1.06	5.93	−1.87
20.09	20.74	3.30	0.78	8.06	−2.31
20.09	16.34	2.60	0.61	10.23	−2.75
20.07	13.82	2.20	0.52	12.08	−3.13
20.08	11.93	1.90	0.45	14.00	−3.59
20.07	10.69	1.70	0.40	15.63	−3.97
20.06	9.43	1.50	0.35	17.71	−4.49
20.07	8.17	1.30	0.31	20.45	−5.18
20.07	7.54	1.20	0.28	22.16	−5.61
20.06	6.91	1.10	0.26	24.16	−6.19
20.05	6.28	1.00	0.24	26.55	−6.60
20.07	5.66	0.90	0.21	29.54	−7.47
20.05	5.03	0.80	0.19	33.20	−8.40
20.06	4.40	0.70	0.17	37.95	−9.90
20.05	3.77	0.60	0.14	44.26	−11.13

Table F.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

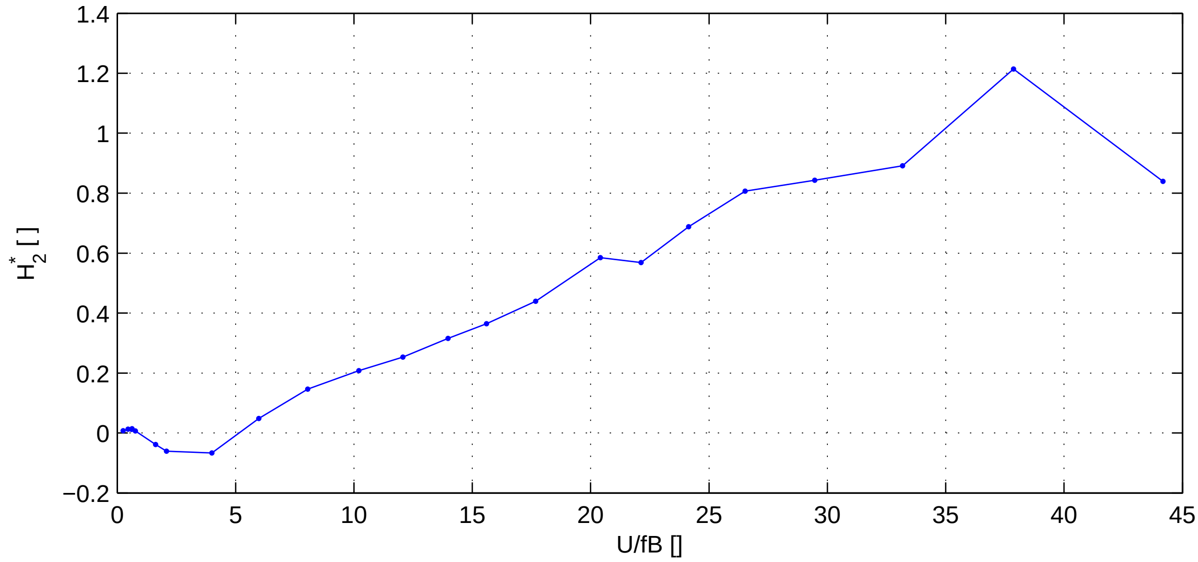


Figure F.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
0.75	25.13	4.00	25.34	0.25	0.01
1.38	25.13	4.00	13.80	0.46	0.01
1.84	25.13	4.00	10.30	0.61	0.01
1.89	25.13	4.00	10.04	0.63	0.01
0.58	6.28	1.00	8.18	0.77	0.01
4.89	25.13	4.00	3.88	1.62	−0.04
6.28	25.13	4.00	3.02	2.08	−0.06
12.07	25.13	4.00	1.57	4.00	−0.07
18.06	25.13	4.00	1.05	5.98	0.05
20.05	20.74	3.30	0.78	8.05	0.15
20.04	16.34	2.60	0.62	10.21	0.21
20.04	13.82	2.20	0.52	12.07	0.25
20.04	11.93	1.90	0.45	13.98	0.32
20.03	10.69	1.70	0.40	15.60	0.36
20.03	9.43	1.50	0.36	17.68	0.44
20.03	8.17	1.30	0.31	20.41	0.58
20.04	7.54	1.20	0.28	22.13	0.57
20.05	6.91	1.10	0.26	24.14	0.69
20.03	6.28	1.00	0.24	26.53	0.81
20.03	5.66	0.90	0.21	29.47	0.84
20.04	5.03	0.80	0.19	33.18	0.89
20.01	4.40	0.70	0.17	37.87	1.21
20.01	3.77	0.60	0.14	44.17	0.84

Table F.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

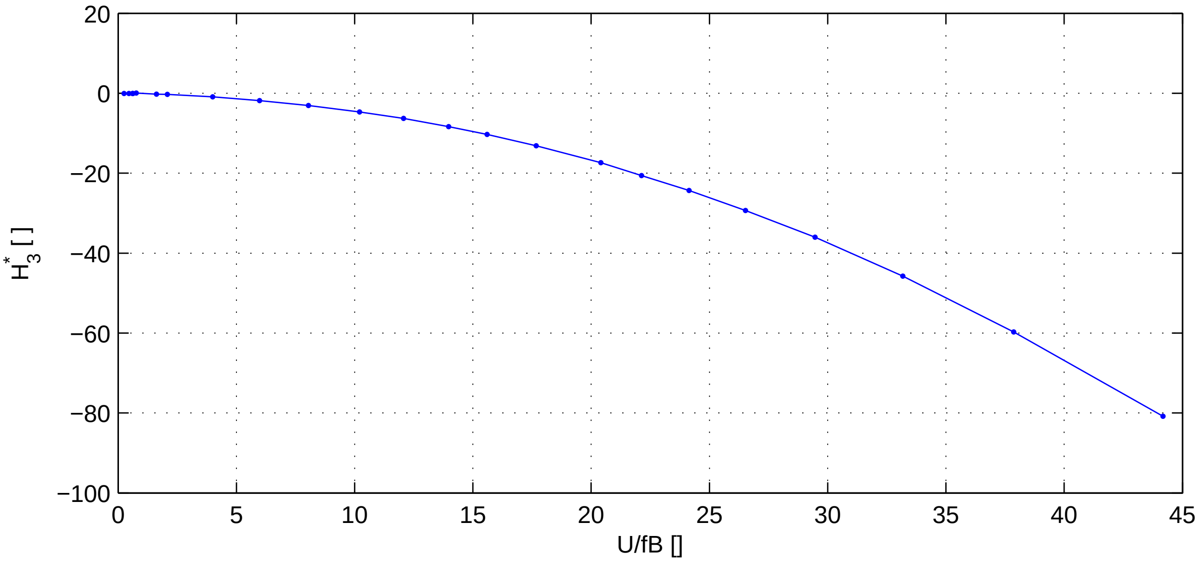


Figure F.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
0.75	25.13	4.00	25.34	0.25	−0.05
1.38	25.13	4.00	13.80	0.46	−0.06
1.84	25.13	4.00	10.30	0.61	−0.07
1.89	25.13	4.00	10.04	0.63	−0.08
0.58	6.28	1.00	8.18	0.77	0.06
4.89	25.13	4.00	3.88	1.62	−0.22
6.28	25.13	4.00	3.02	2.08	−0.30
12.07	25.13	4.00	1.57	4.00	−0.88
18.06	25.13	4.00	1.05	5.98	−1.87
20.05	20.74	3.30	0.78	8.05	−3.09
20.04	16.34	2.60	0.62	10.21	−4.66
20.04	13.82	2.20	0.52	12.07	−6.32
20.04	11.93	1.90	0.45	13.98	−8.36
20.03	10.69	1.70	0.40	15.60	−10.32
20.03	9.43	1.50	0.36	17.68	−13.15
20.03	8.17	1.30	0.31	20.41	−17.38
20.04	7.54	1.20	0.28	22.13	−20.58
20.05	6.91	1.10	0.26	24.14	−24.32
20.03	6.28	1.00	0.24	26.53	−29.33
20.03	5.66	0.90	0.21	29.47	−36.04
20.04	5.03	0.80	0.19	33.18	−45.76
20.01	4.40	0.70	0.17	37.87	−59.75
20.01	3.77	0.60	0.14	44.17	−80.84

Table F.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

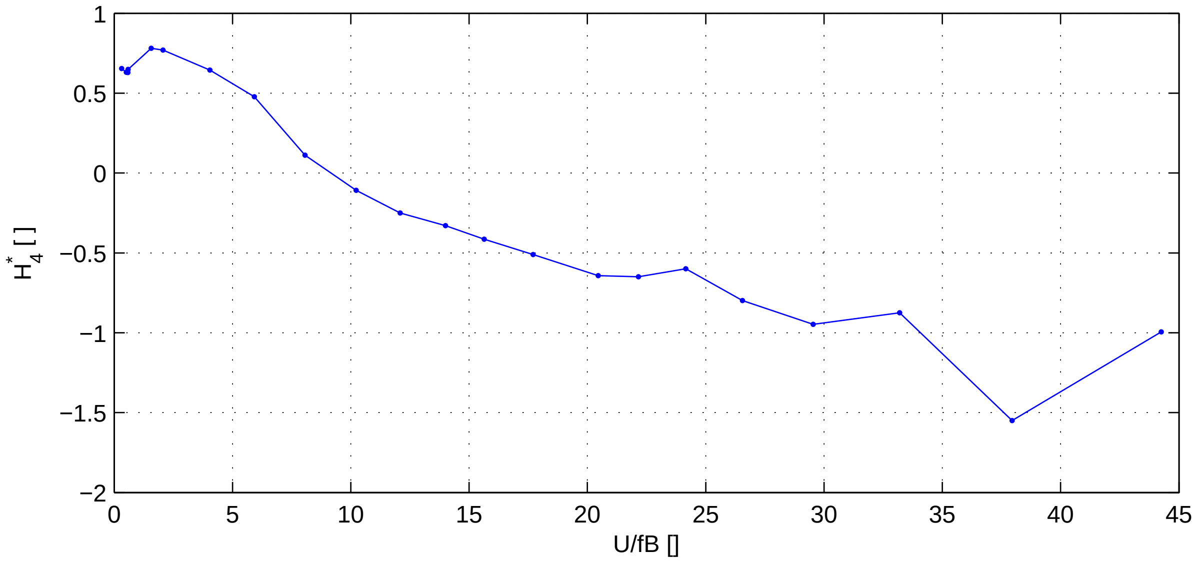


Figure F.4: H^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_4
0.95	25.13	4.00	20.01	0.31	0.65
1.56	25.13	4.00	12.17	0.52	0.63
1.75	25.13	4.00	10.83	0.58	0.63
1.77	25.13	4.00	10.74	0.59	0.65
4.74	25.13	4.00	4.01	1.57	0.78
6.21	25.08	3.99	3.05	2.06	0.77
12.18	25.08	3.99	1.55	4.04	0.64
17.90	25.13	4.00	1.06	5.93	0.48
20.09	20.74	3.30	0.78	8.06	0.11
20.09	16.34	2.60	0.61	10.23	−0.11
20.07	13.82	2.20	0.52	12.08	−0.25
20.08	11.93	1.90	0.45	14.00	−0.33
20.07	10.69	1.70	0.40	15.63	−0.41
20.06	9.43	1.50	0.35	17.71	−0.51
20.07	8.17	1.30	0.31	20.45	−0.64
20.07	7.54	1.20	0.28	22.16	−0.65
20.06	6.91	1.10	0.26	24.16	−0.60
20.05	6.28	1.00	0.24	26.55	−0.80
20.07	5.66	0.90	0.21	29.54	−0.95
20.05	5.03	0.80	0.19	33.20	−0.87
20.06	4.40	0.70	0.17	37.95	−1.55
20.05	3.77	0.60	0.14	44.26	−0.99

Table F.6: H^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

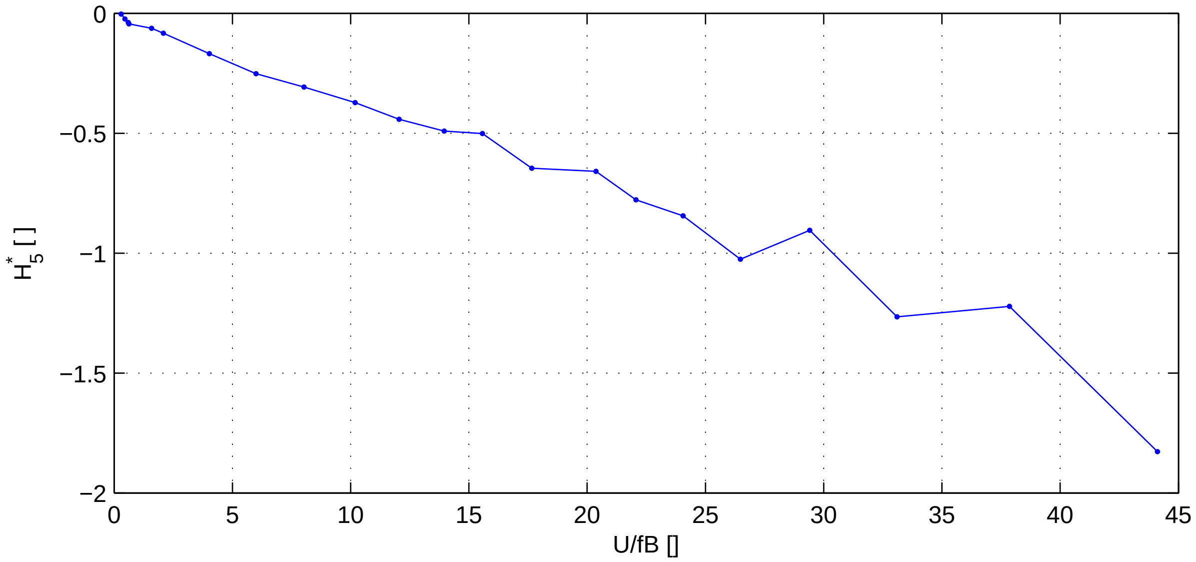


Figure F.5: H^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_5
0.89	25.13	4.00	21.33	0.29	−0.00
1.38	25.13	4.00	13.76	0.46	−0.02
1.80	25.13	4.00	10.52	0.60	−0.04
1.89	25.13	4.00	10.02	0.63	−0.04
4.79	25.13	4.00	3.96	1.58	−0.06
6.27	25.13	4.00	3.03	2.08	−0.08
12.17	25.13	4.00	1.56	4.03	−0.17
18.13	25.13	4.00	1.05	6.00	−0.25
20.00	20.74	3.30	0.78	8.03	−0.31
20.00	16.34	2.60	0.62	10.19	−0.37
20.02	13.82	2.20	0.52	12.05	−0.44
20.01	11.93	1.90	0.45	13.95	−0.49
19.99	10.69	1.70	0.40	15.57	−0.50
20.00	9.43	1.50	0.36	17.65	−0.65
20.00	8.17	1.30	0.31	20.37	−0.66
19.98	7.54	1.20	0.28	22.06	−0.78
19.98	6.91	1.10	0.26	24.06	−0.84
19.99	6.28	1.00	0.24	26.48	−1.03
19.98	5.65	0.90	0.21	29.41	−0.90
20.00	5.03	0.80	0.19	33.10	−1.27
20.00	4.40	0.70	0.17	37.85	−1.22
19.98	3.77	0.60	0.14	44.11	−1.83

Table F.7: H^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

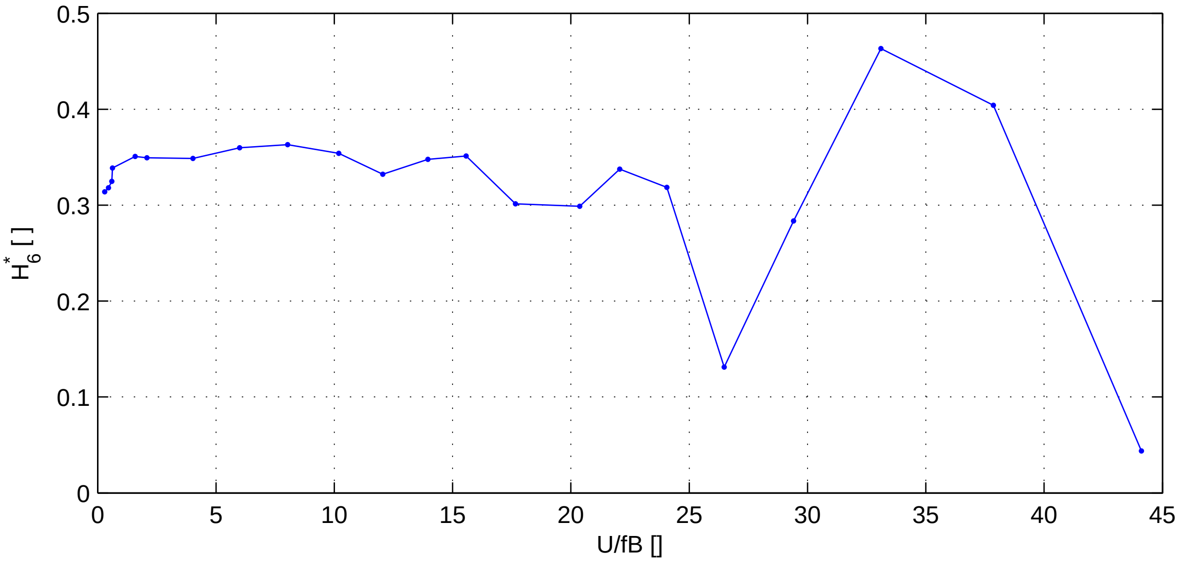


Figure F.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
0.89	25.13	4.00	21.33	0.29	0.31
1.38	25.13	4.00	13.76	0.46	0.32
1.80	25.13	4.00	10.52	0.60	0.32
1.89	25.13	4.00	10.02	0.63	0.34
4.79	25.13	4.00	3.96	1.58	0.35
6.27	25.13	4.00	3.03	2.08	0.35
12.17	25.13	4.00	1.56	4.03	0.35
18.13	25.13	4.00	1.05	6.00	0.36
20.00	20.74	3.30	0.78	8.03	0.36
20.00	16.34	2.60	0.62	10.19	0.35
20.02	13.82	2.20	0.52	12.05	0.33
20.01	11.93	1.90	0.45	13.95	0.35
19.99	10.69	1.70	0.40	15.57	0.35
20.00	9.43	1.50	0.36	17.65	0.30
20.00	8.17	1.30	0.31	20.37	0.30
19.98	7.54	1.20	0.28	22.06	0.34
19.98	6.91	1.10	0.26	24.06	0.32
19.99	6.28	1.00	0.24	26.48	0.13
19.98	5.65	0.90	0.21	29.41	0.28
20.00	5.03	0.80	0.19	33.10	0.46
20.00	4.40	0.70	0.17	37.85	0.40
19.98	3.77	0.60	0.14	44.11	0.04

Table F.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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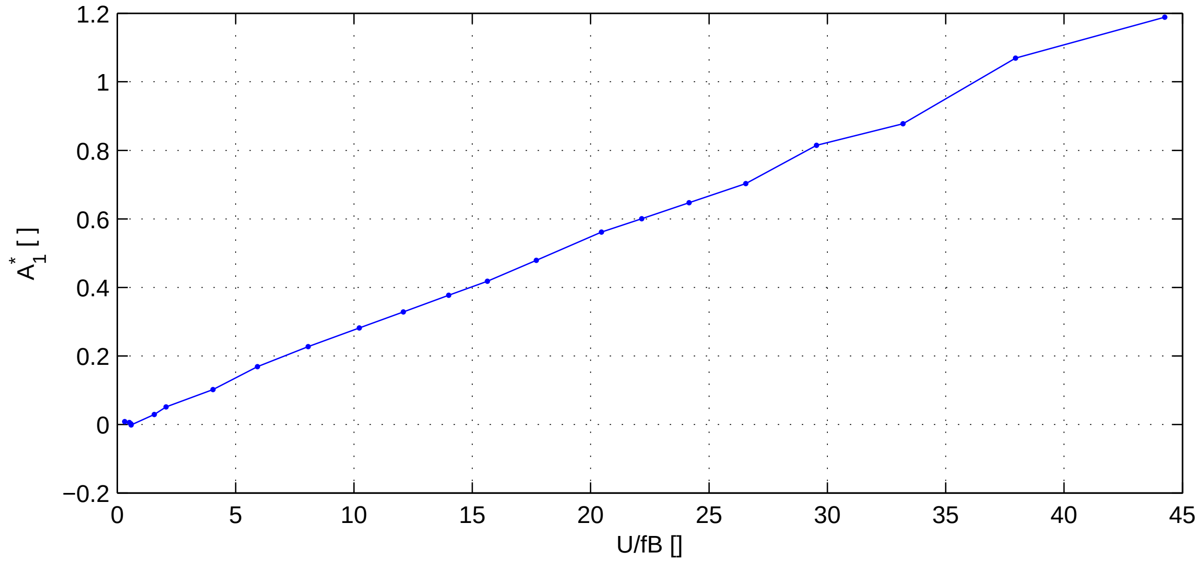

Figure F.7: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_1^*
0.95	25.13	4.00	20.01	0.31	0.01
1.56	25.13	4.00	12.17	0.52	0.01
1.75	25.13	4.00	10.83	0.58	0.00
1.77	25.13	4.00	10.74	0.59	−0.00
4.74	25.13	4.00	4.01	1.57	0.03
6.21	25.08	3.99	3.05	2.06	0.05
12.18	25.08	3.99	1.55	4.04	0.10
17.90	25.13	4.00	1.06	5.93	0.17
20.09	20.74	3.30	0.78	8.06	0.23
20.09	16.34	2.60	0.61	10.23	0.28
20.07	13.82	2.20	0.52	12.08	0.33
20.08	11.93	1.90	0.45	14.00	0.38
20.07	10.69	1.70	0.40	15.63	0.42
20.06	9.43	1.50	0.35	17.71	0.48
20.07	8.17	1.30	0.31	20.45	0.56
20.07	7.54	1.20	0.28	22.16	0.60
20.06	6.91	1.10	0.26	24.16	0.65
20.05	6.28	1.00	0.24	26.55	0.70
20.07	5.66	0.90	0.21	29.54	0.81
20.05	5.03	0.80	0.19	33.20	0.88
20.06	4.40	0.70	0.17	37.95	1.07
20.05	3.77	0.60	0.14	44.26	1.19

Table F.9: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

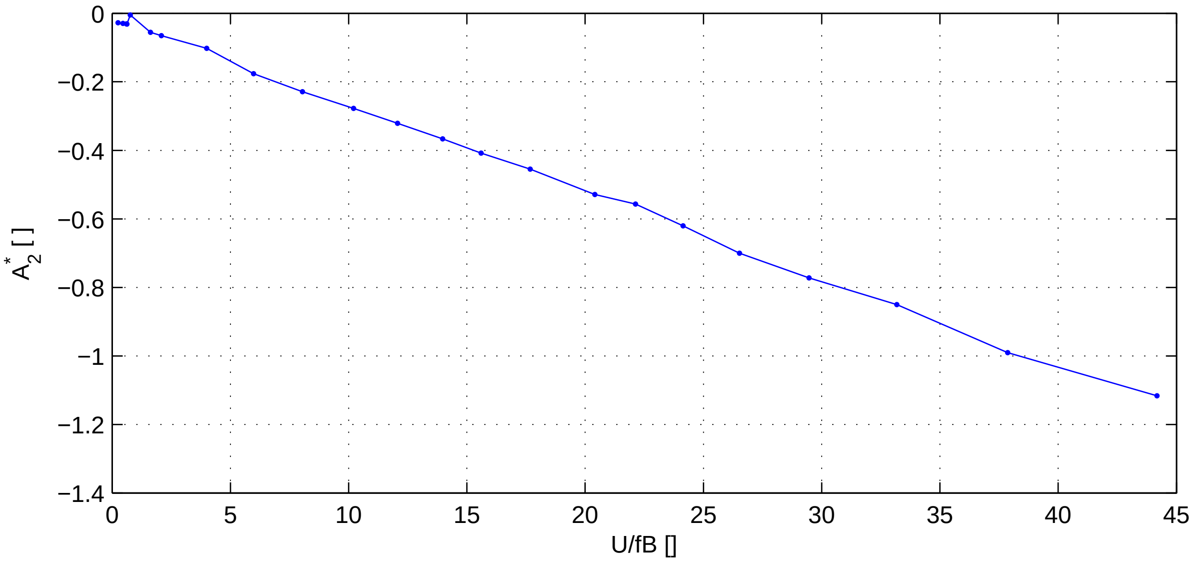

Figure F.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
0.75	25.13	4.00	25.34	0.25	−0.03
1.38	25.13	4.00	13.80	0.46	−0.03
1.84	25.13	4.00	10.30	0.61	−0.03
1.89	25.13	4.00	10.04	0.63	−0.03
0.58	6.28	1.00	8.18	0.77	−0.00
4.89	25.13	4.00	3.88	1.62	−0.06
6.28	25.13	4.00	3.02	2.08	−0.07
12.07	25.13	4.00	1.57	4.00	−0.10
18.06	25.13	4.00	1.05	5.98	−0.18
20.05	20.74	3.30	0.78	8.05	−0.23
20.04	16.34	2.60	0.62	10.21	−0.28
20.04	13.82	2.20	0.52	12.07	−0.32
20.04	11.93	1.90	0.45	13.98	−0.37
20.03	10.69	1.70	0.40	15.60	−0.41
20.03	9.43	1.50	0.36	17.68	−0.46
20.03	8.17	1.30	0.31	20.41	−0.53
20.04	7.54	1.20	0.28	22.13	−0.56
20.05	6.91	1.10	0.26	24.14	−0.62
20.03	6.28	1.00	0.24	26.53	−0.70
20.03	5.66	0.90	0.21	29.47	−0.77
20.04	5.03	0.80	0.19	33.18	−0.85
20.01	4.40	0.70	0.17	37.87	−0.99
20.01	3.77	0.60	0.14	44.17	−1.12

Table F.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

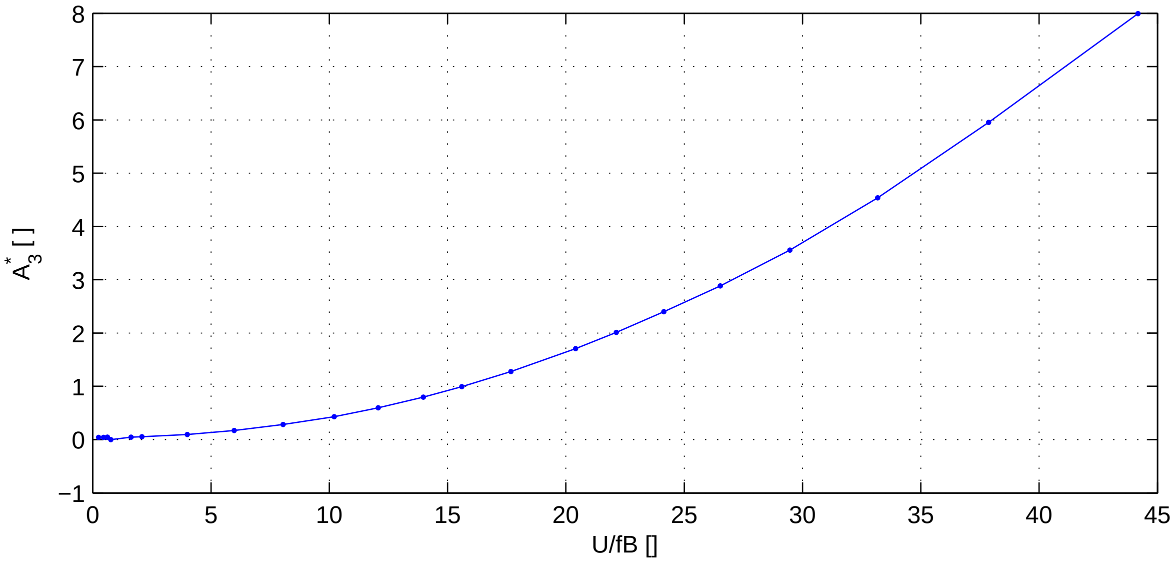

Figure F.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
0.75	25.13	4.00	25.34	0.25	0.04
1.38	25.13	4.00	13.80	0.46	0.04
1.84	25.13	4.00	10.30	0.61	0.04
1.89	25.13	4.00	10.04	0.63	0.04
0.58	6.28	1.00	8.18	0.77	−0.00
4.89	25.13	4.00	3.88	1.62	0.05
6.28	25.13	4.00	3.02	2.08	0.06
12.07	25.13	4.00	1.57	4.00	0.10
18.06	25.13	4.00	1.05	5.98	0.17
20.05	20.74	3.30	0.78	8.05	0.28
20.04	16.34	2.60	0.62	10.21	0.43
20.04	13.82	2.20	0.52	12.07	0.60
20.04	11.93	1.90	0.45	13.98	0.80
20.03	10.69	1.70	0.40	15.60	0.99
20.03	9.43	1.50	0.36	17.68	1.28
20.03	8.17	1.30	0.31	20.41	1.71
20.04	7.54	1.20	0.28	22.13	2.01
20.05	6.91	1.10	0.26	24.14	2.40
20.03	6.28	1.00	0.24	26.53	2.88
20.03	5.66	0.90	0.21	29.47	3.55
20.04	5.03	0.80	0.19	33.18	4.54
20.01	4.40	0.70	0.17	37.87	5.95
20.01	3.77	0.60	0.14	44.17	7.99

Table F.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

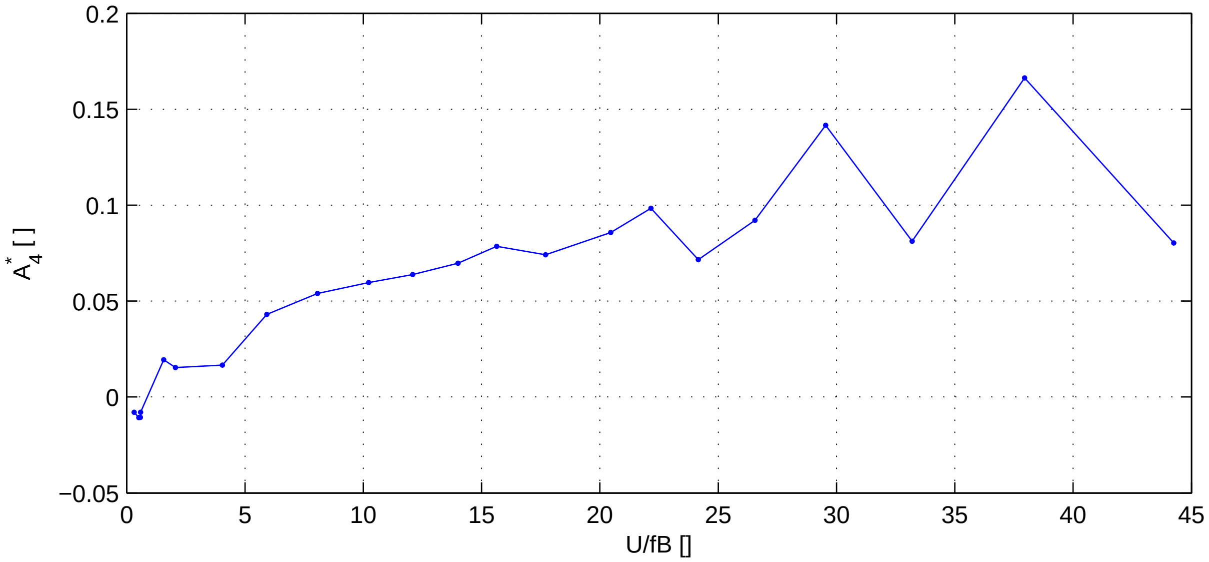

Figure F.10: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_4^*
0.95	25.13	4.00	20.01	0.31	−0.01
1.56	25.13	4.00	12.17	0.52	−0.01
1.75	25.13	4.00	10.83	0.58	−0.01
1.77	25.13	4.00	10.74	0.59	−0.01
4.74	25.13	4.00	4.01	1.57	0.02
6.21	25.08	3.99	3.05	2.06	0.02
12.18	25.08	3.99	1.55	4.04	0.02
17.90	25.13	4.00	1.06	5.93	0.04
20.09	20.74	3.30	0.78	8.06	0.05
20.09	16.34	2.60	0.61	10.23	0.06
20.07	13.82	2.20	0.52	12.08	0.06
20.08	11.93	1.90	0.45	14.00	0.07
20.07	10.69	1.70	0.40	15.63	0.08
20.06	9.43	1.50	0.35	17.71	0.07
20.07	8.17	1.30	0.31	20.45	0.09
20.07	7.54	1.20	0.28	22.16	0.10
20.06	6.91	1.10	0.26	24.16	0.07
20.05	6.28	1.00	0.24	26.55	0.09
20.07	5.66	0.90	0.21	29.54	0.14
20.05	5.03	0.80	0.19	33.20	0.08
20.06	4.40	0.70	0.17	37.95	0.17
20.05	3.77	0.60	0.14	44.26	0.08

Table F.12: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

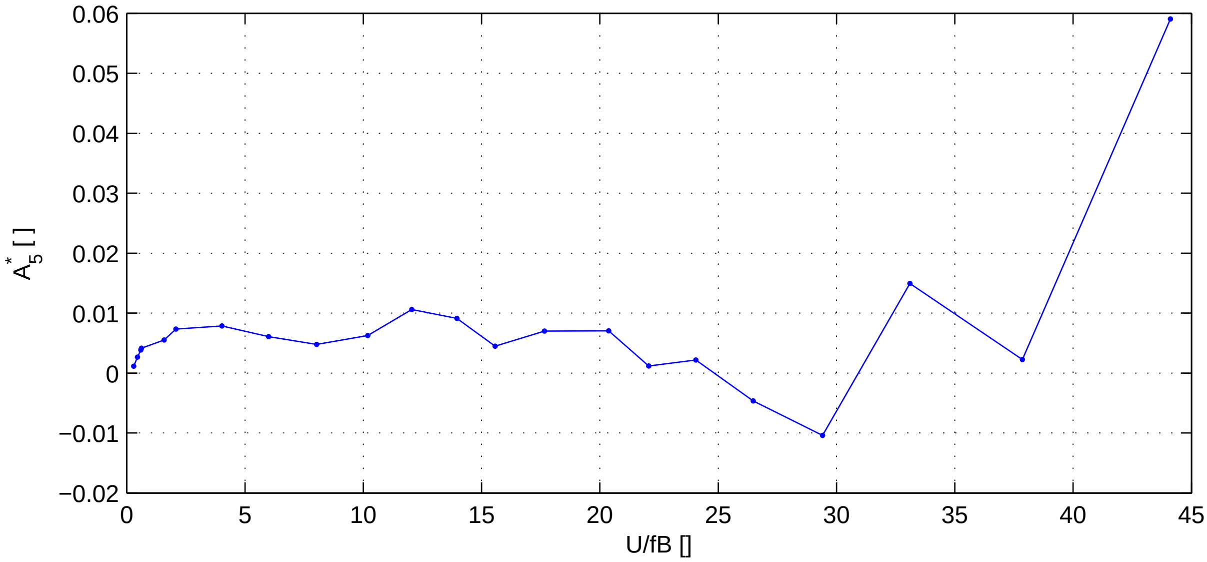

Figure F.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
0.89	25.13	4.00	21.33	0.29	0.00
1.38	25.13	4.00	13.76	0.46	0.00
1.80	25.13	4.00	10.52	0.60	0.00
1.89	25.13	4.00	10.02	0.63	0.00
4.79	25.13	4.00	3.96	1.58	0.01
6.27	25.13	4.00	3.03	2.08	0.01
12.17	25.13	4.00	1.56	4.03	0.01
18.13	25.13	4.00	1.05	6.00	0.01
20.00	20.74	3.30	0.78	8.03	0.00
20.00	16.34	2.60	0.62	10.19	0.01
20.02	13.82	2.20	0.52	12.05	0.01
20.01	11.93	1.90	0.45	13.95	0.01
19.99	10.69	1.70	0.40	15.57	0.00
20.00	9.43	1.50	0.36	17.65	0.01
20.00	8.17	1.30	0.31	20.37	0.01
19.98	7.54	1.20	0.28	22.06	0.00
19.98	6.91	1.10	0.26	24.06	0.00
19.99	6.28	1.00	0.24	26.48	−0.00
19.98	5.65	0.90	0.21	29.41	−0.01
20.00	5.03	0.80	0.19	33.10	0.01
20.00	4.40	0.70	0.17	37.85	0.00
19.98	3.77	0.60	0.14	44.11	0.06

Table F.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

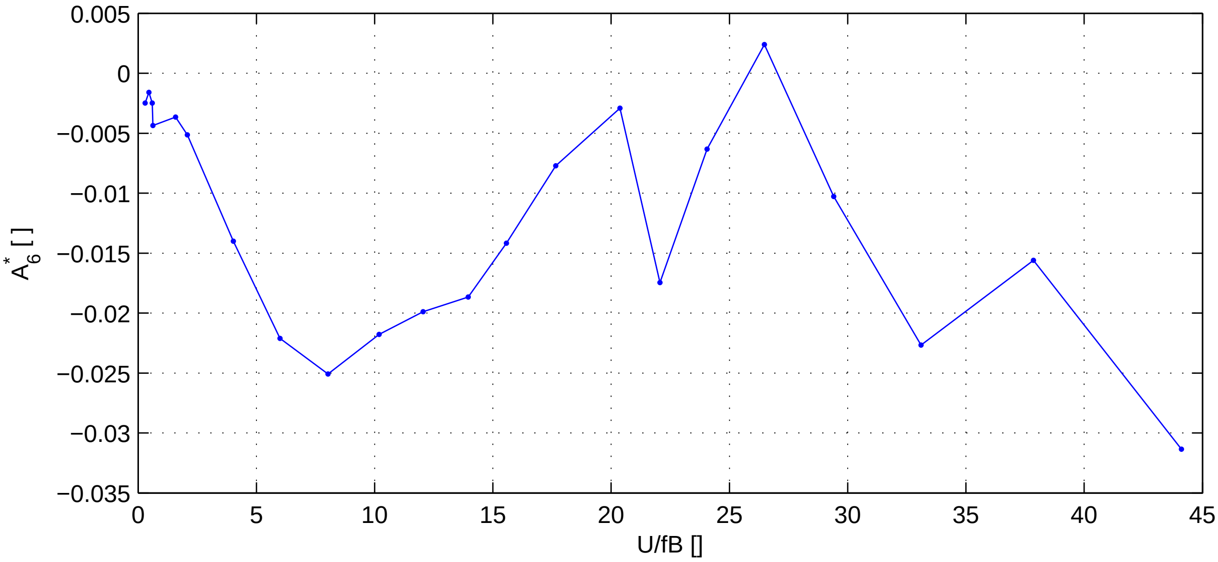

Figure F.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
0.89	25.13	4.00	21.33	0.29	−0.00
1.38	25.13	4.00	13.76	0.46	−0.00
1.80	25.13	4.00	10.52	0.60	−0.00
1.89	25.13	4.00	10.02	0.63	−0.00
4.79	25.13	4.00	3.96	1.58	−0.00
6.27	25.13	4.00	3.03	2.08	−0.01
12.17	25.13	4.00	1.56	4.03	−0.01
18.13	25.13	4.00	1.05	6.00	−0.02
20.00	20.74	3.30	0.78	8.03	−0.03
20.00	16.34	2.60	0.62	10.19	−0.02
20.02	13.82	2.20	0.52	12.05	−0.02
20.01	11.93	1.90	0.45	13.95	−0.02
19.99	10.69	1.70	0.40	15.57	−0.01
20.00	9.43	1.50	0.36	17.65	−0.01
20.00	8.17	1.30	0.31	20.37	−0.00
19.98	7.54	1.20	0.28	22.06	−0.02
19.98	6.91	1.10	0.26	24.06	−0.01
19.99	6.28	1.00	0.24	26.48	0.00
19.98	5.65	0.90	0.21	29.41	−0.01
20.00	5.03	0.80	0.19	33.10	−0.02
20.00	4.40	0.70	0.17	37.85	−0.02
19.98	3.77	0.60	0.14	44.11	−0.03

Table F.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

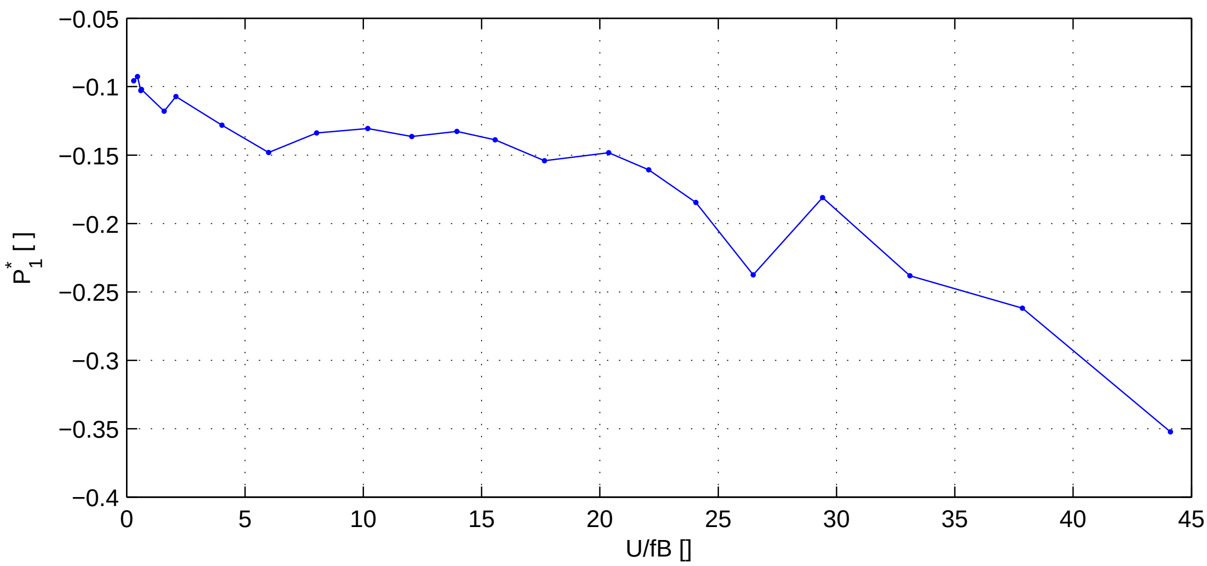

Figure F.13: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_1
0.89	25.13	4.00	21.33	0.29	−0.10
1.38	25.13	4.00	13.76	0.46	−0.09
1.80	25.13	4.00	10.52	0.60	−0.10
1.89	25.13	4.00	10.02	0.63	−0.10
4.79	25.13	4.00	3.96	1.58	−0.12
6.27	25.13	4.00	3.03	2.08	−0.11
12.17	25.13	4.00	1.56	4.03	−0.13
18.13	25.13	4.00	1.05	6.00	−0.15
20.00	20.74	3.30	0.78	8.03	−0.13
20.00	16.34	2.60	0.62	10.19	−0.13
20.02	13.82	2.20	0.52	12.05	−0.14
20.01	11.93	1.90	0.45	13.95	−0.13
19.99	10.69	1.70	0.40	15.57	−0.14
20.00	9.43	1.50	0.36	17.65	−0.15
20.00	8.17	1.30	0.31	20.37	−0.15
19.98	7.54	1.20	0.28	22.06	−0.16
19.98	6.91	1.10	0.26	24.06	−0.18
19.99	6.28	1.00	0.24	26.48	−0.24
19.98	5.65	0.90	0.21	29.41	−0.18
20.00	5.03	0.80	0.19	33.10	−0.24
20.00	4.40	0.70	0.17	37.85	−0.26
19.98	3.77	0.60	0.14	44.11	−0.35

Table F.15: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

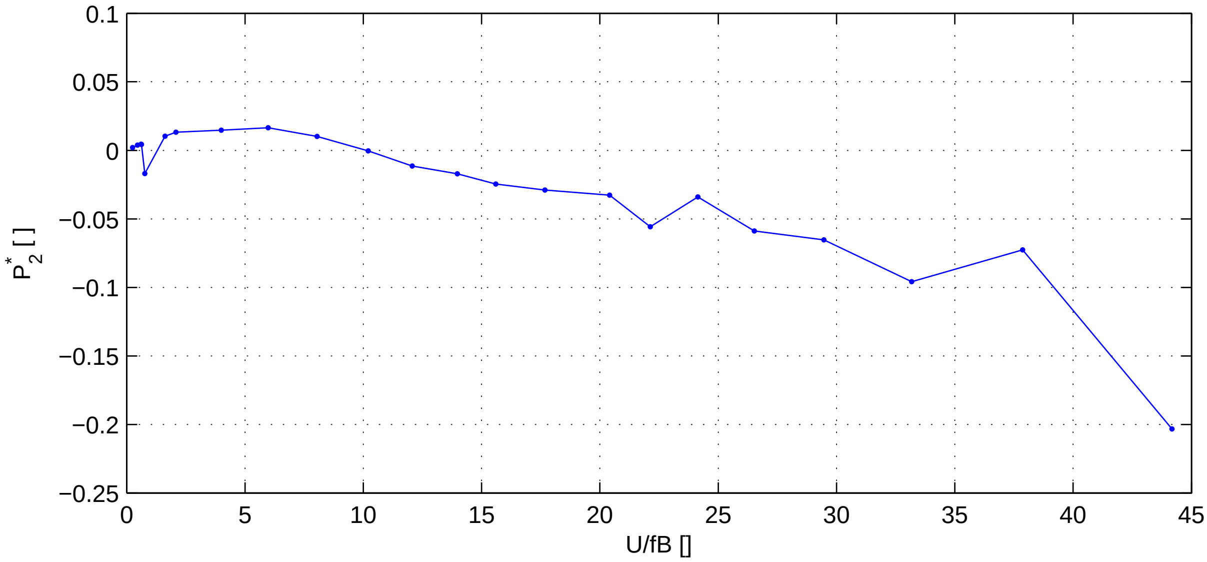

Figure F.14: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_2^*
0.75	25.13	4.00	25.34	0.25	0.00
1.38	25.13	4.00	13.80	0.46	0.00
1.84	25.13	4.00	10.30	0.61	0.00
1.89	25.13	4.00	10.04	0.63	0.00
0.58	6.28	1.00	8.18	0.77	−0.02
4.89	25.13	4.00	3.88	1.62	0.01
6.28	25.13	4.00	3.02	2.08	0.01
12.07	25.13	4.00	1.57	4.00	0.01
18.06	25.13	4.00	1.05	5.98	0.02
20.05	20.74	3.30	0.78	8.05	0.01
20.04	16.34	2.60	0.62	10.21	−0.00
20.04	13.82	2.20	0.52	12.07	−0.01
20.04	11.93	1.90	0.45	13.98	−0.02
20.03	10.69	1.70	0.40	15.60	−0.02
20.03	9.43	1.50	0.36	17.68	−0.03
20.03	8.17	1.30	0.31	20.41	−0.03
20.04	7.54	1.20	0.28	22.13	−0.06
20.05	6.91	1.10	0.26	24.14	−0.03
20.03	6.28	1.00	0.24	26.53	−0.06
20.03	5.66	0.90	0.21	29.47	−0.07
20.04	5.03	0.80	0.19	33.18	−0.10
20.01	4.40	0.70	0.17	37.87	−0.07
20.01	3.77	0.60	0.14	44.17	−0.20

Table F.16: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

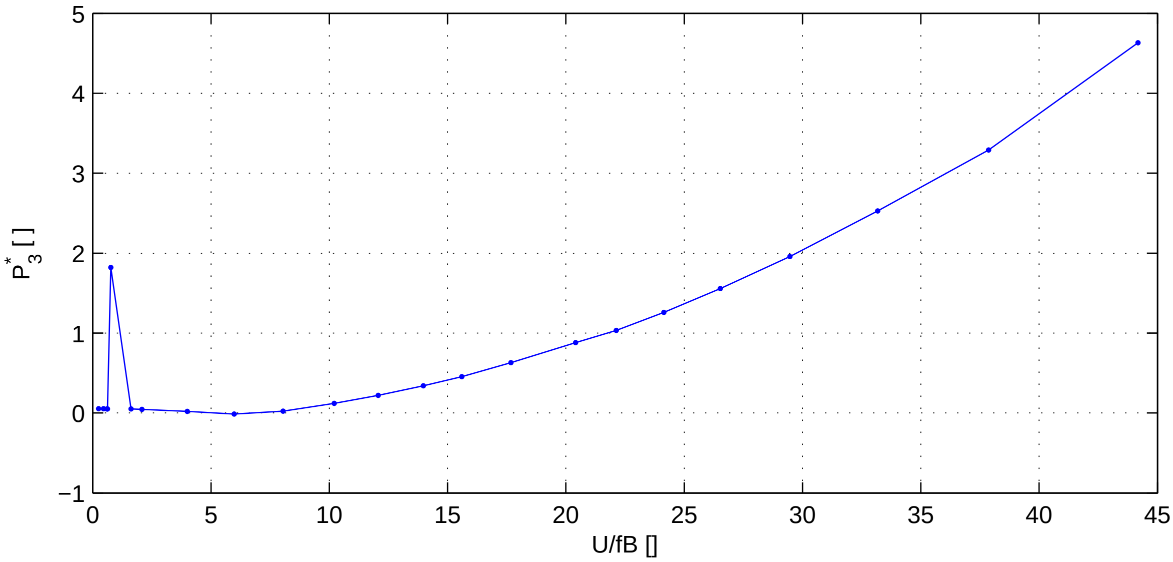

Figure F.15: P_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_3^*
0.75	25.13	4.00	25.34	0.25	0.05
1.38	25.13	4.00	13.80	0.46	0.05
1.84	25.13	4.00	10.30	0.61	0.05
1.89	25.13	4.00	10.04	0.63	0.05
0.58	6.28	1.00	8.18	0.77	1.82
4.89	25.13	4.00	3.88	1.62	0.05
6.28	25.13	4.00	3.02	2.08	0.05
12.07	25.13	4.00	1.57	4.00	0.02
18.06	25.13	4.00	1.05	5.98	−0.01
20.05	20.74	3.30	0.78	8.05	0.02
20.04	16.34	2.60	0.62	10.21	0.12
20.04	13.82	2.20	0.52	12.07	0.22
20.04	11.93	1.90	0.45	13.98	0.34
20.03	10.69	1.70	0.40	15.60	0.45
20.03	9.43	1.50	0.36	17.68	0.63
20.03	8.17	1.30	0.31	20.41	0.88
20.04	7.54	1.20	0.28	22.13	1.03
20.05	6.91	1.10	0.26	24.14	1.26
20.03	6.28	1.00	0.24	26.53	1.56
20.03	5.66	0.90	0.21	29.47	1.96
20.04	5.03	0.80	0.19	33.18	2.53
20.01	4.40	0.70	0.17	37.87	3.29
20.01	3.77	0.60	0.14	44.17	4.63

Table F.17: P_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

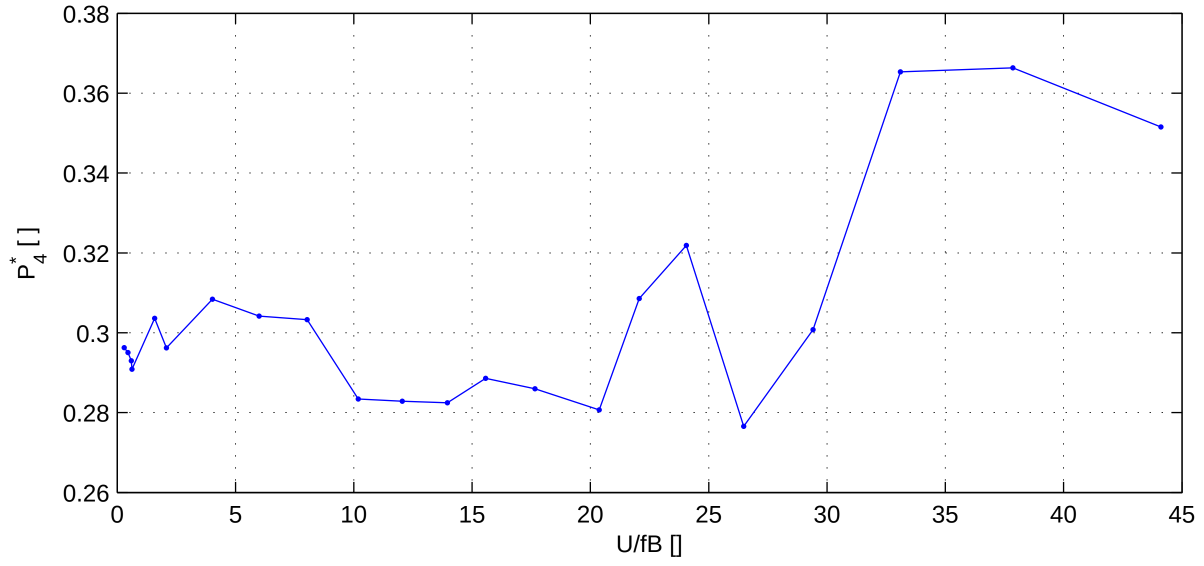

Figure F.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
0.89	25.13	4.00	21.33	0.29	0.30
1.38	25.13	4.00	13.76	0.46	0.30
1.80	25.13	4.00	10.52	0.60	0.29
1.89	25.13	4.00	10.02	0.63	0.29
4.79	25.13	4.00	3.96	1.58	0.30
6.27	25.13	4.00	3.03	2.08	0.30
12.17	25.13	4.00	1.56	4.03	0.31
18.13	25.13	4.00	1.05	6.00	0.30
20.00	20.74	3.30	0.78	8.03	0.30
20.00	16.34	2.60	0.62	10.19	0.28
20.02	13.82	2.20	0.52	12.05	0.28
20.01	11.93	1.90	0.45	13.95	0.28
19.99	10.69	1.70	0.40	15.57	0.29
20.00	9.43	1.50	0.36	17.65	0.29
20.00	8.17	1.30	0.31	20.37	0.28
19.98	7.54	1.20	0.28	22.06	0.31
19.98	6.91	1.10	0.26	24.06	0.32
19.99	6.28	1.00	0.24	26.48	0.28
19.98	5.65	0.90	0.21	29.41	0.30
20.00	5.03	0.80	0.19	33.10	0.37
20.00	4.40	0.70	0.17	37.85	0.37
19.98	3.77	0.60	0.14	44.11	0.35

Table F.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

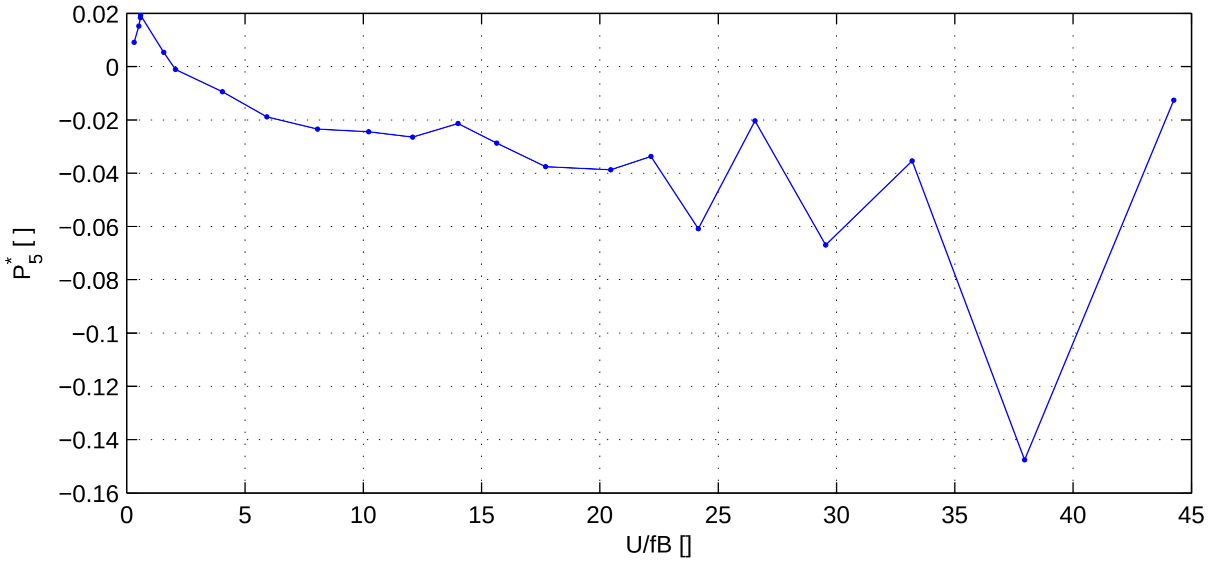

Figure F.17: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_5^*
0.95	25.13	4.00	20.01	0.31	0.01
1.56	25.13	4.00	12.17	0.52	0.02
1.75	25.13	4.00	10.83	0.58	0.02
1.77	25.13	4.00	10.74	0.59	0.02
4.74	25.13	4.00	4.01	1.57	0.01
6.21	25.08	3.99	3.05	2.06	−0.00
12.18	25.08	3.99	1.55	4.04	−0.01
17.90	25.13	4.00	1.06	5.93	−0.02
20.09	20.74	3.30	0.78	8.06	−0.02
20.09	16.34	2.60	0.61	10.23	−0.02
20.07	13.82	2.20	0.52	12.08	−0.03
20.08	11.93	1.90	0.45	14.00	−0.02
20.07	10.69	1.70	0.40	15.63	−0.03
20.06	9.43	1.50	0.35	17.71	−0.04
20.07	8.17	1.30	0.31	20.45	−0.04
20.07	7.54	1.20	0.28	22.16	−0.03
20.06	6.91	1.10	0.26	24.16	−0.06
20.05	6.28	1.00	0.24	26.55	−0.02
20.07	5.66	0.90	0.21	29.54	−0.07
20.05	5.03	0.80	0.19	33.20	−0.04
20.06	4.40	0.70	0.17	37.95	−0.15
20.05	3.77	0.60	0.14	44.26	−0.01

Table F.19: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

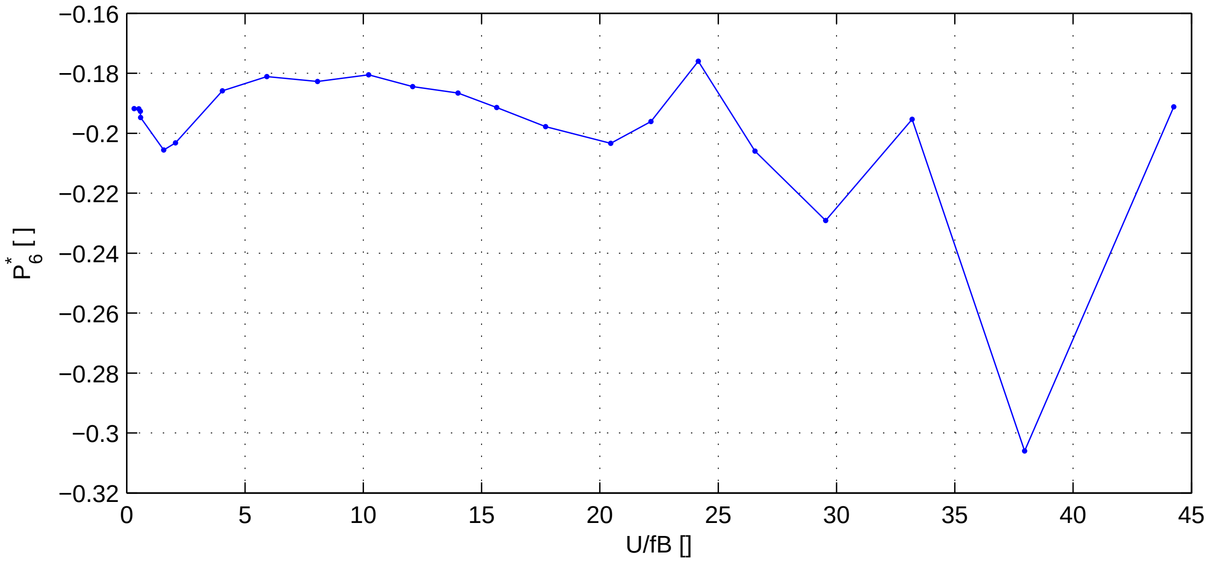

Figure F.18: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_6^*
0.95	25.13	4.00	20.01	0.31	−0.19
1.56	25.13	4.00	12.17	0.52	−0.19
1.75	25.13	4.00	10.83	0.58	−0.19
1.77	25.13	4.00	10.74	0.59	−0.19
4.74	25.13	4.00	4.01	1.57	−0.21
6.21	25.08	3.99	3.05	2.06	−0.20
12.18	25.08	3.99	1.55	4.04	−0.19
17.90	25.13	4.00	1.06	5.93	−0.18
20.09	20.74	3.30	0.78	8.06	−0.18
20.09	16.34	2.60	0.61	10.23	−0.18
20.07	13.82	2.20	0.52	12.08	−0.18
20.08	11.93	1.90	0.45	14.00	−0.19
20.07	10.69	1.70	0.40	15.63	−0.19
20.06	9.43	1.50	0.35	17.71	−0.20
20.07	8.17	1.30	0.31	20.45	−0.20
20.07	7.54	1.20	0.28	22.16	−0.20
20.06	6.91	1.10	0.26	24.16	−0.18
20.05	6.28	1.00	0.24	26.55	−0.21
20.07	5.66	0.90	0.21	29.54	−0.23
20.05	5.03	0.80	0.19	33.20	−0.20
20.06	4.40	0.70	0.17	37.95	−0.31
20.05	3.77	0.60	0.14	44.26	−0.19

Table F.20: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b: buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b: buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b: buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\left(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\left(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\left(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

Formula F.3: Equation of Motion (Stretto di Messina. Ref. [5].)

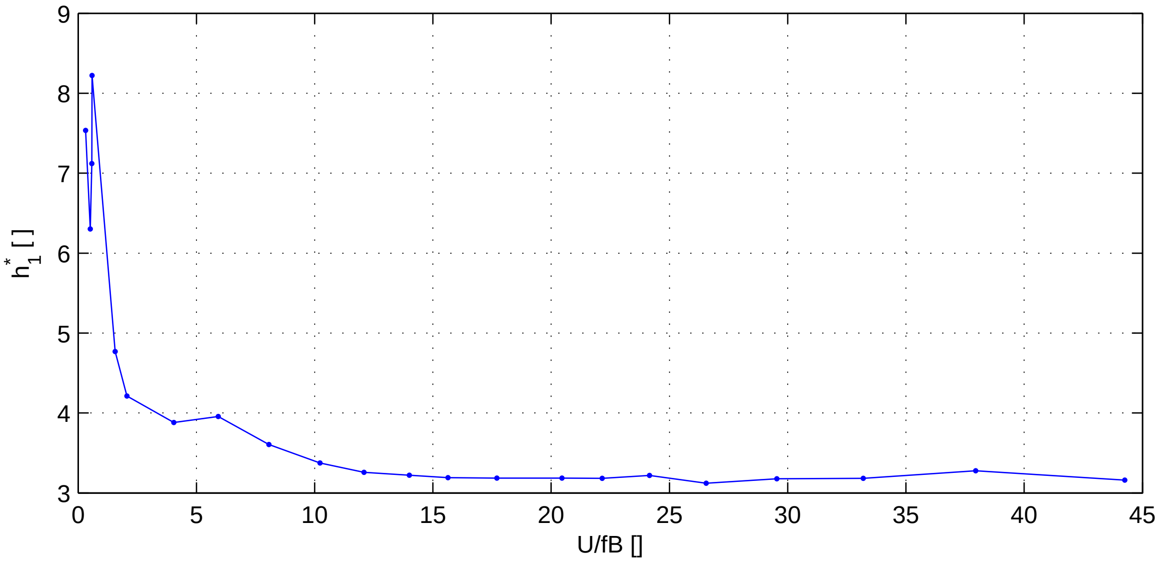

Figure F.19: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_1^*
0.95	25.13	4.00	20.01	0.31	7.53
1.56	25.13	4.00	12.17	0.52	6.30
1.75	25.13	4.00	10.83	0.58	7.12
1.77	25.13	4.00	10.74	0.59	8.22
4.74	25.13	4.00	4.01	1.57	4.77
6.21	25.08	3.99	3.05	2.06	4.21
12.18	25.08	3.99	1.55	4.04	3.88
17.90	25.13	4.00	1.06	5.93	3.96
20.09	20.74	3.30	0.78	8.06	3.61
20.09	16.34	2.60	0.61	10.23	3.37
20.07	13.82	2.20	0.52	12.08	3.26
20.08	11.93	1.90	0.45	14.00	3.22
20.07	10.69	1.70	0.40	15.63	3.19
20.06	9.43	1.50	0.35	17.71	3.19
20.07	8.17	1.30	0.31	20.45	3.19
20.07	7.54	1.20	0.28	22.16	3.18
20.06	6.91	1.10	0.26	24.16	3.22
20.05	6.28	1.00	0.24	26.55	3.12
20.07	5.66	0.90	0.21	29.54	3.18
20.05	5.03	0.80	0.19	33.20	3.18
20.06	4.40	0.70	0.17	37.95	3.28
20.05	3.77	0.60	0.14	44.26	3.16

Table F.21: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

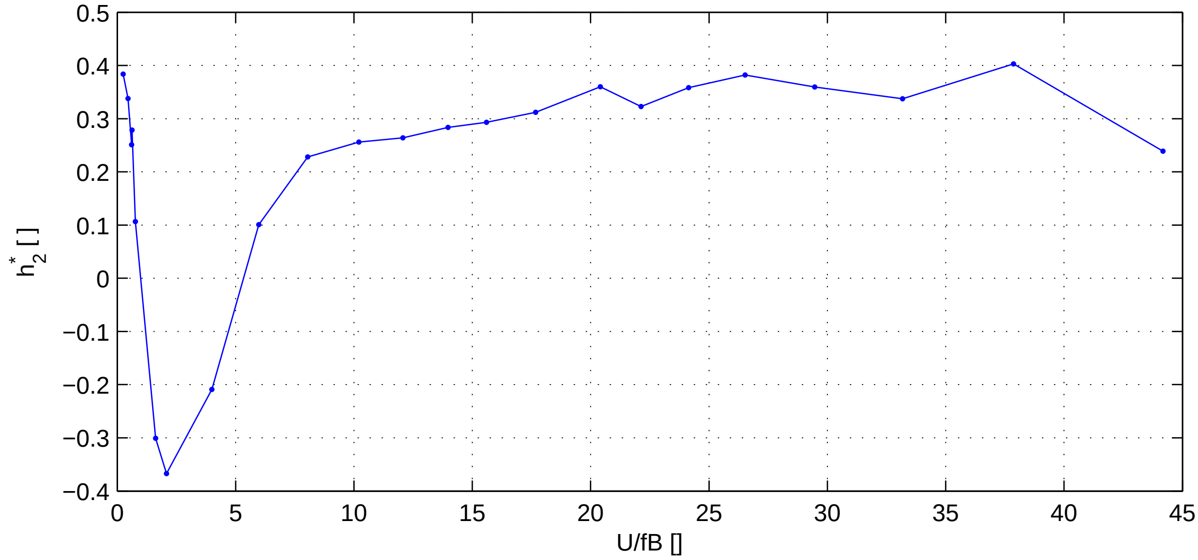

Figure F.20: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_2^*
0.75	25.13	4.00	25.34	0.25	0.38
1.38	25.13	4.00	13.80	0.46	0.34
1.84	25.13	4.00	10.30	0.61	0.25
1.89	25.13	4.00	10.04	0.63	0.28
0.58	6.28	1.00	8.18	0.77	0.11
4.89	25.13	4.00	3.88	1.62	−0.30
6.28	25.13	4.00	3.02	2.08	−0.37
12.07	25.13	4.00	1.57	4.00	−0.21
18.06	25.13	4.00	1.05	5.98	0.10
20.05	20.74	3.30	0.78	8.05	0.23
20.04	16.34	2.60	0.62	10.21	0.26
20.04	13.82	2.20	0.52	12.07	0.26
20.04	11.93	1.90	0.45	13.98	0.28
20.03	10.69	1.70	0.40	15.60	0.29
20.03	9.43	1.50	0.36	17.68	0.31
20.03	8.17	1.30	0.31	20.41	0.36
20.04	7.54	1.20	0.28	22.13	0.32
20.05	6.91	1.10	0.26	24.14	0.36
20.03	6.28	1.00	0.24	26.53	0.38
20.03	5.66	0.90	0.21	29.47	0.36
20.04	5.03	0.80	0.19	33.18	0.34
20.01	4.40	0.70	0.17	37.87	0.40
20.01	3.77	0.60	0.14	44.17	0.24

Table F.22: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

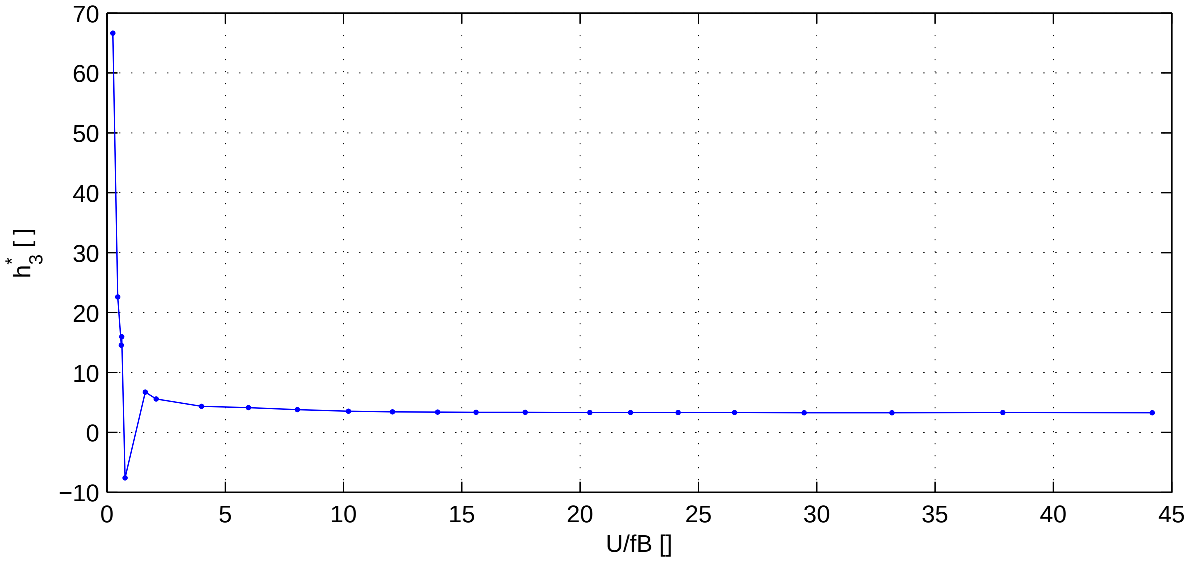

Figure F.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
0.75	25.13	4.00	25.34	0.25	66.63
1.38	25.13	4.00	13.80	0.46	22.61
1.84	25.13	4.00	10.30	0.61	14.53
1.89	25.13	4.00	10.04	0.63	15.96
0.58	6.28	1.00	8.18	0.77	−7.61
4.89	25.13	4.00	3.88	1.62	6.72
6.28	25.13	4.00	3.02	2.08	5.56
12.07	25.13	4.00	1.57	4.00	4.34
18.06	25.13	4.00	1.05	5.98	4.13
20.05	20.74	3.30	0.78	8.05	3.77
20.04	16.34	2.60	0.62	10.21	3.53
20.04	13.82	2.20	0.52	12.07	3.43
20.04	11.93	1.90	0.45	13.98	3.38
20.03	10.69	1.70	0.40	15.60	3.35
20.03	9.43	1.50	0.36	17.68	3.32
20.03	8.17	1.30	0.31	20.41	3.29
20.04	7.54	1.20	0.28	22.13	3.32
20.05	6.91	1.10	0.26	24.14	3.29
20.03	6.28	1.00	0.24	26.53	3.29
20.03	5.66	0.90	0.21	29.47	3.28
20.04	5.03	0.80	0.19	33.18	3.28
20.01	4.40	0.70	0.17	37.87	3.29
20.01	3.77	0.60	0.14	44.17	3.27

Table F.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

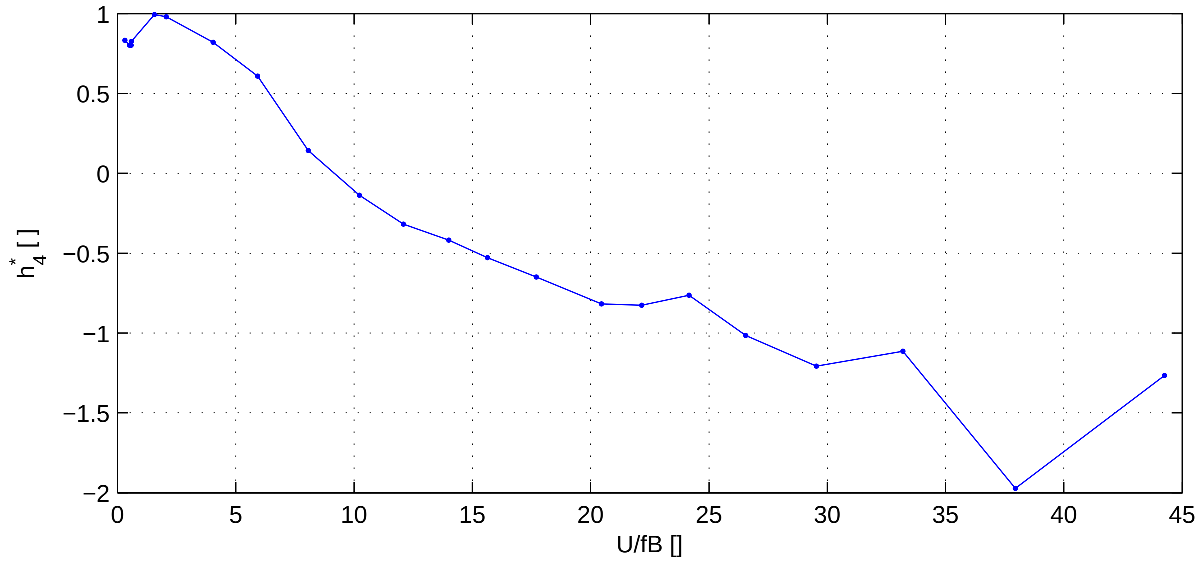

Figure F.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
0.95	25.13	4.00	20.01	0.31	0.83
1.56	25.13	4.00	12.17	0.52	0.80
1.75	25.13	4.00	10.83	0.58	0.80
1.77	25.13	4.00	10.74	0.59	0.83
4.74	25.13	4.00	4.01	1.57	0.99
6.21	25.08	3.99	3.05	2.06	0.98
12.18	25.08	3.99	1.55	4.04	0.82
17.90	25.13	4.00	1.06	5.93	0.61
20.09	20.74	3.30	0.78	8.06	0.14
20.09	16.34	2.60	0.61	10.23	−0.14
20.07	13.82	2.20	0.52	12.08	−0.32
20.08	11.93	1.90	0.45	14.00	−0.42
20.07	10.69	1.70	0.40	15.63	−0.53
20.06	9.43	1.50	0.35	17.71	−0.65
20.07	8.17	1.30	0.31	20.45	−0.82
20.07	7.54	1.20	0.28	22.16	−0.83
20.06	6.91	1.10	0.26	24.16	−0.76
20.05	6.28	1.00	0.24	26.55	−1.02
20.07	5.66	0.90	0.21	29.54	−1.21
20.05	5.03	0.80	0.19	33.20	−1.11
20.06	4.40	0.70	0.17	37.95	−1.97
20.05	3.77	0.60	0.14	44.26	−1.27

Table F.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

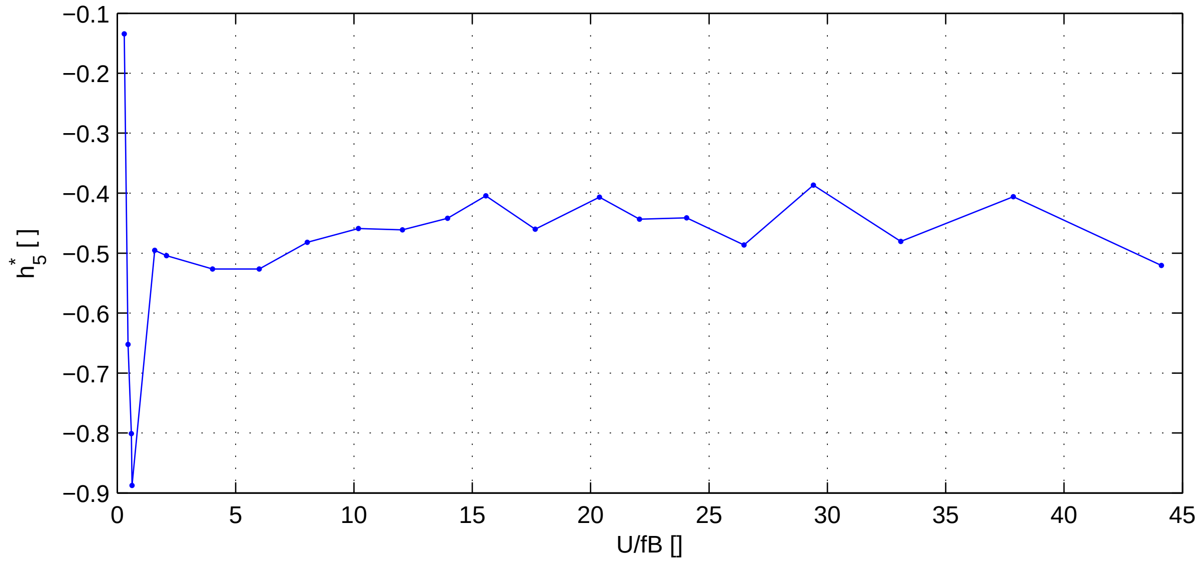

Figure F.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
0.89	25.13	4.00	21.33	0.29	−0.13
1.38	25.13	4.00	13.76	0.46	−0.65
1.80	25.13	4.00	10.52	0.60	−0.80
1.89	25.13	4.00	10.02	0.63	−0.89
4.79	25.13	4.00	3.96	1.58	−0.50
6.27	25.13	4.00	3.03	2.08	−0.50
12.17	25.13	4.00	1.56	4.03	−0.53
18.13	25.13	4.00	1.05	6.00	−0.53
20.00	20.74	3.30	0.78	8.03	−0.48
20.00	16.34	2.60	0.62	10.19	−0.46
20.02	13.82	2.20	0.52	12.05	−0.46
20.01	11.93	1.90	0.45	13.95	−0.44
19.99	10.69	1.70	0.40	15.57	−0.40
20.00	9.43	1.50	0.36	17.65	−0.46
20.00	8.17	1.30	0.31	20.37	−0.41
19.98	7.54	1.20	0.28	22.06	−0.44
19.98	6.91	1.10	0.26	24.06	−0.44
19.99	6.28	1.00	0.24	26.48	−0.49
19.98	5.65	0.90	0.21	29.41	−0.39
20.00	5.03	0.80	0.19	33.10	−0.48
20.00	4.40	0.70	0.17	37.85	−0.41
19.98	3.77	0.60	0.14	44.11	−0.52

Table F.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:11:08

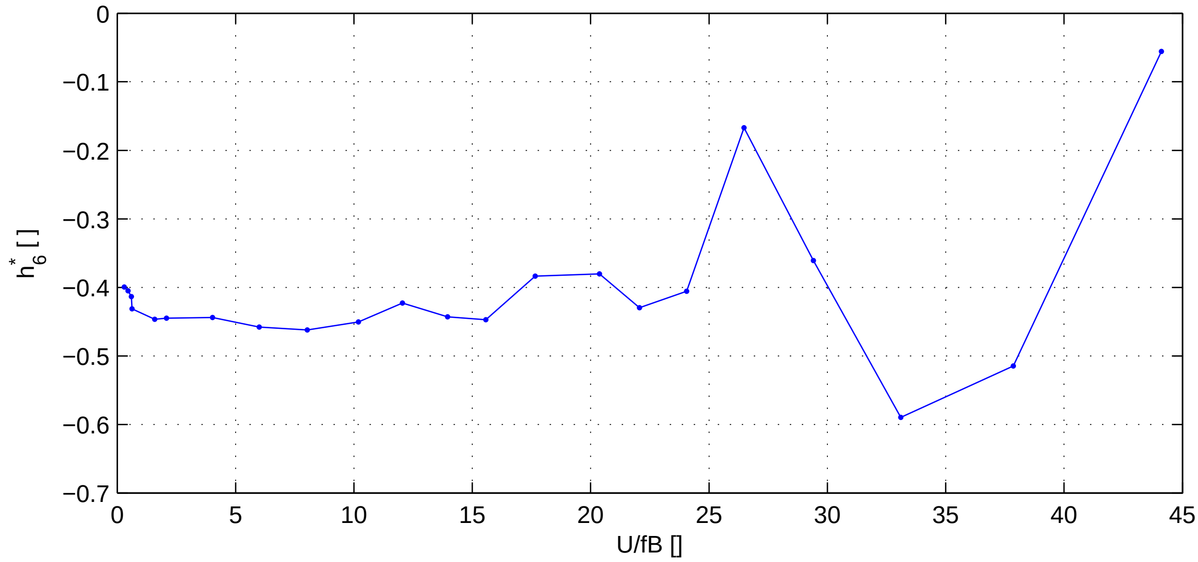

Figure F.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
0.89	25.13	4.00	21.33	0.29	−0.40
1.38	25.13	4.00	13.76	0.46	−0.40
1.80	25.13	4.00	10.52	0.60	−0.41
1.89	25.13	4.00	10.02	0.63	−0.43
4.79	25.13	4.00	3.96	1.58	−0.45
6.27	25.13	4.00	3.03	2.08	−0.44
12.17	25.13	4.00	1.56	4.03	−0.44
18.13	25.13	4.00	1.05	6.00	−0.46
20.00	20.74	3.30	0.78	8.03	−0.46
20.00	16.34	2.60	0.62	10.19	−0.45
20.02	13.82	2.20	0.52	12.05	−0.42
20.01	11.93	1.90	0.45	13.95	−0.44
19.99	10.69	1.70	0.40	15.57	−0.45
20.00	9.43	1.50	0.36	17.65	−0.38
20.00	8.17	1.30	0.31	20.37	−0.38
19.98	7.54	1.20	0.28	22.06	−0.43
19.98	6.91	1.10	0.26	24.06	−0.41
19.99	6.28	1.00	0.24	26.48	−0.17
19.98	5.65	0.90	0.21	29.41	−0.36
20.00	5.03	0.80	0.19	33.10	−0.59
20.00	4.40	0.70	0.17	37.85	−0.51
19.98	3.77	0.60	0.14	44.11	−0.06

Table F.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

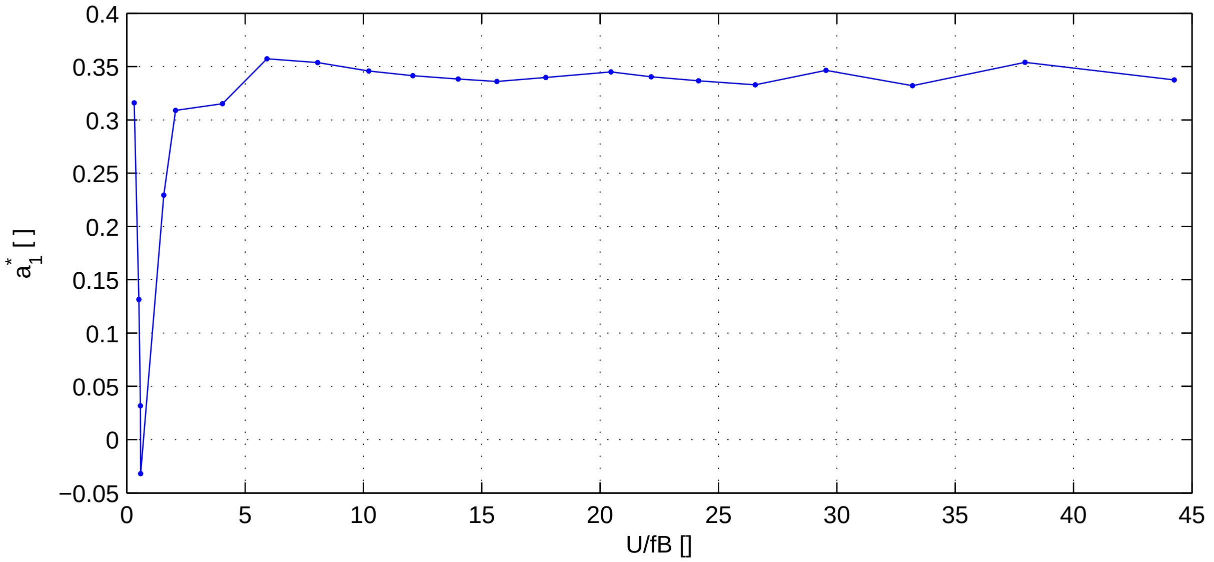

Figure F.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
0.95	25.13	4.00	20.01	0.31	0.32
1.56	25.13	4.00	12.17	0.52	0.13
1.75	25.13	4.00	10.83	0.58	0.03
1.77	25.13	4.00	10.74	0.59	−0.03
4.74	25.13	4.00	4.01	1.57	0.23
6.21	25.08	3.99	3.05	2.06	0.31
12.18	25.08	3.99	1.55	4.04	0.32
17.90	25.13	4.00	1.06	5.93	0.36
20.09	20.74	3.30	0.78	8.06	0.35
20.09	16.34	2.60	0.61	10.23	0.35
20.07	13.82	2.20	0.52	12.08	0.34
20.08	11.93	1.90	0.45	14.00	0.34
20.07	10.69	1.70	0.40	15.63	0.34
20.06	9.43	1.50	0.35	17.71	0.34
20.07	8.17	1.30	0.31	20.45	0.35
20.07	7.54	1.20	0.28	22.16	0.34
20.06	6.91	1.10	0.26	24.16	0.34
20.05	6.28	1.00	0.24	26.55	0.33
20.07	5.66	0.90	0.21	29.54	0.35
20.05	5.03	0.80	0.19	33.20	0.33
20.06	4.40	0.70	0.17	37.95	0.35
20.05	3.77	0.60	0.14	44.26	0.34

Table F.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:11:08

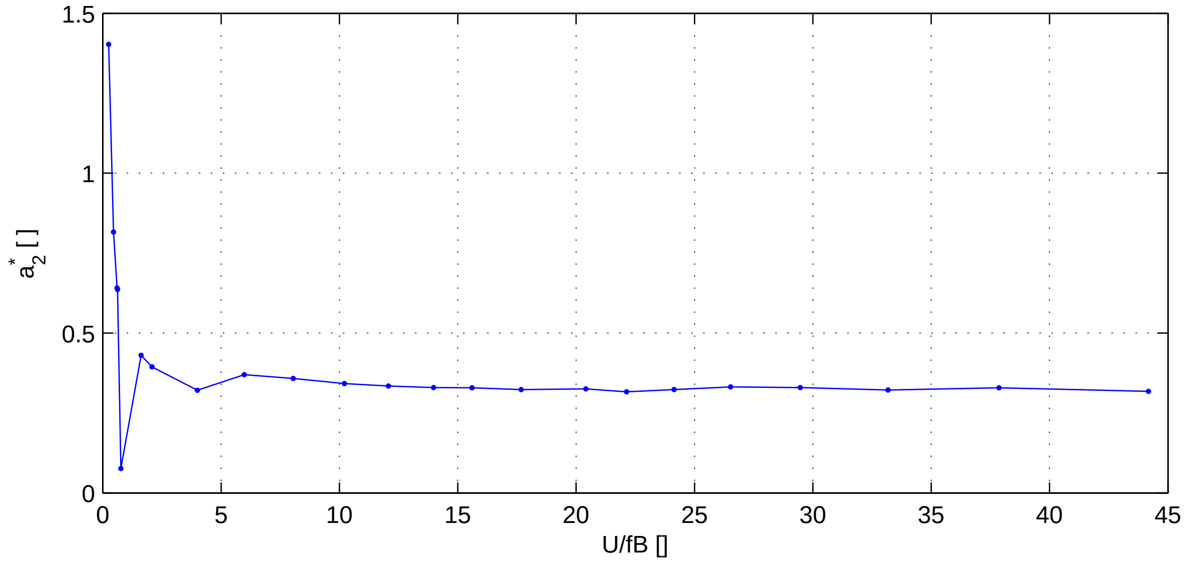

Figure F.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
0.75	25.13	4.00	25.34	0.25	1.40
1.38	25.13	4.00	13.80	0.46	0.82
1.84	25.13	4.00	10.30	0.61	0.64
1.89	25.13	4.00	10.04	0.63	0.64
0.58	6.28	1.00	8.18	0.77	0.08
4.89	25.13	4.00	3.88	1.62	0.43
6.28	25.13	4.00	3.02	2.08	0.39
12.07	25.13	4.00	1.57	4.00	0.32
18.06	25.13	4.00	1.05	5.98	0.37
20.05	20.74	3.30	0.78	8.05	0.36
20.04	16.34	2.60	0.62	10.21	0.34
20.04	13.82	2.20	0.52	12.07	0.33
20.04	11.93	1.90	0.45	13.98	0.33
20.03	10.69	1.70	0.40	15.60	0.33
20.03	9.43	1.50	0.36	17.68	0.32
20.03	8.17	1.30	0.31	20.41	0.33
20.04	7.54	1.20	0.28	22.13	0.32
20.05	6.91	1.10	0.26	24.14	0.32
20.03	6.28	1.00	0.24	26.53	0.33
20.03	5.66	0.90	0.21	29.47	0.33
20.04	5.03	0.80	0.19	33.18	0.32
20.01	4.40	0.70	0.17	37.87	0.33
20.01	3.77	0.60	0.14	44.17	0.32

Table F.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

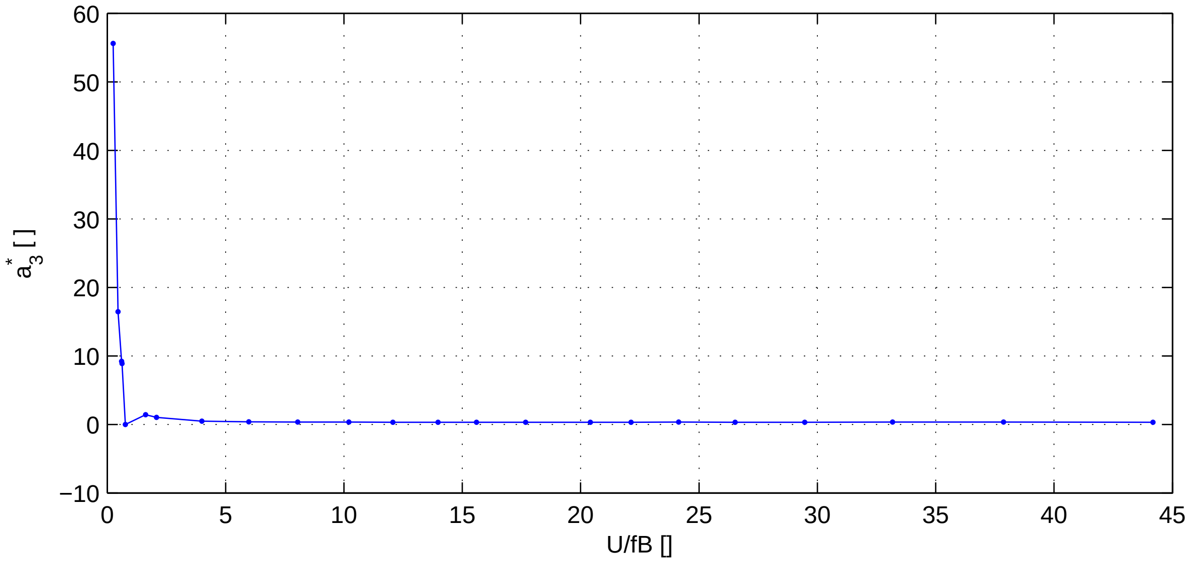

Figure F.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
0.75	25.13	4.00	25.34	0.25	55.60
1.38	25.13	4.00	13.80	0.46	16.44
1.84	25.13	4.00	10.30	0.61	9.21
1.89	25.13	4.00	10.04	0.63	8.87
0.58	6.28	1.00	8.18	0.77	−0.02
4.89	25.13	4.00	3.88	1.62	1.41
6.28	25.13	4.00	3.02	2.08	1.02
12.07	25.13	4.00	1.57	4.00	0.48
18.06	25.13	4.00	1.05	5.98	0.38
20.05	20.74	3.30	0.78	8.05	0.34
20.04	16.34	2.60	0.62	10.21	0.33
20.04	13.82	2.20	0.52	12.07	0.32
20.04	11.93	1.90	0.45	13.98	0.32
20.03	10.69	1.70	0.40	15.60	0.32
20.03	9.43	1.50	0.36	17.68	0.32
20.03	8.17	1.30	0.31	20.41	0.32
20.04	7.54	1.20	0.28	22.13	0.32
20.05	6.91	1.10	0.26	24.14	0.33
20.03	6.28	1.00	0.24	26.53	0.32
20.03	5.66	0.90	0.21	29.47	0.32
20.04	5.03	0.80	0.19	33.18	0.33
20.01	4.40	0.70	0.17	37.87	0.33
20.01	3.77	0.60	0.14	44.17	0.32

Table F.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

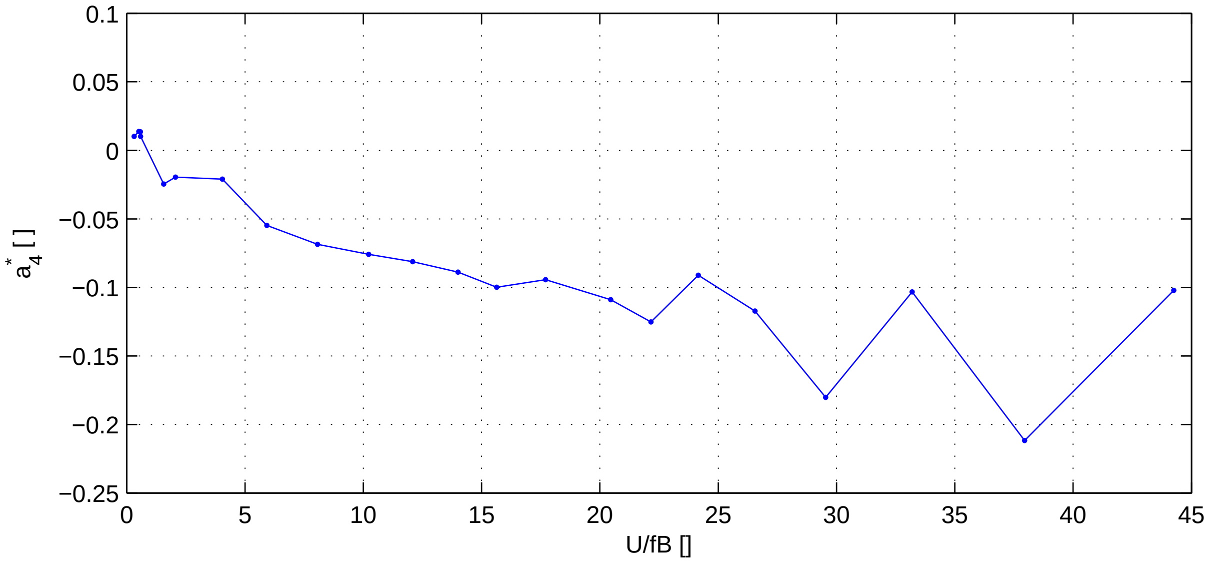

Figure F.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
0.95	25.13	4.00	20.01	0.31	0.01
1.56	25.13	4.00	12.17	0.52	0.01
1.75	25.13	4.00	10.83	0.58	0.01
1.77	25.13	4.00	10.74	0.59	0.01
4.74	25.13	4.00	4.01	1.57	−0.02
6.21	25.08	3.99	3.05	2.06	−0.02
12.18	25.08	3.99	1.55	4.04	−0.02
17.90	25.13	4.00	1.06	5.93	−0.05
20.09	20.74	3.30	0.78	8.06	−0.07
20.09	16.34	2.60	0.61	10.23	−0.08
20.07	13.82	2.20	0.52	12.08	−0.08
20.08	11.93	1.90	0.45	14.00	−0.09
20.07	10.69	1.70	0.40	15.63	−0.10
20.06	9.43	1.50	0.35	17.71	−0.09
20.07	8.17	1.30	0.31	20.45	−0.11
20.07	7.54	1.20	0.28	22.16	−0.13
20.06	6.91	1.10	0.26	24.16	−0.09
20.05	6.28	1.00	0.24	26.55	−0.12
20.07	5.66	0.90	0.21	29.54	−0.18
20.05	5.03	0.80	0.19	33.20	−0.10
20.06	4.40	0.70	0.17	37.95	−0.21
20.05	3.77	0.60	0.14	44.26	−0.10

Table F.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:11:08

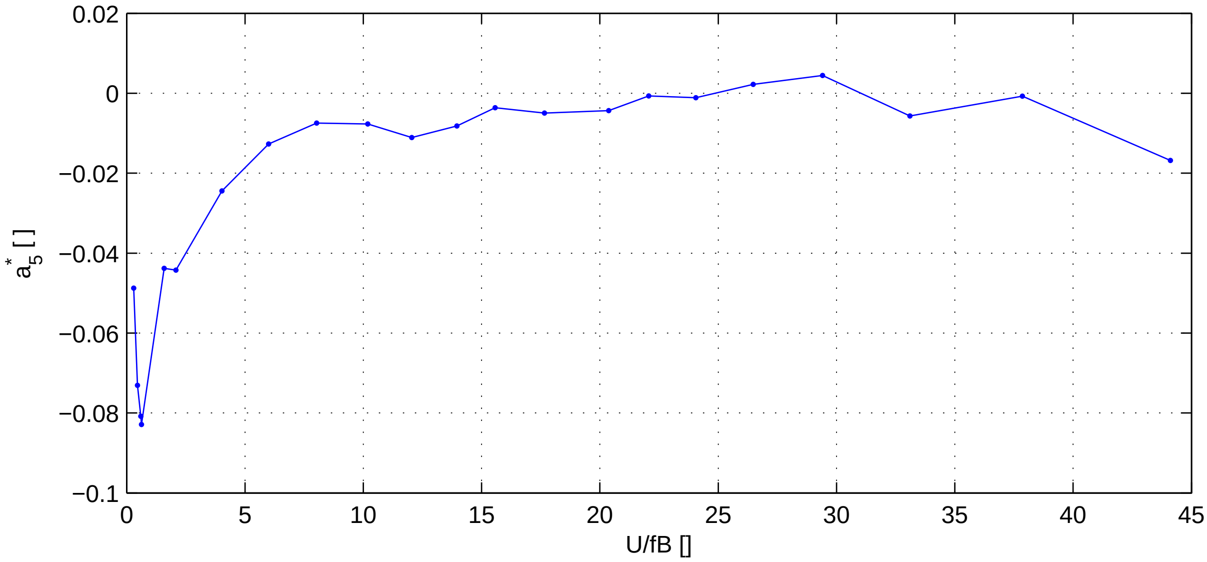

Figure F.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
0.89	25.13	4.00	21.33	0.29	−0.05
1.38	25.13	4.00	13.76	0.46	−0.07
1.80	25.13	4.00	10.52	0.60	−0.08
1.89	25.13	4.00	10.02	0.63	−0.08
4.79	25.13	4.00	3.96	1.58	−0.04
6.27	25.13	4.00	3.03	2.08	−0.04
12.17	25.13	4.00	1.56	4.03	−0.02
18.13	25.13	4.00	1.05	6.00	−0.01
20.00	20.74	3.30	0.78	8.03	−0.01
20.00	16.34	2.60	0.62	10.19	−0.01
20.02	13.82	2.20	0.52	12.05	−0.01
20.01	11.93	1.90	0.45	13.95	−0.01
19.99	10.69	1.70	0.40	15.57	−0.00
20.00	9.43	1.50	0.36	17.65	−0.00
20.00	8.17	1.30	0.31	20.37	−0.00
19.98	7.54	1.20	0.28	22.06	−0.00
19.98	6.91	1.10	0.26	24.06	−0.00
19.99	6.28	1.00	0.24	26.48	0.00
19.98	5.65	0.90	0.21	29.41	0.00
20.00	5.03	0.80	0.19	33.10	−0.01
20.00	4.40	0.70	0.17	37.85	−0.00
19.98	3.77	0.60	0.14	44.11	−0.02

Table F.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

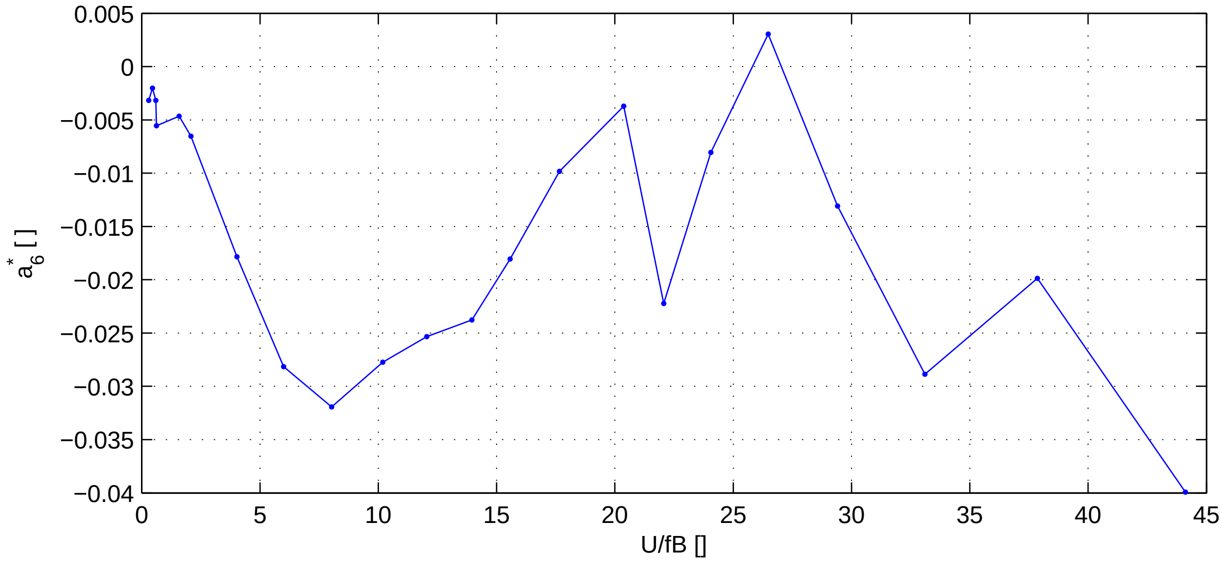

Figure F.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
0.89	25.13	4.00	21.33	0.29	−0.00
1.38	25.13	4.00	13.76	0.46	−0.00
1.80	25.13	4.00	10.52	0.60	−0.00
1.89	25.13	4.00	10.02	0.63	−0.01
4.79	25.13	4.00	3.96	1.58	−0.00
6.27	25.13	4.00	3.03	2.08	−0.01
12.17	25.13	4.00	1.56	4.03	−0.02
18.13	25.13	4.00	1.05	6.00	−0.03
20.00	20.74	3.30	0.78	8.03	−0.03
20.00	16.34	2.60	0.62	10.19	−0.03
20.02	13.82	2.20	0.52	12.05	−0.03
20.01	11.93	1.90	0.45	13.95	−0.02
19.99	10.69	1.70	0.40	15.57	−0.02
20.00	9.43	1.50	0.36	17.65	−0.01
20.00	8.17	1.30	0.31	20.37	−0.00
19.98	7.54	1.20	0.28	22.06	−0.02
19.98	6.91	1.10	0.26	24.06	−0.01
19.99	6.28	1.00	0.24	26.48	0.00
19.98	5.65	0.90	0.21	29.41	−0.01
20.00	5.03	0.80	0.19	33.10	−0.03
20.00	4.40	0.70	0.17	37.85	−0.02
19.98	3.77	0.60	0.14	44.11	−0.04

Table F.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

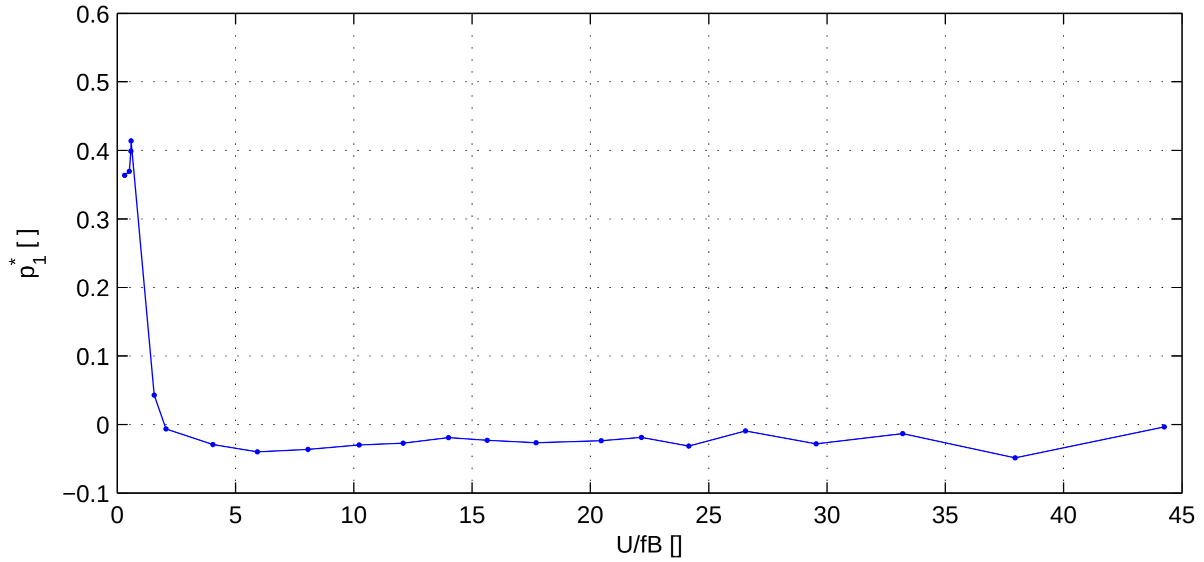

Figure F.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
0.95	25.13	4.00	20.01	0.31	0.36
1.56	25.13	4.00	12.17	0.52	0.37
1.75	25.13	4.00	10.83	0.58	0.40
1.77	25.13	4.00	10.74	0.59	0.41
4.74	25.13	4.00	4.01	1.57	0.04
6.21	25.08	3.99	3.05	2.06	−0.01
12.18	25.08	3.99	1.55	4.04	−0.03
17.90	25.13	4.00	1.06	5.93	−0.04
20.09	20.74	3.30	0.78	8.06	−0.04
20.09	16.34	2.60	0.61	10.23	−0.03
20.07	13.82	2.20	0.52	12.08	−0.03
20.08	11.93	1.90	0.45	14.00	−0.02
20.07	10.69	1.70	0.40	15.63	−0.02
20.06	9.43	1.50	0.35	17.71	−0.03
20.07	8.17	1.30	0.31	20.45	−0.02
20.07	7.54	1.20	0.28	22.16	−0.02
20.06	6.91	1.10	0.26	24.16	−0.03
20.05	6.28	1.00	0.24	26.55	−0.01
20.07	5.66	0.90	0.21	29.54	−0.03
20.05	5.03	0.80	0.19	33.20	−0.01
20.06	4.40	0.70	0.17	37.95	−0.05
20.05	3.77	0.60	0.14	44.26	−0.00

Table F.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

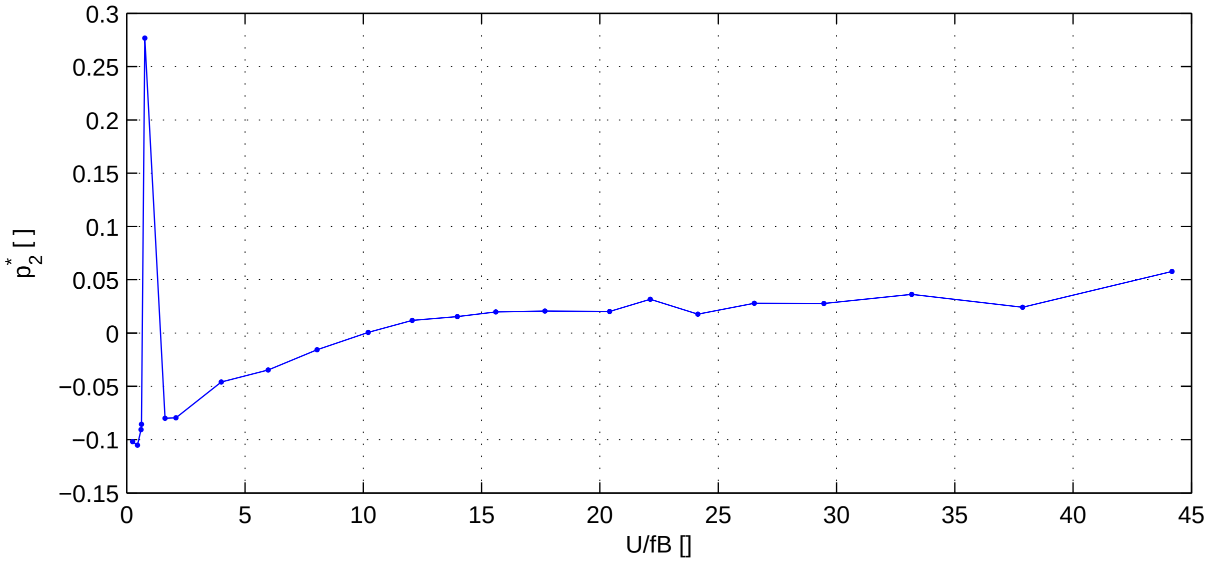

Figure F.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
0.75	25.13	4.00	25.34	0.25	−0.10
1.38	25.13	4.00	13.80	0.46	−0.11
1.84	25.13	4.00	10.30	0.61	−0.09
1.89	25.13	4.00	10.04	0.63	−0.09
0.58	6.28	1.00	8.18	0.77	0.28
4.89	25.13	4.00	3.88	1.62	−0.08
6.28	25.13	4.00	3.02	2.08	−0.08
12.07	25.13	4.00	1.57	4.00	−0.05
18.06	25.13	4.00	1.05	5.98	−0.03
20.05	20.74	3.30	0.78	8.05	−0.02
20.04	16.34	2.60	0.62	10.21	0.00
20.04	13.82	2.20	0.52	12.07	0.01
20.04	11.93	1.90	0.45	13.98	0.02
20.03	10.69	1.70	0.40	15.60	0.02
20.03	9.43	1.50	0.36	17.68	0.02
20.03	8.17	1.30	0.31	20.41	0.02
20.04	7.54	1.20	0.28	22.13	0.03
20.05	6.91	1.10	0.26	24.14	0.02
20.03	6.28	1.00	0.24	26.53	0.03
20.03	5.66	0.90	0.21	29.47	0.03
20.04	5.03	0.80	0.19	33.18	0.04
20.01	4.40	0.70	0.17	37.87	0.02
20.01	3.77	0.60	0.14	44.17	0.06

Table F.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:11:08

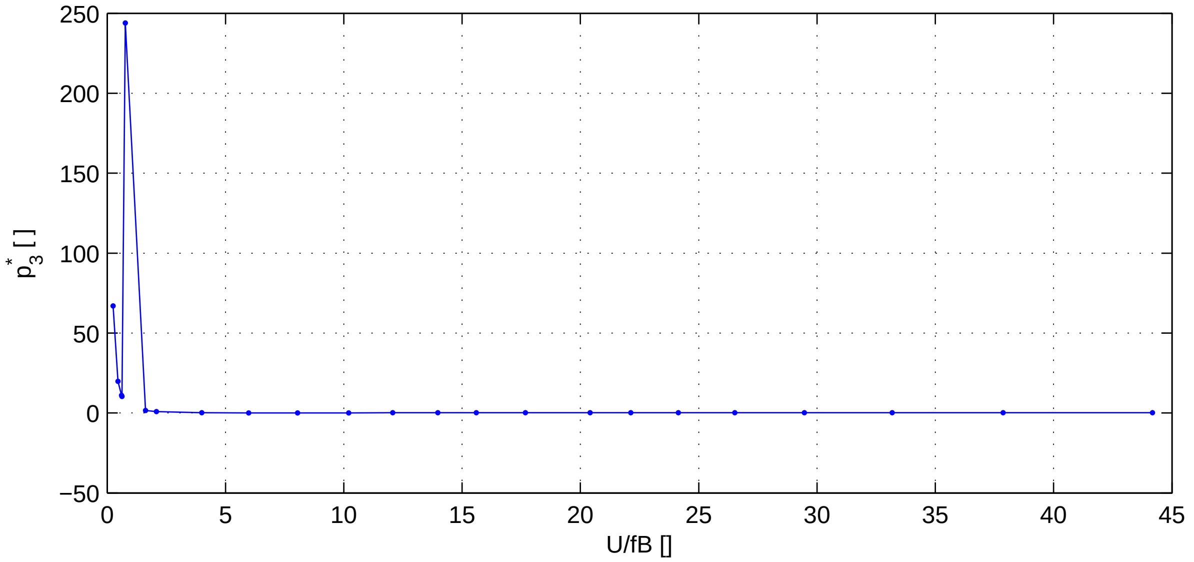

Figure F.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
0.75	25.13	4.00	25.34	0.25	67.00
1.38	25.13	4.00	13.80	0.46	19.82
1.84	25.13	4.00	10.30	0.61	10.95
1.89	25.13	4.00	10.04	0.63	10.34
0.58	6.28	1.00	8.18	0.77	243.90
4.89	25.13	4.00	3.88	1.62	1.49
6.28	25.13	4.00	3.02	2.08	0.83
12.07	25.13	4.00	1.57	4.00	0.10
18.06	25.13	4.00	1.05	5.98	−0.03
20.05	20.74	3.30	0.78	8.05	0.03
20.04	16.34	2.60	0.62	10.21	0.09
20.04	13.82	2.20	0.52	12.07	0.12
20.04	11.93	1.90	0.45	13.98	0.14
20.03	10.69	1.70	0.40	15.60	0.15
20.03	9.43	1.50	0.36	17.68	0.16
20.03	8.17	1.30	0.31	20.41	0.17
20.04	7.54	1.20	0.28	22.13	0.17
20.05	6.91	1.10	0.26	24.14	0.17
20.03	6.28	1.00	0.24	26.53	0.17
20.03	5.66	0.90	0.21	29.47	0.18
20.04	5.03	0.80	0.19	33.18	0.18
20.01	4.40	0.70	0.17	37.87	0.18
20.01	3.77	0.60	0.14	44.17	0.19

Table F.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

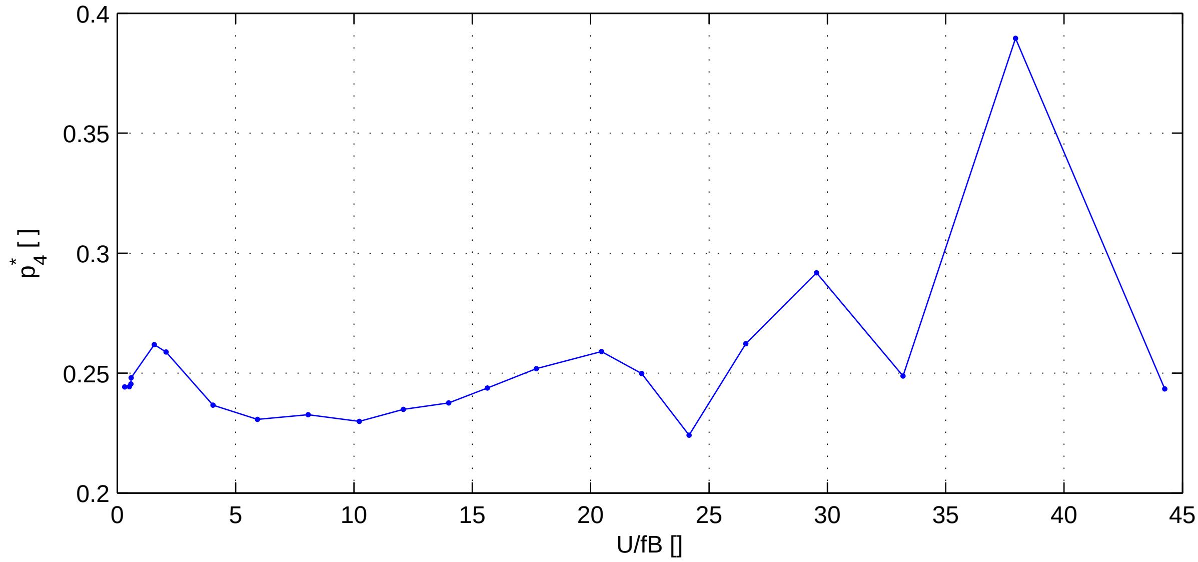

Figure F.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
0.95	25.13	4.00	20.01	0.31	0.24
1.56	25.13	4.00	12.17	0.52	0.24
1.75	25.13	4.00	10.83	0.58	0.25
1.77	25.13	4.00	10.74	0.59	0.25
4.74	25.13	4.00	4.01	1.57	0.26
6.21	25.08	3.99	3.05	2.06	0.26
12.18	25.08	3.99	1.55	4.04	0.24
17.90	25.13	4.00	1.06	5.93	0.23
20.09	20.74	3.30	0.78	8.06	0.23
20.09	16.34	2.60	0.61	10.23	0.23
20.07	13.82	2.20	0.52	12.08	0.23
20.08	11.93	1.90	0.45	14.00	0.24
20.07	10.69	1.70	0.40	15.63	0.24
20.06	9.43	1.50	0.35	17.71	0.25
20.07	8.17	1.30	0.31	20.45	0.26
20.07	7.54	1.20	0.28	22.16	0.25
20.06	6.91	1.10	0.26	24.16	0.22
20.05	6.28	1.00	0.24	26.55	0.26
20.07	5.66	0.90	0.21	29.54	0.29
20.05	5.03	0.80	0.19	33.20	0.25
20.06	4.40	0.70	0.17	37.95	0.39
20.05	3.77	0.60	0.14	44.26	0.24

Table F.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

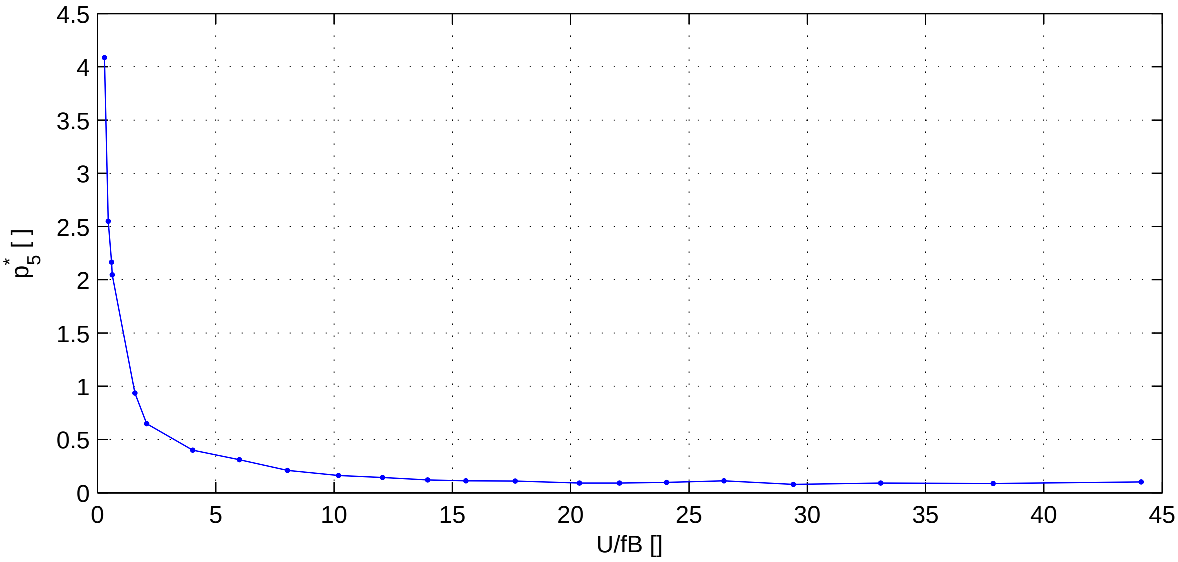

Figure F.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
0.89	25.13	4.00	21.33	0.29	4.08
1.38	25.13	4.00	13.76	0.46	2.55
1.80	25.13	4.00	10.52	0.60	2.16
1.89	25.13	4.00	10.02	0.63	2.05
4.79	25.13	4.00	3.96	1.58	0.94
6.27	25.13	4.00	3.03	2.08	0.65
12.17	25.13	4.00	1.56	4.03	0.40
18.13	25.13	4.00	1.05	6.00	0.31
20.00	20.74	3.30	0.78	8.03	0.21
20.00	16.34	2.60	0.62	10.19	0.16
20.02	13.82	2.20	0.52	12.05	0.14
20.01	11.93	1.90	0.45	13.95	0.12
19.99	10.69	1.70	0.40	15.57	0.11
20.00	9.43	1.50	0.36	17.65	0.11
20.00	8.17	1.30	0.31	20.37	0.09
19.98	7.54	1.20	0.28	22.06	0.09
19.98	6.91	1.10	0.26	24.06	0.10
19.99	6.28	1.00	0.24	26.48	0.11
19.98	5.65	0.90	0.21	29.41	0.08
20.00	5.03	0.80	0.19	33.10	0.09
20.00	4.40	0.70	0.17	37.85	0.09
19.98	3.77	0.60	0.14	44.11	0.10

Table F.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

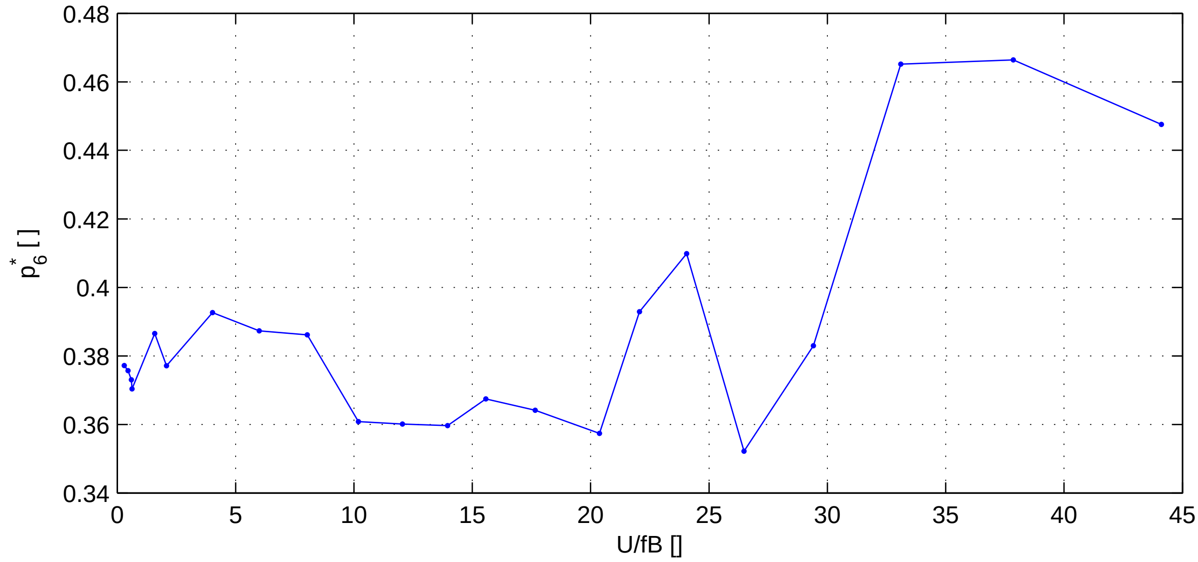

Figure F.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
0.89	25.13	4.00	21.33	0.29	0.38
1.38	25.13	4.00	13.76	0.46	0.38
1.80	25.13	4.00	10.52	0.60	0.37
1.89	25.13	4.00	10.02	0.63	0.37
4.79	25.13	4.00	3.96	1.58	0.39
6.27	25.13	4.00	3.03	2.08	0.38
12.17	25.13	4.00	1.56	4.03	0.39
18.13	25.13	4.00	1.05	6.00	0.39
20.00	20.74	3.30	0.78	8.03	0.39
20.00	16.34	2.60	0.62	10.19	0.36
20.02	13.82	2.20	0.52	12.05	0.36
20.01	11.93	1.90	0.45	13.95	0.36
19.99	10.69	1.70	0.40	15.57	0.37
20.00	9.43	1.50	0.36	17.65	0.36
20.00	8.17	1.30	0.31	20.37	0.36
19.98	7.54	1.20	0.28	22.06	0.39
19.98	6.91	1.10	0.26	24.06	0.41
19.99	6.28	1.00	0.24	26.48	0.35
19.98	5.65	0.90	0.21	29.41	0.38
20.00	5.03	0.80	0.19	33.10	0.47
20.00	4.40	0.70	0.17	37.85	0.47
19.98	3.77	0.60	0.14	44.11	0.45

Table F.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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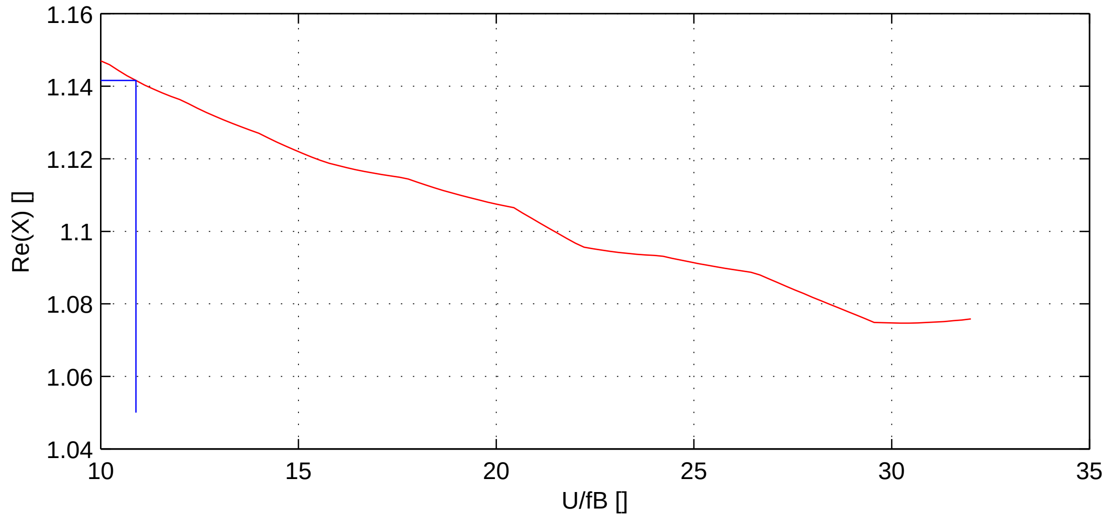


Figure F.37: Real part of the solution to stability equantion

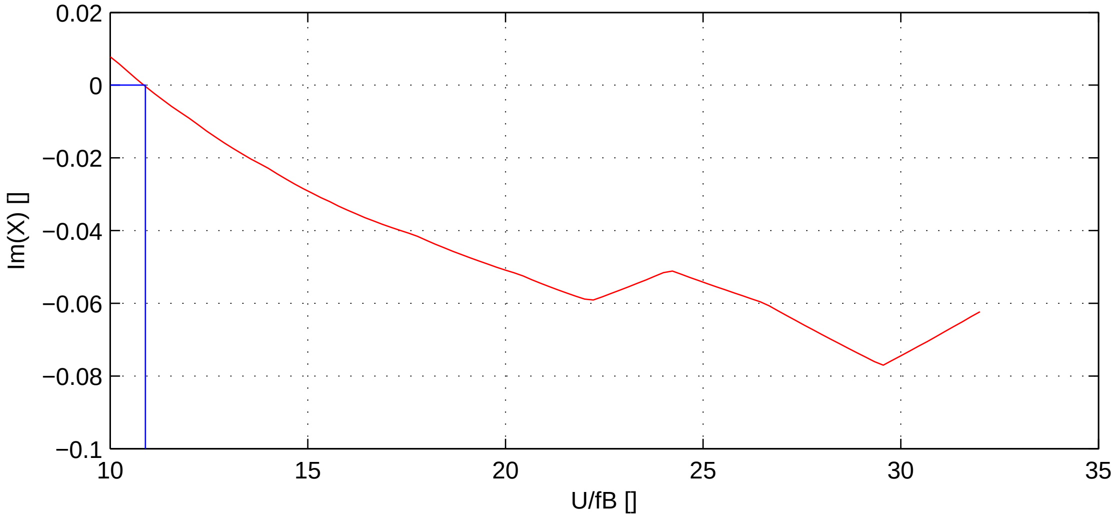


Figure F.38: Imaginary part of the solution to stability equantion

V_{Crit} = 10.9

f_{Crit} = 0.0739 Hz

U_{Crit} = 48.6 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.

[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.

[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.

[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.

[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix G

3D Flutter Tests

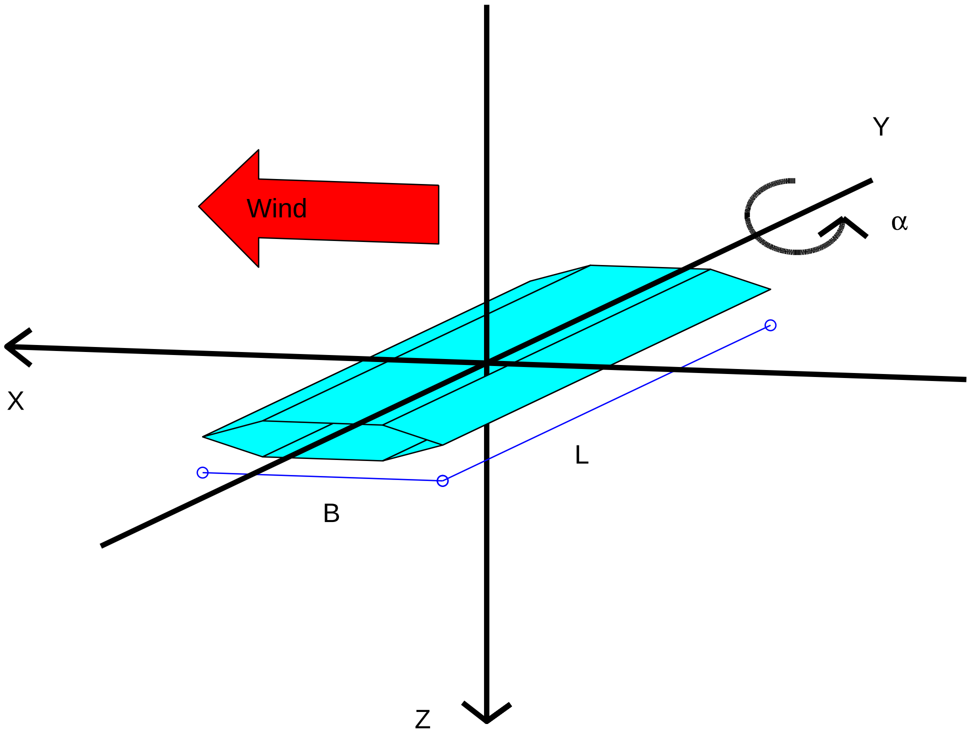
Flutter derivatives, Smooth flow, Angle of incidence = 0 deg.

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^{o}C	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1019.0

Table G.1: Project Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2\,m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2\,m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2\,m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h	: Vertical displacement, displacement along z-axis, [m]
α	: Rotation around y-axis, nose up is positive, [rad]
p	: Horizontal displacement, displacement along the x-axis, [m]
m	: Mass per unit length, [kg/m]
I_y	: Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$	: Added mass in vertical direction, [kg/m]
$m_{a,x}$	: Added mass in horizontal direction, [kg/m]
$I_{a,y}$	: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G	: X-coordinate for centre of gravity, [m]
Z_G	: Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$	: Natural circular frequency for vertical motion, [/s]
ζ_h	: Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$	: Natural circular frequency for rotation around y axis, [/s]
ζ_α	: Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$	: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p	: Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$	: Force from rig per meter section, [N/m]
$M_{Y,external}$	: Moment from rig per meter section, [Nm/m]
$F_{X,external}$	: Force from rig per meter section, [N/m]

Formula G.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.398
Added mass in horizontal	$m_{a,x}$	kg/m	0.549
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.141
Horizontal centre of gravity	x_G	m	−0.000
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.043
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.038
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.007

Table G.2: Mechanical Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula G.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

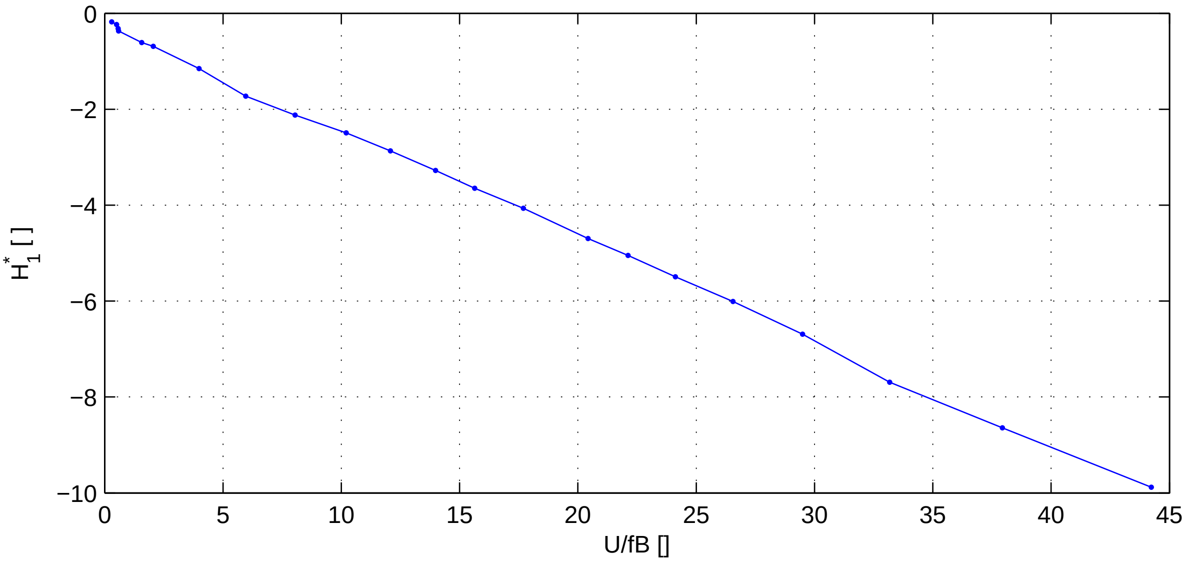


Figure G.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
0.90	25.13	4.00	21.01	0.30	−0.18
1.52	25.13	4.00	12.51	0.50	−0.24
1.73	25.13	4.00	10.97	0.57	−0.32
1.76	25.13	4.00	10.78	0.58	−0.37
4.71	25.13	4.00	4.02	1.56	−0.61
6.19	25.13	4.00	3.07	2.05	−0.69
12.05	25.13	4.00	1.57	3.99	−1.15
17.99	25.13	4.00	1.05	5.96	−1.73
20.05	20.74	3.30	0.78	8.05	−2.12
20.05	16.34	2.60	0.62	10.21	−2.49
20.06	13.82	2.20	0.52	12.07	−2.87
20.05	11.93	1.90	0.45	13.98	−3.28
20.06	10.68	1.70	0.40	15.64	−3.65
20.05	9.43	1.50	0.36	17.70	−4.06
20.04	8.17	1.30	0.31	20.43	−4.70
20.04	7.54	1.20	0.28	22.12	−5.05
20.04	6.91	1.10	0.26	24.13	−5.50
20.05	6.28	1.00	0.24	26.56	−6.01
20.04	5.66	0.90	0.21	29.49	−6.69
20.04	5.03	0.80	0.19	33.18	−7.69
20.05	4.40	0.70	0.17	37.94	−8.64
20.04	3.77	0.60	0.14	44.23	−9.88

Table G.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

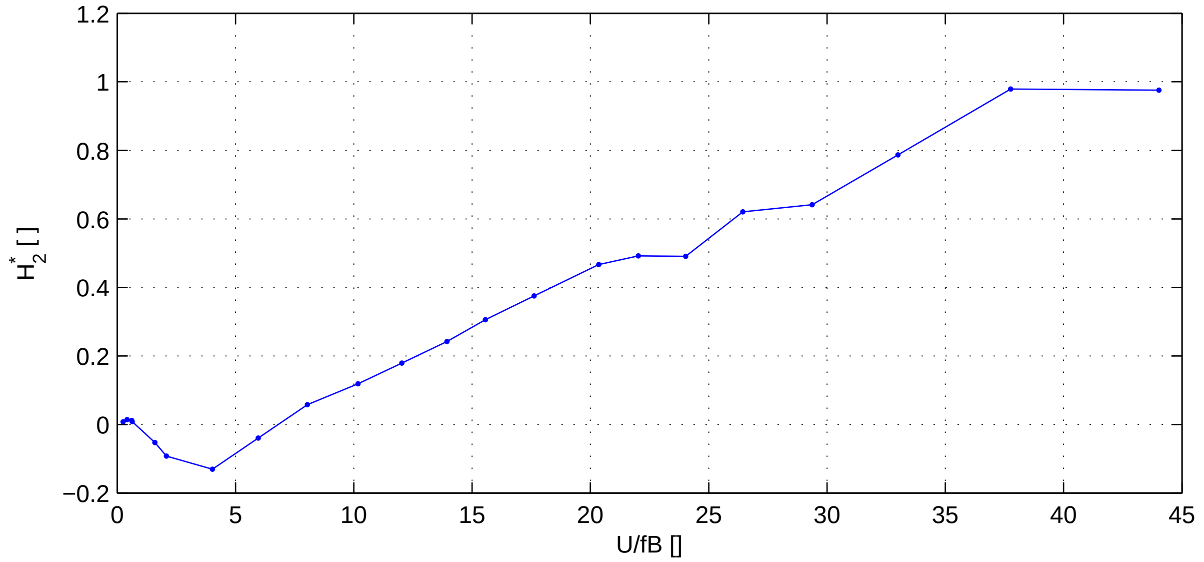


Figure G.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
0.76	25.13	4.00	25.00	0.25	0.01
1.27	25.13	4.00	14.89	0.42	0.01
1.86	25.13	4.00	10.21	0.62	0.01
1.91	25.13	4.00	9.95	0.63	0.01
4.80	25.13	4.00	3.96	1.59	−0.05
6.28	25.13	4.00	3.02	2.08	−0.09
12.16	25.13	4.00	1.56	4.03	−0.13
18.00	25.13	4.00	1.05	5.96	−0.04
20.02	20.74	3.30	0.78	8.03	0.06
19.99	16.34	2.60	0.62	10.18	0.12
19.98	13.82	2.20	0.52	12.03	0.18
19.98	11.93	1.90	0.45	13.94	0.24
19.99	10.69	1.70	0.40	15.57	0.31
19.96	9.43	1.50	0.36	17.62	0.38
19.97	8.17	1.30	0.31	20.35	0.47
19.96	7.54	1.20	0.29	22.03	0.49
19.96	6.91	1.10	0.26	24.03	0.49
19.96	6.28	1.00	0.24	26.44	0.62
19.96	5.66	0.90	0.21	29.37	0.64
19.93	5.03	0.80	0.19	33.00	0.79
19.96	4.40	0.70	0.17	37.76	0.98
19.95	3.77	0.60	0.14	44.03	0.98

Table G.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

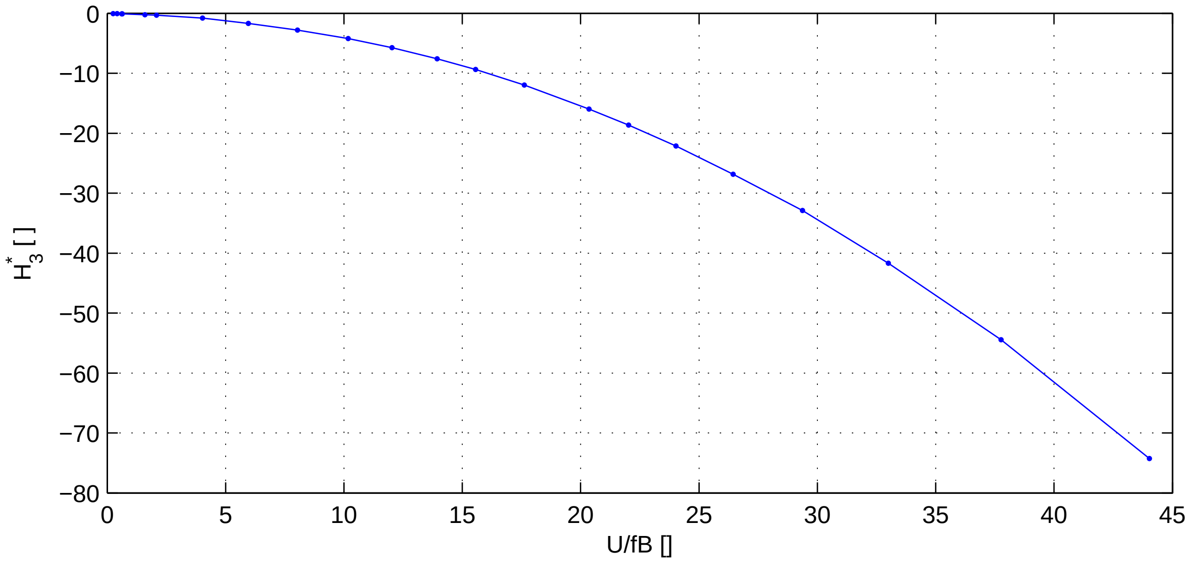


Figure G.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
0.76	25.13	4.00	25.00	0.25	−0.05
1.27	25.13	4.00	14.89	0.42	−0.06
1.86	25.13	4.00	10.21	0.62	−0.08
1.91	25.13	4.00	9.95	0.63	−0.09
4.80	25.13	4.00	3.96	1.59	−0.23
6.28	25.13	4.00	3.02	2.08	−0.31
12.16	25.13	4.00	1.56	4.03	−0.81
18.00	25.13	4.00	1.05	5.96	−1.68
20.02	20.74	3.30	0.78	8.03	−2.79
19.99	16.34	2.60	0.62	10.18	−4.20
19.98	13.82	2.20	0.52	12.03	−5.73
19.98	11.93	1.90	0.45	13.94	−7.59
19.99	10.69	1.70	0.40	15.57	−9.38
19.96	9.43	1.50	0.36	17.62	−11.96
19.97	8.17	1.30	0.31	20.35	−15.97
19.96	7.54	1.20	0.29	22.03	−18.65
19.96	6.91	1.10	0.26	24.03	−22.14
19.96	6.28	1.00	0.24	26.44	−26.85
19.96	5.66	0.90	0.21	29.37	−32.91
19.93	5.03	0.80	0.19	33.00	−41.67
19.96	4.40	0.70	0.17	37.76	−54.44
19.95	3.77	0.60	0.14	44.03	−74.28

Table G.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

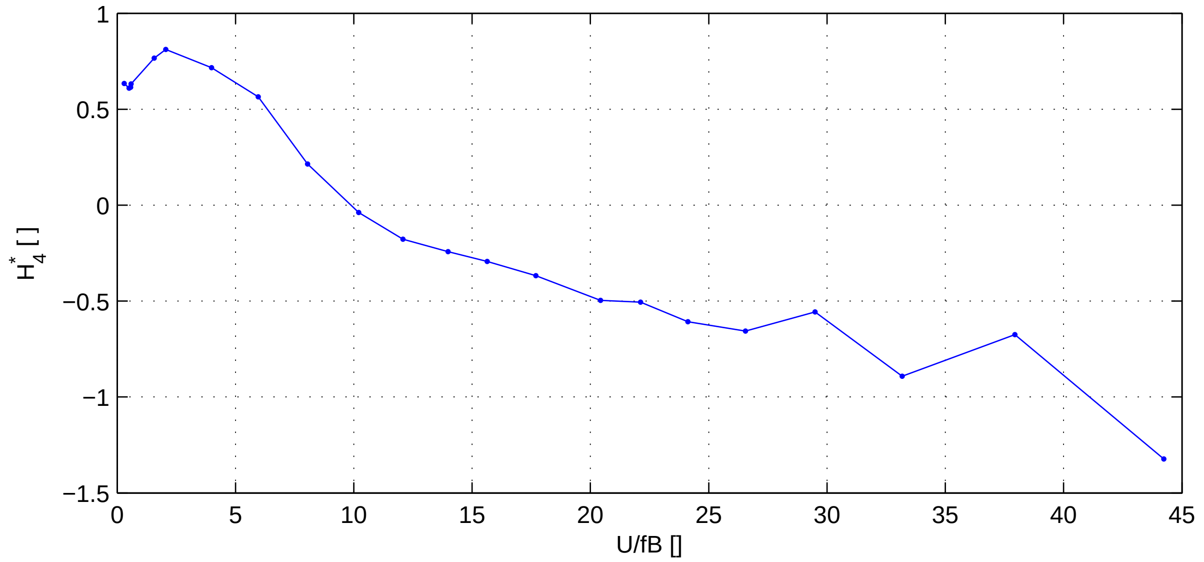


Figure G.4: H^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_4
0.90	25.13	4.00	21.01	0.30	0.63
1.52	25.13	4.00	12.51	0.50	0.61
1.73	25.13	4.00	10.97	0.57	0.61
1.76	25.13	4.00	10.78	0.58	0.63
4.71	25.13	4.00	4.02	1.56	0.77
6.19	25.13	4.00	3.07	2.05	0.81
12.05	25.13	4.00	1.57	3.99	0.72
17.99	25.13	4.00	1.05	5.96	0.56
20.05	20.74	3.30	0.78	8.05	0.21
20.05	16.34	2.60	0.62	10.21	−0.04
20.06	13.82	2.20	0.52	12.07	−0.18
20.05	11.93	1.90	0.45	13.98	−0.24
20.06	10.68	1.70	0.40	15.64	−0.29
20.05	9.43	1.50	0.36	17.70	−0.37
20.04	8.17	1.30	0.31	20.43	−0.50
20.04	7.54	1.20	0.28	22.12	−0.51
20.04	6.91	1.10	0.26	24.13	−0.61
20.05	6.28	1.00	0.24	26.56	−0.66
20.04	5.66	0.90	0.21	29.49	−0.56
20.04	5.03	0.80	0.19	33.18	−0.89
20.05	4.40	0.70	0.17	37.94	−0.67
20.04	3.77	0.60	0.14	44.23	−1.32

Table G.6: H^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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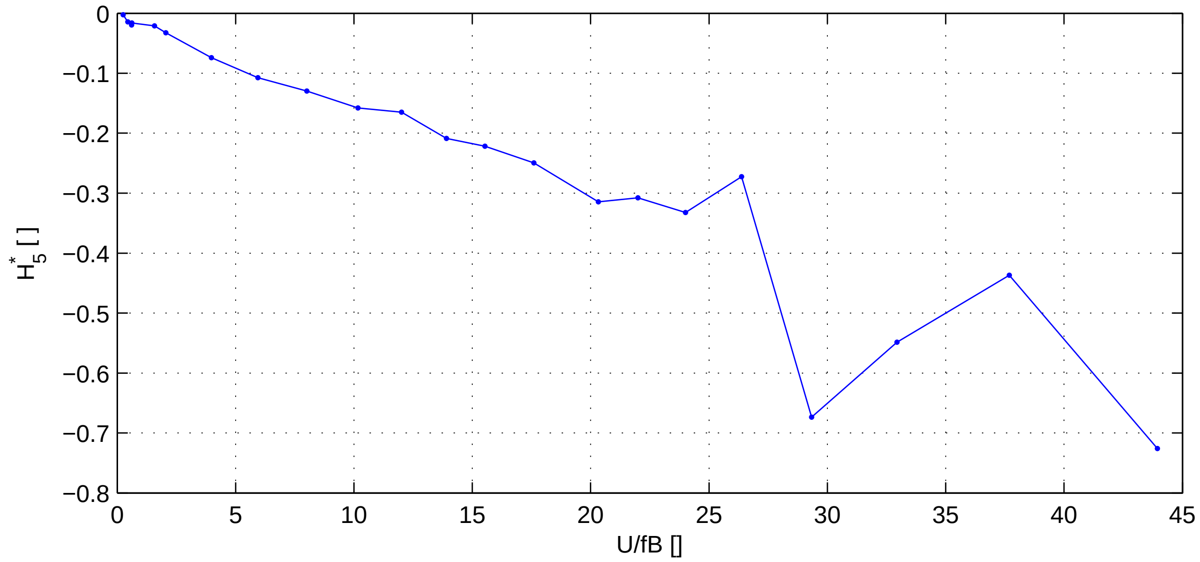


Figure G.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
0.76	25.13	4.00	24.93	0.25	−0.00
1.35	25.13	4.00	14.08	0.45	−0.01
1.82	25.13	4.00	10.45	0.60	−0.02
1.84	25.13	4.00	10.29	0.61	−0.02
4.75	25.13	4.00	3.99	1.57	−0.02
6.21	25.13	4.00	3.05	2.06	−0.03
12.02	25.13	4.00	1.58	3.98	−0.07
17.94	25.13	4.00	1.06	5.94	−0.11
19.96	20.74	3.30	0.78	8.01	−0.13
19.96	16.34	2.60	0.62	10.16	−0.16
19.96	13.82	2.20	0.52	12.01	−0.16
19.95	11.93	1.90	0.45	13.91	−0.21
19.93	10.68	1.70	0.40	15.53	−0.22
19.94	9.43	1.50	0.36	17.60	−0.25
19.94	8.17	1.30	0.31	20.32	−0.31
19.93	7.54	1.20	0.29	22.00	−0.31
19.94	6.91	1.10	0.26	24.00	−0.33
19.91	6.28	1.00	0.24	26.37	−0.27
19.94	5.66	0.90	0.21	29.34	−0.67
19.90	5.03	0.80	0.19	32.94	−0.55
19.92	4.40	0.70	0.17	37.68	−0.44
19.91	3.77	0.60	0.14	43.95	−0.73

Table G.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

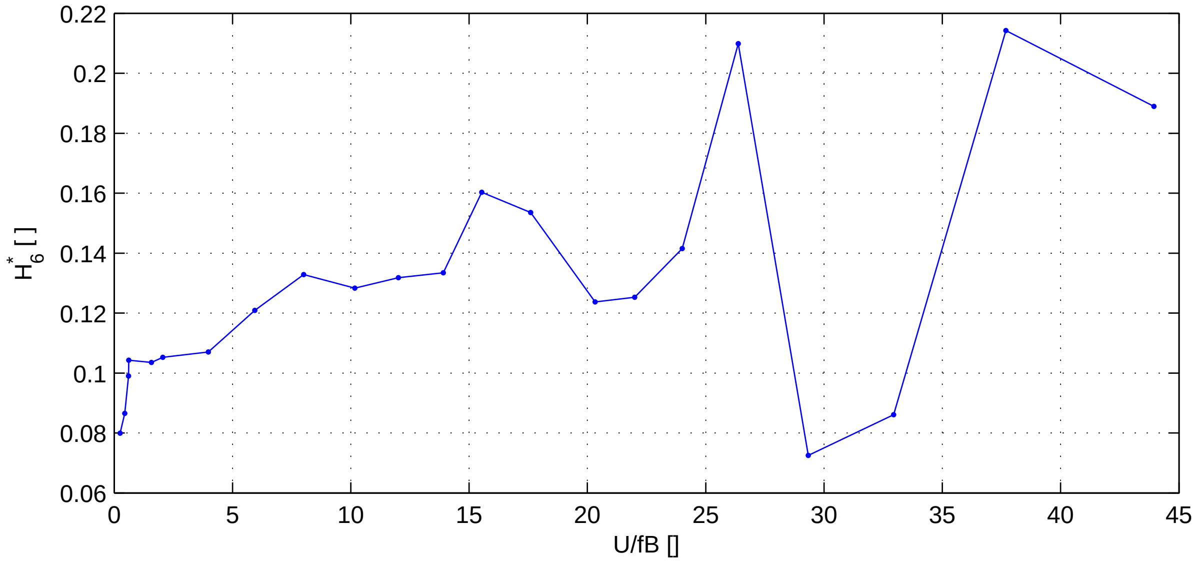


Figure G.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
0.76	25.13	4.00	24.93	0.25	0.08
1.35	25.13	4.00	14.08	0.45	0.09
1.82	25.13	4.00	10.45	0.60	0.10
1.84	25.13	4.00	10.29	0.61	0.10
4.75	25.13	4.00	3.99	1.57	0.10
6.21	25.13	4.00	3.05	2.06	0.11
12.02	25.13	4.00	1.58	3.98	0.11
17.94	25.13	4.00	1.06	5.94	0.12
19.96	20.74	3.30	0.78	8.01	0.13
19.96	16.34	2.60	0.62	10.16	0.13
19.96	13.82	2.20	0.52	12.01	0.13
19.95	11.93	1.90	0.45	13.91	0.13
19.93	10.68	1.70	0.40	15.53	0.16
19.94	9.43	1.50	0.36	17.60	0.15
19.94	8.17	1.30	0.31	20.32	0.12
19.93	7.54	1.20	0.29	22.00	0.13
19.94	6.91	1.10	0.26	24.00	0.14
19.91	6.28	1.00	0.24	26.37	0.21
19.94	5.66	0.90	0.21	29.34	0.07
19.90	5.03	0.80	0.19	32.94	0.09
19.92	4.40	0.70	0.17	37.68	0.21
19.91	3.77	0.60	0.14	43.95	0.19

Table G.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

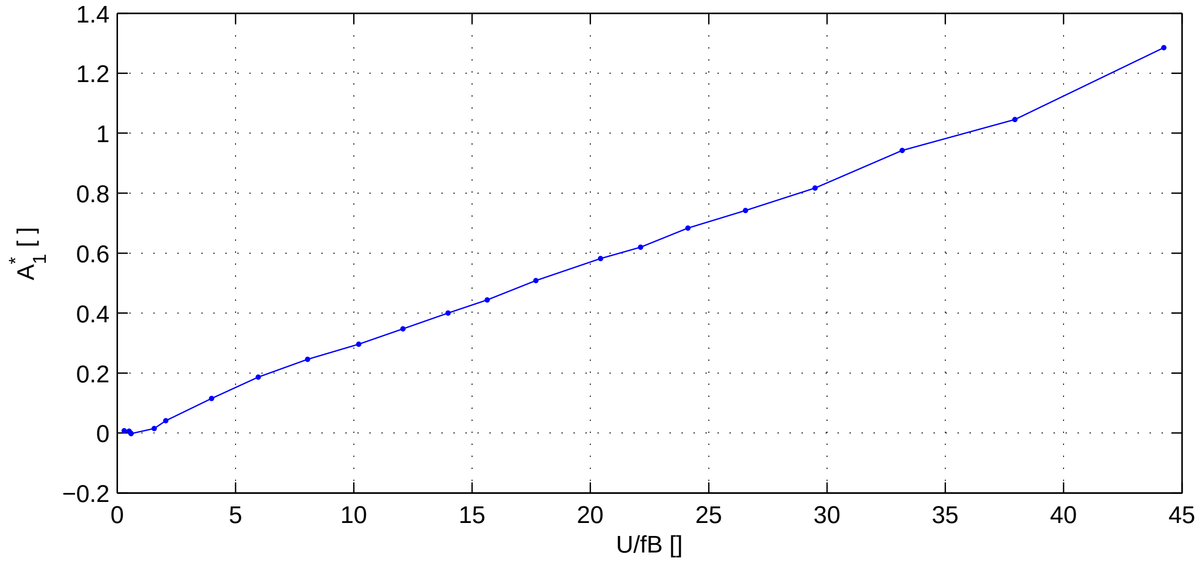


Figure G.7: A^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_1
0.90	25.13	4.00	21.01	0.30	0.01
1.52	25.13	4.00	12.51	0.50	0.01
1.73	25.13	4.00	10.97	0.57	0.00
1.76	25.13	4.00	10.78	0.58	−0.00
4.71	25.13	4.00	4.02	1.56	0.01
6.19	25.13	4.00	3.07	2.05	0.04
12.05	25.13	4.00	1.57	3.99	0.11
17.99	25.13	4.00	1.05	5.96	0.19
20.05	20.74	3.30	0.78	8.05	0.25
20.05	16.34	2.60	0.62	10.21	0.30
20.06	13.82	2.20	0.52	12.07	0.35
20.05	11.93	1.90	0.45	13.98	0.40
20.06	10.68	1.70	0.40	15.64	0.44
20.05	9.43	1.50	0.36	17.70	0.51
20.04	8.17	1.30	0.31	20.43	0.58
20.04	7.54	1.20	0.28	22.12	0.62
20.04	6.91	1.10	0.26	24.13	0.68
20.05	6.28	1.00	0.24	26.56	0.74
20.04	5.66	0.90	0.21	29.49	0.82
20.04	5.03	0.80	0.19	33.18	0.94
20.05	4.40	0.70	0.17	37.94	1.05
20.04	3.77	0.60	0.14	44.23	1.29

Table G.9: A^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

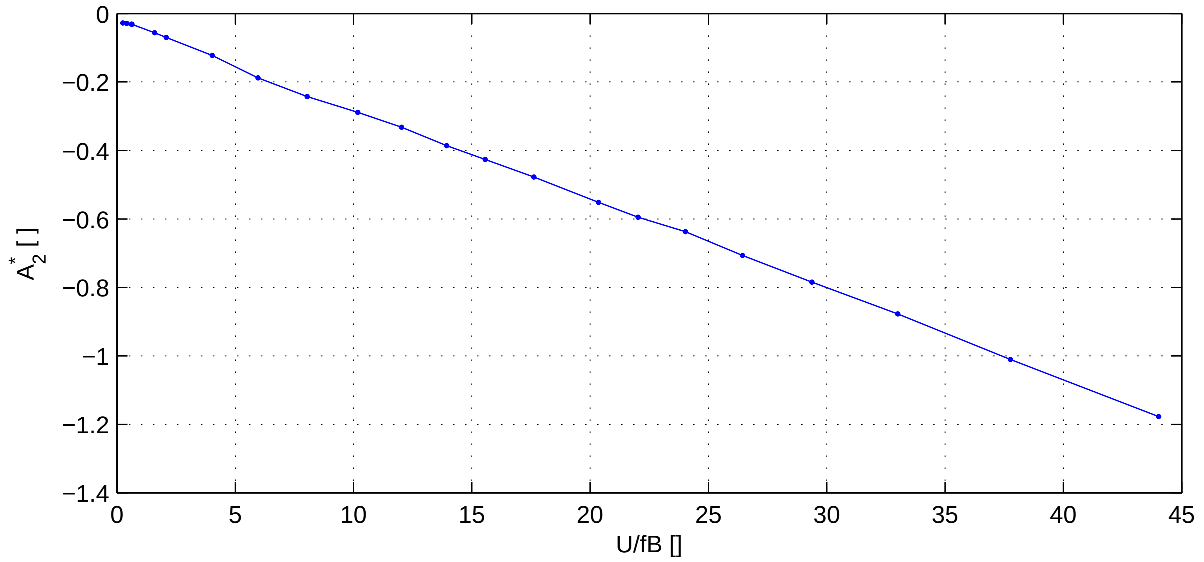


Figure G.8: A^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_2
0.76	25.13	4.00	25.00	0.25	−0.03
1.27	25.13	4.00	14.89	0.42	−0.03
1.86	25.13	4.00	10.21	0.62	−0.03
1.91	25.13	4.00	9.95	0.63	−0.03
4.80	25.13	4.00	3.96	1.59	−0.06
6.28	25.13	4.00	3.02	2.08	−0.07
12.16	25.13	4.00	1.56	4.03	−0.12
18.00	25.13	4.00	1.05	5.96	−0.19
20.02	20.74	3.30	0.78	8.03	−0.24
19.99	16.34	2.60	0.62	10.18	−0.29
19.98	13.82	2.20	0.52	12.03	−0.33
19.98	11.93	1.90	0.45	13.94	−0.39
19.99	10.69	1.70	0.40	15.57	−0.43
19.96	9.43	1.50	0.36	17.62	−0.48
19.97	8.17	1.30	0.31	20.35	−0.55
19.96	7.54	1.20	0.29	22.03	−0.59
19.96	6.91	1.10	0.26	24.03	−0.64
19.96	6.28	1.00	0.24	26.44	−0.71
19.96	5.66	0.90	0.21	29.37	−0.78
19.93	5.03	0.80	0.19	33.00	−0.88
19.96	4.40	0.70	0.17	37.76	−1.01
19.95	3.77	0.60	0.14	44.03	−1.18

Table G.10: A^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

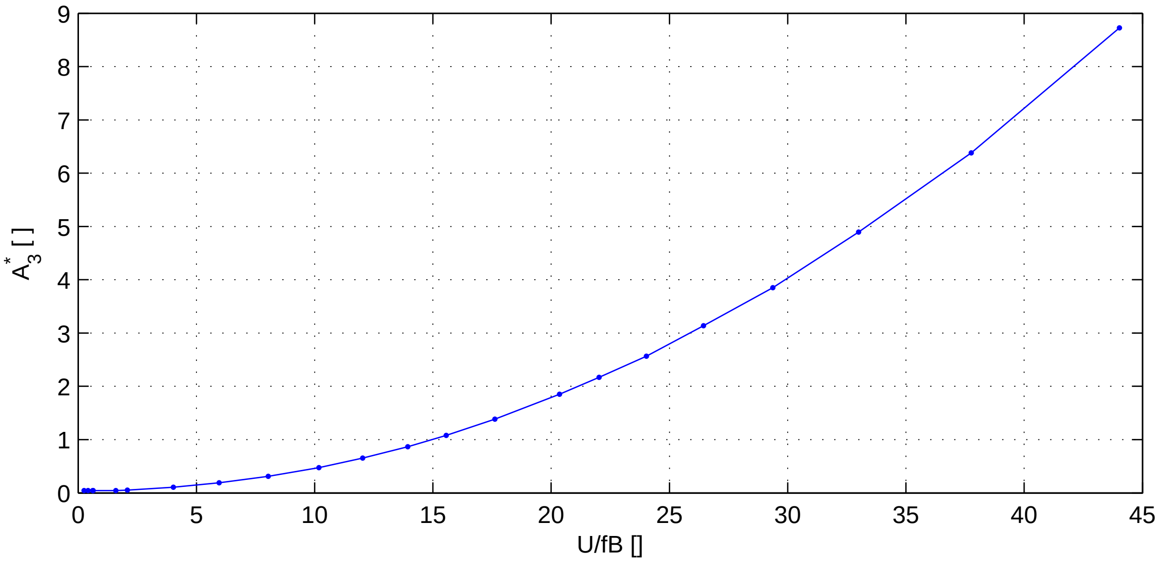


Figure G.9: A^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_3
0.76	25.13	4.00	25.00	0.25	0.04
1.27	25.13	4.00	14.89	0.42	0.04
1.86	25.13	4.00	10.21	0.62	0.04
1.91	25.13	4.00	9.95	0.63	0.04
4.80	25.13	4.00	3.96	1.59	0.04
6.28	25.13	4.00	3.02	2.08	0.05
12.16	25.13	4.00	1.56	4.03	0.10
18.00	25.13	4.00	1.05	5.96	0.19
20.02	20.74	3.30	0.78	8.03	0.31
19.99	16.34	2.60	0.62	10.18	0.47
19.98	13.82	2.20	0.52	12.03	0.65
19.98	11.93	1.90	0.45	13.94	0.87
19.99	10.69	1.70	0.40	15.57	1.08
19.96	9.43	1.50	0.36	17.62	1.38
19.97	8.17	1.30	0.31	20.35	1.85
19.96	7.54	1.20	0.29	22.03	2.17
19.96	6.91	1.10	0.26	24.03	2.56
19.96	6.28	1.00	0.24	26.44	3.14
19.96	5.66	0.90	0.21	29.37	3.85
19.93	5.03	0.80	0.19	33.00	4.89
19.96	4.40	0.70	0.17	37.76	6.38
19.95	3.77	0.60	0.14	44.03	8.73

Table G.11: A^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

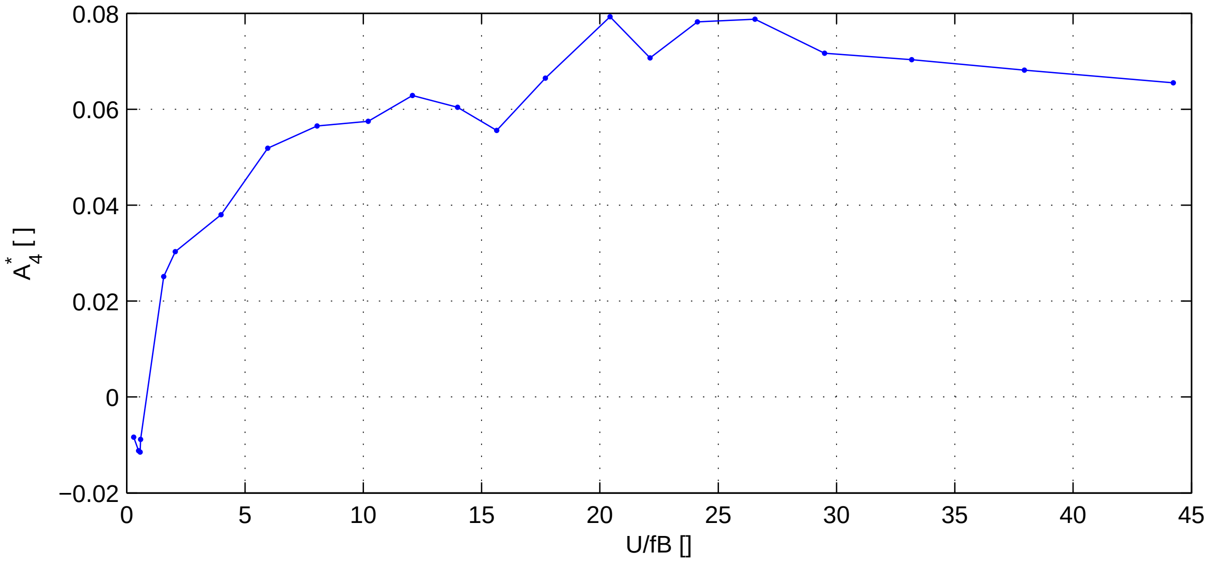


Figure G.10: A^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_4
0.90	25.13	4.00	21.01	0.30	−0.01
1.52	25.13	4.00	12.51	0.50	−0.01
1.73	25.13	4.00	10.97	0.57	−0.01
1.76	25.13	4.00	10.78	0.58	−0.01
4.71	25.13	4.00	4.02	1.56	0.03
6.19	25.13	4.00	3.07	2.05	0.03
12.05	25.13	4.00	1.57	3.99	0.04
17.99	25.13	4.00	1.05	5.96	0.05
20.05	20.74	3.30	0.78	8.05	0.06
20.05	16.34	2.60	0.62	10.21	0.06
20.06	13.82	2.20	0.52	12.07	0.06
20.05	11.93	1.90	0.45	13.98	0.06
20.06	10.68	1.70	0.40	15.64	0.06
20.05	9.43	1.50	0.36	17.70	0.07
20.04	8.17	1.30	0.31	20.43	0.08
20.04	7.54	1.20	0.28	22.12	0.07
20.04	6.91	1.10	0.26	24.13	0.08
20.05	6.28	1.00	0.24	26.56	0.08
20.04	5.66	0.90	0.21	29.49	0.07
20.04	5.03	0.80	0.19	33.18	0.07
20.05	4.40	0.70	0.17	37.94	0.07
20.04	3.77	0.60	0.14	44.23	0.07

Table G.12: A^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

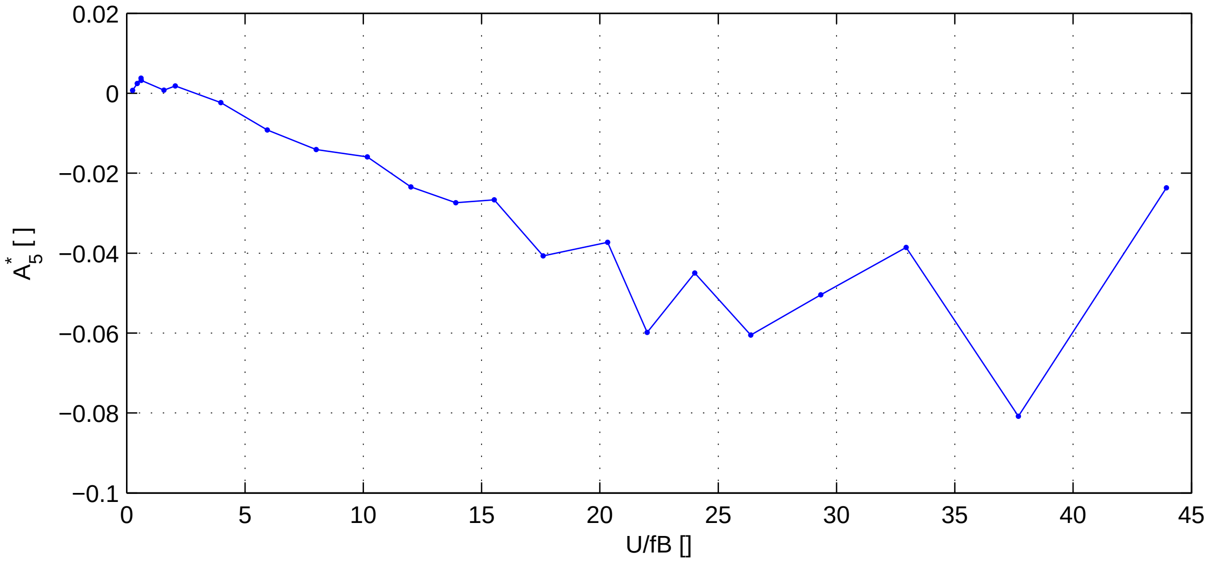


Figure G.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
0.76	25.13	4.00	24.93	0.25	0.00
1.35	25.13	4.00	14.08	0.45	0.00
1.82	25.13	4.00	10.45	0.60	0.00
1.84	25.13	4.00	10.29	0.61	0.00
4.75	25.13	4.00	3.99	1.57	0.00
6.21	25.13	4.00	3.05	2.06	0.00
12.02	25.13	4.00	1.58	3.98	−0.00
17.94	25.13	4.00	1.06	5.94	−0.01
19.96	20.74	3.30	0.78	8.01	−0.01
19.96	16.34	2.60	0.62	10.16	−0.02
19.96	13.82	2.20	0.52	12.01	−0.02
19.95	11.93	1.90	0.45	13.91	−0.03
19.93	10.68	1.70	0.40	15.53	−0.03
19.94	9.43	1.50	0.36	17.60	−0.04
19.94	8.17	1.30	0.31	20.32	−0.04
19.93	7.54	1.20	0.29	22.00	−0.06
19.94	6.91	1.10	0.26	24.00	−0.04
19.91	6.28	1.00	0.24	26.37	−0.06
19.94	5.66	0.90	0.21	29.34	−0.05
19.90	5.03	0.80	0.19	32.94	−0.04
19.92	4.40	0.70	0.17	37.68	−0.08
19.91	3.77	0.60	0.14	43.95	−0.02

Table G.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

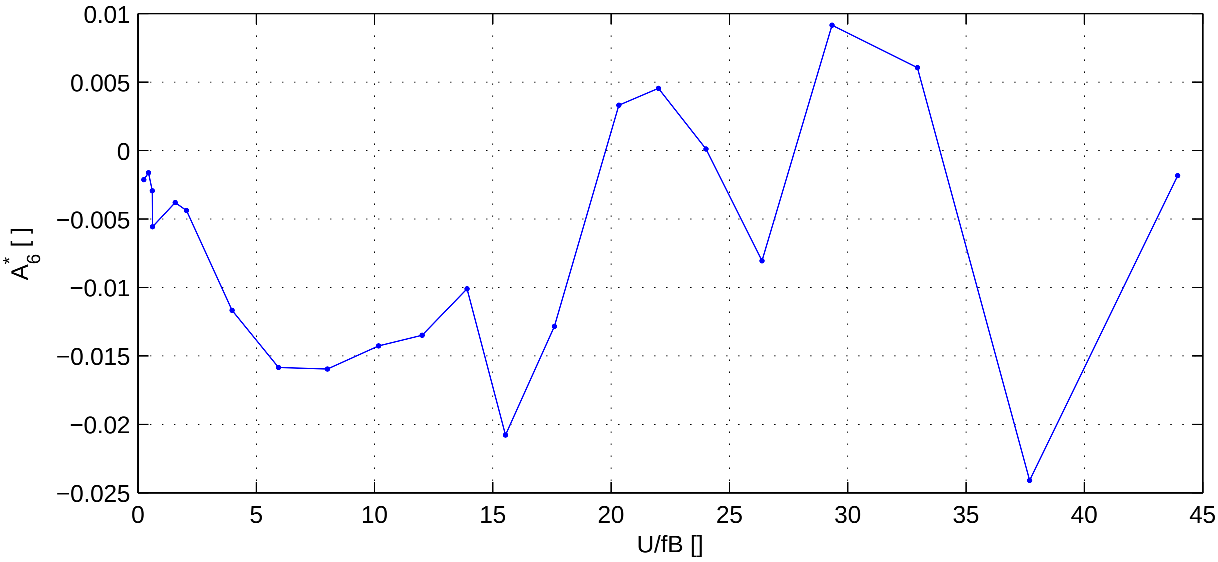


Figure G.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
0.76	25.13	4.00	24.93	0.25	−0.00
1.35	25.13	4.00	14.08	0.45	−0.00
1.82	25.13	4.00	10.45	0.60	−0.00
1.84	25.13	4.00	10.29	0.61	−0.01
4.75	25.13	4.00	3.99	1.57	−0.00
6.21	25.13	4.00	3.05	2.06	−0.00
12.02	25.13	4.00	1.58	3.98	−0.01
17.94	25.13	4.00	1.06	5.94	−0.02
19.96	20.74	3.30	0.78	8.01	−0.02
19.96	16.34	2.60	0.62	10.16	−0.01
19.96	13.82	2.20	0.52	12.01	−0.01
19.95	11.93	1.90	0.45	13.91	−0.01
19.93	10.68	1.70	0.40	15.53	−0.02
19.94	9.43	1.50	0.36	17.60	−0.01
19.94	8.17	1.30	0.31	20.32	0.00
19.93	7.54	1.20	0.29	22.00	0.00
19.94	6.91	1.10	0.26	24.00	0.00
19.91	6.28	1.00	0.24	26.37	−0.01
19.94	5.66	0.90	0.21	29.34	0.01
19.90	5.03	0.80	0.19	32.94	0.01
19.92	4.40	0.70	0.17	37.68	−0.02
19.91	3.77	0.60	0.14	43.95	−0.00

Table G.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

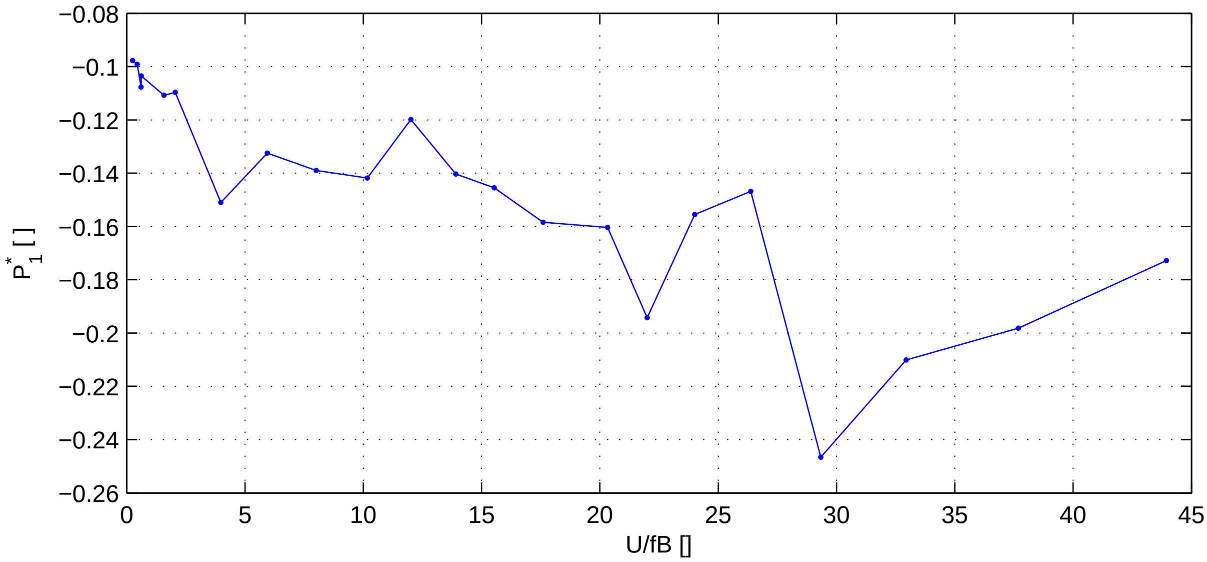


Figure G.13: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_1^*
0.76	25.13	4.00	24.93	0.25	−0.10
1.35	25.13	4.00	14.08	0.45	−0.10
1.82	25.13	4.00	10.45	0.60	−0.11
1.84	25.13	4.00	10.29	0.61	−0.10
4.75	25.13	4.00	3.99	1.57	−0.11
6.21	25.13	4.00	3.05	2.06	−0.11
12.02	25.13	4.00	1.58	3.98	−0.15
17.94	25.13	4.00	1.06	5.94	−0.13
19.96	20.74	3.30	0.78	8.01	−0.14
19.96	16.34	2.60	0.62	10.16	−0.14
19.96	13.82	2.20	0.52	12.01	−0.12
19.95	11.93	1.90	0.45	13.91	−0.14
19.93	10.68	1.70	0.40	15.53	−0.15
19.94	9.43	1.50	0.36	17.60	−0.16
19.94	8.17	1.30	0.31	20.32	−0.16
19.93	7.54	1.20	0.29	22.00	−0.19
19.94	6.91	1.10	0.26	24.00	−0.16
19.91	6.28	1.00	0.24	26.37	−0.15
19.94	5.66	0.90	0.21	29.34	−0.25
19.90	5.03	0.80	0.19	32.94	−0.21
19.92	4.40	0.70	0.17	37.68	−0.20
19.91	3.77	0.60	0.14	43.95	−0.17

Table G.15: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

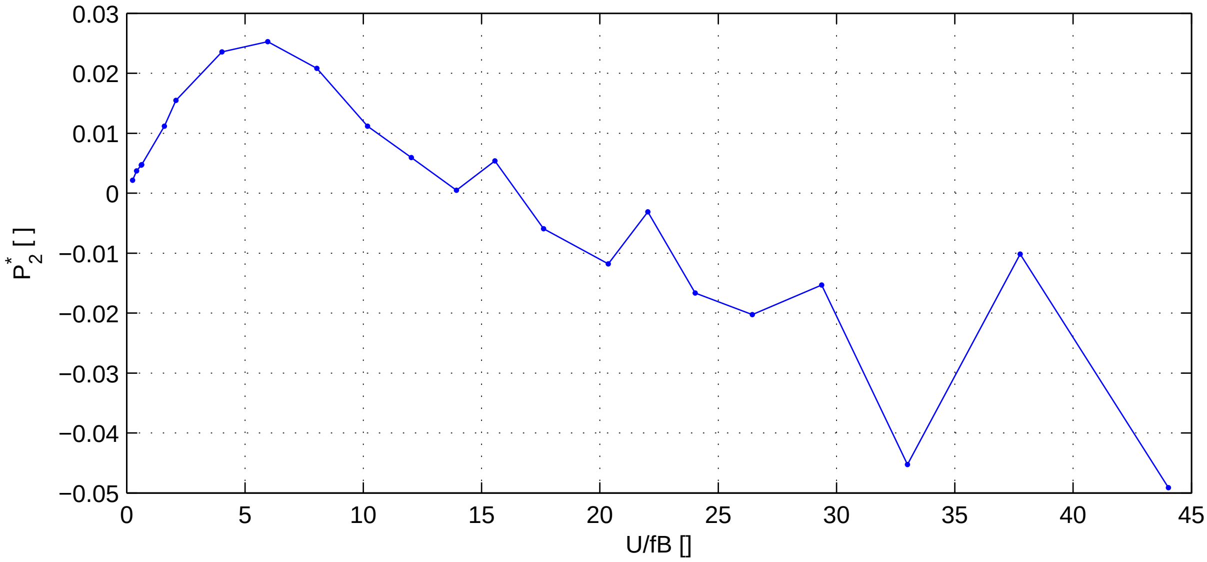


Figure G.14: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_2^*
0.76	25.13	4.00	25.00	0.25	0.00
1.27	25.13	4.00	14.89	0.42	0.00
1.86	25.13	4.00	10.21	0.62	0.00
1.91	25.13	4.00	9.95	0.63	0.00
4.80	25.13	4.00	3.96	1.59	0.01
6.28	25.13	4.00	3.02	2.08	0.02
12.16	25.13	4.00	1.56	4.03	0.02
18.00	25.13	4.00	1.05	5.96	0.03
20.02	20.74	3.30	0.78	8.03	0.02
19.99	16.34	2.60	0.62	10.18	0.01
19.98	13.82	2.20	0.52	12.03	0.01
19.98	11.93	1.90	0.45	13.94	0.00
19.99	10.69	1.70	0.40	15.57	0.01
19.96	9.43	1.50	0.36	17.62	−0.01
19.97	8.17	1.30	0.31	20.35	−0.01
19.96	7.54	1.20	0.29	22.03	−0.00
19.96	6.91	1.10	0.26	24.03	−0.02
19.96	6.28	1.00	0.24	26.44	−0.02
19.96	5.66	0.90	0.21	29.37	−0.02
19.93	5.03	0.80	0.19	33.00	−0.05
19.96	4.40	0.70	0.17	37.76	−0.01
19.95	3.77	0.60	0.14	44.03	−0.05

Table G.16: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

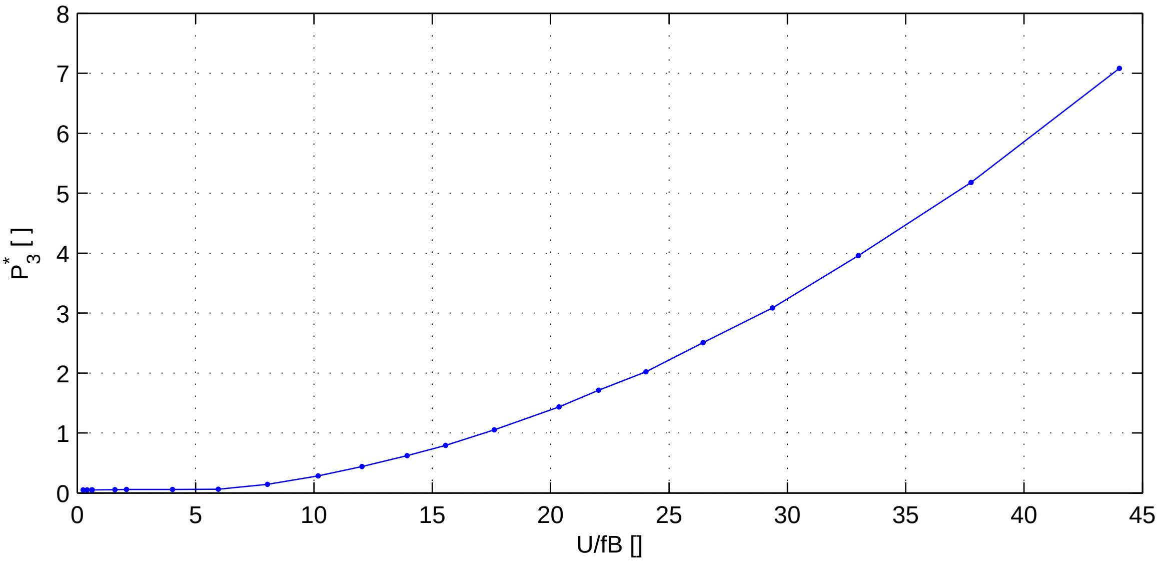


Figure G.15: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_3
0.76	25.13	4.00	25.00	0.25	0.05
1.27	25.13	4.00	14.89	0.42	0.05
1.86	25.13	4.00	10.21	0.62	0.05
1.91	25.13	4.00	9.95	0.63	0.05
4.80	25.13	4.00	3.96	1.59	0.06
6.28	25.13	4.00	3.02	2.08	0.06
12.16	25.13	4.00	1.56	4.03	0.06
18.00	25.13	4.00	1.05	5.96	0.06
20.02	20.74	3.30	0.78	8.03	0.14
19.99	16.34	2.60	0.62	10.18	0.29
19.98	13.82	2.20	0.52	12.03	0.44
19.98	11.93	1.90	0.45	13.94	0.62
19.99	10.69	1.70	0.40	15.57	0.79
19.96	9.43	1.50	0.36	17.62	1.05
19.97	8.17	1.30	0.31	20.35	1.44
19.96	7.54	1.20	0.29	22.03	1.71
19.96	6.91	1.10	0.26	24.03	2.02
19.96	6.28	1.00	0.24	26.44	2.51
19.96	5.66	0.90	0.21	29.37	3.08
19.93	5.03	0.80	0.19	33.00	3.96
19.96	4.40	0.70	0.17	37.76	5.18
19.95	3.77	0.60	0.14	44.03	7.08

Table G.17: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

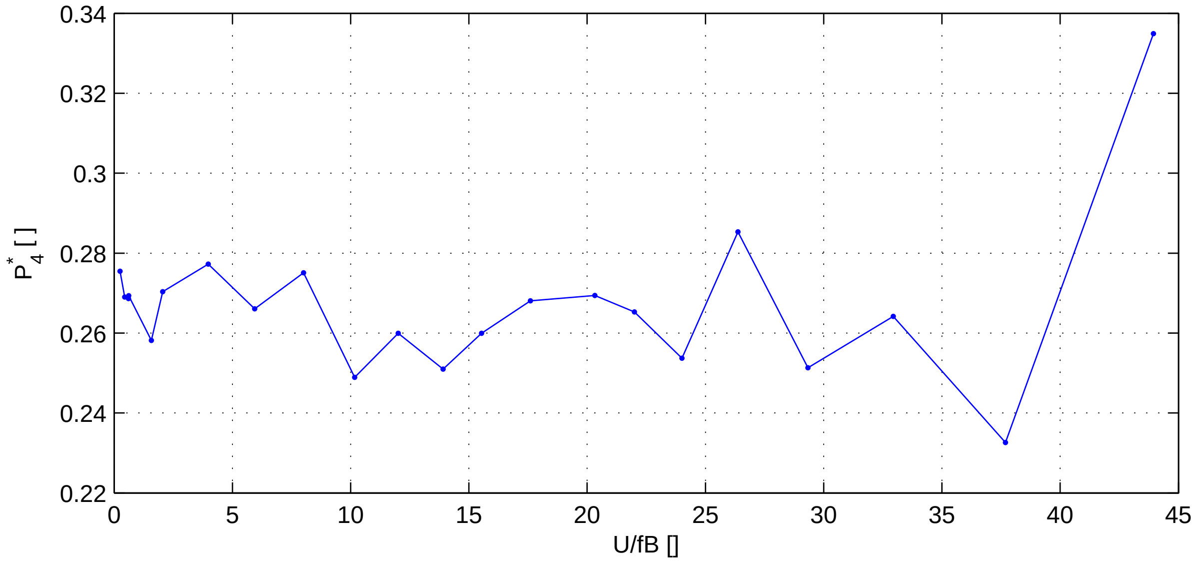


Figure G.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
0.76	25.13	4.00	24.93	0.25	0.28
1.35	25.13	4.00	14.08	0.45	0.27
1.82	25.13	4.00	10.45	0.60	0.27
1.84	25.13	4.00	10.29	0.61	0.27
4.75	25.13	4.00	3.99	1.57	0.26
6.21	25.13	4.00	3.05	2.06	0.27
12.02	25.13	4.00	1.58	3.98	0.28
17.94	25.13	4.00	1.06	5.94	0.27
19.96	20.74	3.30	0.78	8.01	0.28
19.96	16.34	2.60	0.62	10.16	0.25
19.96	13.82	2.20	0.52	12.01	0.26
19.95	11.93	1.90	0.45	13.91	0.25
19.93	10.68	1.70	0.40	15.53	0.26
19.94	9.43	1.50	0.36	17.60	0.27
19.94	8.17	1.30	0.31	20.32	0.27
19.93	7.54	1.20	0.29	22.00	0.27
19.94	6.91	1.10	0.26	24.00	0.25
19.91	6.28	1.00	0.24	26.37	0.29
19.94	5.66	0.90	0.21	29.34	0.25
19.90	5.03	0.80	0.19	32.94	0.26
19.92	4.40	0.70	0.17	37.68	0.23
19.91	3.77	0.60	0.14	43.95	0.33

Table G.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

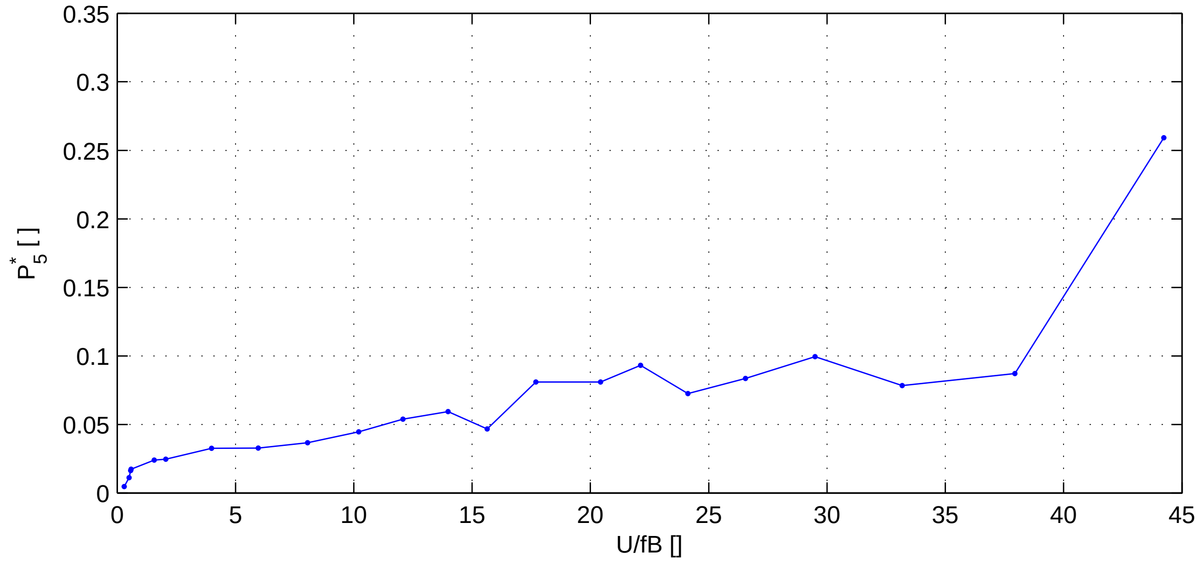


Figure G.17: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_5
0.90	25.13	4.00	21.01	0.30	0.00
1.52	25.13	4.00	12.51	0.50	0.01
1.73	25.13	4.00	10.97	0.57	0.02
1.76	25.13	4.00	10.78	0.58	0.02
4.71	25.13	4.00	4.02	1.56	0.02
6.19	25.13	4.00	3.07	2.05	0.02
12.05	25.13	4.00	1.57	3.99	0.03
17.99	25.13	4.00	1.05	5.96	0.03
20.05	20.74	3.30	0.78	8.05	0.04
20.05	16.34	2.60	0.62	10.21	0.04
20.06	13.82	2.20	0.52	12.07	0.05
20.05	11.93	1.90	0.45	13.98	0.06
20.06	10.68	1.70	0.40	15.64	0.05
20.05	9.43	1.50	0.36	17.70	0.08
20.04	8.17	1.30	0.31	20.43	0.08
20.04	7.54	1.20	0.28	22.12	0.09
20.04	6.91	1.10	0.26	24.13	0.07
20.05	6.28	1.00	0.24	26.56	0.08
20.04	5.66	0.90	0.21	29.49	0.10
20.04	5.03	0.80	0.19	33.18	0.08
20.05	4.40	0.70	0.17	37.94	0.09
20.04	3.77	0.60	0.14	44.23	0.26

Table G.19: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

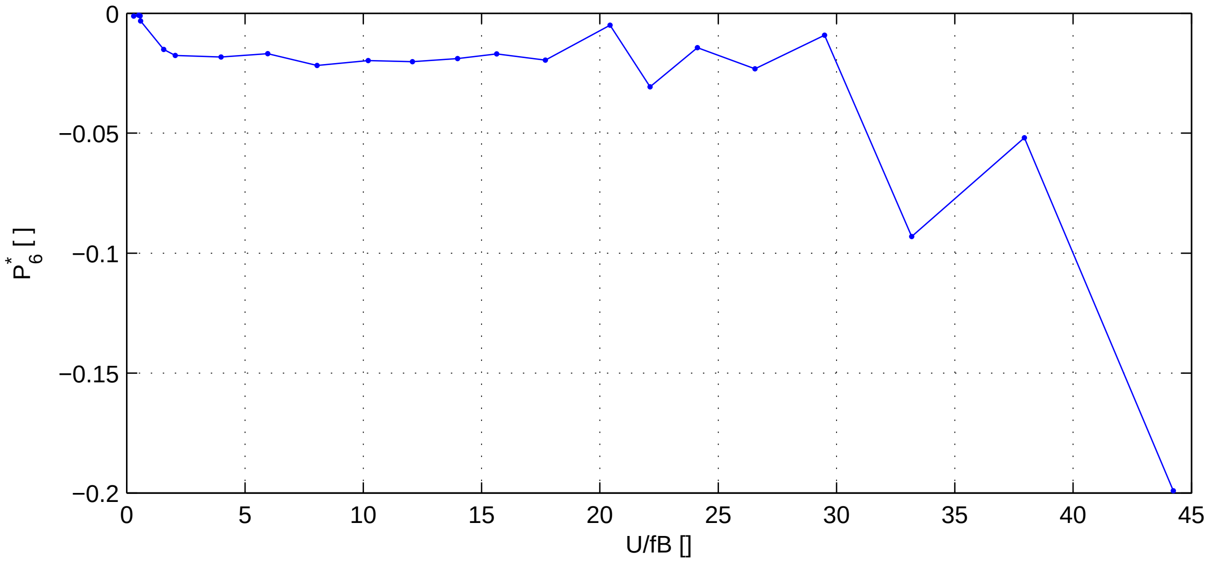


Figure G.18: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_6
0.90	25.13	4.00	21.01	0.30	−0.00
1.52	25.13	4.00	12.51	0.50	−0.00
1.73	25.13	4.00	10.97	0.57	−0.00
1.76	25.13	4.00	10.78	0.58	−0.00
4.71	25.13	4.00	4.02	1.56	−0.02
6.19	25.13	4.00	3.07	2.05	−0.02
12.05	25.13	4.00	1.57	3.99	−0.02
17.99	25.13	4.00	1.05	5.96	−0.02
20.05	20.74	3.30	0.78	8.05	−0.02
20.05	16.34	2.60	0.62	10.21	−0.02
20.06	13.82	2.20	0.52	12.07	−0.02
20.05	11.93	1.90	0.45	13.98	−0.02
20.06	10.68	1.70	0.40	15.64	−0.02
20.05	9.43	1.50	0.36	17.70	−0.02
20.04	8.17	1.30	0.31	20.43	−0.01
20.04	7.54	1.20	0.28	22.12	−0.03
20.04	6.91	1.10	0.26	24.13	−0.01
20.05	6.28	1.00	0.24	26.56	−0.02
20.04	5.66	0.90	0.21	29.49	−0.01
20.04	5.03	0.80	0.19	33.18	−0.09
20.05	4.40	0.70	0.17	37.94	−0.05
20.04	3.77	0.60	0.14	44.23	−0.20

Table G.20: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b: buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b: buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b: buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\,(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\,(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\,(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

Formula G.3: Equation of Motion (Stretto di Messina. Ref. [5].)

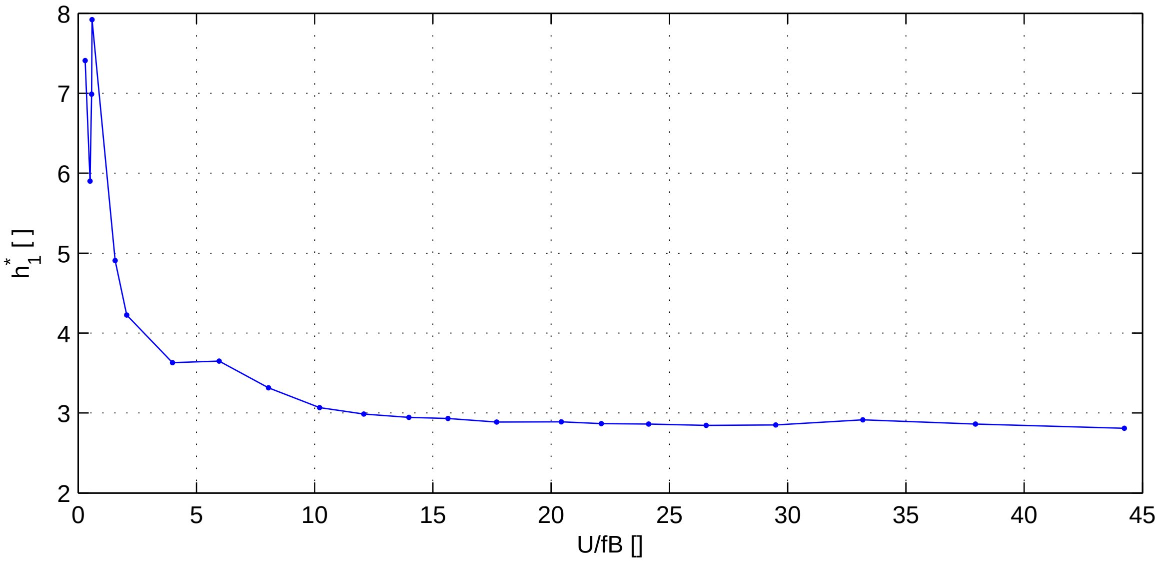


Figure G.19: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_1^*
0.90	25.13	4.00	21.01	0.30	7.41
1.52	25.13	4.00	12.51	0.50	5.90
1.73	25.13	4.00	10.97	0.57	6.99
1.76	25.13	4.00	10.78	0.58	7.92
4.71	25.13	4.00	4.02	1.56	4.91
6.19	25.13	4.00	3.07	2.05	4.23
12.05	25.13	4.00	1.57	3.99	3.63
17.99	25.13	4.00	1.05	5.96	3.65
20.05	20.74	3.30	0.78	8.05	3.32
20.05	16.34	2.60	0.62	10.21	3.07
20.06	13.82	2.20	0.52	12.07	2.99
20.05	11.93	1.90	0.45	13.98	2.94
20.06	10.68	1.70	0.40	15.64	2.93
20.05	9.43	1.50	0.36	17.70	2.89
20.04	8.17	1.30	0.31	20.43	2.89
20.04	7.54	1.20	0.28	22.12	2.87
20.04	6.91	1.10	0.26	24.13	2.86
20.05	6.28	1.00	0.24	26.56	2.84
20.04	5.66	0.90	0.21	29.49	2.85
20.04	5.03	0.80	0.19	33.18	2.91
20.05	4.40	0.70	0.17	37.94	2.86
20.04	3.77	0.60	0.14	44.23	2.81

Table G.21: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:13:32

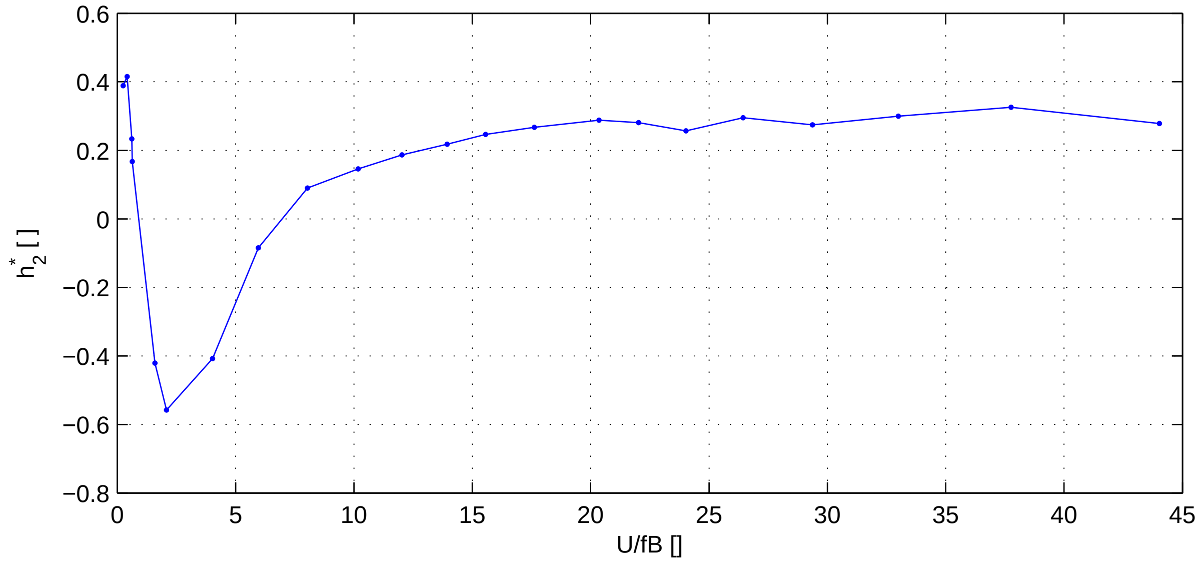


Figure G.20: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_2^*
0.76	25.13	4.00	25.00	0.25	0.39
1.27	25.13	4.00	14.89	0.42	0.42
1.86	25.13	4.00	10.21	0.62	0.23
1.91	25.13	4.00	9.95	0.63	0.17
4.80	25.13	4.00	3.96	1.59	−0.42
6.28	25.13	4.00	3.02	2.08	−0.56
12.16	25.13	4.00	1.56	4.03	−0.41
18.00	25.13	4.00	1.05	5.96	−0.08
20.02	20.74	3.30	0.78	8.03	0.09
19.99	16.34	2.60	0.62	10.18	0.15
19.98	13.82	2.20	0.52	12.03	0.19
19.98	11.93	1.90	0.45	13.94	0.22
19.99	10.69	1.70	0.40	15.57	0.25
19.96	9.43	1.50	0.36	17.62	0.27
19.97	8.17	1.30	0.31	20.35	0.29
19.96	7.54	1.20	0.29	22.03	0.28
19.96	6.91	1.10	0.26	24.03	0.26
19.96	6.28	1.00	0.24	26.44	0.29
19.96	5.66	0.90	0.21	29.37	0.27
19.93	5.03	0.80	0.19	33.00	0.30
19.96	4.40	0.70	0.17	37.76	0.33
19.95	3.77	0.60	0.14	44.03	0.28

Table G.22: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

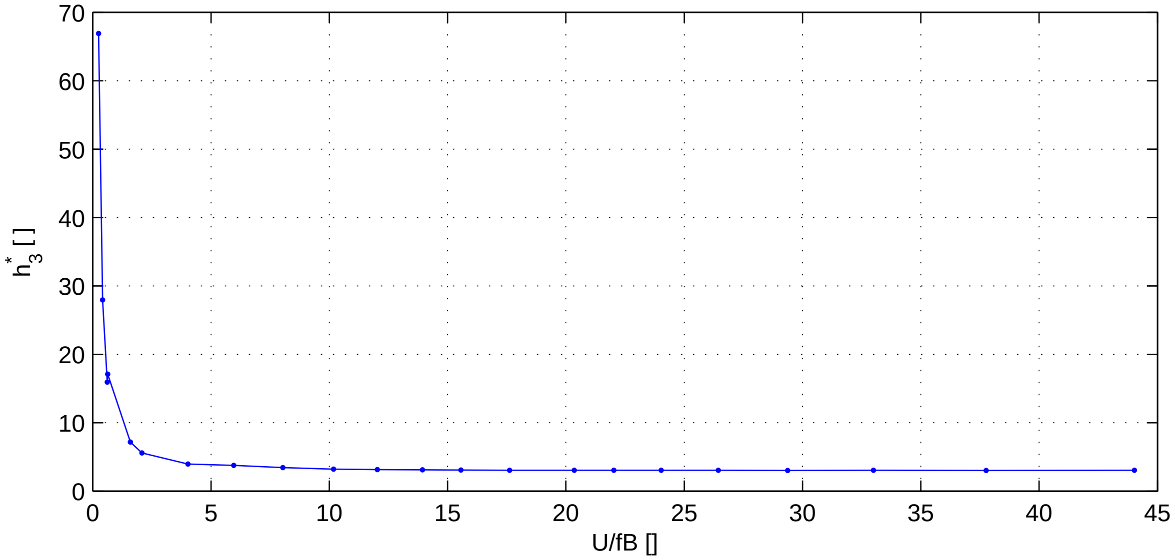


Figure G.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
0.76	25.13	4.00	25.00	0.25	66.90
1.27	25.13	4.00	14.89	0.42	27.93
1.86	25.13	4.00	10.21	0.62	15.92
1.91	25.13	4.00	9.95	0.63	17.10
4.80	25.13	4.00	3.96	1.59	7.14
6.28	25.13	4.00	3.02	2.08	5.58
12.16	25.13	4.00	1.56	4.03	3.95
18.00	25.13	4.00	1.05	5.96	3.74
20.02	20.74	3.30	0.78	8.03	3.41
19.99	16.34	2.60	0.62	10.18	3.20
19.98	13.82	2.20	0.52	12.03	3.13
19.98	11.93	1.90	0.45	13.94	3.09
19.99	10.69	1.70	0.40	15.57	3.06
19.96	9.43	1.50	0.36	17.62	3.04
19.97	8.17	1.30	0.31	20.35	3.04
19.96	7.54	1.20	0.29	22.03	3.03
19.96	6.91	1.10	0.26	24.03	3.03
19.96	6.28	1.00	0.24	26.44	3.03
19.96	5.66	0.90	0.21	29.37	3.01
19.93	5.03	0.80	0.19	33.00	3.02
19.96	4.40	0.70	0.17	37.76	3.01
19.95	3.77	0.60	0.14	44.03	3.02

Table G.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

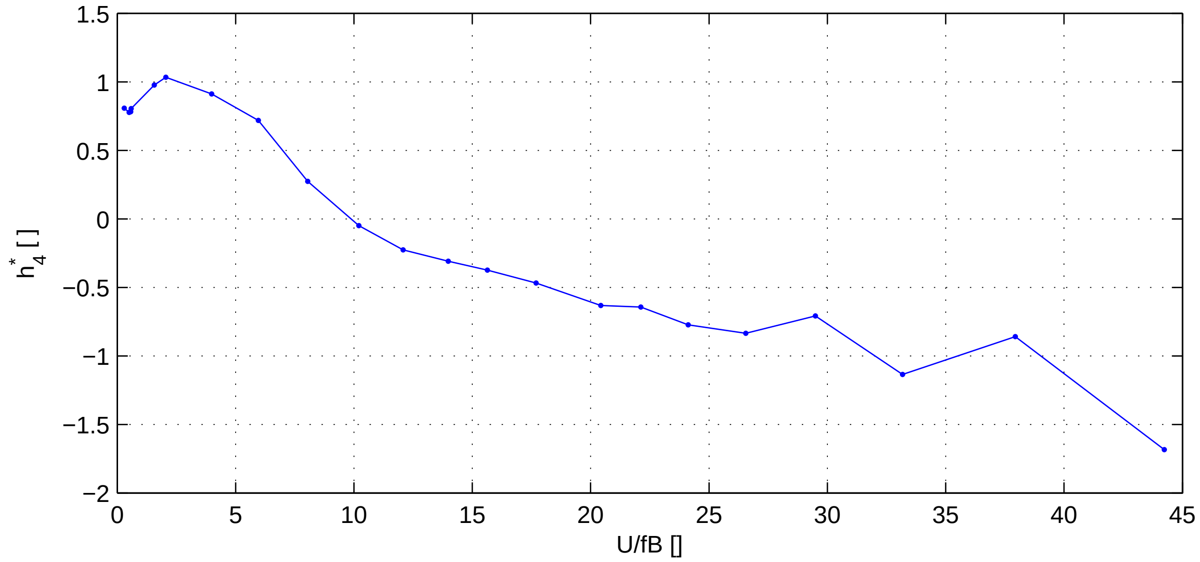


Figure G.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
0.90	25.13	4.00	21.01	0.30	0.81
1.52	25.13	4.00	12.51	0.50	0.78
1.73	25.13	4.00	10.97	0.57	0.78
1.76	25.13	4.00	10.78	0.58	0.80
4.71	25.13	4.00	4.02	1.56	0.98
6.19	25.13	4.00	3.07	2.05	1.03
12.05	25.13	4.00	1.57	3.99	0.91
17.99	25.13	4.00	1.05	5.96	0.72
20.05	20.74	3.30	0.78	8.05	0.27
20.05	16.34	2.60	0.62	10.21	−0.05
20.06	13.82	2.20	0.52	12.07	−0.23
20.05	11.93	1.90	0.45	13.98	−0.31
20.06	10.68	1.70	0.40	15.64	−0.37
20.05	9.43	1.50	0.36	17.70	−0.47
20.04	8.17	1.30	0.31	20.43	−0.63
20.04	7.54	1.20	0.28	22.12	−0.64
20.04	6.91	1.10	0.26	24.13	−0.77
20.05	6.28	1.00	0.24	26.56	−0.84
20.04	5.66	0.90	0.21	29.49	−0.71
20.04	5.03	0.80	0.19	33.18	−1.13
20.05	4.40	0.70	0.17	37.94	−0.86
20.04	3.77	0.60	0.14	44.23	−1.68

Table G.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

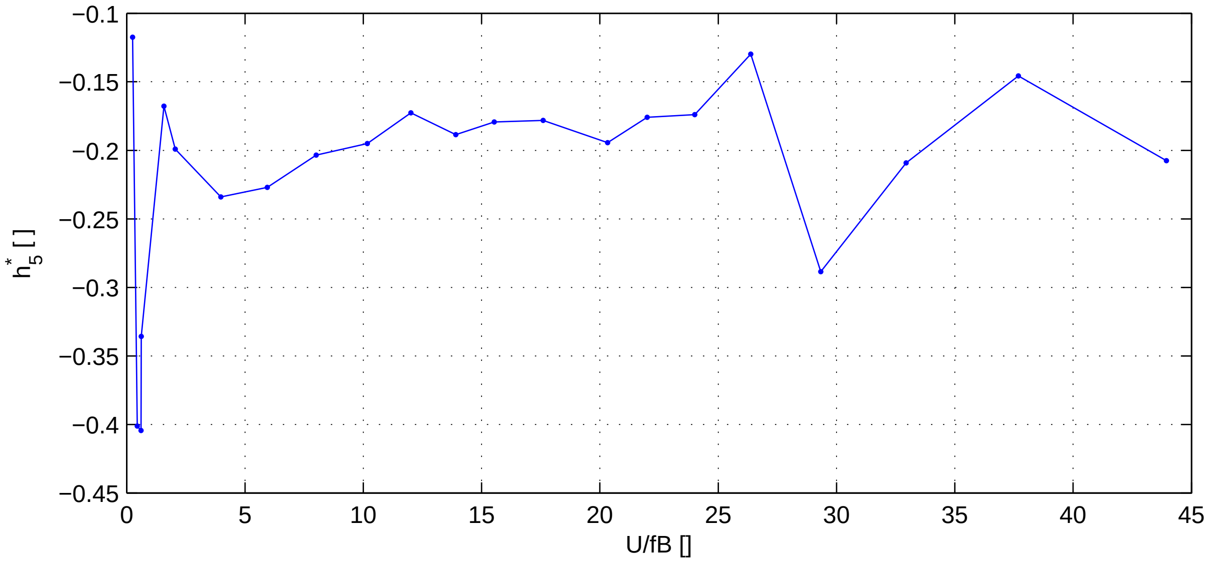


Figure G.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
0.76	25.13	4.00	24.93	0.25	−0.12
1.35	25.13	4.00	14.08	0.45	−0.40
1.82	25.13	4.00	10.45	0.60	−0.40
1.84	25.13	4.00	10.29	0.61	−0.34
4.75	25.13	4.00	3.99	1.57	−0.17
6.21	25.13	4.00	3.05	2.06	−0.20
12.02	25.13	4.00	1.58	3.98	−0.23
17.94	25.13	4.00	1.06	5.94	−0.23
19.96	20.74	3.30	0.78	8.01	−0.20
19.96	16.34	2.60	0.62	10.16	−0.20
19.96	13.82	2.20	0.52	12.01	−0.17
19.95	11.93	1.90	0.45	13.91	−0.19
19.93	10.68	1.70	0.40	15.53	−0.18
19.94	9.43	1.50	0.36	17.60	−0.18
19.94	8.17	1.30	0.31	20.32	−0.19
19.93	7.54	1.20	0.29	22.00	−0.18
19.94	6.91	1.10	0.26	24.00	−0.17
19.91	6.28	1.00	0.24	26.37	−0.13
19.94	5.66	0.90	0.21	29.34	−0.29
19.90	5.03	0.80	0.19	32.94	−0.21
19.92	4.40	0.70	0.17	37.68	−0.15
19.91	3.77	0.60	0.14	43.95	−0.21

Table G.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

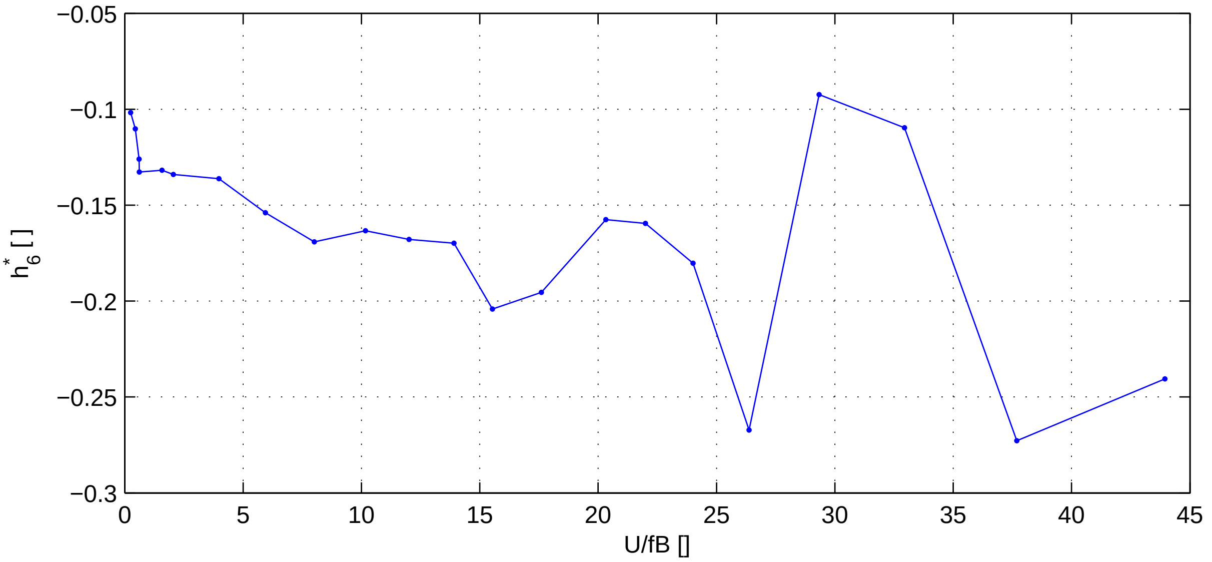


Figure G.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
0.76	25.13	4.00	24.93	0.25	−0.10
1.35	25.13	4.00	14.08	0.45	−0.11
1.82	25.13	4.00	10.45	0.60	−0.13
1.84	25.13	4.00	10.29	0.61	−0.13
4.75	25.13	4.00	3.99	1.57	−0.13
6.21	25.13	4.00	3.05	2.06	−0.13
12.02	25.13	4.00	1.58	3.98	−0.14
17.94	25.13	4.00	1.06	5.94	−0.15
19.96	20.74	3.30	0.78	8.01	−0.17
19.96	16.34	2.60	0.62	10.16	−0.16
19.96	13.82	2.20	0.52	12.01	−0.17
19.95	11.93	1.90	0.45	13.91	−0.17
19.93	10.68	1.70	0.40	15.53	−0.20
19.94	9.43	1.50	0.36	17.60	−0.20
19.94	8.17	1.30	0.31	20.32	−0.16
19.93	7.54	1.20	0.29	22.00	−0.16
19.94	6.91	1.10	0.26	24.00	−0.18
19.91	6.28	1.00	0.24	26.37	−0.27
19.94	5.66	0.90	0.21	29.34	−0.09
19.90	5.03	0.80	0.19	32.94	−0.11
19.92	4.40	0.70	0.17	37.68	−0.27
19.91	3.77	0.60	0.14	43.95	−0.24

Table G.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

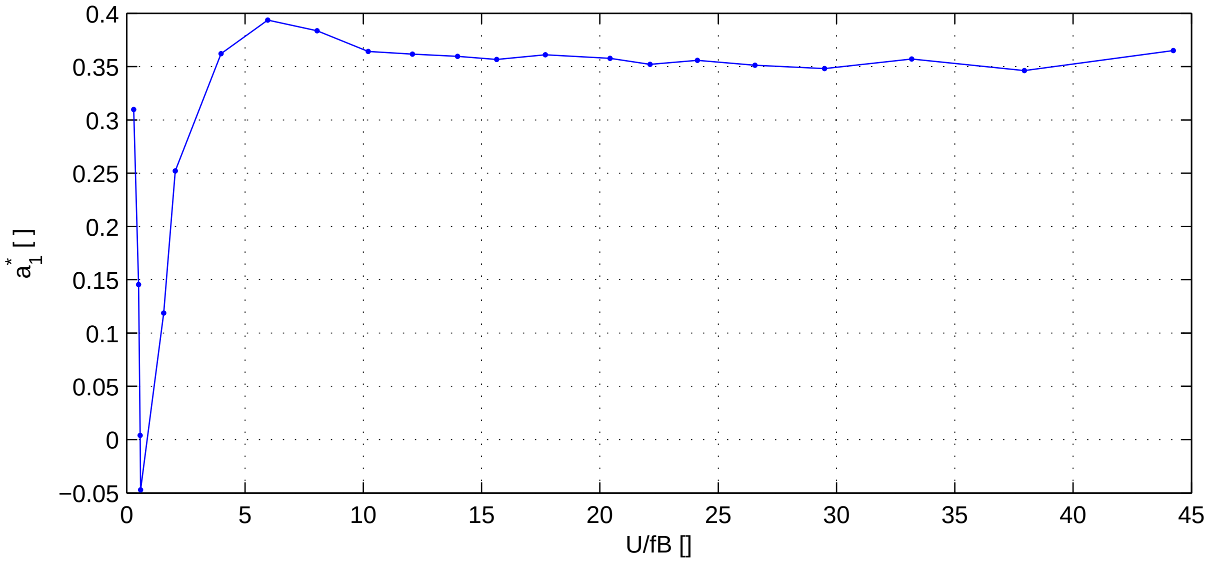


Figure G.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
0.90	25.13	4.00	21.01	0.30	0.31
1.52	25.13	4.00	12.51	0.50	0.15
1.73	25.13	4.00	10.97	0.57	0.00
1.76	25.13	4.00	10.78	0.58	−0.05
4.71	25.13	4.00	4.02	1.56	0.12
6.19	25.13	4.00	3.07	2.05	0.25
12.05	25.13	4.00	1.57	3.99	0.36
17.99	25.13	4.00	1.05	5.96	0.39
20.05	20.74	3.30	0.78	8.05	0.38
20.05	16.34	2.60	0.62	10.21	0.36
20.06	13.82	2.20	0.52	12.07	0.36
20.05	11.93	1.90	0.45	13.98	0.36
20.06	10.68	1.70	0.40	15.64	0.36
20.05	9.43	1.50	0.36	17.70	0.36
20.04	8.17	1.30	0.31	20.43	0.36
20.04	7.54	1.20	0.28	22.12	0.35
20.04	6.91	1.10	0.26	24.13	0.36
20.05	6.28	1.00	0.24	26.56	0.35
20.04	5.66	0.90	0.21	29.49	0.35
20.04	5.03	0.80	0.19	33.18	0.36
20.05	4.40	0.70	0.17	37.94	0.35
20.04	3.77	0.60	0.14	44.23	0.37

Table G.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

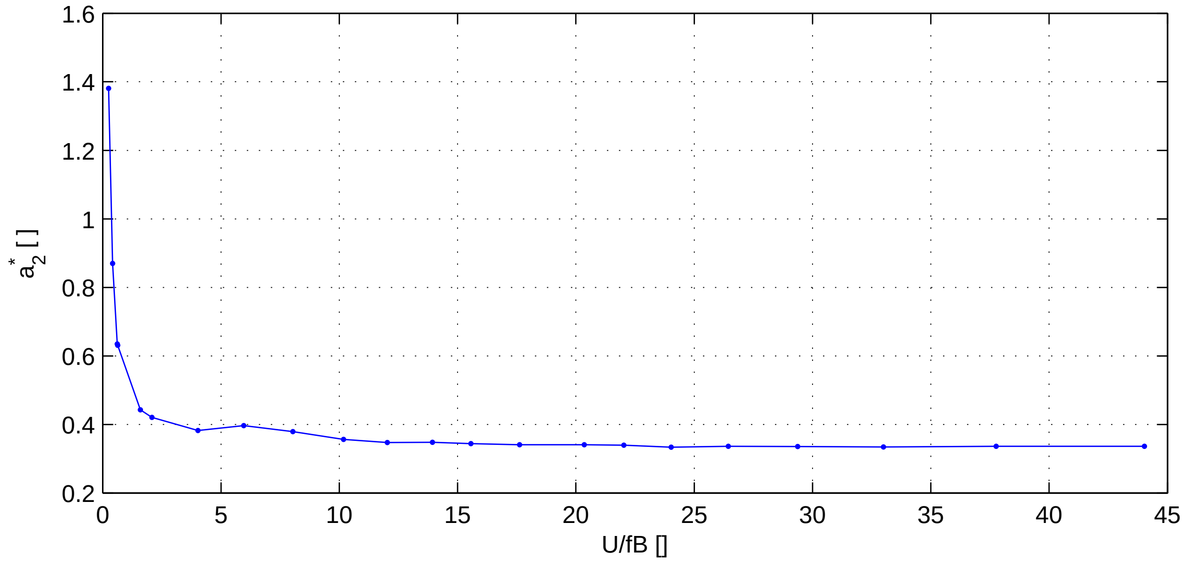


Figure G.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
0.76	25.13	4.00	25.00	0.25	1.38
1.27	25.13	4.00	14.89	0.42	0.87
1.86	25.13	4.00	10.21	0.62	0.63
1.91	25.13	4.00	9.95	0.63	0.63
4.80	25.13	4.00	3.96	1.59	0.44
6.28	25.13	4.00	3.02	2.08	0.42
12.16	25.13	4.00	1.56	4.03	0.38
18.00	25.13	4.00	1.05	5.96	0.40
20.02	20.74	3.30	0.78	8.03	0.38
19.99	16.34	2.60	0.62	10.18	0.36
19.98	13.82	2.20	0.52	12.03	0.35
19.98	11.93	1.90	0.45	13.94	0.35
19.99	10.69	1.70	0.40	15.57	0.34
19.96	9.43	1.50	0.36	17.62	0.34
19.97	8.17	1.30	0.31	20.35	0.34
19.96	7.54	1.20	0.29	22.03	0.34
19.96	6.91	1.10	0.26	24.03	0.33
19.96	6.28	1.00	0.24	26.44	0.34
19.96	5.66	0.90	0.21	29.37	0.34
19.93	5.03	0.80	0.19	33.00	0.33
19.96	4.40	0.70	0.17	37.76	0.34
19.95	3.77	0.60	0.14	44.03	0.34

Table G.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

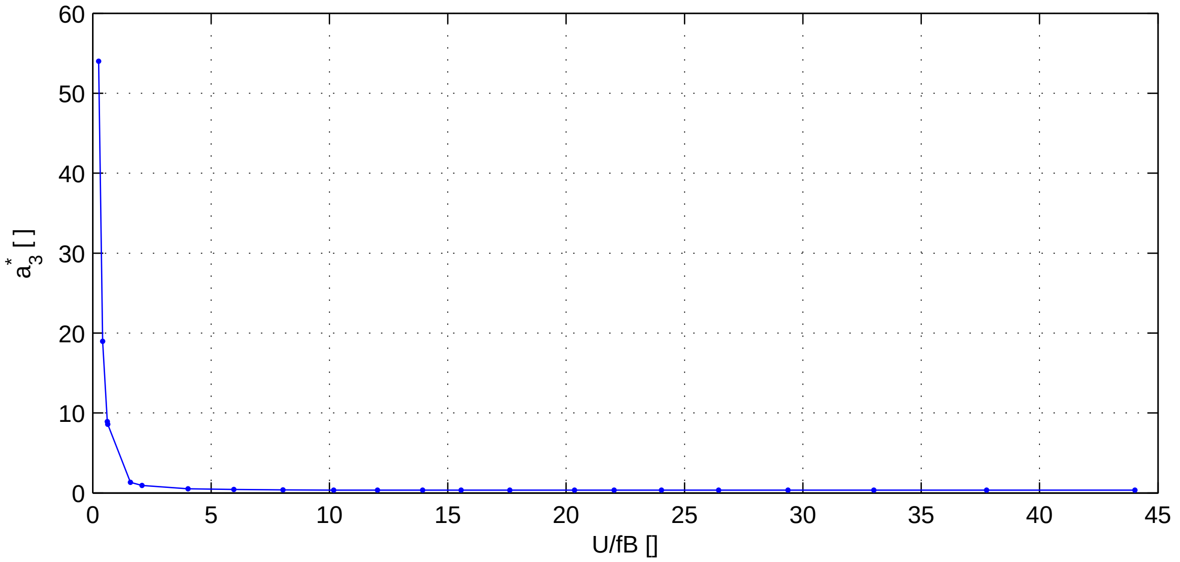


Figure G.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
0.76	25.13	4.00	25.00	0.25	54.01
1.27	25.13	4.00	14.89	0.42	18.98
1.86	25.13	4.00	10.21	0.62	8.91
1.91	25.13	4.00	9.95	0.63	8.60
4.80	25.13	4.00	3.96	1.59	1.32
6.28	25.13	4.00	3.02	2.08	0.94
12.16	25.13	4.00	1.56	4.03	0.51
18.00	25.13	4.00	1.05	5.96	0.43
20.02	20.74	3.30	0.78	8.03	0.38
19.99	16.34	2.60	0.62	10.18	0.36
19.98	13.82	2.20	0.52	12.03	0.36
19.98	11.93	1.90	0.45	13.94	0.35
19.99	10.69	1.70	0.40	15.57	0.35
19.96	9.43	1.50	0.36	17.62	0.35
19.97	8.17	1.30	0.31	20.35	0.35
19.96	7.54	1.20	0.29	22.03	0.35
19.96	6.91	1.10	0.26	24.03	0.35
19.96	6.28	1.00	0.24	26.44	0.35
19.96	5.66	0.90	0.21	29.37	0.35
19.93	5.03	0.80	0.19	33.00	0.35
19.96	4.40	0.70	0.17	37.76	0.35
19.95	3.77	0.60	0.14	44.03	0.36

Table G.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

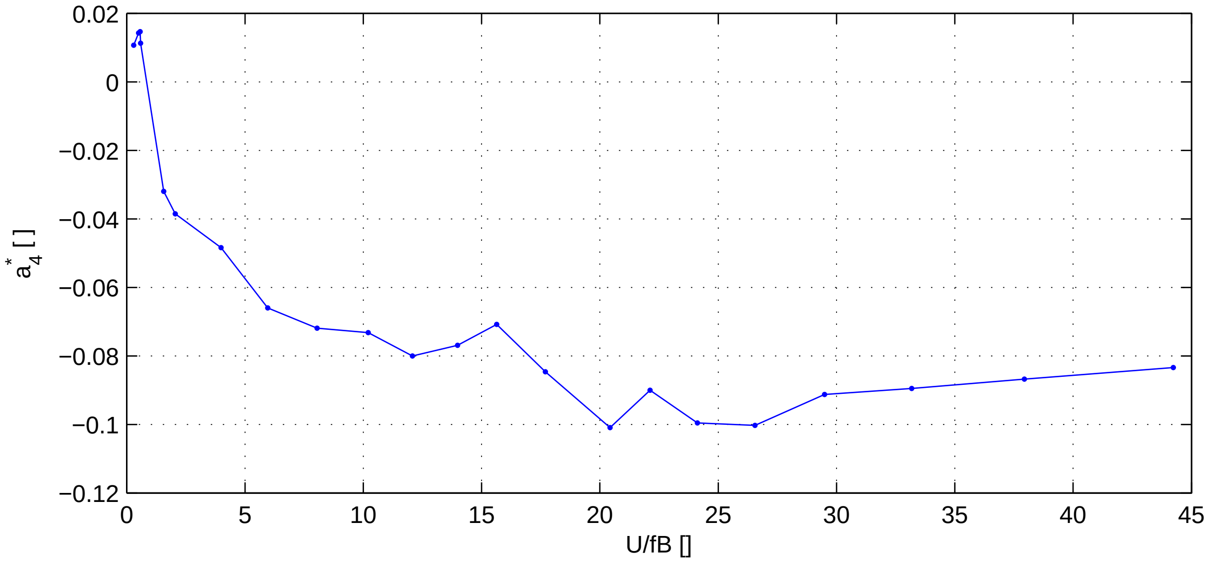


Figure G.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
0.90	25.13	4.00	21.01	0.30	0.01
1.52	25.13	4.00	12.51	0.50	0.01
1.73	25.13	4.00	10.97	0.57	0.01
1.76	25.13	4.00	10.78	0.58	0.01
4.71	25.13	4.00	4.02	1.56	−0.03
6.19	25.13	4.00	3.07	2.05	−0.04
12.05	25.13	4.00	1.57	3.99	−0.05
17.99	25.13	4.00	1.05	5.96	−0.07
20.05	20.74	3.30	0.78	8.05	−0.07
20.05	16.34	2.60	0.62	10.21	−0.07
20.06	13.82	2.20	0.52	12.07	−0.08
20.05	11.93	1.90	0.45	13.98	−0.08
20.06	10.68	1.70	0.40	15.64	−0.07
20.05	9.43	1.50	0.36	17.70	−0.08
20.04	8.17	1.30	0.31	20.43	−0.10
20.04	7.54	1.20	0.28	22.12	−0.09
20.04	6.91	1.10	0.26	24.13	−0.10
20.05	6.28	1.00	0.24	26.56	−0.10
20.04	5.66	0.90	0.21	29.49	−0.09
20.04	5.03	0.80	0.19	33.18	−0.09
20.05	4.40	0.70	0.17	37.94	−0.09
20.04	3.77	0.60	0.14	44.23	−0.08

Table G.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

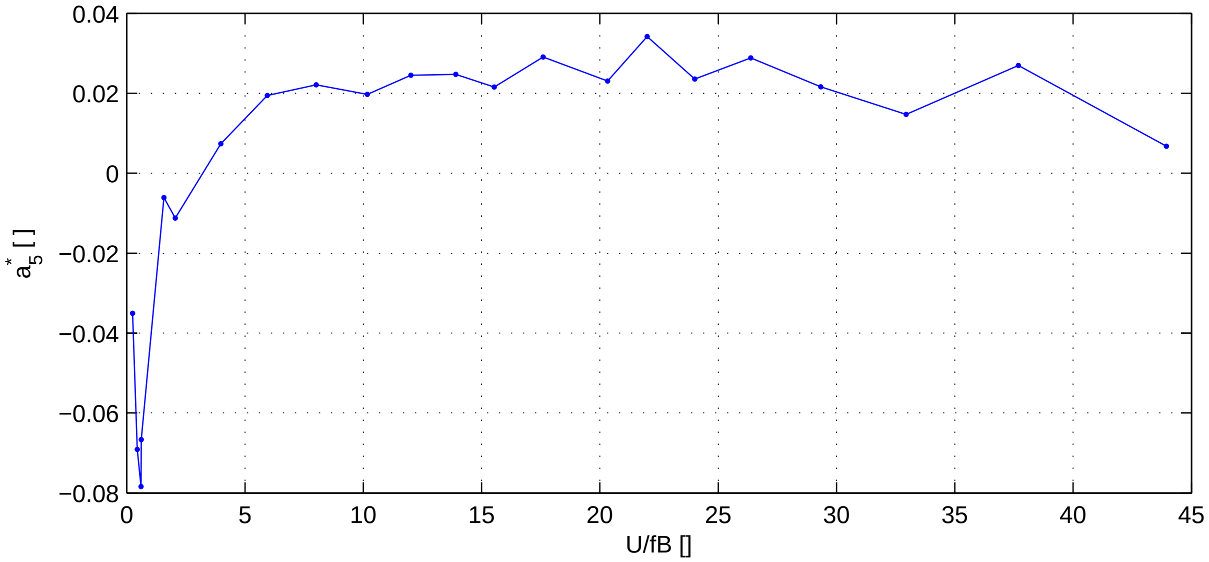


Figure G.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
0.76	25.13	4.00	24.93	0.25	−0.04
1.35	25.13	4.00	14.08	0.45	−0.07
1.82	25.13	4.00	10.45	0.60	−0.08
1.84	25.13	4.00	10.29	0.61	−0.07
4.75	25.13	4.00	3.99	1.57	−0.01
6.21	25.13	4.00	3.05	2.06	−0.01
12.02	25.13	4.00	1.58	3.98	0.01
17.94	25.13	4.00	1.06	5.94	0.02
19.96	20.74	3.30	0.78	8.01	0.02
19.96	16.34	2.60	0.62	10.16	0.02
19.96	13.82	2.20	0.52	12.01	0.02
19.95	11.93	1.90	0.45	13.91	0.02
19.93	10.68	1.70	0.40	15.53	0.02
19.94	9.43	1.50	0.36	17.60	0.03
19.94	8.17	1.30	0.31	20.32	0.02
19.93	7.54	1.20	0.29	22.00	0.03
19.94	6.91	1.10	0.26	24.00	0.02
19.91	6.28	1.00	0.24	26.37	0.03
19.94	5.66	0.90	0.21	29.34	0.02
19.90	5.03	0.80	0.19	32.94	0.01
19.92	4.40	0.70	0.17	37.68	0.03
19.91	3.77	0.60	0.14	43.95	0.01

Table G.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

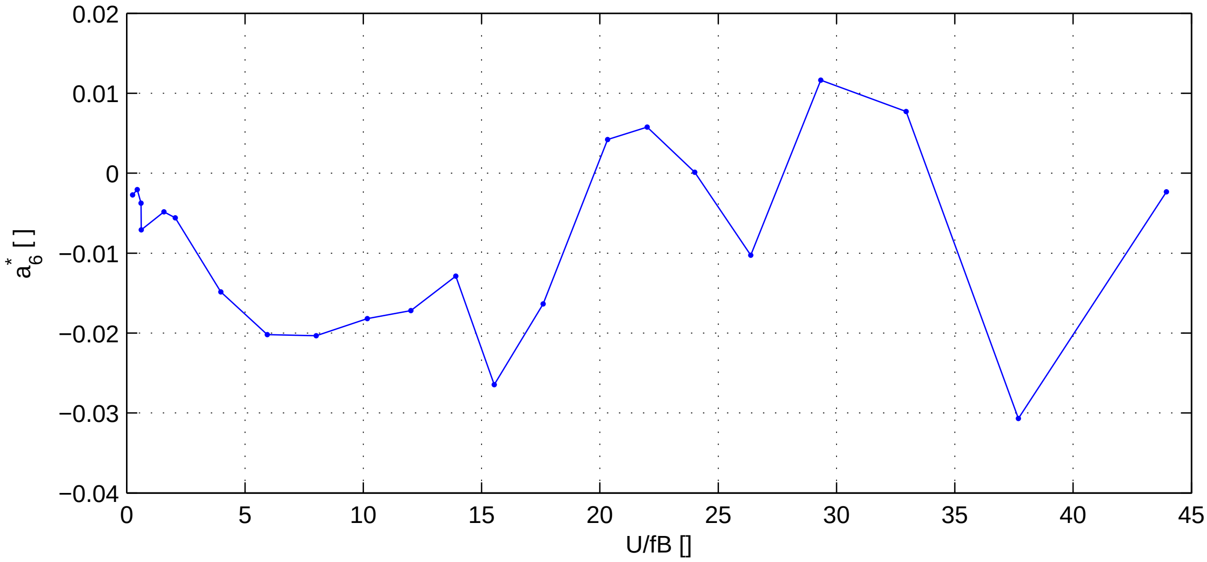


Figure G.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
0.76	25.13	4.00	24.93	0.25	−0.00
1.35	25.13	4.00	14.08	0.45	−0.00
1.82	25.13	4.00	10.45	0.60	−0.00
1.84	25.13	4.00	10.29	0.61	−0.01
4.75	25.13	4.00	3.99	1.57	−0.00
6.21	25.13	4.00	3.05	2.06	−0.01
12.02	25.13	4.00	1.58	3.98	−0.01
17.94	25.13	4.00	1.06	5.94	−0.02
19.96	20.74	3.30	0.78	8.01	−0.02
19.96	16.34	2.60	0.62	10.16	−0.02
19.96	13.82	2.20	0.52	12.01	−0.02
19.95	11.93	1.90	0.45	13.91	−0.01
19.93	10.68	1.70	0.40	15.53	−0.03
19.94	9.43	1.50	0.36	17.60	−0.02
19.94	8.17	1.30	0.31	20.32	0.00
19.93	7.54	1.20	0.29	22.00	0.01
19.94	6.91	1.10	0.26	24.00	0.00
19.91	6.28	1.00	0.24	26.37	−0.01
19.94	5.66	0.90	0.21	29.34	0.01
19.90	5.03	0.80	0.19	32.94	0.01
19.92	4.40	0.70	0.17	37.68	−0.03
19.91	3.77	0.60	0.14	43.95	−0.00

Table G.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

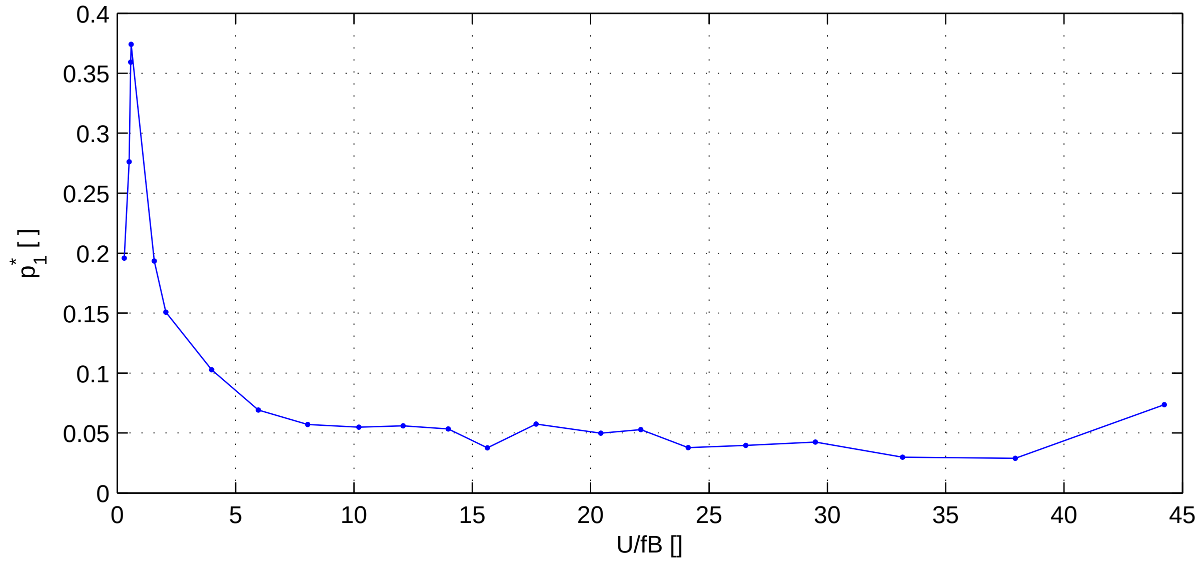


Figure G.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
0.90	25.13	4.00	21.01	0.30	0.20
1.52	25.13	4.00	12.51	0.50	0.28
1.73	25.13	4.00	10.97	0.57	0.36
1.76	25.13	4.00	10.78	0.58	0.37
4.71	25.13	4.00	4.02	1.56	0.19
6.19	25.13	4.00	3.07	2.05	0.15
12.05	25.13	4.00	1.57	3.99	0.10
17.99	25.13	4.00	1.05	5.96	0.07
20.05	20.74	3.30	0.78	8.05	0.06
20.05	16.34	2.60	0.62	10.21	0.05
20.06	13.82	2.20	0.52	12.07	0.06
20.05	11.93	1.90	0.45	13.98	0.05
20.06	10.68	1.70	0.40	15.64	0.04
20.05	9.43	1.50	0.36	17.70	0.06
20.04	8.17	1.30	0.31	20.43	0.05
20.04	7.54	1.20	0.28	22.12	0.05
20.04	6.91	1.10	0.26	24.13	0.04
20.05	6.28	1.00	0.24	26.56	0.04
20.04	5.66	0.90	0.21	29.49	0.04
20.04	5.03	0.80	0.19	33.18	0.03
20.05	4.40	0.70	0.17	37.94	0.03
20.04	3.77	0.60	0.14	44.23	0.07

Table G.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

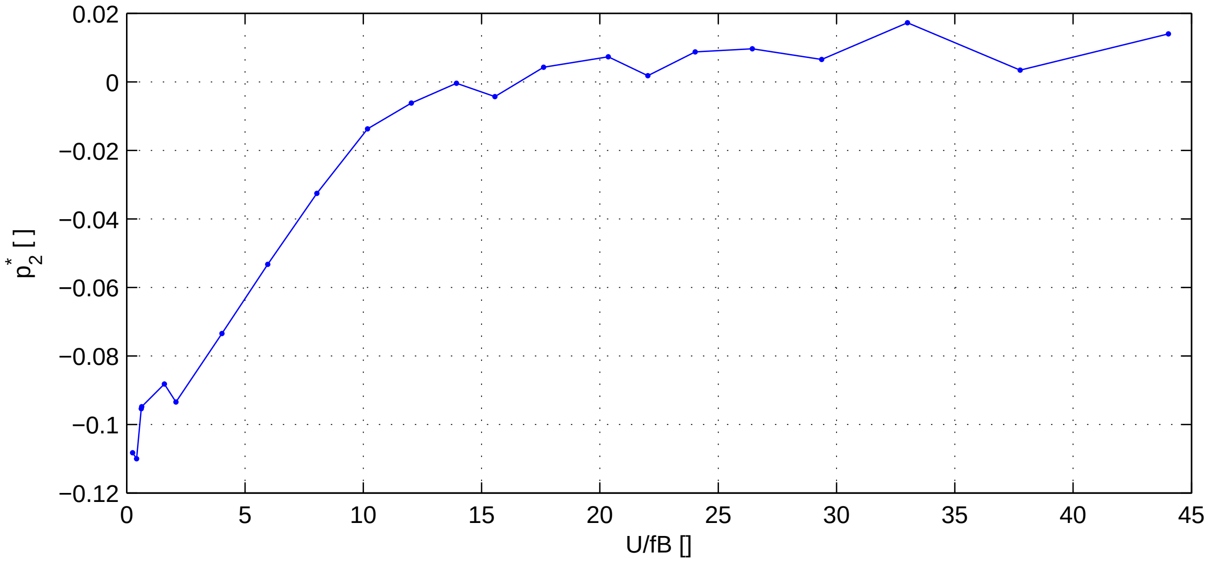


Figure G.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
0.76	25.13	4.00	25.00	0.25	−0.11
1.27	25.13	4.00	14.89	0.42	−0.11
1.86	25.13	4.00	10.21	0.62	−0.10
1.91	25.13	4.00	9.95	0.63	−0.09
4.80	25.13	4.00	3.96	1.59	−0.09
6.28	25.13	4.00	3.02	2.08	−0.09
12.16	25.13	4.00	1.56	4.03	−0.07
18.00	25.13	4.00	1.05	5.96	−0.05
20.02	20.74	3.30	0.78	8.03	−0.03
19.99	16.34	2.60	0.62	10.18	−0.01
19.98	13.82	2.20	0.52	12.03	−0.01
19.98	11.93	1.90	0.45	13.94	−0.00
19.99	10.69	1.70	0.40	15.57	−0.00
19.96	9.43	1.50	0.36	17.62	0.00
19.97	8.17	1.30	0.31	20.35	0.01
19.96	7.54	1.20	0.29	22.03	0.00
19.96	6.91	1.10	0.26	24.03	0.01
19.96	6.28	1.00	0.24	26.44	0.01
19.96	5.66	0.90	0.21	29.37	0.01
19.93	5.03	0.80	0.19	33.00	0.02
19.96	4.40	0.70	0.17	37.76	0.00
19.95	3.77	0.60	0.14	44.03	0.01

Table G.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

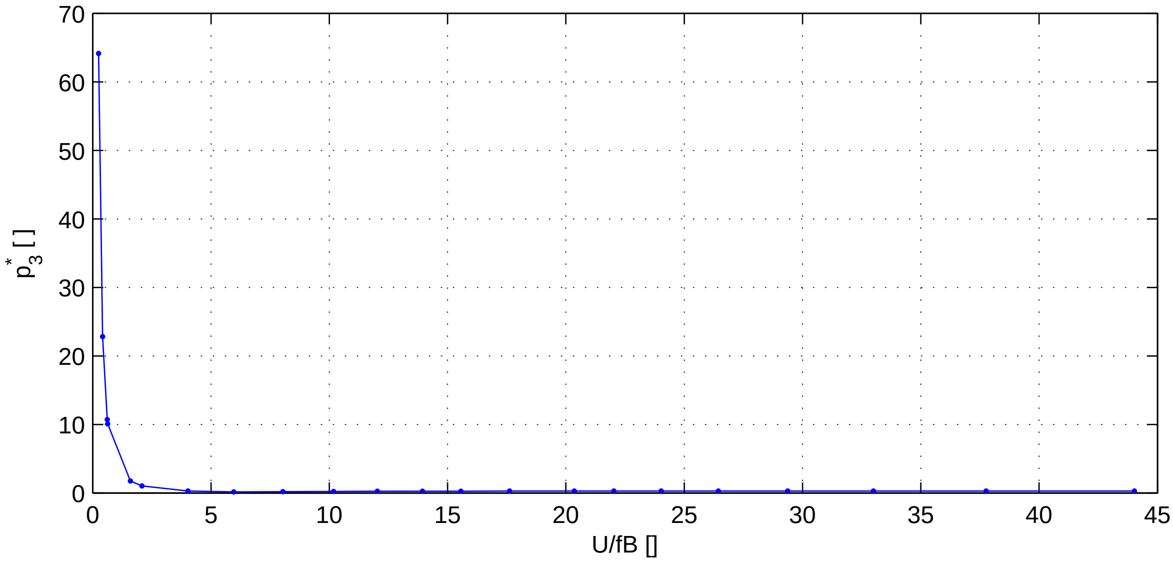


Figure G.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
0.76	25.13	4.00	25.00	0.25	64.13
1.27	25.13	4.00	14.89	0.42	22.80
1.86	25.13	4.00	10.21	0.62	10.69
1.91	25.13	4.00	9.95	0.63	10.08
4.80	25.13	4.00	3.96	1.59	1.74
6.28	25.13	4.00	3.02	2.08	1.03
12.16	25.13	4.00	1.56	4.03	0.29
18.00	25.13	4.00	1.05	5.96	0.14
20.02	20.74	3.30	0.78	8.03	0.17
19.99	16.34	2.60	0.62	10.18	0.22
19.98	13.82	2.20	0.52	12.03	0.24
19.98	11.93	1.90	0.45	13.94	0.25
19.99	10.69	1.70	0.40	15.57	0.26
19.96	9.43	1.50	0.36	17.62	0.27
19.97	8.17	1.30	0.31	20.35	0.27
19.96	7.54	1.20	0.29	22.03	0.28
19.96	6.91	1.10	0.26	24.03	0.28
19.96	6.28	1.00	0.24	26.44	0.28
19.96	5.66	0.90	0.21	29.37	0.28
19.93	5.03	0.80	0.19	33.00	0.29
19.96	4.40	0.70	0.17	37.76	0.29
19.95	3.77	0.60	0.14	44.03	0.29

Table G.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

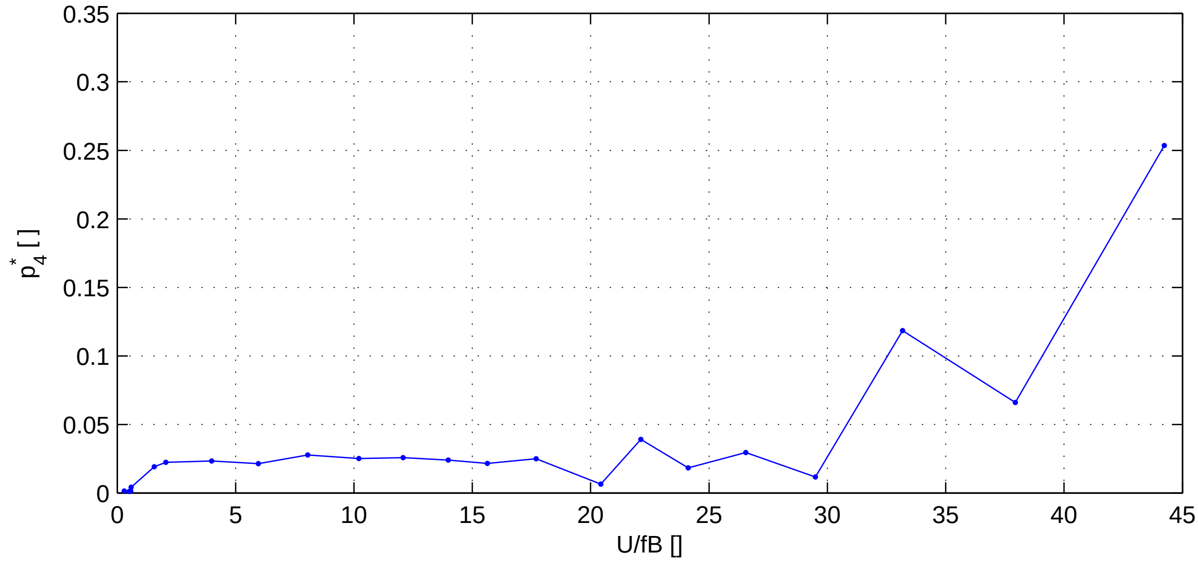


Figure G.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:13:32

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
0.90	25.13	4.00	21.01	0.30	0.00
1.52	25.13	4.00	12.51	0.50	0.00
1.73	25.13	4.00	10.97	0.57	0.00
1.76	25.13	4.00	10.78	0.58	0.00
4.71	25.13	4.00	4.02	1.56	0.02
6.19	25.13	4.00	3.07	2.05	0.02
12.05	25.13	4.00	1.57	3.99	0.02
17.99	25.13	4.00	1.05	5.96	0.02
20.05	20.74	3.30	0.78	8.05	0.03
20.05	16.34	2.60	0.62	10.21	0.03
20.06	13.82	2.20	0.52	12.07	0.03
20.05	11.93	1.90	0.45	13.98	0.02
20.06	10.68	1.70	0.40	15.64	0.02
20.05	9.43	1.50	0.36	17.70	0.02
20.04	8.17	1.30	0.31	20.43	0.01
20.04	7.54	1.20	0.28	22.12	0.04
20.04	6.91	1.10	0.26	24.13	0.02
20.05	6.28	1.00	0.24	26.56	0.03
20.04	5.66	0.90	0.21	29.49	0.01
20.04	5.03	0.80	0.19	33.18	0.12
20.05	4.40	0.70	0.17	37.94	0.07
20.04	3.77	0.60	0.14	44.23	0.25

Table G.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

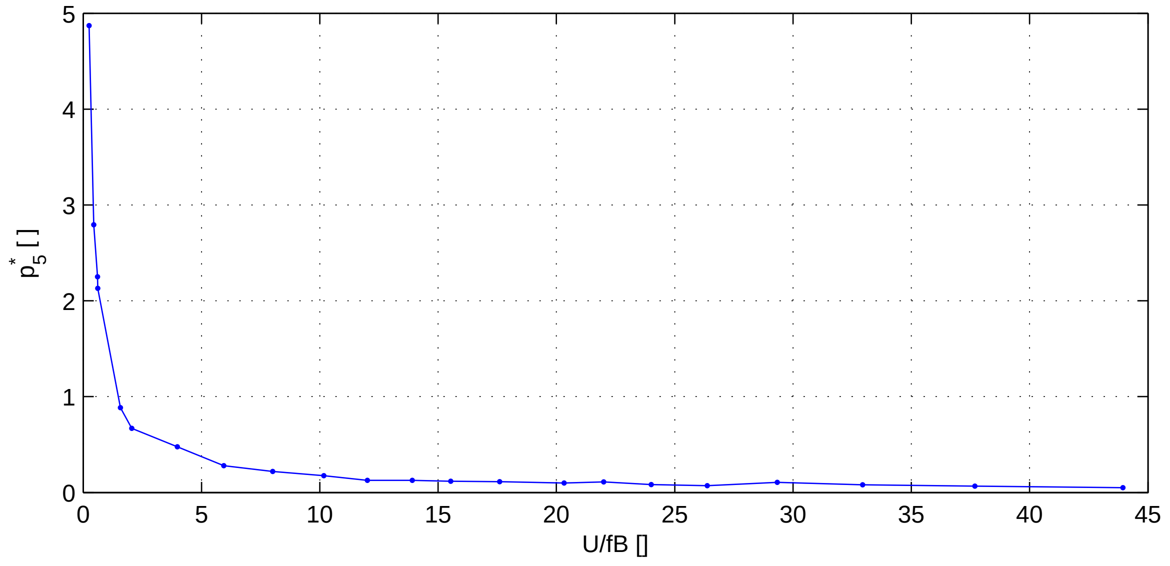


Figure G.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
0.76	25.13	4.00	24.93	0.25	4.87
1.35	25.13	4.00	14.08	0.45	2.79
1.82	25.13	4.00	10.45	0.60	2.25
1.84	25.13	4.00	10.29	0.61	2.13
4.75	25.13	4.00	3.99	1.57	0.89
6.21	25.13	4.00	3.05	2.06	0.67
12.02	25.13	4.00	1.58	3.98	0.48
17.94	25.13	4.00	1.06	5.94	0.28
19.96	20.74	3.30	0.78	8.01	0.22
19.96	16.34	2.60	0.62	10.16	0.18
19.96	13.82	2.20	0.52	12.01	0.13
19.95	11.93	1.90	0.45	13.91	0.13
19.93	10.68	1.70	0.40	15.53	0.12
19.94	9.43	1.50	0.36	17.60	0.11
19.94	8.17	1.30	0.31	20.32	0.10
19.93	7.54	1.20	0.29	22.00	0.11
19.94	6.91	1.10	0.26	24.00	0.08
19.91	6.28	1.00	0.24	26.37	0.07
19.94	5.66	0.90	0.21	29.34	0.11
19.90	5.03	0.80	0.19	32.94	0.08
19.92	4.40	0.70	0.17	37.68	0.07
19.91	3.77	0.60	0.14	43.95	0.05

Table G.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

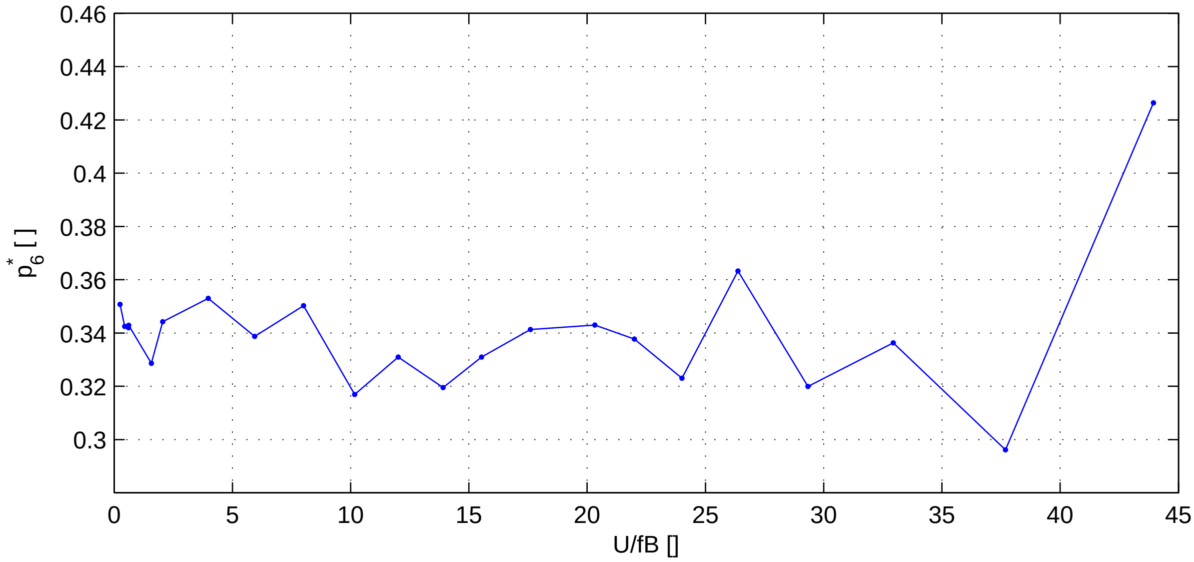


Figure G.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
0.76	25.13	4.00	24.93	0.25	0.35
1.35	25.13	4.00	14.08	0.45	0.34
1.82	25.13	4.00	10.45	0.60	0.34
1.84	25.13	4.00	10.29	0.61	0.34
4.75	25.13	4.00	3.99	1.57	0.33
6.21	25.13	4.00	3.05	2.06	0.34
12.02	25.13	4.00	1.58	3.98	0.35
17.94	25.13	4.00	1.06	5.94	0.34
19.96	20.74	3.30	0.78	8.01	0.35
19.96	16.34	2.60	0.62	10.16	0.32
19.96	13.82	2.20	0.52	12.01	0.33
19.95	11.93	1.90	0.45	13.91	0.32
19.93	10.68	1.70	0.40	15.53	0.33
19.94	9.43	1.50	0.36	17.60	0.34
19.94	8.17	1.30	0.31	20.32	0.34
19.93	7.54	1.20	0.29	22.00	0.34
19.94	6.91	1.10	0.26	24.00	0.32
19.91	6.28	1.00	0.24	26.37	0.36
19.94	5.66	0.90	0.21	29.34	0.32
19.90	5.03	0.80	0.19	32.94	0.34
19.92	4.40	0.70	0.17	37.68	0.30
19.91	3.77	0.60	0.14	43.95	0.43

Table G.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

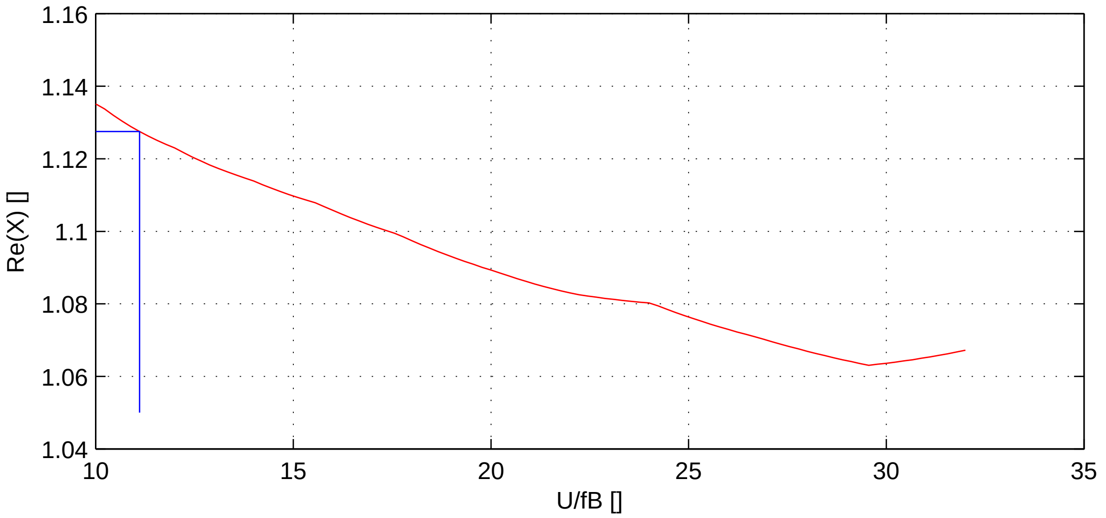


Figure G.37: Real part of the solution to stability equantion

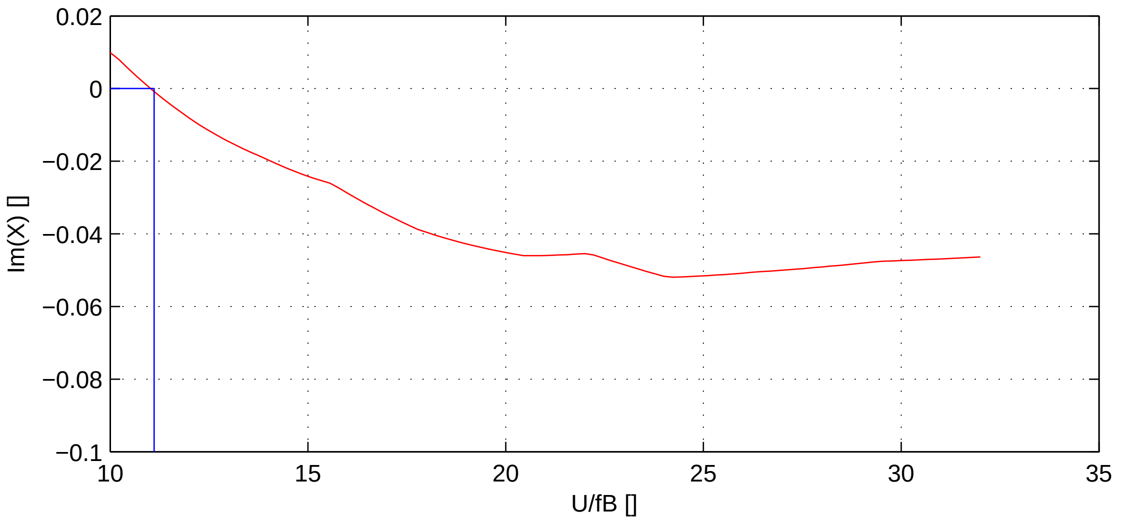


Figure G.38: Imaginary part of the solution to stability equantion

V_{Crit} = 11.1

f_{Crit} = 0.0729 Hz

U_{Crit} = 49.0 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.
[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.
[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.
[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.
[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix H

3D Flutter Tests

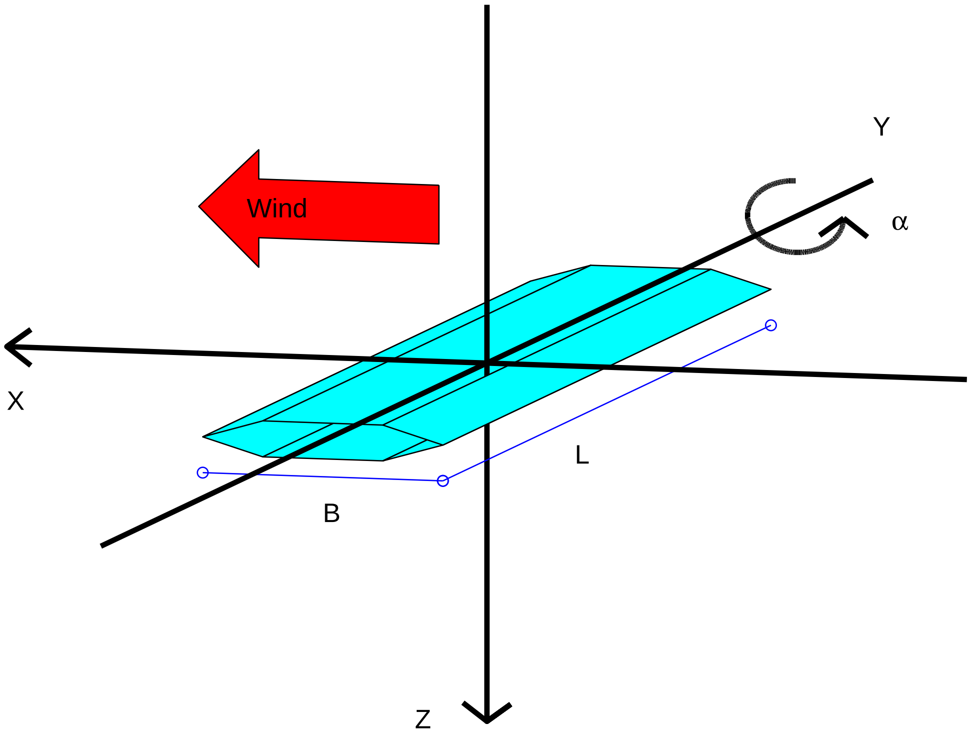
Flutter derivatives, Smooth flow, Angle of incidence = +2 deg.

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^{o}C	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1014.0

Table H.1: Project Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2\,m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$
$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha} m\,g - 2\,m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$
$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2\,m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h	: Vertical displacement, displacement along z-axis, [m]
α	: Rotation around y-axis, nose up is positive, [rad]
p	: Horizontal displacement, displacement along the x-axis, [m]
m	: Mass per unit length, [kg/m]
I_y	: Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$	: Added mass in vertical direction, [kg/m]
$m_{a,x}$	: Added mass in horizontal direction, [kg/m]
$I_{a,y}$	: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G	: X-coordinate for centre of gravity, [m]
Z_G	: Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$	: Natural circular frequency for vertical motion, [/s]
ζ_h	: Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$	: Natural circular frequency for rotation around y axis, [/s]
ζ_α	: Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$	: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p	: Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$	: Force from rig per meter section, [N/m]
$M_{Y,external}$	: Moment from rig per meter section, [Nm/m]
$F_{X,external}$	: Force from rig per meter section, [N/m]

Formula H.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.375
Added mass in horizontal	$m_{a,x}$	kg/m	0.541
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.140
Horizontal centre of gravity	x_G	m	−0.001
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.045
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.031
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.002

Table H.2: Mechanical Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula H.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

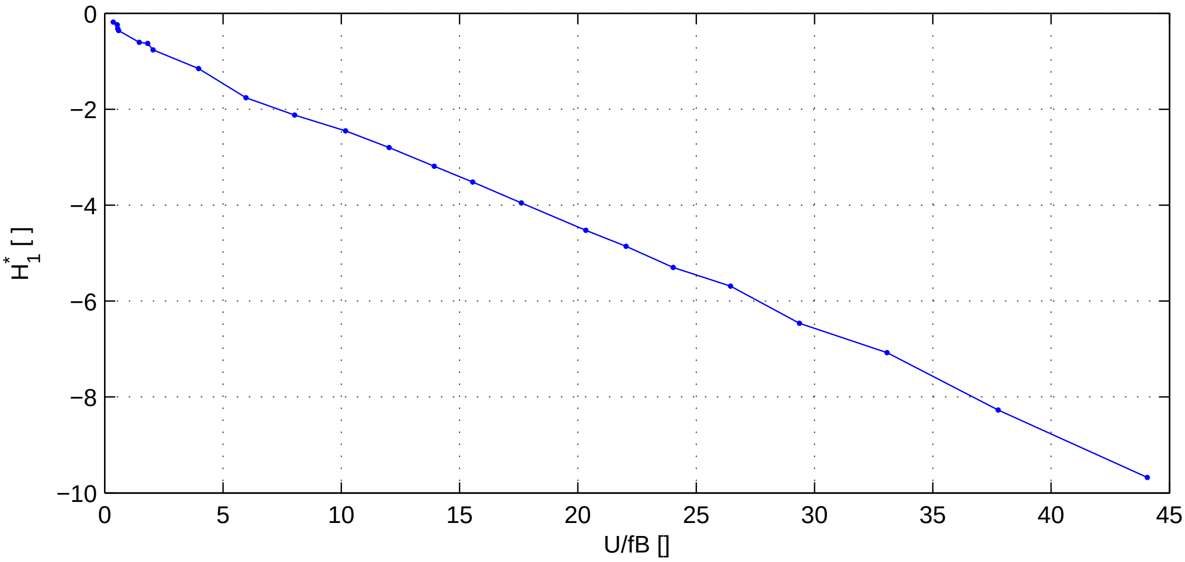


Figure H.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
1.10	25.13	4.00	17.17	0.37	−0.18
1.60	25.13	4.00	11.88	0.53	−0.24
1.67	25.13	4.00	11.37	0.55	−0.32
1.78	25.13	4.00	10.67	0.59	−0.36
4.42	25.13	4.00	4.30	1.46	−0.61
4.52	20.74	3.30	3.46	1.81	−0.63
6.18	25.13	4.00	3.07	2.05	−0.76
11.97	25.13	4.00	1.58	3.96	−1.15
18.03	25.13	4.00	1.05	5.97	−1.76
20.00	20.74	3.30	0.78	8.03	−2.12
19.99	16.34	2.60	0.62	10.18	−2.45
19.97	13.82	2.20	0.52	12.02	−2.80
19.97	11.93	1.90	0.45	13.93	−3.19
19.96	10.68	1.70	0.40	15.56	−3.52
19.95	9.43	1.50	0.36	17.61	−3.95
19.97	8.17	1.30	0.31	20.34	−4.53
19.96	7.54	1.20	0.29	22.03	−4.86
19.96	6.91	1.10	0.26	24.03	−5.30
19.97	6.28	1.00	0.24	26.45	−5.69
19.96	5.66	0.90	0.21	29.37	−6.47
19.97	5.03	0.80	0.19	33.06	−7.08
19.96	4.40	0.70	0.17	37.76	−8.27
19.96	3.77	0.60	0.14	44.07	−9.68

Table H.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

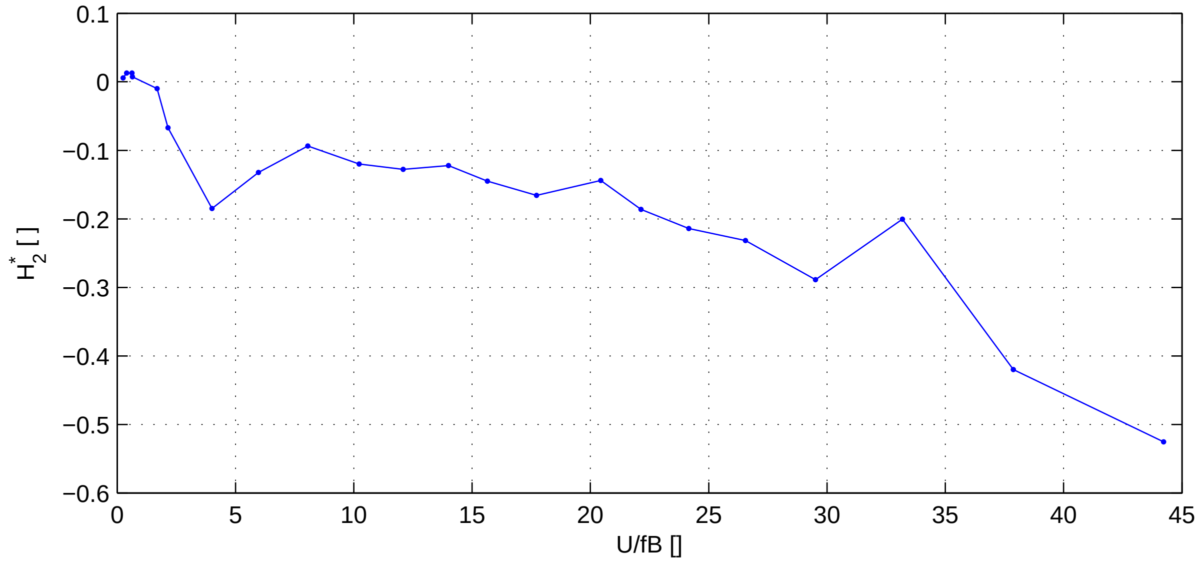


Figure H.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
0.75	25.13	4.00	25.42	0.25	0.01
1.19	25.13	4.00	15.91	0.39	0.01
1.89	25.13	4.00	10.05	0.62	0.01
1.94	25.13	4.00	9.79	0.64	0.01
5.10	25.13	4.00	3.72	1.69	−0.01
6.47	25.13	4.00	2.93	2.14	−0.07
12.11	25.13	4.00	1.57	4.01	−0.19
18.03	25.13	4.00	1.05	5.97	−0.13
20.07	20.74	3.30	0.78	8.05	−0.09
20.08	16.34	2.60	0.61	10.22	−0.12
20.07	13.82	2.20	0.52	12.08	−0.13
20.08	11.93	1.90	0.45	14.00	−0.12
20.07	10.68	1.70	0.40	15.65	−0.15
20.08	9.43	1.50	0.35	17.72	−0.17
20.06	8.17	1.30	0.31	20.44	−0.14
20.06	7.54	1.20	0.28	22.14	−0.19
20.06	6.91	1.10	0.26	24.16	−0.21
20.05	6.28	1.00	0.24	26.55	−0.23
20.06	5.66	0.90	0.21	29.51	−0.29
20.04	5.03	0.80	0.19	33.18	−0.20
20.02	4.40	0.70	0.17	37.88	−0.42
20.04	3.77	0.60	0.14	44.23	−0.53

Table H.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

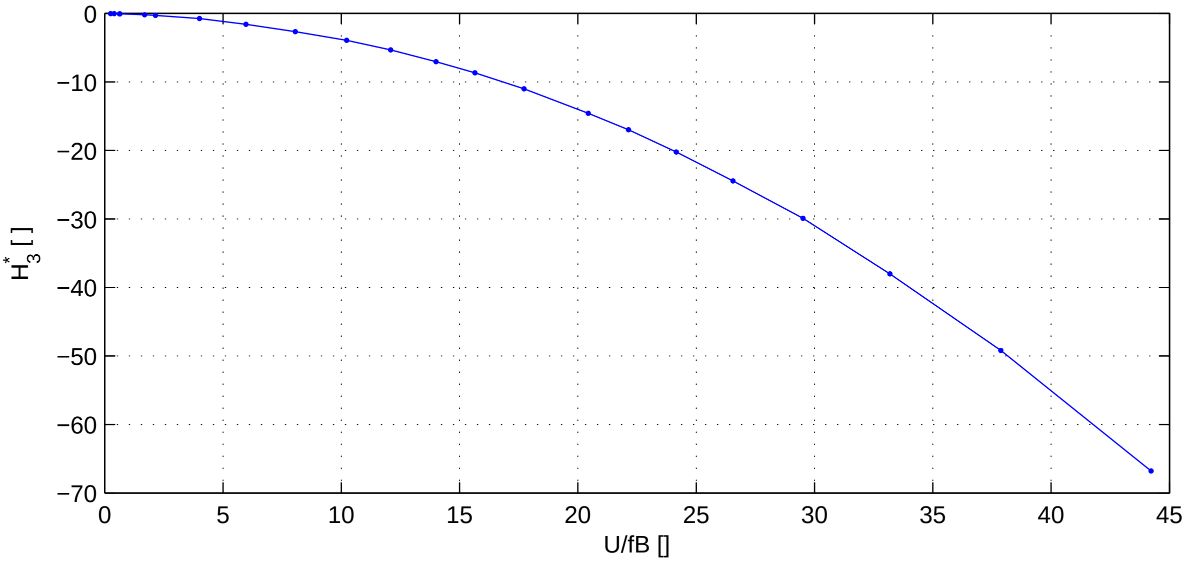


Figure H.3: H^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_3
0.75	25.13	4.00	25.42	0.25	−0.06
1.19	25.13	4.00	15.91	0.39	−0.06
1.89	25.13	4.00	10.05	0.62	−0.08
1.94	25.13	4.00	9.79	0.64	−0.09
5.10	25.13	4.00	3.72	1.69	−0.21
6.47	25.13	4.00	2.93	2.14	−0.31
12.11	25.13	4.00	1.57	4.01	−0.78
18.03	25.13	4.00	1.05	5.97	−1.62
20.07	20.74	3.30	0.78	8.05	−2.66
20.08	16.34	2.60	0.61	10.22	−3.96
20.07	13.82	2.20	0.52	12.08	−5.36
20.08	11.93	1.90	0.45	14.00	−7.06
20.07	10.68	1.70	0.40	15.65	−8.69
20.08	9.43	1.50	0.35	17.72	−11.04
20.06	8.17	1.30	0.31	20.44	−14.60
20.06	7.54	1.20	0.28	22.14	−17.01
20.06	6.91	1.10	0.26	24.16	−20.25
20.05	6.28	1.00	0.24	26.55	−24.46
20.06	5.66	0.90	0.21	29.51	−29.91
20.04	5.03	0.80	0.19	33.18	−38.04
20.02	4.40	0.70	0.17	37.88	−49.21
20.04	3.77	0.60	0.14	44.23	−66.80

Table H.5: H^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

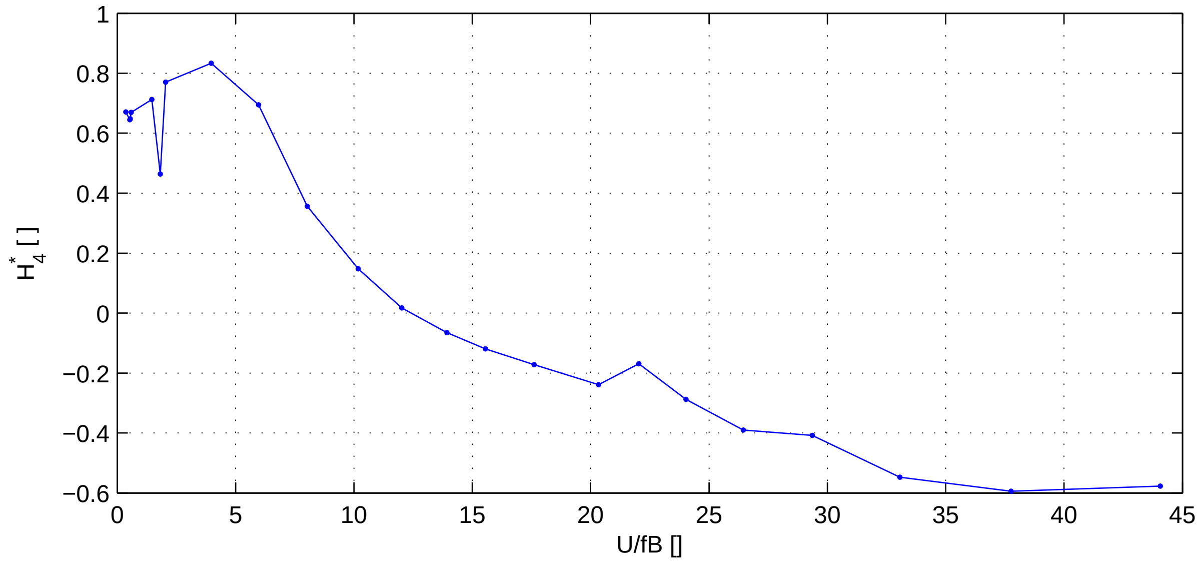


Figure H.4: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_4^*
1.10	25.13	4.00	17.17	0.37	0.67
1.60	25.13	4.00	11.88	0.53	0.65
1.67	25.13	4.00	11.37	0.55	0.65
1.78	25.13	4.00	10.67	0.59	0.67
4.42	25.13	4.00	4.30	1.46	0.71
4.52	20.74	3.30	3.46	1.81	0.46
6.18	25.13	4.00	3.07	2.05	0.77
11.97	25.13	4.00	1.58	3.96	0.83
18.03	25.13	4.00	1.05	5.97	0.69
20.00	20.74	3.30	0.78	8.03	0.36
19.99	16.34	2.60	0.62	10.18	0.15
19.97	13.82	2.20	0.52	12.02	0.02
19.97	11.93	1.90	0.45	13.93	−0.07
19.96	10.68	1.70	0.40	15.56	−0.12
19.95	9.43	1.50	0.36	17.61	−0.17
19.97	8.17	1.30	0.31	20.34	−0.24
19.96	7.54	1.20	0.29	22.03	−0.17
19.96	6.91	1.10	0.26	24.03	−0.29
19.97	6.28	1.00	0.24	26.45	−0.39
19.96	5.66	0.90	0.21	29.37	−0.41
19.97	5.03	0.80	0.19	33.06	−0.55
19.96	4.40	0.70	0.17	37.76	−0.59
19.96	3.77	0.60	0.14	44.07	−0.58

Table H.6: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

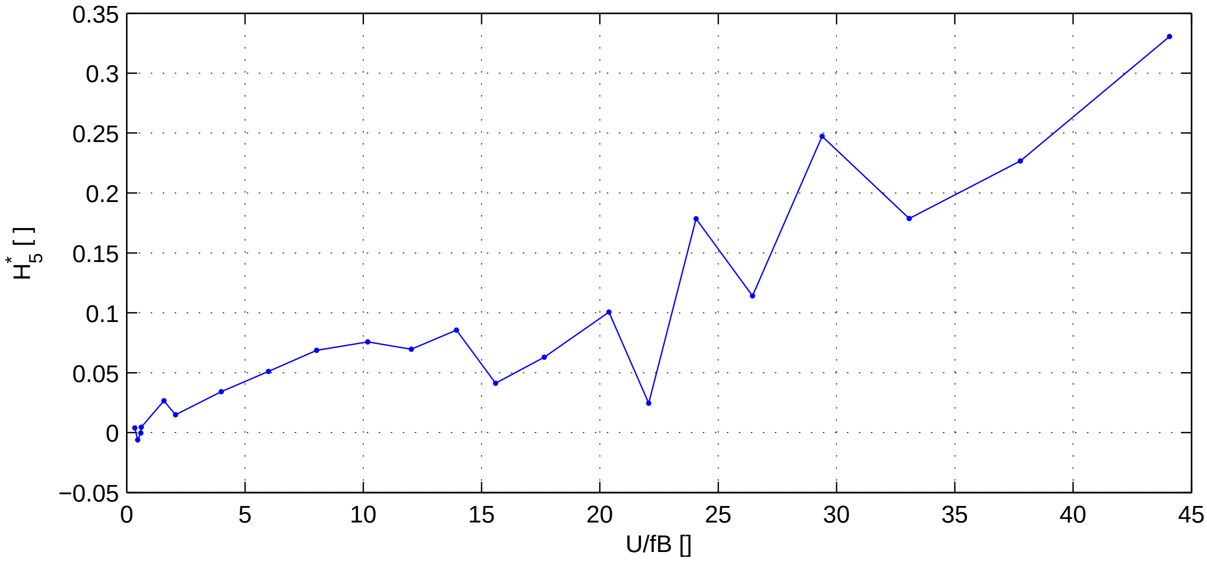


Figure H.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
1.04	25.13	4.00	18.28	0.34	0.00
1.40	25.13	4.00	13.59	0.46	−0.01
1.79	25.13	4.00	10.60	0.59	−0.00
1.85	25.13	4.00	10.26	0.61	0.00
4.76	25.13	4.00	3.99	1.57	0.03
6.22	25.13	4.00	3.05	2.06	0.01
12.06	25.13	4.00	1.57	3.99	0.03
18.09	25.13	4.00	1.05	5.99	0.05
20.00	20.74	3.30	0.78	8.03	0.07
20.00	16.34	2.60	0.62	10.19	0.08
19.98	13.82	2.20	0.52	12.03	0.07
19.99	11.93	1.90	0.45	13.94	0.09
20.00	10.68	1.70	0.40	15.59	0.04
19.99	9.43	1.50	0.36	17.65	0.06
20.00	8.17	1.30	0.31	20.38	0.10
19.98	7.54	1.20	0.28	22.06	0.02
19.99	6.91	1.10	0.26	24.06	0.18
19.97	6.28	1.00	0.24	26.45	0.11
19.98	5.66	0.90	0.21	29.40	0.25
19.98	5.03	0.80	0.19	33.07	0.18
19.96	4.40	0.70	0.17	37.77	0.23
19.97	3.77	0.60	0.14	44.08	0.33

Table H.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

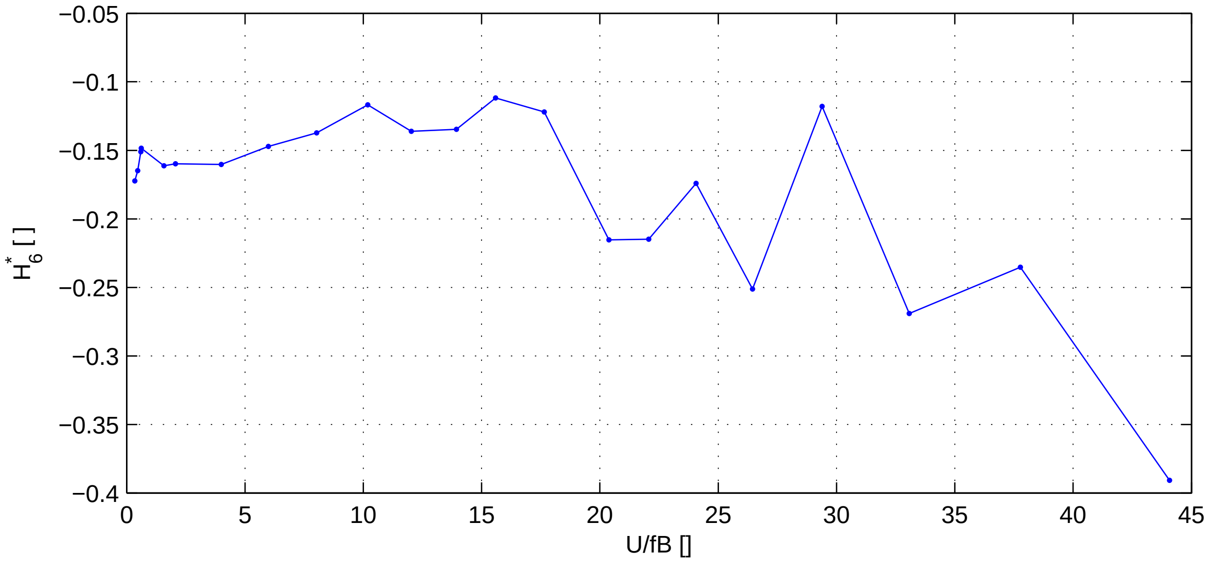


Figure H.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
1.04	25.13	4.00	18.28	0.34	−0.17
1.40	25.13	4.00	13.59	0.46	−0.16
1.79	25.13	4.00	10.60	0.59	−0.15
1.85	25.13	4.00	10.26	0.61	−0.15
4.76	25.13	4.00	3.99	1.57	−0.16
6.22	25.13	4.00	3.05	2.06	−0.16
12.06	25.13	4.00	1.57	3.99	−0.16
18.09	25.13	4.00	1.05	5.99	−0.15
20.00	20.74	3.30	0.78	8.03	−0.14
20.00	16.34	2.60	0.62	10.19	−0.12
19.98	13.82	2.20	0.52	12.03	−0.14
19.99	11.93	1.90	0.45	13.94	−0.13
20.00	10.68	1.70	0.40	15.59	−0.11
19.99	9.43	1.50	0.36	17.65	−0.12
20.00	8.17	1.30	0.31	20.38	−0.22
19.98	7.54	1.20	0.28	22.06	−0.21
19.99	6.91	1.10	0.26	24.06	−0.17
19.97	6.28	1.00	0.24	26.45	−0.25
19.98	5.66	0.90	0.21	29.40	−0.12
19.98	5.03	0.80	0.19	33.07	−0.27
19.96	4.40	0.70	0.17	37.77	−0.24
19.97	3.77	0.60	0.14	44.08	−0.39

Table H.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

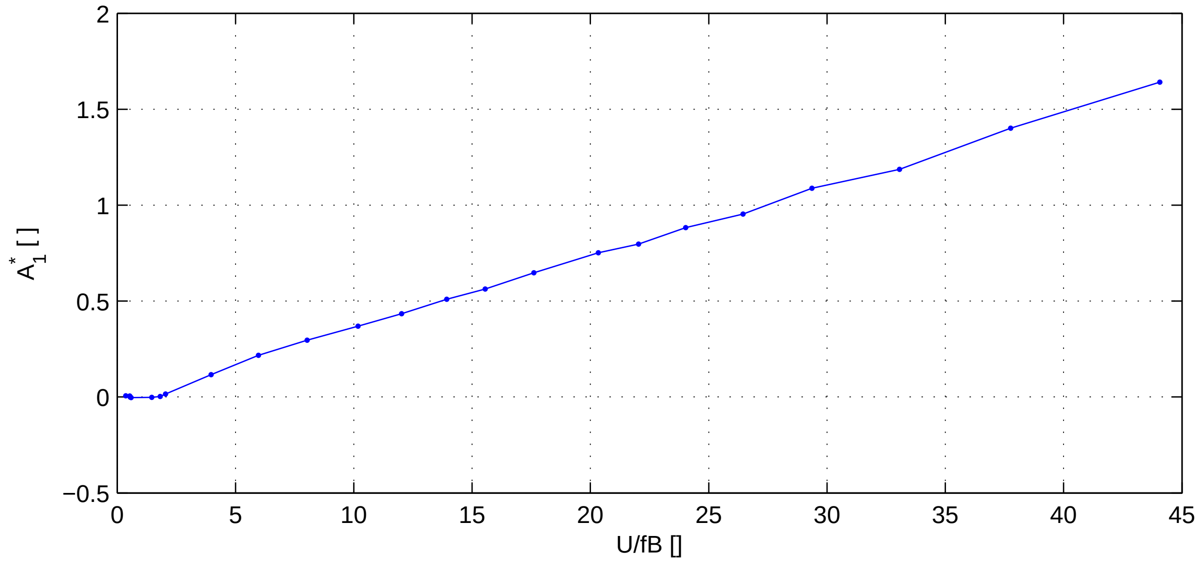


Figure H.7: A^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_1
1.10	25.13	4.00	17.17	0.37	0.01
1.60	25.13	4.00	11.88	0.53	0.00
1.67	25.13	4.00	11.37	0.55	−0.00
1.78	25.13	4.00	10.67	0.59	−0.00
4.42	25.13	4.00	4.30	1.46	−0.00
4.52	20.74	3.30	3.46	1.81	0.00
6.18	25.13	4.00	3.07	2.05	0.02
11.97	25.13	4.00	1.58	3.96	0.12
18.03	25.13	4.00	1.05	5.97	0.22
20.00	20.74	3.30	0.78	8.03	0.30
19.99	16.34	2.60	0.62	10.18	0.37
19.97	13.82	2.20	0.52	12.02	0.43
19.97	11.93	1.90	0.45	13.93	0.51
19.96	10.68	1.70	0.40	15.56	0.56
19.95	9.43	1.50	0.36	17.61	0.65
19.97	8.17	1.30	0.31	20.34	0.75
19.96	7.54	1.20	0.29	22.03	0.80
19.96	6.91	1.10	0.26	24.03	0.88
19.97	6.28	1.00	0.24	26.45	0.95
19.96	5.66	0.90	0.21	29.37	1.09
19.97	5.03	0.80	0.19	33.06	1.19
19.96	4.40	0.70	0.17	37.76	1.40
19.96	3.77	0.60	0.14	44.07	1.64

Table H.9: A^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

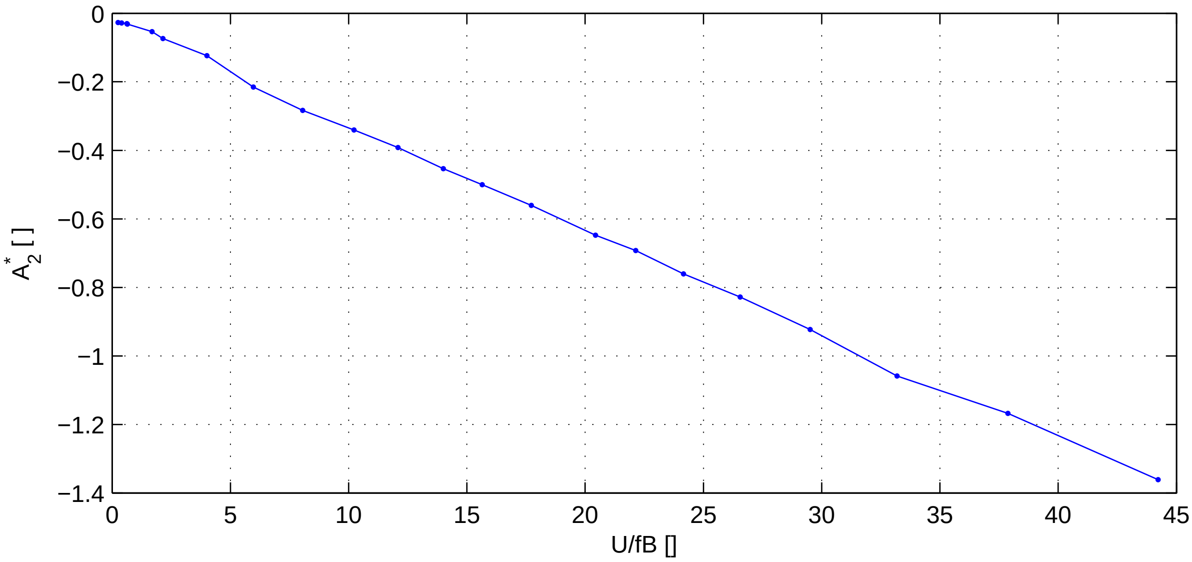


Figure H.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
0.75	25.13	4.00	25.42	0.25	−0.03
1.19	25.13	4.00	15.91	0.39	−0.03
1.89	25.13	4.00	10.05	0.62	−0.03
1.94	25.13	4.00	9.79	0.64	−0.03
5.10	25.13	4.00	3.72	1.69	−0.05
6.47	25.13	4.00	2.93	2.14	−0.07
12.11	25.13	4.00	1.57	4.01	−0.12
18.03	25.13	4.00	1.05	5.97	−0.22
20.07	20.74	3.30	0.78	8.05	−0.28
20.08	16.34	2.60	0.61	10.22	−0.34
20.07	13.82	2.20	0.52	12.08	−0.39
20.08	11.93	1.90	0.45	14.00	−0.45
20.07	10.68	1.70	0.40	15.65	−0.50
20.08	9.43	1.50	0.35	17.72	−0.56
20.06	8.17	1.30	0.31	20.44	−0.65
20.06	7.54	1.20	0.28	22.14	−0.69
20.06	6.91	1.10	0.26	24.16	−0.76
20.05	6.28	1.00	0.24	26.55	−0.83
20.06	5.66	0.90	0.21	29.51	−0.92
20.04	5.03	0.80	0.19	33.18	−1.06
20.02	4.40	0.70	0.17	37.88	−1.17
20.04	3.77	0.60	0.14	44.23	−1.36

Table H.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

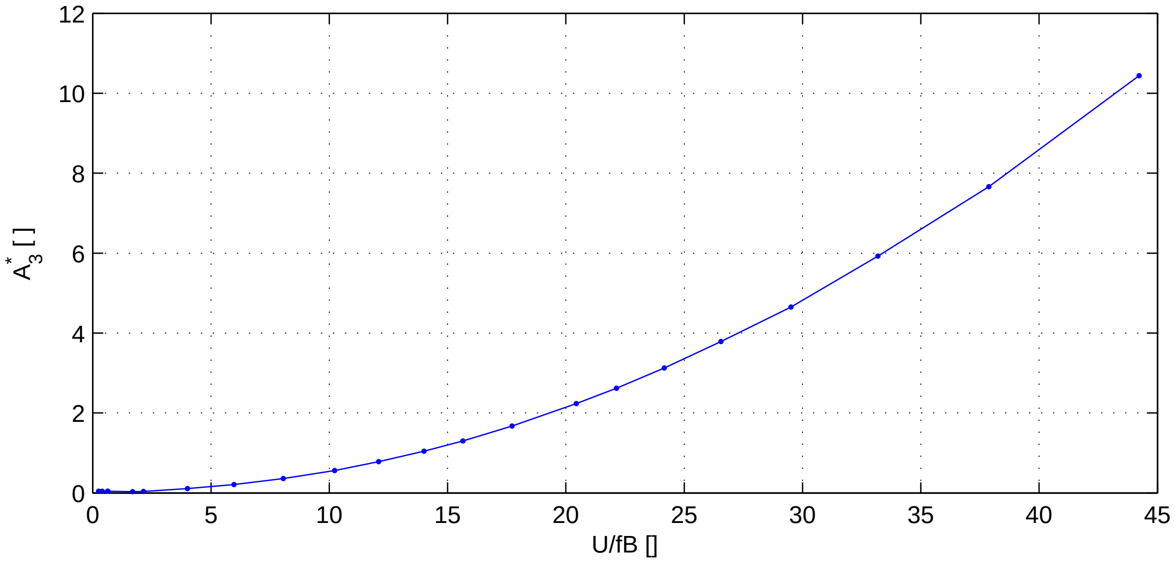


Figure H.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
0.75	25.13	4.00	25.42	0.25	0.04
1.19	25.13	4.00	15.91	0.39	0.04
1.89	25.13	4.00	10.05	0.62	0.04
1.94	25.13	4.00	9.79	0.64	0.04
5.10	25.13	4.00	3.72	1.69	0.03
6.47	25.13	4.00	2.93	2.14	0.04
12.11	25.13	4.00	1.57	4.01	0.11
18.03	25.13	4.00	1.05	5.97	0.21
20.07	20.74	3.30	0.78	8.05	0.36
20.08	16.34	2.60	0.61	10.22	0.56
20.07	13.82	2.20	0.52	12.08	0.78
20.08	11.93	1.90	0.45	14.00	1.05
20.07	10.68	1.70	0.40	15.65	1.30
20.08	9.43	1.50	0.35	17.72	1.67
20.06	8.17	1.30	0.31	20.44	2.23
20.06	7.54	1.20	0.28	22.14	2.62
20.06	6.91	1.10	0.26	24.16	3.12
20.05	6.28	1.00	0.24	26.55	3.79
20.06	5.66	0.90	0.21	29.51	4.65
20.04	5.03	0.80	0.19	33.18	5.92
20.02	4.40	0.70	0.17	37.88	7.66
20.04	3.77	0.60	0.14	44.23	10.44

Table H.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

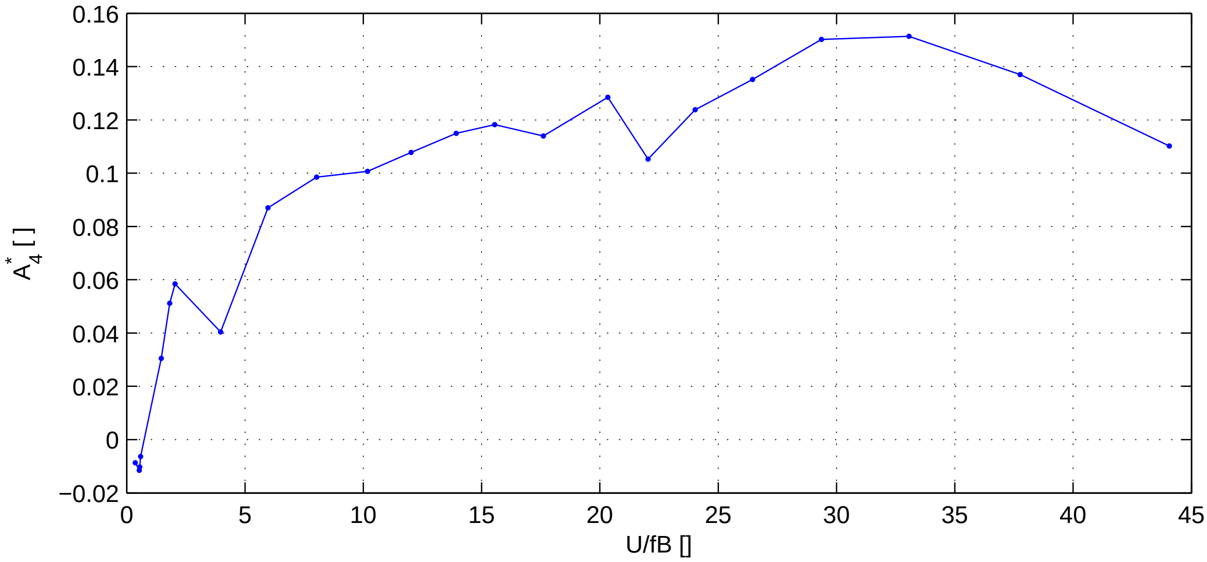


Figure H.10: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_4^*
1.10	25.13	4.00	17.17	0.37	−0.01
1.60	25.13	4.00	11.88	0.53	−0.01
1.67	25.13	4.00	11.37	0.55	−0.01
1.78	25.13	4.00	10.67	0.59	−0.01
4.42	25.13	4.00	4.30	1.46	0.03
4.52	20.74	3.30	3.46	1.81	0.05
6.18	25.13	4.00	3.07	2.05	0.06
11.97	25.13	4.00	1.58	3.96	0.04
18.03	25.13	4.00	1.05	5.97	0.09
20.00	20.74	3.30	0.78	8.03	0.10
19.99	16.34	2.60	0.62	10.18	0.10
19.97	13.82	2.20	0.52	12.02	0.11
19.97	11.93	1.90	0.45	13.93	0.11
19.96	10.68	1.70	0.40	15.56	0.12
19.95	9.43	1.50	0.36	17.61	0.11
19.97	8.17	1.30	0.31	20.34	0.13
19.96	7.54	1.20	0.29	22.03	0.11
19.96	6.91	1.10	0.26	24.03	0.12
19.97	6.28	1.00	0.24	26.45	0.14
19.96	5.66	0.90	0.21	29.37	0.15
19.97	5.03	0.80	0.19	33.06	0.15
19.96	4.40	0.70	0.17	37.76	0.14
19.96	3.77	0.60	0.14	44.07	0.11

Table H.12: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

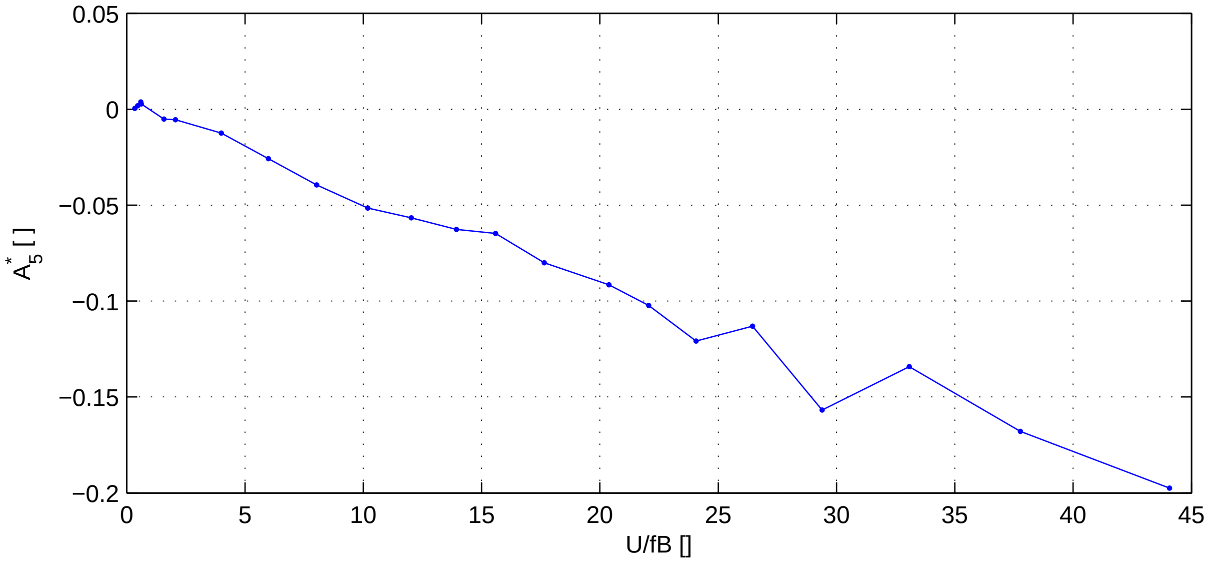


Figure H.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
1.04	25.13	4.00	18.28	0.34	0.00
1.40	25.13	4.00	13.59	0.46	0.00
1.79	25.13	4.00	10.60	0.59	0.00
1.85	25.13	4.00	10.26	0.61	0.00
4.76	25.13	4.00	3.99	1.57	−0.01
6.22	25.13	4.00	3.05	2.06	−0.01
12.06	25.13	4.00	1.57	3.99	−0.01
18.09	25.13	4.00	1.05	5.99	−0.03
20.00	20.74	3.30	0.78	8.03	−0.04
20.00	16.34	2.60	0.62	10.19	−0.05
19.98	13.82	2.20	0.52	12.03	−0.06
19.99	11.93	1.90	0.45	13.94	−0.06
20.00	10.68	1.70	0.40	15.59	−0.06
19.99	9.43	1.50	0.36	17.65	−0.08
20.00	8.17	1.30	0.31	20.38	−0.09
19.98	7.54	1.20	0.28	22.06	−0.10
19.99	6.91	1.10	0.26	24.06	−0.12
19.97	6.28	1.00	0.24	26.45	−0.11
19.98	5.66	0.90	0.21	29.40	−0.16
19.98	5.03	0.80	0.19	33.07	−0.13
19.96	4.40	0.70	0.17	37.77	−0.17
19.97	3.77	0.60	0.14	44.08	−0.20

Table H.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

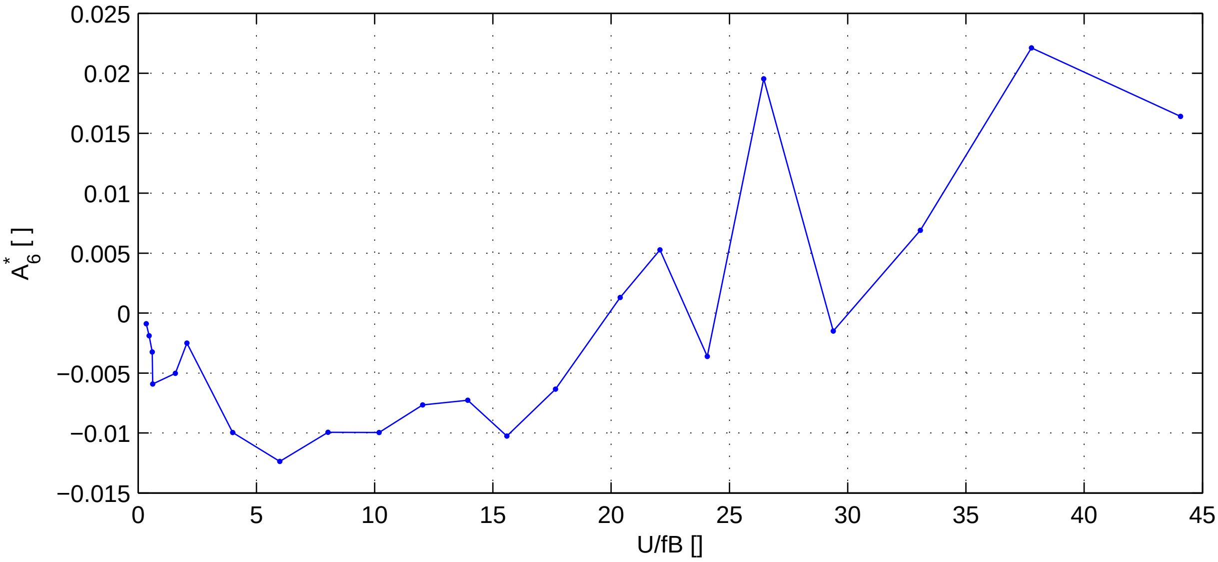


Figure H.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
1.04	25.13	4.00	18.28	0.34	−0.00
1.40	25.13	4.00	13.59	0.46	−0.00
1.79	25.13	4.00	10.60	0.59	−0.00
1.85	25.13	4.00	10.26	0.61	−0.01
4.76	25.13	4.00	3.99	1.57	−0.01
6.22	25.13	4.00	3.05	2.06	−0.00
12.06	25.13	4.00	1.57	3.99	−0.01
18.09	25.13	4.00	1.05	5.99	−0.01
20.00	20.74	3.30	0.78	8.03	−0.01
20.00	16.34	2.60	0.62	10.19	−0.01
19.98	13.82	2.20	0.52	12.03	−0.01
19.99	11.93	1.90	0.45	13.94	−0.01
20.00	10.68	1.70	0.40	15.59	−0.01
19.99	9.43	1.50	0.36	17.65	−0.01
20.00	8.17	1.30	0.31	20.38	0.00
19.98	7.54	1.20	0.28	22.06	0.01
19.99	6.91	1.10	0.26	24.06	−0.00
19.97	6.28	1.00	0.24	26.45	0.02
19.98	5.66	0.90	0.21	29.40	−0.00
19.98	5.03	0.80	0.19	33.07	0.01
19.96	4.40	0.70	0.17	37.77	0.02
19.97	3.77	0.60	0.14	44.08	0.02

Table H.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:16:01

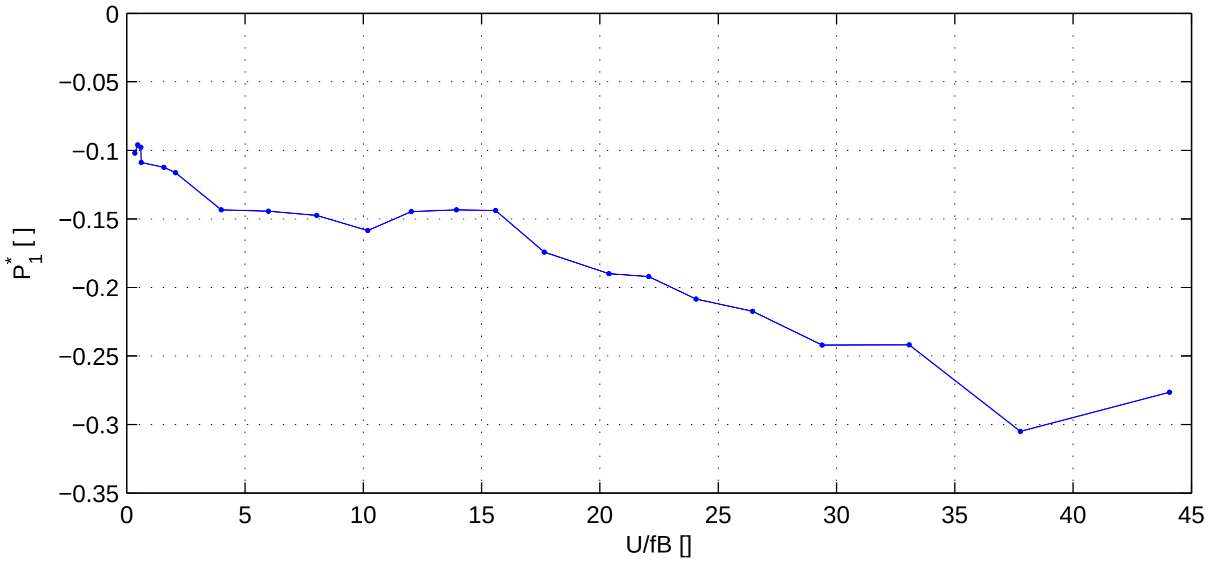


Figure H.13: P^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_1
1.04	25.13	4.00	18.28	0.34	−0.10
1.40	25.13	4.00	13.59	0.46	−0.10
1.79	25.13	4.00	10.60	0.59	−0.10
1.85	25.13	4.00	10.26	0.61	−0.11
4.76	25.13	4.00	3.99	1.57	−0.11
6.22	25.13	4.00	3.05	2.06	−0.12
12.06	25.13	4.00	1.57	3.99	−0.14
18.09	25.13	4.00	1.05	5.99	−0.14
20.00	20.74	3.30	0.78	8.03	−0.15
20.00	16.34	2.60	0.62	10.19	−0.16
19.98	13.82	2.20	0.52	12.03	−0.14
19.99	11.93	1.90	0.45	13.94	−0.14
20.00	10.68	1.70	0.40	15.59	−0.14
19.99	9.43	1.50	0.36	17.65	−0.17
20.00	8.17	1.30	0.31	20.38	−0.19
19.98	7.54	1.20	0.28	22.06	−0.19
19.99	6.91	1.10	0.26	24.06	−0.21
19.97	6.28	1.00	0.24	26.45	−0.22
19.98	5.66	0.90	0.21	29.40	−0.24
19.98	5.03	0.80	0.19	33.07	−0.24
19.96	4.40	0.70	0.17	37.77	−0.31
19.97	3.77	0.60	0.14	44.08	−0.28

Table H.15: P^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

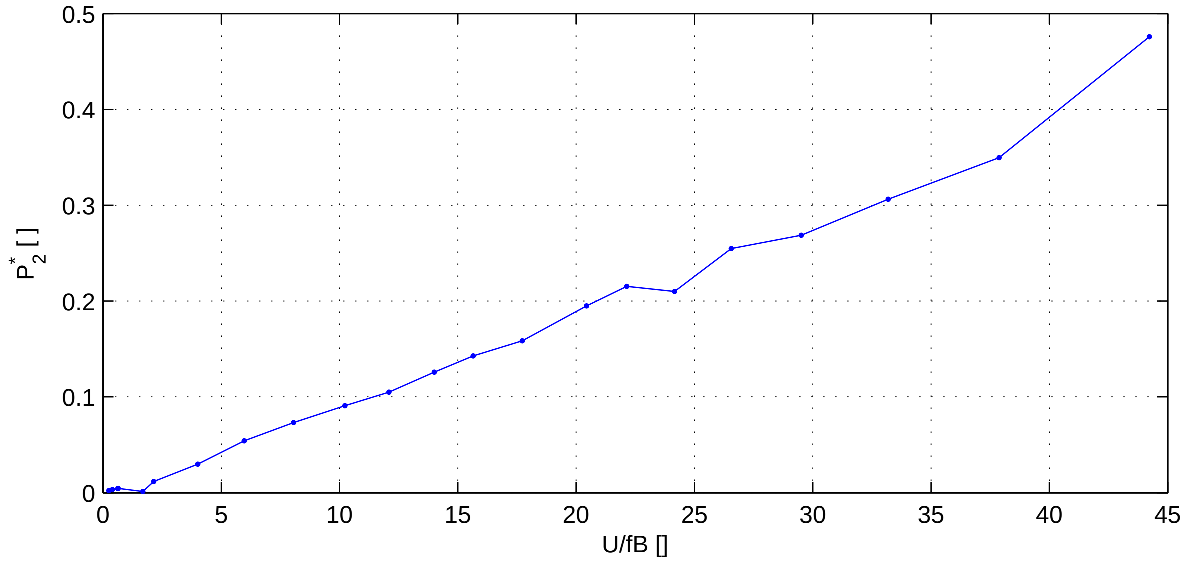


Figure H.14: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_2
0.75	25.13	4.00	25.42	0.25	0.00
1.19	25.13	4.00	15.91	0.39	0.00
1.89	25.13	4.00	10.05	0.62	0.00
1.94	25.13	4.00	9.79	0.64	0.00
5.10	25.13	4.00	3.72	1.69	0.00
6.47	25.13	4.00	2.93	2.14	0.01
12.11	25.13	4.00	1.57	4.01	0.03
18.03	25.13	4.00	1.05	5.97	0.05
20.07	20.74	3.30	0.78	8.05	0.07
20.08	16.34	2.60	0.61	10.22	0.09
20.07	13.82	2.20	0.52	12.08	0.11
20.08	11.93	1.90	0.45	14.00	0.13
20.07	10.68	1.70	0.40	15.65	0.14
20.08	9.43	1.50	0.35	17.72	0.16
20.06	8.17	1.30	0.31	20.44	0.19
20.06	7.54	1.20	0.28	22.14	0.22
20.06	6.91	1.10	0.26	24.16	0.21
20.05	6.28	1.00	0.24	26.55	0.25
20.06	5.66	0.90	0.21	29.51	0.27
20.04	5.03	0.80	0.19	33.18	0.31
20.02	4.40	0.70	0.17	37.88	0.35
20.04	3.77	0.60	0.14	44.23	0.48

Table H.16: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

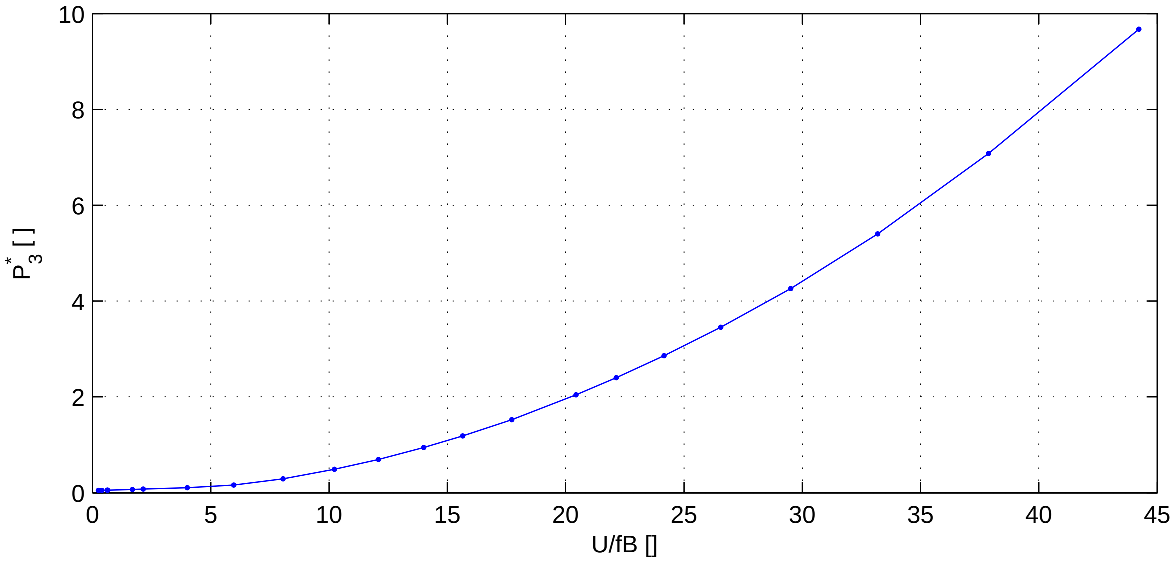


Figure H.15: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_3
0.75	25.13	4.00	25.42	0.25	0.05
1.19	25.13	4.00	15.91	0.39	0.05
1.89	25.13	4.00	10.05	0.62	0.05
1.94	25.13	4.00	9.79	0.64	0.05
5.10	25.13	4.00	3.72	1.69	0.07
6.47	25.13	4.00	2.93	2.14	0.08
12.11	25.13	4.00	1.57	4.01	0.10
18.03	25.13	4.00	1.05	5.97	0.16
20.07	20.74	3.30	0.78	8.05	0.29
20.08	16.34	2.60	0.61	10.22	0.49
20.07	13.82	2.20	0.52	12.08	0.69
20.08	11.93	1.90	0.45	14.00	0.95
20.07	10.68	1.70	0.40	15.65	1.19
20.08	9.43	1.50	0.35	17.72	1.52
20.06	8.17	1.30	0.31	20.44	2.04
20.06	7.54	1.20	0.28	22.14	2.40
20.06	6.91	1.10	0.26	24.16	2.86
20.05	6.28	1.00	0.24	26.55	3.45
20.06	5.66	0.90	0.21	29.51	4.26
20.04	5.03	0.80	0.19	33.18	5.40
20.02	4.40	0.70	0.17	37.88	7.08
20.04	3.77	0.60	0.14	44.23	9.67

Table H.17: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

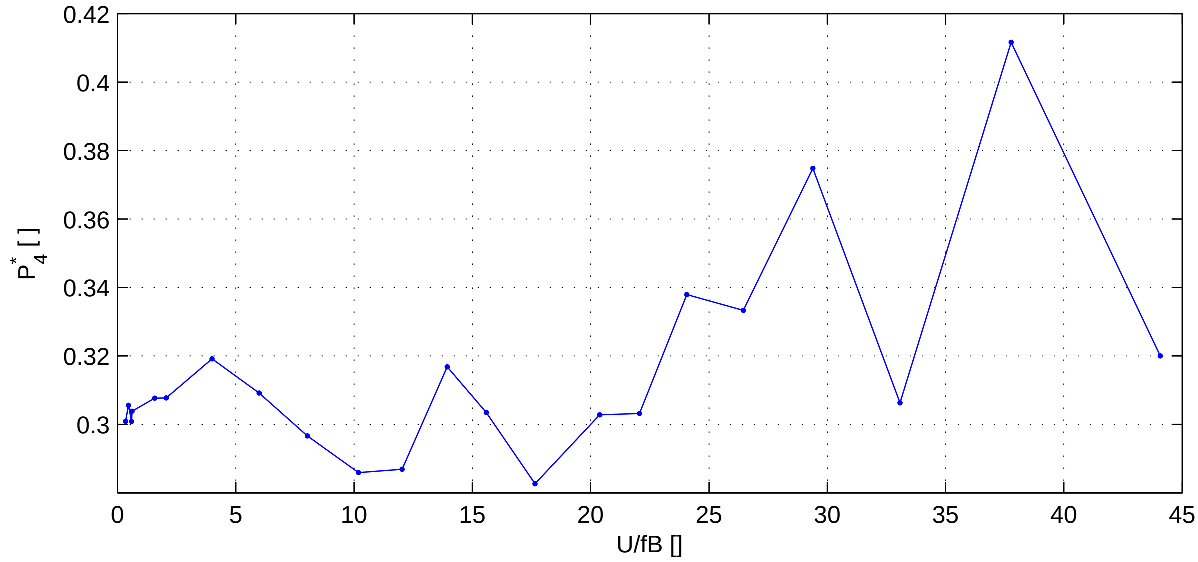


Figure H.16: P^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_4
1.04	25.13	4.00	18.28	0.34	0.30
1.40	25.13	4.00	13.59	0.46	0.31
1.79	25.13	4.00	10.60	0.59	0.30
1.85	25.13	4.00	10.26	0.61	0.30
4.76	25.13	4.00	3.99	1.57	0.31
6.22	25.13	4.00	3.05	2.06	0.31
12.06	25.13	4.00	1.57	3.99	0.32
18.09	25.13	4.00	1.05	5.99	0.31
20.00	20.74	3.30	0.78	8.03	0.30
20.00	16.34	2.60	0.62	10.19	0.29
19.98	13.82	2.20	0.52	12.03	0.29
19.99	11.93	1.90	0.45	13.94	0.32
20.00	10.68	1.70	0.40	15.59	0.30
19.99	9.43	1.50	0.36	17.65	0.28
20.00	8.17	1.30	0.31	20.38	0.30
19.98	7.54	1.20	0.28	22.06	0.30
19.99	6.91	1.10	0.26	24.06	0.34
19.97	6.28	1.00	0.24	26.45	0.33
19.98	5.66	0.90	0.21	29.40	0.37
19.98	5.03	0.80	0.19	33.07	0.31
19.96	4.40	0.70	0.17	37.77	0.41
19.97	3.77	0.60	0.14	44.08	0.32

Table H.18: P^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

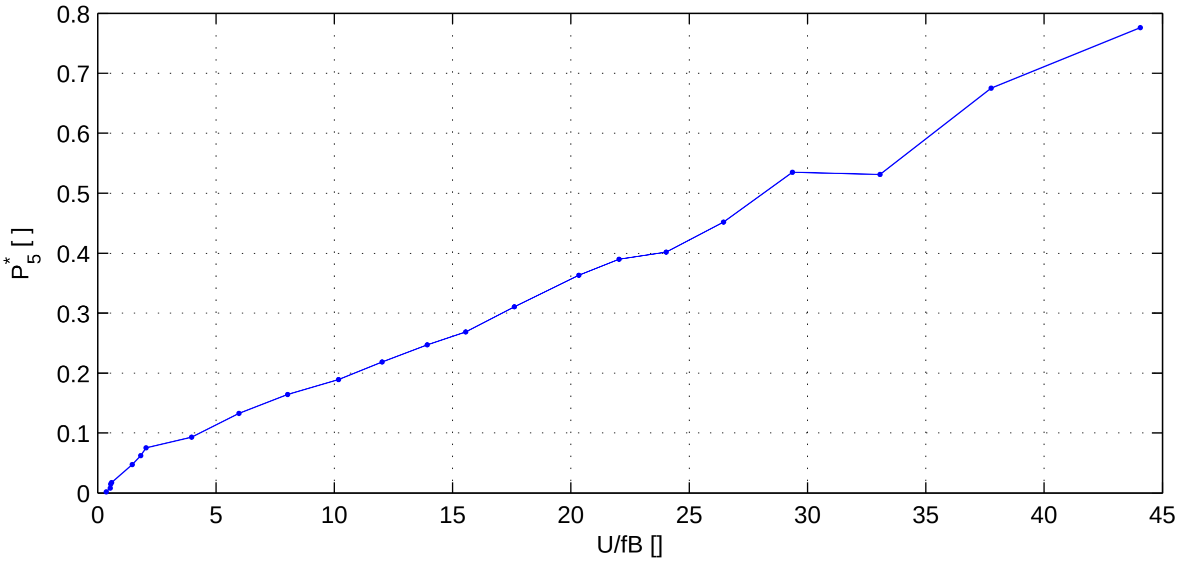


Figure H.17: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_5
1.10	25.13	4.00	17.17	0.37	0.00
1.60	25.13	4.00	11.88	0.53	0.01
1.67	25.13	4.00	11.37	0.55	0.01
1.78	25.13	4.00	10.67	0.59	0.02
4.42	25.13	4.00	4.30	1.46	0.05
4.52	20.74	3.30	3.46	1.81	0.06
6.18	25.13	4.00	3.07	2.05	0.07
11.97	25.13	4.00	1.58	3.96	0.09
18.03	25.13	4.00	1.05	5.97	0.13
20.00	20.74	3.30	0.78	8.03	0.16
19.99	16.34	2.60	0.62	10.18	0.19
19.97	13.82	2.20	0.52	12.02	0.22
19.97	11.93	1.90	0.45	13.93	0.25
19.96	10.68	1.70	0.40	15.56	0.27
19.95	9.43	1.50	0.36	17.61	0.31
19.97	8.17	1.30	0.31	20.34	0.36
19.96	7.54	1.20	0.29	22.03	0.39
19.96	6.91	1.10	0.26	24.03	0.40
19.97	6.28	1.00	0.24	26.45	0.45
19.96	5.66	0.90	0.21	29.37	0.53
19.97	5.03	0.80	0.19	33.06	0.53
19.96	4.40	0.70	0.17	37.76	0.68
19.96	3.77	0.60	0.14	44.07	0.78

Table H.19: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

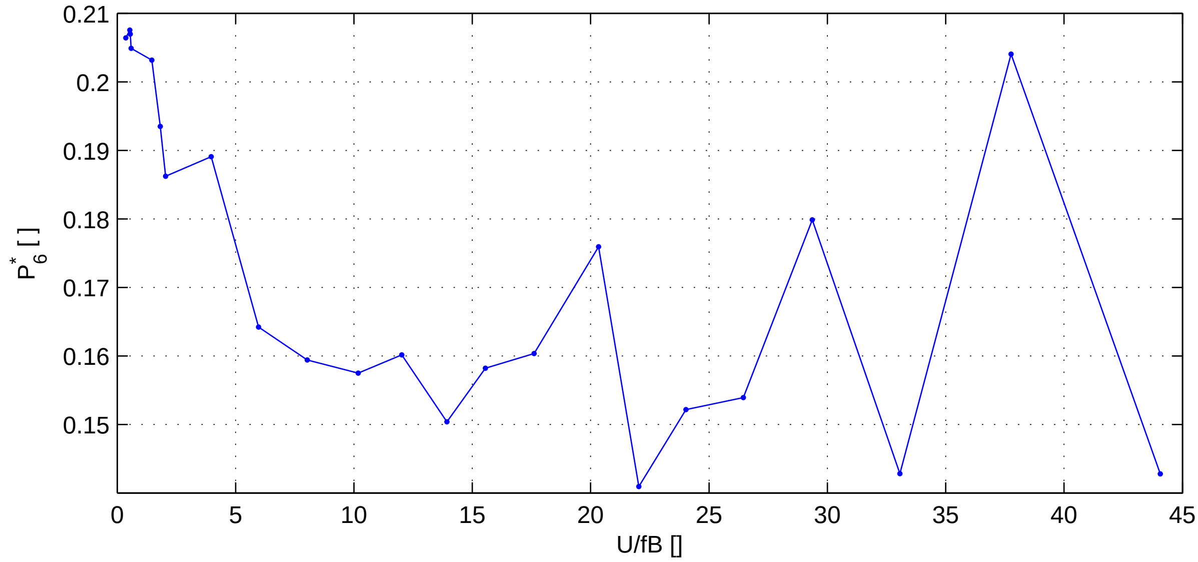


Figure H.18: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_6
1.10	25.13	4.00	17.17	0.37	0.21
1.60	25.13	4.00	11.88	0.53	0.21
1.67	25.13	4.00	11.37	0.55	0.21
1.78	25.13	4.00	10.67	0.59	0.20
4.42	25.13	4.00	4.30	1.46	0.20
4.52	20.74	3.30	3.46	1.81	0.19
6.18	25.13	4.00	3.07	2.05	0.19
11.97	25.13	4.00	1.58	3.96	0.19
18.03	25.13	4.00	1.05	5.97	0.16
20.00	20.74	3.30	0.78	8.03	0.16
19.99	16.34	2.60	0.62	10.18	0.16
19.97	13.82	2.20	0.52	12.02	0.16
19.97	11.93	1.90	0.45	13.93	0.15
19.96	10.68	1.70	0.40	15.56	0.16
19.95	9.43	1.50	0.36	17.61	0.16
19.97	8.17	1.30	0.31	20.34	0.18
19.96	7.54	1.20	0.29	22.03	0.14
19.96	6.91	1.10	0.26	24.03	0.15
19.97	6.28	1.00	0.24	26.45	0.15
19.96	5.66	0.90	0.21	29.37	0.18
19.97	5.03	0.80	0.19	33.06	0.14
19.96	4.40	0.70	0.17	37.76	0.20
19.96	3.77	0.60	0.14	44.07	0.14

Table H.20: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\,(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\,\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\,(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\,\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\,(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\,\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

Formula H.3: Equation of Motion (Stretto di Messina. Ref. [5].)

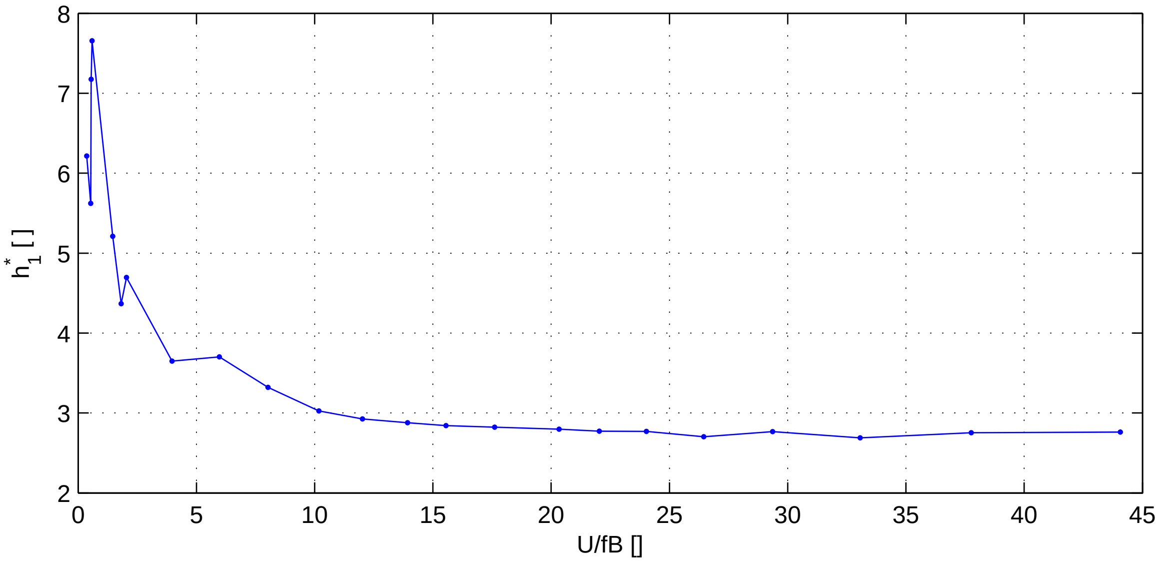


Figure H.19: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_1^*
1.10	25.13	4.00	17.17	0.37	6.21
1.60	25.13	4.00	11.88	0.53	5.62
1.67	25.13	4.00	11.37	0.55	7.18
1.78	25.13	4.00	10.67	0.59	7.66
4.42	25.13	4.00	4.30	1.46	5.21
4.52	20.74	3.30	3.46	1.81	4.37
6.18	25.13	4.00	3.07	2.05	4.70
11.97	25.13	4.00	1.58	3.96	3.65
18.03	25.13	4.00	1.05	5.97	3.70
20.00	20.74	3.30	0.78	8.03	3.32
19.99	16.34	2.60	0.62	10.18	3.03
19.97	13.82	2.20	0.52	12.02	2.93
19.97	11.93	1.90	0.45	13.93	2.88
19.96	10.68	1.70	0.40	15.56	2.84
19.95	9.43	1.50	0.36	17.61	2.82
19.97	8.17	1.30	0.31	20.34	2.80
19.96	7.54	1.20	0.29	22.03	2.77
19.96	6.91	1.10	0.26	24.03	2.77
19.97	6.28	1.00	0.24	26.45	2.70
19.96	5.66	0.90	0.21	29.37	2.77
19.97	5.03	0.80	0.19	33.06	2.69
19.96	4.40	0.70	0.17	37.76	2.75
19.96	3.77	0.60	0.14	44.07	2.76

Table H.21: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

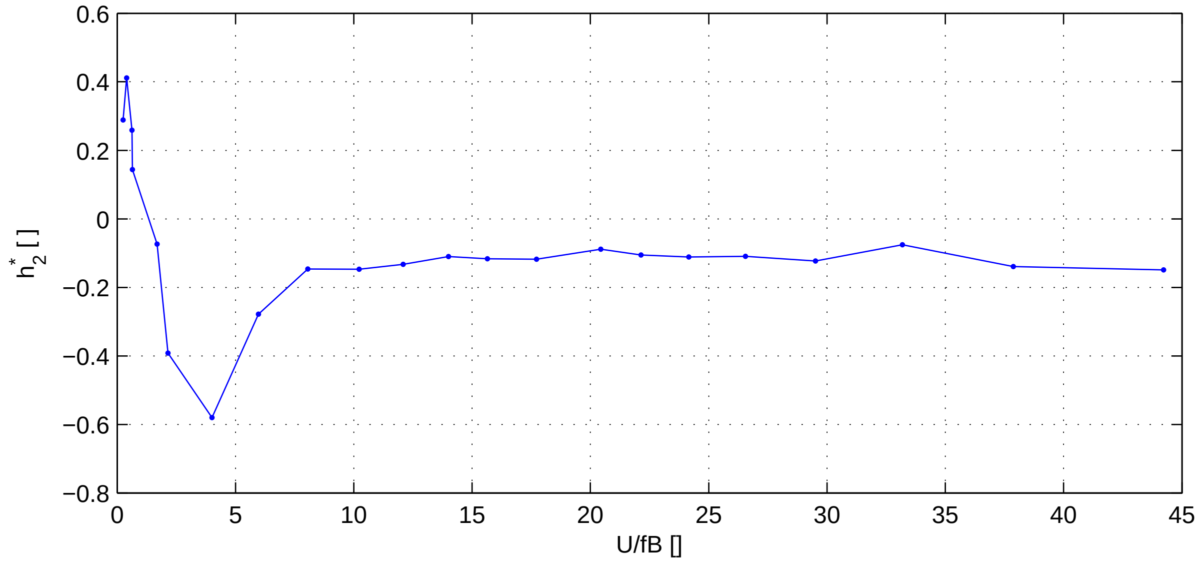


Figure H.20: h^*_2 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_2
0.75	25.13	4.00	25.42	0.25	0.29
1.19	25.13	4.00	15.91	0.39	0.41
1.89	25.13	4.00	10.05	0.62	0.26
1.94	25.13	4.00	9.79	0.64	0.14
5.10	25.13	4.00	3.72	1.69	−0.07
6.47	25.13	4.00	2.93	2.14	−0.39
12.11	25.13	4.00	1.57	4.01	−0.58
18.03	25.13	4.00	1.05	5.97	−0.28
20.07	20.74	3.30	0.78	8.05	−0.15
20.08	16.34	2.60	0.61	10.22	−0.15
20.07	13.82	2.20	0.52	12.08	−0.13
20.08	11.93	1.90	0.45	14.00	−0.11
20.07	10.68	1.70	0.40	15.65	−0.12
20.08	9.43	1.50	0.35	17.72	−0.12
20.06	8.17	1.30	0.31	20.44	−0.09
20.06	7.54	1.20	0.28	22.14	−0.11
20.06	6.91	1.10	0.26	24.16	−0.11
20.05	6.28	1.00	0.24	26.55	−0.11
20.06	5.66	0.90	0.21	29.51	−0.12
20.04	5.03	0.80	0.19	33.18	−0.08
20.02	4.40	0.70	0.17	37.88	−0.14
20.04	3.77	0.60	0.14	44.23	−0.15

Table H.22: h^*_2 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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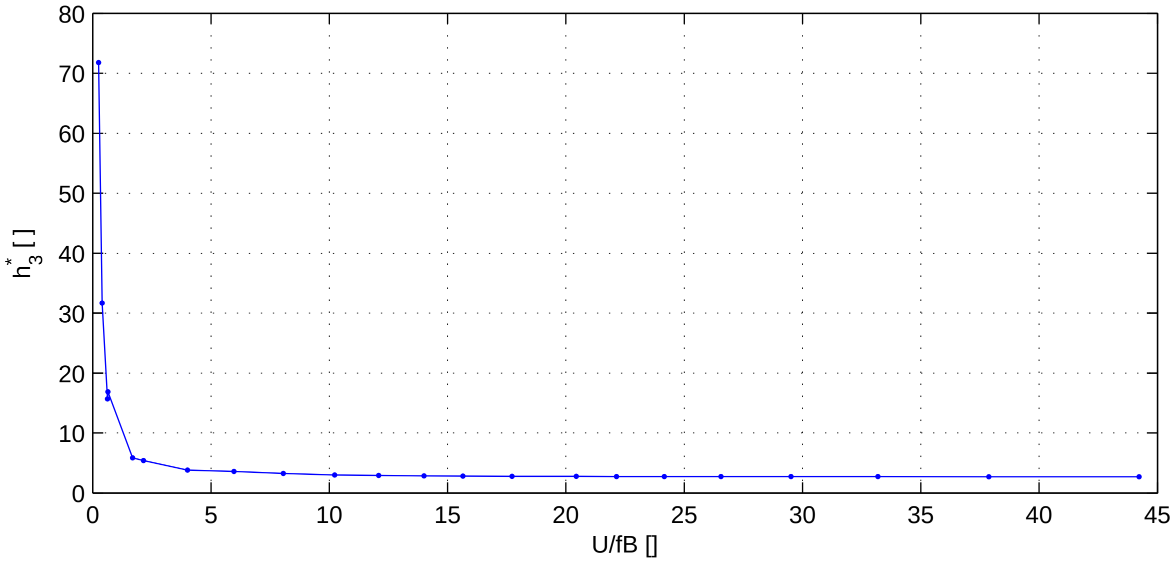


Figure H.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
0.75	25.13	4.00	25.42	0.25	71.77
1.19	25.13	4.00	15.91	0.39	31.66
1.89	25.13	4.00	10.05	0.62	15.68
1.94	25.13	4.00	9.79	0.64	16.87
5.10	25.13	4.00	3.72	1.69	5.86
6.47	25.13	4.00	2.93	2.14	5.40
12.11	25.13	4.00	1.57	4.01	3.82
18.03	25.13	4.00	1.05	5.97	3.58
20.07	20.74	3.30	0.78	8.05	3.24
20.08	16.34	2.60	0.61	10.22	2.99
20.07	13.82	2.20	0.52	12.08	2.90
20.08	11.93	1.90	0.45	14.00	2.84
20.07	10.68	1.70	0.40	15.65	2.80
20.08	9.43	1.50	0.35	17.72	2.77
20.06	8.17	1.30	0.31	20.44	2.76
20.06	7.54	1.20	0.28	22.14	2.74
20.06	6.91	1.10	0.26	24.16	2.74
20.05	6.28	1.00	0.24	26.55	2.74
20.06	5.66	0.90	0.21	29.51	2.71
20.04	5.03	0.80	0.19	33.18	2.73
20.02	4.40	0.70	0.17	37.88	2.71
20.04	3.77	0.60	0.14	44.23	2.70

Table H.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

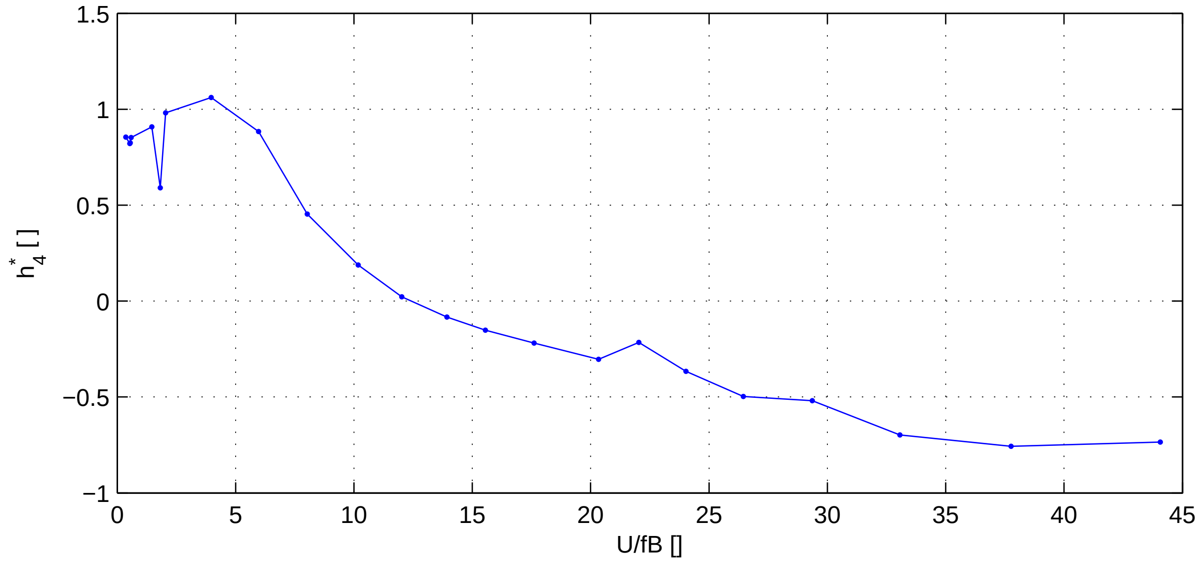


Figure H.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
1.10	25.13	4.00	17.17	0.37	0.85
1.60	25.13	4.00	11.88	0.53	0.82
1.67	25.13	4.00	11.37	0.55	0.82
1.78	25.13	4.00	10.67	0.59	0.85
4.42	25.13	4.00	4.30	1.46	0.91
4.52	20.74	3.30	3.46	1.81	0.59
6.18	25.13	4.00	3.07	2.05	0.98
11.97	25.13	4.00	1.58	3.96	1.06
18.03	25.13	4.00	1.05	5.97	0.88
20.00	20.74	3.30	0.78	8.03	0.45
19.99	16.34	2.60	0.62	10.18	0.19
19.97	13.82	2.20	0.52	12.02	0.02
19.97	11.93	1.90	0.45	13.93	−0.08
19.96	10.68	1.70	0.40	15.56	−0.15
19.95	9.43	1.50	0.36	17.61	−0.22
19.97	8.17	1.30	0.31	20.34	−0.30
19.96	7.54	1.20	0.29	22.03	−0.22
19.96	6.91	1.10	0.26	24.03	−0.37
19.97	6.28	1.00	0.24	26.45	−0.50
19.96	5.66	0.90	0.21	29.37	−0.52
19.97	5.03	0.80	0.19	33.06	−0.70
19.96	4.40	0.70	0.17	37.76	−0.76
19.96	3.77	0.60	0.14	44.07	−0.74

Table H.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

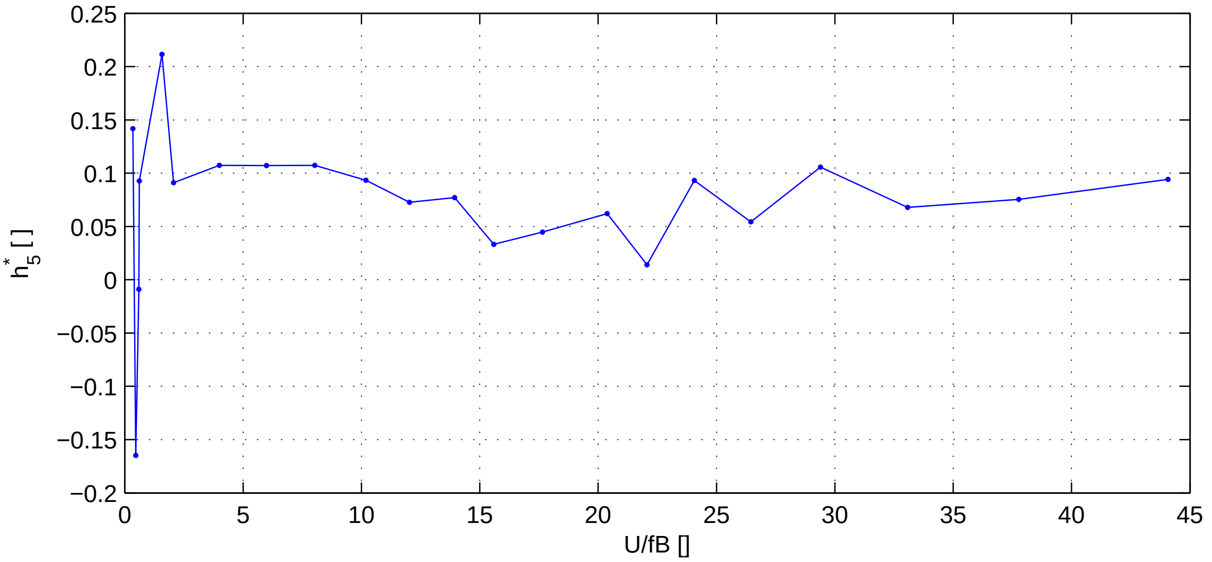


Figure H.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
1.04	25.13	4.00	18.28	0.34	0.14
1.40	25.13	4.00	13.59	0.46	−0.16
1.79	25.13	4.00	10.60	0.59	−0.01
1.85	25.13	4.00	10.26	0.61	0.09
4.76	25.13	4.00	3.99	1.57	0.21
6.22	25.13	4.00	3.05	2.06	0.09
12.06	25.13	4.00	1.57	3.99	0.11
18.09	25.13	4.00	1.05	5.99	0.11
20.00	20.74	3.30	0.78	8.03	0.11
20.00	16.34	2.60	0.62	10.19	0.09
19.98	13.82	2.20	0.52	12.03	0.07
19.99	11.93	1.90	0.45	13.94	0.08
20.00	10.68	1.70	0.40	15.59	0.03
19.99	9.43	1.50	0.36	17.65	0.04
20.00	8.17	1.30	0.31	20.38	0.06
19.98	7.54	1.20	0.28	22.06	0.01
19.99	6.91	1.10	0.26	24.06	0.09
19.97	6.28	1.00	0.24	26.45	0.05
19.98	5.66	0.90	0.21	29.40	0.11
19.98	5.03	0.80	0.19	33.07	0.07
19.96	4.40	0.70	0.17	37.77	0.08
19.97	3.77	0.60	0.14	44.08	0.09

Table H.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

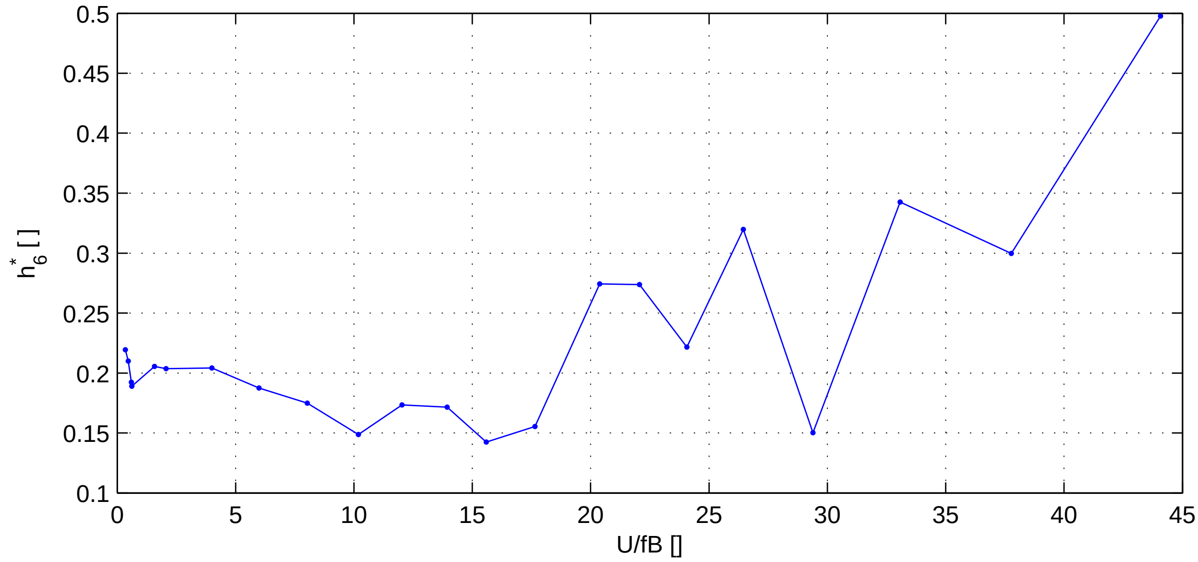


Figure H.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
1.04	25.13	4.00	18.28	0.34	0.22
1.40	25.13	4.00	13.59	0.46	0.21
1.79	25.13	4.00	10.60	0.59	0.19
1.85	25.13	4.00	10.26	0.61	0.19
4.76	25.13	4.00	3.99	1.57	0.21
6.22	25.13	4.00	3.05	2.06	0.20
12.06	25.13	4.00	1.57	3.99	0.20
18.09	25.13	4.00	1.05	5.99	0.19
20.00	20.74	3.30	0.78	8.03	0.17
20.00	16.34	2.60	0.62	10.19	0.15
19.98	13.82	2.20	0.52	12.03	0.17
19.99	11.93	1.90	0.45	13.94	0.17
20.00	10.68	1.70	0.40	15.59	0.14
19.99	9.43	1.50	0.36	17.65	0.16
20.00	8.17	1.30	0.31	20.38	0.27
19.98	7.54	1.20	0.28	22.06	0.27
19.99	6.91	1.10	0.26	24.06	0.22
19.97	6.28	1.00	0.24	26.45	0.32
19.98	5.66	0.90	0.21	29.40	0.15
19.98	5.03	0.80	0.19	33.07	0.34
19.96	4.40	0.70	0.17	37.77	0.30
19.97	3.77	0.60	0.14	44.08	0.50

Table H.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

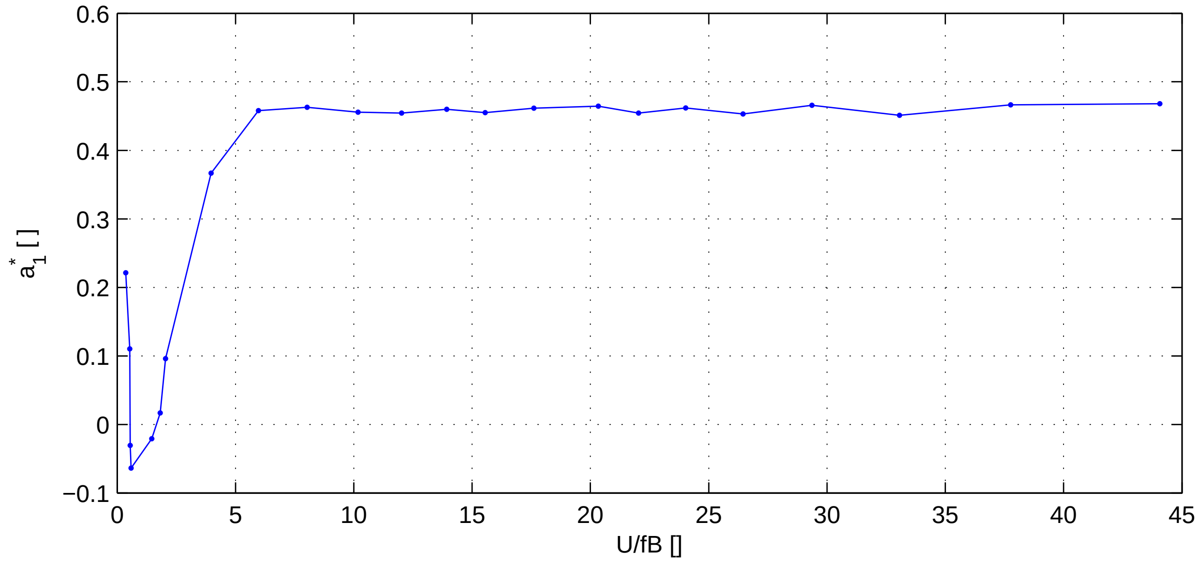


Figure H.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
1.10	25.13	4.00	17.17	0.37	0.22
1.60	25.13	4.00	11.88	0.53	0.11
1.67	25.13	4.00	11.37	0.55	−0.03
1.78	25.13	4.00	10.67	0.59	−0.06
4.42	25.13	4.00	4.30	1.46	−0.02
4.52	20.74	3.30	3.46	1.81	0.02
6.18	25.13	4.00	3.07	2.05	0.10
11.97	25.13	4.00	1.58	3.96	0.37
18.03	25.13	4.00	1.05	5.97	0.46
20.00	20.74	3.30	0.78	8.03	0.46
19.99	16.34	2.60	0.62	10.18	0.46
19.97	13.82	2.20	0.52	12.02	0.45
19.97	11.93	1.90	0.45	13.93	0.46
19.96	10.68	1.70	0.40	15.56	0.45
19.95	9.43	1.50	0.36	17.61	0.46
19.97	8.17	1.30	0.31	20.34	0.46
19.96	7.54	1.20	0.29	22.03	0.45
19.96	6.91	1.10	0.26	24.03	0.46
19.97	6.28	1.00	0.24	26.45	0.45
19.96	5.66	0.90	0.21	29.37	0.47
19.97	5.03	0.80	0.19	33.06	0.45
19.96	4.40	0.70	0.17	37.76	0.47
19.96	3.77	0.60	0.14	44.07	0.47

Table H.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

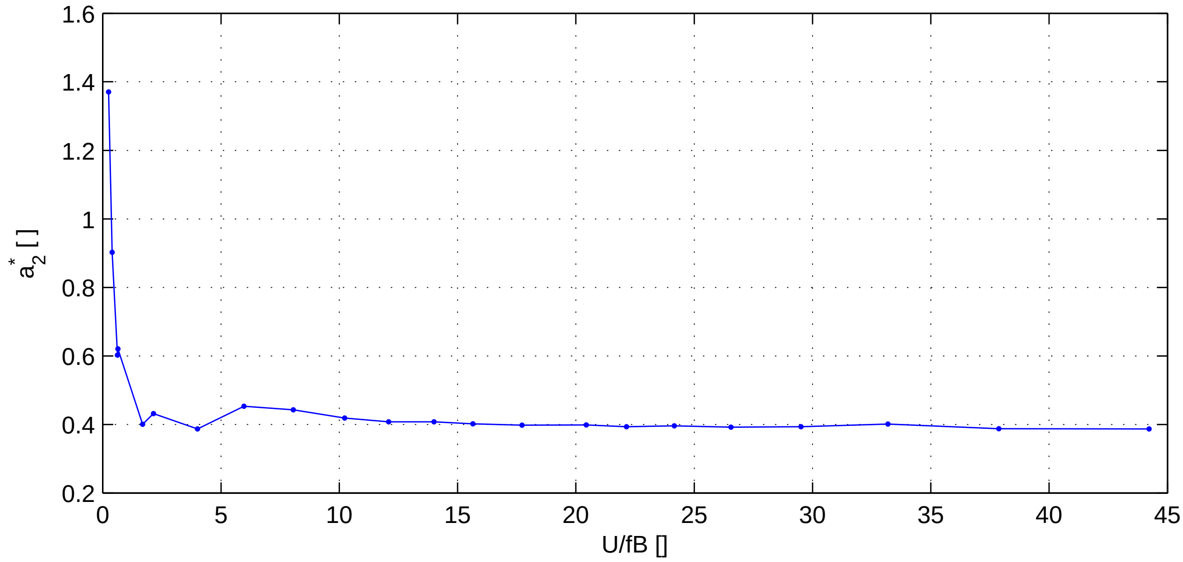


Figure H.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
0.75	25.13	4.00	25.42	0.25	1.37
1.19	25.13	4.00	15.91	0.39	0.90
1.89	25.13	4.00	10.05	0.62	0.60
1.94	25.13	4.00	9.79	0.64	0.62
5.10	25.13	4.00	3.72	1.69	0.40
6.47	25.13	4.00	2.93	2.14	0.43
12.11	25.13	4.00	1.57	4.01	0.39
18.03	25.13	4.00	1.05	5.97	0.45
20.07	20.74	3.30	0.78	8.05	0.44
20.08	16.34	2.60	0.61	10.22	0.42
20.07	13.82	2.20	0.52	12.08	0.41
20.08	11.93	1.90	0.45	14.00	0.41
20.07	10.68	1.70	0.40	15.65	0.40
20.08	9.43	1.50	0.35	17.72	0.40
20.06	8.17	1.30	0.31	20.44	0.40
20.06	7.54	1.20	0.28	22.14	0.39
20.06	6.91	1.10	0.26	24.16	0.40
20.05	6.28	1.00	0.24	26.55	0.39
20.06	5.66	0.90	0.21	29.51	0.39
20.04	5.03	0.80	0.19	33.18	0.40
20.02	4.40	0.70	0.17	37.88	0.39
20.04	3.77	0.60	0.14	44.23	0.39

Table H.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

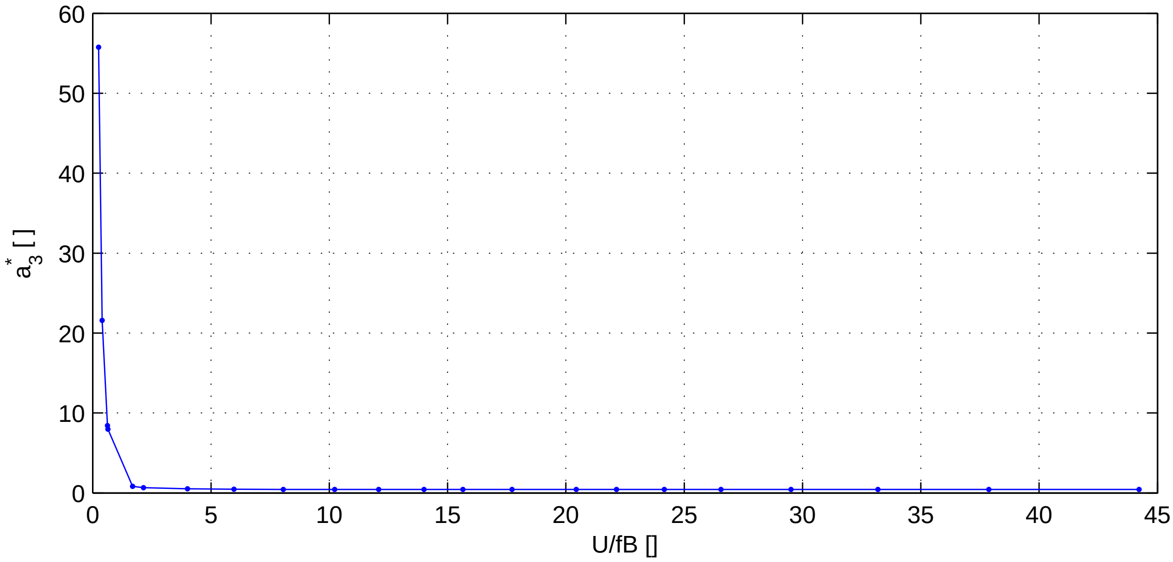


Figure H.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
0.75	25.13	4.00	25.42	0.25	55.76
1.19	25.13	4.00	15.91	0.39	21.58
1.89	25.13	4.00	10.05	0.62	8.42
1.94	25.13	4.00	9.79	0.64	7.96
5.10	25.13	4.00	3.72	1.69	0.82
6.47	25.13	4.00	2.93	2.14	0.66
12.11	25.13	4.00	1.57	4.01	0.52
18.03	25.13	4.00	1.05	5.97	0.47
20.07	20.74	3.30	0.78	8.05	0.44
20.08	16.34	2.60	0.61	10.22	0.42
20.07	13.82	2.20	0.52	12.08	0.42
20.08	11.93	1.90	0.45	14.00	0.42
20.07	10.68	1.70	0.40	15.65	0.42
20.08	9.43	1.50	0.35	17.72	0.42
20.06	8.17	1.30	0.31	20.44	0.42
20.06	7.54	1.20	0.28	22.14	0.42
20.06	6.91	1.10	0.26	24.16	0.42
20.05	6.28	1.00	0.24	26.55	0.42
20.06	5.66	0.90	0.21	29.51	0.42
20.04	5.03	0.80	0.19	33.18	0.42
20.02	4.40	0.70	0.17	37.88	0.42
20.04	3.77	0.60	0.14	44.23	0.42

Table H.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

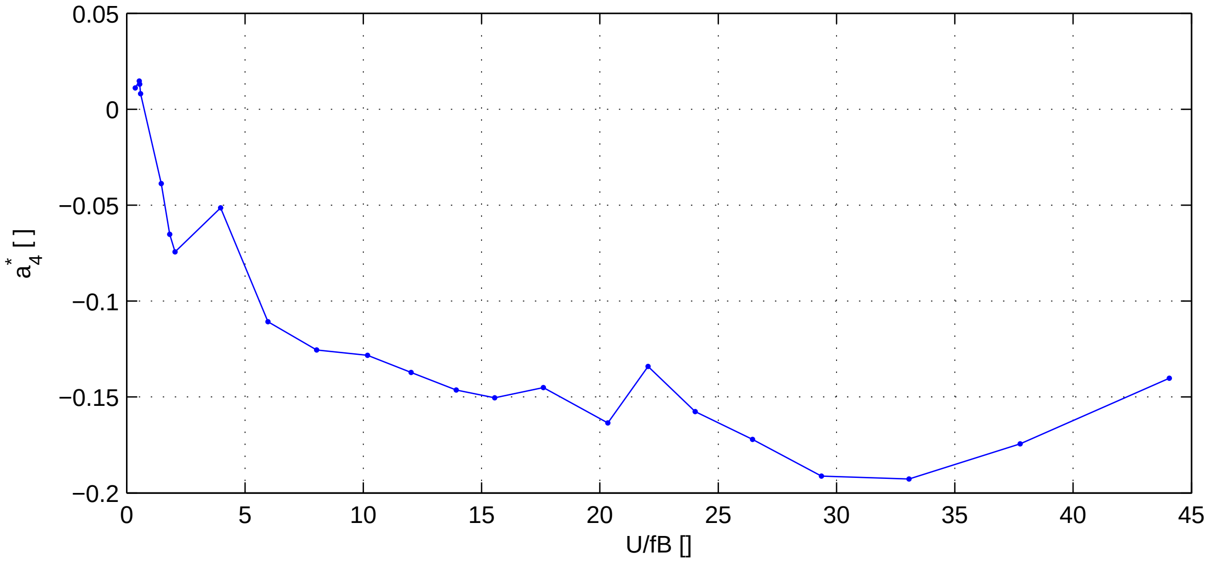


Figure H.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
1.10	25.13	4.00	17.17	0.37	0.01
1.60	25.13	4.00	11.88	0.53	0.01
1.67	25.13	4.00	11.37	0.55	0.01
1.78	25.13	4.00	10.67	0.59	0.01
4.42	25.13	4.00	4.30	1.46	−0.04
4.52	20.74	3.30	3.46	1.81	−0.07
6.18	25.13	4.00	3.07	2.05	−0.07
11.97	25.13	4.00	1.58	3.96	−0.05
18.03	25.13	4.00	1.05	5.97	−0.11
20.00	20.74	3.30	0.78	8.03	−0.13
19.99	16.34	2.60	0.62	10.18	−0.13
19.97	13.82	2.20	0.52	12.02	−0.14
19.97	11.93	1.90	0.45	13.93	−0.15
19.96	10.68	1.70	0.40	15.56	−0.15
19.95	9.43	1.50	0.36	17.61	−0.15
19.97	8.17	1.30	0.31	20.34	−0.16
19.96	7.54	1.20	0.29	22.03	−0.13
19.96	6.91	1.10	0.26	24.03	−0.16
19.97	6.28	1.00	0.24	26.45	−0.17
19.96	5.66	0.90	0.21	29.37	−0.19
19.97	5.03	0.80	0.19	33.06	−0.19
19.96	4.40	0.70	0.17	37.76	−0.17
19.96	3.77	0.60	0.14	44.07	−0.14

Table H.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

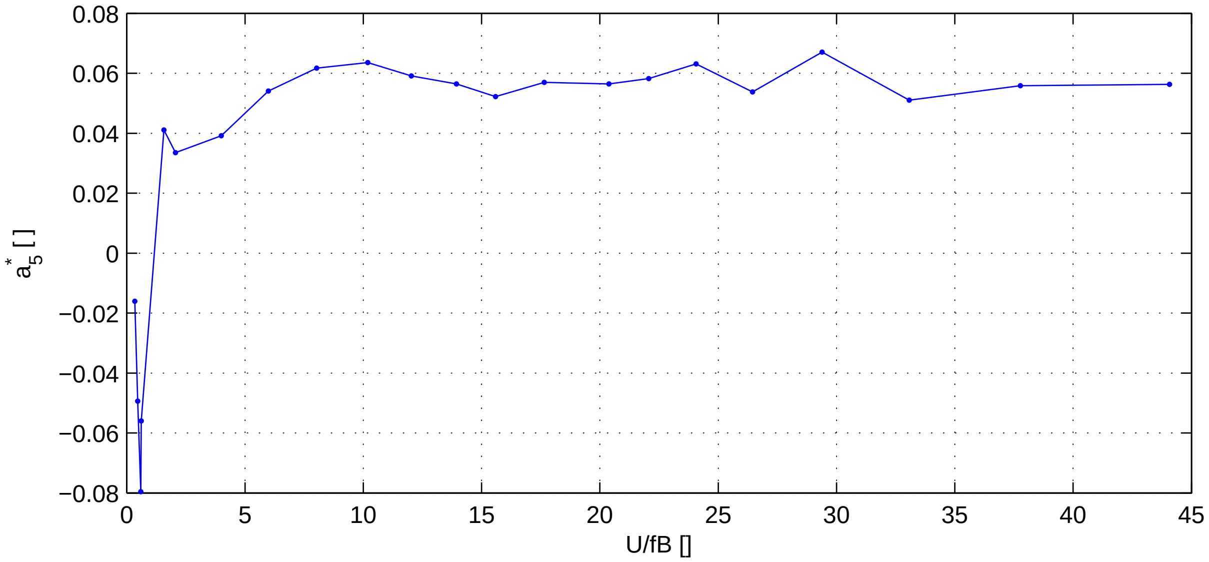


Figure H.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
1.04	25.13	4.00	18.28	0.34	−0.02
1.40	25.13	4.00	13.59	0.46	−0.05
1.79	25.13	4.00	10.60	0.59	−0.08
1.85	25.13	4.00	10.26	0.61	−0.06
4.76	25.13	4.00	3.99	1.57	0.04
6.22	25.13	4.00	3.05	2.06	0.03
12.06	25.13	4.00	1.57	3.99	0.04
18.09	25.13	4.00	1.05	5.99	0.05
20.00	20.74	3.30	0.78	8.03	0.06
20.00	16.34	2.60	0.62	10.19	0.06
19.98	13.82	2.20	0.52	12.03	0.06
19.99	11.93	1.90	0.45	13.94	0.06
20.00	10.68	1.70	0.40	15.59	0.05
19.99	9.43	1.50	0.36	17.65	0.06
20.00	8.17	1.30	0.31	20.38	0.06
19.98	7.54	1.20	0.28	22.06	0.06
19.99	6.91	1.10	0.26	24.06	0.06
19.97	6.28	1.00	0.24	26.45	0.05
19.98	5.66	0.90	0.21	29.40	0.07
19.98	5.03	0.80	0.19	33.07	0.05
19.96	4.40	0.70	0.17	37.77	0.06
19.97	3.77	0.60	0.14	44.08	0.06

Table H.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

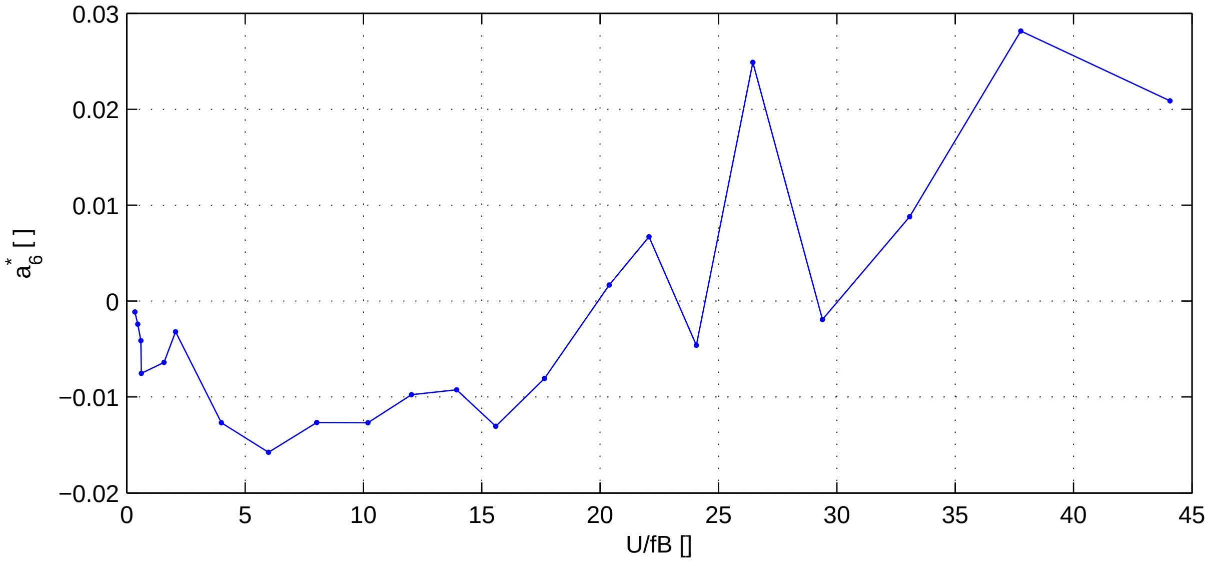


Figure H.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
1.04	25.13	4.00	18.28	0.34	−0.00
1.40	25.13	4.00	13.59	0.46	−0.00
1.79	25.13	4.00	10.60	0.59	−0.00
1.85	25.13	4.00	10.26	0.61	−0.01
4.76	25.13	4.00	3.99	1.57	−0.01
6.22	25.13	4.00	3.05	2.06	−0.00
12.06	25.13	4.00	1.57	3.99	−0.01
18.09	25.13	4.00	1.05	5.99	−0.02
20.00	20.74	3.30	0.78	8.03	−0.01
20.00	16.34	2.60	0.62	10.19	−0.01
19.98	13.82	2.20	0.52	12.03	−0.01
19.99	11.93	1.90	0.45	13.94	−0.01
20.00	10.68	1.70	0.40	15.59	−0.01
19.99	9.43	1.50	0.36	17.65	−0.01
20.00	8.17	1.30	0.31	20.38	0.00
19.98	7.54	1.20	0.28	22.06	0.01
19.99	6.91	1.10	0.26	24.06	−0.00
19.97	6.28	1.00	0.24	26.45	0.02
19.98	5.66	0.90	0.21	29.40	−0.00
19.98	5.03	0.80	0.19	33.07	0.01
19.96	4.40	0.70	0.17	37.77	0.03
19.97	3.77	0.60	0.14	44.08	0.02

Table H.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

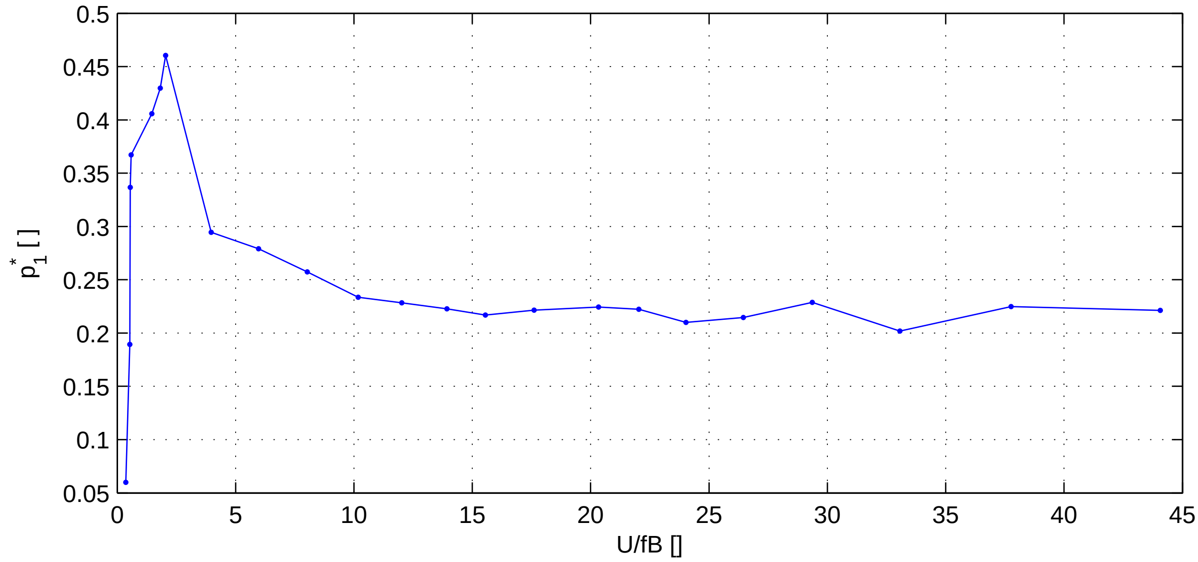


Figure H.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
1.10	25.13	4.00	17.17	0.37	0.06
1.60	25.13	4.00	11.88	0.53	0.19
1.67	25.13	4.00	11.37	0.55	0.34
1.78	25.13	4.00	10.67	0.59	0.37
4.42	25.13	4.00	4.30	1.46	0.41
4.52	20.74	3.30	3.46	1.81	0.43
6.18	25.13	4.00	3.07	2.05	0.46
11.97	25.13	4.00	1.58	3.96	0.29
18.03	25.13	4.00	1.05	5.97	0.28
20.00	20.74	3.30	0.78	8.03	0.26
19.99	16.34	2.60	0.62	10.18	0.23
19.97	13.82	2.20	0.52	12.02	0.23
19.97	11.93	1.90	0.45	13.93	0.22
19.96	10.68	1.70	0.40	15.56	0.22
19.95	9.43	1.50	0.36	17.61	0.22
19.97	8.17	1.30	0.31	20.34	0.22
19.96	7.54	1.20	0.29	22.03	0.22
19.96	6.91	1.10	0.26	24.03	0.21
19.97	6.28	1.00	0.24	26.45	0.21
19.96	5.66	0.90	0.21	29.37	0.23
19.97	5.03	0.80	0.19	33.06	0.20
19.96	4.40	0.70	0.17	37.76	0.22
19.96	3.77	0.60	0.14	44.07	0.22

Table H.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

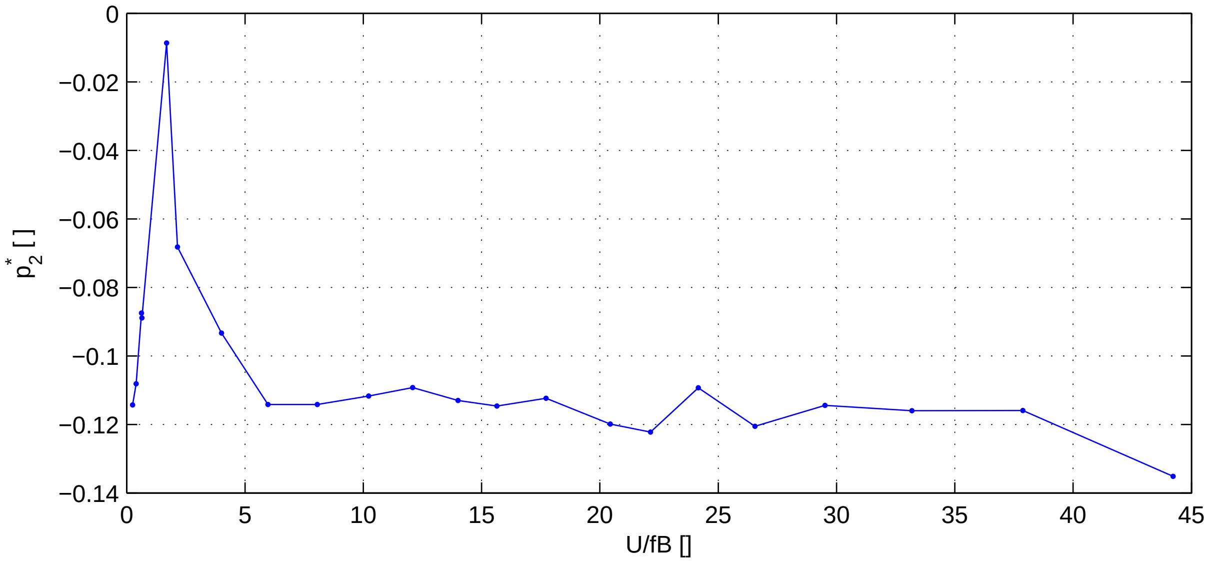


Figure H.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
0.75	25.13	4.00	25.42	0.25	−0.11
1.19	25.13	4.00	15.91	0.39	−0.11
1.89	25.13	4.00	10.05	0.62	−0.09
1.94	25.13	4.00	9.79	0.64	−0.09
5.10	25.13	4.00	3.72	1.69	−0.01
6.47	25.13	4.00	2.93	2.14	−0.07
12.11	25.13	4.00	1.57	4.01	−0.09
18.03	25.13	4.00	1.05	5.97	−0.11
20.07	20.74	3.30	0.78	8.05	−0.11
20.08	16.34	2.60	0.61	10.22	−0.11
20.07	13.82	2.20	0.52	12.08	−0.11
20.08	11.93	1.90	0.45	14.00	−0.11
20.07	10.68	1.70	0.40	15.65	−0.11
20.08	9.43	1.50	0.35	17.72	−0.11
20.06	8.17	1.30	0.31	20.44	−0.12
20.06	7.54	1.20	0.28	22.14	−0.12
20.06	6.91	1.10	0.26	24.16	−0.11
20.05	6.28	1.00	0.24	26.55	−0.12
20.06	5.66	0.90	0.21	29.51	−0.11
20.04	5.03	0.80	0.19	33.18	−0.12
20.02	4.40	0.70	0.17	37.88	−0.12
20.04	3.77	0.60	0.14	44.23	−0.14

Table H.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

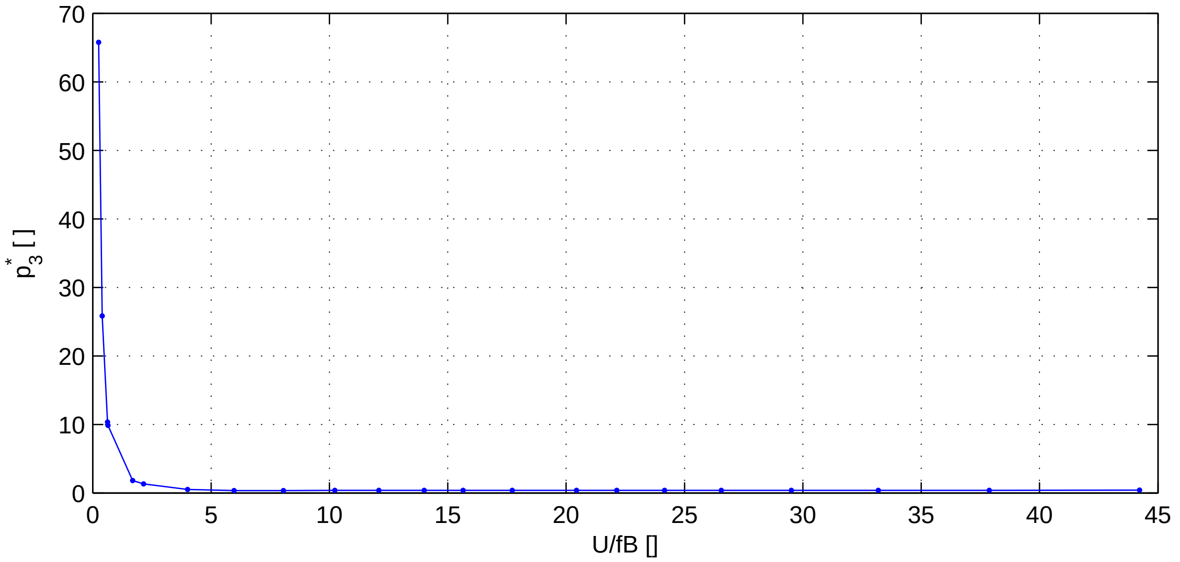


Figure H.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
0.75	25.13	4.00	25.42	0.25	65.75
1.19	25.13	4.00	15.91	0.39	25.81
1.89	25.13	4.00	10.05	0.62	10.35
1.94	25.13	4.00	9.79	0.64	9.86
5.10	25.13	4.00	3.72	1.69	1.81
6.47	25.13	4.00	2.93	2.14	1.33
12.11	25.13	4.00	1.57	4.01	0.51
18.03	25.13	4.00	1.05	5.97	0.36
20.07	20.74	3.30	0.78	8.05	0.36
20.08	16.34	2.60	0.61	10.22	0.37
20.07	13.82	2.20	0.52	12.08	0.38
20.08	11.93	1.90	0.45	14.00	0.38
20.07	10.68	1.70	0.40	15.65	0.38
20.08	9.43	1.50	0.35	17.72	0.38
20.06	8.17	1.30	0.31	20.44	0.39
20.06	7.54	1.20	0.28	22.14	0.39
20.06	6.91	1.10	0.26	24.16	0.39
20.05	6.28	1.00	0.24	26.55	0.39
20.06	5.66	0.90	0.21	29.51	0.39
20.04	5.03	0.80	0.19	33.18	0.39
20.02	4.40	0.70	0.17	37.88	0.39
20.04	3.77	0.60	0.14	44.23	0.39

Table H.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:16:01

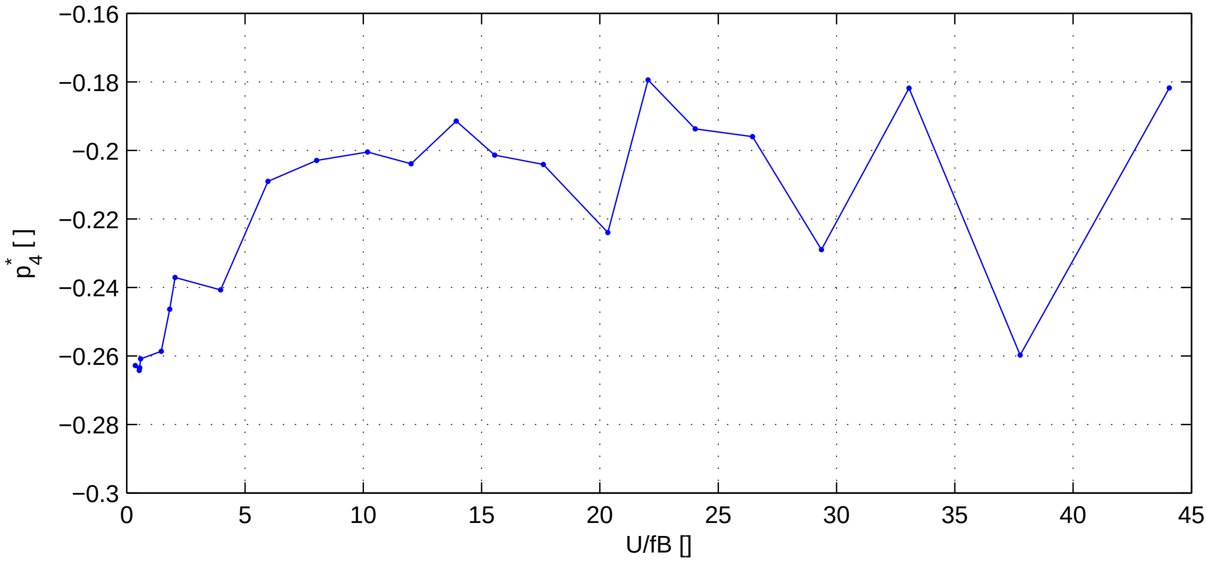


Figure H.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
1.10	25.13	4.00	17.17	0.37	−0.26
1.60	25.13	4.00	11.88	0.53	−0.26
1.67	25.13	4.00	11.37	0.55	−0.26
1.78	25.13	4.00	10.67	0.59	−0.26
4.42	25.13	4.00	4.30	1.46	−0.26
4.52	20.74	3.30	3.46	1.81	−0.25
6.18	25.13	4.00	3.07	2.05	−0.24
11.97	25.13	4.00	1.58	3.96	−0.24
18.03	25.13	4.00	1.05	5.97	−0.21
20.00	20.74	3.30	0.78	8.03	−0.20
19.99	16.34	2.60	0.62	10.18	−0.20
19.97	13.82	2.20	0.52	12.02	−0.20
19.97	11.93	1.90	0.45	13.93	−0.19
19.96	10.68	1.70	0.40	15.56	−0.20
19.95	9.43	1.50	0.36	17.61	−0.20
19.97	8.17	1.30	0.31	20.34	−0.22
19.96	7.54	1.20	0.29	22.03	−0.18
19.96	6.91	1.10	0.26	24.03	−0.19
19.97	6.28	1.00	0.24	26.45	−0.20
19.96	5.66	0.90	0.21	29.37	−0.23
19.97	5.03	0.80	0.19	33.06	−0.18
19.96	4.40	0.70	0.17	37.76	−0.26
19.96	3.77	0.60	0.14	44.07	−0.18

Table H.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

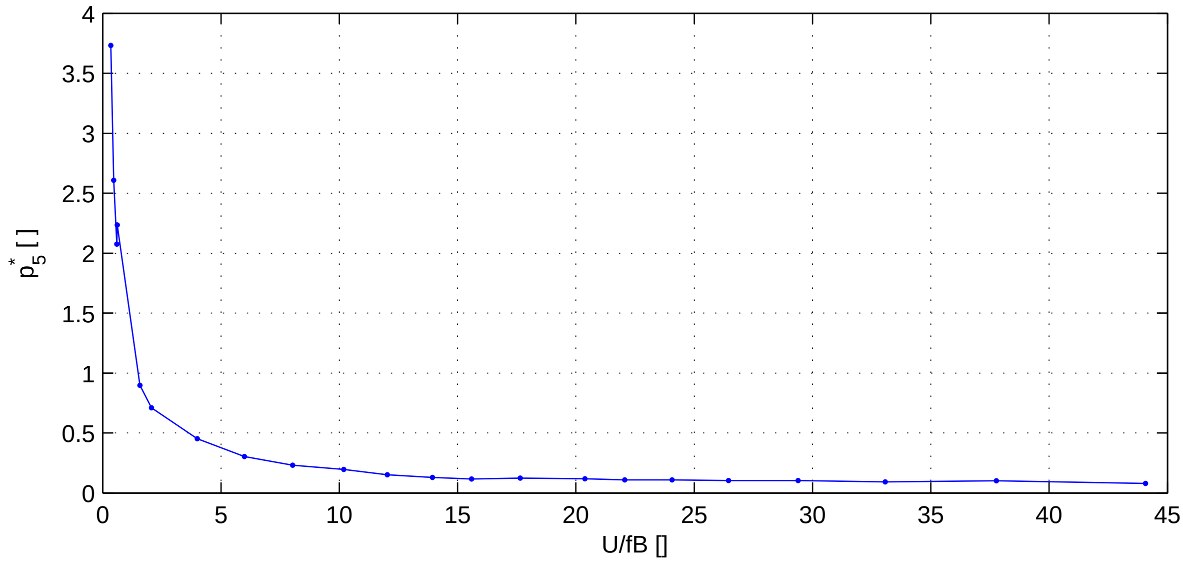


Figure H.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
1.04	25.13	4.00	18.28	0.34	3.73
1.40	25.13	4.00	13.59	0.46	2.61
1.79	25.13	4.00	10.60	0.59	2.08
1.85	25.13	4.00	10.26	0.61	2.23
4.76	25.13	4.00	3.99	1.57	0.90
6.22	25.13	4.00	3.05	2.06	0.71
12.06	25.13	4.00	1.57	3.99	0.45
18.09	25.13	4.00	1.05	5.99	0.30
20.00	20.74	3.30	0.78	8.03	0.23
20.00	16.34	2.60	0.62	10.19	0.20
19.98	13.82	2.20	0.52	12.03	0.15
19.99	11.93	1.90	0.45	13.94	0.13
20.00	10.68	1.70	0.40	15.59	0.12
19.99	9.43	1.50	0.36	17.65	0.12
20.00	8.17	1.30	0.31	20.38	0.12
19.98	7.54	1.20	0.28	22.06	0.11
19.99	6.91	1.10	0.26	24.06	0.11
19.97	6.28	1.00	0.24	26.45	0.10
19.98	5.66	0.90	0.21	29.40	0.10
19.98	5.03	0.80	0.19	33.07	0.09
19.96	4.40	0.70	0.17	37.77	0.10
19.97	3.77	0.60	0.14	44.08	0.08

Table H.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

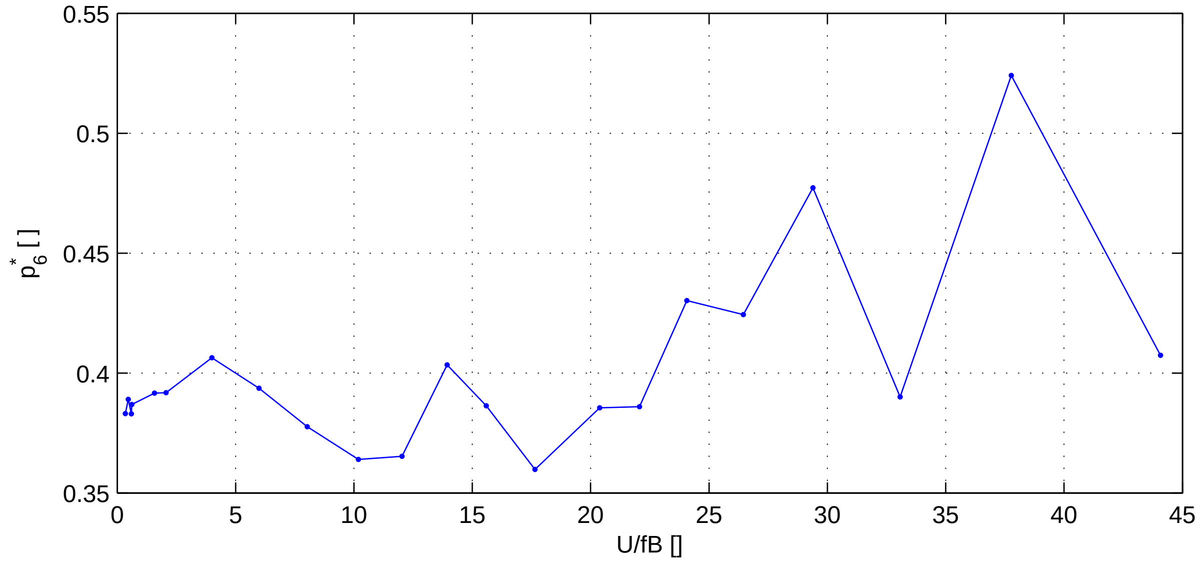


Figure H.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
1.04	25.13	4.00	18.28	0.34	0.38
1.40	25.13	4.00	13.59	0.46	0.39
1.79	25.13	4.00	10.60	0.59	0.38
1.85	25.13	4.00	10.26	0.61	0.39
4.76	25.13	4.00	3.99	1.57	0.39
6.22	25.13	4.00	3.05	2.06	0.39
12.06	25.13	4.00	1.57	3.99	0.41
18.09	25.13	4.00	1.05	5.99	0.39
20.00	20.74	3.30	0.78	8.03	0.38
20.00	16.34	2.60	0.62	10.19	0.36
19.98	13.82	2.20	0.52	12.03	0.37
19.99	11.93	1.90	0.45	13.94	0.40
20.00	10.68	1.70	0.40	15.59	0.39
19.99	9.43	1.50	0.36	17.65	0.36
20.00	8.17	1.30	0.31	20.38	0.39
19.98	7.54	1.20	0.28	22.06	0.39
19.99	6.91	1.10	0.26	24.06	0.43
19.97	6.28	1.00	0.24	26.45	0.42
19.98	5.66	0.90	0.21	29.40	0.48
19.98	5.03	0.80	0.19	33.07	0.39
19.96	4.40	0.70	0.17	37.77	0.52
19.97	3.77	0.60	0.14	44.08	0.41

Table H.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

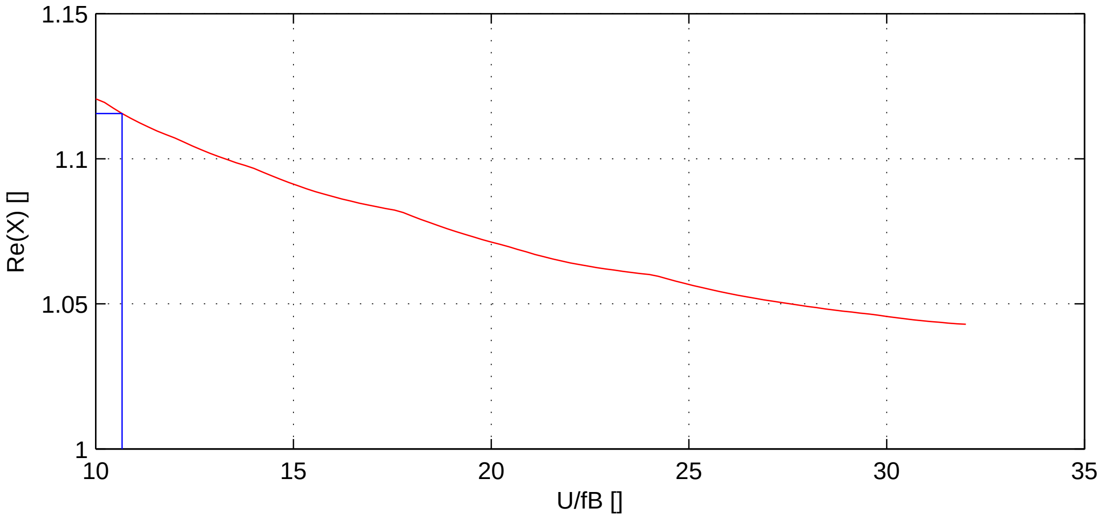


Figure H.37: Real part of the solution to stability equantion

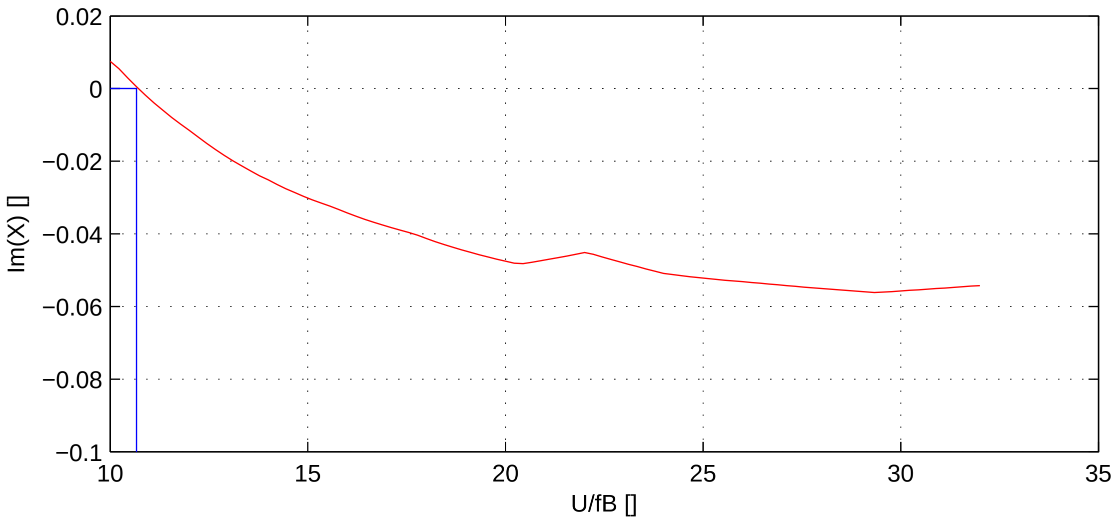


Figure H.38: Imaginary part of the solution to stability equantion

V_{Crit} = 10.7

f_{Crit} = 0.0722 Hz

U_{Crit} = 46.5 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.

[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.

[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.

[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.

[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix I

3D Flutter Tests

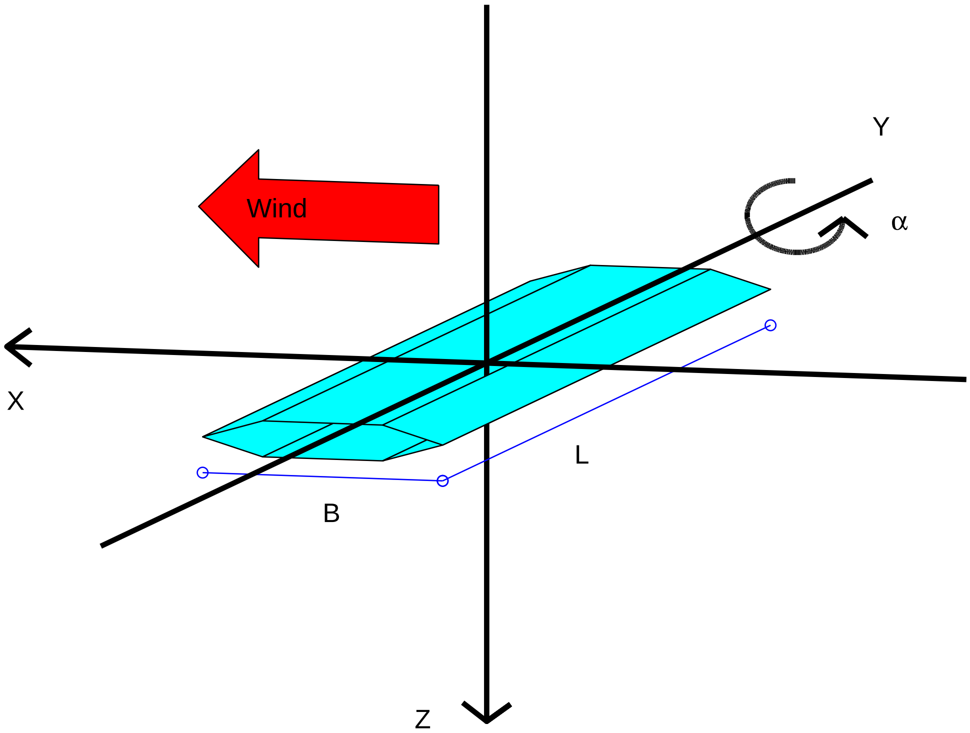
Flutter derivatives, Smooth flow, Angle of incidence = +4 deg.

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^{o}C	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1014.0

Table I.1: Project Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2\,m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha} m\,g - 2\,m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2\,m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h	: Vertical displacement, displacement along z-axis, [m]
α	: Rotation around y-axis, nose up is positive, [rad]
p	: Horizontal displacement, displacement along the x-axis, [m]
m	: Mass per unit length, [kg/m]
I_y	: Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$	: Added mass in vertical direction, [kg/m]
$m_{a,x}$	: Added mass in horizontal direction, [kg/m]
$I_{a,y}$	: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G	: X-coordinate for centre of gravity, [m]
Z_G	: Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$	: Natural circular frequency for vertical motion, [/s]
ζ_h	: Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$	: Natural circular frequency for rotation around y axis, [/s]
ζ_α	: Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$	: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p	: Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$	: Force from rig per meter section, [N/m]
$M_{Y,external}$	: Moment from rig per meter section, [Nm/m]
$F_{X,external}$	: Force from rig per meter section, [N/m]

Formula I.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.368
Added mass in horizontal	$m_{a,x}$	kg/m	0.539
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.138
Horizontal centre of gravity	x_G	m	−0.001
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.040
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.032
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.004

Table I.2: Mechanical Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b: buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b: buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b: buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula I.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

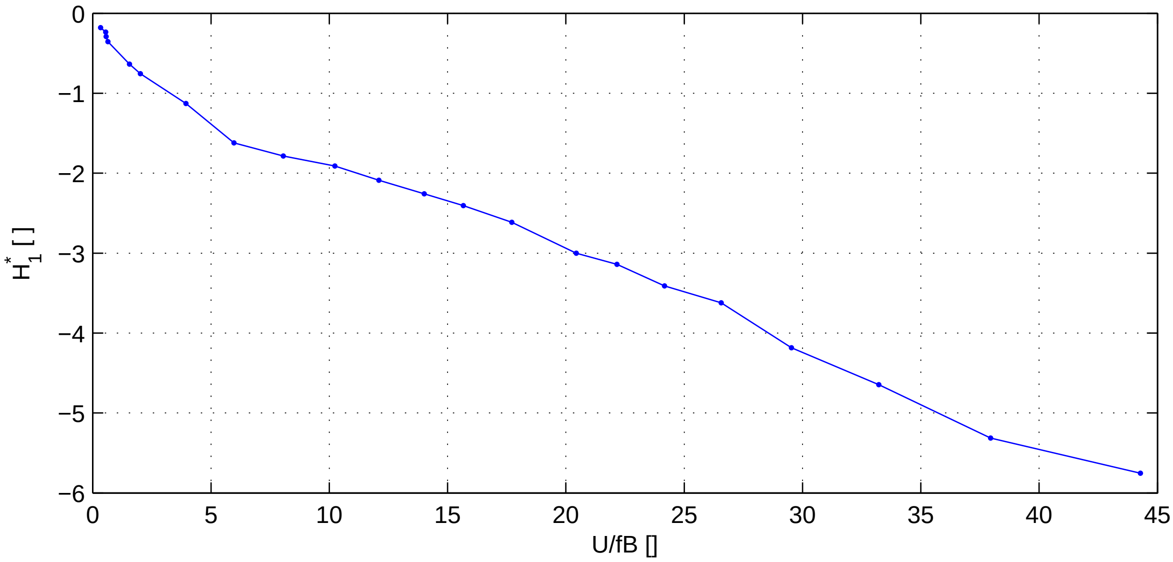


Figure I.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
1.01	25.13	4.00	18.80	0.33	−0.18
1.65	25.13	4.00	11.48	0.55	−0.23
1.72	25.13	4.00	11.02	0.57	−0.29
1.96	25.13	4.00	9.70	0.65	−0.36
4.71	25.13	4.00	4.03	1.56	−0.63
6.08	25.13	4.00	3.12	2.01	−0.76
11.90	25.13	4.00	1.59	3.94	−1.13
18.02	25.13	4.00	1.05	5.97	−1.62
20.08	20.74	3.30	0.78	8.06	−1.78
20.09	16.34	2.60	0.61	10.23	−1.91
20.10	13.82	2.20	0.52	12.10	−2.09
20.09	11.93	1.90	0.45	14.01	−2.26
20.10	10.68	1.70	0.40	15.66	−2.41
20.07	9.43	1.50	0.35	17.71	−2.61
20.07	8.17	1.30	0.31	20.44	−3.00
20.07	7.54	1.20	0.28	22.16	−3.14
20.07	6.91	1.10	0.26	24.17	−3.41
20.06	6.28	1.00	0.24	26.57	−3.62
20.07	5.66	0.90	0.21	29.54	−4.18
20.06	5.03	0.80	0.19	33.22	−4.65
20.06	4.40	0.70	0.17	37.95	−5.31
20.05	3.77	0.60	0.14	44.28	−5.75

Table I.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

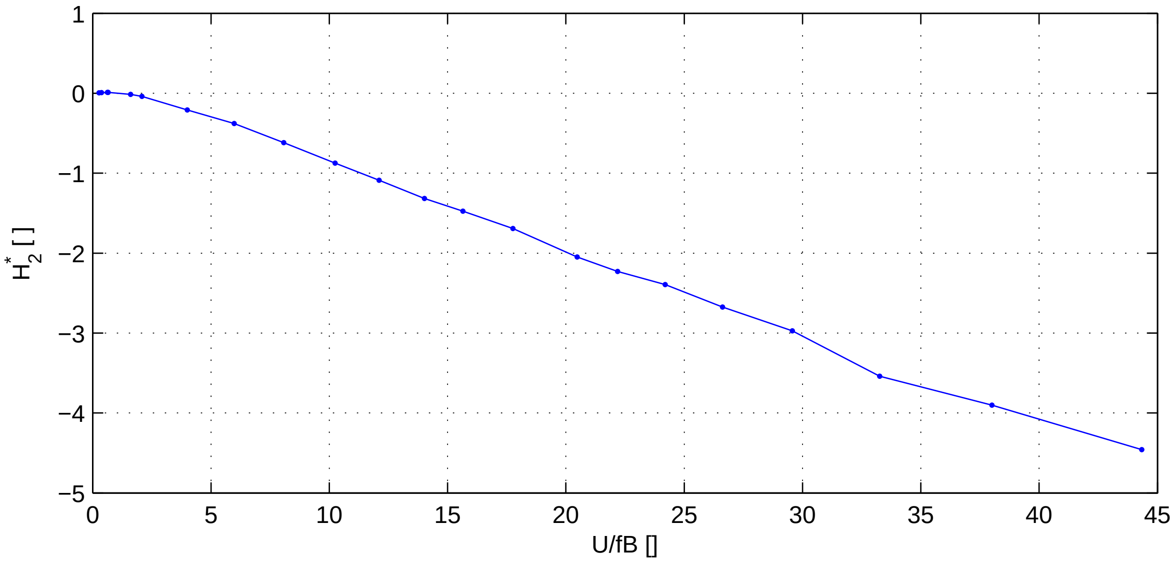


Figure I.2: H^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_2
0.80	25.13	4.00	23.70	0.27	0.00
1.12	25.13	4.00	17.01	0.37	0.01
1.90	25.13	4.00	10.01	0.63	0.01
1.96	25.13	4.00	9.69	0.65	0.01
4.84	25.13	4.00	3.92	1.60	−0.01
6.29	25.13	4.00	3.01	2.08	−0.04
12.08	25.13	4.00	1.57	4.00	−0.21
18.06	25.13	4.00	1.05	5.98	−0.38
20.11	20.74	3.30	0.78	8.07	−0.62
20.11	16.34	2.60	0.61	10.24	−0.87
20.11	13.82	2.20	0.52	12.10	−1.09
20.11	11.93	1.90	0.45	14.02	−1.32
20.09	10.69	1.70	0.40	15.64	−1.47
20.12	9.43	1.50	0.35	17.76	−1.69
20.09	8.17	1.30	0.31	20.48	−2.05
20.10	7.54	1.20	0.28	22.19	−2.23
20.10	6.91	1.10	0.26	24.20	−2.39
20.10	6.28	1.00	0.24	26.62	−2.67
20.10	5.66	0.90	0.21	29.57	−2.97
20.09	5.03	0.80	0.19	33.26	−3.54
20.09	4.40	0.70	0.17	38.00	−3.90
20.09	3.77	0.60	0.14	44.34	−4.46

Table I.4: H^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

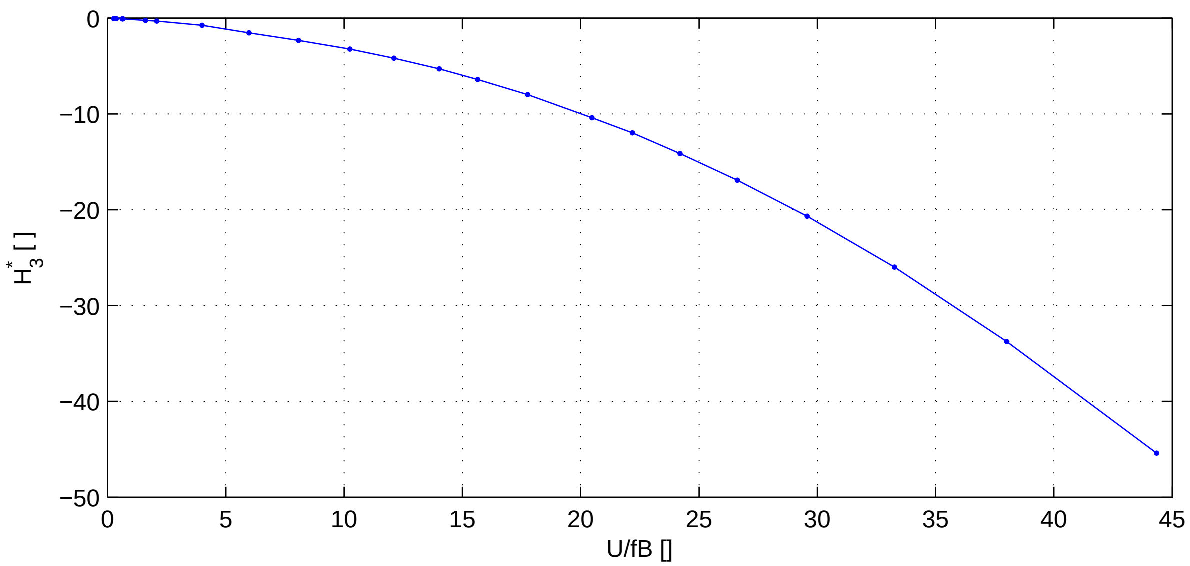


Figure I.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
0.80	25.13	4.00	23.70	0.27	−0.06
1.12	25.13	4.00	17.01	0.37	−0.06
1.90	25.13	4.00	10.01	0.63	−0.07
1.96	25.13	4.00	9.69	0.65	−0.08
4.84	25.13	4.00	3.92	1.60	−0.24
6.29	25.13	4.00	3.01	2.08	−0.32
12.08	25.13	4.00	1.57	4.00	−0.76
18.06	25.13	4.00	1.05	5.98	−1.54
20.11	20.74	3.30	0.78	8.07	−2.34
20.11	16.34	2.60	0.61	10.24	−3.24
20.11	13.82	2.20	0.52	12.10	−4.18
20.11	11.93	1.90	0.45	14.02	−5.31
20.09	10.69	1.70	0.40	15.64	−6.41
20.12	9.43	1.50	0.35	17.76	−7.99
20.09	8.17	1.30	0.31	20.48	−10.40
20.10	7.54	1.20	0.28	22.19	−11.97
20.10	6.91	1.10	0.26	24.20	−14.14
20.10	6.28	1.00	0.24	26.62	−16.91
20.10	5.66	0.90	0.21	29.57	−20.68
20.09	5.03	0.80	0.19	33.26	−25.99
20.09	4.40	0.70	0.17	38.00	−33.76
20.09	3.77	0.60	0.14	44.34	−45.39

Table I.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

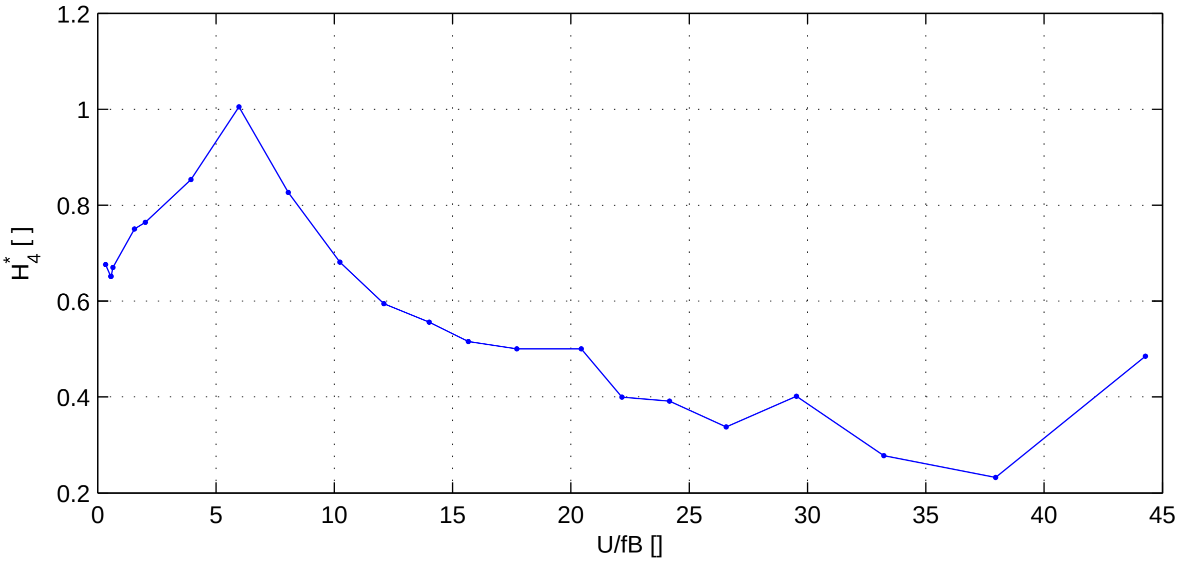


Figure I.4: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_4^*
1.01	25.13	4.00	18.80	0.33	0.68
1.65	25.13	4.00	11.48	0.55	0.65
1.72	25.13	4.00	11.02	0.57	0.65
1.96	25.13	4.00	9.70	0.65	0.67
4.71	25.13	4.00	4.03	1.56	0.75
6.08	25.13	4.00	3.12	2.01	0.76
11.90	25.13	4.00	1.59	3.94	0.85
18.02	25.13	4.00	1.05	5.97	1.01
20.08	20.74	3.30	0.78	8.06	0.83
20.09	16.34	2.60	0.61	10.23	0.68
20.10	13.82	2.20	0.52	12.10	0.59
20.09	11.93	1.90	0.45	14.01	0.56
20.10	10.68	1.70	0.40	15.66	0.52
20.07	9.43	1.50	0.35	17.71	0.50
20.07	8.17	1.30	0.31	20.44	0.50
20.07	7.54	1.20	0.28	22.16	0.40
20.07	6.91	1.10	0.26	24.17	0.39
20.06	6.28	1.00	0.24	26.57	0.34
20.07	5.66	0.90	0.21	29.54	0.40
20.06	5.03	0.80	0.19	33.22	0.28
20.06	4.40	0.70	0.17	37.95	0.23
20.05	3.77	0.60	0.14	44.28	0.49

Table I.6: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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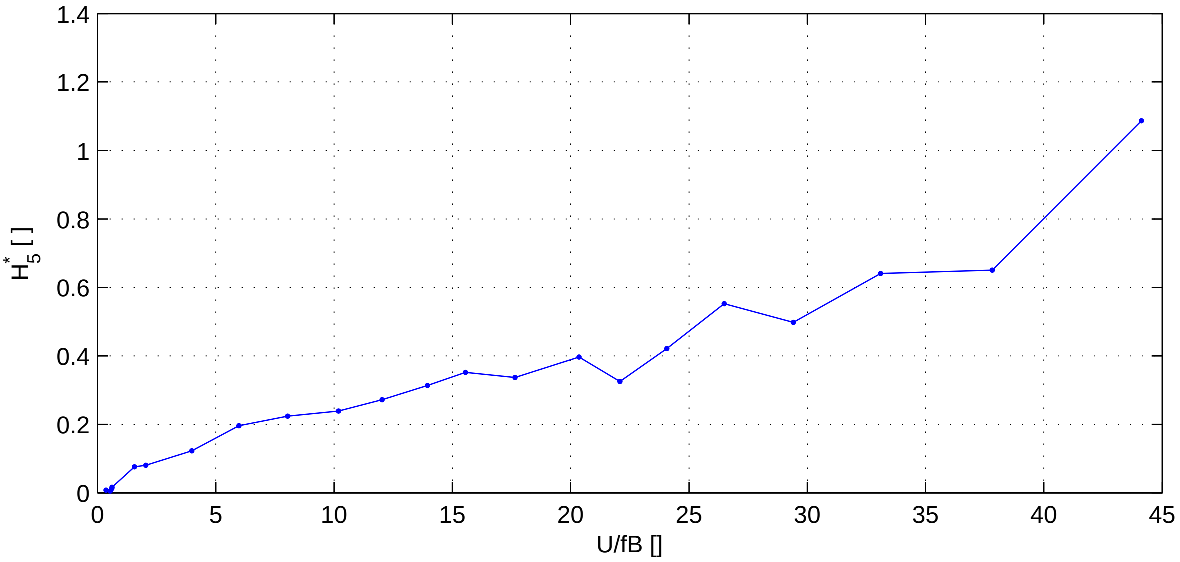

Figure I.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
1.08	25.13	4.00	17.53	0.36	0.01
1.65	25.13	4.00	11.53	0.54	0.00
1.84	25.13	4.00	10.33	0.61	0.01
1.85	25.13	4.00	10.25	0.61	0.02
4.73	25.13	4.00	4.01	1.57	0.08
6.17	25.13	4.00	3.08	2.04	0.08
12.05	25.13	4.00	1.57	3.99	0.12
18.05	25.13	4.00	1.05	5.98	0.20
20.02	20.74	3.30	0.78	8.03	0.22
20.01	16.34	2.60	0.62	10.19	0.24
19.99	13.82	2.20	0.52	12.03	0.27
20.00	11.93	1.90	0.45	13.95	0.31
19.97	10.69	1.70	0.40	15.56	0.35
19.99	9.43	1.50	0.36	17.65	0.34
19.99	8.17	1.30	0.31	20.36	0.40
20.00	7.54	1.20	0.28	22.08	0.33
19.99	6.91	1.10	0.26	24.07	0.42
20.00	6.28	1.00	0.24	26.49	0.55
19.99	5.66	0.90	0.21	29.41	0.50
19.99	5.03	0.80	0.19	33.10	0.64
19.98	4.40	0.70	0.17	37.82	0.65
19.99	3.77	0.60	0.14	44.13	1.09

Table I.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

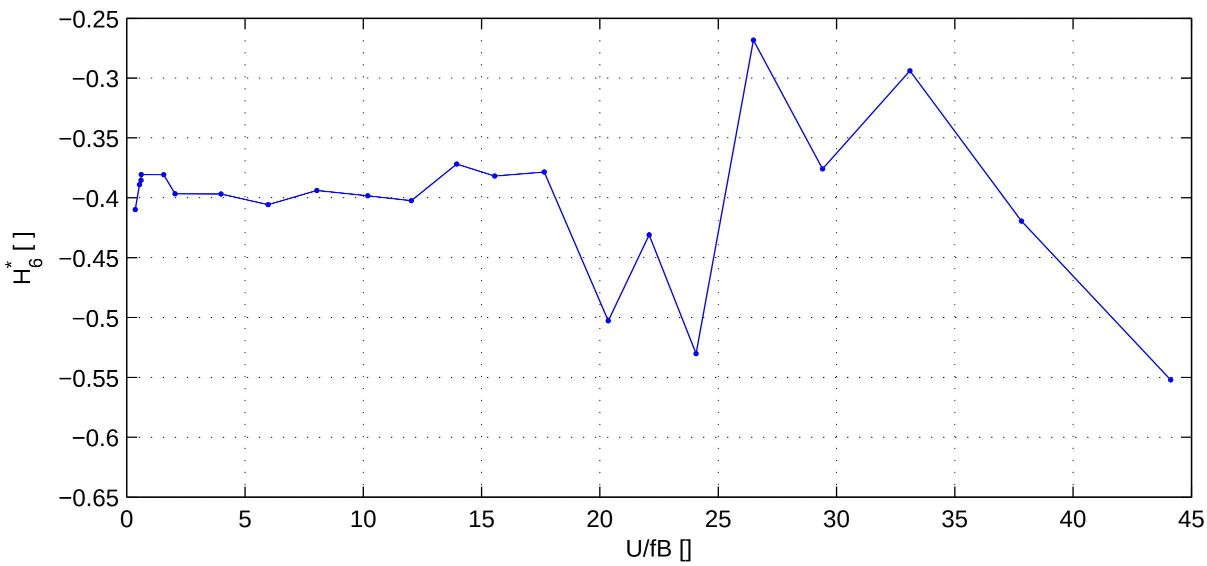

Figure I.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
1.08	25.13	4.00	17.53	0.36	−0.41
1.65	25.13	4.00	11.53	0.54	−0.39
1.84	25.13	4.00	10.33	0.61	−0.39
1.85	25.13	4.00	10.25	0.61	−0.38
4.73	25.13	4.00	4.01	1.57	−0.38
6.17	25.13	4.00	3.08	2.04	−0.40
12.05	25.13	4.00	1.57	3.99	−0.40
18.05	25.13	4.00	1.05	5.98	−0.41
20.02	20.74	3.30	0.78	8.03	−0.39
20.01	16.34	2.60	0.62	10.19	−0.40
19.99	13.82	2.20	0.52	12.03	−0.40
20.00	11.93	1.90	0.45	13.95	−0.37
19.97	10.69	1.70	0.40	15.56	−0.38
19.99	9.43	1.50	0.36	17.65	−0.38
19.99	8.17	1.30	0.31	20.36	−0.50
20.00	7.54	1.20	0.28	22.08	−0.43
19.99	6.91	1.10	0.26	24.07	−0.53
20.00	6.28	1.00	0.24	26.49	−0.27
19.99	5.66	0.90	0.21	29.41	−0.38
19.99	5.03	0.80	0.19	33.10	−0.29
19.98	4.40	0.70	0.17	37.82	−0.42
19.99	3.77	0.60	0.14	44.13	−0.55

Table I.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

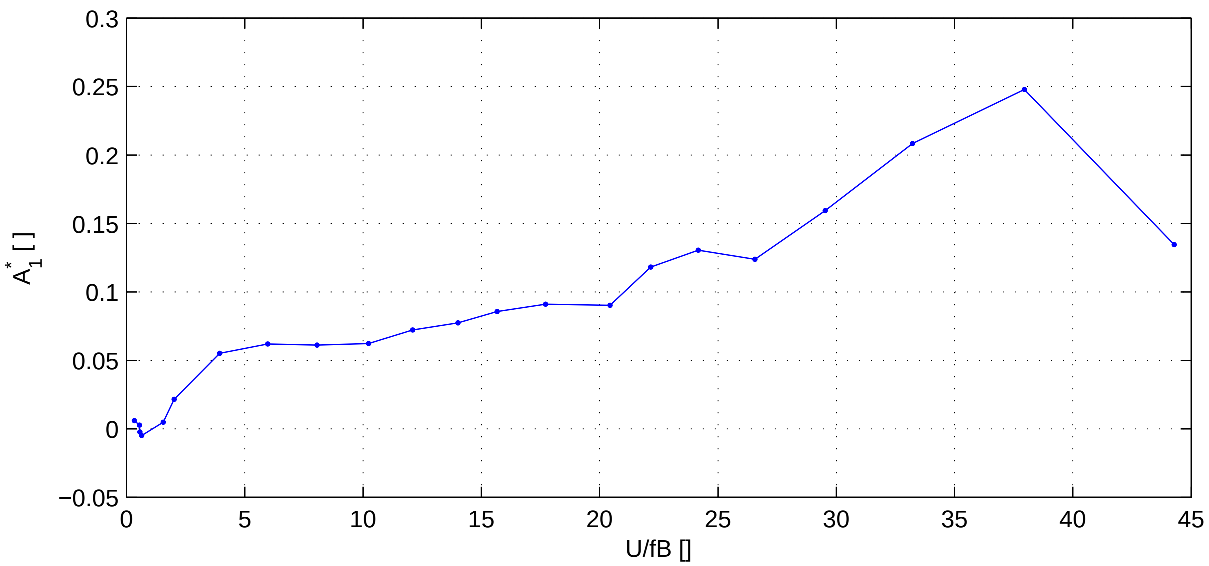

Figure I.7: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_1^*
1.01	25.13	4.00	18.80	0.33	0.01
1.65	25.13	4.00	11.48	0.55	0.00
1.72	25.13	4.00	11.02	0.57	−0.00
1.96	25.13	4.00	9.70	0.65	−0.01
4.71	25.13	4.00	4.03	1.56	0.00
6.08	25.13	4.00	3.12	2.01	0.02
11.90	25.13	4.00	1.59	3.94	0.06
18.02	25.13	4.00	1.05	5.97	0.06
20.08	20.74	3.30	0.78	8.06	0.06
20.09	16.34	2.60	0.61	10.23	0.06
20.10	13.82	2.20	0.52	12.10	0.07
20.09	11.93	1.90	0.45	14.01	0.08
20.10	10.68	1.70	0.40	15.66	0.09
20.07	9.43	1.50	0.35	17.71	0.09
20.07	8.17	1.30	0.31	20.44	0.09
20.07	7.54	1.20	0.28	22.16	0.12
20.07	6.91	1.10	0.26	24.17	0.13
20.06	6.28	1.00	0.24	26.57	0.12
20.07	5.66	0.90	0.21	29.54	0.16
20.06	5.03	0.80	0.19	33.22	0.21
20.06	4.40	0.70	0.17	37.95	0.25
20.05	3.77	0.60	0.14	44.28	0.13

Table I.9: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

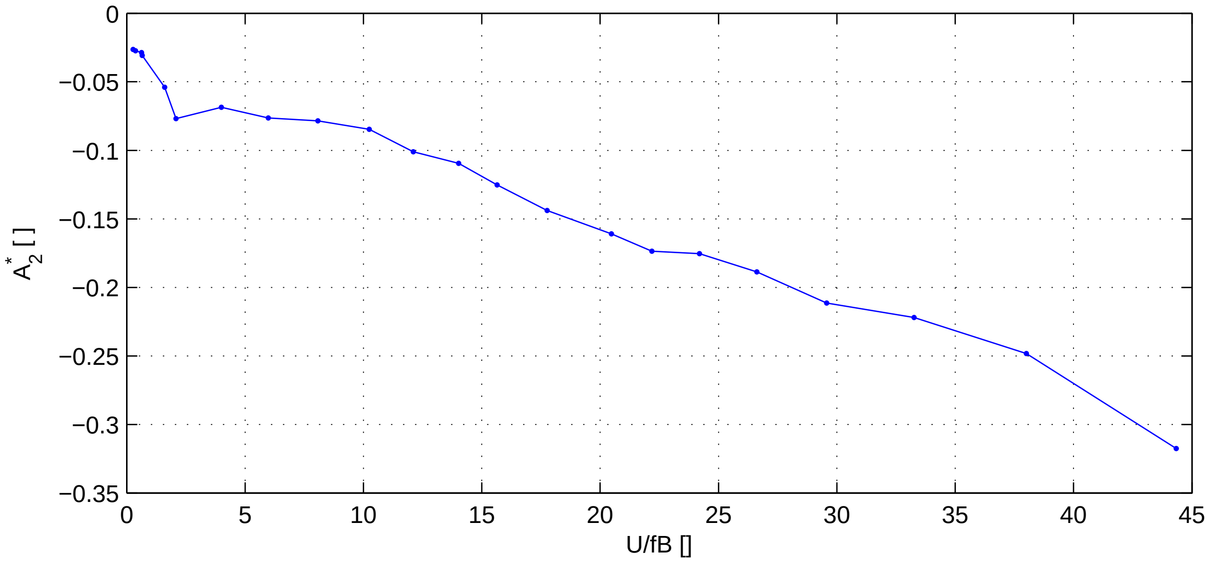

Figure I.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
0.80	25.13	4.00	23.70	0.27	−0.03
1.12	25.13	4.00	17.01	0.37	−0.03
1.90	25.13	4.00	10.01	0.63	−0.03
1.96	25.13	4.00	9.69	0.65	−0.03
4.84	25.13	4.00	3.92	1.60	−0.05
6.29	25.13	4.00	3.01	2.08	−0.08
12.08	25.13	4.00	1.57	4.00	−0.07
18.06	25.13	4.00	1.05	5.98	−0.08
20.11	20.74	3.30	0.78	8.07	−0.08
20.11	16.34	2.60	0.61	10.24	−0.08
20.11	13.82	2.20	0.52	12.10	−0.10
20.11	11.93	1.90	0.45	14.02	−0.11
20.09	10.69	1.70	0.40	15.64	−0.13
20.12	9.43	1.50	0.35	17.76	−0.14
20.09	8.17	1.30	0.31	20.48	−0.16
20.10	7.54	1.20	0.28	22.19	−0.17
20.10	6.91	1.10	0.26	24.20	−0.18
20.10	6.28	1.00	0.24	26.62	−0.19
20.10	5.66	0.90	0.21	29.57	−0.21
20.09	5.03	0.80	0.19	33.26	−0.22
20.09	4.40	0.70	0.17	38.00	−0.25
20.09	3.77	0.60	0.14	44.34	−0.32

Table I.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

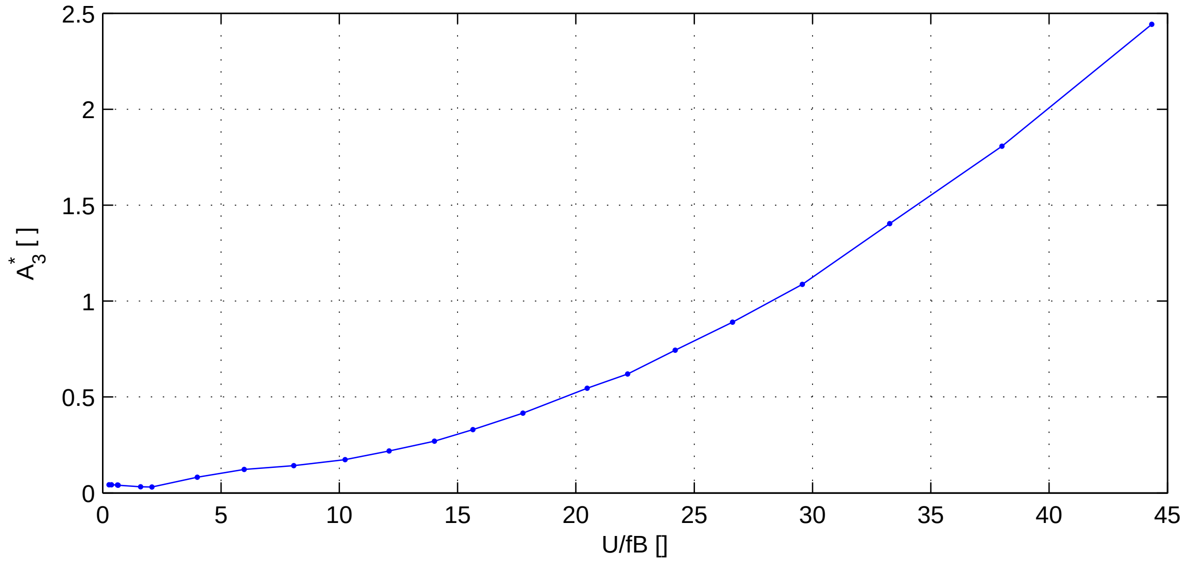

Figure I.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
0.80	25.13	4.00	23.70	0.27	0.04
1.12	25.13	4.00	17.01	0.37	0.04
1.90	25.13	4.00	10.01	0.63	0.04
1.96	25.13	4.00	9.69	0.65	0.04
4.84	25.13	4.00	3.92	1.60	0.03
6.29	25.13	4.00	3.01	2.08	0.03
12.08	25.13	4.00	1.57	4.00	0.08
18.06	25.13	4.00	1.05	5.98	0.12
20.11	20.74	3.30	0.78	8.07	0.14
20.11	16.34	2.60	0.61	10.24	0.17
20.11	13.82	2.20	0.52	12.10	0.22
20.11	11.93	1.90	0.45	14.02	0.27
20.09	10.69	1.70	0.40	15.64	0.33
20.12	9.43	1.50	0.35	17.76	0.42
20.09	8.17	1.30	0.31	20.48	0.55
20.10	7.54	1.20	0.28	22.19	0.62
20.10	6.91	1.10	0.26	24.20	0.74
20.10	6.28	1.00	0.24	26.62	0.89
20.10	5.66	0.90	0.21	29.57	1.09
20.09	5.03	0.80	0.19	33.26	1.40
20.09	4.40	0.70	0.17	38.00	1.81
20.09	3.77	0.60	0.14	44.34	2.44

Table I.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

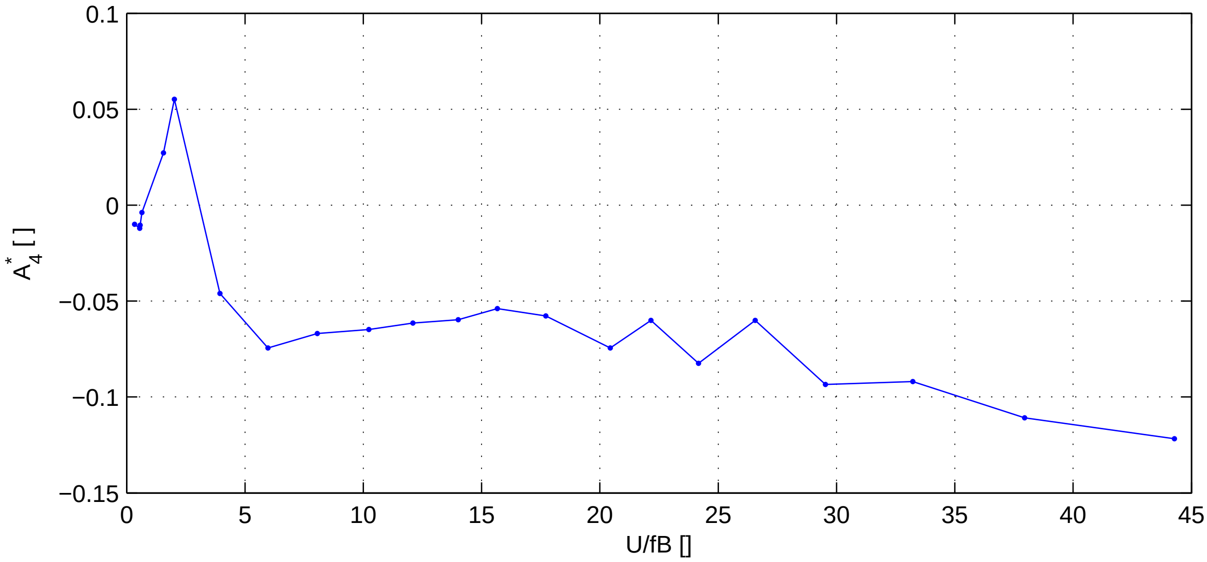

Figure I.10: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_4^*
1.01	25.13	4.00	18.80	0.33	−0.01
1.65	25.13	4.00	11.48	0.55	−0.01
1.72	25.13	4.00	11.02	0.57	−0.01
1.96	25.13	4.00	9.70	0.65	−0.00
4.71	25.13	4.00	4.03	1.56	0.03
6.08	25.13	4.00	3.12	2.01	0.06
11.90	25.13	4.00	1.59	3.94	−0.05
18.02	25.13	4.00	1.05	5.97	−0.07
20.08	20.74	3.30	0.78	8.06	−0.07
20.09	16.34	2.60	0.61	10.23	−0.06
20.10	13.82	2.20	0.52	12.10	−0.06
20.09	11.93	1.90	0.45	14.01	−0.06
20.10	10.68	1.70	0.40	15.66	−0.05
20.07	9.43	1.50	0.35	17.71	−0.06
20.07	8.17	1.30	0.31	20.44	−0.07
20.07	7.54	1.20	0.28	22.16	−0.06
20.07	6.91	1.10	0.26	24.17	−0.08
20.06	6.28	1.00	0.24	26.57	−0.06
20.07	5.66	0.90	0.21	29.54	−0.09
20.06	5.03	0.80	0.19	33.22	−0.09
20.06	4.40	0.70	0.17	37.95	−0.11
20.05	3.77	0.60	0.14	44.28	−0.12

Table I.12: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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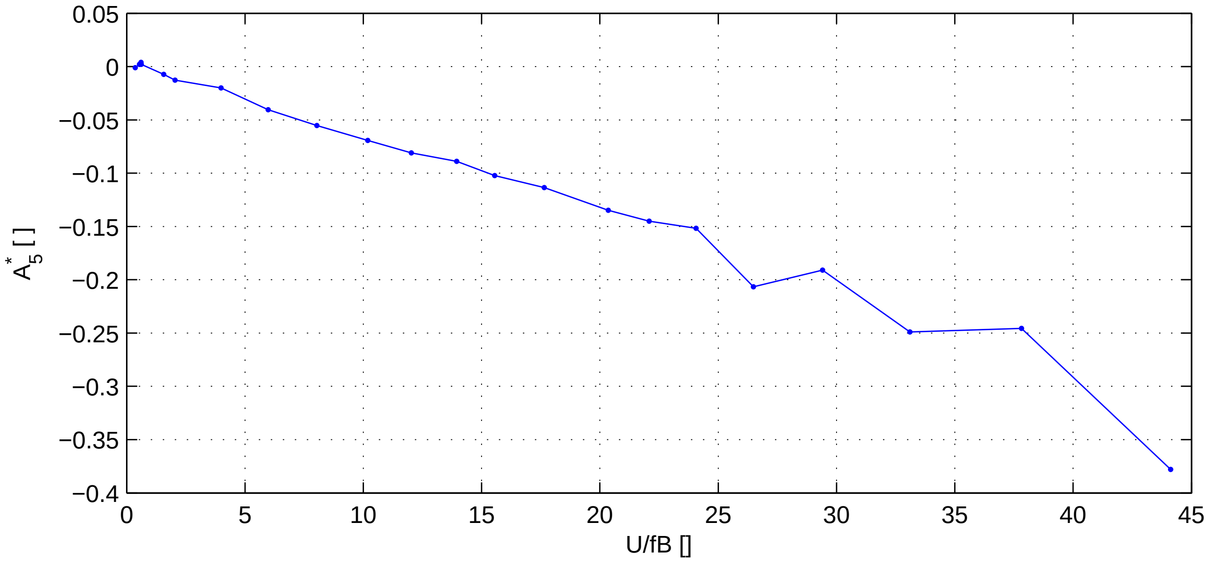

Figure I.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
1.08	25.13	4.00	17.53	0.36	−0.00
1.65	25.13	4.00	11.53	0.54	0.00
1.84	25.13	4.00	10.33	0.61	0.00
1.85	25.13	4.00	10.25	0.61	0.00
4.73	25.13	4.00	4.01	1.57	−0.01
6.17	25.13	4.00	3.08	2.04	−0.01
12.05	25.13	4.00	1.57	3.99	−0.02
18.05	25.13	4.00	1.05	5.98	−0.04
20.02	20.74	3.30	0.78	8.03	−0.06
20.01	16.34	2.60	0.62	10.19	−0.07
19.99	13.82	2.20	0.52	12.03	−0.08
20.00	11.93	1.90	0.45	13.95	−0.09
19.97	10.69	1.70	0.40	15.56	−0.10
19.99	9.43	1.50	0.36	17.65	−0.11
19.99	8.17	1.30	0.31	20.36	−0.13
20.00	7.54	1.20	0.28	22.08	−0.15
19.99	6.91	1.10	0.26	24.07	−0.15
20.00	6.28	1.00	0.24	26.49	−0.21
19.99	5.66	0.90	0.21	29.41	−0.19
19.99	5.03	0.80	0.19	33.10	−0.25
19.98	4.40	0.70	0.17	37.82	−0.25
19.99	3.77	0.60	0.14	44.13	−0.38

Table I.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

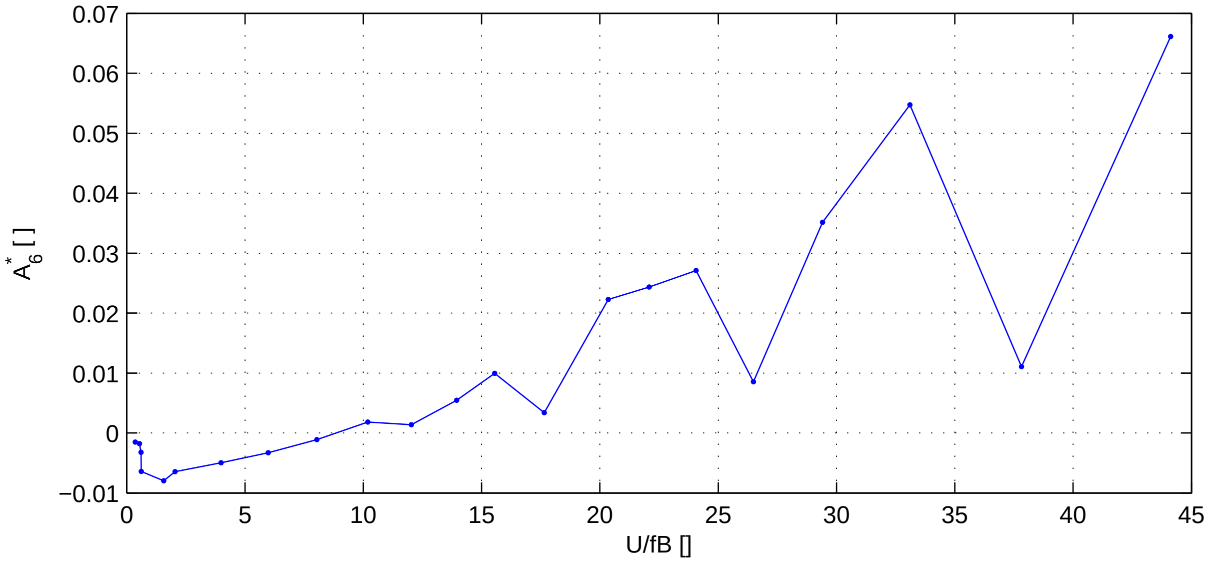

Figure I.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
1.08	25.13	4.00	17.53	0.36	−0.00
1.65	25.13	4.00	11.53	0.54	−0.00
1.84	25.13	4.00	10.33	0.61	−0.00
1.85	25.13	4.00	10.25	0.61	−0.01
4.73	25.13	4.00	4.01	1.57	−0.01
6.17	25.13	4.00	3.08	2.04	−0.01
12.05	25.13	4.00	1.57	3.99	−0.00
18.05	25.13	4.00	1.05	5.98	−0.00
20.02	20.74	3.30	0.78	8.03	−0.00
20.01	16.34	2.60	0.62	10.19	0.00
19.99	13.82	2.20	0.52	12.03	0.00
20.00	11.93	1.90	0.45	13.95	0.01
19.97	10.69	1.70	0.40	15.56	0.01
19.99	9.43	1.50	0.36	17.65	0.00
19.99	8.17	1.30	0.31	20.36	0.02
20.00	7.54	1.20	0.28	22.08	0.02
19.99	6.91	1.10	0.26	24.07	0.03
20.00	6.28	1.00	0.24	26.49	0.01
19.99	5.66	0.90	0.21	29.41	0.04
19.99	5.03	0.80	0.19	33.10	0.05
19.98	4.40	0.70	0.17	37.82	0.01
19.99	3.77	0.60	0.14	44.13	0.07

Table I.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

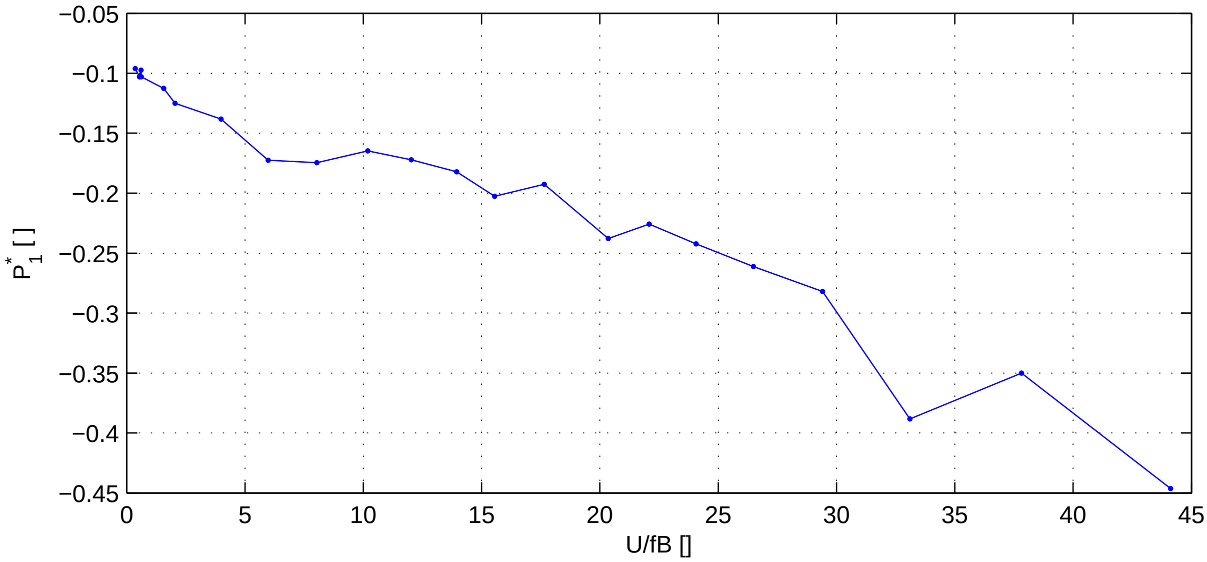

Figure I.13: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_1^*
1.08	25.13	4.00	17.53	0.36	−0.10
1.65	25.13	4.00	11.53	0.54	−0.10
1.84	25.13	4.00	10.33	0.61	−0.10
1.85	25.13	4.00	10.25	0.61	−0.10
4.73	25.13	4.00	4.01	1.57	−0.11
6.17	25.13	4.00	3.08	2.04	−0.13
12.05	25.13	4.00	1.57	3.99	−0.14
18.05	25.13	4.00	1.05	5.98	−0.17
20.02	20.74	3.30	0.78	8.03	−0.17
20.01	16.34	2.60	0.62	10.19	−0.16
19.99	13.82	2.20	0.52	12.03	−0.17
20.00	11.93	1.90	0.45	13.95	−0.18
19.97	10.69	1.70	0.40	15.56	−0.20
19.99	9.43	1.50	0.36	17.65	−0.19
19.99	8.17	1.30	0.31	20.36	−0.24
20.00	7.54	1.20	0.28	22.08	−0.23
19.99	6.91	1.10	0.26	24.07	−0.24
20.00	6.28	1.00	0.24	26.49	−0.26
19.99	5.66	0.90	0.21	29.41	−0.28
19.99	5.03	0.80	0.19	33.10	−0.39
19.98	4.40	0.70	0.17	37.82	−0.35
19.99	3.77	0.60	0.14	44.13	−0.45

Table I.15: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

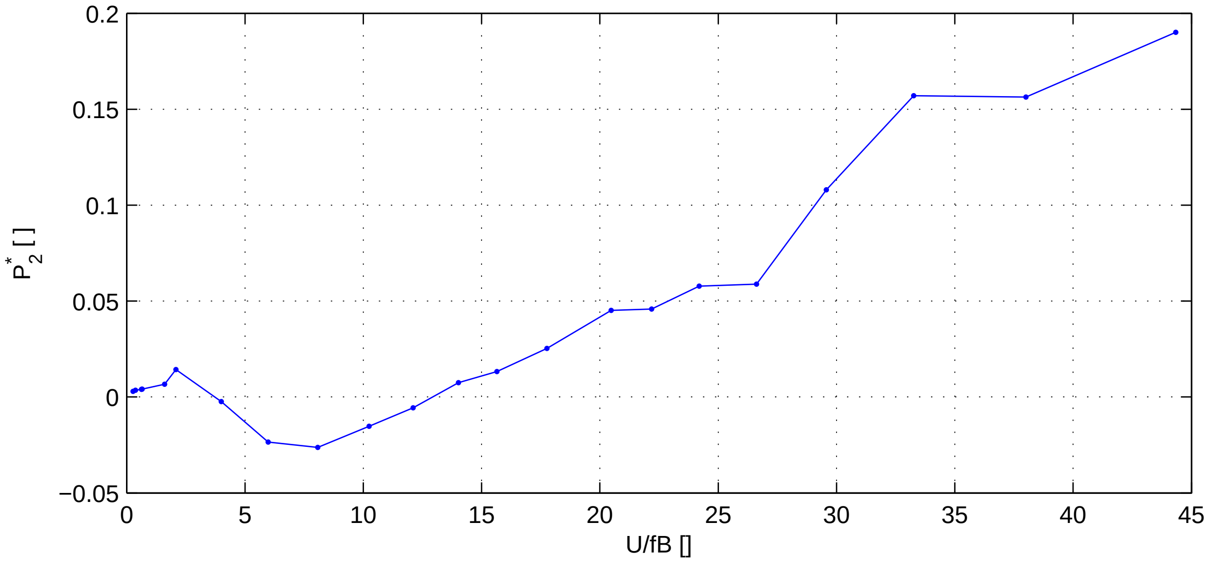

Figure I.14: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_2
0.80	25.13	4.00	23.70	0.27	0.00
1.12	25.13	4.00	17.01	0.37	0.00
1.90	25.13	4.00	10.01	0.63	0.00
1.96	25.13	4.00	9.69	0.65	0.00
4.84	25.13	4.00	3.92	1.60	0.01
6.29	25.13	4.00	3.01	2.08	0.01
12.08	25.13	4.00	1.57	4.00	−0.00
18.06	25.13	4.00	1.05	5.98	−0.02
20.11	20.74	3.30	0.78	8.07	−0.03
20.11	16.34	2.60	0.61	10.24	−0.02
20.11	13.82	2.20	0.52	12.10	−0.01
20.11	11.93	1.90	0.45	14.02	0.01
20.09	10.69	1.70	0.40	15.64	0.01
20.12	9.43	1.50	0.35	17.76	0.03
20.09	8.17	1.30	0.31	20.48	0.05
20.10	7.54	1.20	0.28	22.19	0.05
20.10	6.91	1.10	0.26	24.20	0.06
20.10	6.28	1.00	0.24	26.62	0.06
20.10	5.66	0.90	0.21	29.57	0.11
20.09	5.03	0.80	0.19	33.26	0.16
20.09	4.40	0.70	0.17	38.00	0.16
20.09	3.77	0.60	0.14	44.34	0.19

Table I.16: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

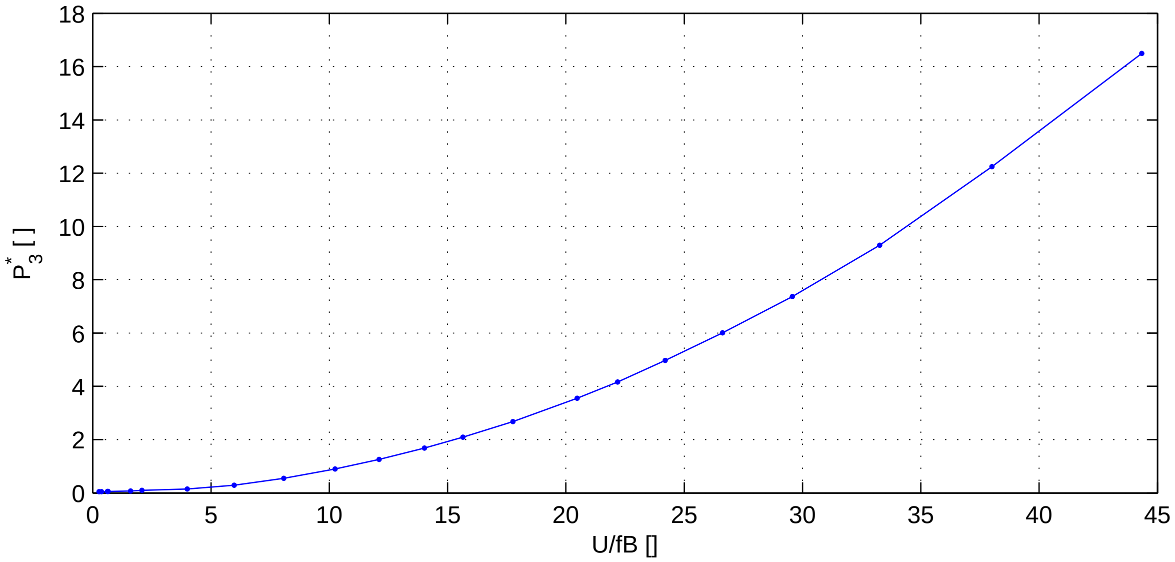

Figure I.15: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_3
0.80	25.13	4.00	23.70	0.27	0.05
1.12	25.13	4.00	17.01	0.37	0.05
1.90	25.13	4.00	10.01	0.63	0.05
1.96	25.13	4.00	9.69	0.65	0.05
4.84	25.13	4.00	3.92	1.60	0.07
6.29	25.13	4.00	3.01	2.08	0.09
12.08	25.13	4.00	1.57	4.00	0.15
18.06	25.13	4.00	1.05	5.98	0.29
20.11	20.74	3.30	0.78	8.07	0.55
20.11	16.34	2.60	0.61	10.24	0.90
20.11	13.82	2.20	0.52	12.10	1.26
20.11	11.93	1.90	0.45	14.02	1.68
20.09	10.69	1.70	0.40	15.64	2.09
20.12	9.43	1.50	0.35	17.76	2.67
20.09	8.17	1.30	0.31	20.48	3.56
20.10	7.54	1.20	0.28	22.19	4.16
20.10	6.91	1.10	0.26	24.20	4.97
20.10	6.28	1.00	0.24	26.62	6.00
20.10	5.66	0.90	0.21	29.57	7.37
20.09	5.03	0.80	0.19	33.26	9.30
20.09	4.40	0.70	0.17	38.00	12.25
20.09	3.77	0.60	0.14	44.34	16.49

Table I.17: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

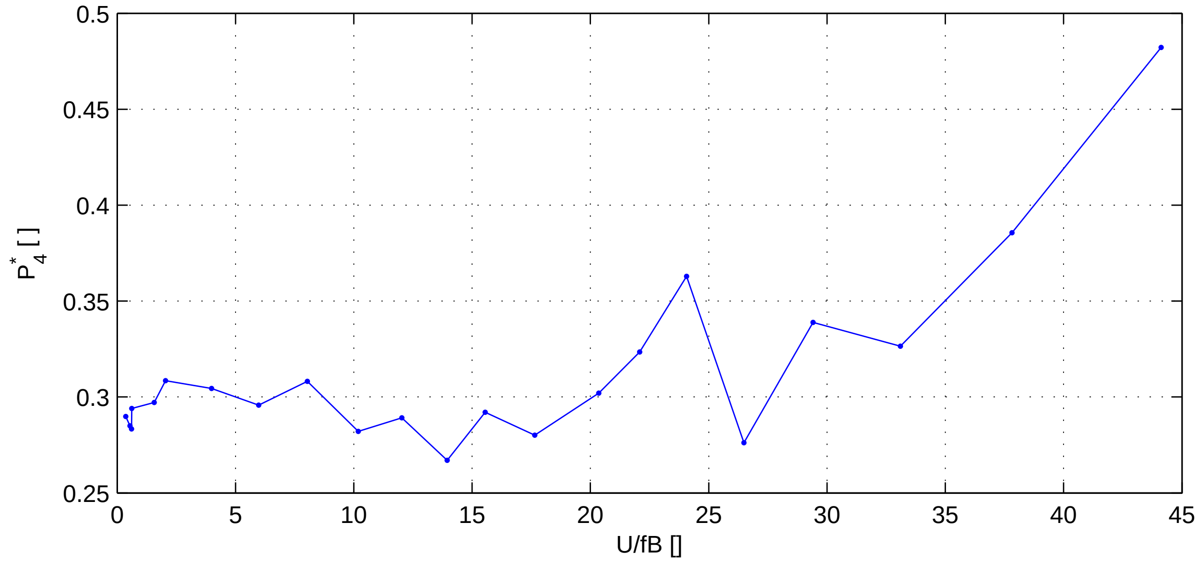

Figure I.16: P^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_4
1.08	25.13	4.00	17.53	0.36	0.29
1.65	25.13	4.00	11.53	0.54	0.28
1.84	25.13	4.00	10.33	0.61	0.28
1.85	25.13	4.00	10.25	0.61	0.29
4.73	25.13	4.00	4.01	1.57	0.30
6.17	25.13	4.00	3.08	2.04	0.31
12.05	25.13	4.00	1.57	3.99	0.30
18.05	25.13	4.00	1.05	5.98	0.30
20.02	20.74	3.30	0.78	8.03	0.31
20.01	16.34	2.60	0.62	10.19	0.28
19.99	13.82	2.20	0.52	12.03	0.29
20.00	11.93	1.90	0.45	13.95	0.27
19.97	10.69	1.70	0.40	15.56	0.29
19.99	9.43	1.50	0.36	17.65	0.28
19.99	8.17	1.30	0.31	20.36	0.30
20.00	7.54	1.20	0.28	22.08	0.32
19.99	6.91	1.10	0.26	24.07	0.36
20.00	6.28	1.00	0.24	26.49	0.28
19.99	5.66	0.90	0.21	29.41	0.34
19.99	5.03	0.80	0.19	33.10	0.33
19.98	4.40	0.70	0.17	37.82	0.39
19.99	3.77	0.60	0.14	44.13	0.48

Table I.18: P^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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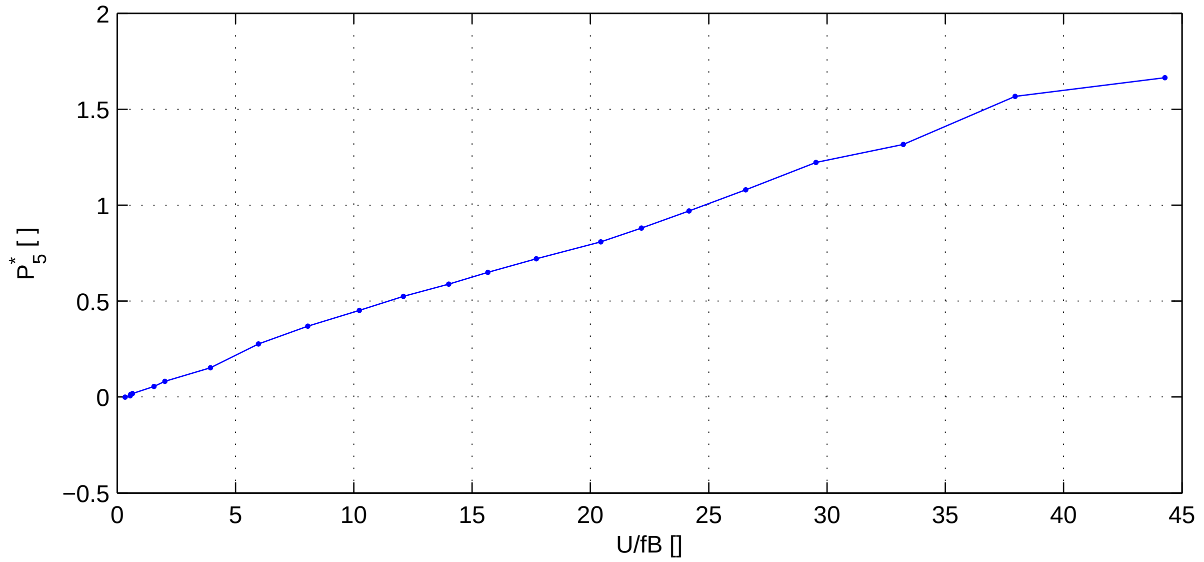

Figure I.17: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:18:27

U m/s	Omega rad/s	f /s	K	U/fB	P_5^*
1.01	25.13	4.00	18.80	0.33	−0.00
1.65	25.13	4.00	11.48	0.55	0.01
1.72	25.13	4.00	11.02	0.57	0.01
1.96	25.13	4.00	9.70	0.65	0.02
4.71	25.13	4.00	4.03	1.56	0.06
6.08	25.13	4.00	3.12	2.01	0.08
11.90	25.13	4.00	1.59	3.94	0.15
18.02	25.13	4.00	1.05	5.97	0.28
20.08	20.74	3.30	0.78	8.06	0.37
20.09	16.34	2.60	0.61	10.23	0.45
20.10	13.82	2.20	0.52	12.10	0.52
20.09	11.93	1.90	0.45	14.01	0.59
20.10	10.68	1.70	0.40	15.66	0.65
20.07	9.43	1.50	0.35	17.71	0.72
20.07	8.17	1.30	0.31	20.44	0.81
20.07	7.54	1.20	0.28	22.16	0.88
20.07	6.91	1.10	0.26	24.17	0.97
20.06	6.28	1.00	0.24	26.57	1.08
20.07	5.66	0.90	0.21	29.54	1.22
20.06	5.03	0.80	0.19	33.22	1.32
20.06	4.40	0.70	0.17	37.95	1.57
20.05	3.77	0.60	0.14	44.28	1.66

Table I.19: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

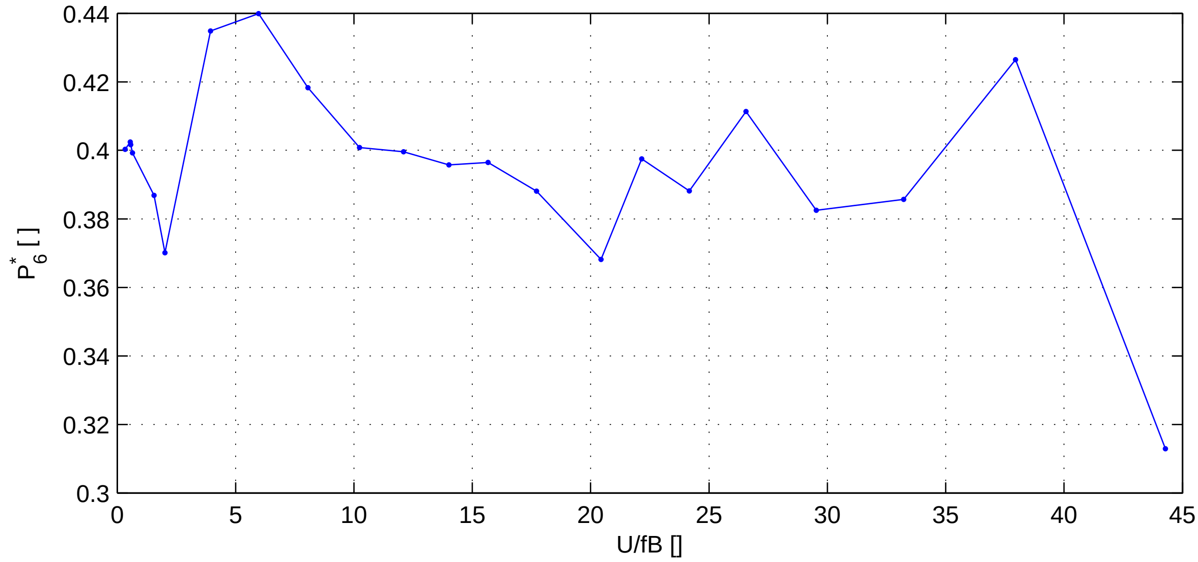

Figure I.18: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_6^*
1.01	25.13	4.00	18.80	0.33	0.40
1.65	25.13	4.00	11.48	0.55	0.40
1.72	25.13	4.00	11.02	0.57	0.40
1.96	25.13	4.00	9.70	0.65	0.40
4.71	25.13	4.00	4.03	1.56	0.39
6.08	25.13	4.00	3.12	2.01	0.37
11.90	25.13	4.00	1.59	3.94	0.43
18.02	25.13	4.00	1.05	5.97	0.44
20.08	20.74	3.30	0.78	8.06	0.42
20.09	16.34	2.60	0.61	10.23	0.40
20.10	13.82	2.20	0.52	12.10	0.40
20.09	11.93	1.90	0.45	14.01	0.40
20.10	10.68	1.70	0.40	15.66	0.40
20.07	9.43	1.50	0.35	17.71	0.39
20.07	8.17	1.30	0.31	20.44	0.37
20.07	7.54	1.20	0.28	22.16	0.40
20.07	6.91	1.10	0.26	24.17	0.39
20.06	6.28	1.00	0.24	26.57	0.41
20.07	5.66	0.90	0.21	29.54	0.38
20.06	5.03	0.80	0.19	33.22	0.39
20.06	4.40	0.70	0.17	37.95	0.43
20.05	3.77	0.60	0.14	44.28	0.31

Table I.20: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N / m]

L_{ae}: aeroelastic lift, [N / m]

L_b : buffeting lift, [N / m]

M_{ad}: aero dynamic lift, [N m / m]

M_{ae}: aeroelastic lift, [N m / m]

M_b : buffeting lift, [N m / m]

D_{ad}: aero dynamic lift, [N / m]

D_{ae}: aeroelastic lift, [N / m]

D_b : buffeting lift, [N / m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\,(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\,\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\,(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\,\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\,(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\,\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

Formula I.3: Equation of Motion (Stretto di Messina. Ref. [5].)

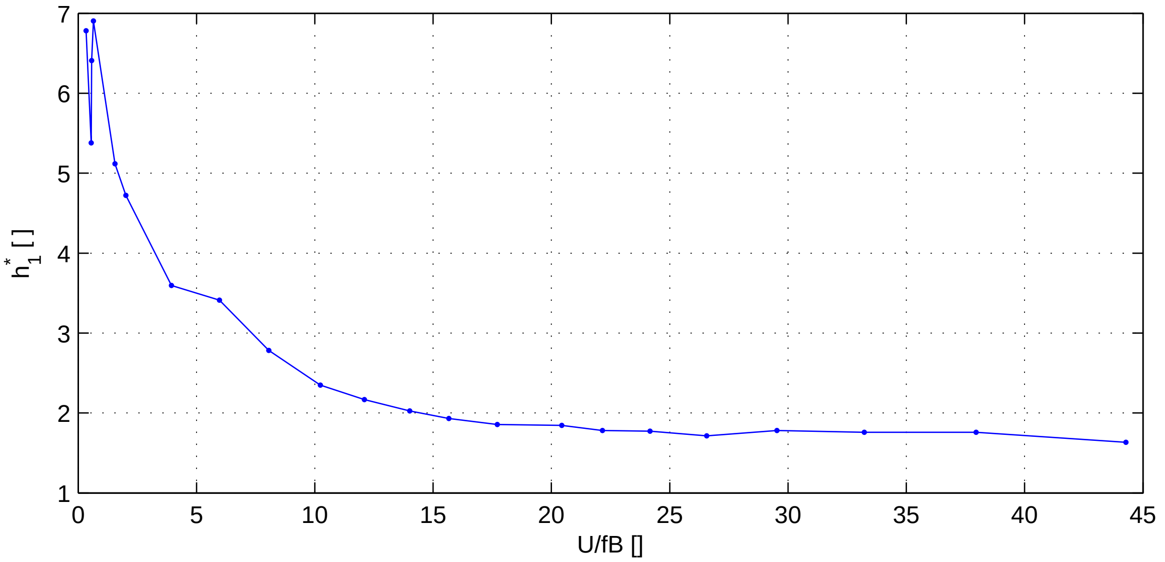

Figure I.19: h^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_1
1.01	25.13	4.00	18.80	0.33	6.78
1.65	25.13	4.00	11.48	0.55	5.38
1.72	25.13	4.00	11.02	0.57	6.41
1.96	25.13	4.00	9.70	0.65	6.90
4.71	25.13	4.00	4.03	1.56	5.12
6.08	25.13	4.00	3.12	2.01	4.72
11.90	25.13	4.00	1.59	3.94	3.59
18.02	25.13	4.00	1.05	5.97	3.41
20.08	20.74	3.30	0.78	8.06	2.78
20.09	16.34	2.60	0.61	10.23	2.35
20.10	13.82	2.20	0.52	12.10	2.17
20.09	11.93	1.90	0.45	14.01	2.02
20.10	10.68	1.70	0.40	15.66	1.93
20.07	9.43	1.50	0.35	17.71	1.85
20.07	8.17	1.30	0.31	20.44	1.84
20.07	7.54	1.20	0.28	22.16	1.78
20.07	6.91	1.10	0.26	24.17	1.77
20.06	6.28	1.00	0.24	26.57	1.71
20.07	5.66	0.90	0.21	29.54	1.78
20.06	5.03	0.80	0.19	33.22	1.76
20.06	4.40	0.70	0.17	37.95	1.76
20.05	3.77	0.60	0.14	44.28	1.63

Table I.21: h^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:18:27

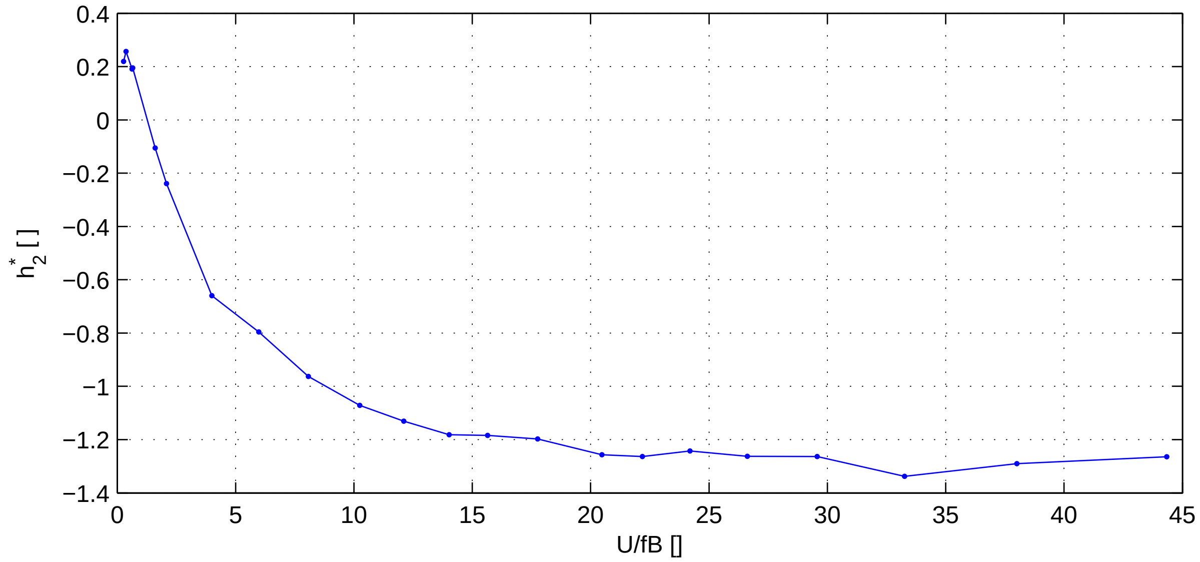

Figure I.20: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_2^*
0.80	25.13	4.00	23.70	0.27	0.22
1.12	25.13	4.00	17.01	0.37	0.26
1.90	25.13	4.00	10.01	0.63	0.19
1.96	25.13	4.00	9.69	0.65	0.19
4.84	25.13	4.00	3.92	1.60	−0.11
6.29	25.13	4.00	3.01	2.08	−0.24
12.08	25.13	4.00	1.57	4.00	−0.66
18.06	25.13	4.00	1.05	5.98	−0.80
20.11	20.74	3.30	0.78	8.07	−0.96
20.11	16.34	2.60	0.61	10.24	−1.07
20.11	13.82	2.20	0.52	12.10	−1.13
20.11	11.93	1.90	0.45	14.02	−1.18
20.09	10.69	1.70	0.40	15.64	−1.18
20.12	9.43	1.50	0.35	17.76	−1.20
20.09	8.17	1.30	0.31	20.48	−1.26
20.10	7.54	1.20	0.28	22.19	−1.26
20.10	6.91	1.10	0.26	24.20	−1.24
20.10	6.28	1.00	0.24	26.62	−1.26
20.10	5.66	0.90	0.21	29.57	−1.26
20.09	5.03	0.80	0.19	33.26	−1.34
20.09	4.40	0.70	0.17	38.00	−1.29
20.09	3.77	0.60	0.14	44.34	−1.26

Table I.22: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:18:27

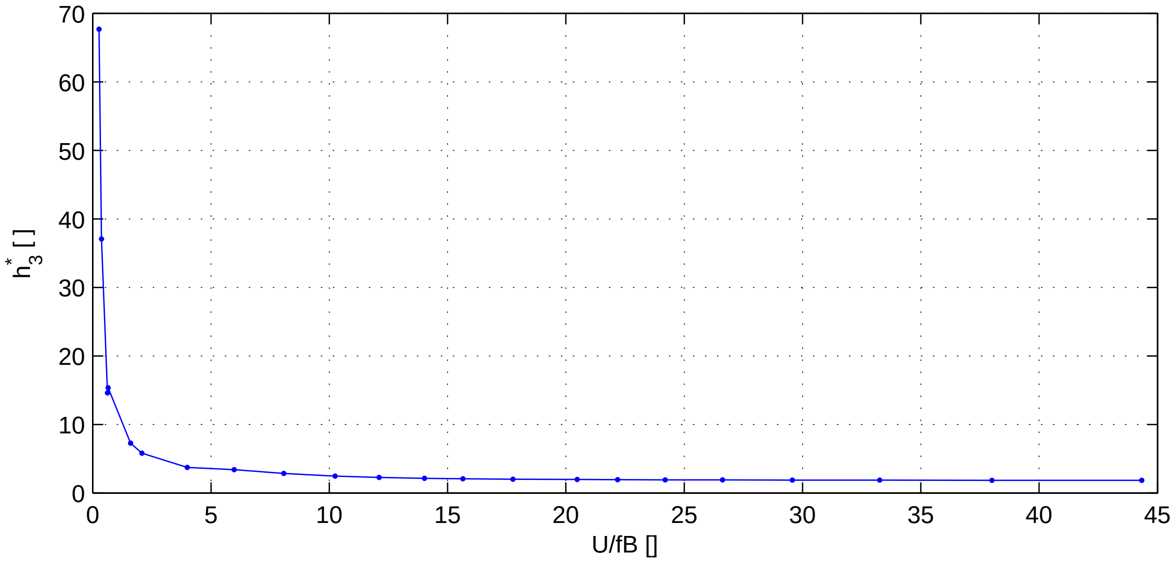

Figure I.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
0.80	25.13	4.00	23.70	0.27	67.67
1.12	25.13	4.00	17.01	0.37	37.06
1.90	25.13	4.00	10.01	0.63	14.58
1.96	25.13	4.00	9.69	0.65	15.34
4.84	25.13	4.00	3.92	1.60	7.27
6.29	25.13	4.00	3.01	2.08	5.81
12.08	25.13	4.00	1.57	4.00	3.73
18.06	25.13	4.00	1.05	5.98	3.40
20.11	20.74	3.30	0.78	8.07	2.83
20.11	16.34	2.60	0.61	10.24	2.44
20.11	13.82	2.20	0.52	12.10	2.25
20.11	11.93	1.90	0.45	14.02	2.13
20.09	10.69	1.70	0.40	15.64	2.07
20.12	9.43	1.50	0.35	17.76	2.00
20.09	8.17	1.30	0.31	20.48	1.96
20.10	7.54	1.20	0.28	22.19	1.92
20.10	6.91	1.10	0.26	24.20	1.91
20.10	6.28	1.00	0.24	26.62	1.88
20.10	5.66	0.90	0.21	29.57	1.87
20.09	5.03	0.80	0.19	33.26	1.85
20.09	4.40	0.70	0.17	38.00	1.85
20.09	3.77	0.60	0.14	44.34	1.82

Table I.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

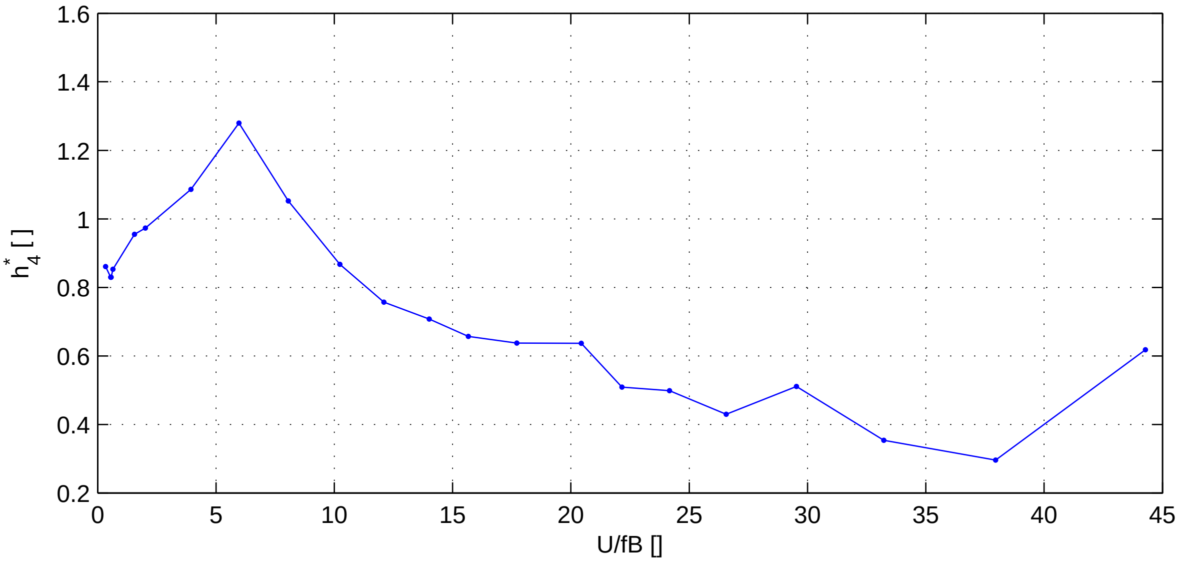

Figure I.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
1.01	25.13	4.00	18.80	0.33	0.86
1.65	25.13	4.00	11.48	0.55	0.83
1.72	25.13	4.00	11.02	0.57	0.83
1.96	25.13	4.00	9.70	0.65	0.85
4.71	25.13	4.00	4.03	1.56	0.96
6.08	25.13	4.00	3.12	2.01	0.97
11.90	25.13	4.00	1.59	3.94	1.09
18.02	25.13	4.00	1.05	5.97	1.28
20.08	20.74	3.30	0.78	8.06	1.05
20.09	16.34	2.60	0.61	10.23	0.87
20.10	13.82	2.20	0.52	12.10	0.76
20.09	11.93	1.90	0.45	14.01	0.71
20.10	10.68	1.70	0.40	15.66	0.66
20.07	9.43	1.50	0.35	17.71	0.64
20.07	8.17	1.30	0.31	20.44	0.64
20.07	7.54	1.20	0.28	22.16	0.51
20.07	6.91	1.10	0.26	24.17	0.50
20.06	6.28	1.00	0.24	26.57	0.43
20.07	5.66	0.90	0.21	29.54	0.51
20.06	5.03	0.80	0.19	33.22	0.35
20.06	4.40	0.70	0.17	37.95	0.30
20.05	3.77	0.60	0.14	44.28	0.62

Table I.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

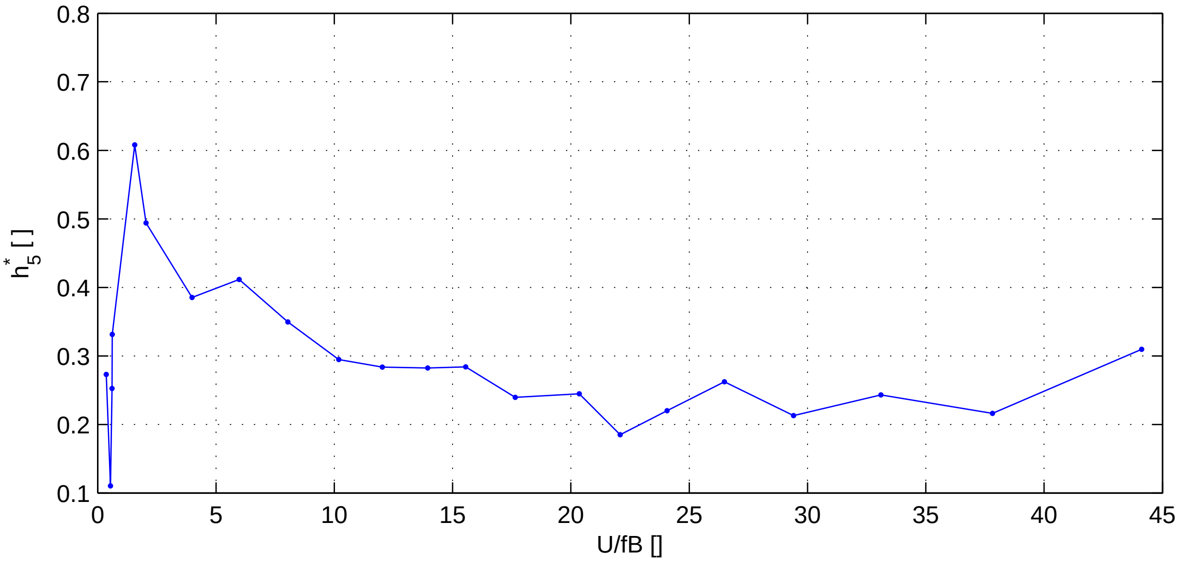

Figure I.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
1.08	25.13	4.00	17.53	0.36	0.27
1.65	25.13	4.00	11.53	0.54	0.11
1.84	25.13	4.00	10.33	0.61	0.25
1.85	25.13	4.00	10.25	0.61	0.33
4.73	25.13	4.00	4.01	1.57	0.61
6.17	25.13	4.00	3.08	2.04	0.49
12.05	25.13	4.00	1.57	3.99	0.39
18.05	25.13	4.00	1.05	5.98	0.41
20.02	20.74	3.30	0.78	8.03	0.35
20.01	16.34	2.60	0.62	10.19	0.29
19.99	13.82	2.20	0.52	12.03	0.28
20.00	11.93	1.90	0.45	13.95	0.28
19.97	10.69	1.70	0.40	15.56	0.28
19.99	9.43	1.50	0.36	17.65	0.24
19.99	8.17	1.30	0.31	20.36	0.24
20.00	7.54	1.20	0.28	22.08	0.18
19.99	6.91	1.10	0.26	24.07	0.22
20.00	6.28	1.00	0.24	26.49	0.26
19.99	5.66	0.90	0.21	29.41	0.21
19.99	5.03	0.80	0.19	33.10	0.24
19.98	4.40	0.70	0.17	37.82	0.22
19.99	3.77	0.60	0.14	44.13	0.31

Table I.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

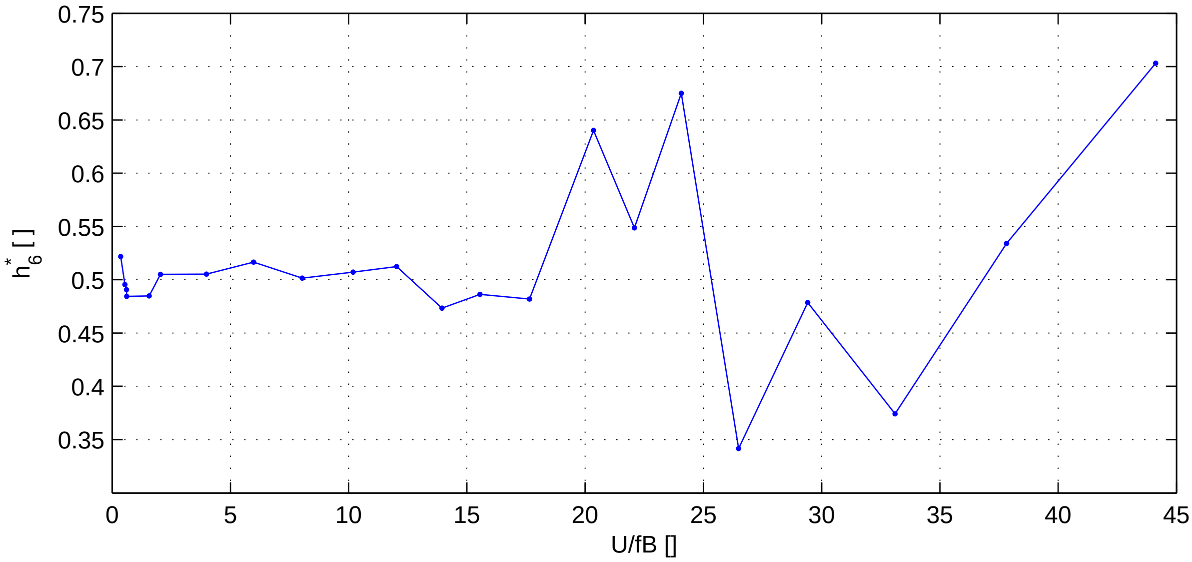

Figure I.24: h^*_6 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_6
1.08	25.13	4.00	17.53	0.36	0.52
1.65	25.13	4.00	11.53	0.54	0.50
1.84	25.13	4.00	10.33	0.61	0.49
1.85	25.13	4.00	10.25	0.61	0.48
4.73	25.13	4.00	4.01	1.57	0.48
6.17	25.13	4.00	3.08	2.04	0.51
12.05	25.13	4.00	1.57	3.99	0.51
18.05	25.13	4.00	1.05	5.98	0.52
20.02	20.74	3.30	0.78	8.03	0.50
20.01	16.34	2.60	0.62	10.19	0.51
19.99	13.82	2.20	0.52	12.03	0.51
20.00	11.93	1.90	0.45	13.95	0.47
19.97	10.69	1.70	0.40	15.56	0.49
19.99	9.43	1.50	0.36	17.65	0.48
19.99	8.17	1.30	0.31	20.36	0.64
20.00	7.54	1.20	0.28	22.08	0.55
19.99	6.91	1.10	0.26	24.07	0.68
20.00	6.28	1.00	0.24	26.49	0.34
19.99	5.66	0.90	0.21	29.41	0.48
19.99	5.03	0.80	0.19	33.10	0.37
19.98	4.40	0.70	0.17	37.82	0.53
19.99	3.77	0.60	0.14	44.13	0.70

Table I.26: h^*_6 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

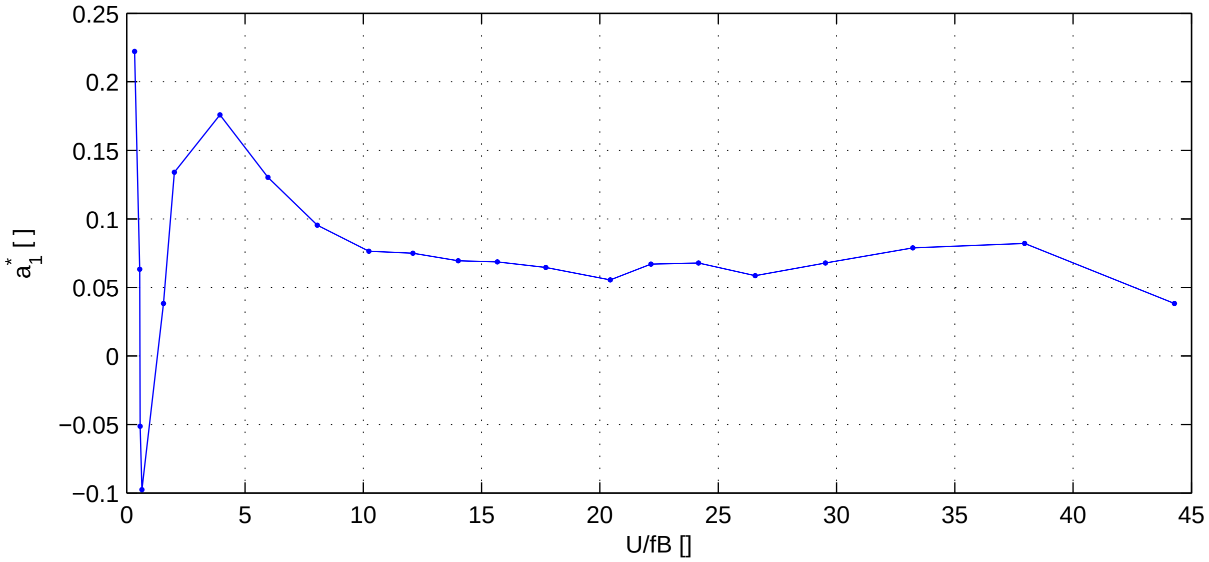

Figure I.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
1.01	25.13	4.00	18.80	0.33	0.22
1.65	25.13	4.00	11.48	0.55	0.06
1.72	25.13	4.00	11.02	0.57	−0.05
1.96	25.13	4.00	9.70	0.65	−0.10
4.71	25.13	4.00	4.03	1.56	0.04
6.08	25.13	4.00	3.12	2.01	0.13
11.90	25.13	4.00	1.59	3.94	0.18
18.02	25.13	4.00	1.05	5.97	0.13
20.08	20.74	3.30	0.78	8.06	0.10
20.09	16.34	2.60	0.61	10.23	0.08
20.10	13.82	2.20	0.52	12.10	0.07
20.09	11.93	1.90	0.45	14.01	0.07
20.10	10.68	1.70	0.40	15.66	0.07
20.07	9.43	1.50	0.35	17.71	0.06
20.07	8.17	1.30	0.31	20.44	0.06
20.07	7.54	1.20	0.28	22.16	0.07
20.07	6.91	1.10	0.26	24.17	0.07
20.06	6.28	1.00	0.24	26.57	0.06
20.07	5.66	0.90	0.21	29.54	0.07
20.06	5.03	0.80	0.19	33.22	0.08
20.06	4.40	0.70	0.17	37.95	0.08
20.05	3.77	0.60	0.14	44.28	0.04

Table I.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:18:27

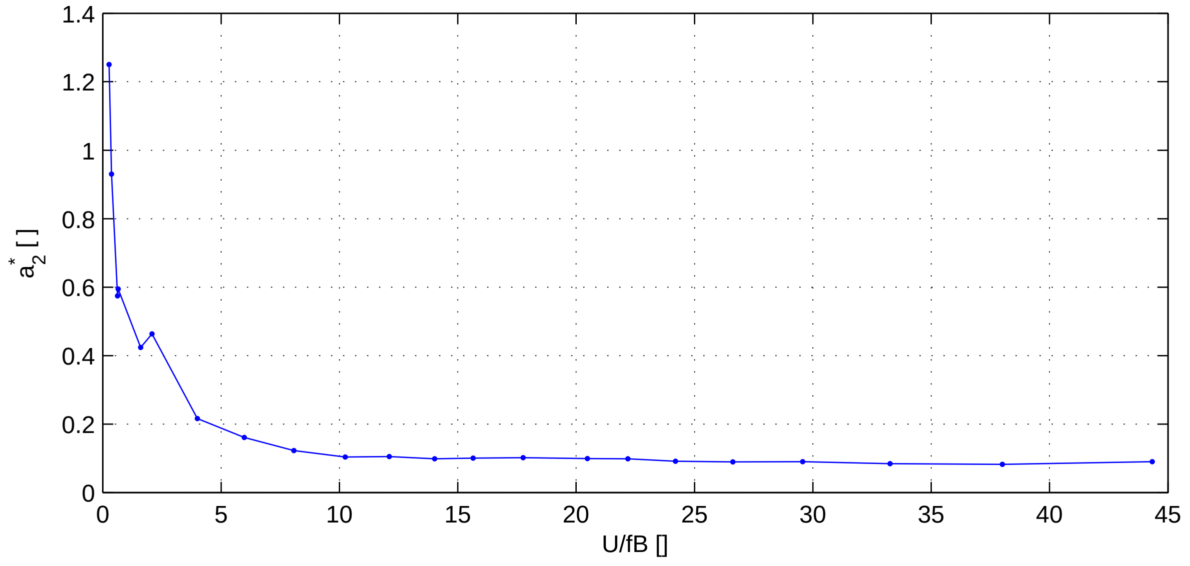

Figure I.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
0.80	25.13	4.00	23.70	0.27	1.25
1.12	25.13	4.00	17.01	0.37	0.93
1.90	25.13	4.00	10.01	0.63	0.57
1.96	25.13	4.00	9.69	0.65	0.59
4.84	25.13	4.00	3.92	1.60	0.42
6.29	25.13	4.00	3.01	2.08	0.46
12.08	25.13	4.00	1.57	4.00	0.22
18.06	25.13	4.00	1.05	5.98	0.16
20.11	20.74	3.30	0.78	8.07	0.12
20.11	16.34	2.60	0.61	10.24	0.10
20.11	13.82	2.20	0.52	12.10	0.10
20.11	11.93	1.90	0.45	14.02	0.10
20.09	10.69	1.70	0.40	15.64	0.10
20.12	9.43	1.50	0.35	17.76	0.10
20.09	8.17	1.30	0.31	20.48	0.10
20.10	7.54	1.20	0.28	22.19	0.10
20.10	6.91	1.10	0.26	24.20	0.09
20.10	6.28	1.00	0.24	26.62	0.09
20.10	5.66	0.90	0.21	29.57	0.09
20.09	5.03	0.80	0.19	33.26	0.08
20.09	4.40	0.70	0.17	38.00	0.08
20.09	3.77	0.60	0.14	44.34	0.09

Table I.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:18:27

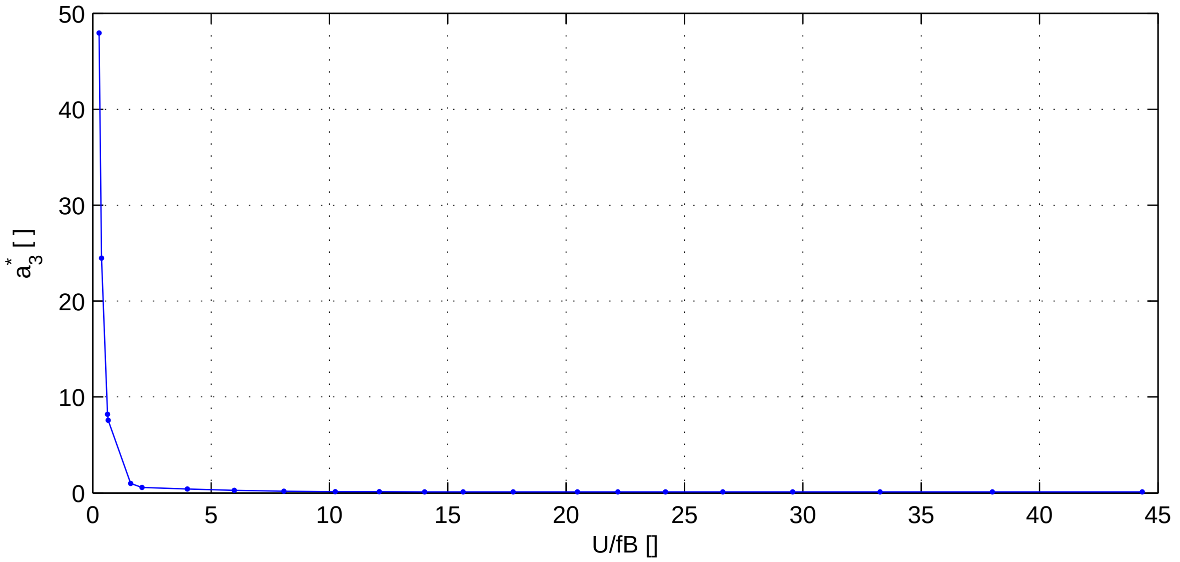

Figure I.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
0.80	25.13	4.00	23.70	0.27	47.94
1.12	25.13	4.00	17.01	0.37	24.47
1.90	25.13	4.00	10.01	0.63	8.19
1.96	25.13	4.00	9.69	0.65	7.57
4.84	25.13	4.00	3.92	1.60	0.98
6.29	25.13	4.00	3.01	2.08	0.56
12.08	25.13	4.00	1.57	4.00	0.41
18.06	25.13	4.00	1.05	5.98	0.27
20.11	20.74	3.30	0.78	8.07	0.17
20.11	16.34	2.60	0.61	10.24	0.13
20.11	13.82	2.20	0.52	12.10	0.12
20.11	11.93	1.90	0.45	14.02	0.11
20.09	10.69	1.70	0.40	15.64	0.11
20.12	9.43	1.50	0.35	17.76	0.10
20.09	8.17	1.30	0.31	20.48	0.10
20.10	7.54	1.20	0.28	22.19	0.10
20.10	6.91	1.10	0.26	24.20	0.10
20.10	6.28	1.00	0.24	26.62	0.10
20.10	5.66	0.90	0.21	29.57	0.10
20.09	5.03	0.80	0.19	33.26	0.10
20.09	4.40	0.70	0.17	38.00	0.10
20.09	3.77	0.60	0.14	44.34	0.10

Table I.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

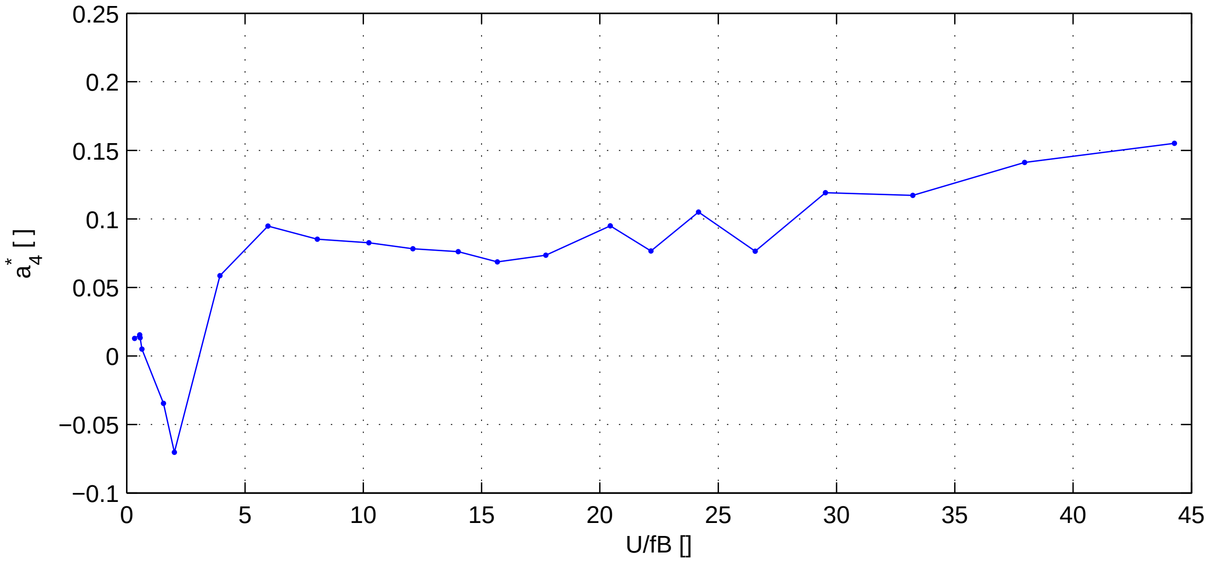

Figure I.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
1.01	25.13	4.00	18.80	0.33	0.01
1.65	25.13	4.00	11.48	0.55	0.02
1.72	25.13	4.00	11.02	0.57	0.01
1.96	25.13	4.00	9.70	0.65	0.00
4.71	25.13	4.00	4.03	1.56	−0.03
6.08	25.13	4.00	3.12	2.01	−0.07
11.90	25.13	4.00	1.59	3.94	0.06
18.02	25.13	4.00	1.05	5.97	0.09
20.08	20.74	3.30	0.78	8.06	0.09
20.09	16.34	2.60	0.61	10.23	0.08
20.10	13.82	2.20	0.52	12.10	0.08
20.09	11.93	1.90	0.45	14.01	0.08
20.10	10.68	1.70	0.40	15.66	0.07
20.07	9.43	1.50	0.35	17.71	0.07
20.07	8.17	1.30	0.31	20.44	0.09
20.07	7.54	1.20	0.28	22.16	0.08
20.07	6.91	1.10	0.26	24.17	0.11
20.06	6.28	1.00	0.24	26.57	0.08
20.07	5.66	0.90	0.21	29.54	0.12
20.06	5.03	0.80	0.19	33.22	0.12
20.06	4.40	0.70	0.17	37.95	0.14
20.05	3.77	0.60	0.14	44.28	0.16

Table I.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

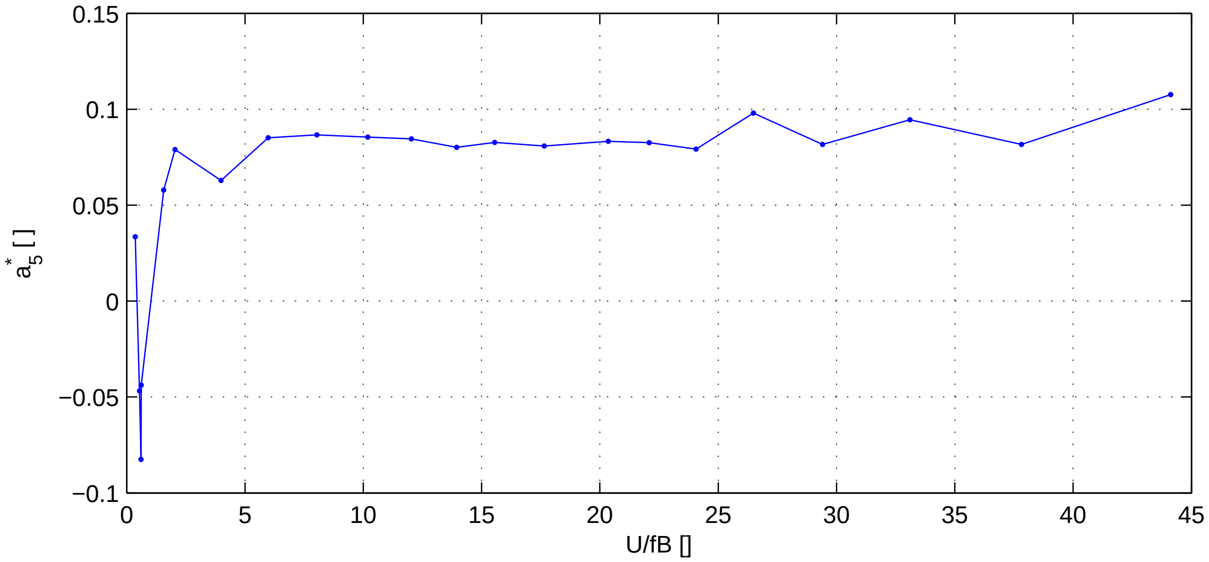

Figure I.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
1.08	25.13	4.00	17.53	0.36	0.03
1.65	25.13	4.00	11.53	0.54	−0.05
1.84	25.13	4.00	10.33	0.61	−0.08
1.85	25.13	4.00	10.25	0.61	−0.04
4.73	25.13	4.00	4.01	1.57	0.06
6.17	25.13	4.00	3.08	2.04	0.08
12.05	25.13	4.00	1.57	3.99	0.06
18.05	25.13	4.00	1.05	5.98	0.09
20.02	20.74	3.30	0.78	8.03	0.09
20.01	16.34	2.60	0.62	10.19	0.09
19.99	13.82	2.20	0.52	12.03	0.08
20.00	11.93	1.90	0.45	13.95	0.08
19.97	10.69	1.70	0.40	15.56	0.08
19.99	9.43	1.50	0.36	17.65	0.08
19.99	8.17	1.30	0.31	20.36	0.08
20.00	7.54	1.20	0.28	22.08	0.08
19.99	6.91	1.10	0.26	24.07	0.08
20.00	6.28	1.00	0.24	26.49	0.10
19.99	5.66	0.90	0.21	29.41	0.08
19.99	5.03	0.80	0.19	33.10	0.09
19.98	4.40	0.70	0.17	37.82	0.08
19.99	3.77	0.60	0.14	44.13	0.11

Table I.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:18:27

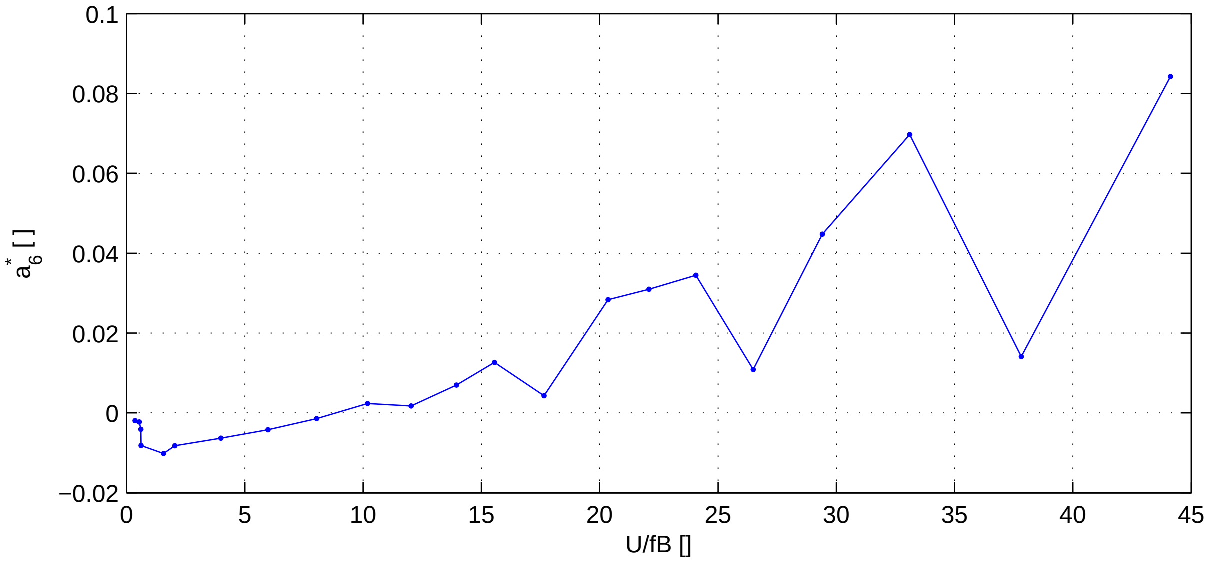

Figure I.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
1.08	25.13	4.00	17.53	0.36	−0.00
1.65	25.13	4.00	11.53	0.54	−0.00
1.84	25.13	4.00	10.33	0.61	−0.00
1.85	25.13	4.00	10.25	0.61	−0.01
4.73	25.13	4.00	4.01	1.57	−0.01
6.17	25.13	4.00	3.08	2.04	−0.01
12.05	25.13	4.00	1.57	3.99	−0.01
18.05	25.13	4.00	1.05	5.98	−0.00
20.02	20.74	3.30	0.78	8.03	−0.00
20.01	16.34	2.60	0.62	10.19	0.00
19.99	13.82	2.20	0.52	12.03	0.00
20.00	11.93	1.90	0.45	13.95	0.01
19.97	10.69	1.70	0.40	15.56	0.01
19.99	9.43	1.50	0.36	17.65	0.00
19.99	8.17	1.30	0.31	20.36	0.03
20.00	7.54	1.20	0.28	22.08	0.03
19.99	6.91	1.10	0.26	24.07	0.03
20.00	6.28	1.00	0.24	26.49	0.01
19.99	5.66	0.90	0.21	29.41	0.04
19.99	5.03	0.80	0.19	33.10	0.07
19.98	4.40	0.70	0.17	37.82	0.01
19.99	3.77	0.60	0.14	44.13	0.08

Table I.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

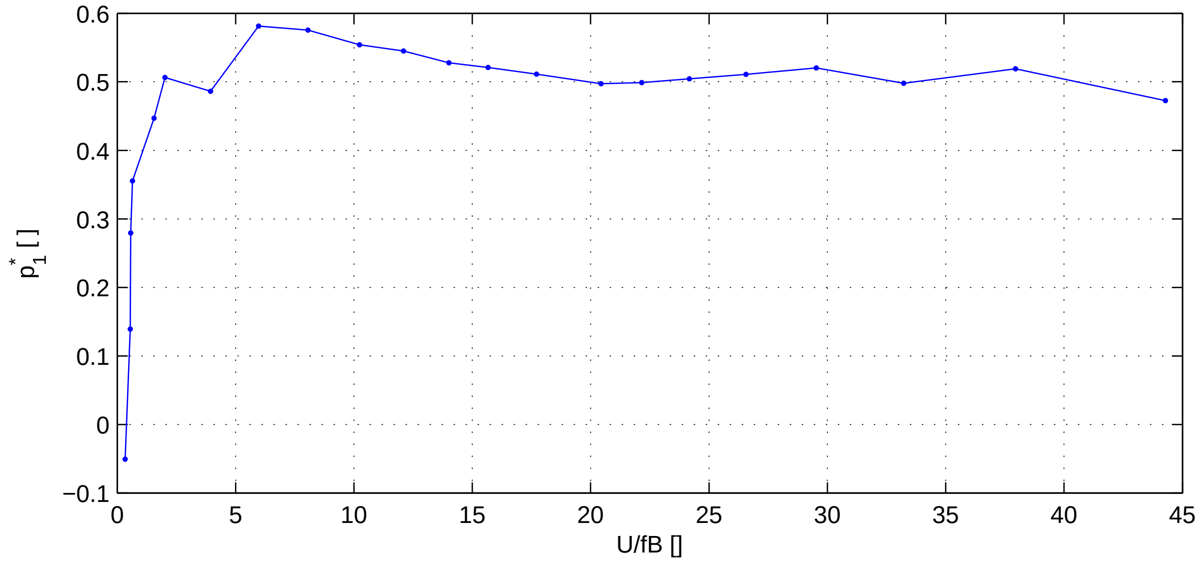

Figure I.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
1.01	25.13	4.00	18.80	0.33	−0.05
1.65	25.13	4.00	11.48	0.55	0.14
1.72	25.13	4.00	11.02	0.57	0.28
1.96	25.13	4.00	9.70	0.65	0.36
4.71	25.13	4.00	4.03	1.56	0.45
6.08	25.13	4.00	3.12	2.01	0.51
11.90	25.13	4.00	1.59	3.94	0.49
18.02	25.13	4.00	1.05	5.97	0.58
20.08	20.74	3.30	0.78	8.06	0.58
20.09	16.34	2.60	0.61	10.23	0.55
20.10	13.82	2.20	0.52	12.10	0.54
20.09	11.93	1.90	0.45	14.01	0.53
20.10	10.68	1.70	0.40	15.66	0.52
20.07	9.43	1.50	0.35	17.71	0.51
20.07	8.17	1.30	0.31	20.44	0.50
20.07	7.54	1.20	0.28	22.16	0.50
20.07	6.91	1.10	0.26	24.17	0.50
20.06	6.28	1.00	0.24	26.57	0.51
20.07	5.66	0.90	0.21	29.54	0.52
20.06	5.03	0.80	0.19	33.22	0.50
20.06	4.40	0.70	0.17	37.95	0.52
20.05	3.77	0.60	0.14	44.28	0.47

Table I.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

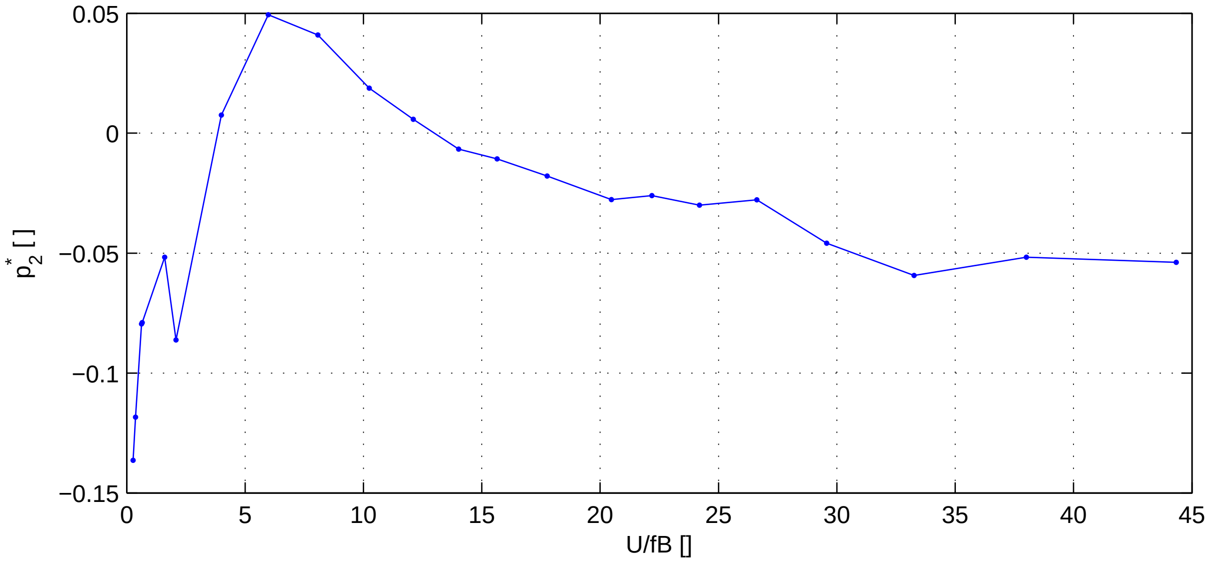

Figure I.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
0.80	25.13	4.00	23.70	0.27	−0.14
1.12	25.13	4.00	17.01	0.37	−0.12
1.90	25.13	4.00	10.01	0.63	−0.08
1.96	25.13	4.00	9.69	0.65	−0.08
4.84	25.13	4.00	3.92	1.60	−0.05
6.29	25.13	4.00	3.01	2.08	−0.09
12.08	25.13	4.00	1.57	4.00	0.01
18.06	25.13	4.00	1.05	5.98	0.05
20.11	20.74	3.30	0.78	8.07	0.04
20.11	16.34	2.60	0.61	10.24	0.02
20.11	13.82	2.20	0.52	12.10	0.01
20.11	11.93	1.90	0.45	14.02	−0.01
20.09	10.69	1.70	0.40	15.64	−0.01
20.12	9.43	1.50	0.35	17.76	−0.02
20.09	8.17	1.30	0.31	20.48	−0.03
20.10	7.54	1.20	0.28	22.19	−0.03
20.10	6.91	1.10	0.26	24.20	−0.03
20.10	6.28	1.00	0.24	26.62	−0.03
20.10	5.66	0.90	0.21	29.57	−0.05
20.09	5.03	0.80	0.19	33.26	−0.06
20.09	4.40	0.70	0.17	38.00	−0.05
20.09	3.77	0.60	0.14	44.34	−0.05

Table I.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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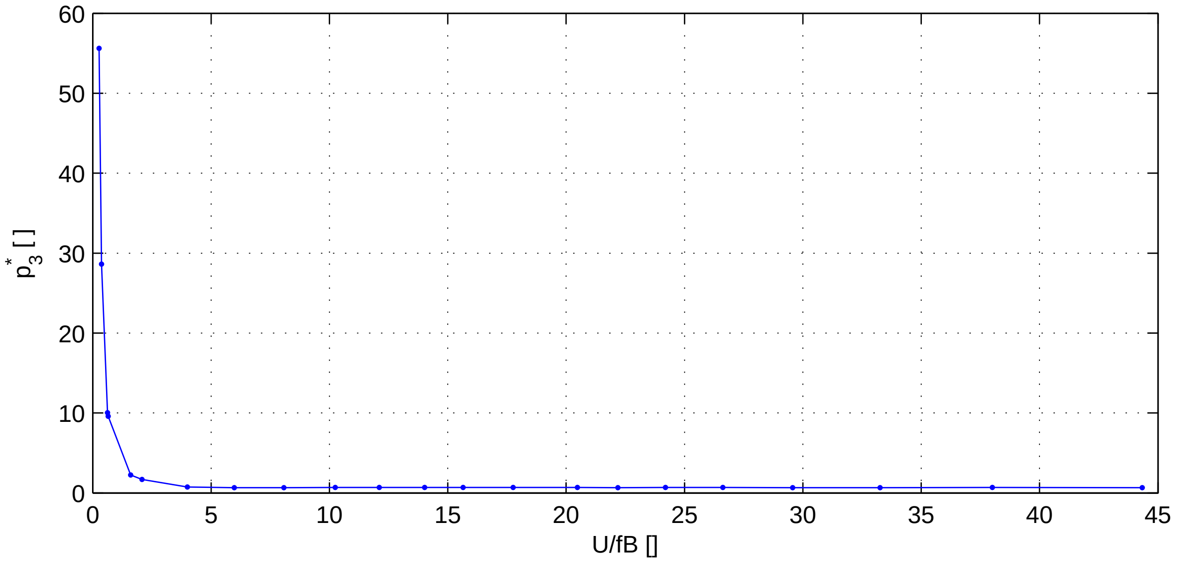

Figure I.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
0.80	25.13	4.00	23.70	0.27	55.62
1.12	25.13	4.00	17.01	0.37	28.62
1.90	25.13	4.00	10.01	0.63	10.04
1.96	25.13	4.00	9.69	0.65	9.58
4.84	25.13	4.00	3.92	1.60	2.24
6.29	25.13	4.00	3.01	2.08	1.67
12.08	25.13	4.00	1.57	4.00	0.72
18.06	25.13	4.00	1.05	5.98	0.64
20.11	20.74	3.30	0.78	8.07	0.67
20.11	16.34	2.60	0.61	10.24	0.68
20.11	13.82	2.20	0.52	12.10	0.68
20.11	11.93	1.90	0.45	14.02	0.68
20.09	10.69	1.70	0.40	15.64	0.67
20.12	9.43	1.50	0.35	17.76	0.67
20.09	8.17	1.30	0.31	20.48	0.67
20.10	7.54	1.20	0.28	22.19	0.67
20.10	6.91	1.10	0.26	24.20	0.67
20.10	6.28	1.00	0.24	26.62	0.67
20.10	5.66	0.90	0.21	29.57	0.67
20.09	5.03	0.80	0.19	33.26	0.66
20.09	4.40	0.70	0.17	38.00	0.67
20.09	3.77	0.60	0.14	44.34	0.66

Table I.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

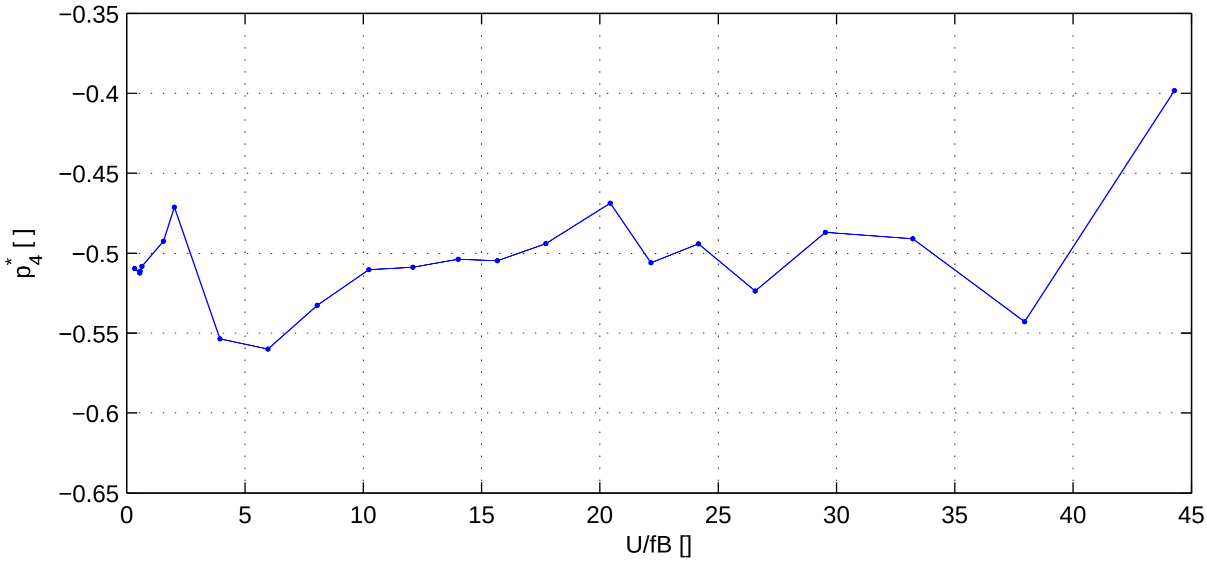

Figure I.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
1.01	25.13	4.00	18.80	0.33	−0.51
1.65	25.13	4.00	11.48	0.55	−0.51
1.72	25.13	4.00	11.02	0.57	−0.51
1.96	25.13	4.00	9.70	0.65	−0.51
4.71	25.13	4.00	4.03	1.56	−0.49
6.08	25.13	4.00	3.12	2.01	−0.47
11.90	25.13	4.00	1.59	3.94	−0.55
18.02	25.13	4.00	1.05	5.97	−0.56
20.08	20.74	3.30	0.78	8.06	−0.53
20.09	16.34	2.60	0.61	10.23	−0.51
20.10	13.82	2.20	0.52	12.10	−0.51
20.09	11.93	1.90	0.45	14.01	−0.50
20.10	10.68	1.70	0.40	15.66	−0.50
20.07	9.43	1.50	0.35	17.71	−0.49
20.07	8.17	1.30	0.31	20.44	−0.47
20.07	7.54	1.20	0.28	22.16	−0.51
20.07	6.91	1.10	0.26	24.17	−0.49
20.06	6.28	1.00	0.24	26.57	−0.52
20.07	5.66	0.90	0.21	29.54	−0.49
20.06	5.03	0.80	0.19	33.22	−0.49
20.06	4.40	0.70	0.17	37.95	−0.54
20.05	3.77	0.60	0.14	44.28	−0.40

Table I.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

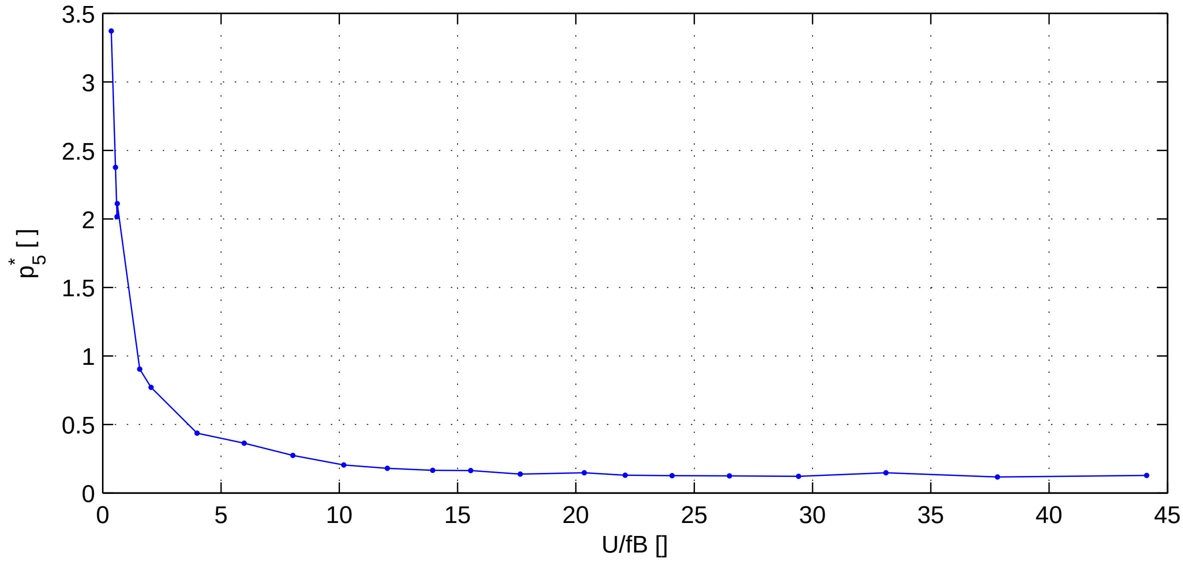

Figure I.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
1.08	25.13	4.00	17.53	0.36	3.37
1.65	25.13	4.00	11.53	0.54	2.38
1.84	25.13	4.00	10.33	0.61	2.02
1.85	25.13	4.00	10.25	0.61	2.11
4.73	25.13	4.00	4.01	1.57	0.90
6.17	25.13	4.00	3.08	2.04	0.77
12.05	25.13	4.00	1.57	3.99	0.44
18.05	25.13	4.00	1.05	5.98	0.36
20.02	20.74	3.30	0.78	8.03	0.27
20.01	16.34	2.60	0.62	10.19	0.20
19.99	13.82	2.20	0.52	12.03	0.18
20.00	11.93	1.90	0.45	13.95	0.16
19.97	10.69	1.70	0.40	15.56	0.16
19.99	9.43	1.50	0.36	17.65	0.14
19.99	8.17	1.30	0.31	20.36	0.15
20.00	7.54	1.20	0.28	22.08	0.13
19.99	6.91	1.10	0.26	24.07	0.13
20.00	6.28	1.00	0.24	26.49	0.12
19.99	5.66	0.90	0.21	29.41	0.12
19.99	5.03	0.80	0.19	33.10	0.15
19.98	4.40	0.70	0.17	37.82	0.12
19.99	3.77	0.60	0.14	44.13	0.13

Table I.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

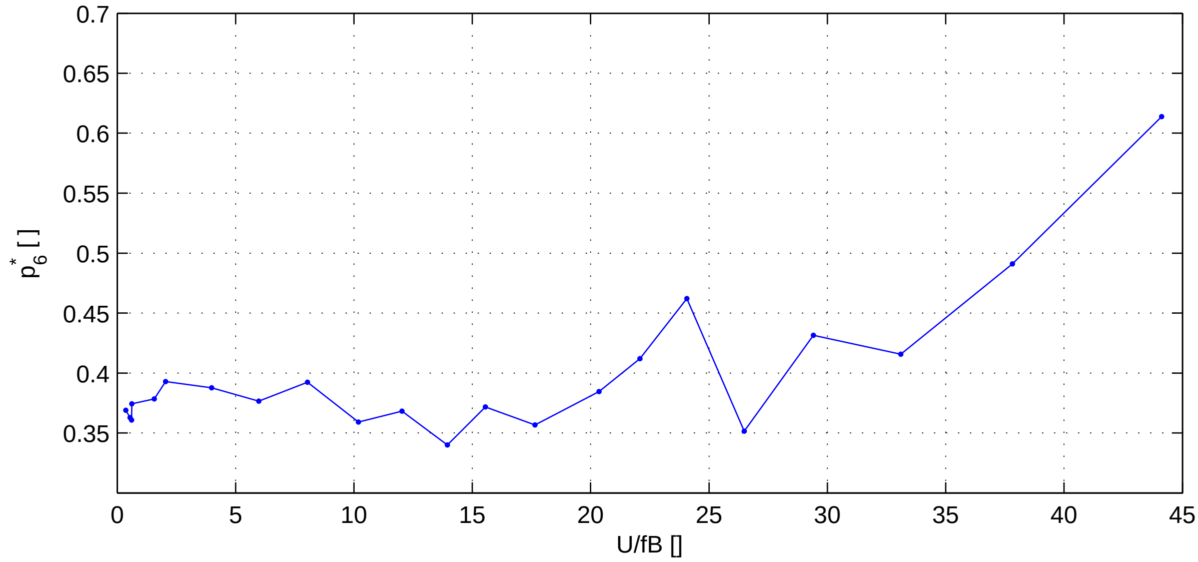

Figure I.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
1.08	25.13	4.00	17.53	0.36	0.37
1.65	25.13	4.00	11.53	0.54	0.36
1.84	25.13	4.00	10.33	0.61	0.36
1.85	25.13	4.00	10.25	0.61	0.37
4.73	25.13	4.00	4.01	1.57	0.38
6.17	25.13	4.00	3.08	2.04	0.39
12.05	25.13	4.00	1.57	3.99	0.39
18.05	25.13	4.00	1.05	5.98	0.38
20.02	20.74	3.30	0.78	8.03	0.39
20.01	16.34	2.60	0.62	10.19	0.36
19.99	13.82	2.20	0.52	12.03	0.37
20.00	11.93	1.90	0.45	13.95	0.34
19.97	10.69	1.70	0.40	15.56	0.37
19.99	9.43	1.50	0.36	17.65	0.36
19.99	8.17	1.30	0.31	20.36	0.38
20.00	7.54	1.20	0.28	22.08	0.41
19.99	6.91	1.10	0.26	24.07	0.46
20.00	6.28	1.00	0.24	26.49	0.35
19.99	5.66	0.90	0.21	29.41	0.43
19.99	5.03	0.80	0.19	33.10	0.42
19.98	4.40	0.70	0.17	37.82	0.49
19.99	3.77	0.60	0.14	44.13	0.61

Table I.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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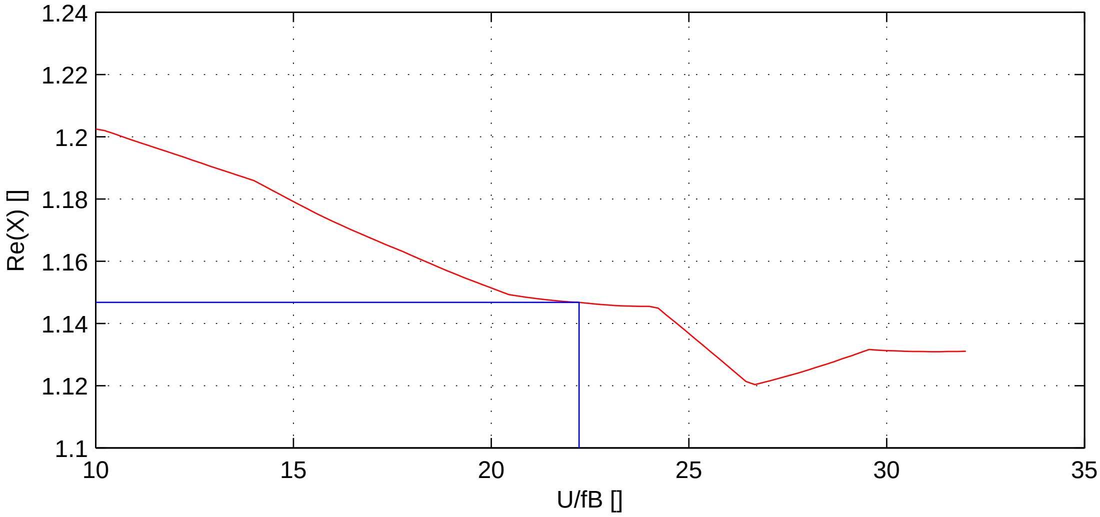


Figure I.37: Real part of the solution to stability equantion

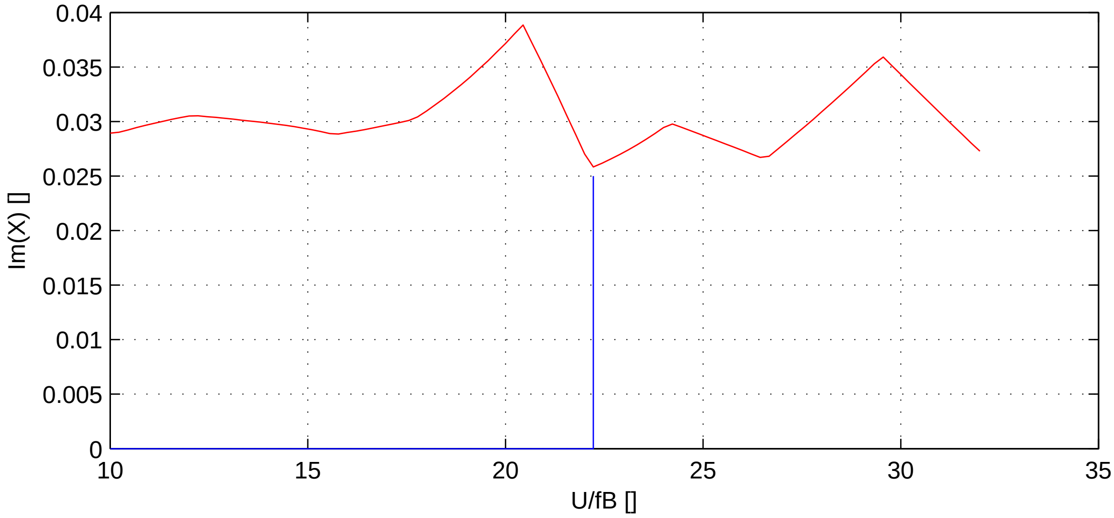


Figure I.38: Imaginary part of the solution to stability equantion

V_{Crit} = 22.2

f_{Crit} = 0.0742 Hz

U_{Crit} = 99.6 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.
[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.
[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.
[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.
[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix J

3D Flutter Tests

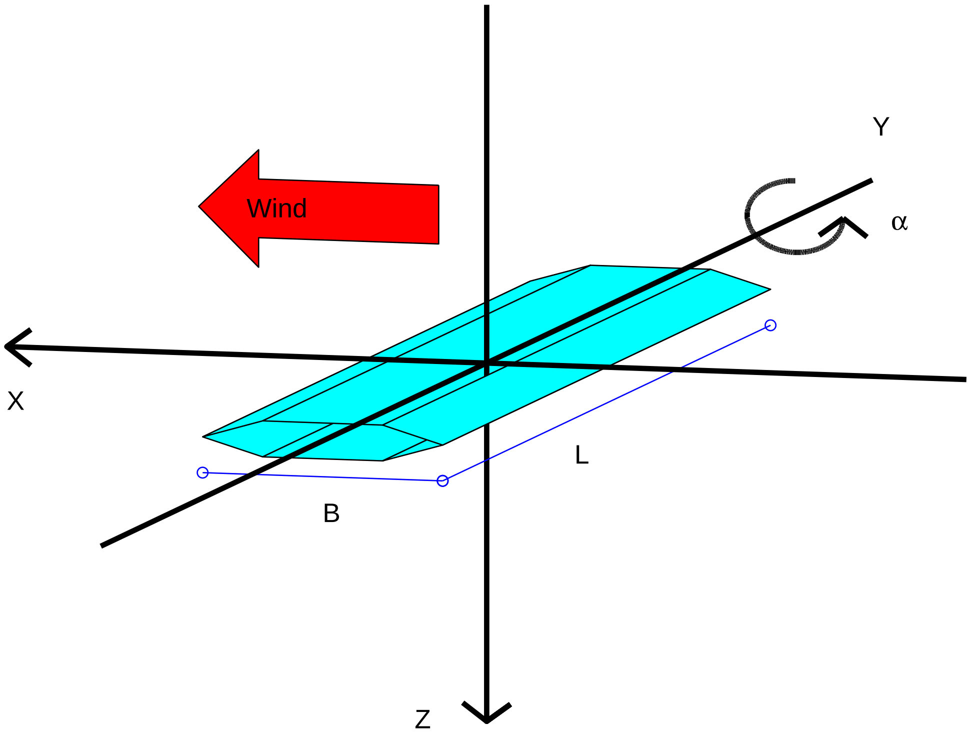
Flutter derivatives, Smooth flow, Angle of incidence = +6 deg.

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^{o}C	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1014.0

Table J.1: Project Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2\,m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$
$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2\,m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$
$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2\,m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h : Vertical displacement, displacement along z-axis, [m]
α : Rotation around y-axis, nose up is positive, [rad]
p : Horizontal displacement, displacement along the x-axis, [m]
m : Mass per unit length, [kg/m]
I_y : Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$: Added mass in vertical direction, [kg/m]
$m_{a,x}$: Added mass in horizontal direction, [kg/m]
$I_{a,y}$: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G : X-coordinate for centre of gravity, [m]
Z_G : Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$: Natural circular frequency for vertical motion, [/s]
ζ_h : Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$: Natural circular frequency for rotation around y axis, [/s]
ζ_α : Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p : Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$: Force from rig per meter section, [N/m]
$M_{Y,external}$: Moment from rig per meter section, [Nm/m]
$F_{X,external}$: Force from rig per meter section, [N/m]

Formula J.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.386
Added mass in horizontal	$m_{a,x}$	kg/m	0.515
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.140
Horizontal centre of gravity	x_G	m	−0.001
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.027
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.029
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.002

Table J.2: Mechanical Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula J.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

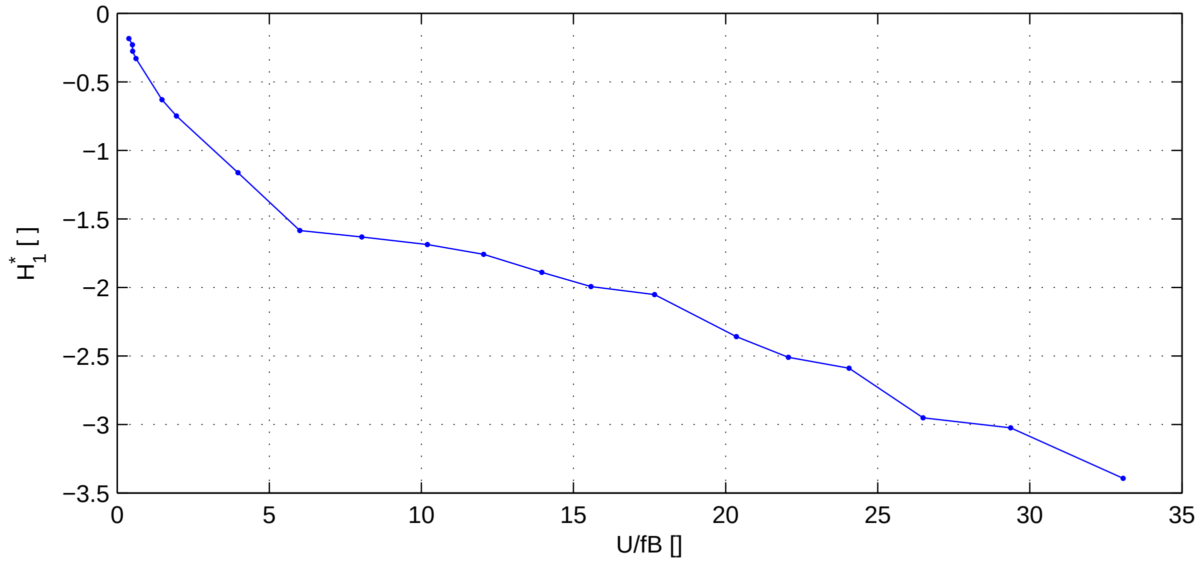


Figure J.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
1.17	25.13	4.00	16.26	0.39	−0.18
1.52	25.13	4.00	12.49	0.50	−0.23
1.53	25.13	4.00	12.43	0.51	−0.28
1.86	25.13	4.00	10.22	0.61	−0.33
4.44	25.13	4.00	4.27	1.47	−0.63
5.88	25.13	4.00	3.23	1.95	−0.75
12.00	25.13	4.00	1.58	3.97	−1.16
18.13	25.13	4.00	1.05	6.00	−1.59
20.03	20.74	3.30	0.78	8.04	−1.63
20.03	16.34	2.60	0.62	10.20	−1.69
20.02	13.82	2.20	0.52	12.05	−1.76
20.02	11.93	1.90	0.45	13.96	−1.89
20.00	10.69	1.70	0.40	15.57	−1.99
20.01	9.43	1.50	0.36	17.66	−2.05
19.98	8.17	1.30	0.31	20.35	−2.36
19.99	7.54	1.20	0.28	22.07	−2.51
19.98	6.91	1.10	0.26	24.06	−2.59
20.00	6.28	1.00	0.24	26.49	−2.95
19.96	5.66	0.90	0.21	29.37	−3.02
19.97	5.03	0.80	0.19	33.07	−3.39

Table J.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

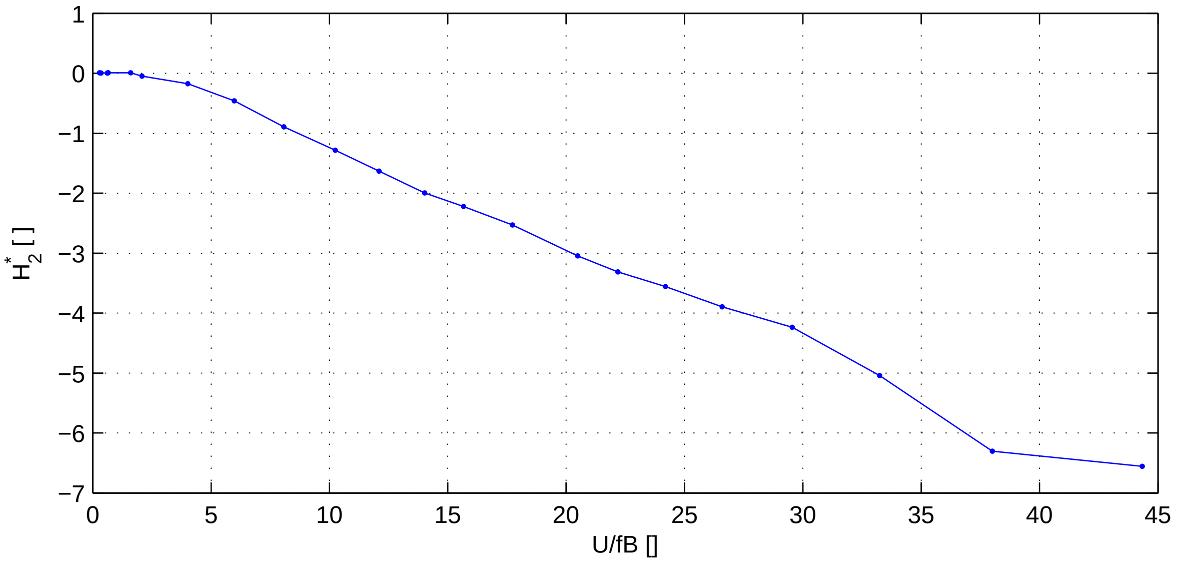


Figure J.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
0.85	25.13	4.00	22.23	0.28	0.01
1.07	25.13	4.00	17.67	0.36	0.00
1.85	25.13	4.00	10.25	0.61	0.00
1.99	25.13	4.00	9.56	0.66	0.01
4.84	25.13	4.00	3.92	1.60	0.01
6.29	25.13	4.00	3.02	2.08	−0.05
12.14	25.13	4.00	1.56	4.02	−0.17
18.07	25.13	4.00	1.05	5.98	−0.46
20.11	20.74	3.30	0.78	8.07	−0.89
20.11	16.34	2.60	0.61	10.24	−1.28
20.10	13.82	2.20	0.52	12.10	−1.63
20.11	11.93	1.90	0.45	14.02	−2.00
20.10	10.68	1.70	0.40	15.67	−2.22
20.09	9.43	1.50	0.35	17.73	−2.53
20.10	8.17	1.30	0.31	20.49	−3.05
20.10	7.54	1.20	0.28	22.19	−3.31
20.10	6.91	1.10	0.26	24.19	−3.56
20.08	6.28	1.00	0.24	26.59	−3.90
20.08	5.66	0.90	0.21	29.56	−4.24
20.08	5.03	0.80	0.19	33.24	−5.04
20.08	4.40	0.70	0.17	38.00	−6.31
20.09	3.77	0.60	0.14	44.33	−6.56

Table J.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

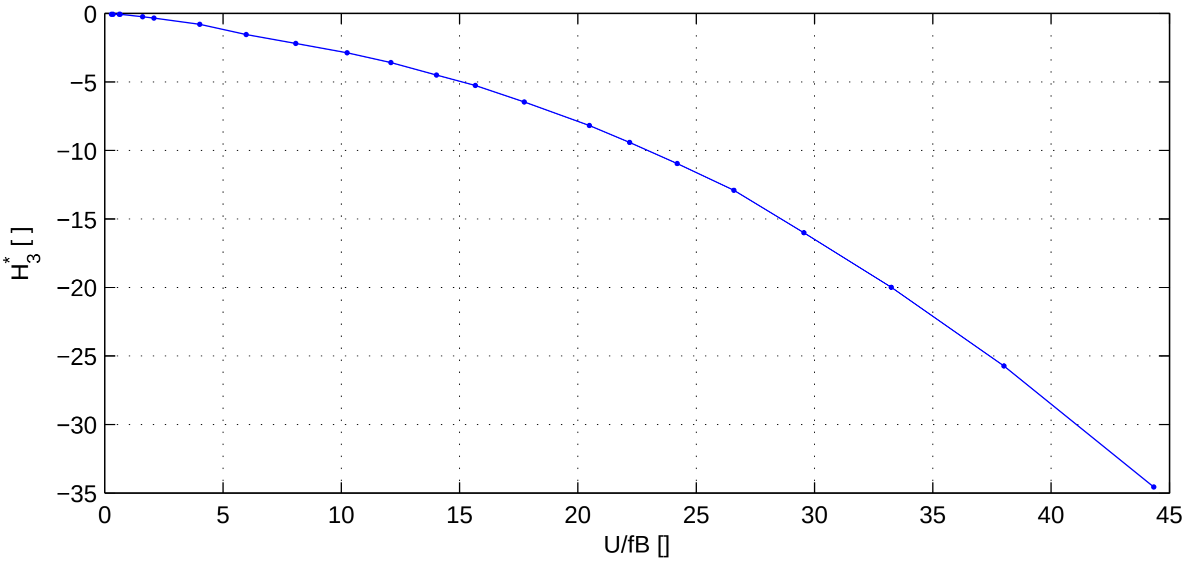


Figure J.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
0.85	25.13	4.00	22.23	0.28	−0.07
1.07	25.13	4.00	17.67	0.36	−0.07
1.85	25.13	4.00	10.25	0.61	−0.07
1.99	25.13	4.00	9.56	0.66	−0.07
4.84	25.13	4.00	3.92	1.60	−0.25
6.29	25.13	4.00	3.02	2.08	−0.36
12.14	25.13	4.00	1.56	4.02	−0.80
18.07	25.13	4.00	1.05	5.98	−1.55
20.11	20.74	3.30	0.78	8.07	−2.20
20.11	16.34	2.60	0.61	10.24	−2.88
20.10	13.82	2.20	0.52	12.10	−3.60
20.11	11.93	1.90	0.45	14.02	−4.51
20.10	10.68	1.70	0.40	15.67	−5.26
20.09	9.43	1.50	0.35	17.73	−6.46
20.10	8.17	1.30	0.31	20.49	−8.18
20.10	7.54	1.20	0.28	22.19	−9.42
20.10	6.91	1.10	0.26	24.19	−10.97
20.08	6.28	1.00	0.24	26.59	−12.92
20.08	5.66	0.90	0.21	29.56	−16.02
20.08	5.03	0.80	0.19	33.24	−19.99
20.08	4.40	0.70	0.17	38.00	−25.74
20.09	3.77	0.60	0.14	44.33	−34.57

Table J.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

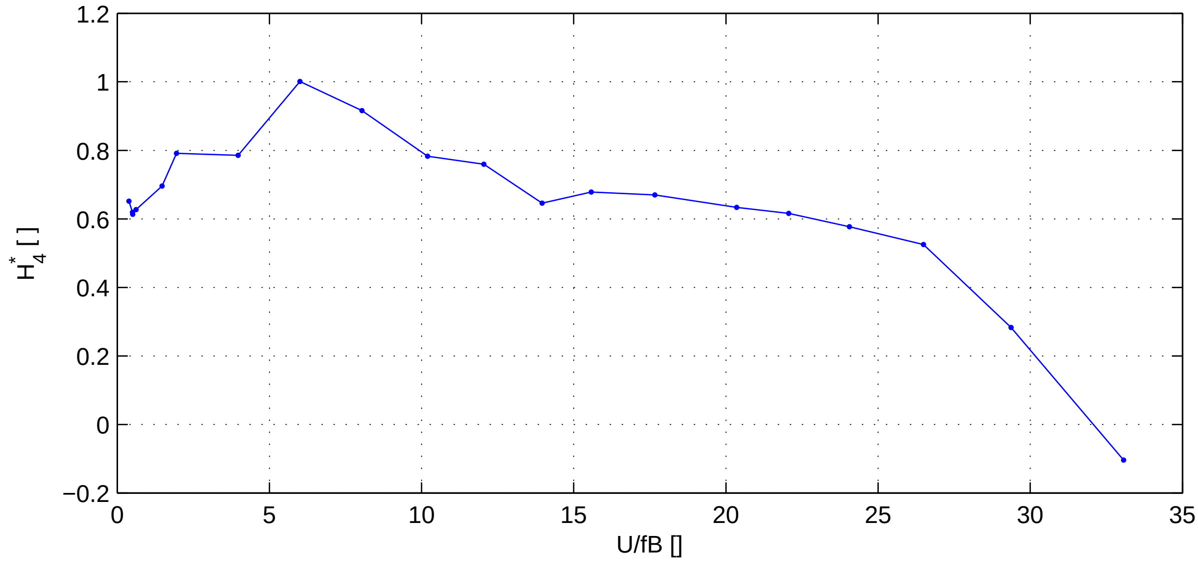


Figure J.4: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_4^*
1.17	25.13	4.00	16.26	0.39	0.65
1.52	25.13	4.00	12.49	0.50	0.62
1.53	25.13	4.00	12.43	0.51	0.61
1.86	25.13	4.00	10.22	0.61	0.63
4.44	25.13	4.00	4.27	1.47	0.70
5.88	25.13	4.00	3.23	1.95	0.79
12.00	25.13	4.00	1.58	3.97	0.79
18.13	25.13	4.00	1.05	6.00	1.00
20.03	20.74	3.30	0.78	8.04	0.92
20.03	16.34	2.60	0.62	10.20	0.78
20.02	13.82	2.20	0.52	12.05	0.76
20.02	11.93	1.90	0.45	13.96	0.65
20.00	10.69	1.70	0.40	15.57	0.68
20.01	9.43	1.50	0.36	17.66	0.67
19.98	8.17	1.30	0.31	20.35	0.63
19.99	7.54	1.20	0.28	22.07	0.62
19.98	6.91	1.10	0.26	24.06	0.58
20.00	6.28	1.00	0.24	26.49	0.52
19.96	5.66	0.90	0.21	29.37	0.28
19.97	5.03	0.80	0.19	33.07	−0.10

Table J.6: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

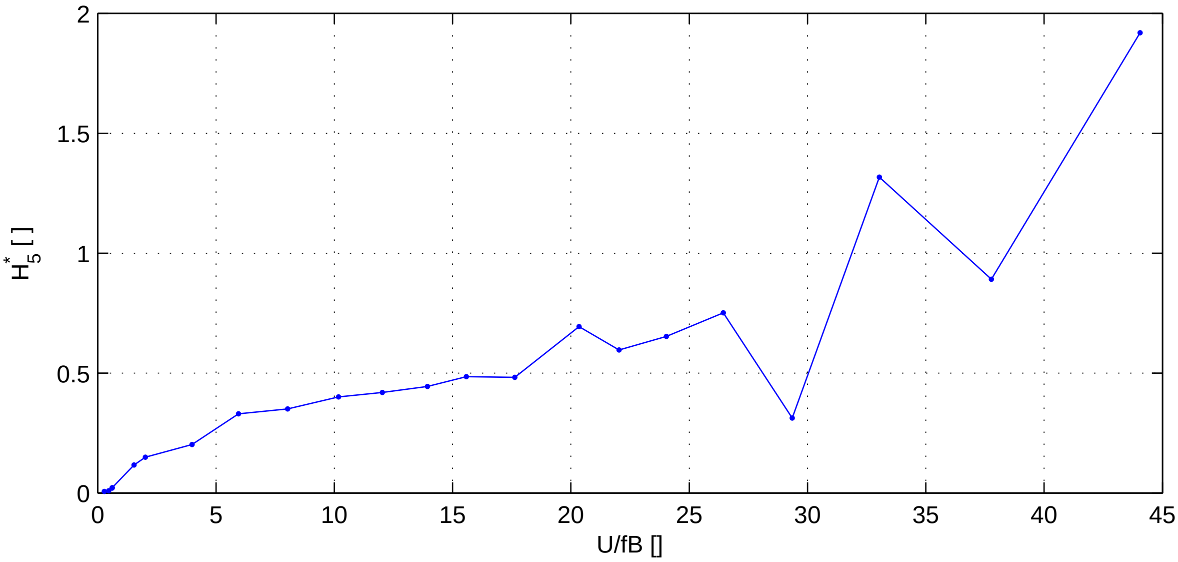


Figure J.5: H^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_5
0.85	25.13	4.00	22.38	0.28	0.01
1.41	25.13	4.00	13.43	0.47	0.01
1.83	25.13	4.00	10.35	0.61	0.02
1.85	25.13	4.00	10.24	0.61	0.02
4.65	25.13	4.00	4.08	1.54	0.12
6.09	25.13	4.00	3.12	2.02	0.15
12.05	25.13	4.00	1.57	3.99	0.20
17.98	25.13	4.00	1.06	5.95	0.33
19.99	20.74	3.30	0.78	8.02	0.35
19.99	16.34	2.60	0.62	10.18	0.40
19.99	13.82	2.20	0.52	12.03	0.42
19.98	11.93	1.90	0.45	13.94	0.44
19.98	10.68	1.70	0.40	15.58	0.48
19.97	9.43	1.50	0.36	17.63	0.48
19.96	8.17	1.30	0.31	20.34	0.69
19.96	7.54	1.20	0.29	22.04	0.60
19.96	6.91	1.10	0.26	24.03	0.65
19.96	6.28	1.00	0.24	26.44	0.75
19.95	5.66	0.90	0.21	29.35	0.31
19.95	5.03	0.80	0.19	33.03	1.32
19.96	4.40	0.70	0.17	37.77	0.89
19.96	3.77	0.60	0.14	44.06	1.92

Table J.7: H^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

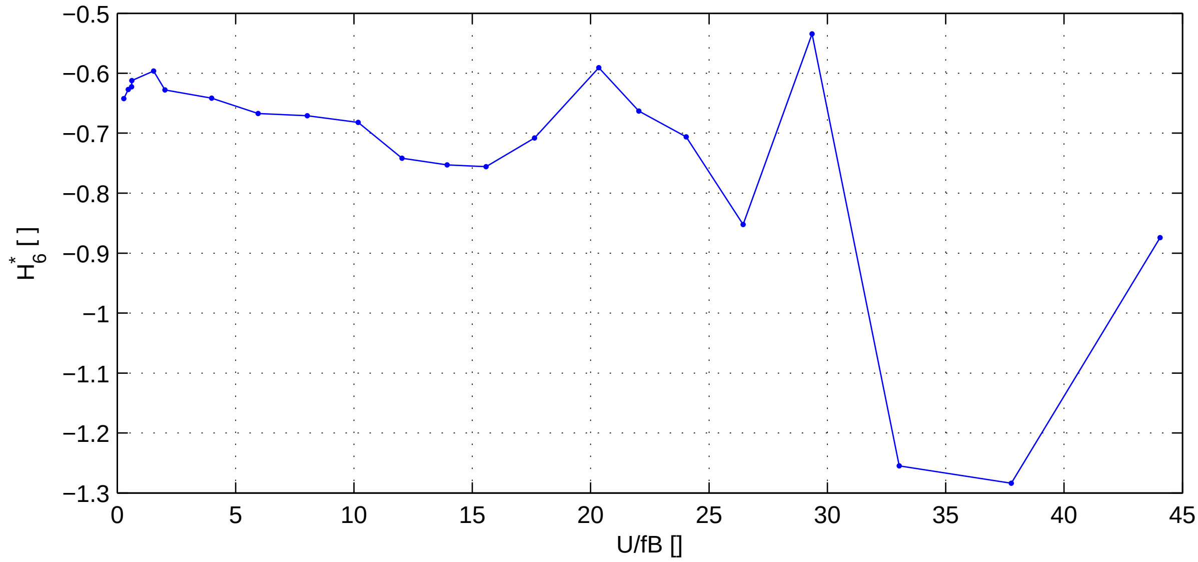


Figure J.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
0.85	25.13	4.00	22.38	0.28	−0.64
1.41	25.13	4.00	13.43	0.47	−0.63
1.83	25.13	4.00	10.35	0.61	−0.62
1.85	25.13	4.00	10.24	0.61	−0.61
4.65	25.13	4.00	4.08	1.54	−0.60
6.09	25.13	4.00	3.12	2.02	−0.63
12.05	25.13	4.00	1.57	3.99	−0.64
17.98	25.13	4.00	1.06	5.95	−0.67
19.99	20.74	3.30	0.78	8.02	−0.67
19.99	16.34	2.60	0.62	10.18	−0.68
19.99	13.82	2.20	0.52	12.03	−0.74
19.98	11.93	1.90	0.45	13.94	−0.75
19.98	10.68	1.70	0.40	15.58	−0.76
19.97	9.43	1.50	0.36	17.63	−0.71
19.96	8.17	1.30	0.31	20.34	−0.59
19.96	7.54	1.20	0.29	22.04	−0.66
19.96	6.91	1.10	0.26	24.03	−0.71
19.96	6.28	1.00	0.24	26.44	−0.85
19.95	5.66	0.90	0.21	29.35	−0.53
19.95	5.03	0.80	0.19	33.03	−1.25
19.96	4.40	0.70	0.17	37.77	−1.28
19.96	3.77	0.60	0.14	44.06	−0.87

Table J.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

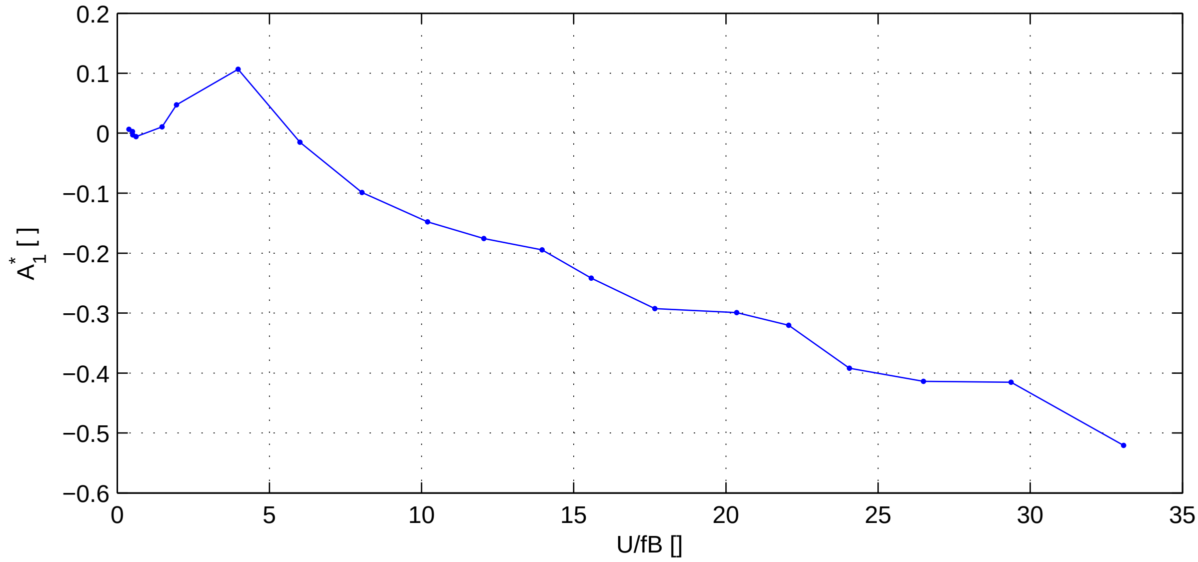


Figure J.7: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_1^*
1.17	25.13	4.00	16.26	0.39	0.01
1.52	25.13	4.00	12.49	0.50	0.00
1.53	25.13	4.00	12.43	0.51	−0.00
1.86	25.13	4.00	10.22	0.61	−0.01
4.44	25.13	4.00	4.27	1.47	0.01
5.88	25.13	4.00	3.23	1.95	0.05
12.00	25.13	4.00	1.58	3.97	0.11
18.13	25.13	4.00	1.05	6.00	−0.02
20.03	20.74	3.30	0.78	8.04	−0.10
20.03	16.34	2.60	0.62	10.20	−0.15
20.02	13.82	2.20	0.52	12.05	−0.18
20.02	11.93	1.90	0.45	13.96	−0.19
20.00	10.69	1.70	0.40	15.57	−0.24
20.01	9.43	1.50	0.36	17.66	−0.29
19.98	8.17	1.30	0.31	20.35	−0.30
19.99	7.54	1.20	0.28	22.07	−0.32
19.98	6.91	1.10	0.26	24.06	−0.39
20.00	6.28	1.00	0.24	26.49	−0.41
19.96	5.66	0.90	0.21	29.37	−0.42
19.97	5.03	0.80	0.19	33.07	−0.52

Table J.9: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

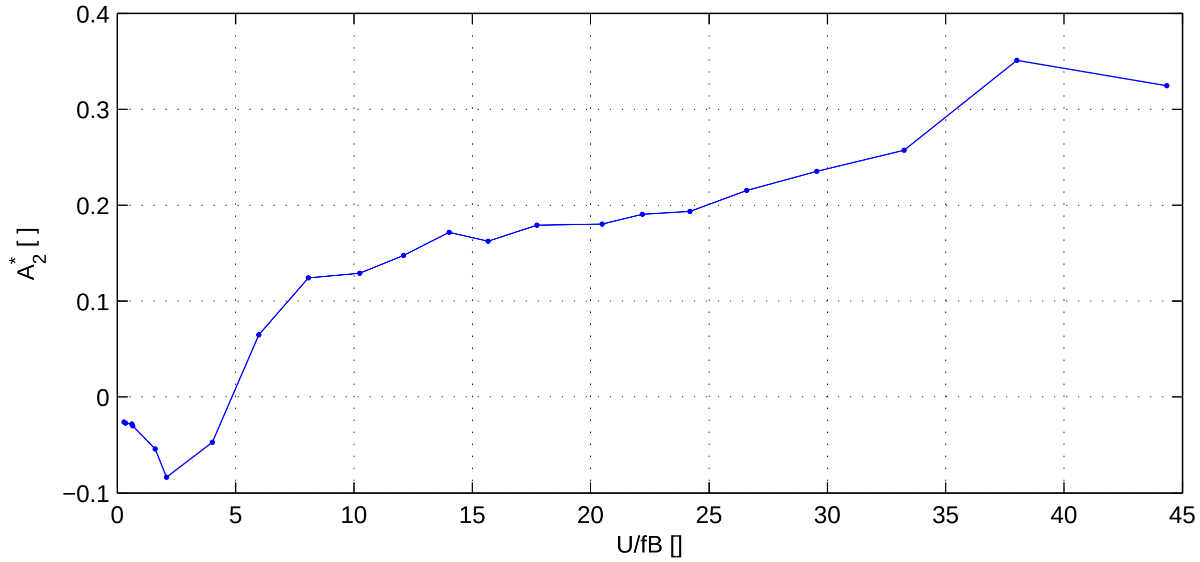


Figure J.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
0.85	25.13	4.00	22.23	0.28	−0.03
1.07	25.13	4.00	17.67	0.36	−0.03
1.85	25.13	4.00	10.25	0.61	−0.03
1.99	25.13	4.00	9.56	0.66	−0.03
4.84	25.13	4.00	3.92	1.60	−0.05
6.29	25.13	4.00	3.02	2.08	−0.08
12.14	25.13	4.00	1.56	4.02	−0.05
18.07	25.13	4.00	1.05	5.98	0.06
20.11	20.74	3.30	0.78	8.07	0.12
20.11	16.34	2.60	0.61	10.24	0.13
20.10	13.82	2.20	0.52	12.10	0.15
20.11	11.93	1.90	0.45	14.02	0.17
20.10	10.68	1.70	0.40	15.67	0.16
20.09	9.43	1.50	0.35	17.73	0.18
20.10	8.17	1.30	0.31	20.49	0.18
20.10	7.54	1.20	0.28	22.19	0.19
20.10	6.91	1.10	0.26	24.19	0.19
20.08	6.28	1.00	0.24	26.59	0.22
20.08	5.66	0.90	0.21	29.56	0.24
20.08	5.03	0.80	0.19	33.24	0.26
20.08	4.40	0.70	0.17	38.00	0.35
20.09	3.77	0.60	0.14	44.33	0.32

Table J.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:20:49

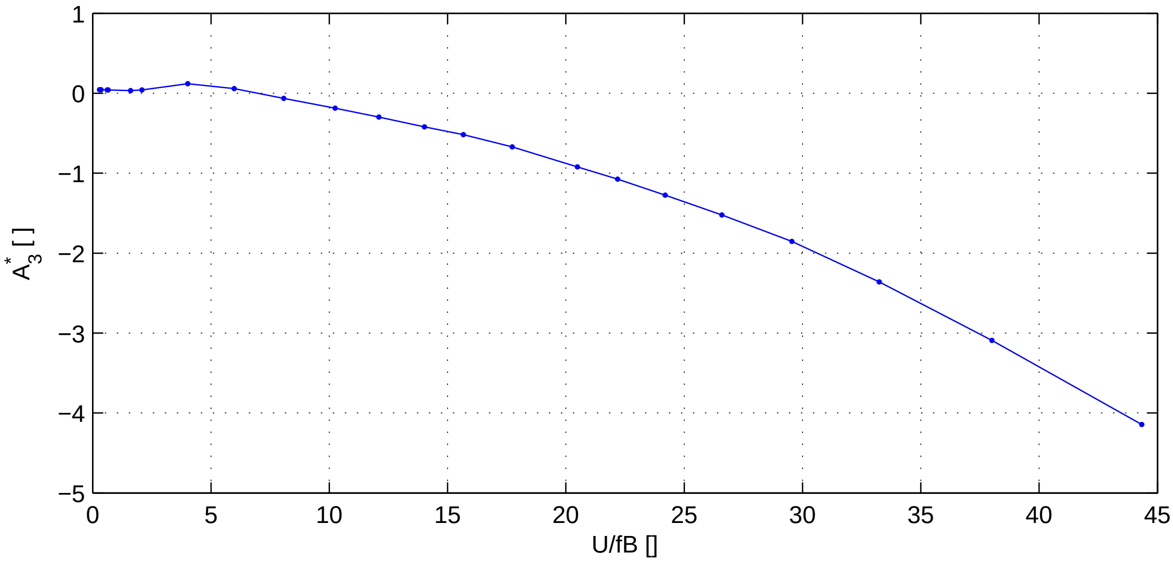


Figure J.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
0.85	25.13	4.00	22.23	0.28	0.04
1.07	25.13	4.00	17.67	0.36	0.04
1.85	25.13	4.00	10.25	0.61	0.04
1.99	25.13	4.00	9.56	0.66	0.04
4.84	25.13	4.00	3.92	1.60	0.03
6.29	25.13	4.00	3.02	2.08	0.04
12.14	25.13	4.00	1.56	4.02	0.12
18.07	25.13	4.00	1.05	5.98	0.06
20.11	20.74	3.30	0.78	8.07	−0.06
20.11	16.34	2.60	0.61	10.24	−0.19
20.10	13.82	2.20	0.52	12.10	−0.30
20.11	11.93	1.90	0.45	14.02	−0.42
20.10	10.68	1.70	0.40	15.67	−0.52
20.09	9.43	1.50	0.35	17.73	−0.67
20.10	8.17	1.30	0.31	20.49	−0.92
20.10	7.54	1.20	0.28	22.19	−1.07
20.10	6.91	1.10	0.26	24.19	−1.27
20.08	6.28	1.00	0.24	26.59	−1.52
20.08	5.66	0.90	0.21	29.56	−1.85
20.08	5.03	0.80	0.19	33.24	−2.36
20.08	4.40	0.70	0.17	38.00	−3.09
20.09	3.77	0.60	0.14	44.33	−4.15

Table J.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

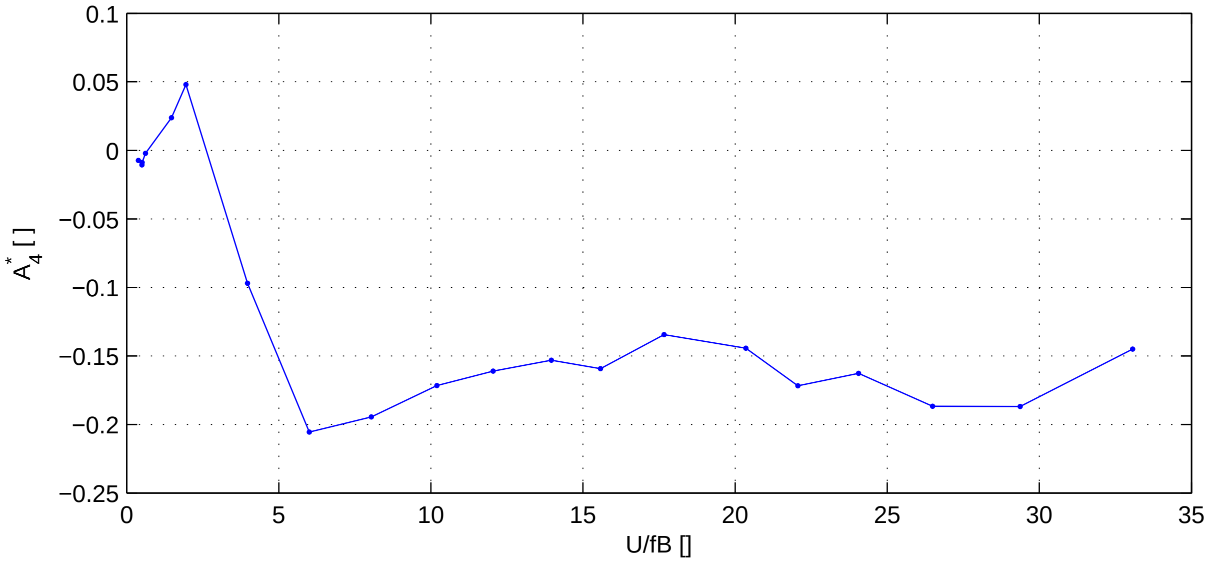


Figure J.10: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_4^*
1.17	25.13	4.00	16.26	0.39	−0.01
1.52	25.13	4.00	12.49	0.50	−0.01
1.53	25.13	4.00	12.43	0.51	−0.01
1.86	25.13	4.00	10.22	0.61	−0.00
4.44	25.13	4.00	4.27	1.47	0.02
5.88	25.13	4.00	3.23	1.95	0.05
12.00	25.13	4.00	1.58	3.97	−0.10
18.13	25.13	4.00	1.05	6.00	−0.21
20.03	20.74	3.30	0.78	8.04	−0.19
20.03	16.34	2.60	0.62	10.20	−0.17
20.02	13.82	2.20	0.52	12.05	−0.16
20.02	11.93	1.90	0.45	13.96	−0.15
20.00	10.69	1.70	0.40	15.57	−0.16
20.01	9.43	1.50	0.36	17.66	−0.13
19.98	8.17	1.30	0.31	20.35	−0.14
19.99	7.54	1.20	0.28	22.07	−0.17
19.98	6.91	1.10	0.26	24.06	−0.16
20.00	6.28	1.00	0.24	26.49	−0.19
19.96	5.66	0.90	0.21	29.37	−0.19
19.97	5.03	0.80	0.19	33.07	−0.14

Table J.12: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

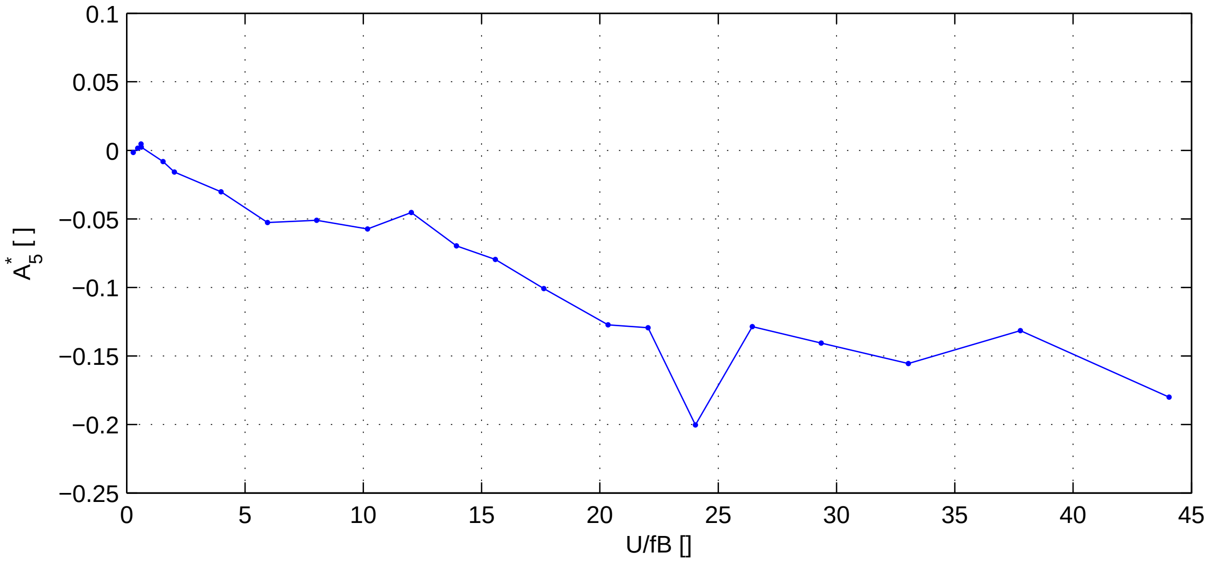


Figure J.11: A^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_5
0.85	25.13	4.00	22.38	0.28	−0.00
1.41	25.13	4.00	13.43	0.47	0.00
1.83	25.13	4.00	10.35	0.61	0.00
1.85	25.13	4.00	10.24	0.61	0.00
4.65	25.13	4.00	4.08	1.54	−0.01
6.09	25.13	4.00	3.12	2.02	−0.02
12.05	25.13	4.00	1.57	3.99	−0.03
17.98	25.13	4.00	1.06	5.95	−0.05
19.99	20.74	3.30	0.78	8.02	−0.05
19.99	16.34	2.60	0.62	10.18	−0.06
19.99	13.82	2.20	0.52	12.03	−0.05
19.98	11.93	1.90	0.45	13.94	−0.07
19.98	10.68	1.70	0.40	15.58	−0.08
19.97	9.43	1.50	0.36	17.63	−0.10
19.96	8.17	1.30	0.31	20.34	−0.13
19.96	7.54	1.20	0.29	22.04	−0.13
19.96	6.91	1.10	0.26	24.03	−0.20
19.96	6.28	1.00	0.24	26.44	−0.13
19.95	5.66	0.90	0.21	29.35	−0.14
19.95	5.03	0.80	0.19	33.03	−0.16
19.96	4.40	0.70	0.17	37.77	−0.13
19.96	3.77	0.60	0.14	44.06	−0.18

Table J.13: A^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

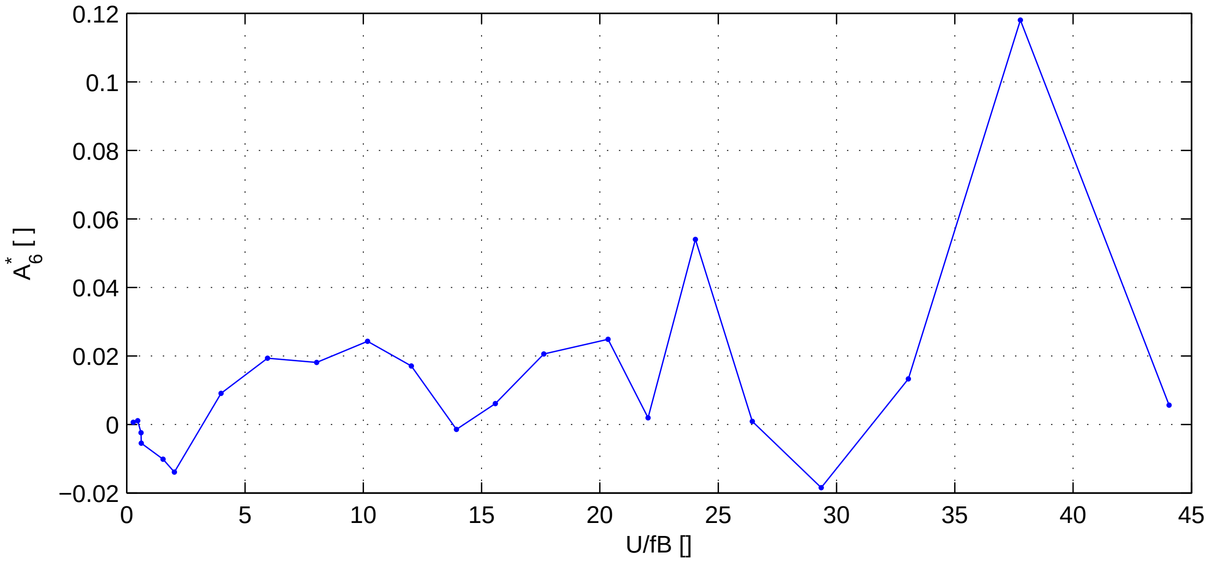


Figure J.12: A^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_6
0.85	25.13	4.00	22.38	0.28	0.00
1.41	25.13	4.00	13.43	0.47	0.00
1.83	25.13	4.00	10.35	0.61	−0.00
1.85	25.13	4.00	10.24	0.61	−0.01
4.65	25.13	4.00	4.08	1.54	−0.01
6.09	25.13	4.00	3.12	2.02	−0.01
12.05	25.13	4.00	1.57	3.99	0.01
17.98	25.13	4.00	1.06	5.95	0.02
19.99	20.74	3.30	0.78	8.02	0.02
19.99	16.34	2.60	0.62	10.18	0.02
19.99	13.82	2.20	0.52	12.03	0.02
19.98	11.93	1.90	0.45	13.94	−0.00
19.98	10.68	1.70	0.40	15.58	0.01
19.97	9.43	1.50	0.36	17.63	0.02
19.96	8.17	1.30	0.31	20.34	0.02
19.96	7.54	1.20	0.29	22.04	0.00
19.96	6.91	1.10	0.26	24.03	0.05
19.96	6.28	1.00	0.24	26.44	0.00
19.95	5.66	0.90	0.21	29.35	−0.02
19.95	5.03	0.80	0.19	33.03	0.01
19.96	4.40	0.70	0.17	37.77	0.12
19.96	3.77	0.60	0.14	44.06	0.01

Table J.14: A^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

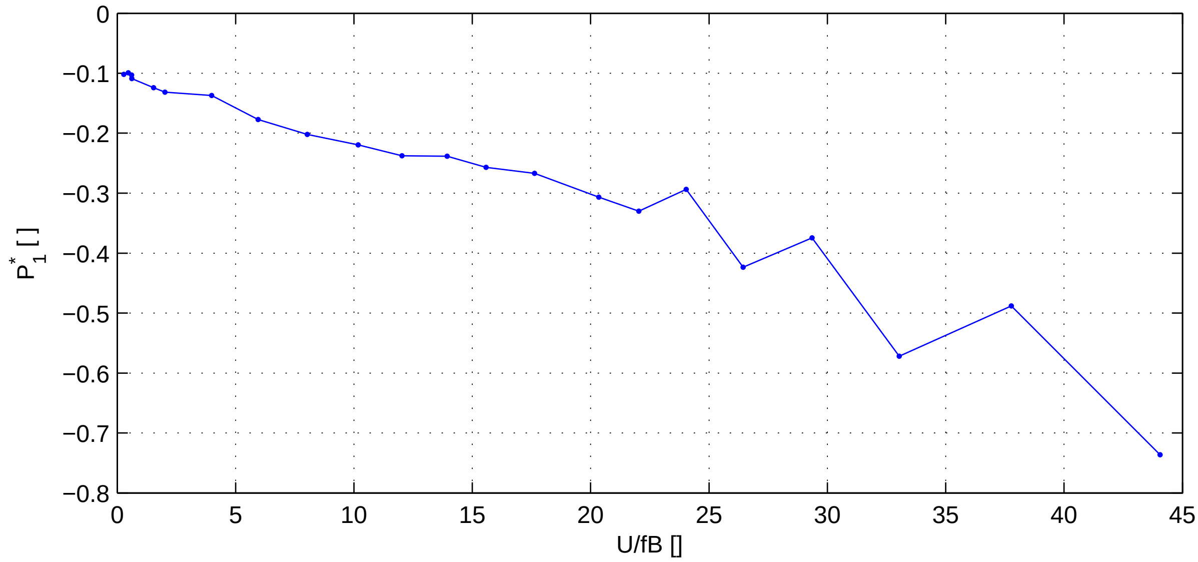


Figure J.13: P^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_1
0.85	25.13	4.00	22.38	0.28	−0.10
1.41	25.13	4.00	13.43	0.47	−0.10
1.83	25.13	4.00	10.35	0.61	−0.10
1.85	25.13	4.00	10.24	0.61	−0.11
4.65	25.13	4.00	4.08	1.54	−0.12
6.09	25.13	4.00	3.12	2.02	−0.13
12.05	25.13	4.00	1.57	3.99	−0.14
17.98	25.13	4.00	1.06	5.95	−0.18
19.99	20.74	3.30	0.78	8.02	−0.20
19.99	16.34	2.60	0.62	10.18	−0.22
19.99	13.82	2.20	0.52	12.03	−0.24
19.98	11.93	1.90	0.45	13.94	−0.24
19.98	10.68	1.70	0.40	15.58	−0.26
19.97	9.43	1.50	0.36	17.63	−0.27
19.96	8.17	1.30	0.31	20.34	−0.31
19.96	7.54	1.20	0.29	22.04	−0.33
19.96	6.91	1.10	0.26	24.03	−0.29
19.96	6.28	1.00	0.24	26.44	−0.42
19.95	5.66	0.90	0.21	29.35	−0.37
19.95	5.03	0.80	0.19	33.03	−0.57
19.96	4.40	0.70	0.17	37.77	−0.49
19.96	3.77	0.60	0.14	44.06	−0.74

Table J.15: P^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

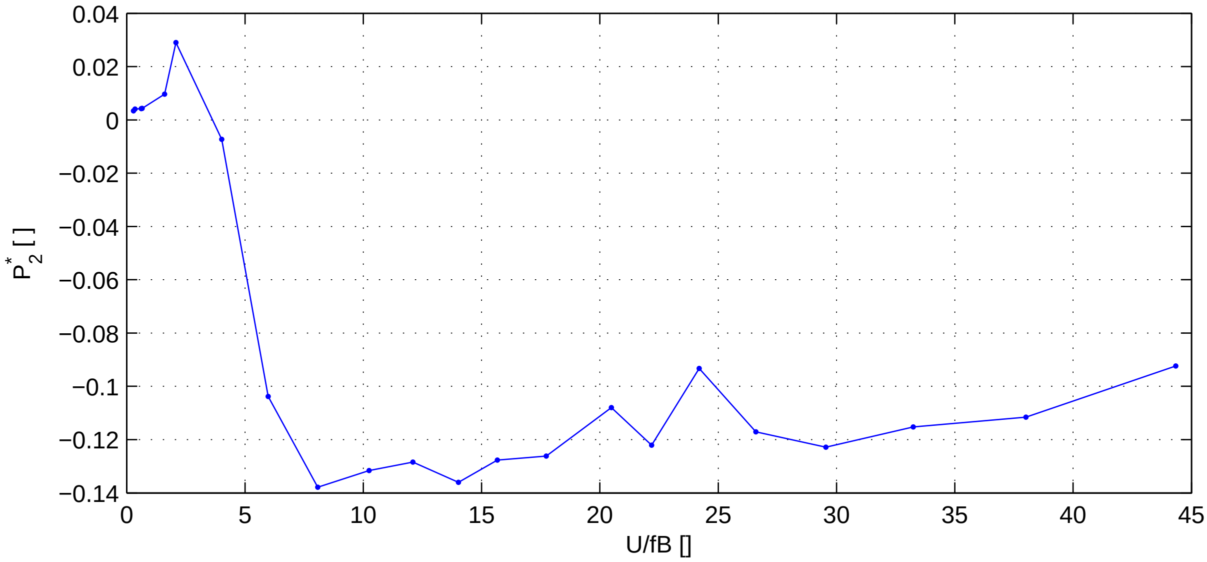


Figure J.14: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_2^*
0.85	25.13	4.00	22.23	0.28	0.00
1.07	25.13	4.00	17.67	0.36	0.00
1.85	25.13	4.00	10.25	0.61	0.00
1.99	25.13	4.00	9.56	0.66	0.00
4.84	25.13	4.00	3.92	1.60	0.01
6.29	25.13	4.00	3.02	2.08	0.03
12.14	25.13	4.00	1.56	4.02	−0.01
18.07	25.13	4.00	1.05	5.98	−0.10
20.11	20.74	3.30	0.78	8.07	−0.14
20.11	16.34	2.60	0.61	10.24	−0.13
20.10	13.82	2.20	0.52	12.10	−0.13
20.11	11.93	1.90	0.45	14.02	−0.14
20.10	10.68	1.70	0.40	15.67	−0.13
20.09	9.43	1.50	0.35	17.73	−0.13
20.10	8.17	1.30	0.31	20.49	−0.11
20.10	7.54	1.20	0.28	22.19	−0.12
20.10	6.91	1.10	0.26	24.19	−0.09
20.08	6.28	1.00	0.24	26.59	−0.12
20.08	5.66	0.90	0.21	29.56	−0.12
20.08	5.03	0.80	0.19	33.24	−0.12
20.08	4.40	0.70	0.17	38.00	−0.11
20.09	3.77	0.60	0.14	44.33	−0.09

Table J.16: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

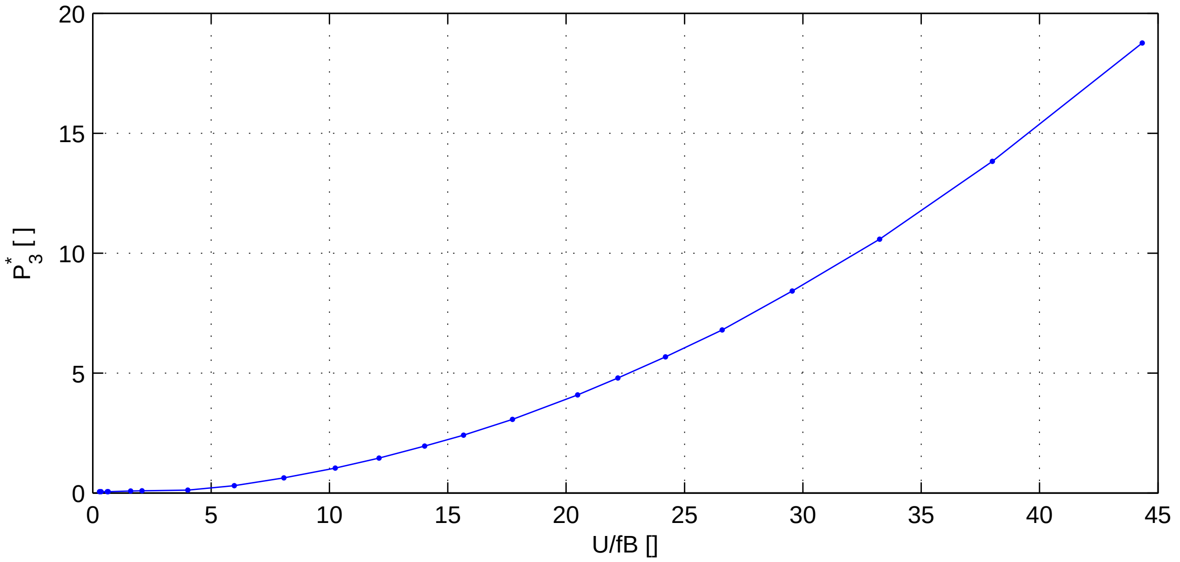


Figure J.15: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_3
0.85	25.13	4.00	22.23	0.28	0.05
1.07	25.13	4.00	17.67	0.36	0.05
1.85	25.13	4.00	10.25	0.61	0.05
1.99	25.13	4.00	9.56	0.66	0.05
4.84	25.13	4.00	3.92	1.60	0.08
6.29	25.13	4.00	3.02	2.08	0.09
12.14	25.13	4.00	1.56	4.02	0.12
18.07	25.13	4.00	1.05	5.98	0.30
20.11	20.74	3.30	0.78	8.07	0.62
20.11	16.34	2.60	0.61	10.24	1.03
20.10	13.82	2.20	0.52	12.10	1.45
20.11	11.93	1.90	0.45	14.02	1.95
20.10	10.68	1.70	0.40	15.67	2.41
20.09	9.43	1.50	0.35	17.73	3.07
20.10	8.17	1.30	0.31	20.49	4.09
20.10	7.54	1.20	0.28	22.19	4.79
20.10	6.91	1.10	0.26	24.19	5.68
20.08	6.28	1.00	0.24	26.59	6.79
20.08	5.66	0.90	0.21	29.56	8.41
20.08	5.03	0.80	0.19	33.24	10.58
20.08	4.40	0.70	0.17	38.00	13.82
20.09	3.77	0.60	0.14	44.33	18.76

Table J.17: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

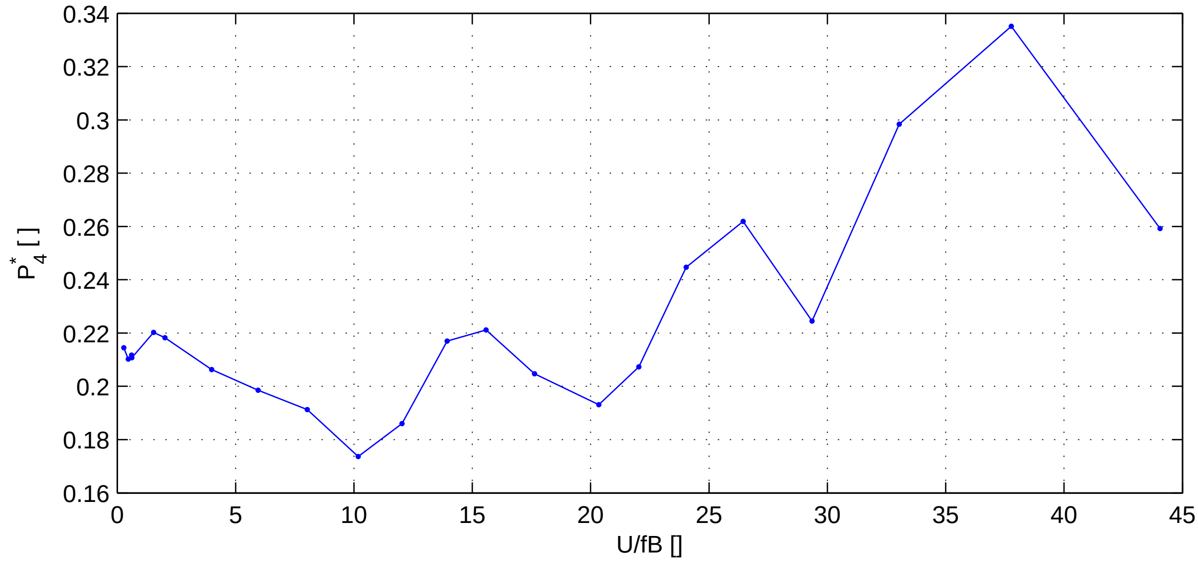


Figure J.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
0.85	25.13	4.00	22.38	0.28	0.21
1.41	25.13	4.00	13.43	0.47	0.21
1.83	25.13	4.00	10.35	0.61	0.21
1.85	25.13	4.00	10.24	0.61	0.21
4.65	25.13	4.00	4.08	1.54	0.22
6.09	25.13	4.00	3.12	2.02	0.22
12.05	25.13	4.00	1.57	3.99	0.21
17.98	25.13	4.00	1.06	5.95	0.20
19.99	20.74	3.30	0.78	8.02	0.19
19.99	16.34	2.60	0.62	10.18	0.17
19.99	13.82	2.20	0.52	12.03	0.19
19.98	11.93	1.90	0.45	13.94	0.22
19.98	10.68	1.70	0.40	15.58	0.22
19.97	9.43	1.50	0.36	17.63	0.20
19.96	8.17	1.30	0.31	20.34	0.19
19.96	7.54	1.20	0.29	22.04	0.21
19.96	6.91	1.10	0.26	24.03	0.24
19.96	6.28	1.00	0.24	26.44	0.26
19.95	5.66	0.90	0.21	29.35	0.22
19.95	5.03	0.80	0.19	33.03	0.30
19.96	4.40	0.70	0.17	37.77	0.34
19.96	3.77	0.60	0.14	44.06	0.26

Table J.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:20:49

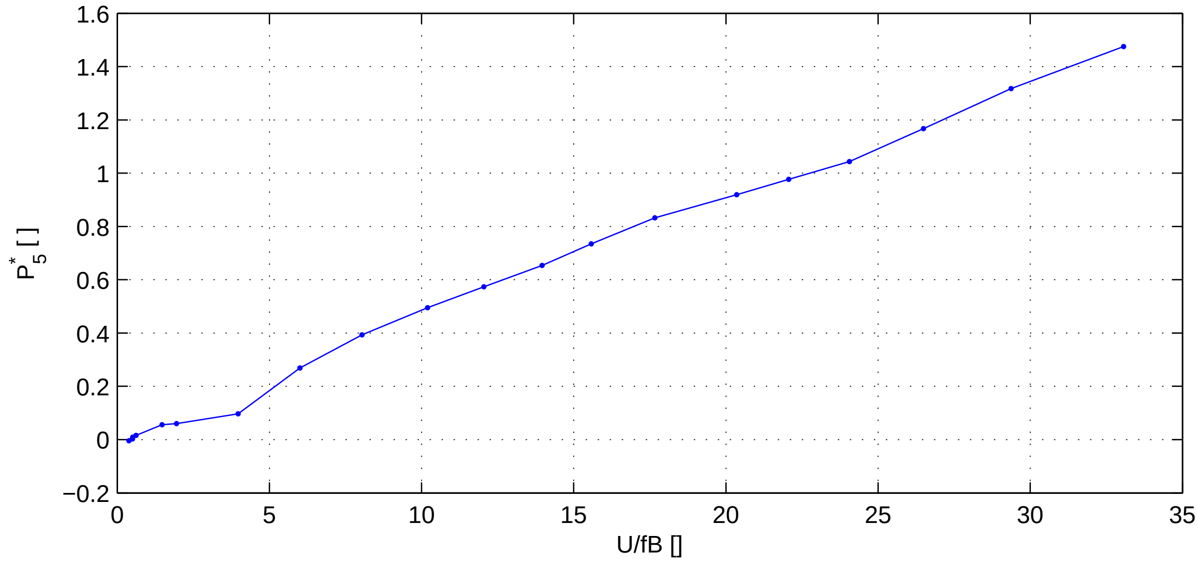


Figure J.17: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_5^*
1.17	25.13	4.00	16.26	0.39	−0.00
1.52	25.13	4.00	12.49	0.50	0.00
1.53	25.13	4.00	12.43	0.51	0.01
1.86	25.13	4.00	10.22	0.61	0.02
4.44	25.13	4.00	4.27	1.47	0.06
5.88	25.13	4.00	3.23	1.95	0.06
12.00	25.13	4.00	1.58	3.97	0.10
18.13	25.13	4.00	1.05	6.00	0.27
20.03	20.74	3.30	0.78	8.04	0.39
20.03	16.34	2.60	0.62	10.20	0.49
20.02	13.82	2.20	0.52	12.05	0.57
20.02	11.93	1.90	0.45	13.96	0.65
20.00	10.69	1.70	0.40	15.57	0.73
20.01	9.43	1.50	0.36	17.66	0.83
19.98	8.17	1.30	0.31	20.35	0.92
19.99	7.54	1.20	0.28	22.07	0.98
19.98	6.91	1.10	0.26	24.06	1.04
20.00	6.28	1.00	0.24	26.49	1.17
19.96	5.66	0.90	0.21	29.37	1.32
19.97	5.03	0.80	0.19	33.07	1.48

Table J.19: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

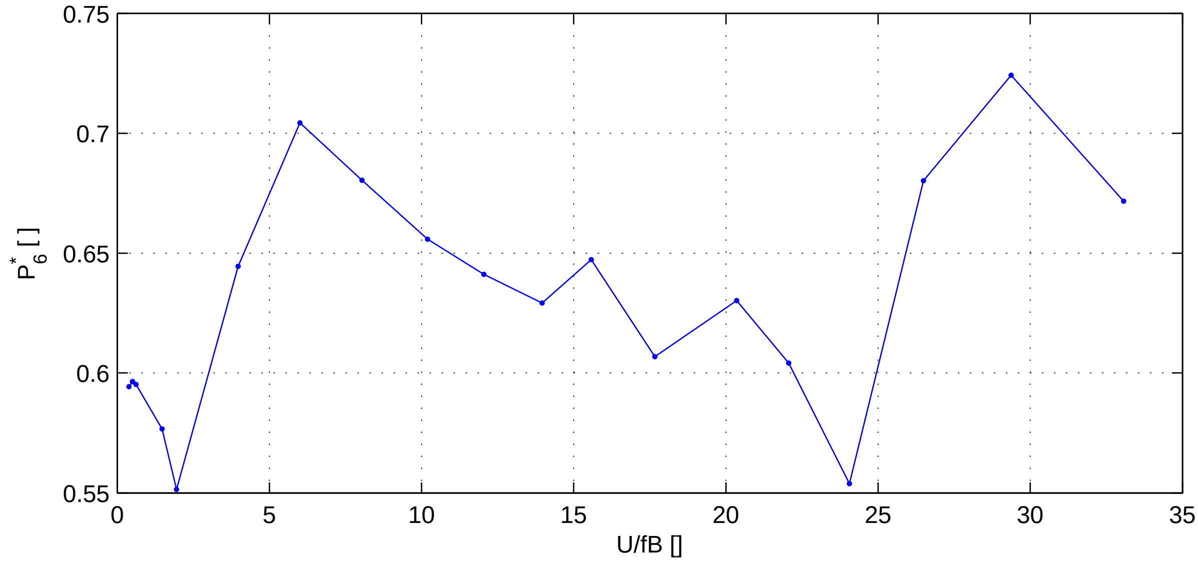


Figure J.18: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_6
1.17	25.13	4.00	16.26	0.39	0.59
1.52	25.13	4.00	12.49	0.50	0.60
1.53	25.13	4.00	12.43	0.51	0.60
1.86	25.13	4.00	10.22	0.61	0.60
4.44	25.13	4.00	4.27	1.47	0.58
5.88	25.13	4.00	3.23	1.95	0.55
12.00	25.13	4.00	1.58	3.97	0.64
18.13	25.13	4.00	1.05	6.00	0.70
20.03	20.74	3.30	0.78	8.04	0.68
20.03	16.34	2.60	0.62	10.20	0.66
20.02	13.82	2.20	0.52	12.05	0.64
20.02	11.93	1.90	0.45	13.96	0.63
20.00	10.69	1.70	0.40	15.57	0.65
20.01	9.43	1.50	0.36	17.66	0.61
19.98	8.17	1.30	0.31	20.35	0.63
19.99	7.54	1.20	0.28	22.07	0.60
19.98	6.91	1.10	0.26	24.06	0.55
20.00	6.28	1.00	0.24	26.49	0.68
19.96	5.66	0.90	0.21	29.37	0.72
19.97	5.03	0.80	0.19	33.07	0.67

Table J.20: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\left(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\,\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\left(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\,\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\left(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\,\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

Formula J.3: Equation of Motion (Stretto di Messina. Ref. [5].)

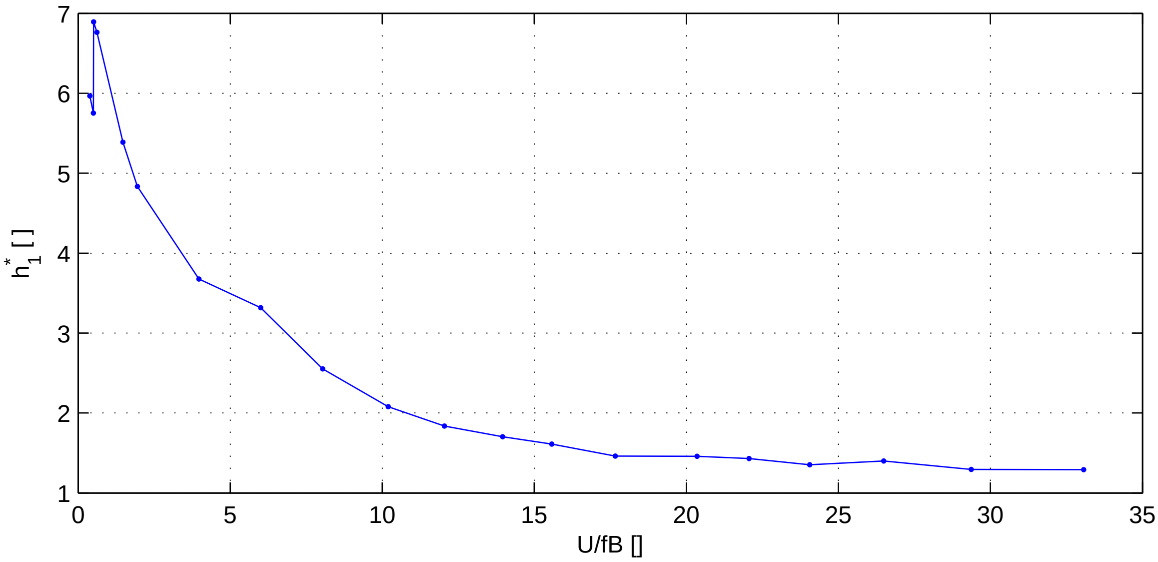


Figure J.19: h^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_1
1.17	25.13	4.00	16.26	0.39	5.97
1.52	25.13	4.00	12.49	0.50	5.75
1.53	25.13	4.00	12.43	0.51	6.89
1.86	25.13	4.00	10.22	0.61	6.76
4.44	25.13	4.00	4.27	1.47	5.39
5.88	25.13	4.00	3.23	1.95	4.83
12.00	25.13	4.00	1.58	3.97	3.68
18.13	25.13	4.00	1.05	6.00	3.32
20.03	20.74	3.30	0.78	8.04	2.55
20.03	16.34	2.60	0.62	10.20	2.08
20.02	13.82	2.20	0.52	12.05	1.83
20.02	11.93	1.90	0.45	13.96	1.70
20.00	10.69	1.70	0.40	15.57	1.61
20.01	9.43	1.50	0.36	17.66	1.46
19.98	8.17	1.30	0.31	20.35	1.46
19.99	7.54	1.20	0.28	22.07	1.43
19.98	6.91	1.10	0.26	24.06	1.35
20.00	6.28	1.00	0.24	26.49	1.40
19.96	5.66	0.90	0.21	29.37	1.29
19.97	5.03	0.80	0.19	33.07	1.29

Table J.21: h^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

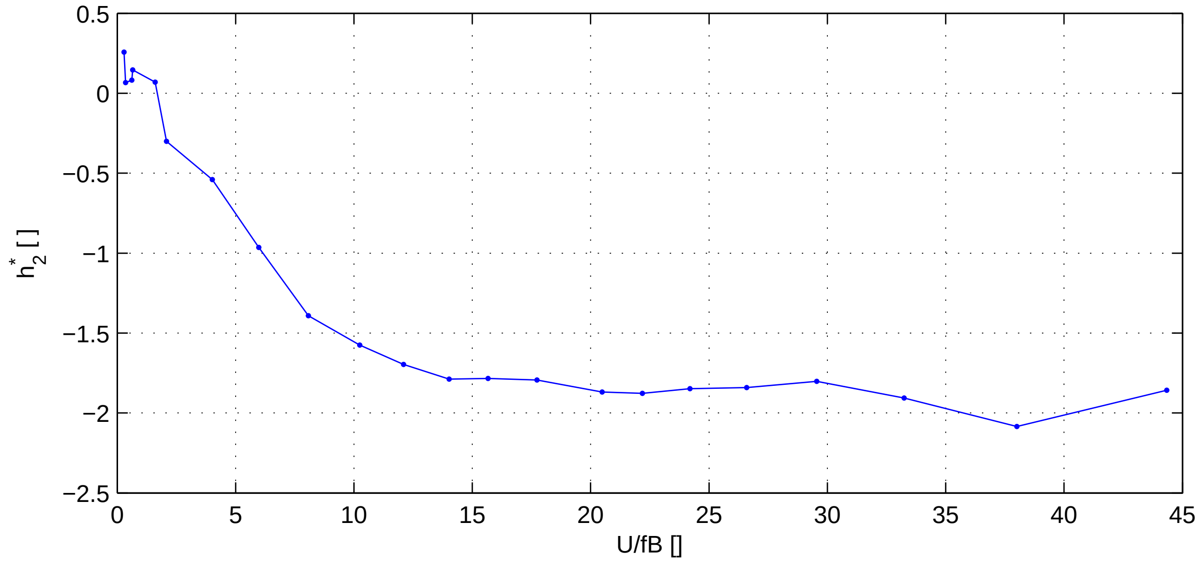


Figure J.20: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_2^*
0.85	25.13	4.00	22.23	0.28	0.26
1.07	25.13	4.00	17.67	0.36	0.07
1.85	25.13	4.00	10.25	0.61	0.08
1.99	25.13	4.00	9.56	0.66	0.15
4.84	25.13	4.00	3.92	1.60	0.07
6.29	25.13	4.00	3.02	2.08	−0.30
12.14	25.13	4.00	1.56	4.02	−0.54
18.07	25.13	4.00	1.05	5.98	−0.96
20.11	20.74	3.30	0.78	8.07	−1.39
20.11	16.34	2.60	0.61	10.24	−1.58
20.10	13.82	2.20	0.52	12.10	−1.70
20.11	11.93	1.90	0.45	14.02	−1.79
20.10	10.68	1.70	0.40	15.67	−1.78
20.09	9.43	1.50	0.35	17.73	−1.79
20.10	8.17	1.30	0.31	20.49	−1.87
20.10	7.54	1.20	0.28	22.19	−1.88
20.10	6.91	1.10	0.26	24.19	−1.85
20.08	6.28	1.00	0.24	26.59	−1.84
20.08	5.66	0.90	0.21	29.56	−1.80
20.08	5.03	0.80	0.19	33.24	−1.91
20.08	4.40	0.70	0.17	38.00	−2.09
20.09	3.77	0.60	0.14	44.33	−1.86

Table J.22: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

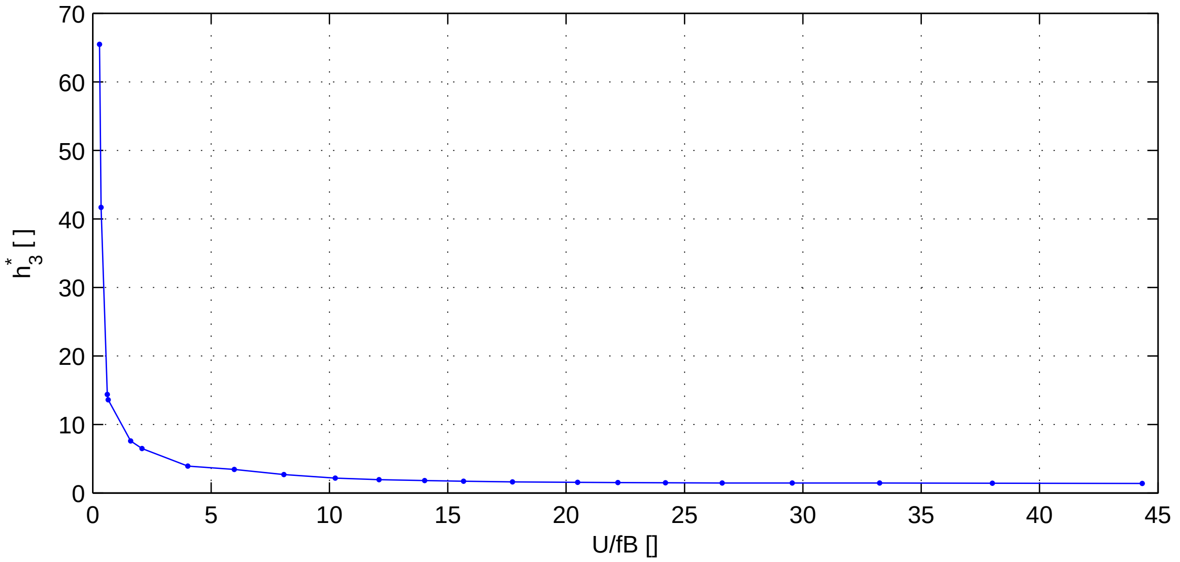


Figure J.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
0.85	25.13	4.00	22.23	0.28	65.47
1.07	25.13	4.00	17.67	0.36	41.68
1.85	25.13	4.00	10.25	0.61	14.36
1.99	25.13	4.00	9.56	0.66	13.58
4.84	25.13	4.00	3.92	1.60	7.59
6.29	25.13	4.00	3.02	2.08	6.46
12.14	25.13	4.00	1.56	4.02	3.93
18.07	25.13	4.00	1.05	5.98	3.42
20.11	20.74	3.30	0.78	8.07	2.67
20.11	16.34	2.60	0.61	10.24	2.17
20.10	13.82	2.20	0.52	12.10	1.94
20.11	11.93	1.90	0.45	14.02	1.81
20.10	10.68	1.70	0.40	15.67	1.69
20.09	9.43	1.50	0.35	17.73	1.62
20.10	8.17	1.30	0.31	20.49	1.54
20.10	7.54	1.20	0.28	22.19	1.51
20.10	6.91	1.10	0.26	24.19	1.48
20.08	6.28	1.00	0.24	26.59	1.44
20.08	5.66	0.90	0.21	29.56	1.45
20.08	5.03	0.80	0.19	33.24	1.43
20.08	4.40	0.70	0.17	38.00	1.41
20.09	3.77	0.60	0.14	44.33	1.39

Table J.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

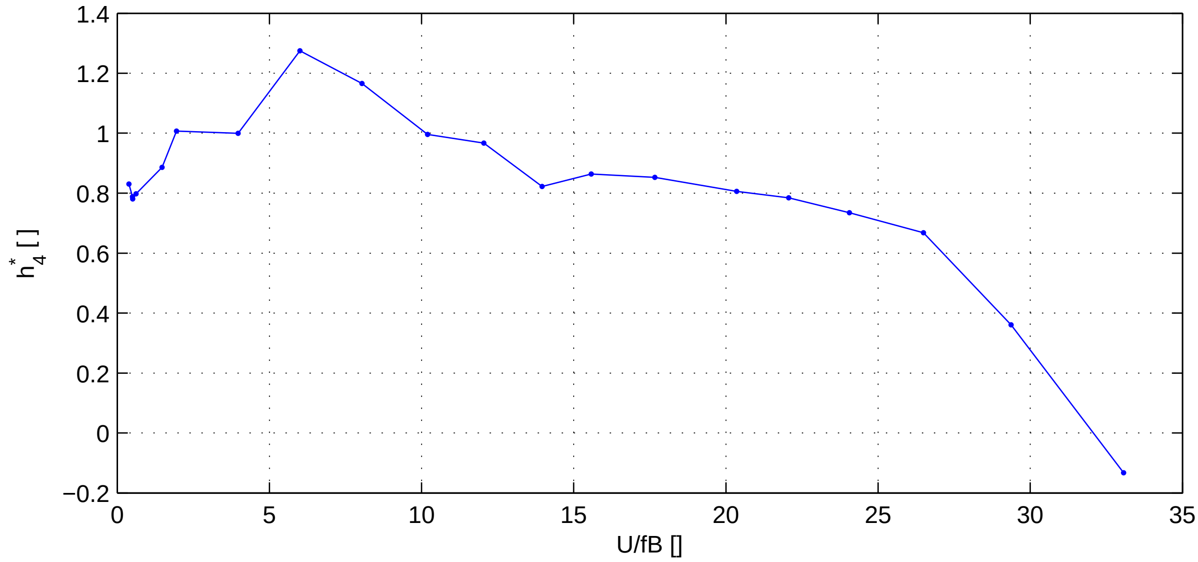


Figure J.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
1.17	25.13	4.00	16.26	0.39	0.83
1.52	25.13	4.00	12.49	0.50	0.79
1.53	25.13	4.00	12.43	0.51	0.78
1.86	25.13	4.00	10.22	0.61	0.80
4.44	25.13	4.00	4.27	1.47	0.89
5.88	25.13	4.00	3.23	1.95	1.01
12.00	25.13	4.00	1.58	3.97	1.00
18.13	25.13	4.00	1.05	6.00	1.27
20.03	20.74	3.30	0.78	8.04	1.17
20.03	16.34	2.60	0.62	10.20	1.00
20.02	13.82	2.20	0.52	12.05	0.97
20.02	11.93	1.90	0.45	13.96	0.82
20.00	10.69	1.70	0.40	15.57	0.86
20.01	9.43	1.50	0.36	17.66	0.85
19.98	8.17	1.30	0.31	20.35	0.81
19.99	7.54	1.20	0.28	22.07	0.78
19.98	6.91	1.10	0.26	24.06	0.73
20.00	6.28	1.00	0.24	26.49	0.67
19.96	5.66	0.90	0.21	29.37	0.36
19.97	5.03	0.80	0.19	33.07	−0.13

Table J.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

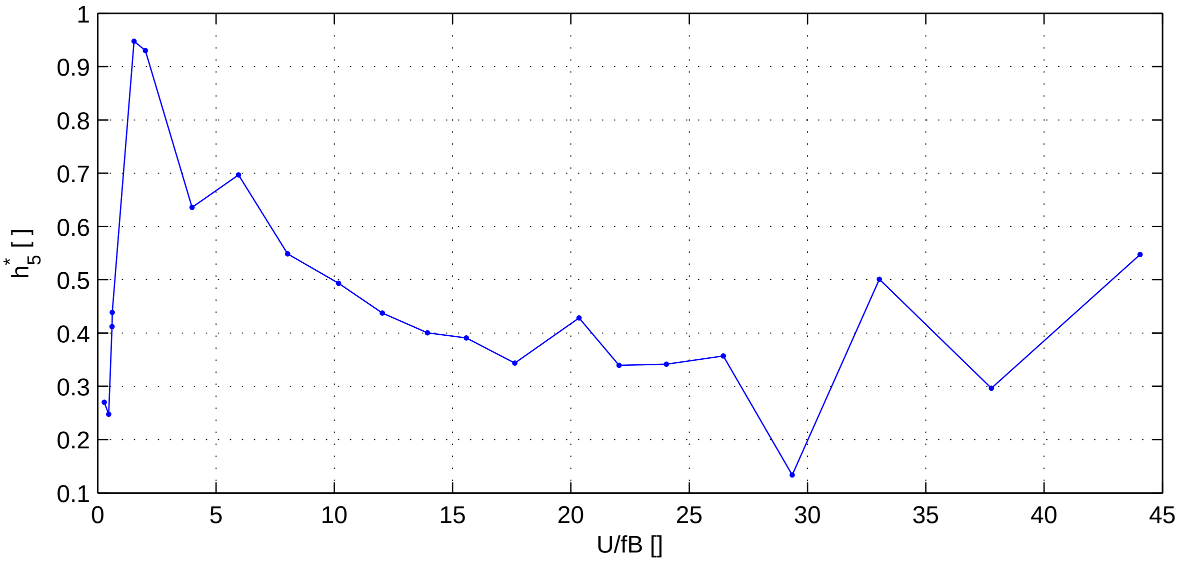


Figure J.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
0.85	25.13	4.00	22.38	0.28	0.27
1.41	25.13	4.00	13.43	0.47	0.25
1.83	25.13	4.00	10.35	0.61	0.41
1.85	25.13	4.00	10.24	0.61	0.44
4.65	25.13	4.00	4.08	1.54	0.95
6.09	25.13	4.00	3.12	2.02	0.93
12.05	25.13	4.00	1.57	3.99	0.64
17.98	25.13	4.00	1.06	5.95	0.70
19.99	20.74	3.30	0.78	8.02	0.55
19.99	16.34	2.60	0.62	10.18	0.49
19.99	13.82	2.20	0.52	12.03	0.44
19.98	11.93	1.90	0.45	13.94	0.40
19.98	10.68	1.70	0.40	15.58	0.39
19.97	9.43	1.50	0.36	17.63	0.34
19.96	8.17	1.30	0.31	20.34	0.43
19.96	7.54	1.20	0.29	22.04	0.34
19.96	6.91	1.10	0.26	24.03	0.34
19.96	6.28	1.00	0.24	26.44	0.36
19.95	5.66	0.90	0.21	29.35	0.13
19.95	5.03	0.80	0.19	33.03	0.50
19.96	4.40	0.70	0.17	37.77	0.30
19.96	3.77	0.60	0.14	44.06	0.55

Table J.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

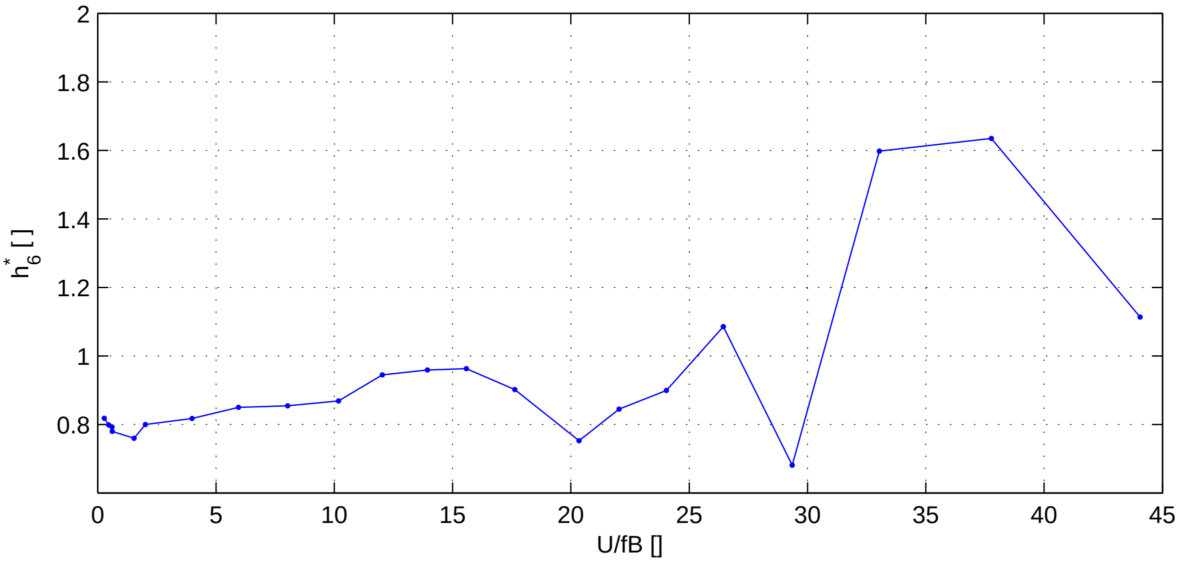


Figure J.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
0.85	25.13	4.00	22.38	0.28	0.82
1.41	25.13	4.00	13.43	0.47	0.80
1.83	25.13	4.00	10.35	0.61	0.79
1.85	25.13	4.00	10.24	0.61	0.78
4.65	25.13	4.00	4.08	1.54	0.76
6.09	25.13	4.00	3.12	2.02	0.80
12.05	25.13	4.00	1.57	3.99	0.82
17.98	25.13	4.00	1.06	5.95	0.85
19.99	20.74	3.30	0.78	8.02	0.85
19.99	16.34	2.60	0.62	10.18	0.87
19.99	13.82	2.20	0.52	12.03	0.94
19.98	11.93	1.90	0.45	13.94	0.96
19.98	10.68	1.70	0.40	15.58	0.96
19.97	9.43	1.50	0.36	17.63	0.90
19.96	8.17	1.30	0.31	20.34	0.75
19.96	7.54	1.20	0.29	22.04	0.84
19.96	6.91	1.10	0.26	24.03	0.90
19.96	6.28	1.00	0.24	26.44	1.09
19.95	5.66	0.90	0.21	29.35	0.68
19.95	5.03	0.80	0.19	33.03	1.60
19.96	4.40	0.70	0.17	37.77	1.63
19.96	3.77	0.60	0.14	44.06	1.11

Table J.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

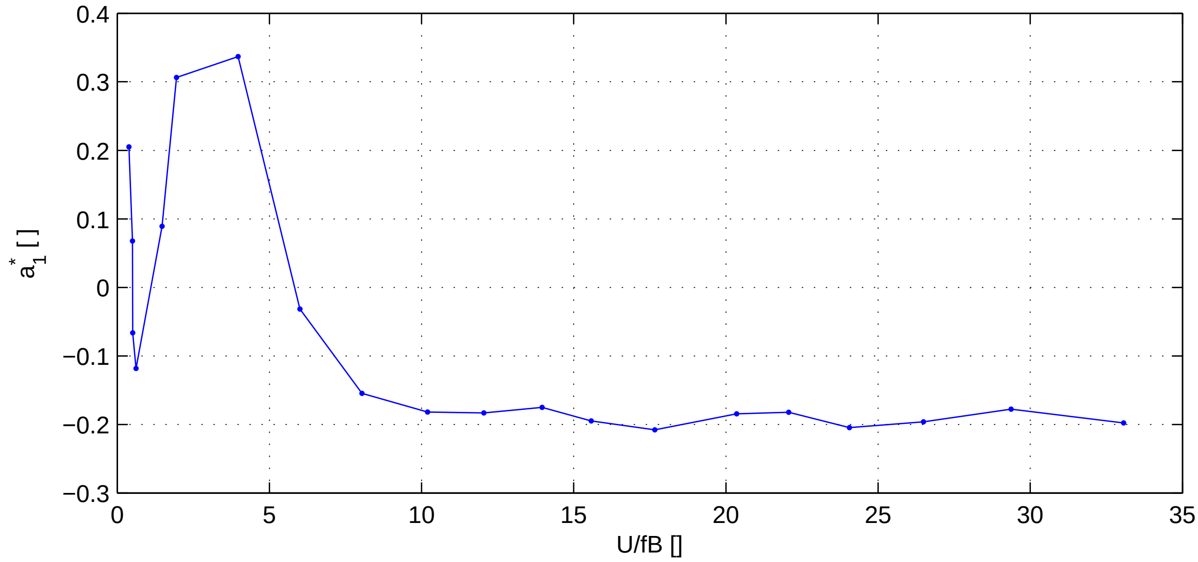


Figure J.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
1.17	25.13	4.00	16.26	0.39	0.21
1.52	25.13	4.00	12.49	0.50	0.07
1.53	25.13	4.00	12.43	0.51	−0.07
1.86	25.13	4.00	10.22	0.61	−0.12
4.44	25.13	4.00	4.27	1.47	0.09
5.88	25.13	4.00	3.23	1.95	0.31
12.00	25.13	4.00	1.58	3.97	0.34
18.13	25.13	4.00	1.05	6.00	−0.03
20.03	20.74	3.30	0.78	8.04	−0.15
20.03	16.34	2.60	0.62	10.20	−0.18
20.02	13.82	2.20	0.52	12.05	−0.18
20.02	11.93	1.90	0.45	13.96	−0.18
20.00	10.69	1.70	0.40	15.57	−0.20
20.01	9.43	1.50	0.36	17.66	−0.21
19.98	8.17	1.30	0.31	20.35	−0.18
19.99	7.54	1.20	0.28	22.07	−0.18
19.98	6.91	1.10	0.26	24.06	−0.20
20.00	6.28	1.00	0.24	26.49	−0.20
19.96	5.66	0.90	0.21	29.37	−0.18
19.97	5.03	0.80	0.19	33.07	−0.20

Table J.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

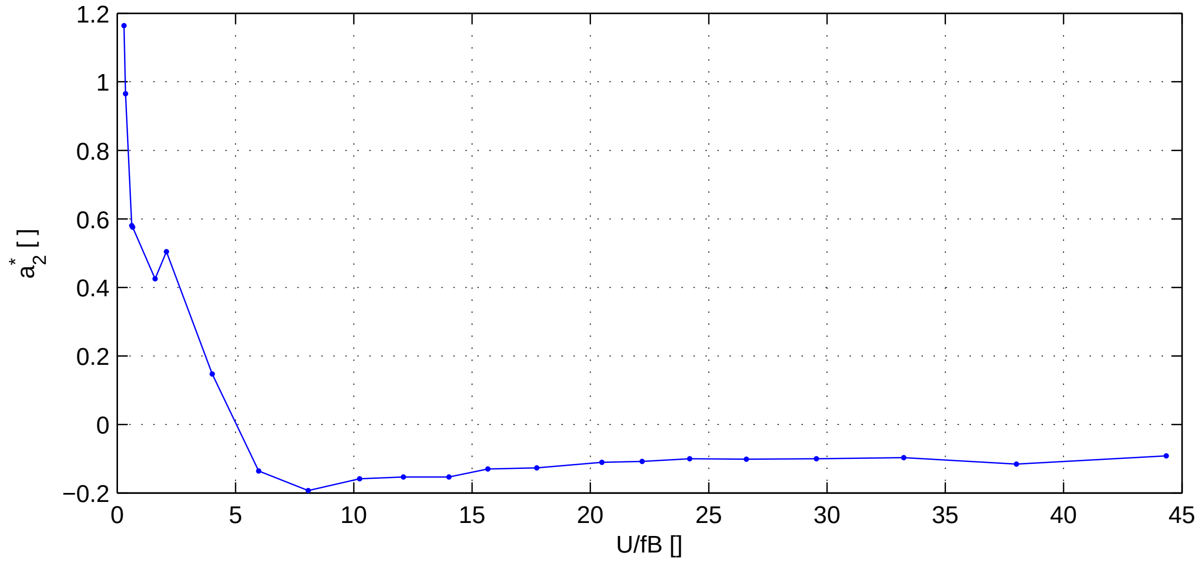


Figure J.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
0.85	25.13	4.00	22.23	0.28	1.16
1.07	25.13	4.00	17.67	0.36	0.97
1.85	25.13	4.00	10.25	0.61	0.58
1.99	25.13	4.00	9.56	0.66	0.58
4.84	25.13	4.00	3.92	1.60	0.42
6.29	25.13	4.00	3.02	2.08	0.50
12.14	25.13	4.00	1.56	4.02	0.15
18.07	25.13	4.00	1.05	5.98	−0.14
20.11	20.74	3.30	0.78	8.07	−0.19
20.11	16.34	2.60	0.61	10.24	−0.16
20.10	13.82	2.20	0.52	12.10	−0.15
20.11	11.93	1.90	0.45	14.02	−0.15
20.10	10.68	1.70	0.40	15.67	−0.13
20.09	9.43	1.50	0.35	17.73	−0.13
20.10	8.17	1.30	0.31	20.49	−0.11
20.10	7.54	1.20	0.28	22.19	−0.11
20.10	6.91	1.10	0.26	24.19	−0.10
20.08	6.28	1.00	0.24	26.59	−0.10
20.08	5.66	0.90	0.21	29.56	−0.10
20.08	5.03	0.80	0.19	33.24	−0.10
20.08	4.40	0.70	0.17	38.00	−0.12
20.09	3.77	0.60	0.14	44.33	−0.09

Table J.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

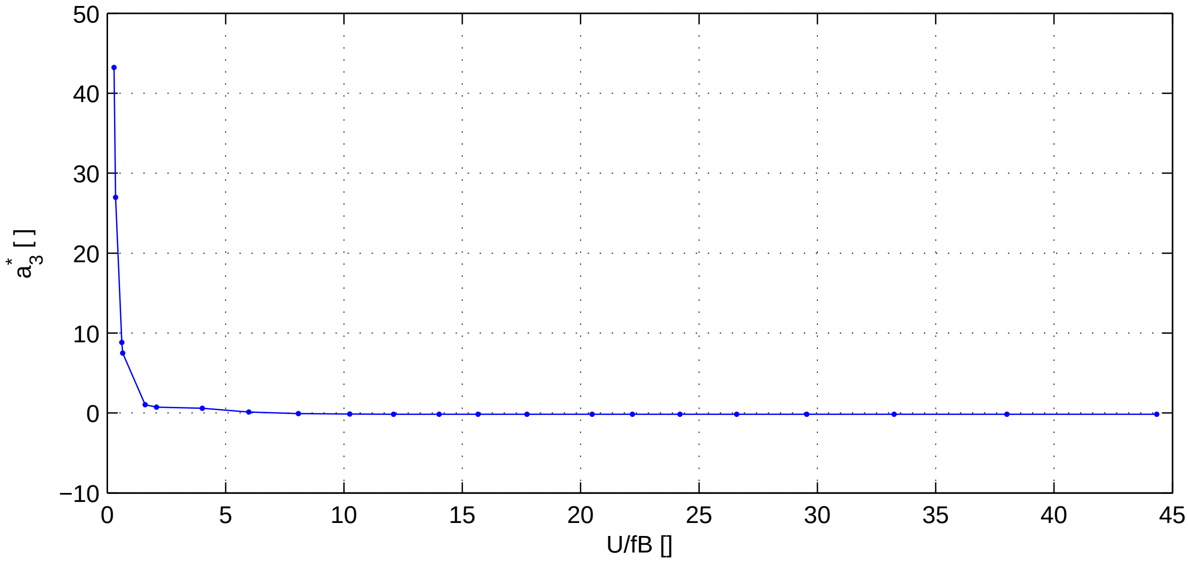


Figure J.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
0.85	25.13	4.00	22.23	0.28	43.22
1.07	25.13	4.00	17.67	0.36	26.96
1.85	25.13	4.00	10.25	0.61	8.82
1.99	25.13	4.00	9.56	0.66	7.49
4.84	25.13	4.00	3.92	1.60	1.03
6.29	25.13	4.00	3.02	2.08	0.73
12.14	25.13	4.00	1.56	4.02	0.58
18.07	25.13	4.00	1.05	5.98	0.13
20.11	20.74	3.30	0.78	8.07	−0.08
20.11	16.34	2.60	0.61	10.24	−0.14
20.10	13.82	2.20	0.52	12.10	−0.16
20.11	11.93	1.90	0.45	14.02	−0.17
20.10	10.68	1.70	0.40	15.67	−0.17
20.09	9.43	1.50	0.35	17.73	−0.17
20.10	8.17	1.30	0.31	20.49	−0.17
20.10	7.54	1.20	0.28	22.19	−0.17
20.10	6.91	1.10	0.26	24.19	−0.17
20.08	6.28	1.00	0.24	26.59	−0.17
20.08	5.66	0.90	0.21	29.56	−0.17
20.08	5.03	0.80	0.19	33.24	−0.17
20.08	4.40	0.70	0.17	38.00	−0.17
20.09	3.77	0.60	0.14	44.33	−0.17

Table J.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

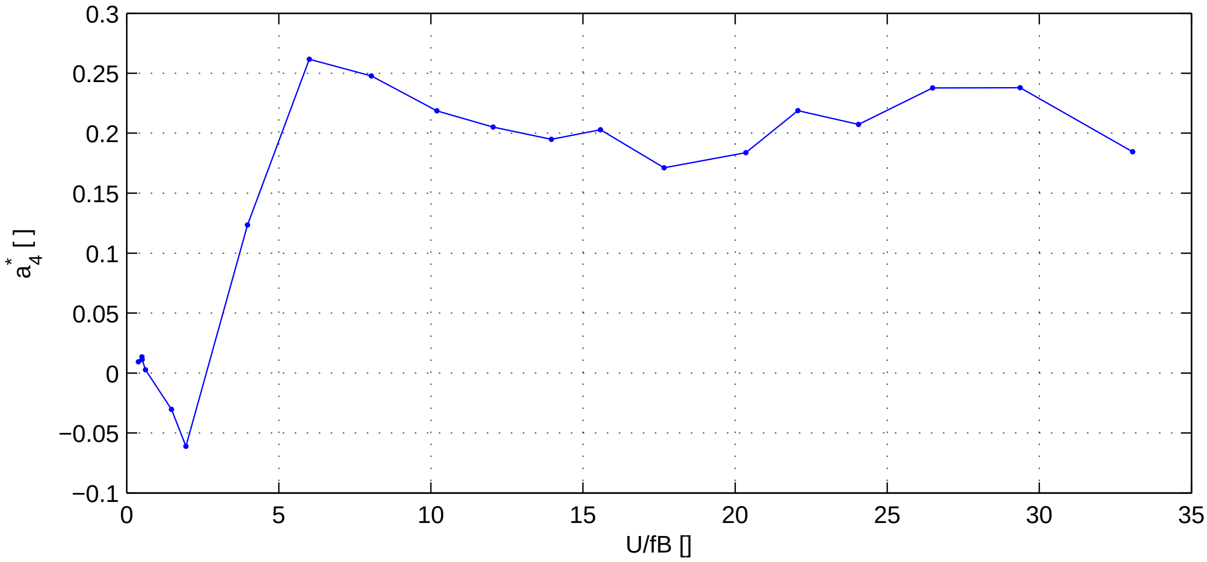


Figure J.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
1.17	25.13	4.00	16.26	0.39	0.01
1.52	25.13	4.00	12.49	0.50	0.01
1.53	25.13	4.00	12.43	0.51	0.01
1.86	25.13	4.00	10.22	0.61	0.00
4.44	25.13	4.00	4.27	1.47	−0.03
5.88	25.13	4.00	3.23	1.95	−0.06
12.00	25.13	4.00	1.58	3.97	0.12
18.13	25.13	4.00	1.05	6.00	0.26
20.03	20.74	3.30	0.78	8.04	0.25
20.03	16.34	2.60	0.62	10.20	0.22
20.02	13.82	2.20	0.52	12.05	0.21
20.02	11.93	1.90	0.45	13.96	0.19
20.00	10.69	1.70	0.40	15.57	0.20
20.01	9.43	1.50	0.36	17.66	0.17
19.98	8.17	1.30	0.31	20.35	0.18
19.99	7.54	1.20	0.28	22.07	0.22
19.98	6.91	1.10	0.26	24.06	0.21
20.00	6.28	1.00	0.24	26.49	0.24
19.96	5.66	0.90	0.21	29.37	0.24
19.97	5.03	0.80	0.19	33.07	0.18

Table J.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

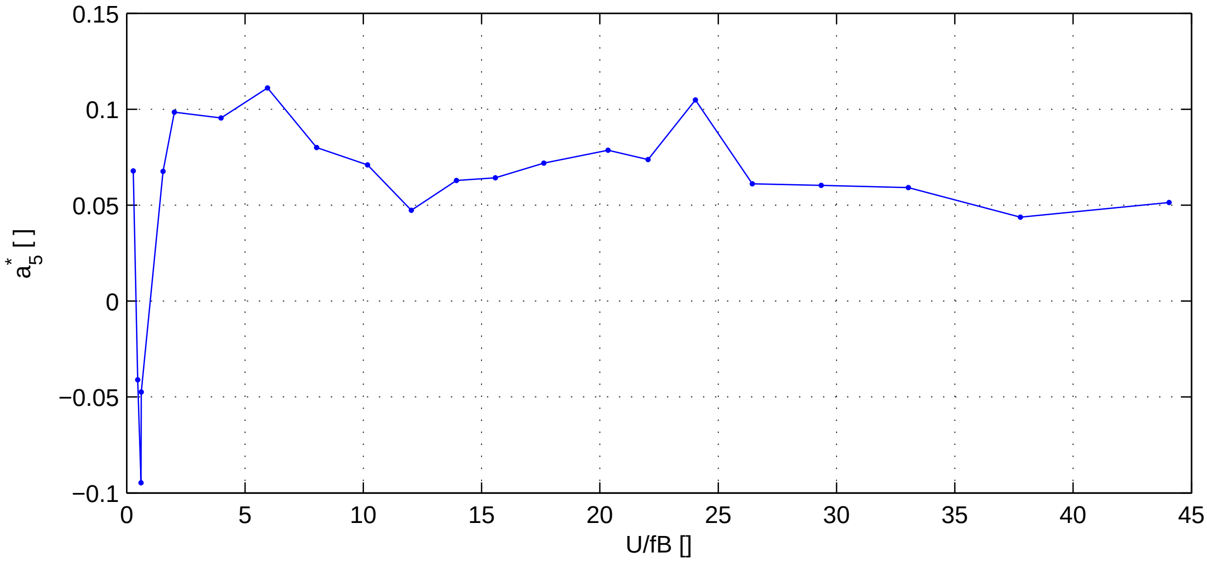


Figure J.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
0.85	25.13	4.00	22.38	0.28	0.07
1.41	25.13	4.00	13.43	0.47	−0.04
1.83	25.13	4.00	10.35	0.61	−0.09
1.85	25.13	4.00	10.24	0.61	−0.05
4.65	25.13	4.00	4.08	1.54	0.07
6.09	25.13	4.00	3.12	2.02	0.10
12.05	25.13	4.00	1.57	3.99	0.10
17.98	25.13	4.00	1.06	5.95	0.11
19.99	20.74	3.30	0.78	8.02	0.08
19.99	16.34	2.60	0.62	10.18	0.07
19.99	13.82	2.20	0.52	12.03	0.05
19.98	11.93	1.90	0.45	13.94	0.06
19.98	10.68	1.70	0.40	15.58	0.06
19.97	9.43	1.50	0.36	17.63	0.07
19.96	8.17	1.30	0.31	20.34	0.08
19.96	7.54	1.20	0.29	22.04	0.07
19.96	6.91	1.10	0.26	24.03	0.10
19.96	6.28	1.00	0.24	26.44	0.06
19.95	5.66	0.90	0.21	29.35	0.06
19.95	5.03	0.80	0.19	33.03	0.06
19.96	4.40	0.70	0.17	37.77	0.04
19.96	3.77	0.60	0.14	44.06	0.05

Table J.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

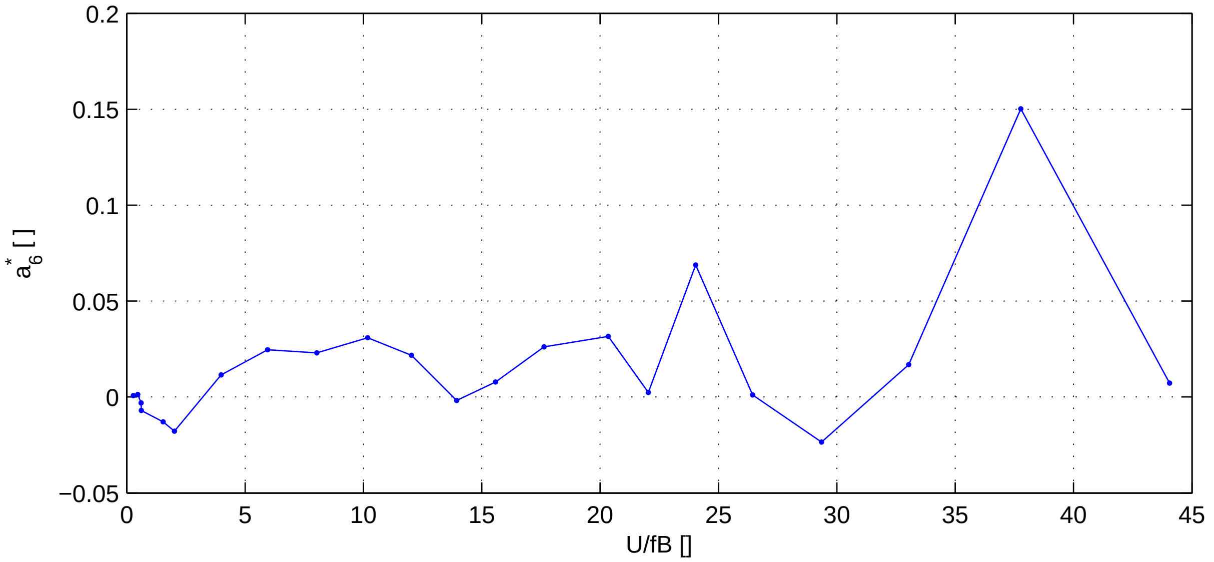


Figure J.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
0.85	25.13	4.00	22.38	0.28	0.00
1.41	25.13	4.00	13.43	0.47	0.00
1.83	25.13	4.00	10.35	0.61	−0.00
1.85	25.13	4.00	10.24	0.61	−0.01
4.65	25.13	4.00	4.08	1.54	−0.01
6.09	25.13	4.00	3.12	2.02	−0.02
12.05	25.13	4.00	1.57	3.99	0.01
17.98	25.13	4.00	1.06	5.95	0.02
19.99	20.74	3.30	0.78	8.02	0.02
19.99	16.34	2.60	0.62	10.18	0.03
19.99	13.82	2.20	0.52	12.03	0.02
19.98	11.93	1.90	0.45	13.94	−0.00
19.98	10.68	1.70	0.40	15.58	0.01
19.97	9.43	1.50	0.36	17.63	0.03
19.96	8.17	1.30	0.31	20.34	0.03
19.96	7.54	1.20	0.29	22.04	0.00
19.96	6.91	1.10	0.26	24.03	0.07
19.96	6.28	1.00	0.24	26.44	0.00
19.95	5.66	0.90	0.21	29.35	−0.02
19.95	5.03	0.80	0.19	33.03	0.02
19.96	4.40	0.70	0.17	37.77	0.15
19.96	3.77	0.60	0.14	44.06	0.01

Table J.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

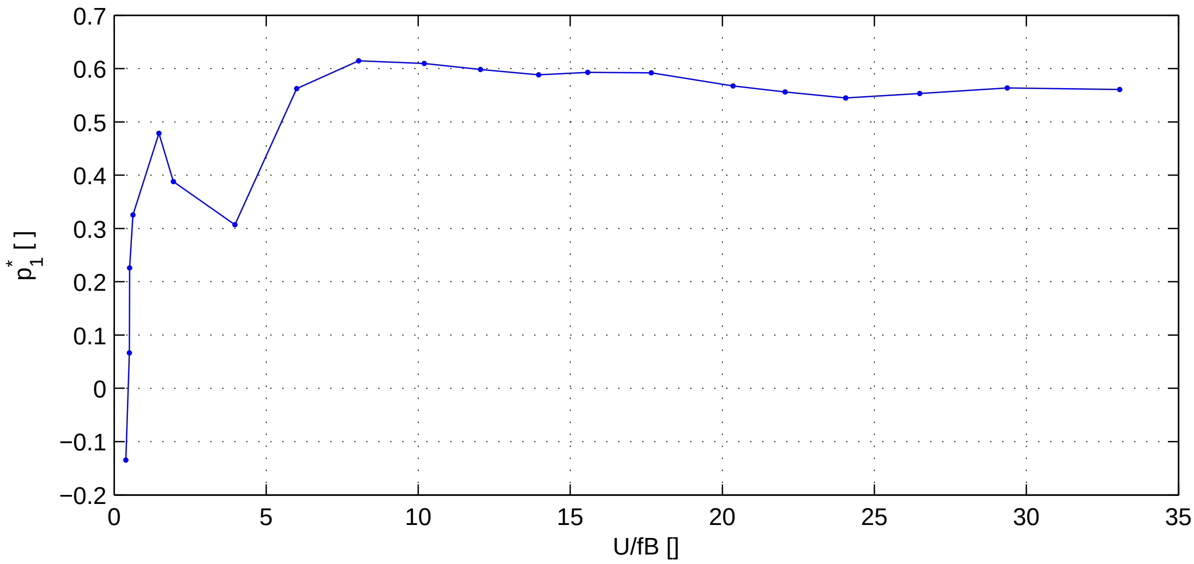


Figure J.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
1.17	25.13	4.00	16.26	0.39	−0.13
1.52	25.13	4.00	12.49	0.50	0.07
1.53	25.13	4.00	12.43	0.51	0.23
1.86	25.13	4.00	10.22	0.61	0.33
4.44	25.13	4.00	4.27	1.47	0.48
5.88	25.13	4.00	3.23	1.95	0.39
12.00	25.13	4.00	1.58	3.97	0.31
18.13	25.13	4.00	1.05	6.00	0.56
20.03	20.74	3.30	0.78	8.04	0.61
20.03	16.34	2.60	0.62	10.20	0.61
20.02	13.82	2.20	0.52	12.05	0.60
20.02	11.93	1.90	0.45	13.96	0.59
20.00	10.69	1.70	0.40	15.57	0.59
20.01	9.43	1.50	0.36	17.66	0.59
19.98	8.17	1.30	0.31	20.35	0.57
19.99	7.54	1.20	0.28	22.07	0.56
19.98	6.91	1.10	0.26	24.06	0.55
20.00	6.28	1.00	0.24	26.49	0.55
19.96	5.66	0.90	0.21	29.37	0.56
19.97	5.03	0.80	0.19	33.07	0.56

Table J.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

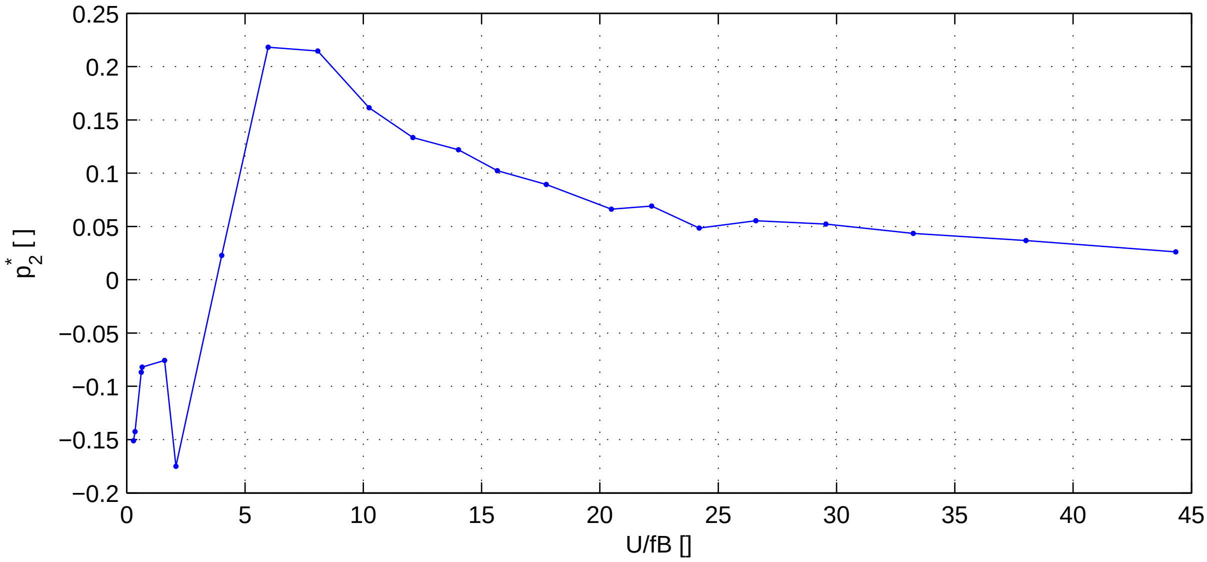


Figure J.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
0.85	25.13	4.00	22.23	0.28	−0.15
1.07	25.13	4.00	17.67	0.36	−0.14
1.85	25.13	4.00	10.25	0.61	−0.09
1.99	25.13	4.00	9.56	0.66	−0.08
4.84	25.13	4.00	3.92	1.60	−0.08
6.29	25.13	4.00	3.02	2.08	−0.18
12.14	25.13	4.00	1.56	4.02	0.02
18.07	25.13	4.00	1.05	5.98	0.22
20.11	20.74	3.30	0.78	8.07	0.21
20.11	16.34	2.60	0.61	10.24	0.16
20.10	13.82	2.20	0.52	12.10	0.13
20.11	11.93	1.90	0.45	14.02	0.12
20.10	10.68	1.70	0.40	15.67	0.10
20.09	9.43	1.50	0.35	17.73	0.09
20.10	8.17	1.30	0.31	20.49	0.07
20.10	7.54	1.20	0.28	22.19	0.07
20.10	6.91	1.10	0.26	24.19	0.05
20.08	6.28	1.00	0.24	26.59	0.06
20.08	5.66	0.90	0.21	29.56	0.05
20.08	5.03	0.80	0.19	33.24	0.04
20.08	4.40	0.70	0.17	38.00	0.04
20.09	3.77	0.60	0.14	44.33	0.03

Table J.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

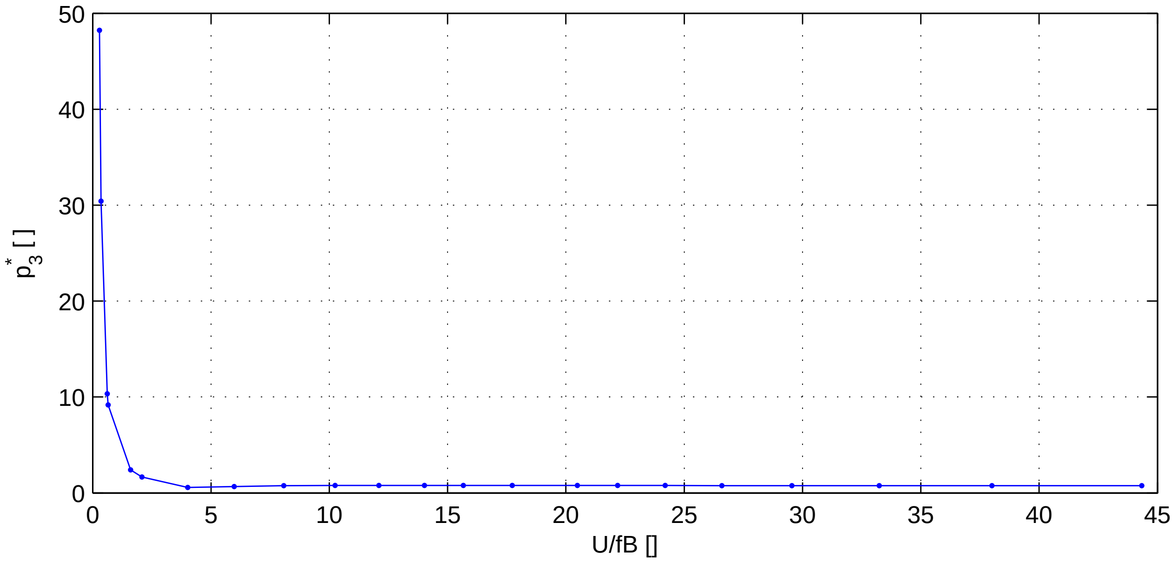


Figure J.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
0.85	25.13	4.00	22.23	0.28	48.22
1.07	25.13	4.00	17.67	0.36	30.42
1.85	25.13	4.00	10.25	0.61	10.32
1.99	25.13	4.00	9.56	0.66	9.18
4.84	25.13	4.00	3.92	1.60	2.41
6.29	25.13	4.00	3.02	2.08	1.65
12.14	25.13	4.00	1.56	4.02	0.57
18.07	25.13	4.00	1.05	5.98	0.67
20.11	20.74	3.30	0.78	8.07	0.75
20.11	16.34	2.60	0.61	10.24	0.78
20.10	13.82	2.20	0.52	12.10	0.78
20.11	11.93	1.90	0.45	14.02	0.78
20.10	10.68	1.70	0.40	15.67	0.77
20.09	9.43	1.50	0.35	17.73	0.77
20.10	8.17	1.30	0.31	20.49	0.77
20.10	7.54	1.20	0.28	22.19	0.77
20.10	6.91	1.10	0.26	24.19	0.77
20.08	6.28	1.00	0.24	26.59	0.76
20.08	5.66	0.90	0.21	29.56	0.76
20.08	5.03	0.80	0.19	33.24	0.76
20.08	4.40	0.70	0.17	38.00	0.76
20.09	3.77	0.60	0.14	44.33	0.75

Table J.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

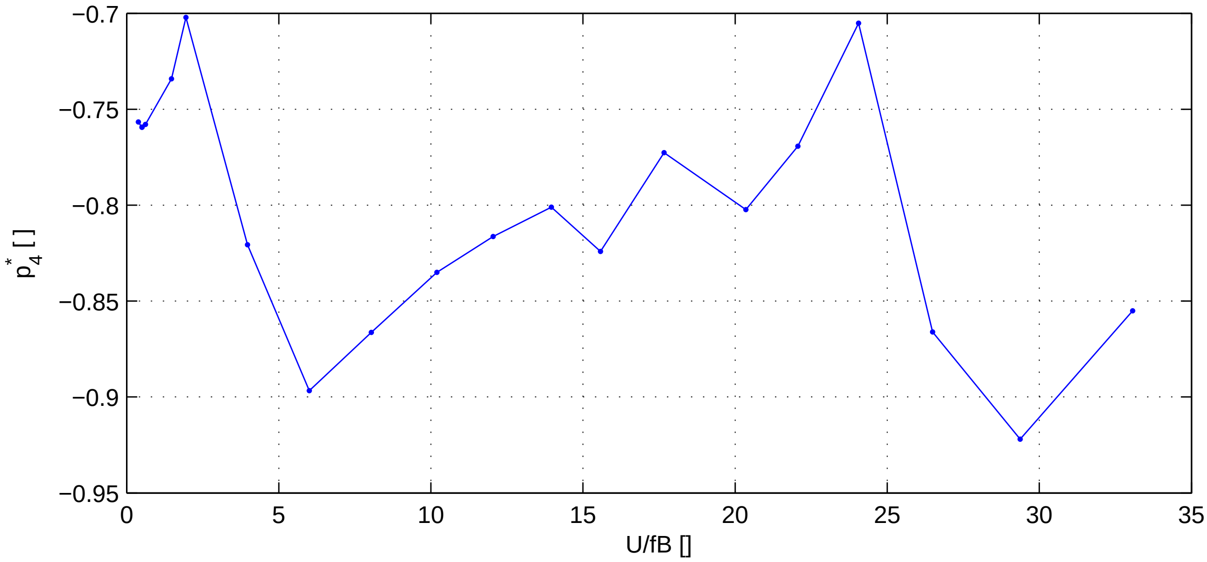


Figure J.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
1.17	25.13	4.00	16.26	0.39	−0.76
1.52	25.13	4.00	12.49	0.50	−0.76
1.53	25.13	4.00	12.43	0.51	−0.76
1.86	25.13	4.00	10.22	0.61	−0.76
4.44	25.13	4.00	4.27	1.47	−0.73
5.88	25.13	4.00	3.23	1.95	−0.70
12.00	25.13	4.00	1.58	3.97	−0.82
18.13	25.13	4.00	1.05	6.00	−0.90
20.03	20.74	3.30	0.78	8.04	−0.87
20.03	16.34	2.60	0.62	10.20	−0.83
20.02	13.82	2.20	0.52	12.05	−0.82
20.02	11.93	1.90	0.45	13.96	−0.80
20.00	10.69	1.70	0.40	15.57	−0.82
20.01	9.43	1.50	0.36	17.66	−0.77
19.98	8.17	1.30	0.31	20.35	−0.80
19.99	7.54	1.20	0.28	22.07	−0.77
19.98	6.91	1.10	0.26	24.06	−0.71
20.00	6.28	1.00	0.24	26.49	−0.87
19.96	5.66	0.90	0.21	29.37	−0.92
19.97	5.03	0.80	0.19	33.07	−0.86

Table J.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

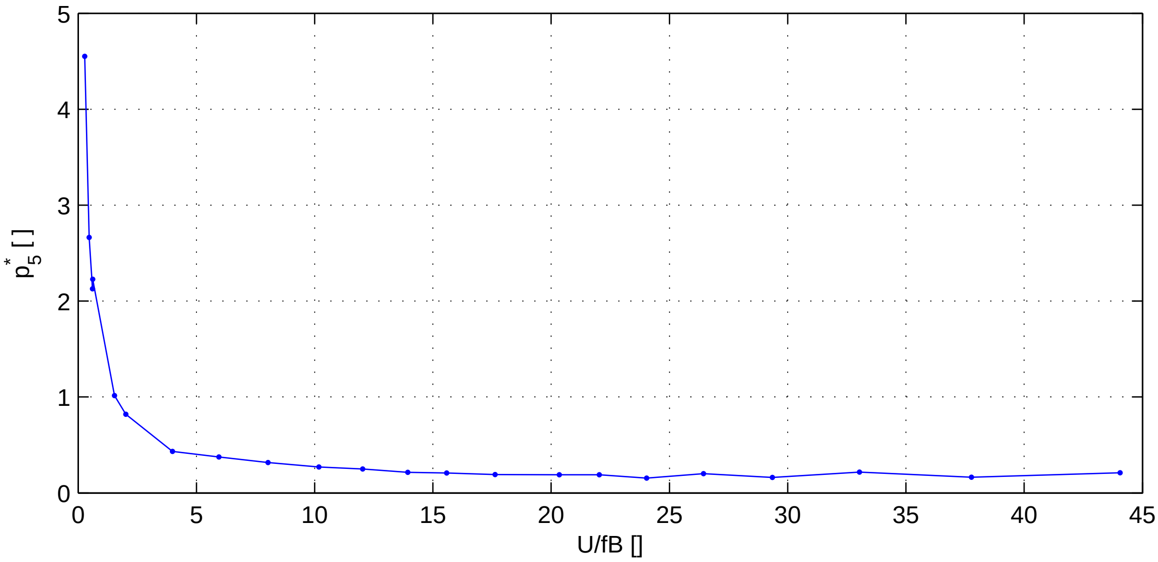


Figure J.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
0.85	25.13	4.00	22.38	0.28	4.55
1.41	25.13	4.00	13.43	0.47	2.66
1.83	25.13	4.00	10.35	0.61	2.13
1.85	25.13	4.00	10.24	0.61	2.23
4.65	25.13	4.00	4.08	1.54	1.01
6.09	25.13	4.00	3.12	2.02	0.82
12.05	25.13	4.00	1.57	3.99	0.43
17.98	25.13	4.00	1.06	5.95	0.37
19.99	20.74	3.30	0.78	8.02	0.32
19.99	16.34	2.60	0.62	10.18	0.27
19.99	13.82	2.20	0.52	12.03	0.25
19.98	11.93	1.90	0.45	13.94	0.21
19.98	10.68	1.70	0.40	15.58	0.21
19.97	9.43	1.50	0.36	17.63	0.19
19.96	8.17	1.30	0.31	20.34	0.19
19.96	7.54	1.20	0.29	22.04	0.19
19.96	6.91	1.10	0.26	24.03	0.15
19.96	6.28	1.00	0.24	26.44	0.20
19.95	5.66	0.90	0.21	29.35	0.16
19.95	5.03	0.80	0.19	33.03	0.22
19.96	4.40	0.70	0.17	37.77	0.16
19.96	3.77	0.60	0.14	44.06	0.21

Table J.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

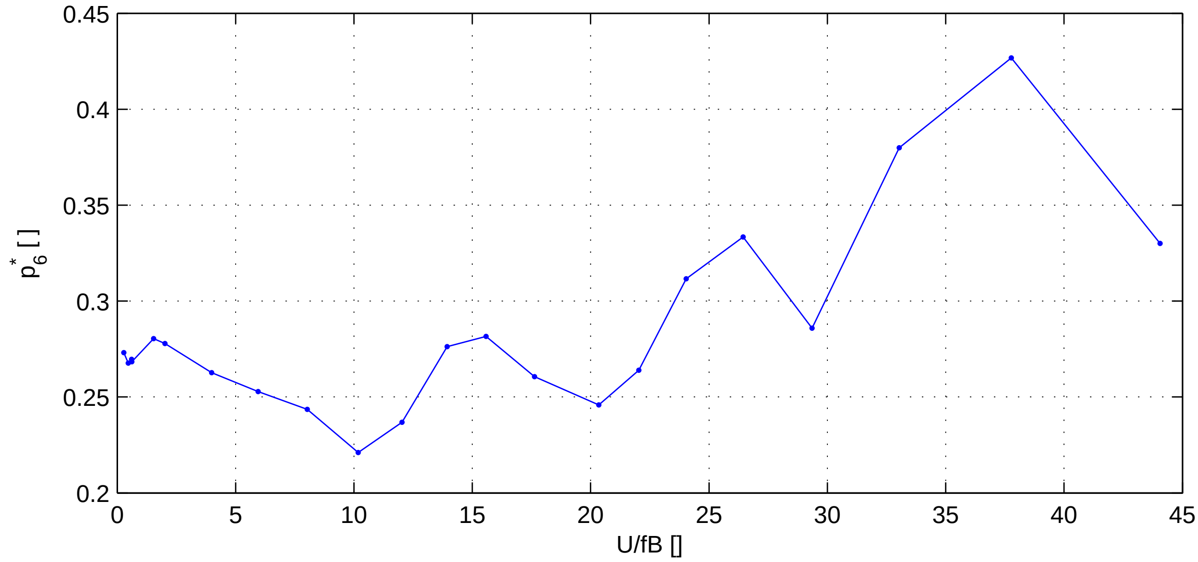


Figure J.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
0.85	25.13	4.00	22.38	0.28	0.27
1.41	25.13	4.00	13.43	0.47	0.27
1.83	25.13	4.00	10.35	0.61	0.27
1.85	25.13	4.00	10.24	0.61	0.27
4.65	25.13	4.00	4.08	1.54	0.28
6.09	25.13	4.00	3.12	2.02	0.28
12.05	25.13	4.00	1.57	3.99	0.26
17.98	25.13	4.00	1.06	5.95	0.25
19.99	20.74	3.30	0.78	8.02	0.24
19.99	16.34	2.60	0.62	10.18	0.22
19.99	13.82	2.20	0.52	12.03	0.24
19.98	11.93	1.90	0.45	13.94	0.28
19.98	10.68	1.70	0.40	15.58	0.28
19.97	9.43	1.50	0.36	17.63	0.26
19.96	8.17	1.30	0.31	20.34	0.25
19.96	7.54	1.20	0.29	22.04	0.26
19.96	6.91	1.10	0.26	24.03	0.31
19.96	6.28	1.00	0.24	26.44	0.33
19.95	5.66	0.90	0.21	29.35	0.29
19.95	5.03	0.80	0.19	33.03	0.38
19.96	4.40	0.70	0.17	37.77	0.43
19.96	3.77	0.60	0.14	44.06	0.33

Table J.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

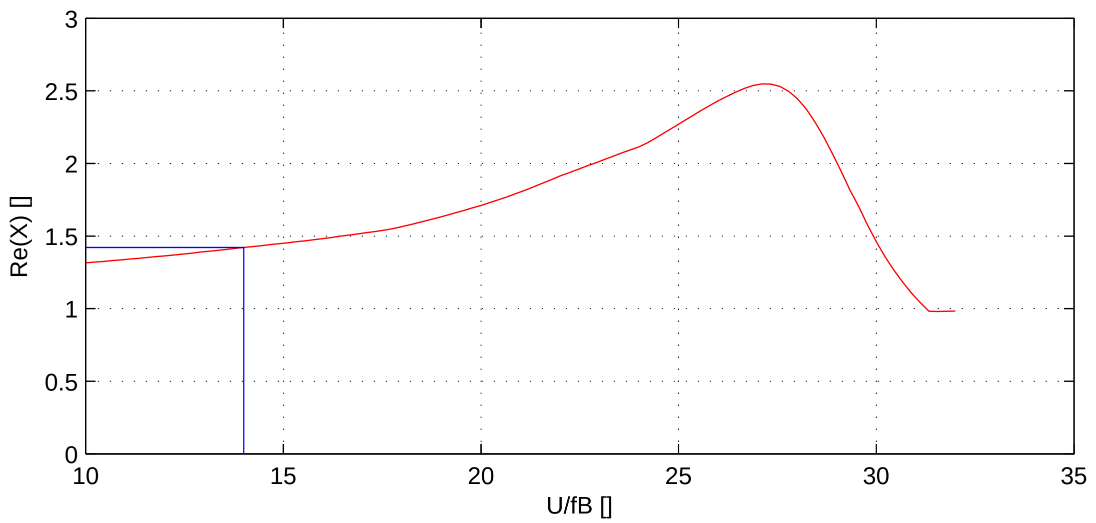


Figure J.37: Real part of the solution to stability equantion

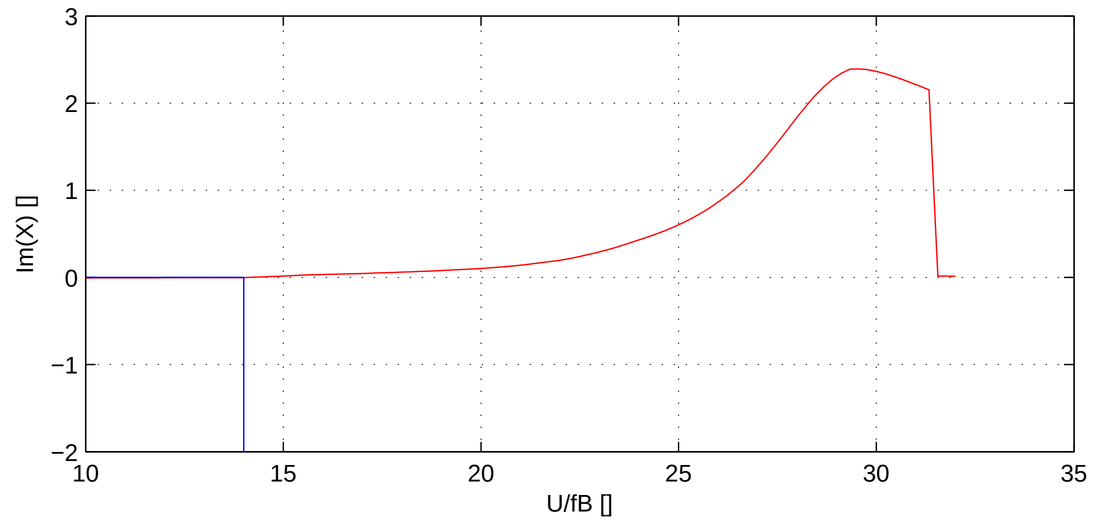


Figure J.38: Imaginary part of the solution to stability equantion

V_{Crit} = 14.0

f_{Crit} = 0.0919 Hz

U_{Crit} = 77.8 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.
[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.
[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.
[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.
[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix K

3D Flutter Tests

Flutter derivatives, Erection stage, Turbulent flow, Angle of incidence = −6 deg

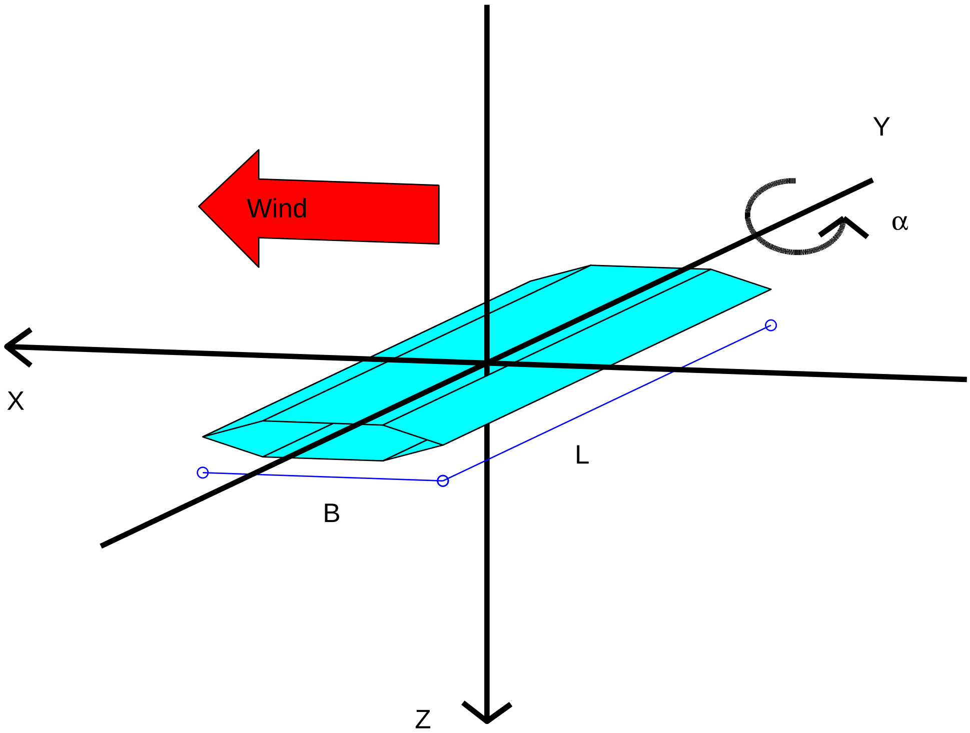
ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:21:52

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^{o}C	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1019.0

Table K.1: Project Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$
$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$
$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h	: Vertical displacement, displacement along z-axis, [m]
α	: Rotation around y-axis, nose up is positive, [rad]
p	: Horizontal displacement, displacement along the x-axis, [m]
m	: Mass per unit length, [kg/m]
I_y	: Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$	: Added mass in vertical direction, [kg/m]
$m_{a,x}$	: Added mass in horizontal direction, [kg/m]
$I_{a,y}$	: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G	: X-coordinate for centre of gravity, [m]
Z_G	: Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$	: Natural circular frequency for vertical motion, [/s]
ζ_h	: Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$	: Natural circular frequency for rotation around y axis, [/s]
ζ_α	: Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$	: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p	: Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$	: Force from rig per meter section, [N/m]
$M_{Y,external}$	: Moment from rig per meter section, [Nm/m]
$F_{X,external}$	: Force from rig per meter section, [N/m]

Formula K.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.633
Added mass in horizontal	$m_{a,x}$	kg/m	0.594
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.150
Horizontal centre of gravity	x_G	m	0.000
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.293
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.155
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.125

Table K.2: Mechanical Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = mg - m_{a,z}\ddot{h} - 2m\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + mz_G\ddot{p} + mx_G\ddot{h}) = -I_{a,y}\ddot{\alpha}mg - 2m\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\rho U^2 B C_z$$

$$M_{ad} = 1/2\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\rho U^2 B C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + KH_1^*\frac{\dot{h}}{U} + KH_2^*\frac{B\dot{\alpha}}{U} + KH_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + KA_1^*\frac{\dot{h}}{U} + KA_2^*\frac{B\dot{\alpha}}{U} + KA_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + KP_5^*\frac{\dot{h}}{U} + KP_2^*\frac{B\dot{\alpha}}{U} + KP_1^*\frac{\dot{p}}{U})$$

Formula K.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

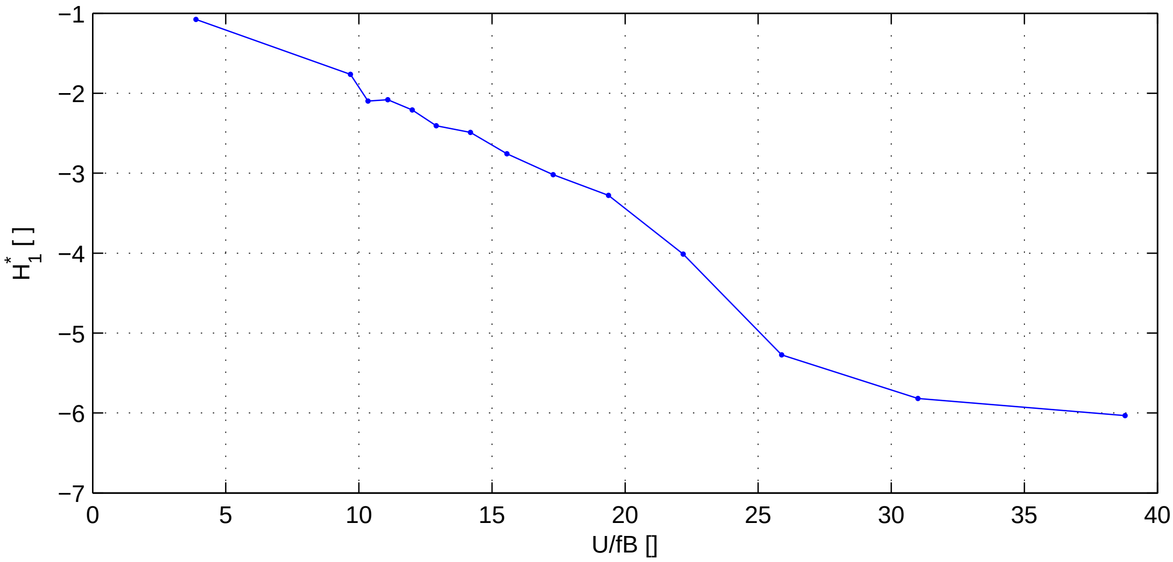


Figure K.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
11.72	25.13	4.00	1.62	3.88	−1.08
11.70	10.05	1.60	0.65	9.68	−1.76
11.74	9.45	1.50	0.61	10.34	−2.10
11.71	8.79	1.40	0.57	11.09	−2.08
11.77	8.16	1.30	0.52	12.00	−2.21
11.67	7.52	1.20	0.49	12.91	−2.41
11.77	6.90	1.10	0.44	14.19	−2.49
11.75	6.28	1.00	0.40	15.56	−2.76
11.77	5.66	0.90	0.36	17.30	−3.02
11.70	5.03	0.80	0.32	19.38	−3.28
11.71	4.39	0.70	0.28	22.19	−4.01
11.74	3.77	0.60	0.24	25.88	−5.27
11.70	3.14	0.50	0.20	31.00	−5.82
11.71	2.51	0.40	0.16	38.78	−6.03

Table K.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

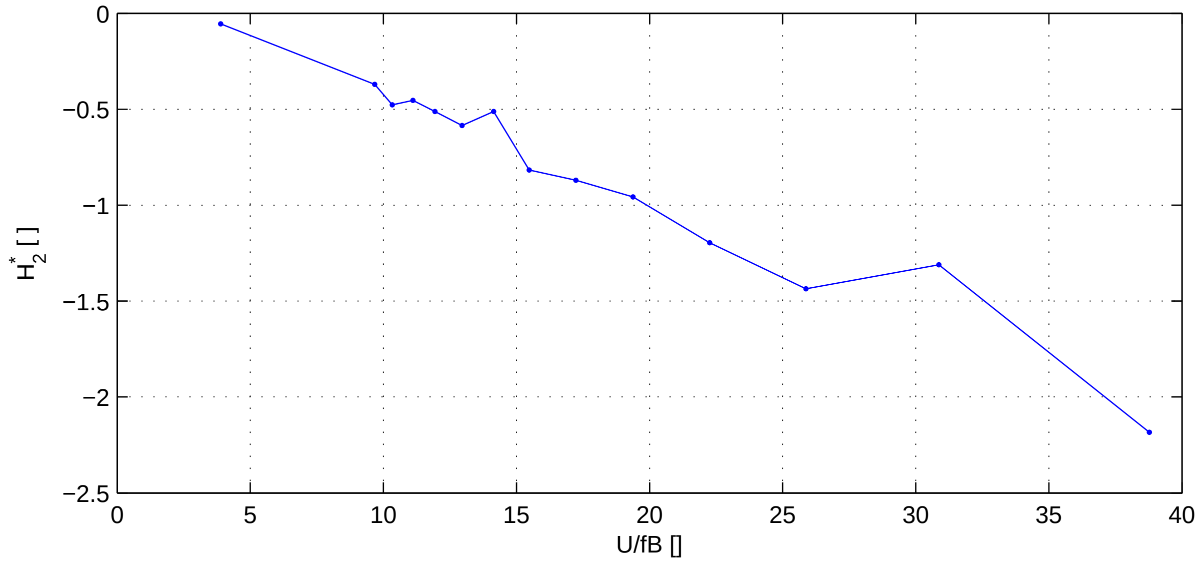


Figure K.2: H^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_2
11.74	25.13	4.00	1.62	3.89	−0.06
11.68	10.05	1.60	0.65	9.67	−0.37
11.73	9.45	1.50	0.61	10.33	−0.48
11.73	8.79	1.40	0.57	11.11	−0.45
11.71	8.16	1.30	0.53	11.94	−0.51
11.71	7.52	1.20	0.49	12.95	−0.58
11.73	6.90	1.10	0.44	14.14	−0.51
11.69	6.28	1.00	0.41	15.48	−0.82
11.72	5.66	0.90	0.36	17.23	−0.87
11.71	5.03	0.80	0.32	19.38	−0.96
11.75	4.39	0.70	0.28	22.26	−1.20
11.73	3.77	0.60	0.24	25.87	−1.44
11.65	3.14	0.50	0.20	30.87	−1.31
11.71	2.51	0.40	0.16	38.77	−2.18

Table K.4: H^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

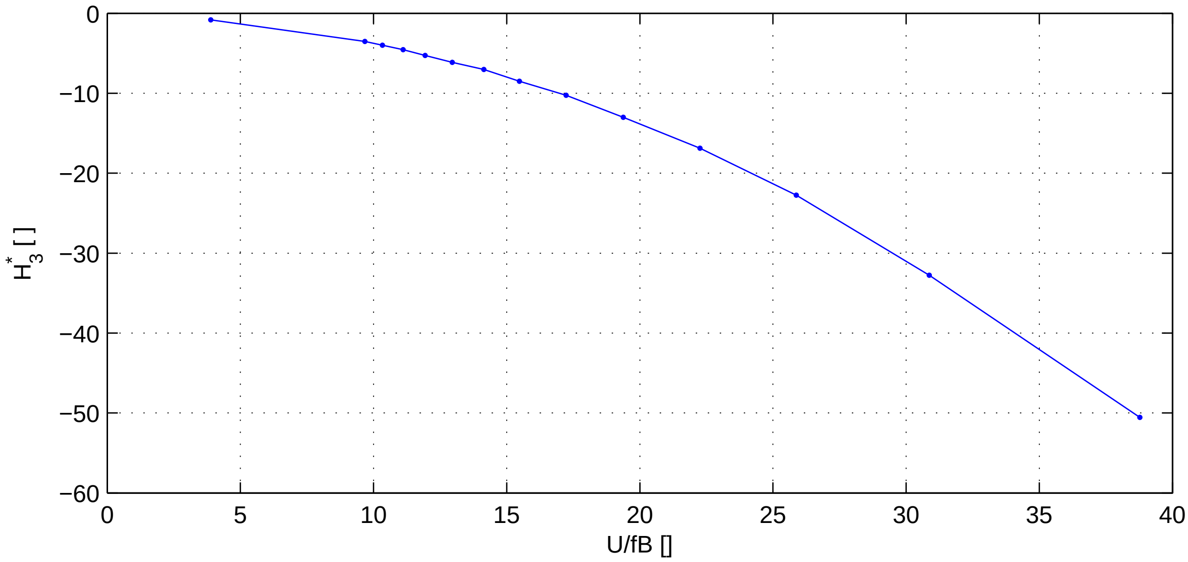


Figure K.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
11.74	25.13	4.00	1.62	3.89	−0.82
11.68	10.05	1.60	0.65	9.67	−3.53
11.73	9.45	1.50	0.61	10.33	−3.98
11.73	8.79	1.40	0.57	11.11	−4.56
11.71	8.16	1.30	0.53	11.94	−5.28
11.71	7.52	1.20	0.49	12.95	−6.12
11.73	6.90	1.10	0.44	14.14	−7.03
11.69	6.28	1.00	0.41	15.48	−8.50
11.72	5.66	0.90	0.36	17.23	−10.25
11.71	5.03	0.80	0.32	19.38	−13.02
11.75	4.39	0.70	0.28	22.26	−16.87
11.73	3.77	0.60	0.24	25.87	−22.75
11.65	3.14	0.50	0.20	30.87	−32.78
11.71	2.51	0.40	0.16	38.77	−50.56

Table K.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

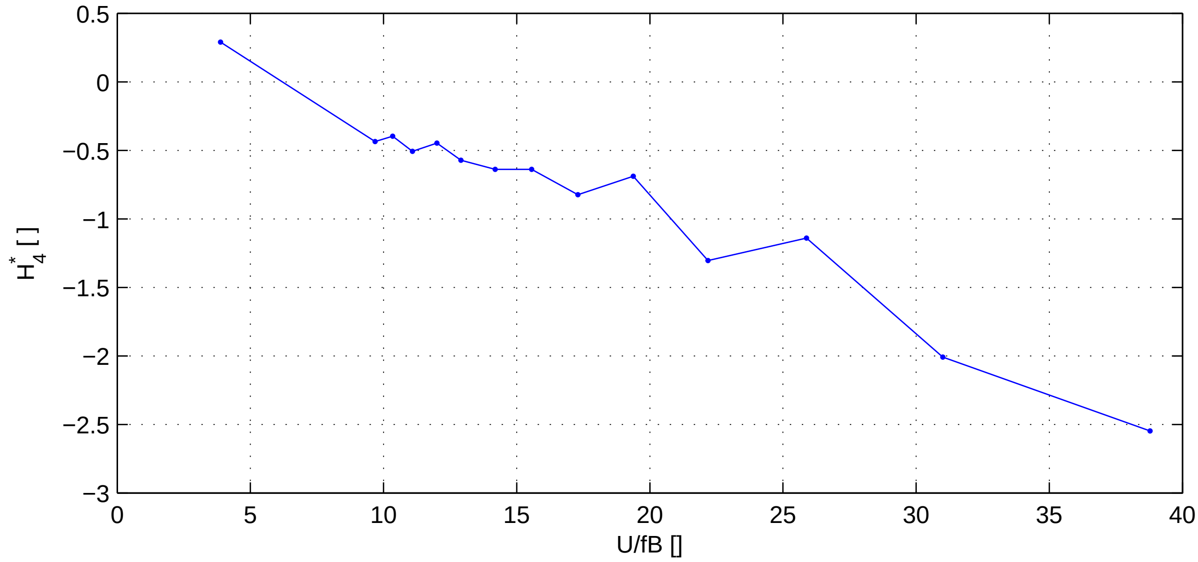


Figure K.4: H^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_4
11.72	25.13	4.00	1.62	3.88	0.29
11.70	10.05	1.60	0.65	9.68	−0.44
11.74	9.45	1.50	0.61	10.34	−0.40
11.71	8.79	1.40	0.57	11.09	−0.51
11.77	8.16	1.30	0.52	12.00	−0.45
11.67	7.52	1.20	0.49	12.91	−0.57
11.77	6.90	1.10	0.44	14.19	−0.64
11.75	6.28	1.00	0.40	15.56	−0.64
11.77	5.66	0.90	0.36	17.30	−0.82
11.70	5.03	0.80	0.32	19.38	−0.69
11.71	4.39	0.70	0.28	22.19	−1.31
11.74	3.77	0.60	0.24	25.88	−1.14
11.70	3.14	0.50	0.20	31.00	−2.01
11.71	2.51	0.40	0.16	38.78	−2.55

Table K.6: H^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

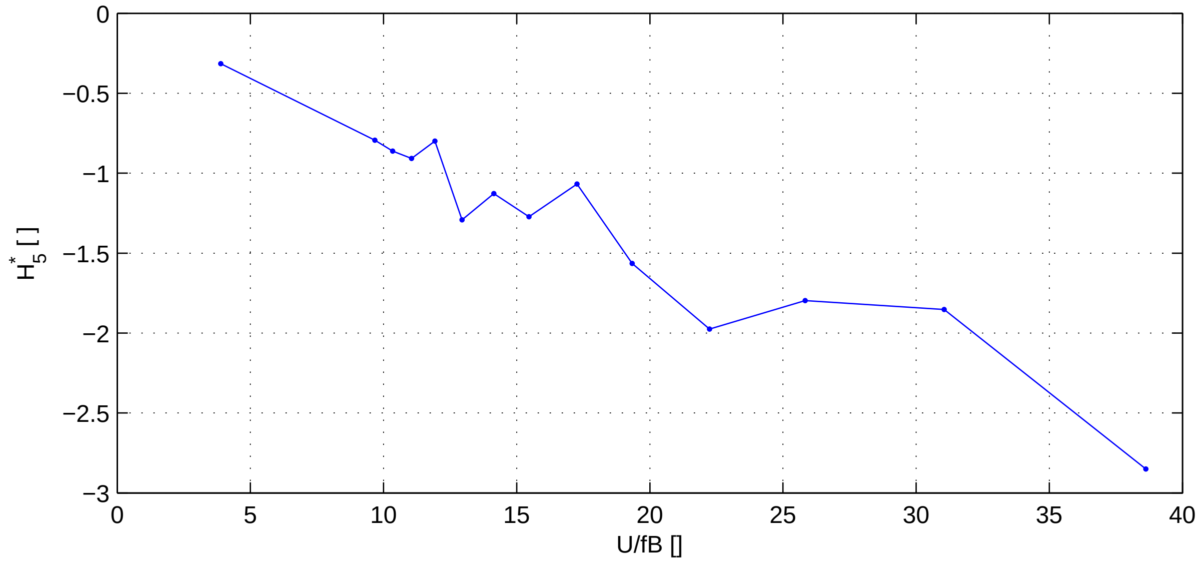


Figure K.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
11.74	25.13	4.00	1.62	3.89	−0.32
11.69	10.05	1.60	0.65	9.68	−0.79
11.74	9.45	1.50	0.61	10.34	−0.86
11.67	8.79	1.40	0.57	11.05	−0.91
11.70	8.16	1.30	0.53	11.93	−0.80
11.71	7.52	1.20	0.49	12.95	−1.29
11.74	6.90	1.10	0.44	14.14	−1.13
11.67	6.28	1.00	0.41	15.46	−1.27
11.74	5.66	0.90	0.36	17.27	−1.07
11.68	5.03	0.80	0.32	19.34	−1.56
11.74	4.39	0.70	0.28	22.24	−1.97
11.71	3.77	0.60	0.24	25.83	−1.80
11.72	3.14	0.50	0.20	31.05	−1.85
11.67	2.51	0.40	0.16	38.63	−2.85

Table K.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

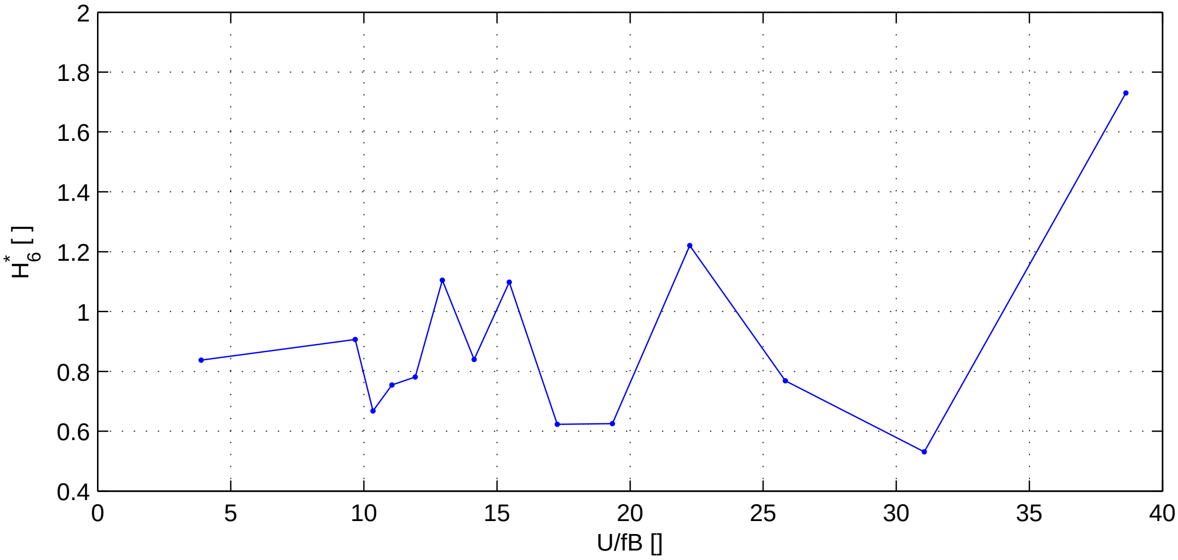


Figure K.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
11.74	25.13	4.00	1.62	3.89	0.84
11.69	10.05	1.60	0.65	9.68	0.91
11.74	9.45	1.50	0.61	10.34	0.67
11.67	8.79	1.40	0.57	11.05	0.75
11.70	8.16	1.30	0.53	11.93	0.78
11.71	7.52	1.20	0.49	12.95	1.10
11.74	6.90	1.10	0.44	14.14	0.84
11.67	6.28	1.00	0.41	15.46	1.10
11.74	5.66	0.90	0.36	17.27	0.62
11.68	5.03	0.80	0.32	19.34	0.63
11.74	4.39	0.70	0.28	22.24	1.22
11.71	3.77	0.60	0.24	25.83	0.77
11.72	3.14	0.50	0.20	31.05	0.53
11.67	2.51	0.40	0.16	38.63	1.73

Table K.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

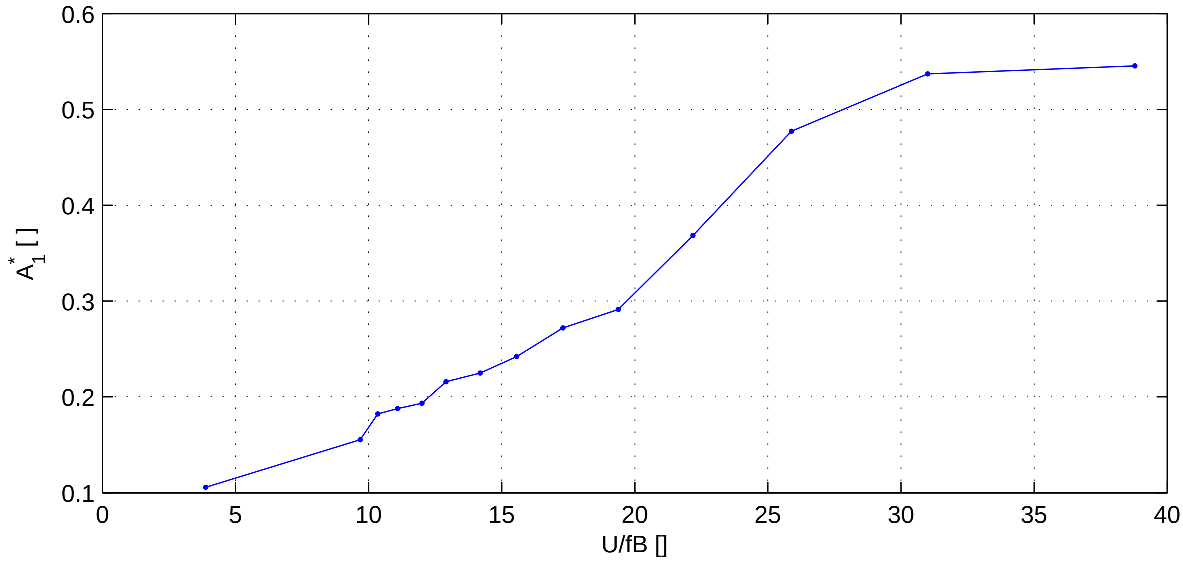


Figure K.7: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_1^*
11.72	25.13	4.00	1.62	3.88	0.11
11.70	10.05	1.60	0.65	9.68	0.16
11.74	9.45	1.50	0.61	10.34	0.18
11.71	8.79	1.40	0.57	11.09	0.19
11.77	8.16	1.30	0.52	12.00	0.19
11.67	7.52	1.20	0.49	12.91	0.22
11.77	6.90	1.10	0.44	14.19	0.22
11.75	6.28	1.00	0.40	15.56	0.24
11.77	5.66	0.90	0.36	17.30	0.27
11.70	5.03	0.80	0.32	19.38	0.29
11.71	4.39	0.70	0.28	22.19	0.37
11.74	3.77	0.60	0.24	25.88	0.48
11.70	3.14	0.50	0.20	31.00	0.54
11.71	2.51	0.40	0.16	38.78	0.55

Table K.9: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

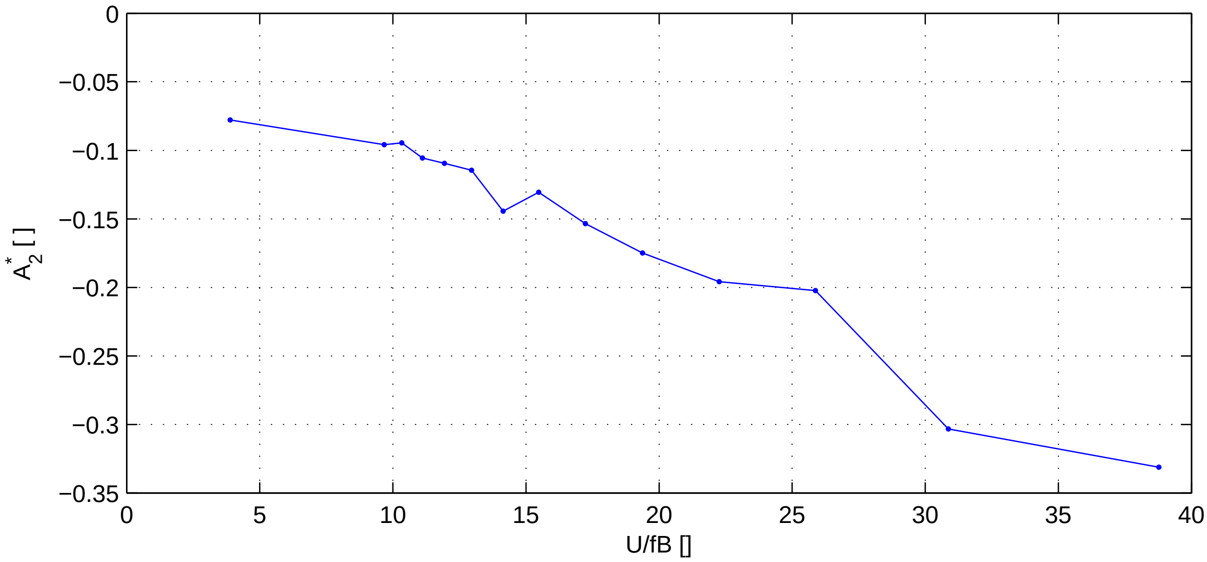


Figure K.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
11.74	25.13	4.00	1.62	3.89	−0.08
11.68	10.05	1.60	0.65	9.67	−0.10
11.73	9.45	1.50	0.61	10.33	−0.09
11.73	8.79	1.40	0.57	11.11	−0.11
11.71	8.16	1.30	0.53	11.94	−0.11
11.71	7.52	1.20	0.49	12.95	−0.11
11.73	6.90	1.10	0.44	14.14	−0.14
11.69	6.28	1.00	0.41	15.48	−0.13
11.72	5.66	0.90	0.36	17.23	−0.15
11.71	5.03	0.80	0.32	19.38	−0.17
11.75	4.39	0.70	0.28	22.26	−0.20
11.73	3.77	0.60	0.24	25.87	−0.20
11.65	3.14	0.50	0.20	30.87	−0.30
11.71	2.51	0.40	0.16	38.77	−0.33

Table K.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

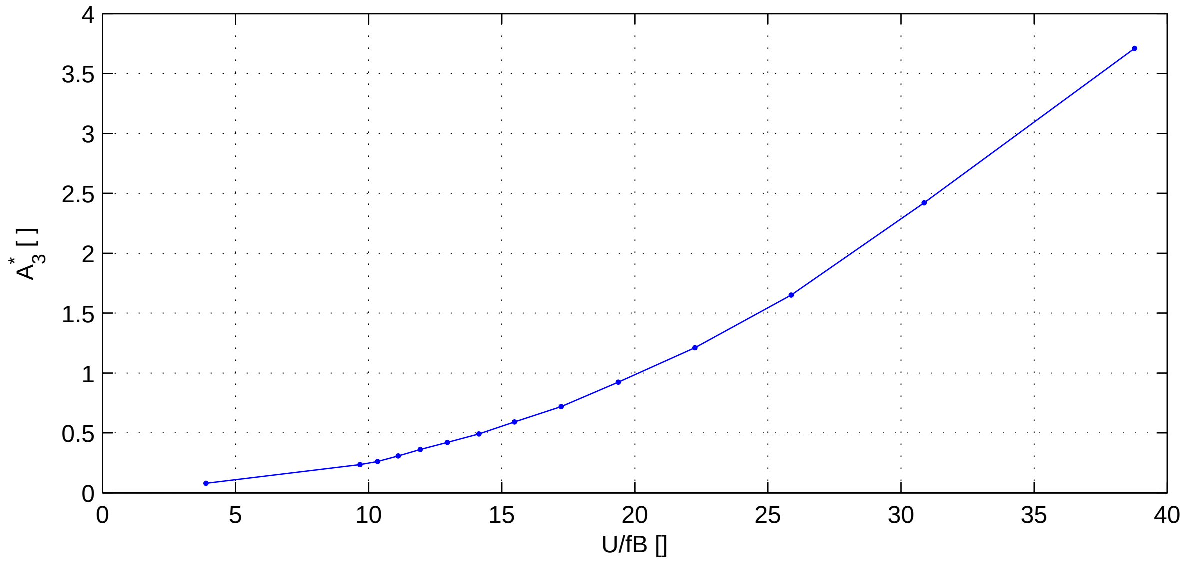


Figure K.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
11.74	25.13	4.00	1.62	3.89	0.08
11.68	10.05	1.60	0.65	9.67	0.23
11.73	9.45	1.50	0.61	10.33	0.26
11.73	8.79	1.40	0.57	11.11	0.31
11.71	8.16	1.30	0.53	11.94	0.36
11.71	7.52	1.20	0.49	12.95	0.42
11.73	6.90	1.10	0.44	14.14	0.49
11.69	6.28	1.00	0.41	15.48	0.59
11.72	5.66	0.90	0.36	17.23	0.72
11.71	5.03	0.80	0.32	19.38	0.92
11.75	4.39	0.70	0.28	22.26	1.21
11.73	3.77	0.60	0.24	25.87	1.65
11.65	3.14	0.50	0.20	30.87	2.42
11.71	2.51	0.40	0.16	38.77	3.71

Table K.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

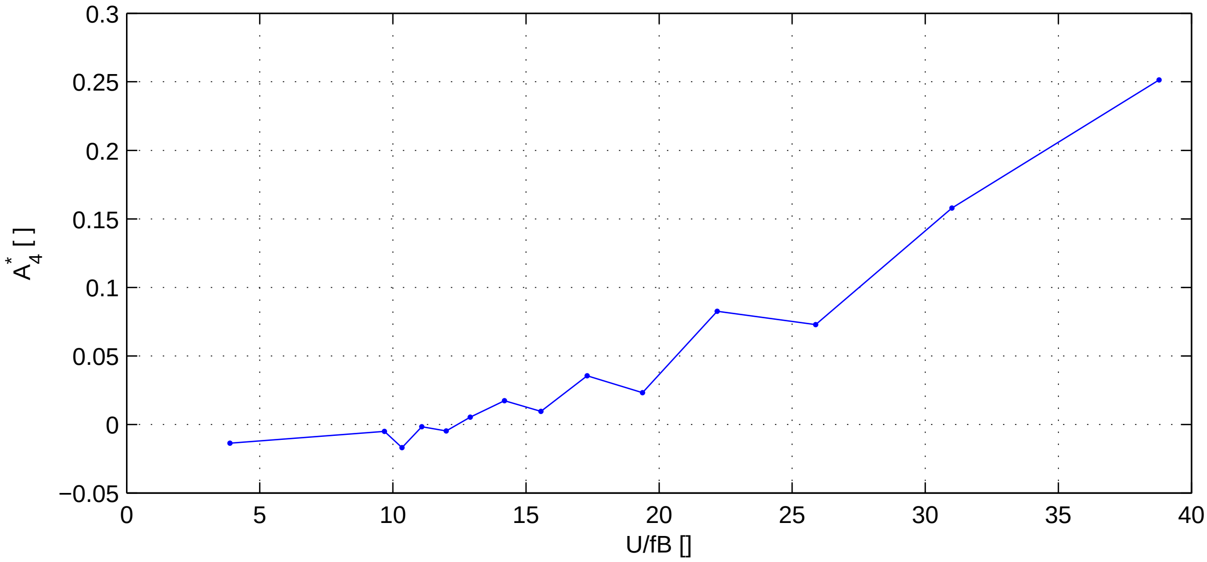


Figure K.10: A^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_4
11.72	25.13	4.00	1.62	3.88	−0.01
11.70	10.05	1.60	0.65	9.68	−0.01
11.74	9.45	1.50	0.61	10.34	−0.02
11.71	8.79	1.40	0.57	11.09	−0.00
11.77	8.16	1.30	0.52	12.00	−0.00
11.67	7.52	1.20	0.49	12.91	0.01
11.77	6.90	1.10	0.44	14.19	0.02
11.75	6.28	1.00	0.40	15.56	0.01
11.77	5.66	0.90	0.36	17.30	0.04
11.70	5.03	0.80	0.32	19.38	0.02
11.71	4.39	0.70	0.28	22.19	0.08
11.74	3.77	0.60	0.24	25.88	0.07
11.70	3.14	0.50	0.20	31.00	0.16
11.71	2.51	0.40	0.16	38.78	0.25

Table K.12: A^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

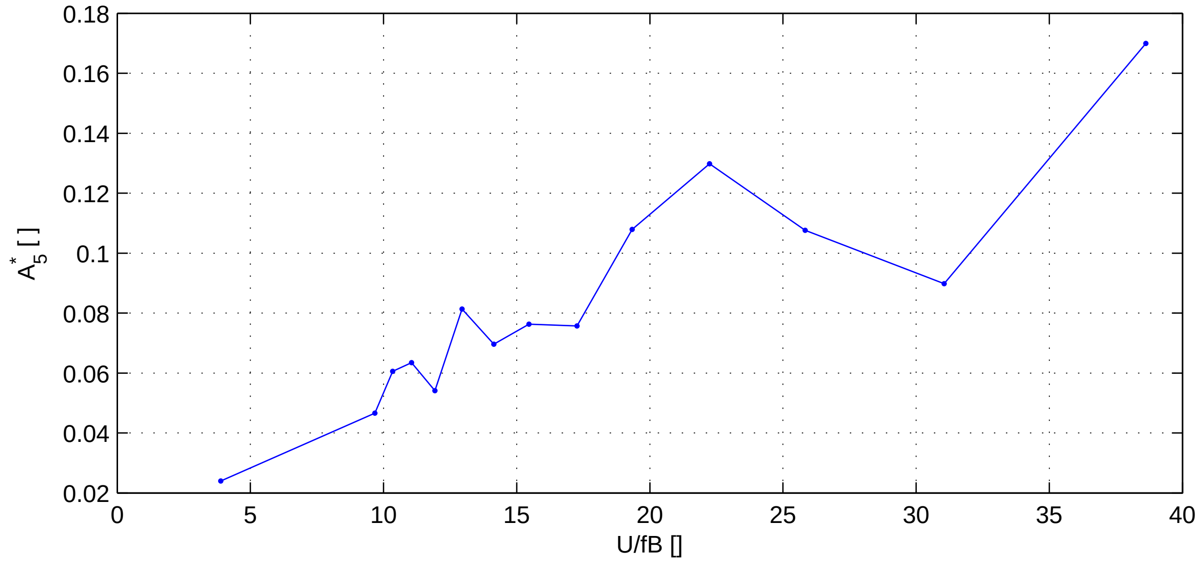


Figure K.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
11.74	25.13	4.00	1.62	3.89	0.02
11.69	10.05	1.60	0.65	9.68	0.05
11.74	9.45	1.50	0.61	10.34	0.06
11.67	8.79	1.40	0.57	11.05	0.06
11.70	8.16	1.30	0.53	11.93	0.05
11.71	7.52	1.20	0.49	12.95	0.08
11.74	6.90	1.10	0.44	14.14	0.07
11.67	6.28	1.00	0.41	15.46	0.08
11.74	5.66	0.90	0.36	17.27	0.08
11.68	5.03	0.80	0.32	19.34	0.11
11.74	4.39	0.70	0.28	22.24	0.13
11.71	3.77	0.60	0.24	25.83	0.11
11.72	3.14	0.50	0.20	31.05	0.09
11.67	2.51	0.40	0.16	38.63	0.17

Table K.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

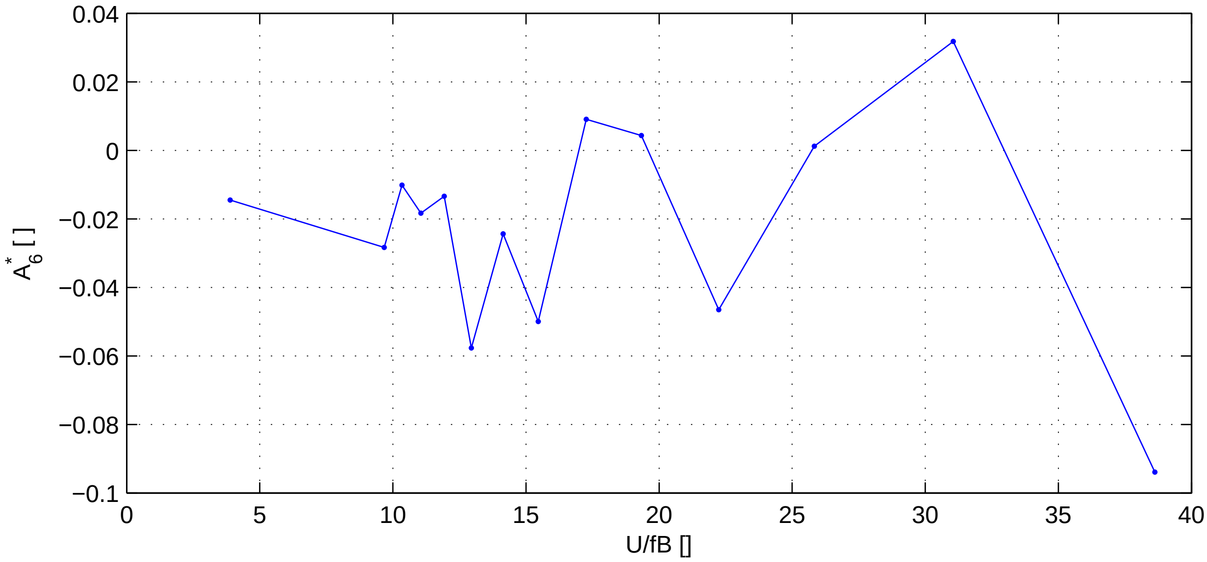


Figure K.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
11.74	25.13	4.00	1.62	3.89	−0.01
11.69	10.05	1.60	0.65	9.68	−0.03
11.74	9.45	1.50	0.61	10.34	−0.01
11.67	8.79	1.40	0.57	11.05	−0.02
11.70	8.16	1.30	0.53	11.93	−0.01
11.71	7.52	1.20	0.49	12.95	−0.06
11.74	6.90	1.10	0.44	14.14	−0.02
11.67	6.28	1.00	0.41	15.46	−0.05
11.74	5.66	0.90	0.36	17.27	0.01
11.68	5.03	0.80	0.32	19.34	0.00
11.74	4.39	0.70	0.28	22.24	−0.05
11.71	3.77	0.60	0.24	25.83	0.00
11.72	3.14	0.50	0.20	31.05	0.03
11.67	2.51	0.40	0.16	38.63	−0.09

Table K.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

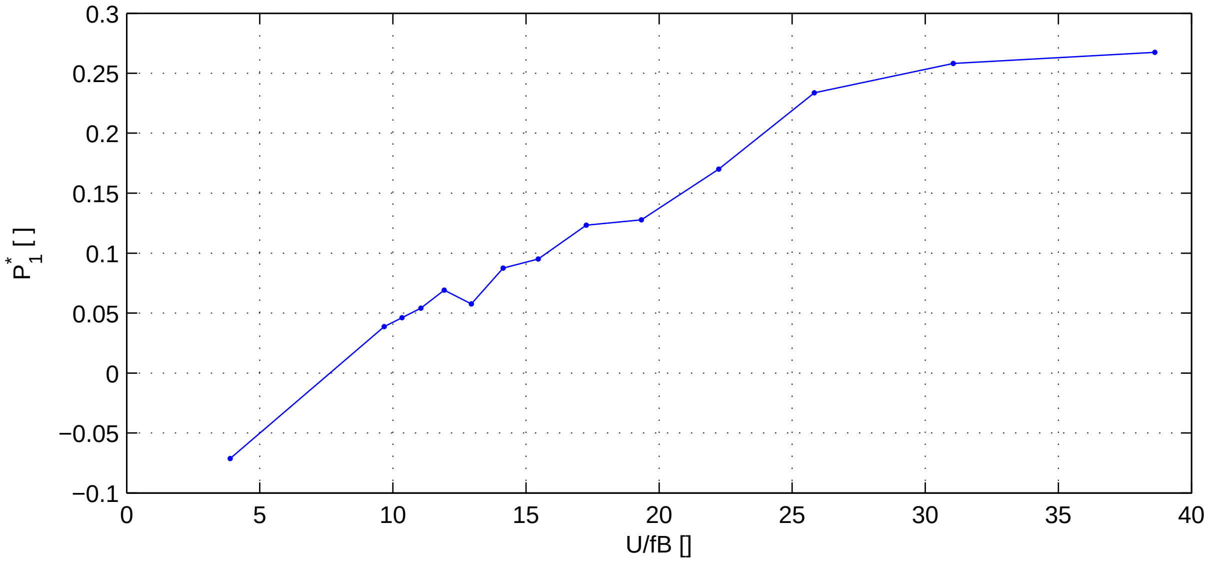


Figure K.13: P^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_1
11.74	25.13	4.00	1.62	3.89	−0.07
11.69	10.05	1.60	0.65	9.68	0.04
11.74	9.45	1.50	0.61	10.34	0.05
11.67	8.79	1.40	0.57	11.05	0.05
11.70	8.16	1.30	0.53	11.93	0.07
11.71	7.52	1.20	0.49	12.95	0.06
11.74	6.90	1.10	0.44	14.14	0.09
11.67	6.28	1.00	0.41	15.46	0.10
11.74	5.66	0.90	0.36	17.27	0.12
11.68	5.03	0.80	0.32	19.34	0.13
11.74	4.39	0.70	0.28	22.24	0.17
11.71	3.77	0.60	0.24	25.83	0.23
11.72	3.14	0.50	0.20	31.05	0.26
11.67	2.51	0.40	0.16	38.63	0.27

Table K.15: P^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

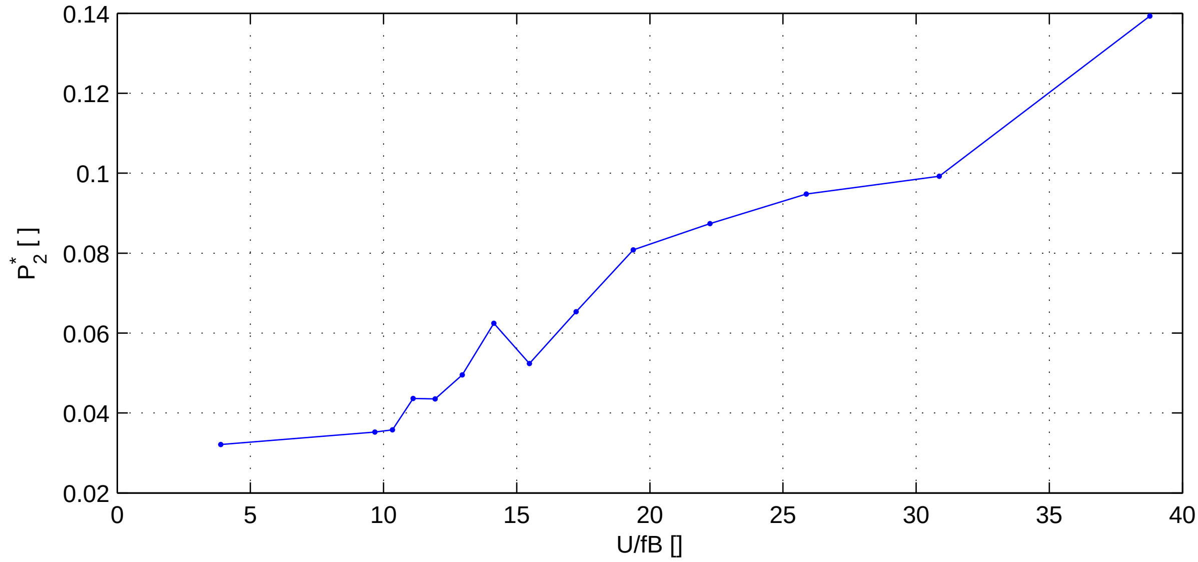


Figure K.14: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_2
11.74	25.13	4.00	1.62	3.89	0.03
11.68	10.05	1.60	0.65	9.67	0.04
11.73	9.45	1.50	0.61	10.33	0.04
11.73	8.79	1.40	0.57	11.11	0.04
11.71	8.16	1.30	0.53	11.94	0.04
11.71	7.52	1.20	0.49	12.95	0.05
11.73	6.90	1.10	0.44	14.14	0.06
11.69	6.28	1.00	0.41	15.48	0.05
11.72	5.66	0.90	0.36	17.23	0.07
11.71	5.03	0.80	0.32	19.38	0.08
11.75	4.39	0.70	0.28	22.26	0.09
11.73	3.77	0.60	0.24	25.87	0.09
11.65	3.14	0.50	0.20	30.87	0.10
11.71	2.51	0.40	0.16	38.77	0.14

Table K.16: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

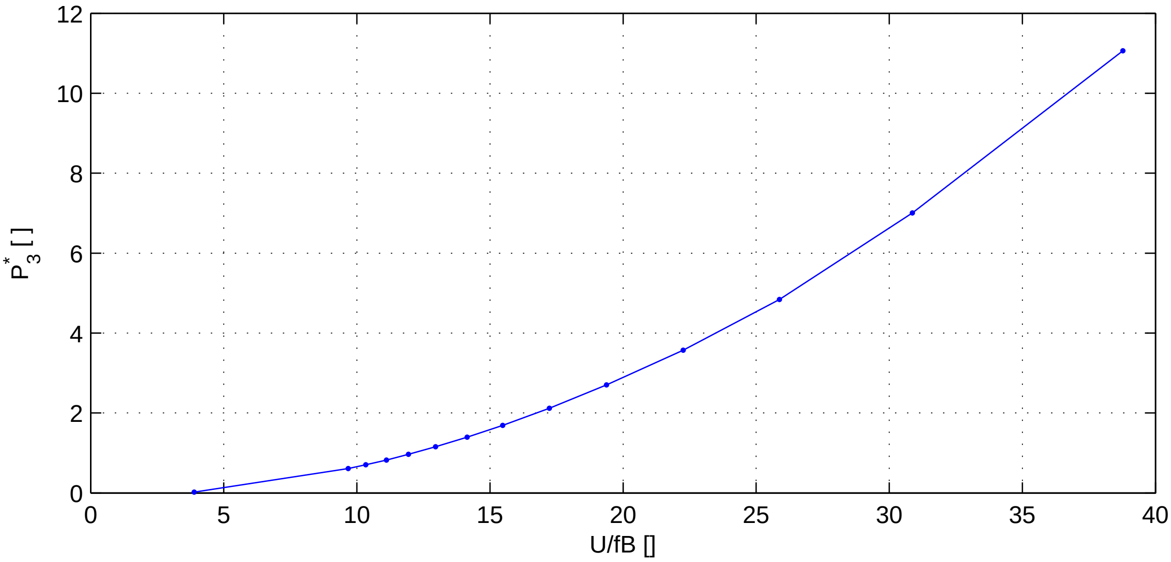


Figure K.15: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_3
11.74	25.13	4.00	1.62	3.89	0.02
11.68	10.05	1.60	0.65	9.67	0.61
11.73	9.45	1.50	0.61	10.33	0.71
11.73	8.79	1.40	0.57	11.11	0.82
11.71	8.16	1.30	0.53	11.94	0.97
11.71	7.52	1.20	0.49	12.95	1.15
11.73	6.90	1.10	0.44	14.14	1.39
11.69	6.28	1.00	0.41	15.48	1.69
11.72	5.66	0.90	0.36	17.23	2.12
11.71	5.03	0.80	0.32	19.38	2.70
11.75	4.39	0.70	0.28	22.26	3.57
11.73	3.77	0.60	0.24	25.87	4.84
11.65	3.14	0.50	0.20	30.87	7.00
11.71	2.51	0.40	0.16	38.77	11.06

Table K.17: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

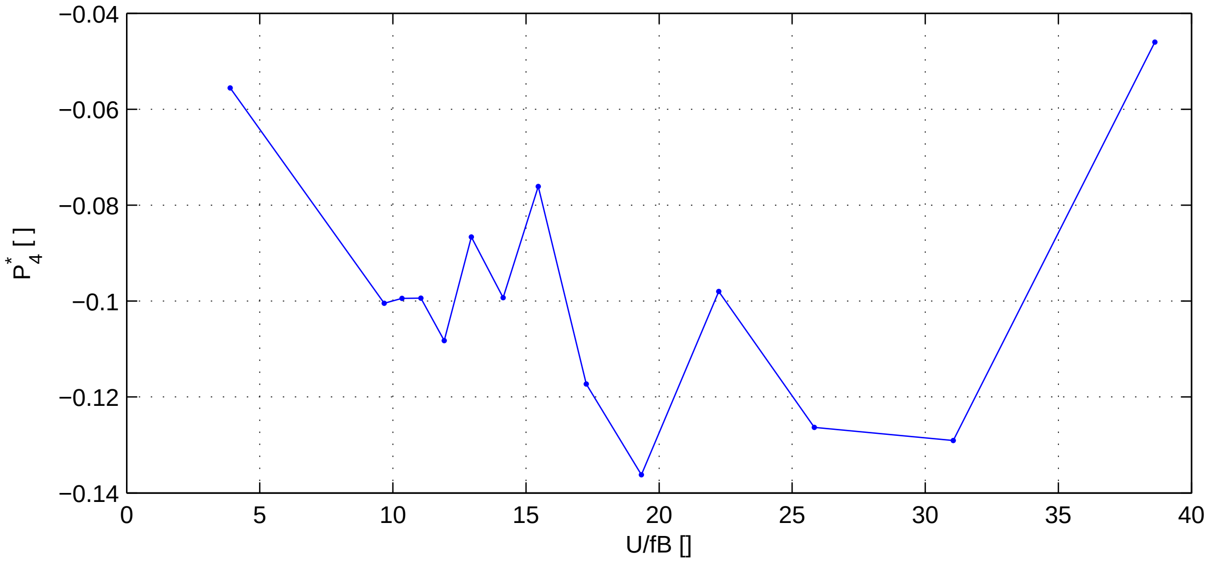


Figure K.16: P^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_4
11.74	25.13	4.00	1.62	3.89	−0.06
11.69	10.05	1.60	0.65	9.68	−0.10
11.74	9.45	1.50	0.61	10.34	−0.10
11.67	8.79	1.40	0.57	11.05	−0.10
11.70	8.16	1.30	0.53	11.93	−0.11
11.71	7.52	1.20	0.49	12.95	−0.09
11.74	6.90	1.10	0.44	14.14	−0.10
11.67	6.28	1.00	0.41	15.46	−0.08
11.74	5.66	0.90	0.36	17.27	−0.12
11.68	5.03	0.80	0.32	19.34	−0.14
11.74	4.39	0.70	0.28	22.24	−0.10
11.71	3.77	0.60	0.24	25.83	−0.13
11.72	3.14	0.50	0.20	31.05	−0.13
11.67	2.51	0.40	0.16	38.63	−0.05

Table K.18: P^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

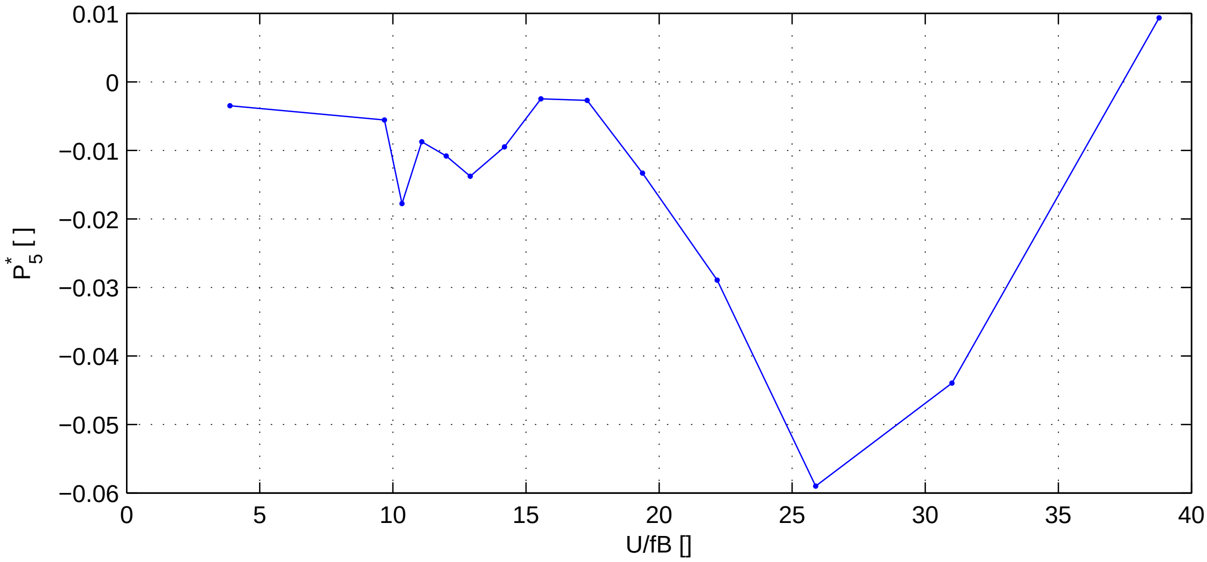


Figure K.17: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_5^*
11.72	25.13	4.00	1.62	3.88	−0.00
11.70	10.05	1.60	0.65	9.68	−0.01
11.74	9.45	1.50	0.61	10.34	−0.02
11.71	8.79	1.40	0.57	11.09	−0.01
11.77	8.16	1.30	0.52	12.00	−0.01
11.67	7.52	1.20	0.49	12.91	−0.01
11.77	6.90	1.10	0.44	14.19	−0.01
11.75	6.28	1.00	0.40	15.56	−0.00
11.77	5.66	0.90	0.36	17.30	−0.00
11.70	5.03	0.80	0.32	19.38	−0.01
11.71	4.39	0.70	0.28	22.19	−0.03
11.74	3.77	0.60	0.24	25.88	−0.06
11.70	3.14	0.50	0.20	31.00	−0.04
11.71	2.51	0.40	0.16	38.78	0.01

Table K.19: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

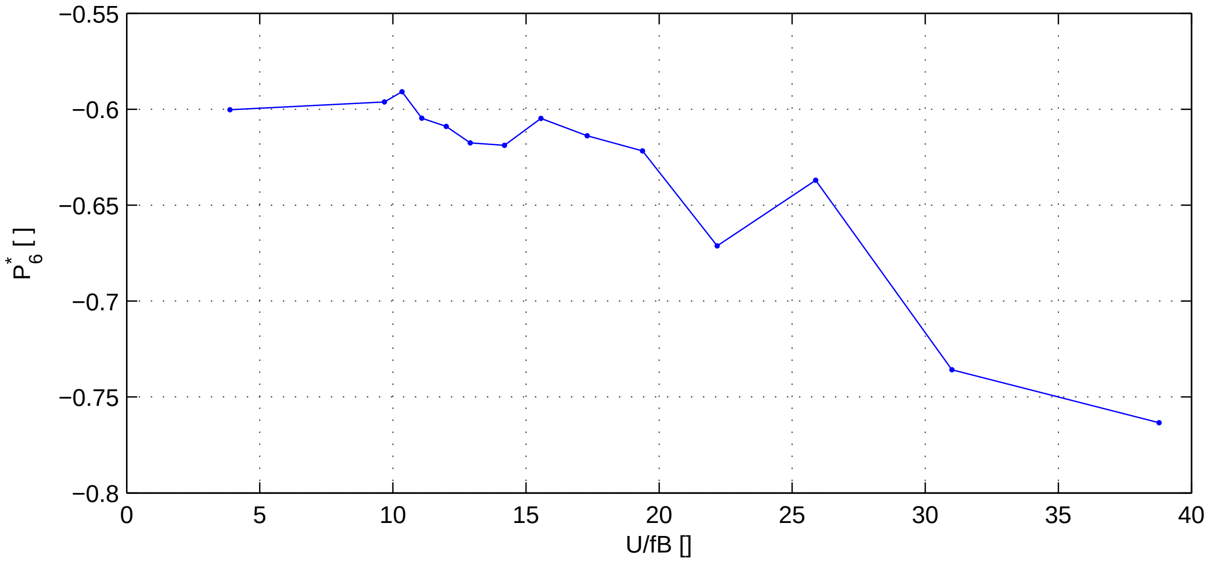


Figure K.18: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_6^*
11.72	25.13	4.00	1.62	3.88	−0.60
11.70	10.05	1.60	0.65	9.68	−0.60
11.74	9.45	1.50	0.61	10.34	−0.59
11.71	8.79	1.40	0.57	11.09	−0.60
11.77	8.16	1.30	0.52	12.00	−0.61
11.67	7.52	1.20	0.49	12.91	−0.62
11.77	6.90	1.10	0.44	14.19	−0.62
11.75	6.28	1.00	0.40	15.56	−0.60
11.77	5.66	0.90	0.36	17.30	−0.61
11.70	5.03	0.80	0.32	19.38	−0.62
11.71	4.39	0.70	0.28	22.19	−0.67
11.74	3.77	0.60	0.24	25.88	−0.64
11.70	3.14	0.50	0.20	31.00	−0.74
11.71	2.51	0.40	0.16	38.78	−0.76

Table K.20: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\left(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\,\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\left(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\,\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\left(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\,\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

Formula K.3: Equation of Motion (Stretto di Messina. Ref. [5].)

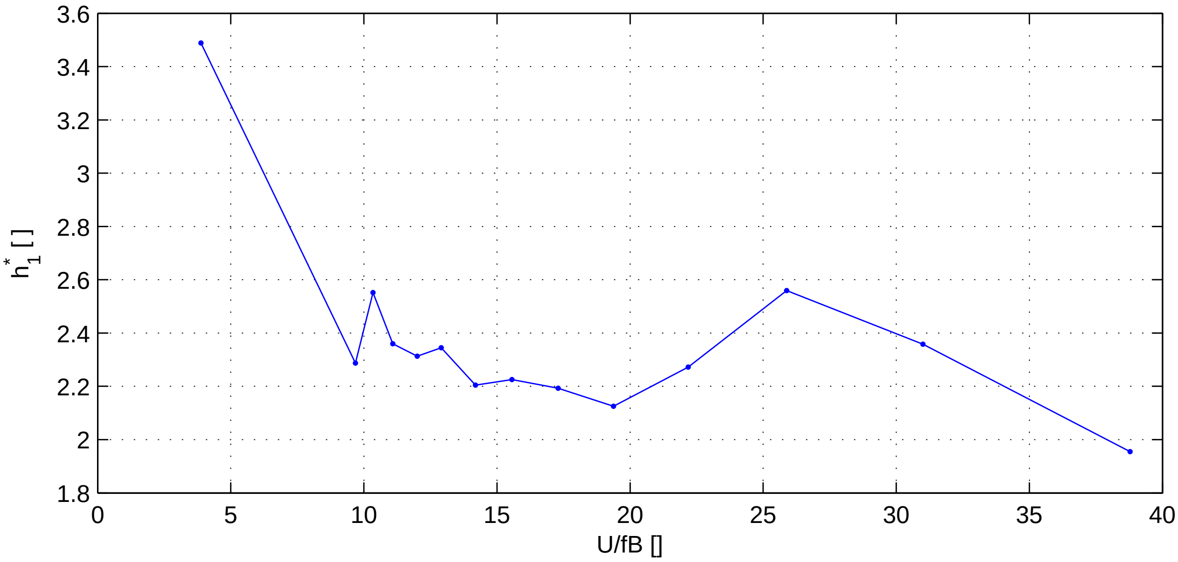


Figure K.19: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_1^*
11.72	25.13	4.00	1.62	3.88	3.49
11.70	10.05	1.60	0.65	9.68	2.29
11.74	9.45	1.50	0.61	10.34	2.55
11.71	8.79	1.40	0.57	11.09	2.36
11.77	8.16	1.30	0.52	12.00	2.31
11.67	7.52	1.20	0.49	12.91	2.34
11.77	6.90	1.10	0.44	14.19	2.20
11.75	6.28	1.00	0.40	15.56	2.23
11.77	5.66	0.90	0.36	17.30	2.19
11.70	5.03	0.80	0.32	19.38	2.12
11.71	4.39	0.70	0.28	22.19	2.27
11.74	3.77	0.60	0.24	25.88	2.56
11.70	3.14	0.50	0.20	31.00	2.36
11.71	2.51	0.40	0.16	38.78	1.95

Table K.21: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

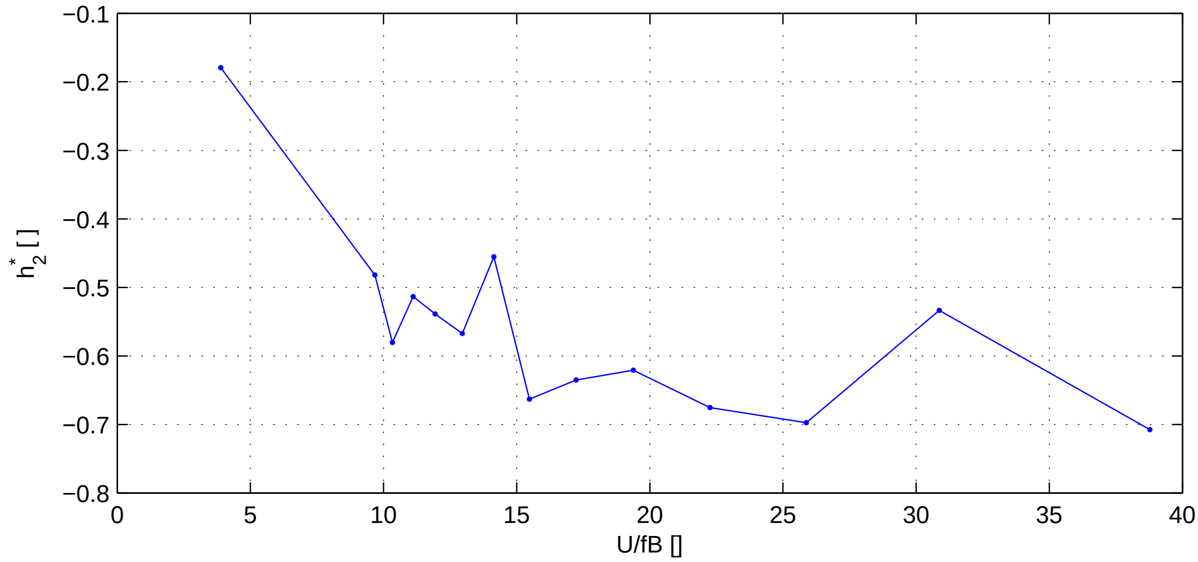


Figure K.20: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_2^*
11.74	25.13	4.00	1.62	3.89	−0.18
11.68	10.05	1.60	0.65	9.67	−0.48
11.73	9.45	1.50	0.61	10.33	−0.58
11.73	8.79	1.40	0.57	11.11	−0.51
11.71	8.16	1.30	0.53	11.94	−0.54
11.71	7.52	1.20	0.49	12.95	−0.57
11.73	6.90	1.10	0.44	14.14	−0.46
11.69	6.28	1.00	0.41	15.48	−0.66
11.72	5.66	0.90	0.36	17.23	−0.64
11.71	5.03	0.80	0.32	19.38	−0.62
11.75	4.39	0.70	0.28	22.26	−0.68
11.73	3.77	0.60	0.24	25.87	−0.70
11.65	3.14	0.50	0.20	30.87	−0.53
11.71	2.51	0.40	0.16	38.77	−0.71

Table K.22: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

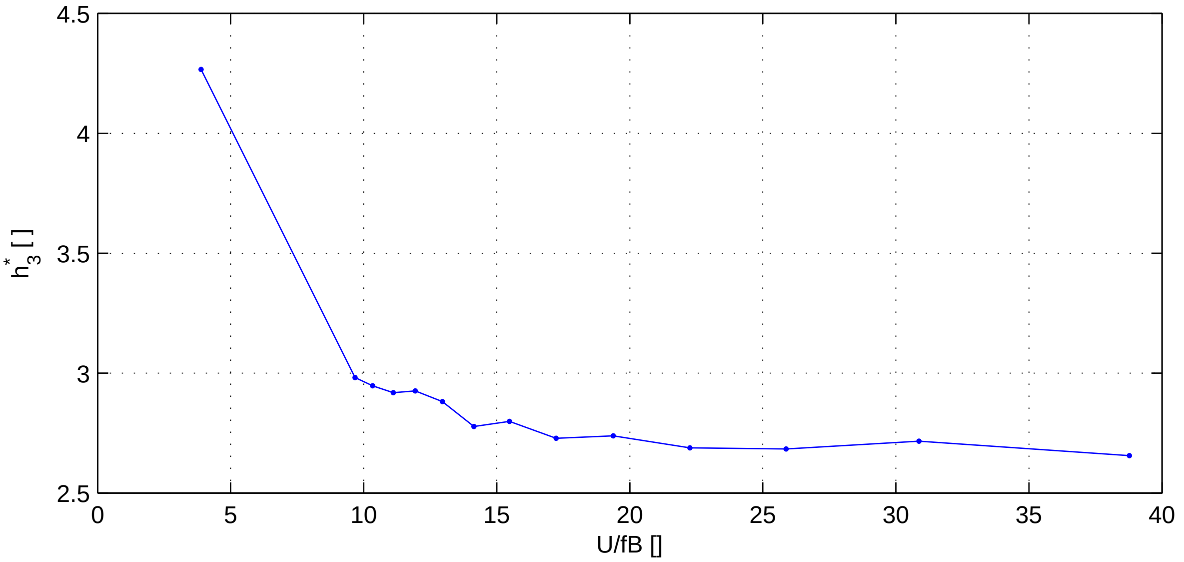


Figure K.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
11.74	25.13	4.00	1.62	3.89	4.27
11.68	10.05	1.60	0.65	9.67	2.98
11.73	9.45	1.50	0.61	10.33	2.95
11.73	8.79	1.40	0.57	11.11	2.92
11.71	8.16	1.30	0.53	11.94	2.93
11.71	7.52	1.20	0.49	12.95	2.88
11.73	6.90	1.10	0.44	14.14	2.78
11.69	6.28	1.00	0.41	15.48	2.80
11.72	5.66	0.90	0.36	17.23	2.73
11.71	5.03	0.80	0.32	19.38	2.74
11.75	4.39	0.70	0.28	22.26	2.69
11.73	3.77	0.60	0.24	25.87	2.68
11.65	3.14	0.50	0.20	30.87	2.72
11.71	2.51	0.40	0.16	38.77	2.66

Table K.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

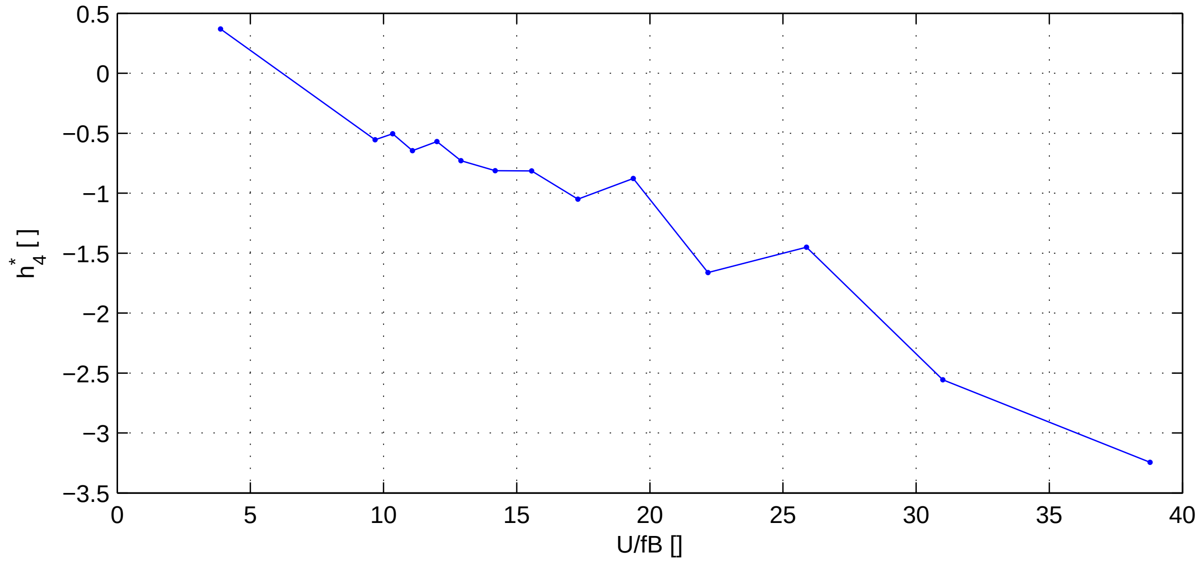


Figure K.22: h^*_4 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_4
11.72	25.13	4.00	1.62	3.88	0.37
11.70	10.05	1.60	0.65	9.68	−0.55
11.74	9.45	1.50	0.61	10.34	−0.50
11.71	8.79	1.40	0.57	11.09	−0.64
11.77	8.16	1.30	0.52	12.00	−0.57
11.67	7.52	1.20	0.49	12.91	−0.73
11.77	6.90	1.10	0.44	14.19	−0.81
11.75	6.28	1.00	0.40	15.56	−0.81
11.77	5.66	0.90	0.36	17.30	−1.05
11.70	5.03	0.80	0.32	19.38	−0.88
11.71	4.39	0.70	0.28	22.19	−1.66
11.74	3.77	0.60	0.24	25.88	−1.45
11.70	3.14	0.50	0.20	31.00	−2.56
11.71	2.51	0.40	0.16	38.78	−3.24

Table K.24: h^*_4 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

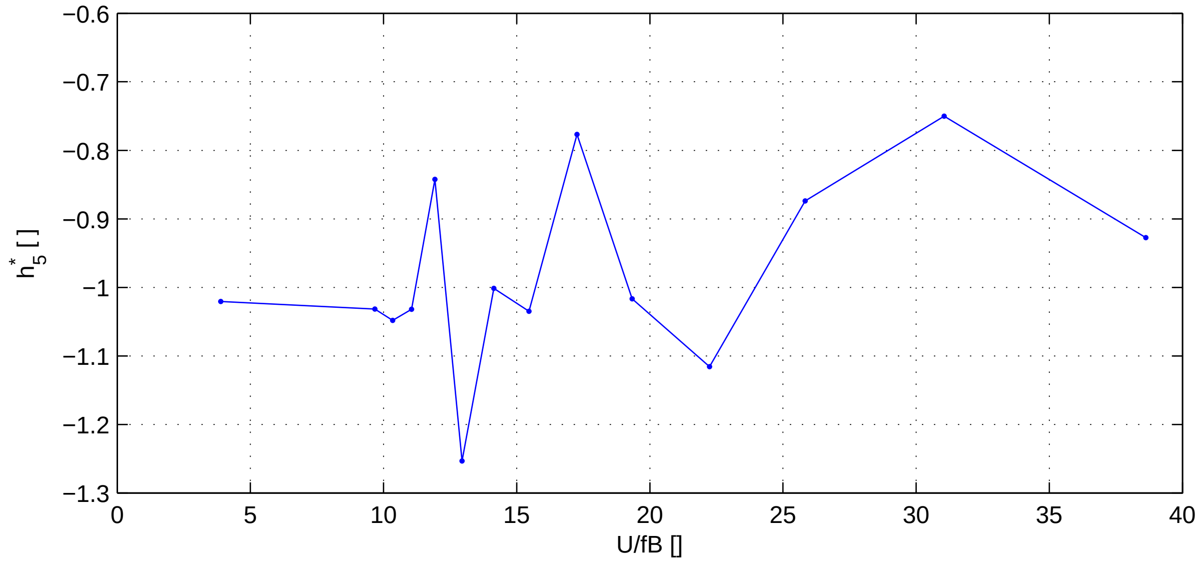


Figure K.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
11.74	25.13	4.00	1.62	3.89	−1.02
11.69	10.05	1.60	0.65	9.68	−1.03
11.74	9.45	1.50	0.61	10.34	−1.05
11.67	8.79	1.40	0.57	11.05	−1.03
11.70	8.16	1.30	0.53	11.93	−0.84
11.71	7.52	1.20	0.49	12.95	−1.25
11.74	6.90	1.10	0.44	14.14	−1.00
11.67	6.28	1.00	0.41	15.46	−1.03
11.74	5.66	0.90	0.36	17.27	−0.78
11.68	5.03	0.80	0.32	19.34	−1.02
11.74	4.39	0.70	0.28	22.24	−1.12
11.71	3.77	0.60	0.24	25.83	−0.87
11.72	3.14	0.50	0.20	31.05	−0.75
11.67	2.51	0.40	0.16	38.63	−0.93

Table K.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

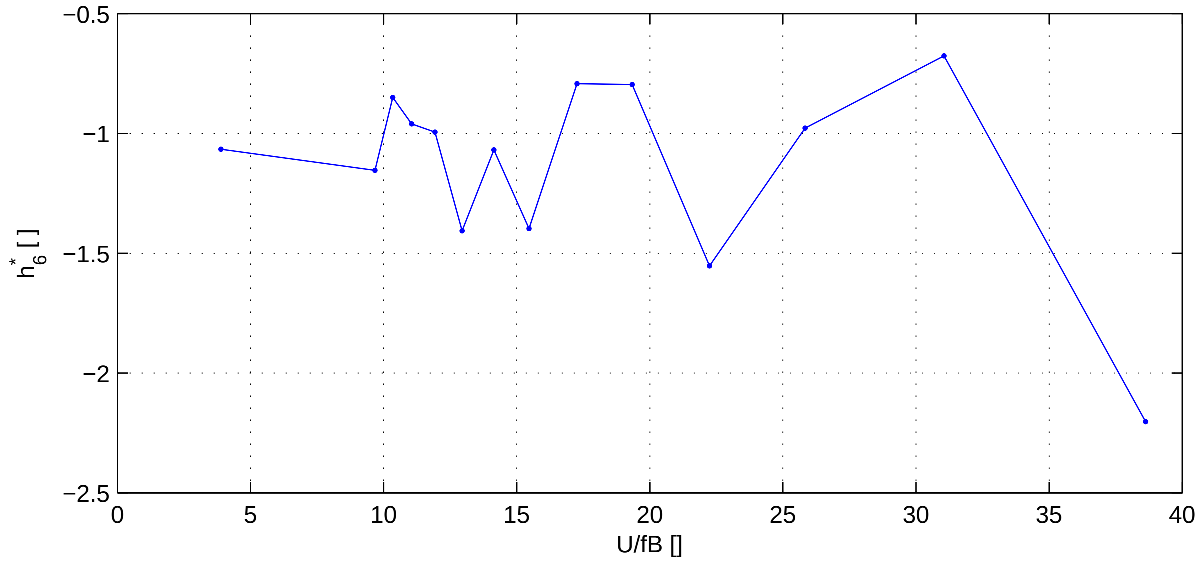


Figure K.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
11.74	25.13	4.00	1.62	3.89	−1.07
11.69	10.05	1.60	0.65	9.68	−1.15
11.74	9.45	1.50	0.61	10.34	−0.85
11.67	8.79	1.40	0.57	11.05	−0.96
11.70	8.16	1.30	0.53	11.93	−0.99
11.71	7.52	1.20	0.49	12.95	−1.41
11.74	6.90	1.10	0.44	14.14	−1.07
11.67	6.28	1.00	0.41	15.46	−1.40
11.74	5.66	0.90	0.36	17.27	−0.79
11.68	5.03	0.80	0.32	19.34	−0.80
11.74	4.39	0.70	0.28	22.24	−1.55
11.71	3.77	0.60	0.24	25.83	−0.98
11.72	3.14	0.50	0.20	31.05	−0.68
11.67	2.51	0.40	0.16	38.63	−2.20

Table K.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

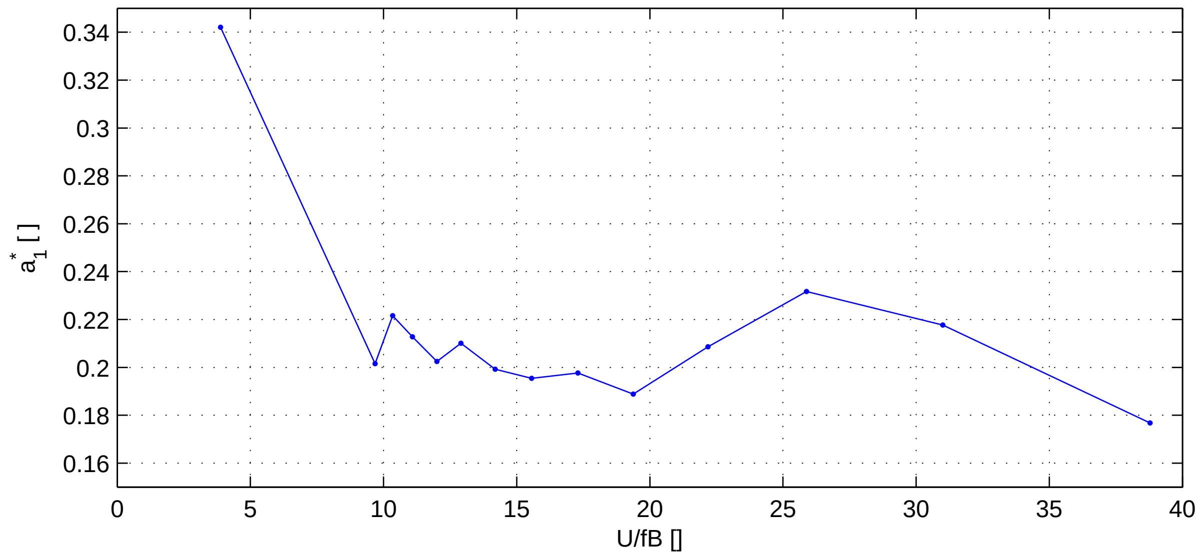


Figure K.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
11.72	25.13	4.00	1.62	3.88	0.34
11.70	10.05	1.60	0.65	9.68	0.20
11.74	9.45	1.50	0.61	10.34	0.22
11.71	8.79	1.40	0.57	11.09	0.21
11.77	8.16	1.30	0.52	12.00	0.20
11.67	7.52	1.20	0.49	12.91	0.21
11.77	6.90	1.10	0.44	14.19	0.20
11.75	6.28	1.00	0.40	15.56	0.20
11.77	5.66	0.90	0.36	17.30	0.20
11.70	5.03	0.80	0.32	19.38	0.19
11.71	4.39	0.70	0.28	22.19	0.21
11.74	3.77	0.60	0.24	25.88	0.23
11.70	3.14	0.50	0.20	31.00	0.22
11.71	2.51	0.40	0.16	38.78	0.18

Table K.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

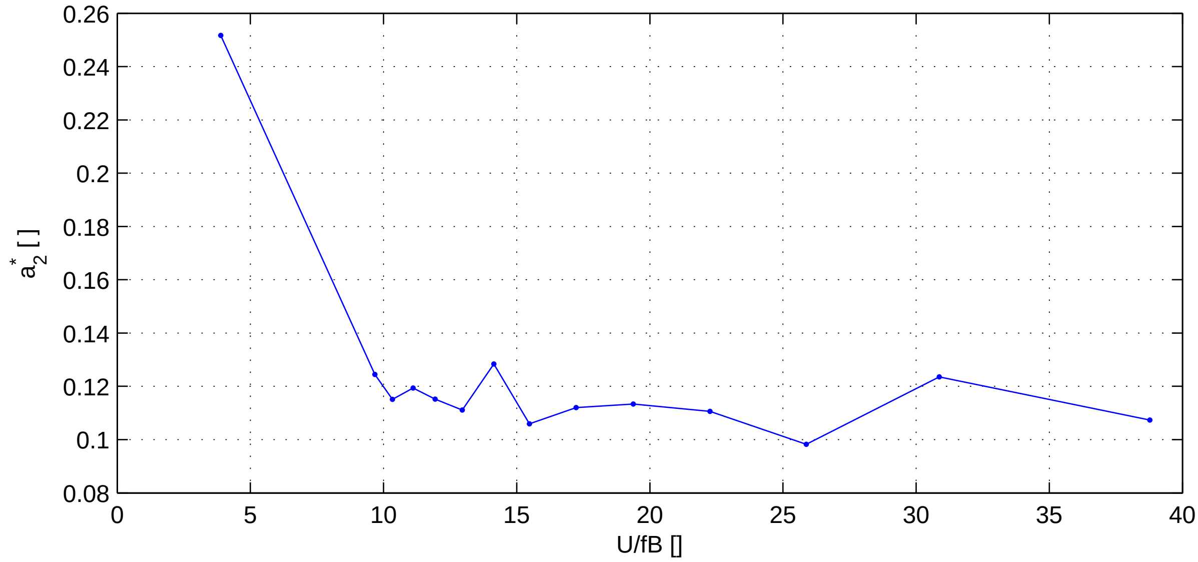


Figure K.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
11.74	25.13	4.00	1.62	3.89	0.25
11.68	10.05	1.60	0.65	9.67	0.12
11.73	9.45	1.50	0.61	10.33	0.12
11.73	8.79	1.40	0.57	11.11	0.12
11.71	8.16	1.30	0.53	11.94	0.12
11.71	7.52	1.20	0.49	12.95	0.11
11.73	6.90	1.10	0.44	14.14	0.13
11.69	6.28	1.00	0.41	15.48	0.11
11.72	5.66	0.90	0.36	17.23	0.11
11.71	5.03	0.80	0.32	19.38	0.11
11.75	4.39	0.70	0.28	22.26	0.11
11.73	3.77	0.60	0.24	25.87	0.10
11.65	3.14	0.50	0.20	30.87	0.12
11.71	2.51	0.40	0.16	38.77	0.11

Table K.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

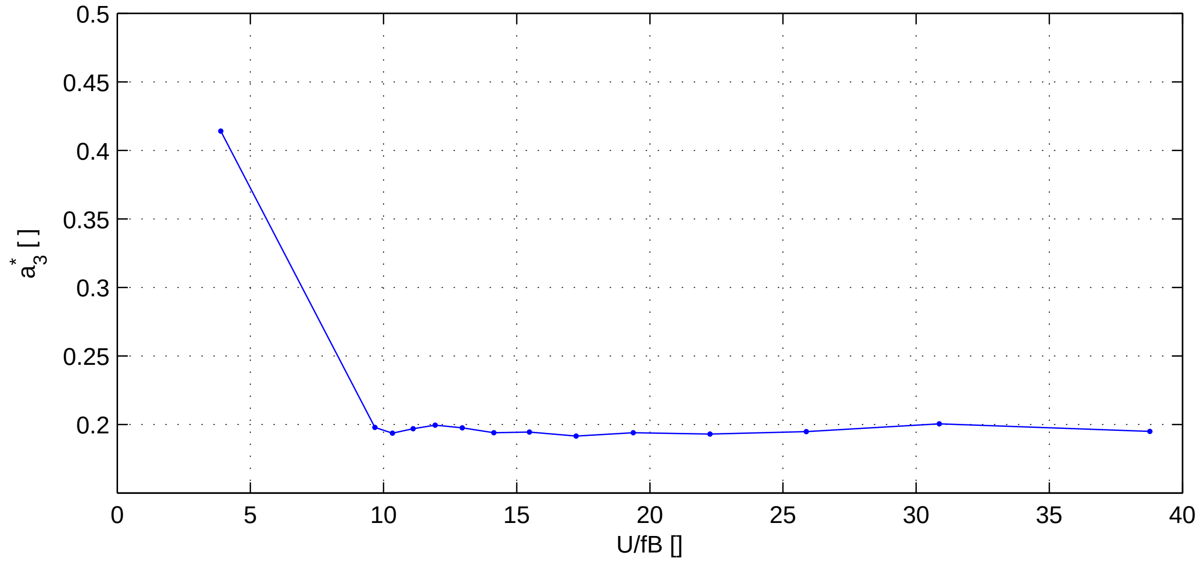


Figure K.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
11.74	25.13	4.00	1.62	3.89	0.41
11.68	10.05	1.60	0.65	9.67	0.20
11.73	9.45	1.50	0.61	10.33	0.19
11.73	8.79	1.40	0.57	11.11	0.20
11.71	8.16	1.30	0.53	11.94	0.20
11.71	7.52	1.20	0.49	12.95	0.20
11.73	6.90	1.10	0.44	14.14	0.19
11.69	6.28	1.00	0.41	15.48	0.19
11.72	5.66	0.90	0.36	17.23	0.19
11.71	5.03	0.80	0.32	19.38	0.19
11.75	4.39	0.70	0.28	22.26	0.19
11.73	3.77	0.60	0.24	25.87	0.19
11.65	3.14	0.50	0.20	30.87	0.20
11.71	2.51	0.40	0.16	38.77	0.19

Table K.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

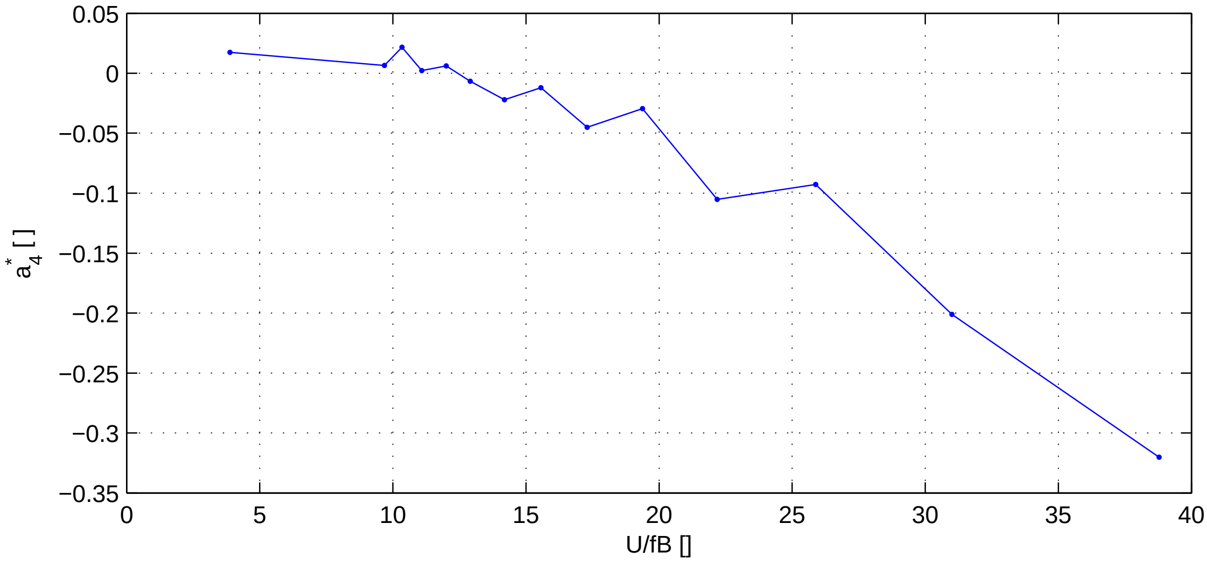


Figure K.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
11.72	25.13	4.00	1.62	3.88	0.02
11.70	10.05	1.60	0.65	9.68	0.01
11.74	9.45	1.50	0.61	10.34	0.02
11.71	8.79	1.40	0.57	11.09	0.00
11.77	8.16	1.30	0.52	12.00	0.01
11.67	7.52	1.20	0.49	12.91	−0.01
11.77	6.90	1.10	0.44	14.19	−0.02
11.75	6.28	1.00	0.40	15.56	−0.01
11.77	5.66	0.90	0.36	17.30	−0.05
11.70	5.03	0.80	0.32	19.38	−0.03
11.71	4.39	0.70	0.28	22.19	−0.11
11.74	3.77	0.60	0.24	25.88	−0.09
11.70	3.14	0.50	0.20	31.00	−0.20
11.71	2.51	0.40	0.16	38.78	−0.32

Table K.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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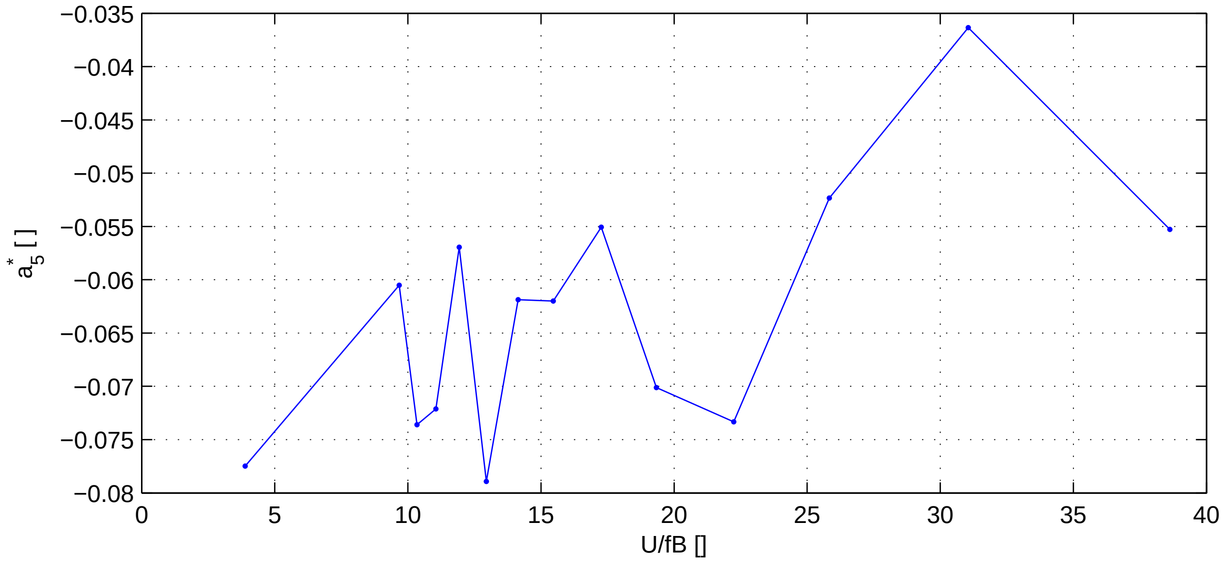

Figure K.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
11.74	25.13	4.00	1.62	3.89	−0.08
11.69	10.05	1.60	0.65	9.68	−0.06
11.74	9.45	1.50	0.61	10.34	−0.07
11.67	8.79	1.40	0.57	11.05	−0.07
11.70	8.16	1.30	0.53	11.93	−0.06
11.71	7.52	1.20	0.49	12.95	−0.08
11.74	6.90	1.10	0.44	14.14	−0.06
11.67	6.28	1.00	0.41	15.46	−0.06
11.74	5.66	0.90	0.36	17.27	−0.06
11.68	5.03	0.80	0.32	19.34	−0.07
11.74	4.39	0.70	0.28	22.24	−0.07
11.71	3.77	0.60	0.24	25.83	−0.05
11.72	3.14	0.50	0.20	31.05	−0.04
11.67	2.51	0.40	0.16	38.63	−0.06

Table K.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

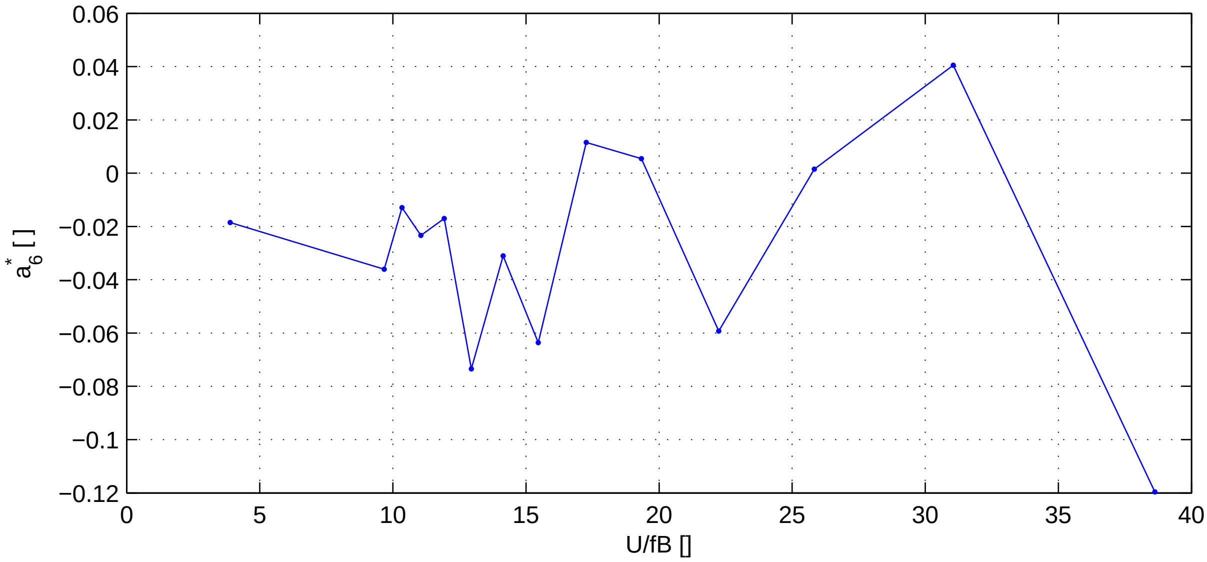

Figure K.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
11.74	25.13	4.00	1.62	3.89	−0.02
11.69	10.05	1.60	0.65	9.68	−0.04
11.74	9.45	1.50	0.61	10.34	−0.01
11.67	8.79	1.40	0.57	11.05	−0.02
11.70	8.16	1.30	0.53	11.93	−0.02
11.71	7.52	1.20	0.49	12.95	−0.07
11.74	6.90	1.10	0.44	14.14	−0.03
11.67	6.28	1.00	0.41	15.46	−0.06
11.74	5.66	0.90	0.36	17.27	0.01
11.68	5.03	0.80	0.32	19.34	0.01
11.74	4.39	0.70	0.28	22.24	−0.06
11.71	3.77	0.60	0.24	25.83	0.00
11.72	3.14	0.50	0.20	31.05	0.04
11.67	2.51	0.40	0.16	38.63	−0.12

Table K.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

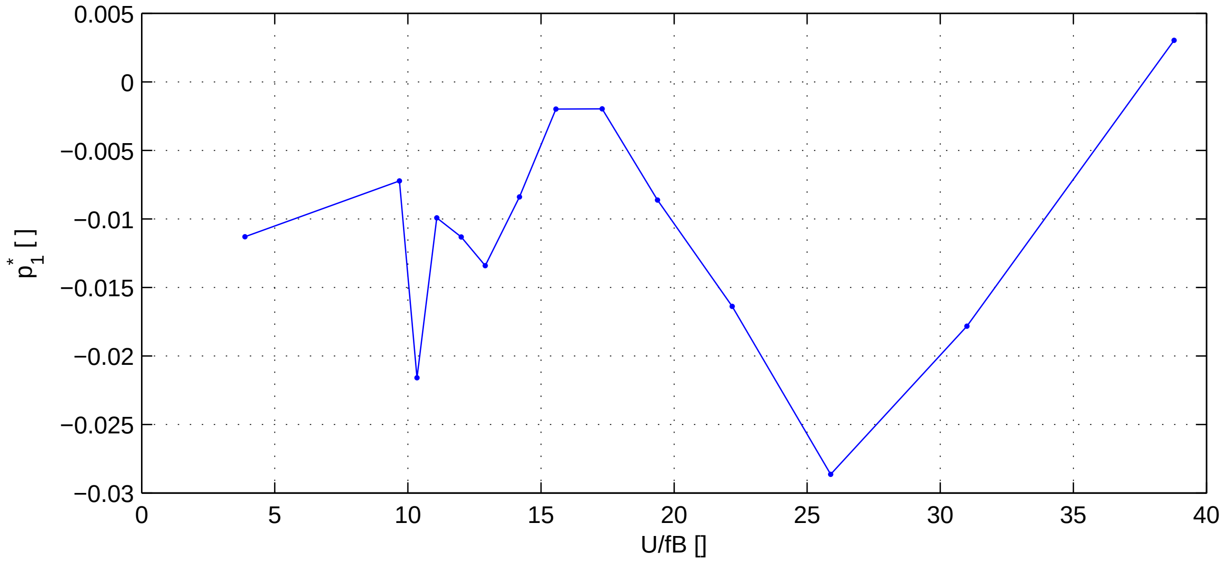

Figure K.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
11.72	25.13	4.00	1.62	3.88	−0.01
11.70	10.05	1.60	0.65	9.68	−0.01
11.74	9.45	1.50	0.61	10.34	−0.02
11.71	8.79	1.40	0.57	11.09	−0.01
11.77	8.16	1.30	0.52	12.00	−0.01
11.67	7.52	1.20	0.49	12.91	−0.01
11.77	6.90	1.10	0.44	14.19	−0.01
11.75	6.28	1.00	0.40	15.56	−0.00
11.77	5.66	0.90	0.36	17.30	−0.00
11.70	5.03	0.80	0.32	19.38	−0.01
11.71	4.39	0.70	0.28	22.19	−0.02
11.74	3.77	0.60	0.24	25.88	−0.03
11.70	3.14	0.50	0.20	31.00	−0.02
11.71	2.51	0.40	0.16	38.78	0.00

Table K.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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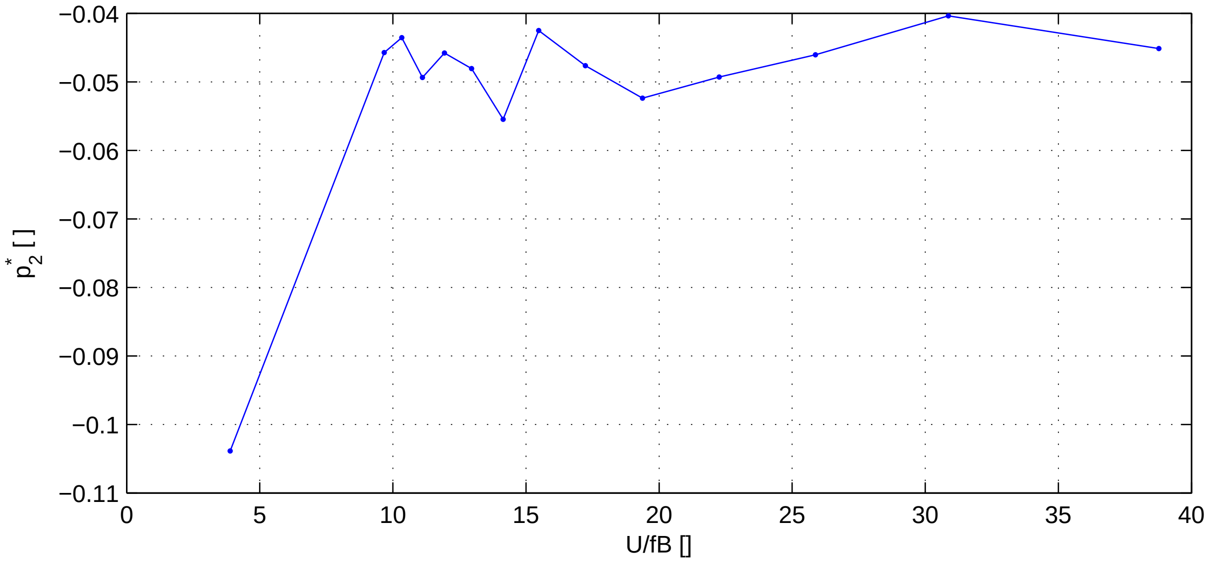


Figure K.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
11.74	25.13	4.00	1.62	3.89	−0.10
11.68	10.05	1.60	0.65	9.67	−0.05
11.73	9.45	1.50	0.61	10.33	−0.04
11.73	8.79	1.40	0.57	11.11	−0.05
11.71	8.16	1.30	0.53	11.94	−0.05
11.71	7.52	1.20	0.49	12.95	−0.05
11.73	6.90	1.10	0.44	14.14	−0.06
11.69	6.28	1.00	0.41	15.48	−0.04
11.72	5.66	0.90	0.36	17.23	−0.05
11.71	5.03	0.80	0.32	19.38	−0.05
11.75	4.39	0.70	0.28	22.26	−0.05
11.73	3.77	0.60	0.24	25.87	−0.05
11.65	3.14	0.50	0.20	30.87	−0.04
11.71	2.51	0.40	0.16	38.77	−0.05

Table K.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

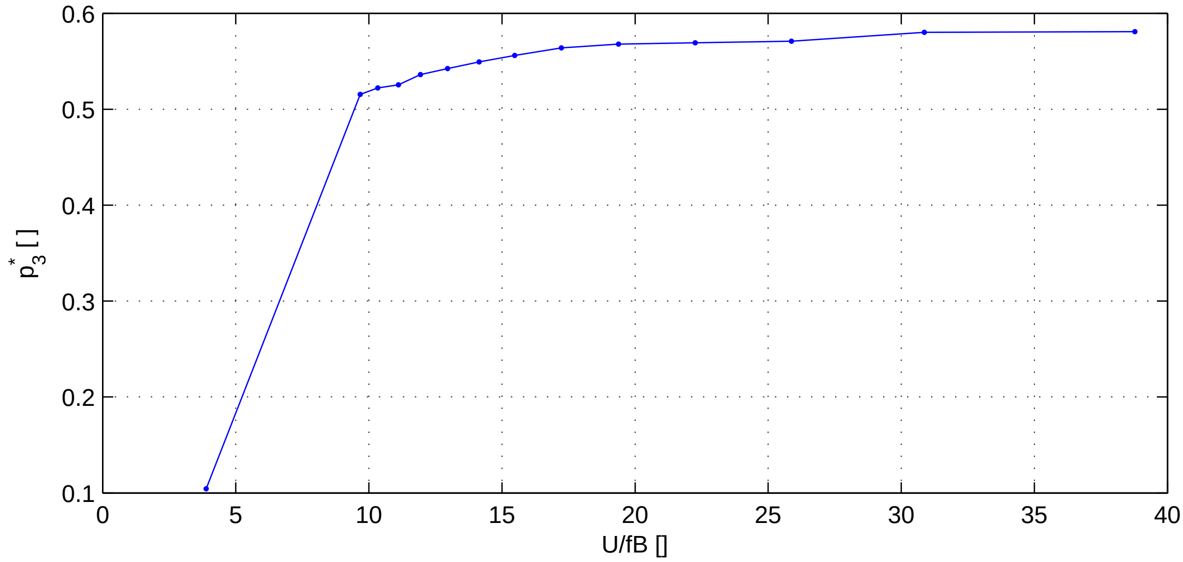


Figure K.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
11.74	25.13	4.00	1.62	3.89	0.10
11.68	10.05	1.60	0.65	9.67	0.52
11.73	9.45	1.50	0.61	10.33	0.52
11.73	8.79	1.40	0.57	11.11	0.53
11.71	8.16	1.30	0.53	11.94	0.54
11.71	7.52	1.20	0.49	12.95	0.54
11.73	6.90	1.10	0.44	14.14	0.55
11.69	6.28	1.00	0.41	15.48	0.56
11.72	5.66	0.90	0.36	17.23	0.56
11.71	5.03	0.80	0.32	19.38	0.57
11.75	4.39	0.70	0.28	22.26	0.57
11.73	3.77	0.60	0.24	25.87	0.57
11.65	3.14	0.50	0.20	30.87	0.58
11.71	2.51	0.40	0.16	38.77	0.58

Table K.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

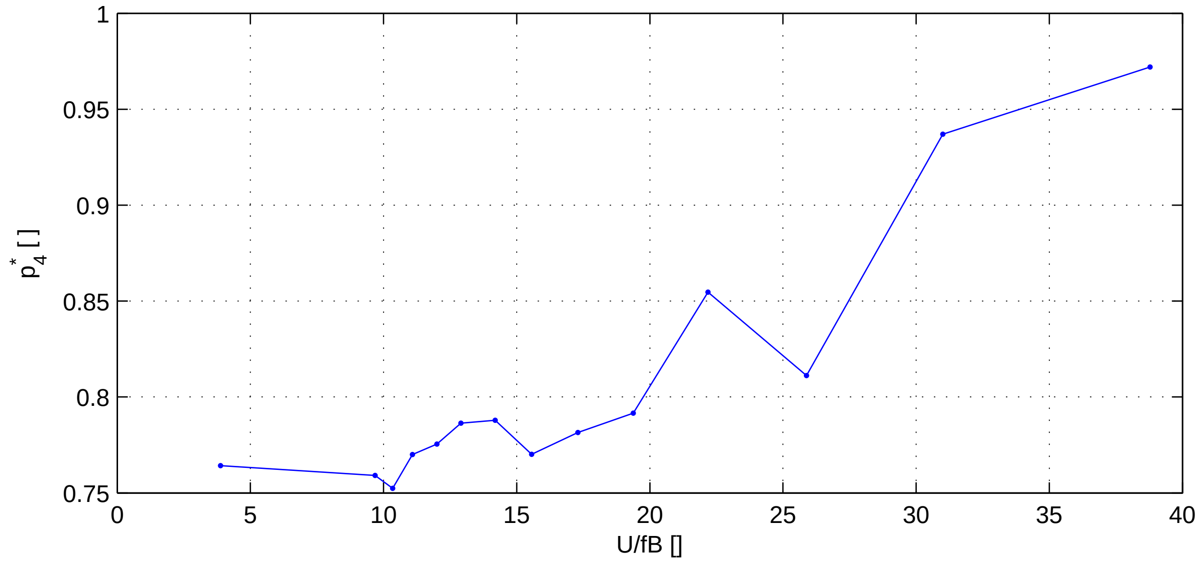


Figure K.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
11.72	25.13	4.00	1.62	3.88	0.76
11.70	10.05	1.60	0.65	9.68	0.76
11.74	9.45	1.50	0.61	10.34	0.75
11.71	8.79	1.40	0.57	11.09	0.77
11.77	8.16	1.30	0.52	12.00	0.78
11.67	7.52	1.20	0.49	12.91	0.79
11.77	6.90	1.10	0.44	14.19	0.79
11.75	6.28	1.00	0.40	15.56	0.77
11.77	5.66	0.90	0.36	17.30	0.78
11.70	5.03	0.80	0.32	19.38	0.79
11.71	4.39	0.70	0.28	22.19	0.85
11.74	3.77	0.60	0.24	25.88	0.81
11.70	3.14	0.50	0.20	31.00	0.94
11.71	2.51	0.40	0.16	38.78	0.97

Table K.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

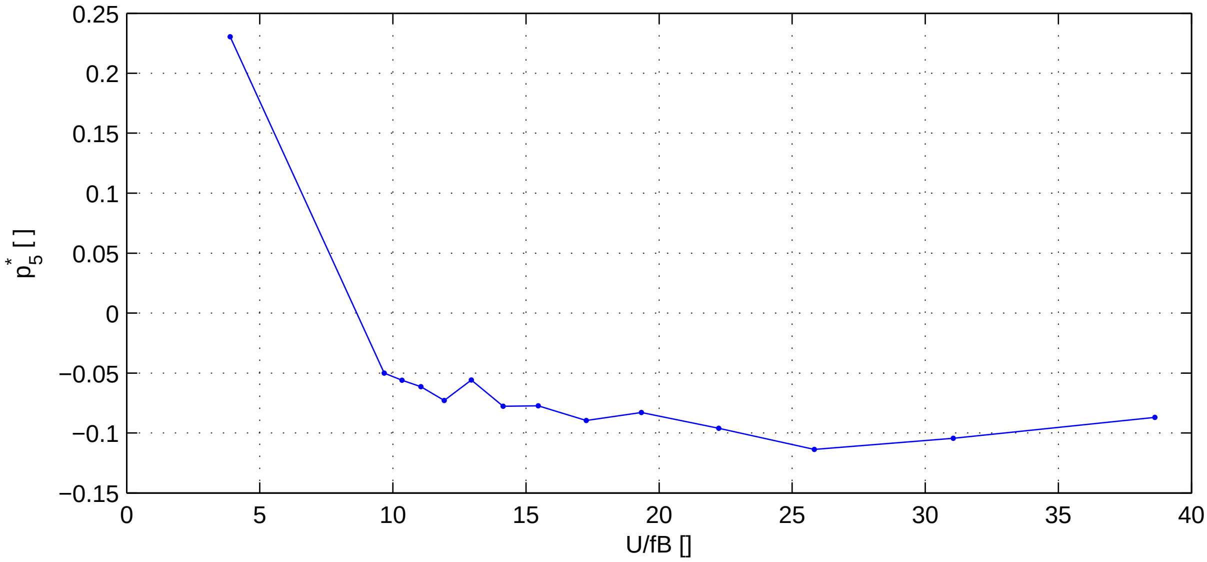


Figure K.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
11.74	25.13	4.00	1.62	3.89	0.23
11.69	10.05	1.60	0.65	9.68	−0.05
11.74	9.45	1.50	0.61	10.34	−0.06
11.67	8.79	1.40	0.57	11.05	−0.06
11.70	8.16	1.30	0.53	11.93	−0.07
11.71	7.52	1.20	0.49	12.95	−0.06
11.74	6.90	1.10	0.44	14.14	−0.08
11.67	6.28	1.00	0.41	15.46	−0.08
11.74	5.66	0.90	0.36	17.27	−0.09
11.68	5.03	0.80	0.32	19.34	−0.08
11.74	4.39	0.70	0.28	22.24	−0.10
11.71	3.77	0.60	0.24	25.83	−0.11
11.72	3.14	0.50	0.20	31.05	−0.10
11.67	2.51	0.40	0.16	38.63	−0.09

Table K.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

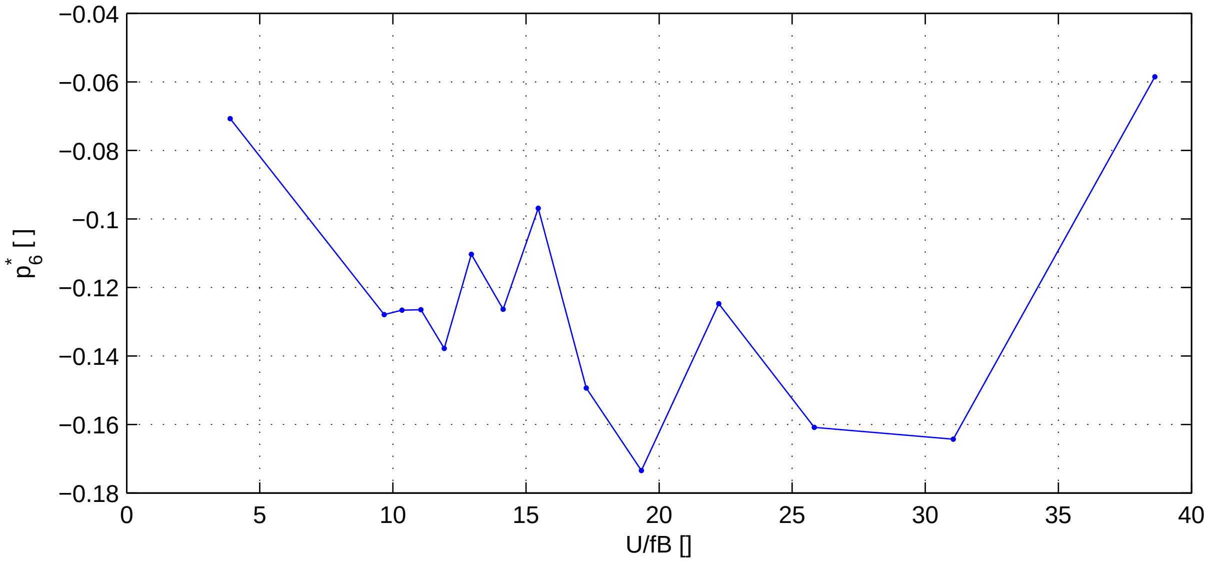


Figure K.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
11.74	25.13	4.00	1.62	3.89	−0.07
11.69	10.05	1.60	0.65	9.68	−0.13
11.74	9.45	1.50	0.61	10.34	−0.13
11.67	8.79	1.40	0.57	11.05	−0.13
11.70	8.16	1.30	0.53	11.93	−0.14
11.71	7.52	1.20	0.49	12.95	−0.11
11.74	6.90	1.10	0.44	14.14	−0.13
11.67	6.28	1.00	0.41	15.46	−0.10
11.74	5.66	0.90	0.36	17.27	−0.15
11.68	5.03	0.80	0.32	19.34	−0.17
11.74	4.39	0.70	0.28	22.24	−0.12
11.71	3.77	0.60	0.24	25.83	−0.16
11.72	3.14	0.50	0.20	31.05	−0.16
11.67	2.51	0.40	0.16	38.63	−0.06

Table K.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

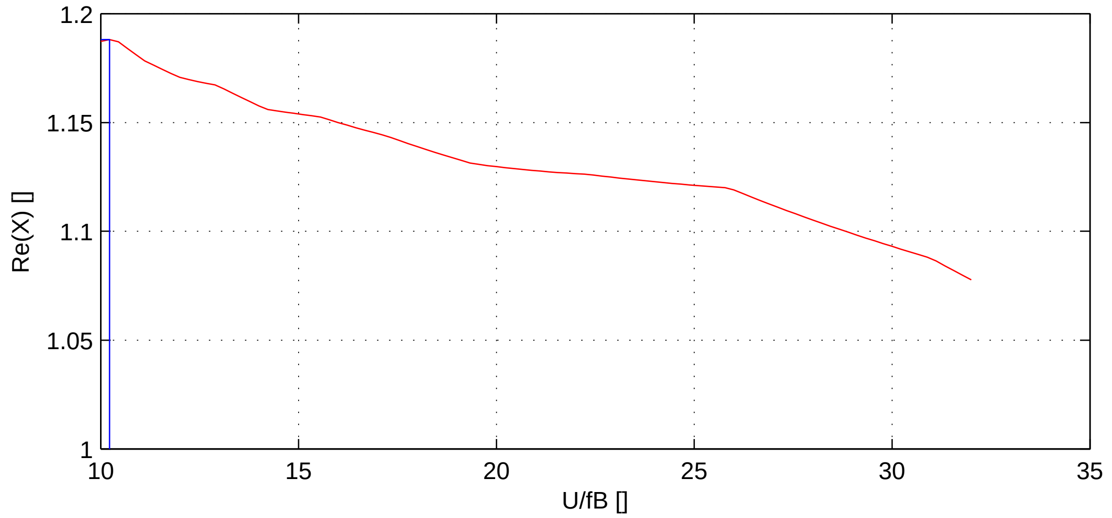


Figure K.37: Real part of the solution to stability equantion

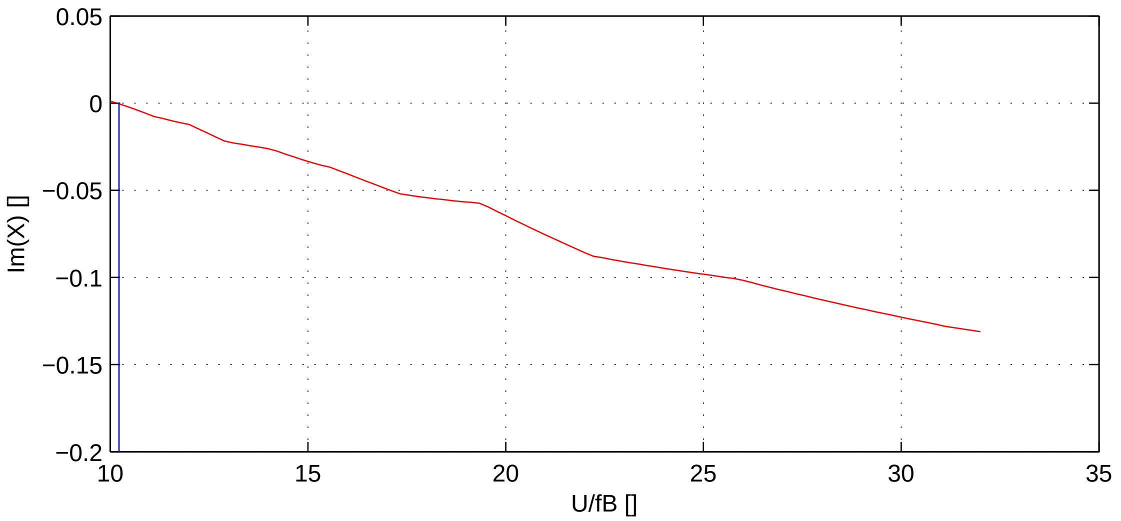


Figure K.38: Imaginary part of the solution to stability equantion

V_{Crit} = 10.2

f_{Crit} = 0.0769 Hz

U_{Crit} = 47.5 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.
[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.
[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.
[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.
[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix L

3D Flutter Tests

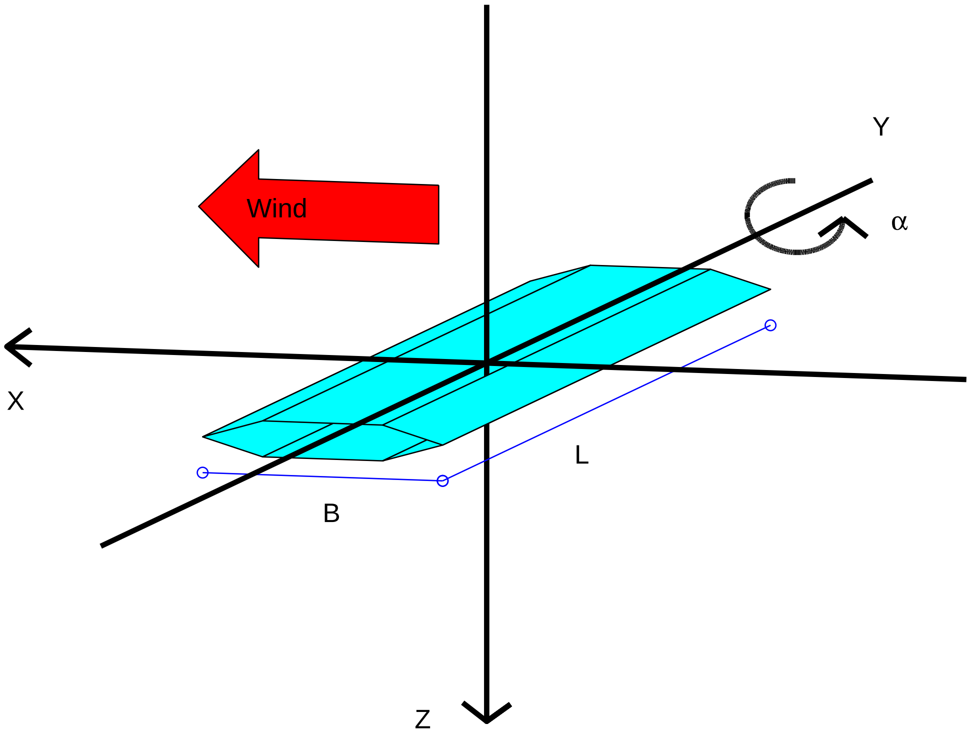
Flutter derivatives, Erection stage, Turbulent flow, Angle of incidence = −4 deg

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^oC	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1019.0

Table L.1: Project Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = mg - m_{a,z}\ddot{h} - 2m\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$
$$I_y\ddot{\alpha} + m z_G\ddot{p} + m x_G\ddot{h}) = -I_{a,y}\ddot{\alpha} m g - 2m\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$
$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h	: Vertical displacement, displacement along z-axis, [m]
α	: Rotation around y-axis, nose up is positive, [rad]
p	: Horizontal displacement, displacement along the x-axis, [m]
m	: Mass per unit length, [kg/m]
I_y	: Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$	: Added mass in vertical direction, [kg/m]
$m_{a,x}$	: Added mass in horizontal direction, [kg/m]
$I_{a,y}$	: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G	: X-coordinate for centre of gravity, [m]
Z_G	: Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$	: Natural circular frequency for vertical motion, [/s]
ζ_h	: Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$	: Natural circular frequency for rotation around y axis, [/s]
ζ_α	: Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$	: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p	: Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$	: Force from rig per meter section, [N/m]
$M_{Y,external}$	: Moment from rig per meter section, [Nm/m]
$F_{X,external}$	: Force from rig per meter section, [N/m]

Formula L.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.628
Added mass in horizontal	$m_{a,x}$	kg/m	0.602
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.152
Horizontal centre of gravity	x_G	m	−0.000
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.288
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.159
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.132

Table L.2: Mechanical Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = mg - m_{a,z}\ddot{h} - 2m\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m z_G\ddot{p} + m x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}mg - 2m\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\rho U^2 B C_z$$

$$M_{ad} = 1/2\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\rho U^2 B C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + KH_1^*\frac{\dot{h}}{U} + KH_2^*\frac{B\dot{\alpha}}{U} + KH_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + KA_1^*\frac{\dot{h}}{U} + KA_2^*\frac{B\dot{\alpha}}{U} + KA_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + KP_5^*\frac{\dot{h}}{U} + KP_2^*\frac{B\dot{\alpha}}{U} + KP_1^*\frac{\dot{p}}{U})$$

Formula L.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

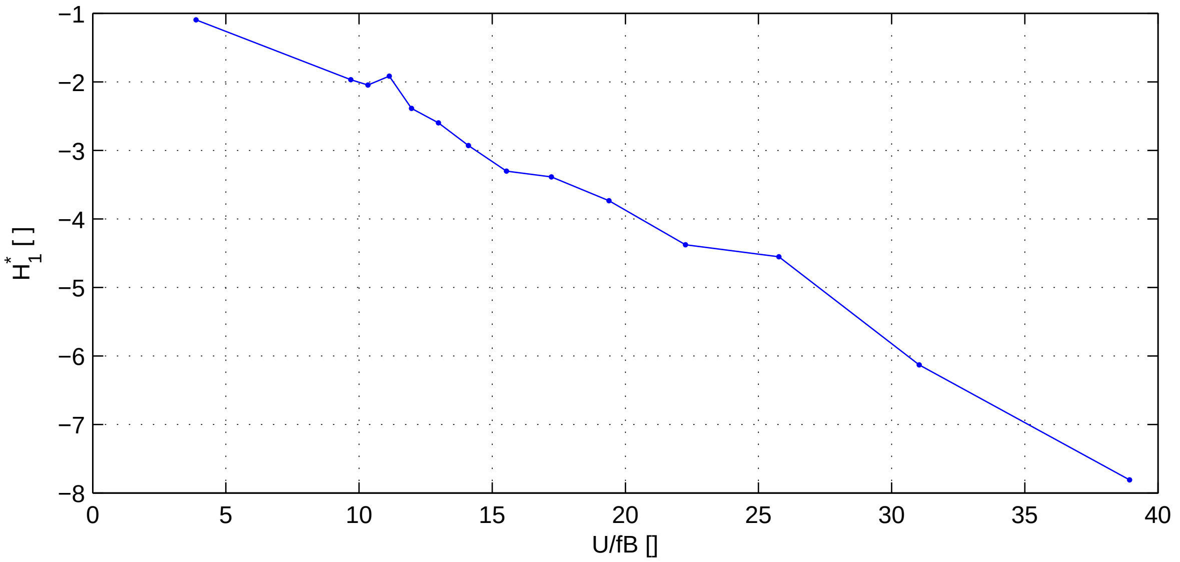


Figure L.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
11.72	25.13	4.00	1.62	3.88	−1.10
11.71	10.05	1.60	0.65	9.69	−1.97
11.73	9.45	1.50	0.61	10.33	−2.05
11.76	8.79	1.40	0.56	11.14	−1.92
11.74	8.16	1.30	0.52	11.97	−2.39
11.74	7.52	1.20	0.48	12.98	−2.60
11.70	6.90	1.10	0.45	14.11	−2.93
11.73	6.28	1.00	0.40	15.54	−3.30
11.71	5.66	0.90	0.36	17.22	−3.39
11.71	5.03	0.80	0.32	19.39	−3.74
11.75	4.39	0.70	0.28	22.26	−4.38
11.68	3.77	0.60	0.24	25.76	−4.55
11.72	3.14	0.50	0.20	31.03	−6.13
11.76	2.51	0.40	0.16	38.93	−7.81

Table L.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

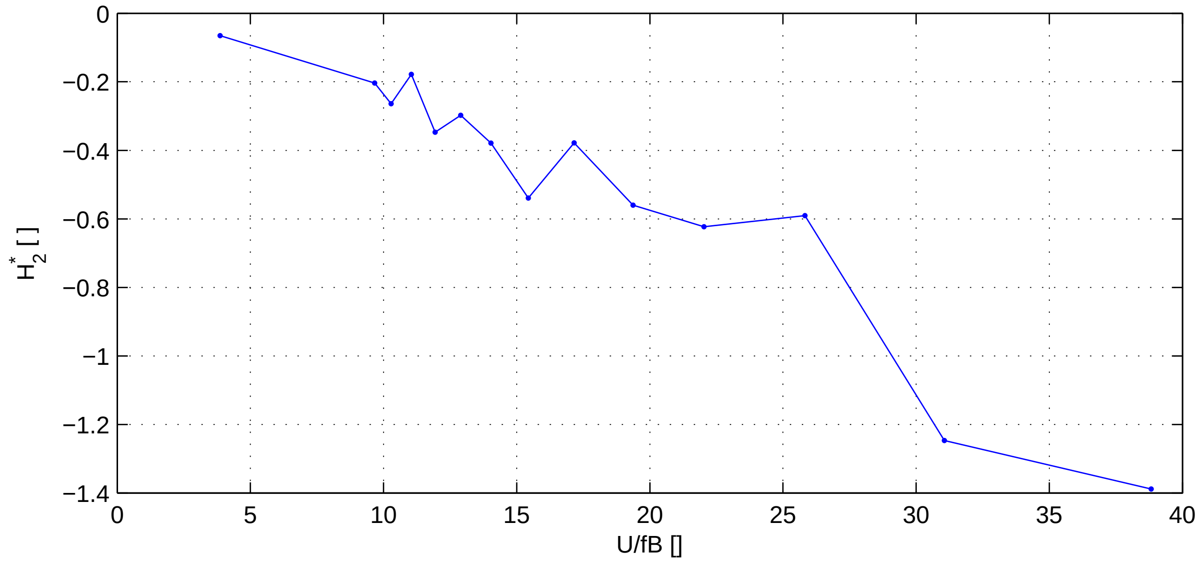


Figure L.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
11.67	25.13	4.00	1.63	3.86	−0.07
11.68	10.05	1.60	0.65	9.67	−0.20
11.67	9.45	1.50	0.61	10.28	−0.26
11.66	8.79	1.40	0.57	11.04	−0.18
11.71	8.16	1.30	0.53	11.94	−0.35
11.66	7.52	1.20	0.49	12.90	−0.30
11.64	6.90	1.10	0.45	14.03	−0.38
11.66	6.28	1.00	0.41	15.44	−0.54
11.67	5.66	0.90	0.37	17.16	−0.38
11.70	5.03	0.80	0.32	19.37	−0.56
11.63	4.39	0.70	0.29	22.03	−0.62
11.71	3.77	0.60	0.24	25.83	−0.59
11.73	3.14	0.50	0.20	31.06	−1.25
11.72	2.51	0.40	0.16	38.82	−1.39

Table L.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

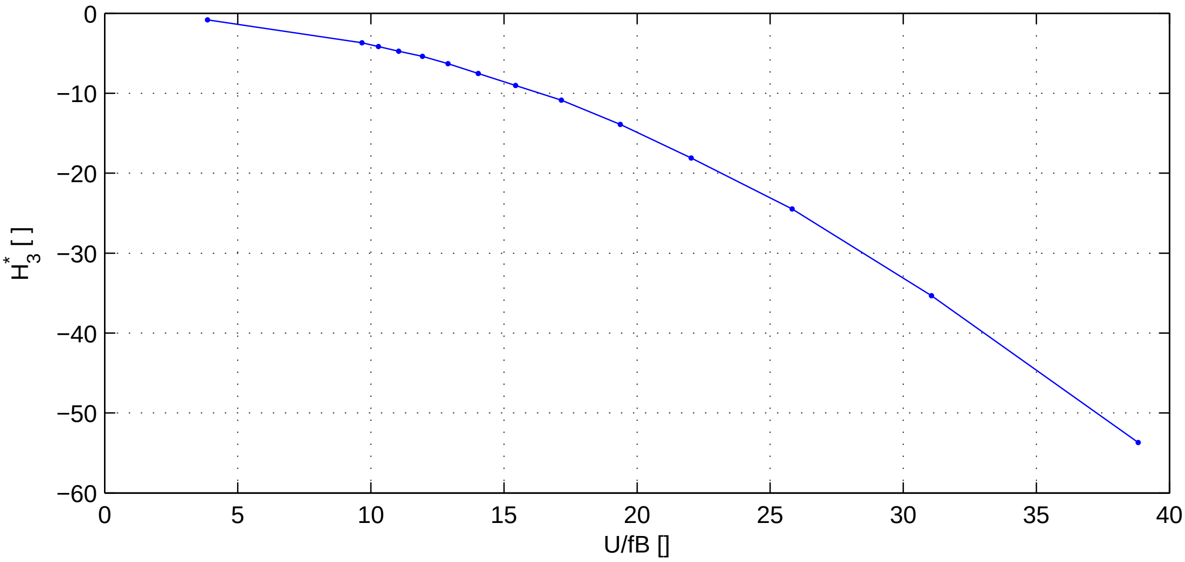


Figure L.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
11.67	25.13	4.00	1.63	3.86	−0.81
11.68	10.05	1.60	0.65	9.67	−3.67
11.67	9.45	1.50	0.61	10.28	−4.16
11.66	8.79	1.40	0.57	11.04	−4.75
11.71	8.16	1.30	0.53	11.94	−5.40
11.66	7.52	1.20	0.49	12.90	−6.29
11.64	6.90	1.10	0.45	14.03	−7.53
11.66	6.28	1.00	0.41	15.44	−9.02
11.67	5.66	0.90	0.37	17.16	−10.88
11.70	5.03	0.80	0.32	19.37	−13.89
11.63	4.39	0.70	0.29	22.03	−18.11
11.71	3.77	0.60	0.24	25.83	−24.47
11.73	3.14	0.50	0.20	31.06	−35.32
11.72	2.51	0.40	0.16	38.82	−53.69

Table L.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

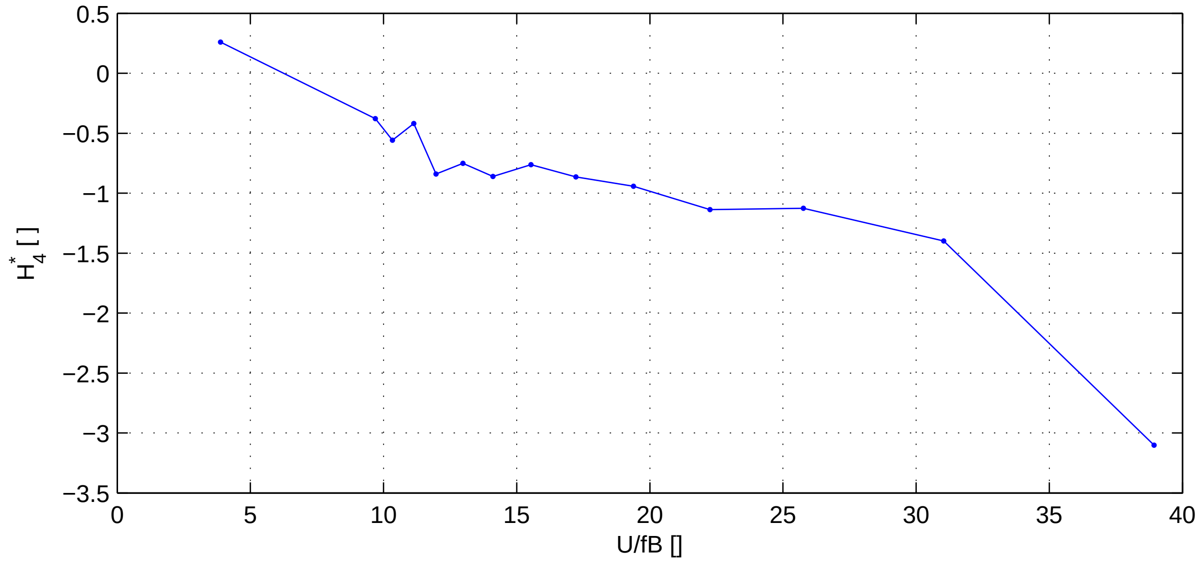


Figure L.4: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_4^*
11.72	25.13	4.00	1.62	3.88	0.26
11.71	10.05	1.60	0.65	9.69	−0.38
11.73	9.45	1.50	0.61	10.33	−0.56
11.76	8.79	1.40	0.56	11.14	−0.42
11.74	8.16	1.30	0.52	11.97	−0.84
11.74	7.52	1.20	0.48	12.98	−0.75
11.70	6.90	1.10	0.45	14.11	−0.86
11.73	6.28	1.00	0.40	15.54	−0.76
11.71	5.66	0.90	0.36	17.22	−0.86
11.71	5.03	0.80	0.32	19.39	−0.94
11.75	4.39	0.70	0.28	22.26	−1.14
11.68	3.77	0.60	0.24	25.76	−1.13
11.72	3.14	0.50	0.20	31.03	−1.40
11.76	2.51	0.40	0.16	38.93	−3.10

Table L.6: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

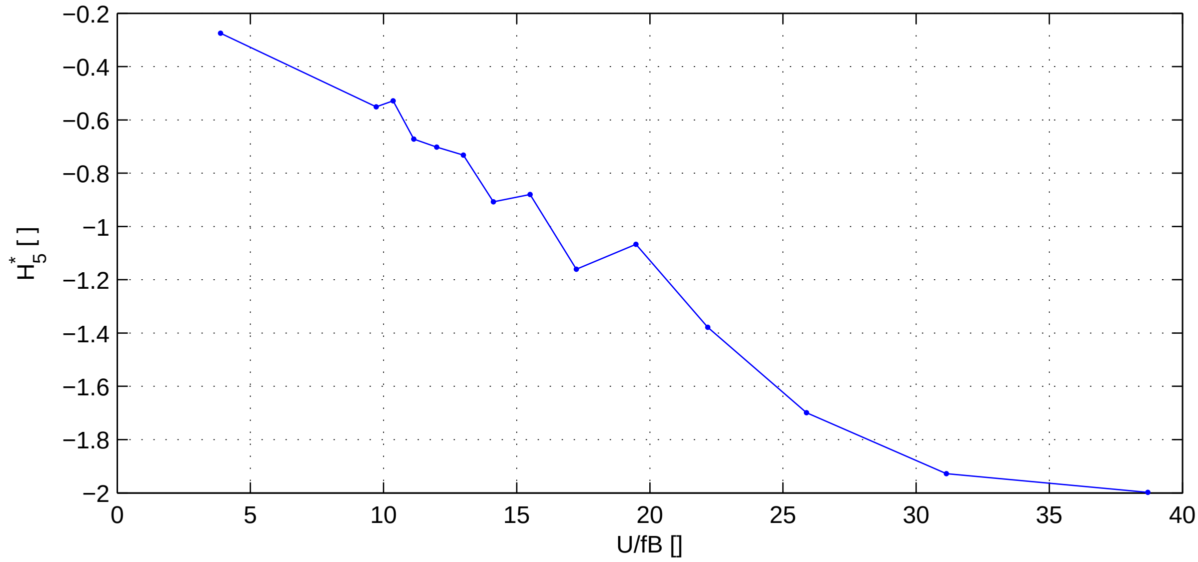


Figure L.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
11.71	25.13	4.00	1.62	3.88	−0.27
11.75	10.05	1.60	0.65	9.73	−0.55
11.76	9.45	1.50	0.61	10.36	−0.53
11.75	8.79	1.40	0.56	11.13	−0.67
11.76	8.16	1.30	0.52	11.99	−0.70
11.75	7.52	1.20	0.48	12.99	−0.73
11.72	6.90	1.10	0.44	14.13	−0.91
11.71	6.28	1.00	0.41	15.51	−0.88
11.72	5.66	0.90	0.36	17.24	−1.16
11.76	5.03	0.80	0.32	19.48	−1.07
11.71	4.39	0.70	0.28	22.17	−1.38
11.74	3.77	0.60	0.24	25.88	−1.70
11.76	3.14	0.50	0.20	31.14	−1.93
11.69	2.51	0.40	0.16	38.70	−2.00

Table L.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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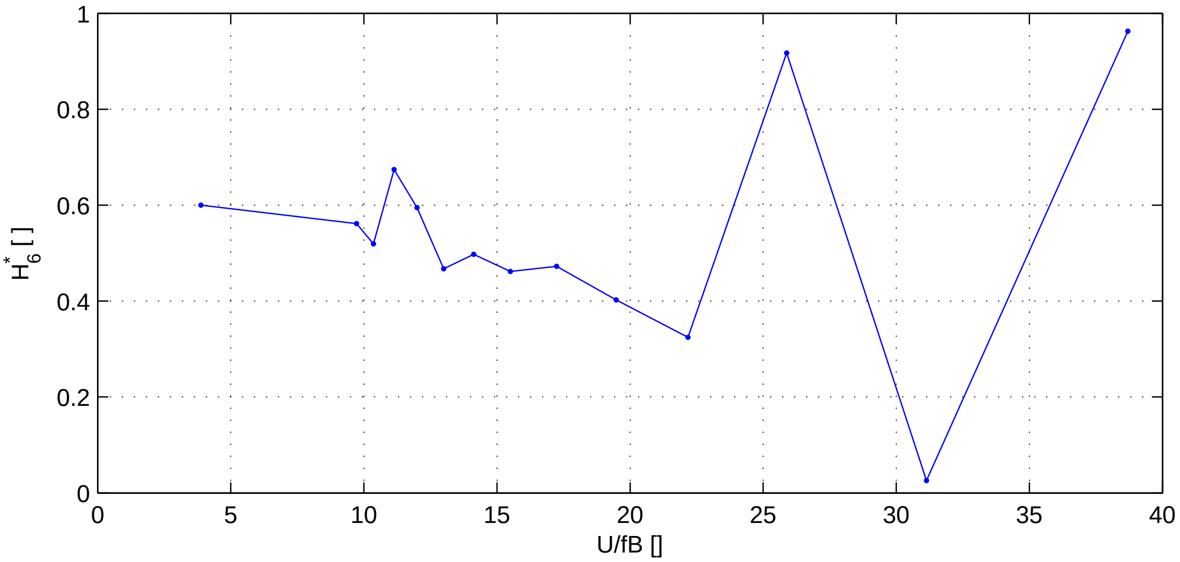

Figure L.6: H^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_6
11.71	25.13	4.00	1.62	3.88	0.60
11.75	10.05	1.60	0.65	9.73	0.56
11.76	9.45	1.50	0.61	10.36	0.52
11.75	8.79	1.40	0.56	11.13	0.67
11.76	8.16	1.30	0.52	11.99	0.59
11.75	7.52	1.20	0.48	12.99	0.47
11.72	6.90	1.10	0.44	14.13	0.50
11.71	6.28	1.00	0.41	15.51	0.46
11.72	5.66	0.90	0.36	17.24	0.47
11.76	5.03	0.80	0.32	19.48	0.40
11.71	4.39	0.70	0.28	22.17	0.32
11.74	3.77	0.60	0.24	25.88	0.92
11.76	3.14	0.50	0.20	31.14	0.03
11.69	2.51	0.40	0.16	38.70	0.96

Table L.8: H^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

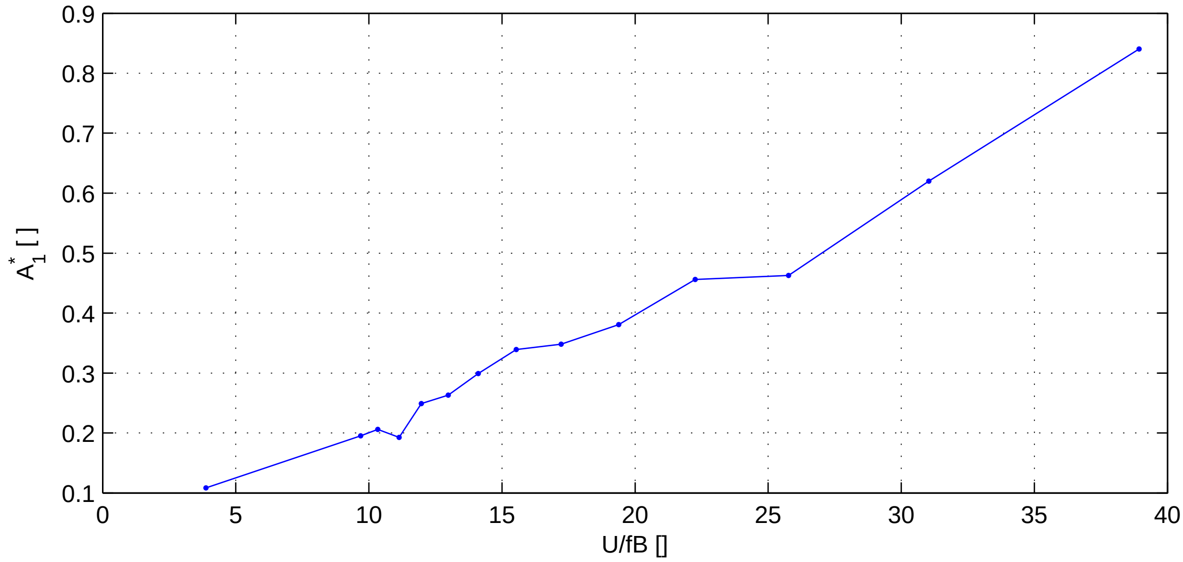

Figure L.7: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_1^*
11.72	25.13	4.00	1.62	3.88	0.11
11.71	10.05	1.60	0.65	9.69	0.20
11.73	9.45	1.50	0.61	10.33	0.21
11.76	8.79	1.40	0.56	11.14	0.19
11.74	8.16	1.30	0.52	11.97	0.25
11.74	7.52	1.20	0.48	12.98	0.26
11.70	6.90	1.10	0.45	14.11	0.30
11.73	6.28	1.00	0.40	15.54	0.34
11.71	5.66	0.90	0.36	17.22	0.35
11.71	5.03	0.80	0.32	19.39	0.38
11.75	4.39	0.70	0.28	22.26	0.46
11.68	3.77	0.60	0.24	25.76	0.46
11.72	3.14	0.50	0.20	31.03	0.62
11.76	2.51	0.40	0.16	38.93	0.84

Table L.9: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

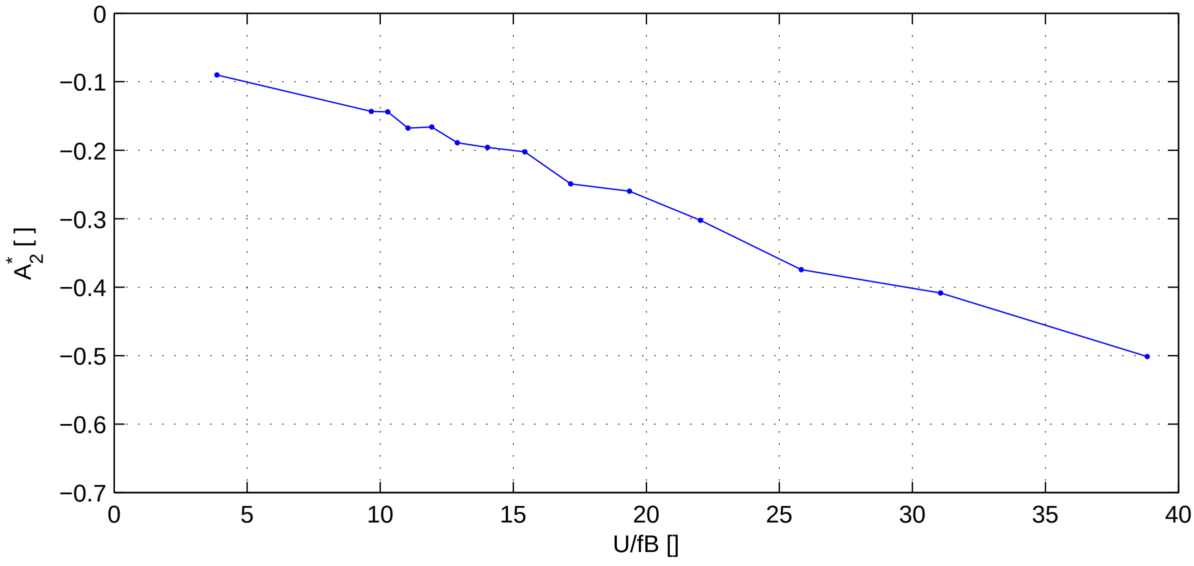

Figure L.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
11.67	25.13	4.00	1.63	3.86	−0.09
11.68	10.05	1.60	0.65	9.67	−0.14
11.67	9.45	1.50	0.61	10.28	−0.14
11.66	8.79	1.40	0.57	11.04	−0.17
11.71	8.16	1.30	0.53	11.94	−0.17
11.66	7.52	1.20	0.49	12.90	−0.19
11.64	6.90	1.10	0.45	14.03	−0.20
11.66	6.28	1.00	0.41	15.44	−0.20
11.67	5.66	0.90	0.37	17.16	−0.25
11.70	5.03	0.80	0.32	19.37	−0.26
11.63	4.39	0.70	0.29	22.03	−0.30
11.71	3.77	0.60	0.24	25.83	−0.37
11.73	3.14	0.50	0.20	31.06	−0.41
11.72	2.51	0.40	0.16	38.82	−0.50

Table L.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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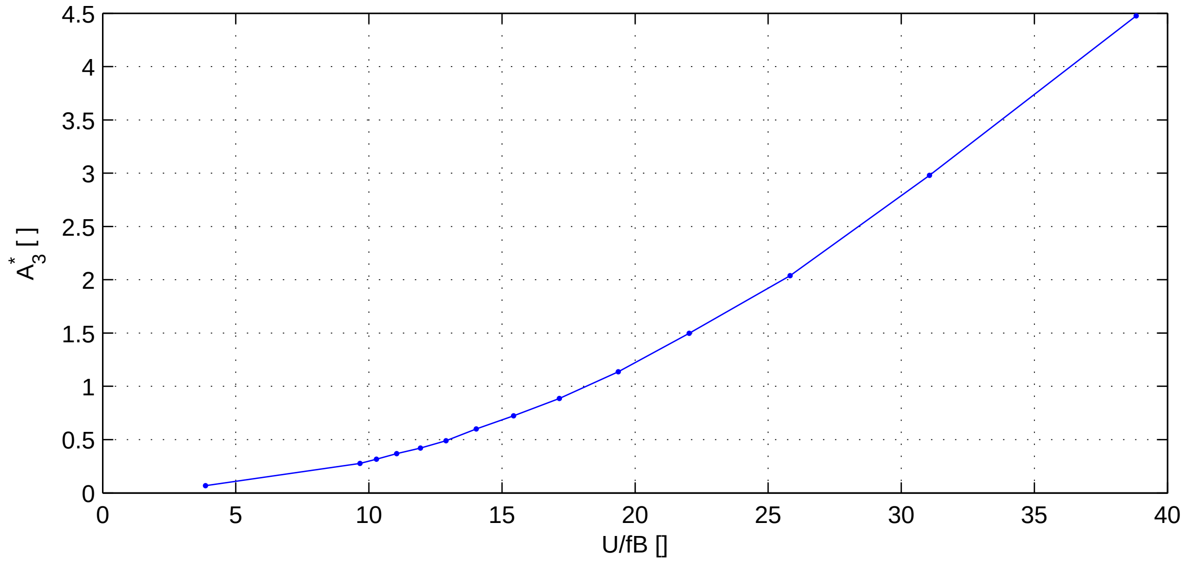

Figure L.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
11.67	25.13	4.00	1.63	3.86	0.07
11.68	10.05	1.60	0.65	9.67	0.28
11.67	9.45	1.50	0.61	10.28	0.32
11.66	8.79	1.40	0.57	11.04	0.37
11.71	8.16	1.30	0.53	11.94	0.42
11.66	7.52	1.20	0.49	12.90	0.49
11.64	6.90	1.10	0.45	14.03	0.60
11.66	6.28	1.00	0.41	15.44	0.72
11.67	5.66	0.90	0.37	17.16	0.89
11.70	5.03	0.80	0.32	19.37	1.14
11.63	4.39	0.70	0.29	22.03	1.50
11.71	3.77	0.60	0.24	25.83	2.04
11.73	3.14	0.50	0.20	31.06	2.98
11.72	2.51	0.40	0.16	38.82	4.48

Table L.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

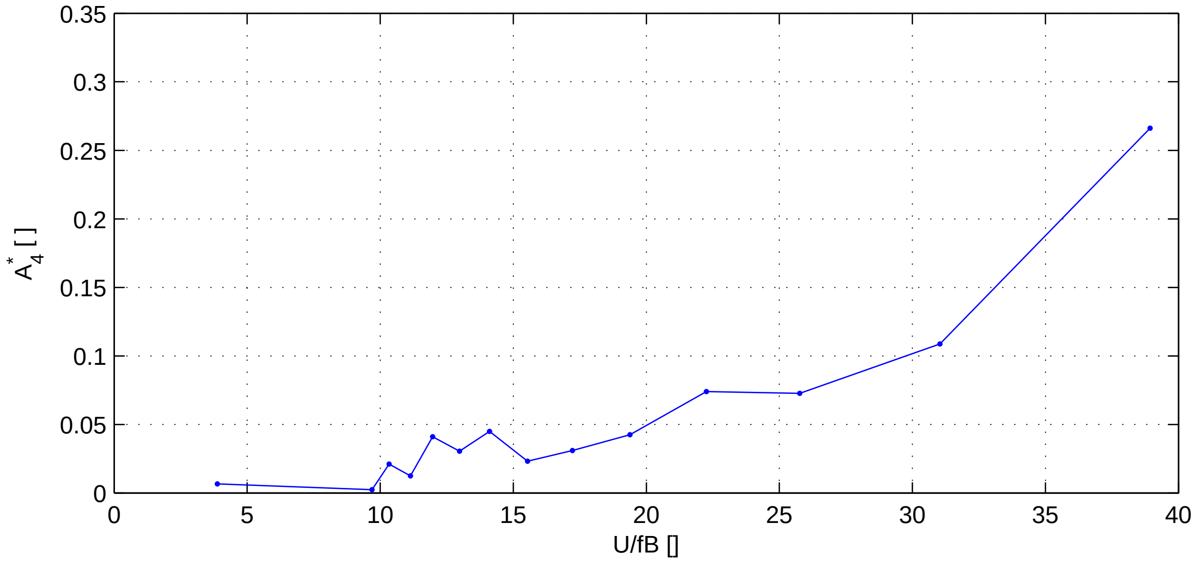

Figure L.10: A^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_4
11.72	25.13	4.00	1.62	3.88	0.01
11.71	10.05	1.60	0.65	9.69	0.00
11.73	9.45	1.50	0.61	10.33	0.02
11.76	8.79	1.40	0.56	11.14	0.01
11.74	8.16	1.30	0.52	11.97	0.04
11.74	7.52	1.20	0.48	12.98	0.03
11.70	6.90	1.10	0.45	14.11	0.04
11.73	6.28	1.00	0.40	15.54	0.02
11.71	5.66	0.90	0.36	17.22	0.03
11.71	5.03	0.80	0.32	19.39	0.04
11.75	4.39	0.70	0.28	22.26	0.07
11.68	3.77	0.60	0.24	25.76	0.07
11.72	3.14	0.50	0.20	31.03	0.11
11.76	2.51	0.40	0.16	38.93	0.27

Table L.12: A^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

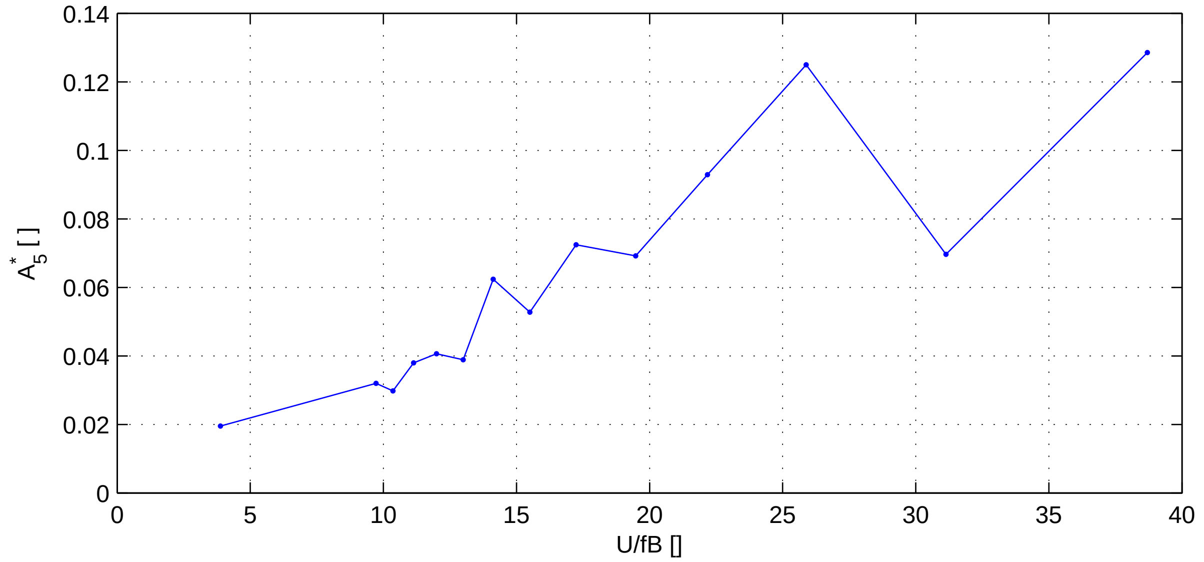

Figure L.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
11.71	25.13	4.00	1.62	3.88	0.02
11.75	10.05	1.60	0.65	9.73	0.03
11.76	9.45	1.50	0.61	10.36	0.03
11.75	8.79	1.40	0.56	11.13	0.04
11.76	8.16	1.30	0.52	11.99	0.04
11.75	7.52	1.20	0.48	12.99	0.04
11.72	6.90	1.10	0.44	14.13	0.06
11.71	6.28	1.00	0.41	15.51	0.05
11.72	5.66	0.90	0.36	17.24	0.07
11.76	5.03	0.80	0.32	19.48	0.07
11.71	4.39	0.70	0.28	22.17	0.09
11.74	3.77	0.60	0.24	25.88	0.12
11.76	3.14	0.50	0.20	31.14	0.07
11.69	2.51	0.40	0.16	38.70	0.13

Table L.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

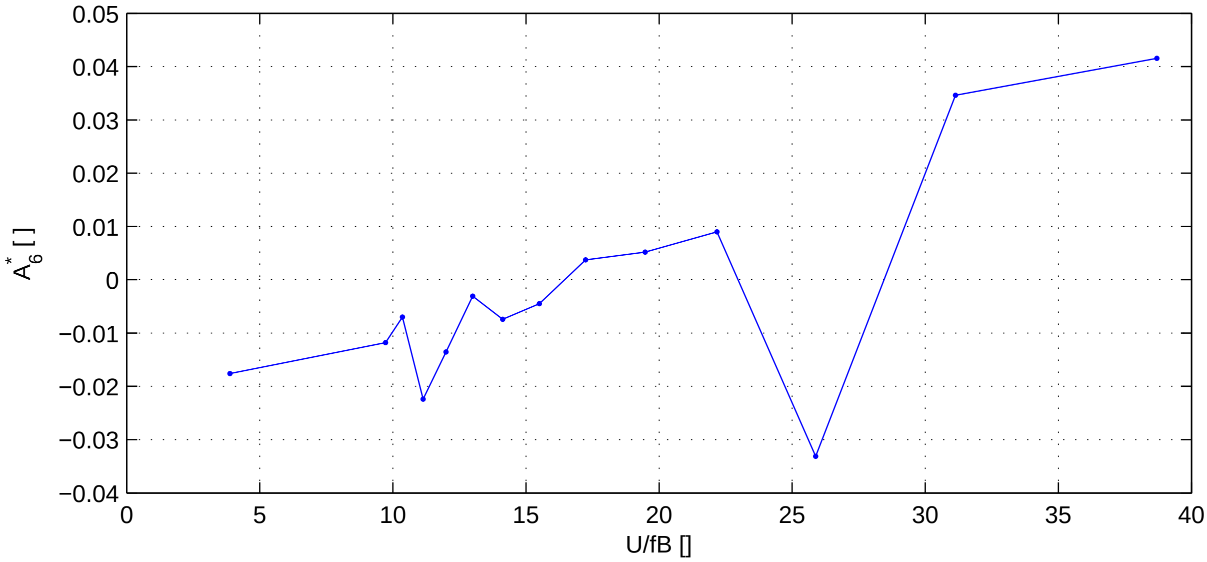

Figure L.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
11.71	25.13	4.00	1.62	3.88	−0.02
11.75	10.05	1.60	0.65	9.73	−0.01
11.76	9.45	1.50	0.61	10.36	−0.01
11.75	8.79	1.40	0.56	11.13	−0.02
11.76	8.16	1.30	0.52	11.99	−0.01
11.75	7.52	1.20	0.48	12.99	−0.00
11.72	6.90	1.10	0.44	14.13	−0.01
11.71	6.28	1.00	0.41	15.51	−0.00
11.72	5.66	0.90	0.36	17.24	0.00
11.76	5.03	0.80	0.32	19.48	0.01
11.71	4.39	0.70	0.28	22.17	0.01
11.74	3.77	0.60	0.24	25.88	−0.03
11.76	3.14	0.50	0.20	31.14	0.03
11.69	2.51	0.40	0.16	38.70	0.04

Table L.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

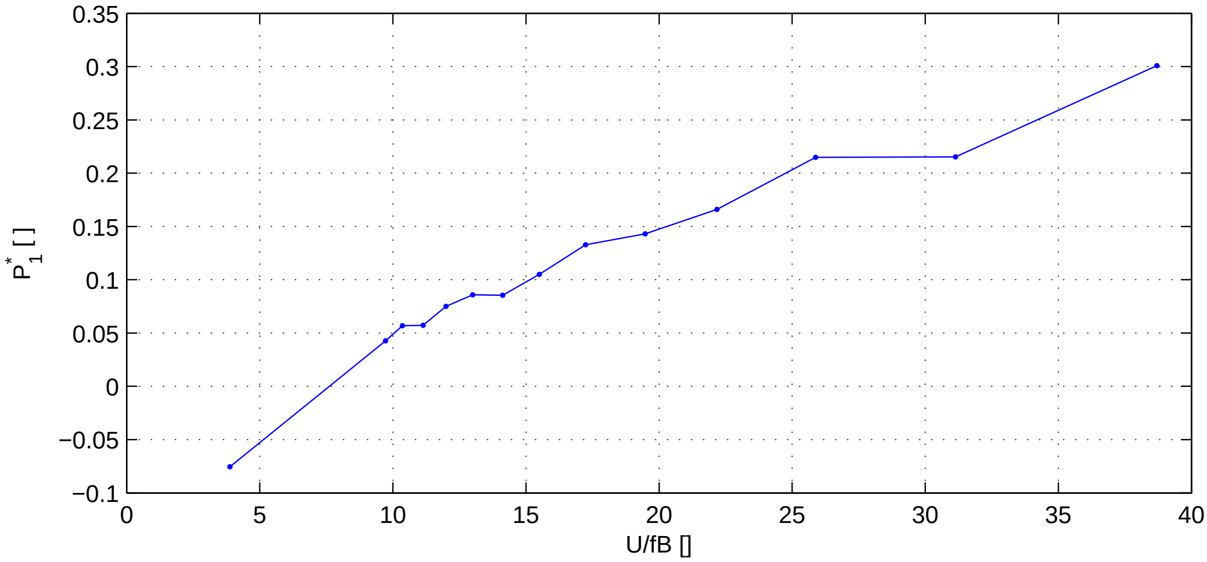

Figure L.13: P^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_1
11.71	25.13	4.00	1.62	3.88	−0.08
11.75	10.05	1.60	0.65	9.73	0.04
11.76	9.45	1.50	0.61	10.36	0.06
11.75	8.79	1.40	0.56	11.13	0.06
11.76	8.16	1.30	0.52	11.99	0.08
11.75	7.52	1.20	0.48	12.99	0.09
11.72	6.90	1.10	0.44	14.13	0.09
11.71	6.28	1.00	0.41	15.51	0.11
11.72	5.66	0.90	0.36	17.24	0.13
11.76	5.03	0.80	0.32	19.48	0.14
11.71	4.39	0.70	0.28	22.17	0.17
11.74	3.77	0.60	0.24	25.88	0.21
11.76	3.14	0.50	0.20	31.14	0.22
11.69	2.51	0.40	0.16	38.70	0.30

Table L.15: P^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

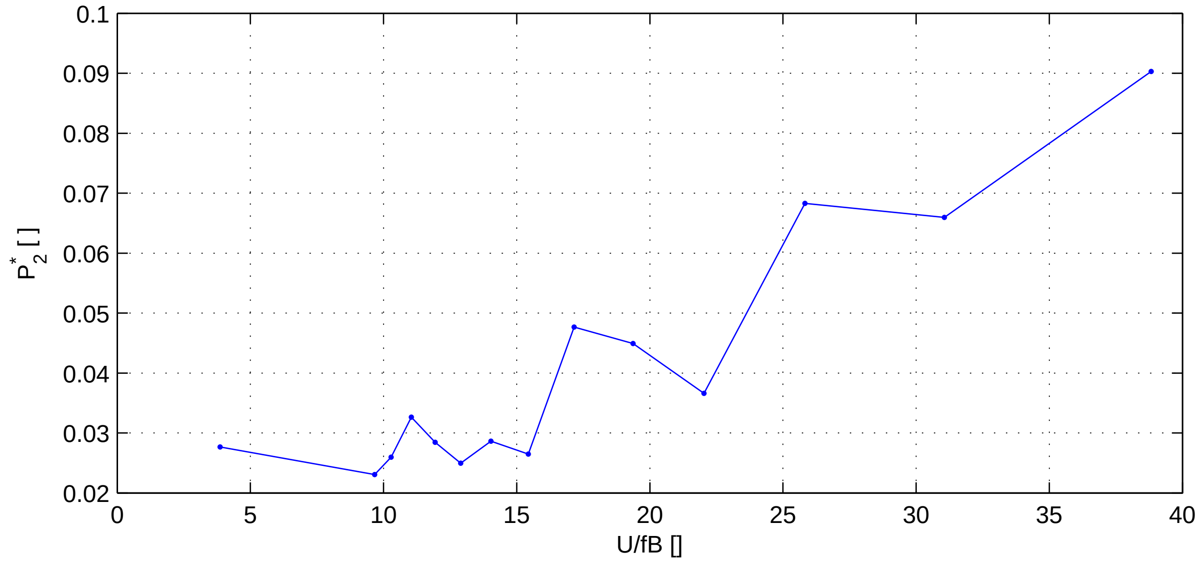

Figure L.14: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_2^*
11.67	25.13	4.00	1.63	3.86	0.03
11.68	10.05	1.60	0.65	9.67	0.02
11.67	9.45	1.50	0.61	10.28	0.03
11.66	8.79	1.40	0.57	11.04	0.03
11.71	8.16	1.30	0.53	11.94	0.03
11.66	7.52	1.20	0.49	12.90	0.02
11.64	6.90	1.10	0.45	14.03	0.03
11.66	6.28	1.00	0.41	15.44	0.03
11.67	5.66	0.90	0.37	17.16	0.05
11.70	5.03	0.80	0.32	19.37	0.04
11.63	4.39	0.70	0.29	22.03	0.04
11.71	3.77	0.60	0.24	25.83	0.07
11.73	3.14	0.50	0.20	31.06	0.07
11.72	2.51	0.40	0.16	38.82	0.09

Table L.16: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

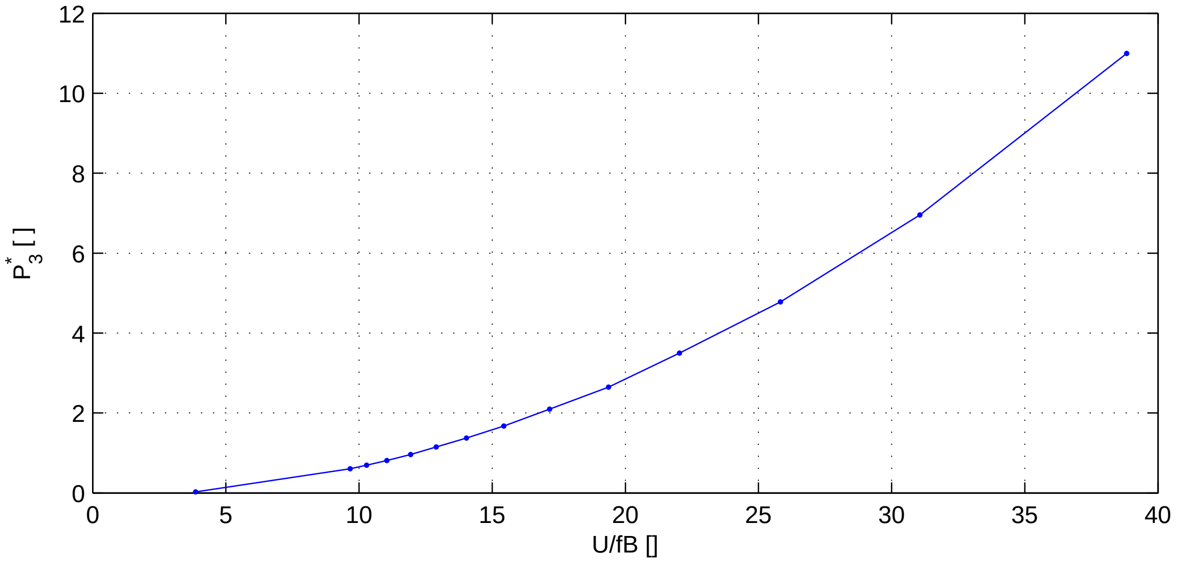

Figure L.15: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_3
11.67	25.13	4.00	1.63	3.86	0.02
11.68	10.05	1.60	0.65	9.67	0.60
11.67	9.45	1.50	0.61	10.28	0.69
11.66	8.79	1.40	0.57	11.04	0.81
11.71	8.16	1.30	0.53	11.94	0.96
11.66	7.52	1.20	0.49	12.90	1.15
11.64	6.90	1.10	0.45	14.03	1.37
11.66	6.28	1.00	0.41	15.44	1.67
11.67	5.66	0.90	0.37	17.16	2.10
11.70	5.03	0.80	0.32	19.37	2.65
11.63	4.39	0.70	0.29	22.03	3.50
11.71	3.77	0.60	0.24	25.83	4.78
11.73	3.14	0.50	0.20	31.06	6.96
11.72	2.51	0.40	0.16	38.82	11.00

Table L.17: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

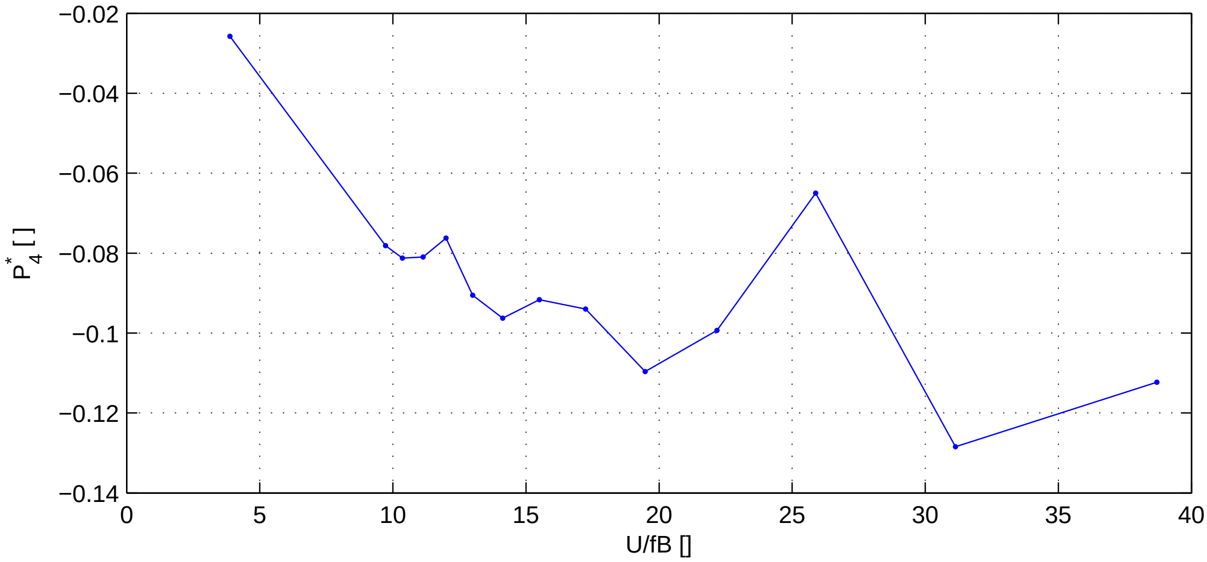

Figure L.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
11.71	25.13	4.00	1.62	3.88	−0.03
11.75	10.05	1.60	0.65	9.73	−0.08
11.76	9.45	1.50	0.61	10.36	−0.08
11.75	8.79	1.40	0.56	11.13	−0.08
11.76	8.16	1.30	0.52	11.99	−0.08
11.75	7.52	1.20	0.48	12.99	−0.09
11.72	6.90	1.10	0.44	14.13	−0.10
11.71	6.28	1.00	0.41	15.51	−0.09
11.72	5.66	0.90	0.36	17.24	−0.09
11.76	5.03	0.80	0.32	19.48	−0.11
11.71	4.39	0.70	0.28	22.17	−0.10
11.74	3.77	0.60	0.24	25.88	−0.07
11.76	3.14	0.50	0.20	31.14	−0.13
11.69	2.51	0.40	0.16	38.70	−0.11

Table L.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

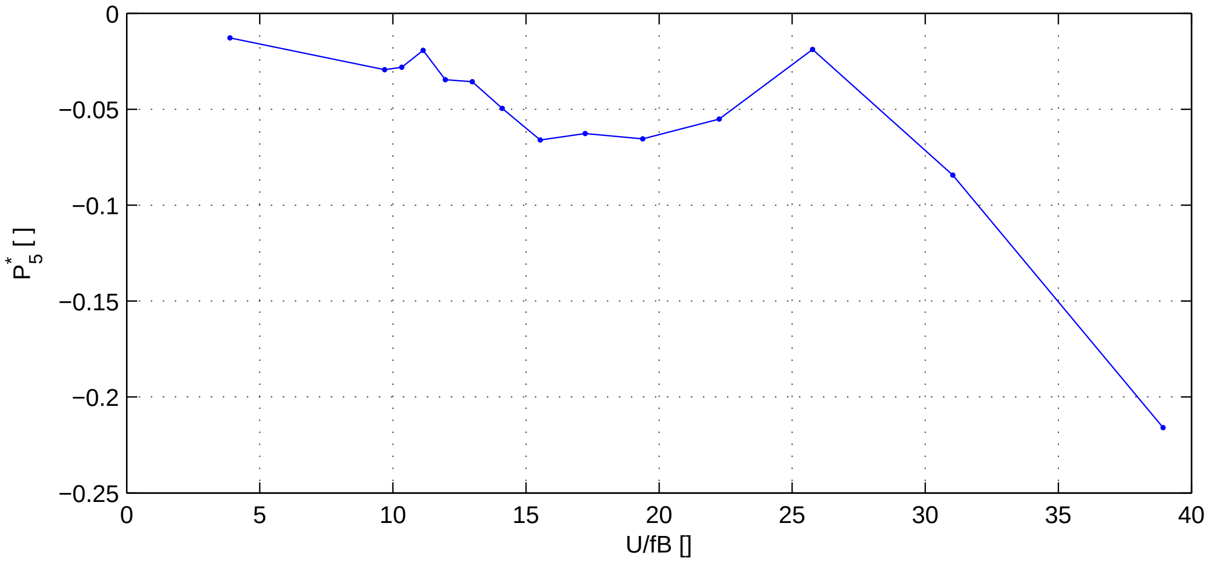

Figure L.17: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_5
11.72	25.13	4.00	1.62	3.88	−0.01
11.71	10.05	1.60	0.65	9.69	−0.03
11.73	9.45	1.50	0.61	10.33	−0.03
11.76	8.79	1.40	0.56	11.14	−0.02
11.74	8.16	1.30	0.52	11.97	−0.03
11.74	7.52	1.20	0.48	12.98	−0.04
11.70	6.90	1.10	0.45	14.11	−0.05
11.73	6.28	1.00	0.40	15.54	−0.07
11.71	5.66	0.90	0.36	17.22	−0.06
11.71	5.03	0.80	0.32	19.39	−0.07
11.75	4.39	0.70	0.28	22.26	−0.06
11.68	3.77	0.60	0.24	25.76	−0.02
11.72	3.14	0.50	0.20	31.03	−0.08
11.76	2.51	0.40	0.16	38.93	−0.22

Table L.19: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

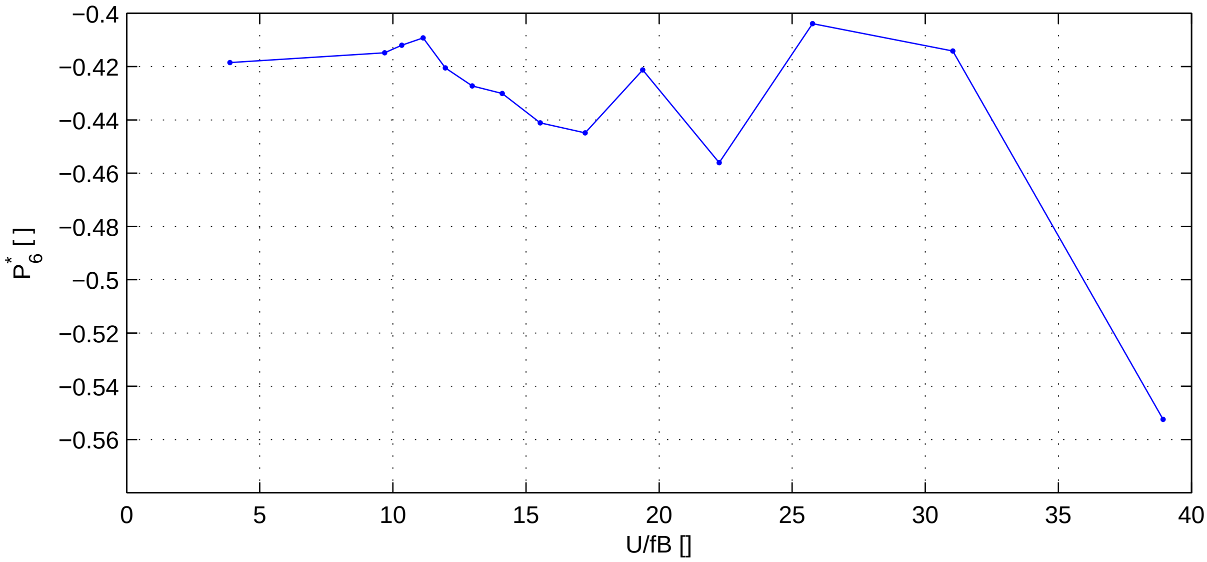

Figure L.18: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_6^*
11.72	25.13	4.00	1.62	3.88	−0.42
11.71	10.05	1.60	0.65	9.69	−0.41
11.73	9.45	1.50	0.61	10.33	−0.41
11.76	8.79	1.40	0.56	11.14	−0.41
11.74	8.16	1.30	0.52	11.97	−0.42
11.74	7.52	1.20	0.48	12.98	−0.43
11.70	6.90	1.10	0.45	14.11	−0.43
11.73	6.28	1.00	0.40	15.54	−0.44
11.71	5.66	0.90	0.36	17.22	−0.44
11.71	5.03	0.80	0.32	19.39	−0.42
11.75	4.39	0.70	0.28	22.26	−0.46
11.68	3.77	0.60	0.24	25.76	−0.40
11.72	3.14	0.50	0.20	31.03	−0.41
11.76	2.51	0.40	0.16	38.93	−0.55

Table L.20: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\,(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\,\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\,(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\,\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\,(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\,\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

Formula L.3: Equation of Motion (Stretto di Messina. Ref. [5].)

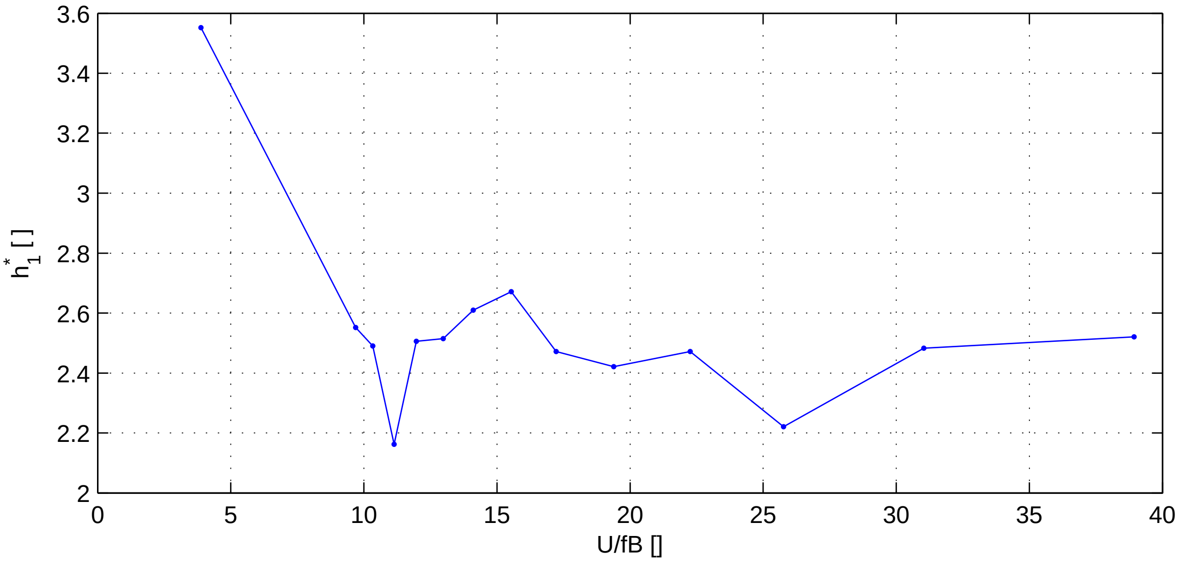


Figure L.19: h^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_1
11.72	25.13	4.00	1.62	3.88	3.55
11.71	10.05	1.60	0.65	9.69	2.55
11.73	9.45	1.50	0.61	10.33	2.49
11.76	8.79	1.40	0.56	11.14	2.16
11.74	8.16	1.30	0.52	11.97	2.51
11.74	7.52	1.20	0.48	12.98	2.51
11.70	6.90	1.10	0.45	14.11	2.61
11.73	6.28	1.00	0.40	15.54	2.67
11.71	5.66	0.90	0.36	17.22	2.47
11.71	5.03	0.80	0.32	19.39	2.42
11.75	4.39	0.70	0.28	22.26	2.47
11.68	3.77	0.60	0.24	25.76	2.22
11.72	3.14	0.50	0.20	31.03	2.48
11.76	2.51	0.40	0.16	38.93	2.52

Table L.21: h^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

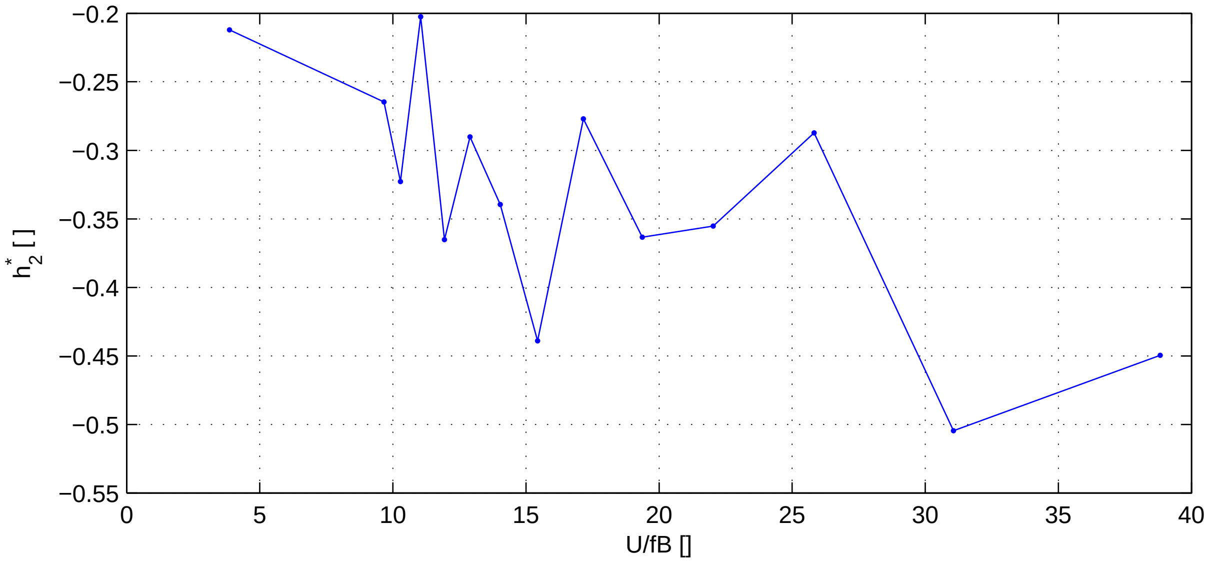


Figure L.20: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_2^*
11.67	25.13	4.00	1.63	3.86	−0.21
11.68	10.05	1.60	0.65	9.67	−0.26
11.67	9.45	1.50	0.61	10.28	−0.32
11.66	8.79	1.40	0.57	11.04	−0.20
11.71	8.16	1.30	0.53	11.94	−0.37
11.66	7.52	1.20	0.49	12.90	−0.29
11.64	6.90	1.10	0.45	14.03	−0.34
11.66	6.28	1.00	0.41	15.44	−0.44
11.67	5.66	0.90	0.37	17.16	−0.28
11.70	5.03	0.80	0.32	19.37	−0.36
11.63	4.39	0.70	0.29	22.03	−0.36
11.71	3.77	0.60	0.24	25.83	−0.29
11.73	3.14	0.50	0.20	31.06	−0.50
11.72	2.51	0.40	0.16	38.82	−0.45

Table L.22: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

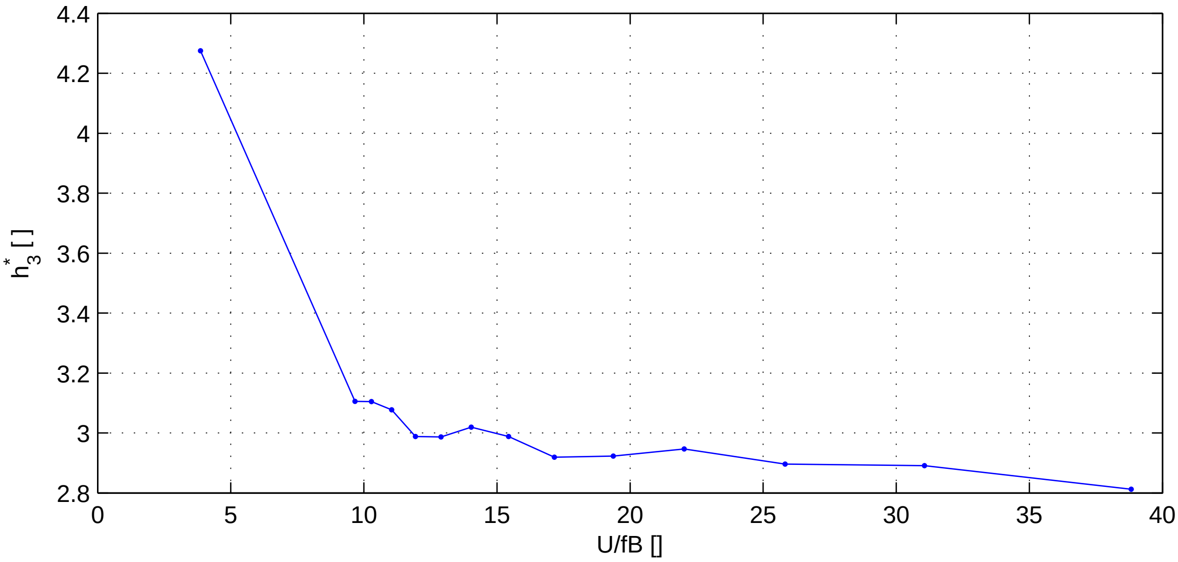


Figure L.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
11.67	25.13	4.00	1.63	3.86	4.28
11.68	10.05	1.60	0.65	9.67	3.11
11.67	9.45	1.50	0.61	10.28	3.10
11.66	8.79	1.40	0.57	11.04	3.08
11.71	8.16	1.30	0.53	11.94	2.99
11.66	7.52	1.20	0.49	12.90	2.99
11.64	6.90	1.10	0.45	14.03	3.02
11.66	6.28	1.00	0.41	15.44	2.99
11.67	5.66	0.90	0.37	17.16	2.92
11.70	5.03	0.80	0.32	19.37	2.92
11.63	4.39	0.70	0.29	22.03	2.95
11.71	3.77	0.60	0.24	25.83	2.90
11.73	3.14	0.50	0.20	31.06	2.89
11.72	2.51	0.40	0.16	38.82	2.81

Table L.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

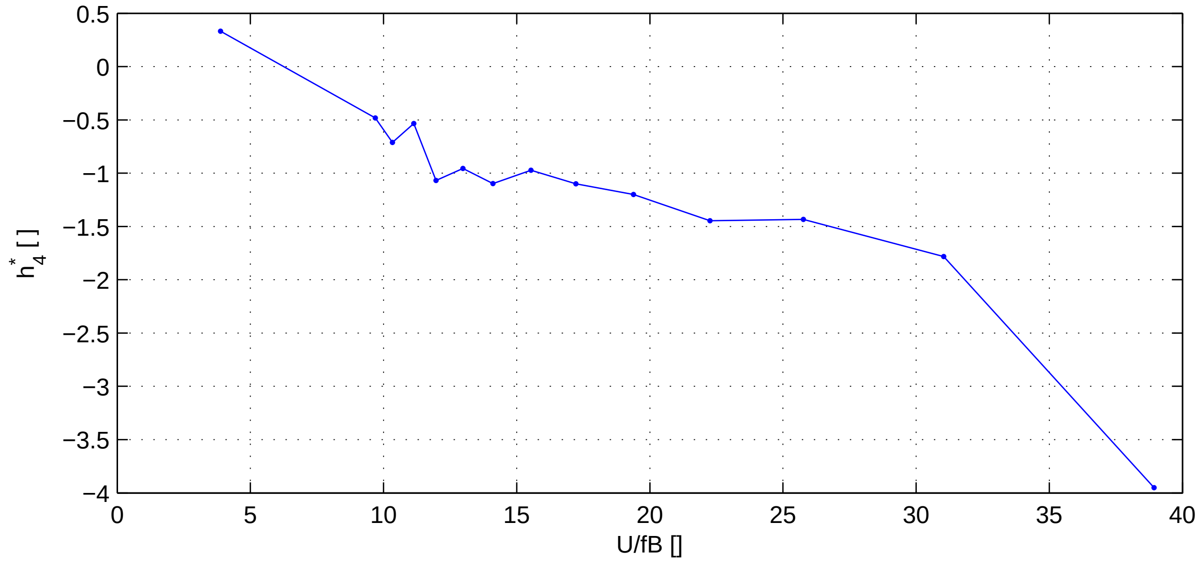


Figure L.22: h^*_4 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_4
11.72	25.13	4.00	1.62	3.88	0.33
11.71	10.05	1.60	0.65	9.69	−0.48
11.73	9.45	1.50	0.61	10.33	−0.71
11.76	8.79	1.40	0.56	11.14	−0.53
11.74	8.16	1.30	0.52	11.97	−1.07
11.74	7.52	1.20	0.48	12.98	−0.96
11.70	6.90	1.10	0.45	14.11	−1.10
11.73	6.28	1.00	0.40	15.54	−0.97
11.71	5.66	0.90	0.36	17.22	−1.10
11.71	5.03	0.80	0.32	19.39	−1.20
11.75	4.39	0.70	0.28	22.26	−1.45
11.68	3.77	0.60	0.24	25.76	−1.43
11.72	3.14	0.50	0.20	31.03	−1.78
11.76	2.51	0.40	0.16	38.93	−3.95

Table L.24: h^*_4 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:23:00

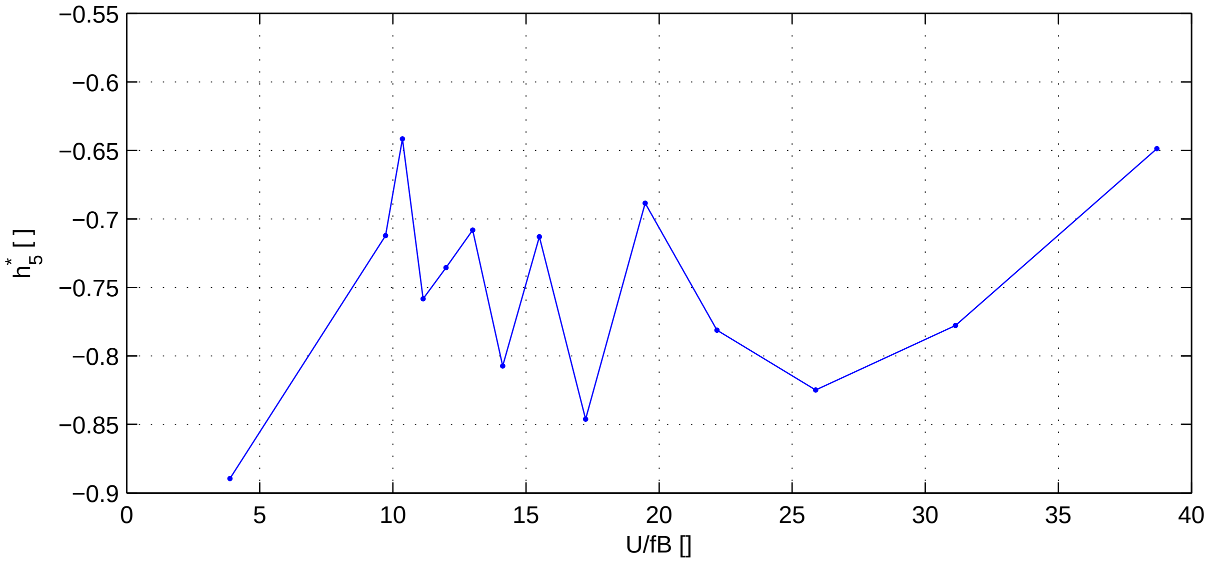


Figure L.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
11.71	25.13	4.00	1.62	3.88	−0.89
11.75	10.05	1.60	0.65	9.73	−0.71
11.76	9.45	1.50	0.61	10.36	−0.64
11.75	8.79	1.40	0.56	11.13	−0.76
11.76	8.16	1.30	0.52	11.99	−0.74
11.75	7.52	1.20	0.48	12.99	−0.71
11.72	6.90	1.10	0.44	14.13	−0.81
11.71	6.28	1.00	0.41	15.51	−0.71
11.72	5.66	0.90	0.36	17.24	−0.85
11.76	5.03	0.80	0.32	19.48	−0.69
11.71	4.39	0.70	0.28	22.17	−0.78
11.74	3.77	0.60	0.24	25.88	−0.82
11.76	3.14	0.50	0.20	31.14	−0.78
11.69	2.51	0.40	0.16	38.70	−0.65

Table L.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

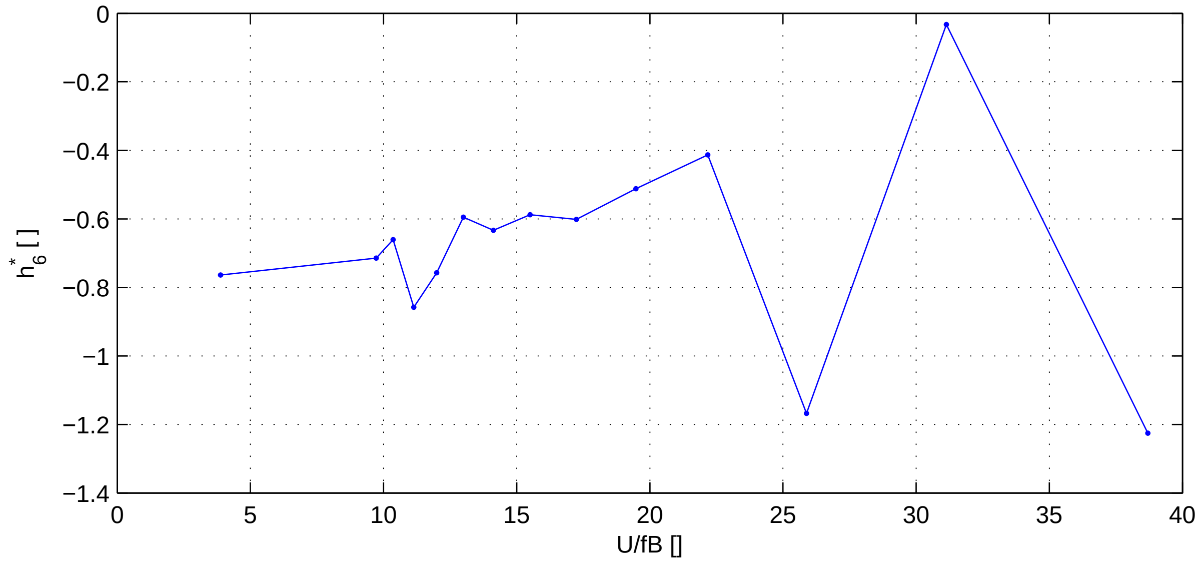


Figure L.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
11.71	25.13	4.00	1.62	3.88	−0.76
11.75	10.05	1.60	0.65	9.73	−0.71
11.76	9.45	1.50	0.61	10.36	−0.66
11.75	8.79	1.40	0.56	11.13	−0.86
11.76	8.16	1.30	0.52	11.99	−0.76
11.75	7.52	1.20	0.48	12.99	−0.60
11.72	6.90	1.10	0.44	14.13	−0.63
11.71	6.28	1.00	0.41	15.51	−0.59
11.72	5.66	0.90	0.36	17.24	−0.60
11.76	5.03	0.80	0.32	19.48	−0.51
11.71	4.39	0.70	0.28	22.17	−0.41
11.74	3.77	0.60	0.24	25.88	−1.17
11.76	3.14	0.50	0.20	31.14	−0.03
11.69	2.51	0.40	0.16	38.70	−1.23

Table L.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

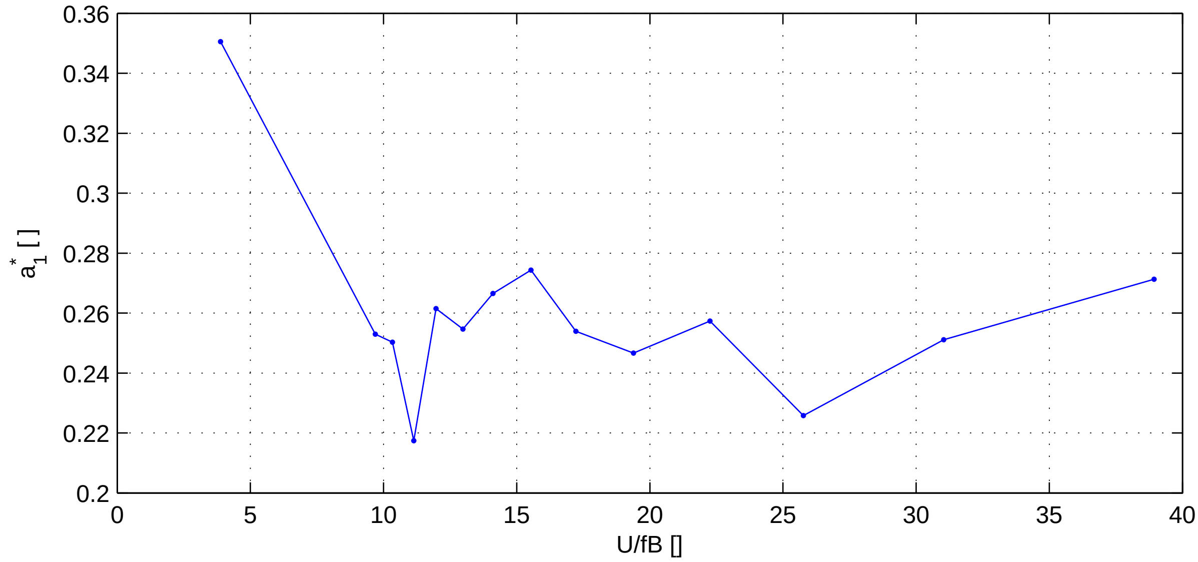


Figure L.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
11.72	25.13	4.00	1.62	3.88	0.35
11.71	10.05	1.60	0.65	9.69	0.25
11.73	9.45	1.50	0.61	10.33	0.25
11.76	8.79	1.40	0.56	11.14	0.22
11.74	8.16	1.30	0.52	11.97	0.26
11.74	7.52	1.20	0.48	12.98	0.25
11.70	6.90	1.10	0.45	14.11	0.27
11.73	6.28	1.00	0.40	15.54	0.27
11.71	5.66	0.90	0.36	17.22	0.25
11.71	5.03	0.80	0.32	19.39	0.25
11.75	4.39	0.70	0.28	22.26	0.26
11.68	3.77	0.60	0.24	25.76	0.23
11.72	3.14	0.50	0.20	31.03	0.25
11.76	2.51	0.40	0.16	38.93	0.27

Table L.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

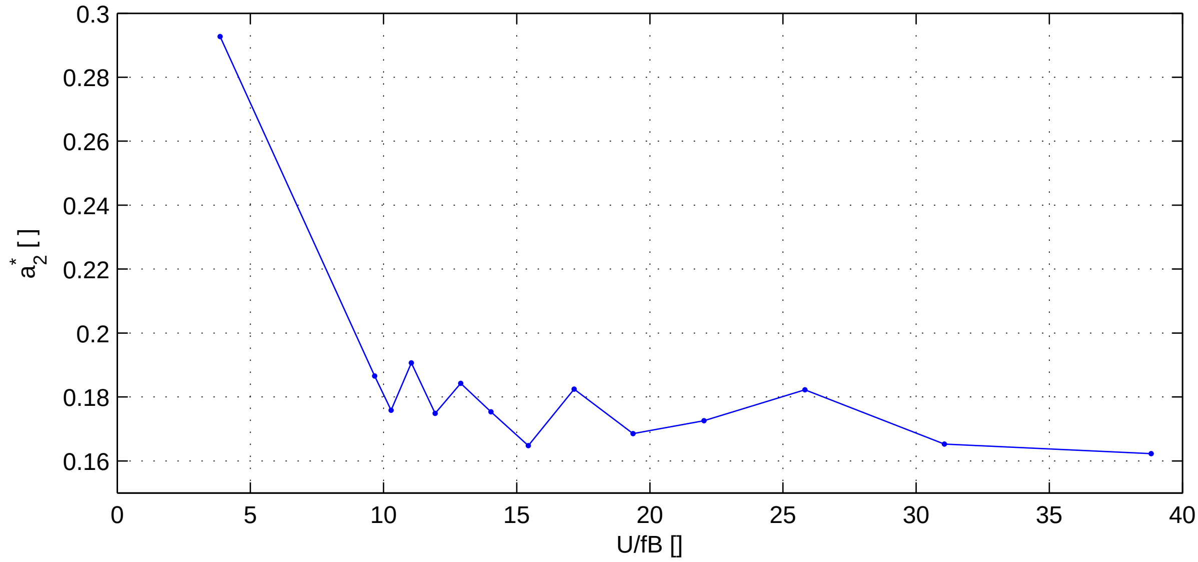


Figure L.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
11.67	25.13	4.00	1.63	3.86	0.29
11.68	10.05	1.60	0.65	9.67	0.19
11.67	9.45	1.50	0.61	10.28	0.18
11.66	8.79	1.40	0.57	11.04	0.19
11.71	8.16	1.30	0.53	11.94	0.17
11.66	7.52	1.20	0.49	12.90	0.18
11.64	6.90	1.10	0.45	14.03	0.18
11.66	6.28	1.00	0.41	15.44	0.16
11.67	5.66	0.90	0.37	17.16	0.18
11.70	5.03	0.80	0.32	19.37	0.17
11.63	4.39	0.70	0.29	22.03	0.17
11.71	3.77	0.60	0.24	25.83	0.18
11.73	3.14	0.50	0.20	31.06	0.17
11.72	2.51	0.40	0.16	38.82	0.16

Table L.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:23:00

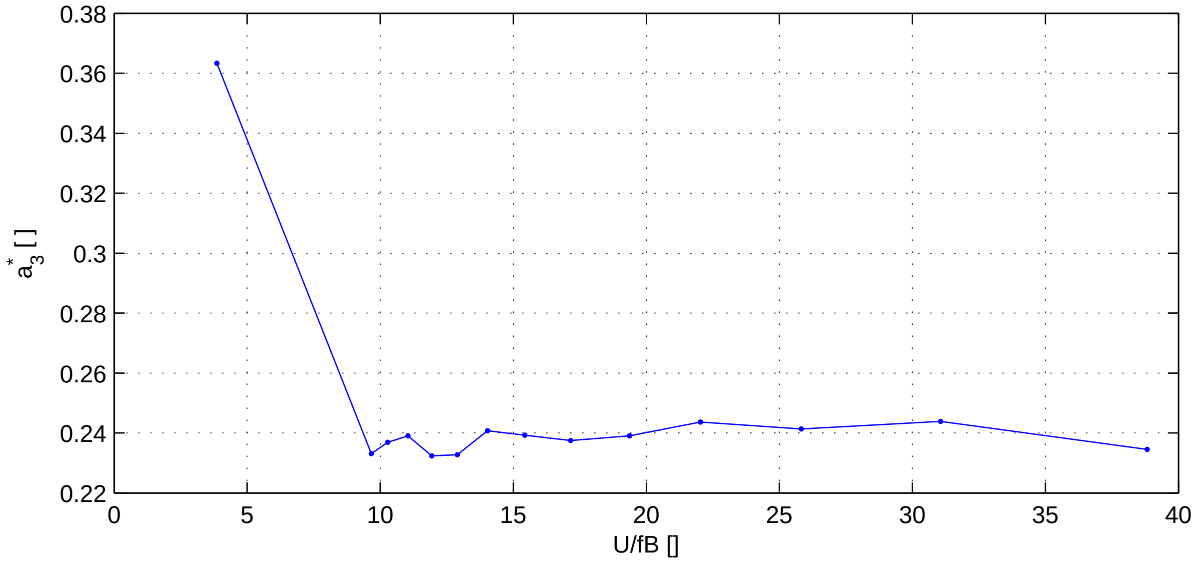


Figure L.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
11.67	25.13	4.00	1.63	3.86	0.36
11.68	10.05	1.60	0.65	9.67	0.23
11.67	9.45	1.50	0.61	10.28	0.24
11.66	8.79	1.40	0.57	11.04	0.24
11.71	8.16	1.30	0.53	11.94	0.23
11.66	7.52	1.20	0.49	12.90	0.23
11.64	6.90	1.10	0.45	14.03	0.24
11.66	6.28	1.00	0.41	15.44	0.24
11.67	5.66	0.90	0.37	17.16	0.24
11.70	5.03	0.80	0.32	19.37	0.24
11.63	4.39	0.70	0.29	22.03	0.24
11.71	3.77	0.60	0.24	25.83	0.24
11.73	3.14	0.50	0.20	31.06	0.24
11.72	2.51	0.40	0.16	38.82	0.23

Table L.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:23:00

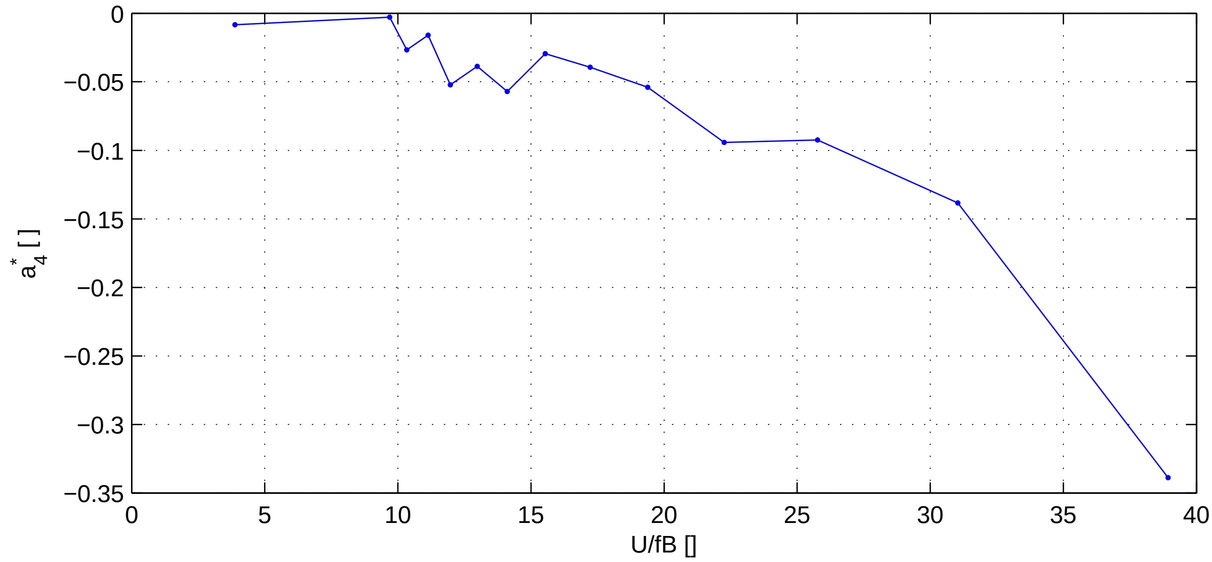


Figure L.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
11.72	25.13	4.00	1.62	3.88	−0.01
11.71	10.05	1.60	0.65	9.69	−0.00
11.73	9.45	1.50	0.61	10.33	−0.03
11.76	8.79	1.40	0.56	11.14	−0.02
11.74	8.16	1.30	0.52	11.97	−0.05
11.74	7.52	1.20	0.48	12.98	−0.04
11.70	6.90	1.10	0.45	14.11	−0.06
11.73	6.28	1.00	0.40	15.54	−0.03
11.71	5.66	0.90	0.36	17.22	−0.04
11.71	5.03	0.80	0.32	19.39	−0.05
11.75	4.39	0.70	0.28	22.26	−0.09
11.68	3.77	0.60	0.24	25.76	−0.09
11.72	3.14	0.50	0.20	31.03	−0.14
11.76	2.51	0.40	0.16	38.93	−0.34

Table L.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

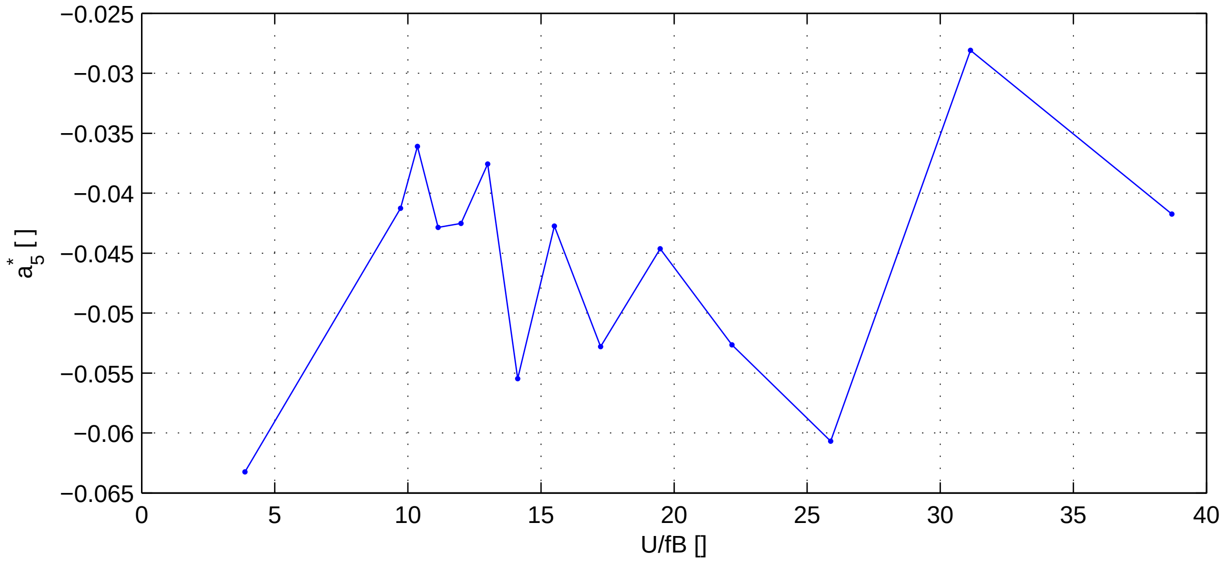


Figure L.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
11.71	25.13	4.00	1.62	3.88	−0.06
11.75	10.05	1.60	0.65	9.73	−0.04
11.76	9.45	1.50	0.61	10.36	−0.04
11.75	8.79	1.40	0.56	11.13	−0.04
11.76	8.16	1.30	0.52	11.99	−0.04
11.75	7.52	1.20	0.48	12.99	−0.04
11.72	6.90	1.10	0.44	14.13	−0.06
11.71	6.28	1.00	0.41	15.51	−0.04
11.72	5.66	0.90	0.36	17.24	−0.05
11.76	5.03	0.80	0.32	19.48	−0.04
11.71	4.39	0.70	0.28	22.17	−0.05
11.74	3.77	0.60	0.24	25.88	−0.06
11.76	3.14	0.50	0.20	31.14	−0.03
11.69	2.51	0.40	0.16	38.70	−0.04

Table L.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

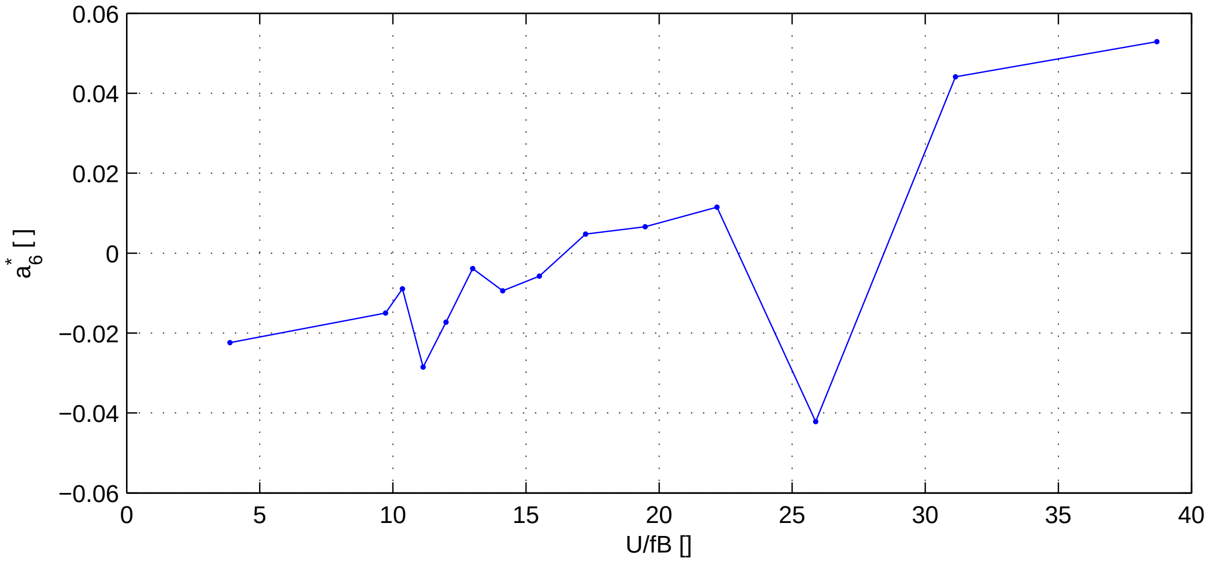


Figure L.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
11.71	25.13	4.00	1.62	3.88	−0.02
11.75	10.05	1.60	0.65	9.73	−0.02
11.76	9.45	1.50	0.61	10.36	−0.01
11.75	8.79	1.40	0.56	11.13	−0.03
11.76	8.16	1.30	0.52	11.99	−0.02
11.75	7.52	1.20	0.48	12.99	−0.00
11.72	6.90	1.10	0.44	14.13	−0.01
11.71	6.28	1.00	0.41	15.51	−0.01
11.72	5.66	0.90	0.36	17.24	0.00
11.76	5.03	0.80	0.32	19.48	0.01
11.71	4.39	0.70	0.28	22.17	0.01
11.74	3.77	0.60	0.24	25.88	−0.04
11.76	3.14	0.50	0.20	31.14	0.04
11.69	2.51	0.40	0.16	38.70	0.05

Table L.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

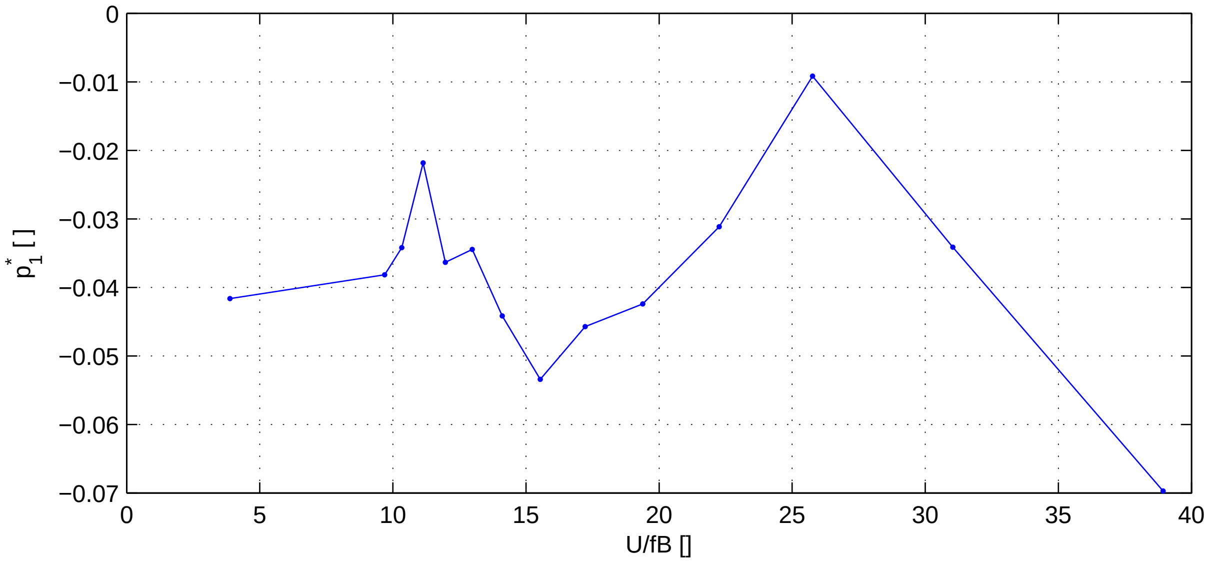


Figure L.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
11.72	25.13	4.00	1.62	3.88	−0.04
11.71	10.05	1.60	0.65	9.69	−0.04
11.73	9.45	1.50	0.61	10.33	−0.03
11.76	8.79	1.40	0.56	11.14	−0.02
11.74	8.16	1.30	0.52	11.97	−0.04
11.74	7.52	1.20	0.48	12.98	−0.03
11.70	6.90	1.10	0.45	14.11	−0.04
11.73	6.28	1.00	0.40	15.54	−0.05
11.71	5.66	0.90	0.36	17.22	−0.05
11.71	5.03	0.80	0.32	19.39	−0.04
11.75	4.39	0.70	0.28	22.26	−0.03
11.68	3.77	0.60	0.24	25.76	−0.01
11.72	3.14	0.50	0.20	31.03	−0.03
11.76	2.51	0.40	0.16	38.93	−0.07

Table L.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

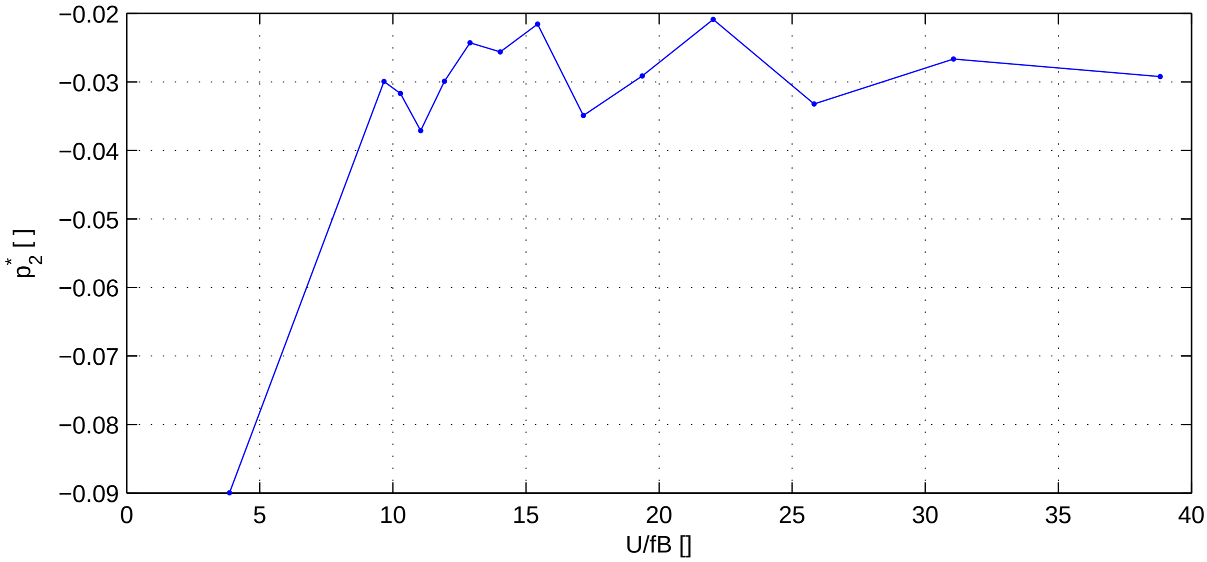


Figure L.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
11.67	25.13	4.00	1.63	3.86	−0.09
11.68	10.05	1.60	0.65	9.67	−0.03
11.67	9.45	1.50	0.61	10.28	−0.03
11.66	8.79	1.40	0.57	11.04	−0.04
11.71	8.16	1.30	0.53	11.94	−0.03
11.66	7.52	1.20	0.49	12.90	−0.02
11.64	6.90	1.10	0.45	14.03	−0.03
11.66	6.28	1.00	0.41	15.44	−0.02
11.67	5.66	0.90	0.37	17.16	−0.03
11.70	5.03	0.80	0.32	19.37	−0.03
11.63	4.39	0.70	0.29	22.03	−0.02
11.71	3.77	0.60	0.24	25.83	−0.03
11.73	3.14	0.50	0.20	31.06	−0.03
11.72	2.51	0.40	0.16	38.82	−0.03

Table L.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:23:00

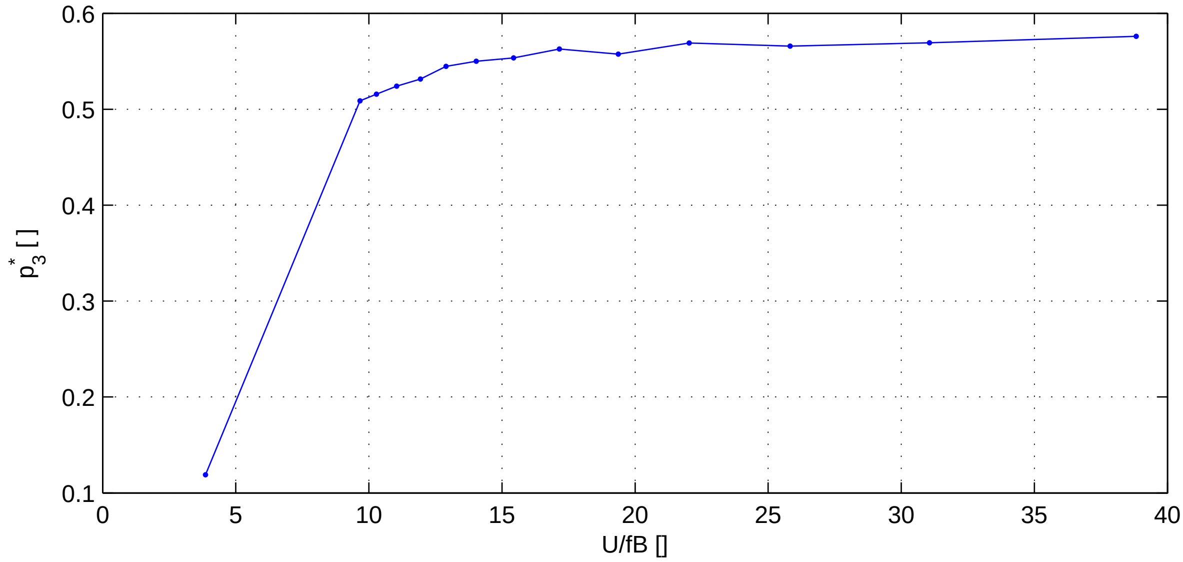


Figure L.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
11.67	25.13	4.00	1.63	3.86	0.12
11.68	10.05	1.60	0.65	9.67	0.51
11.67	9.45	1.50	0.61	10.28	0.52
11.66	8.79	1.40	0.57	11.04	0.52
11.71	8.16	1.30	0.53	11.94	0.53
11.66	7.52	1.20	0.49	12.90	0.54
11.64	6.90	1.10	0.45	14.03	0.55
11.66	6.28	1.00	0.41	15.44	0.55
11.67	5.66	0.90	0.37	17.16	0.56
11.70	5.03	0.80	0.32	19.37	0.56
11.63	4.39	0.70	0.29	22.03	0.57
11.71	3.77	0.60	0.24	25.83	0.57
11.73	3.14	0.50	0.20	31.06	0.57
11.72	2.51	0.40	0.16	38.82	0.58

Table L.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:23:00

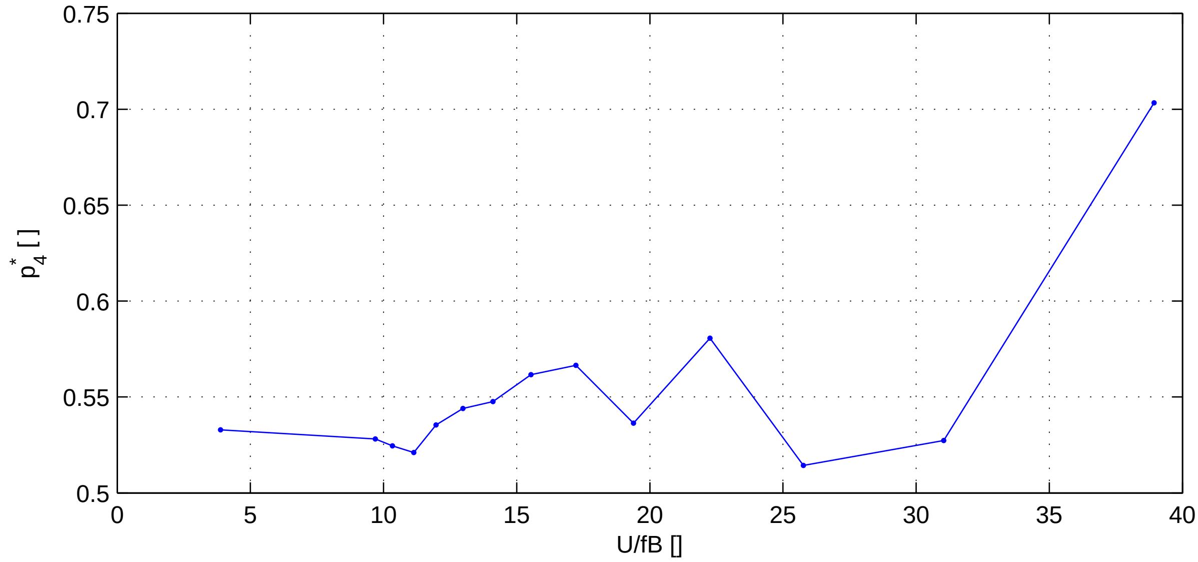


Figure L.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
11.72	25.13	4.00	1.62	3.88	0.53
11.71	10.05	1.60	0.65	9.69	0.53
11.73	9.45	1.50	0.61	10.33	0.52
11.76	8.79	1.40	0.56	11.14	0.52
11.74	8.16	1.30	0.52	11.97	0.54
11.74	7.52	1.20	0.48	12.98	0.54
11.70	6.90	1.10	0.45	14.11	0.55
11.73	6.28	1.00	0.40	15.54	0.56
11.71	5.66	0.90	0.36	17.22	0.57
11.71	5.03	0.80	0.32	19.39	0.54
11.75	4.39	0.70	0.28	22.26	0.58
11.68	3.77	0.60	0.24	25.76	0.51
11.72	3.14	0.50	0.20	31.03	0.53
11.76	2.51	0.40	0.16	38.93	0.70

Table L.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:23:00

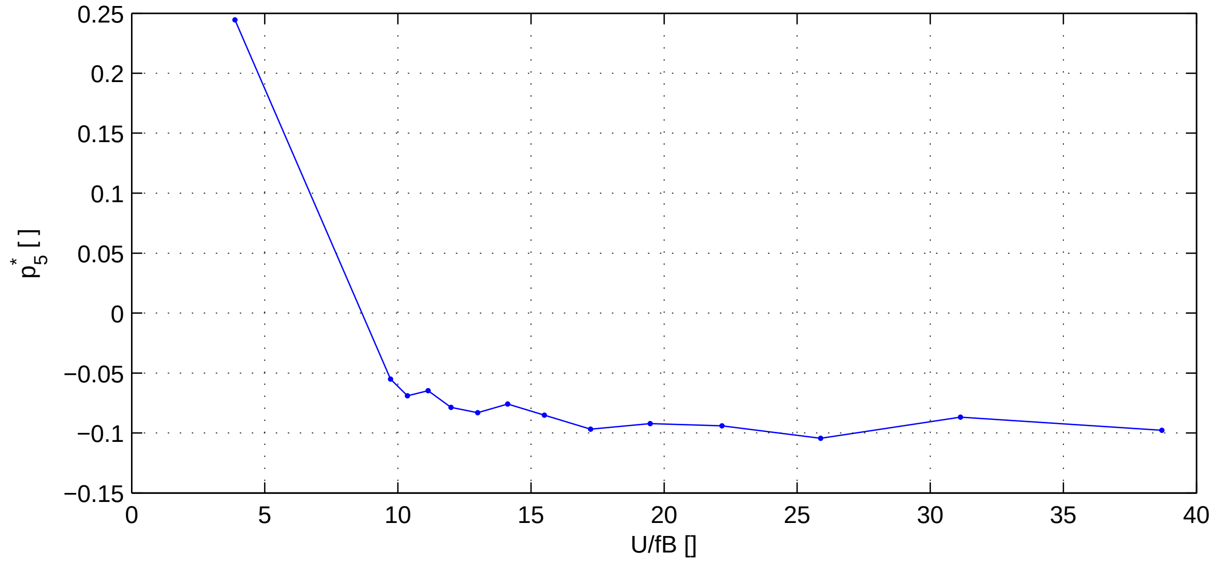


Figure L.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:23:00

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
11.71	25.13	4.00	1.62	3.88	0.24
11.75	10.05	1.60	0.65	9.73	−0.06
11.76	9.45	1.50	0.61	10.36	−0.07
11.75	8.79	1.40	0.56	11.13	−0.06
11.76	8.16	1.30	0.52	11.99	−0.08
11.75	7.52	1.20	0.48	12.99	−0.08
11.72	6.90	1.10	0.44	14.13	−0.08
11.71	6.28	1.00	0.41	15.51	−0.09
11.72	5.66	0.90	0.36	17.24	−0.10
11.76	5.03	0.80	0.32	19.48	−0.09
11.71	4.39	0.70	0.28	22.17	−0.09
11.74	3.77	0.60	0.24	25.88	−0.10
11.76	3.14	0.50	0.20	31.14	−0.09
11.69	2.51	0.40	0.16	38.70	−0.10

Table L.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

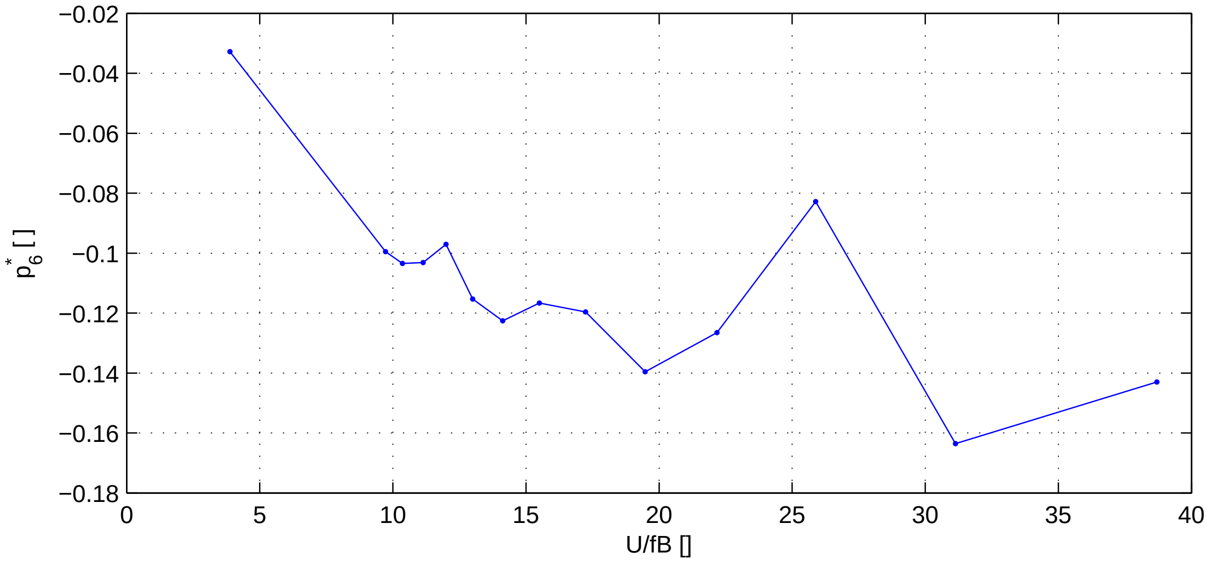


Figure L.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
11.71	25.13	4.00	1.62	3.88	−0.03
11.75	10.05	1.60	0.65	9.73	−0.10
11.76	9.45	1.50	0.61	10.36	−0.10
11.75	8.79	1.40	0.56	11.13	−0.10
11.76	8.16	1.30	0.52	11.99	−0.10
11.75	7.52	1.20	0.48	12.99	−0.12
11.72	6.90	1.10	0.44	14.13	−0.12
11.71	6.28	1.00	0.41	15.51	−0.12
11.72	5.66	0.90	0.36	17.24	−0.12
11.76	5.03	0.80	0.32	19.48	−0.14
11.71	4.39	0.70	0.28	22.17	−0.13
11.74	3.77	0.60	0.24	25.88	−0.08
11.76	3.14	0.50	0.20	31.14	−0.16
11.69	2.51	0.40	0.16	38.70	−0.14

Table L.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

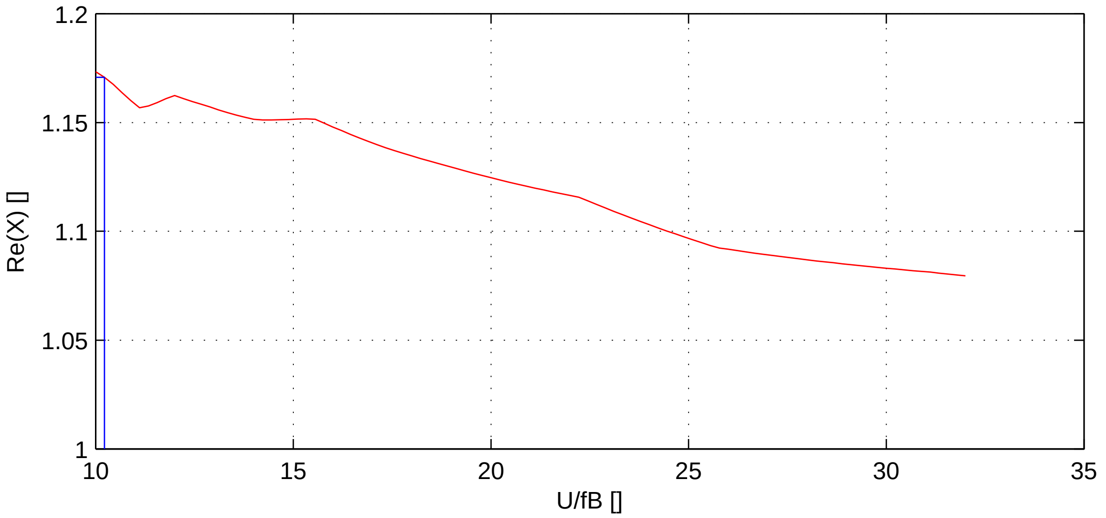


Figure L.37: Real part of the solution to stability equantion

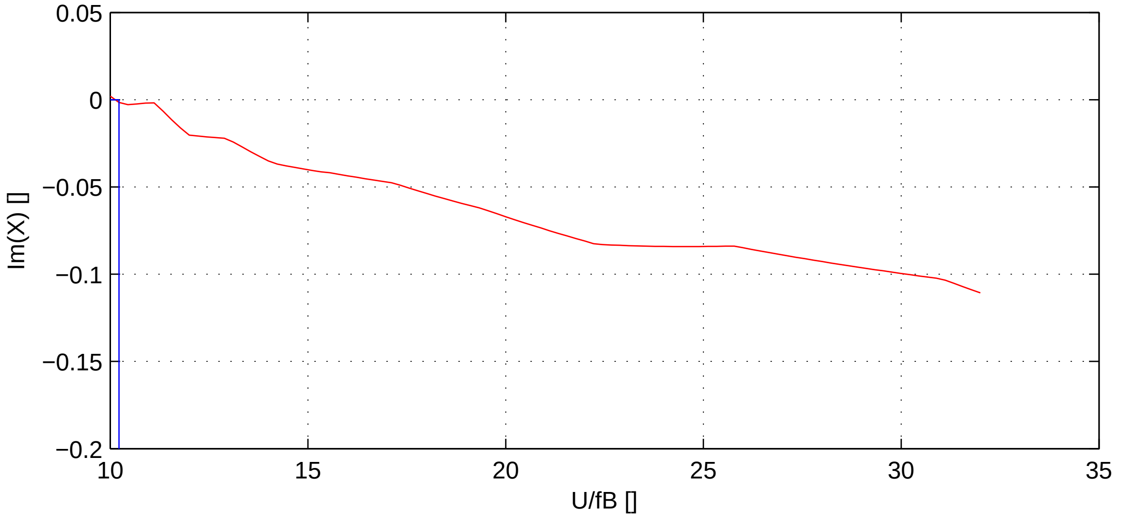


Figure L.38: Imaginary part of the solution to stability equantion

V_{Crit} = 10.2

f_{Crit} = 0.0758 Hz

U_{Crit} = 46.8 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.
[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.
[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.
[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.
[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix M

3D Flutter Tests

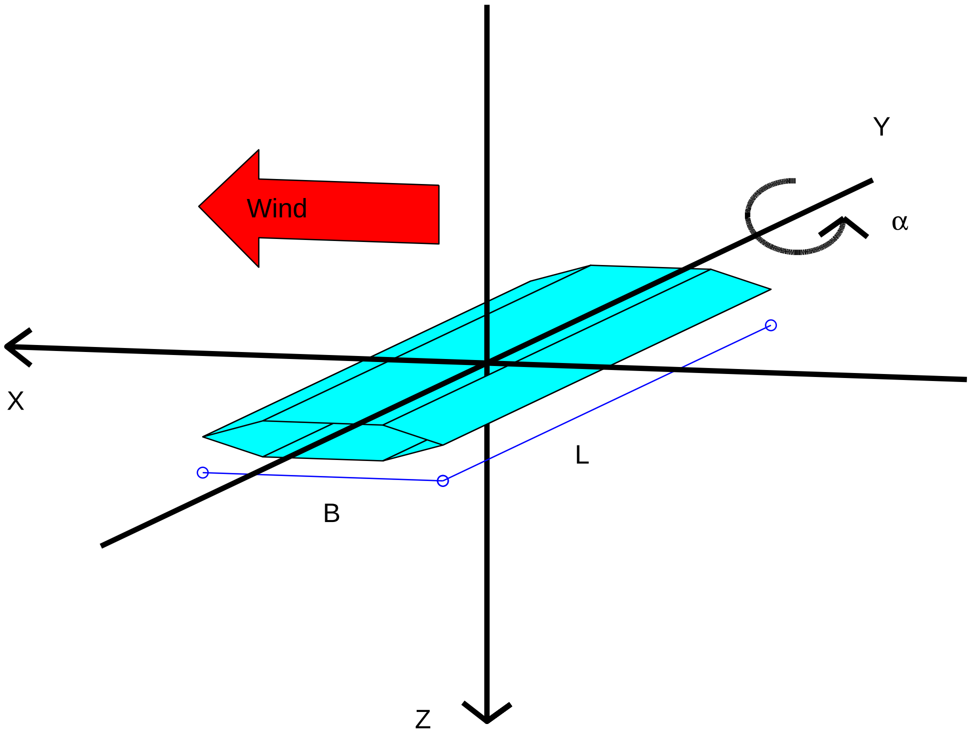
Flutter derivatives, Erection stage, Turbulent flow, Angle of incidence = −2 deg

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	°C	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1019.0

Table M.1: Project Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2\,m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2\,m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2\,m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h : Vertical displacement, displacement along z-axis, [m]
α : Rotation around y-axis, nose up is positive, [rad]
p : Horizontal displacement, displacement along the x-axis, [m]
m : Mass per unit length, [kg/m]
I_y : Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$: Added mass in vertical direction, [kg/m]
$m_{a,x}$: Added mass in horizontal direction, [kg/m]
$I_{a,y}$: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G : X-coordinate for centre of gravity, [m]
Z_G : Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$: Natural circular frequency for vertical motion, [/s]
ζ_h : Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$: Natural circular frequency for rotation around y axis, [/s]
ζ_α : Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p : Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$: Force from rig per meter section, [N/m]
$M_{Y,external}$: Moment from rig per meter section, [Nm/m]
$F_{X,external}$: Force from rig per meter section, [N/m]

Formula M.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.630
Added mass in horizontal	$m_{a,x}$	kg/m	0.575
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.152
Horizontal centre of gravity	x_G	m	−0.000
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.292
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.162
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.139

Table M.2: Mechanical Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula M.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

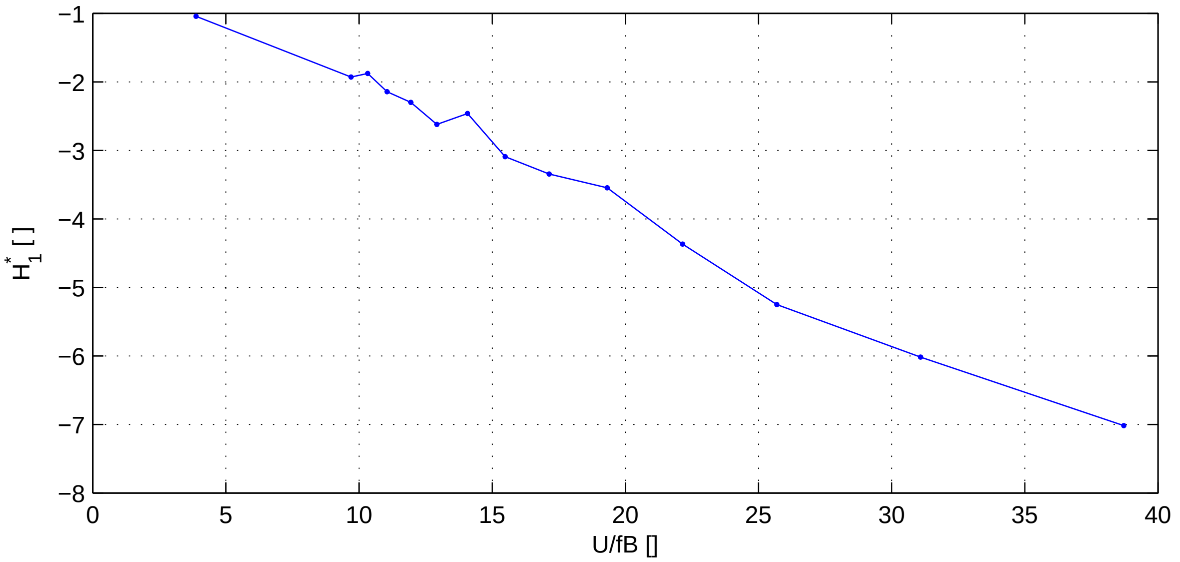


Figure M.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
11.70	25.13	4.00	1.62	3.87	−1.04
11.71	10.05	1.60	0.65	9.70	−1.93
11.72	9.45	1.50	0.61	10.33	−1.88
11.67	8.79	1.40	0.57	11.06	−2.14
11.71	8.16	1.30	0.53	11.94	−2.30
11.69	7.52	1.20	0.49	12.92	−2.62
11.68	6.90	1.10	0.45	14.07	−2.46
11.70	6.28	1.00	0.41	15.49	−3.09
11.66	5.66	0.90	0.37	17.14	−3.35
11.67	5.03	0.80	0.33	19.32	−3.55
11.70	4.39	0.70	0.28	22.15	−4.37
11.65	3.77	0.60	0.24	25.69	−5.25
11.74	3.14	0.50	0.20	31.09	−6.02
11.69	2.51	0.40	0.16	38.72	−7.02

Table M.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

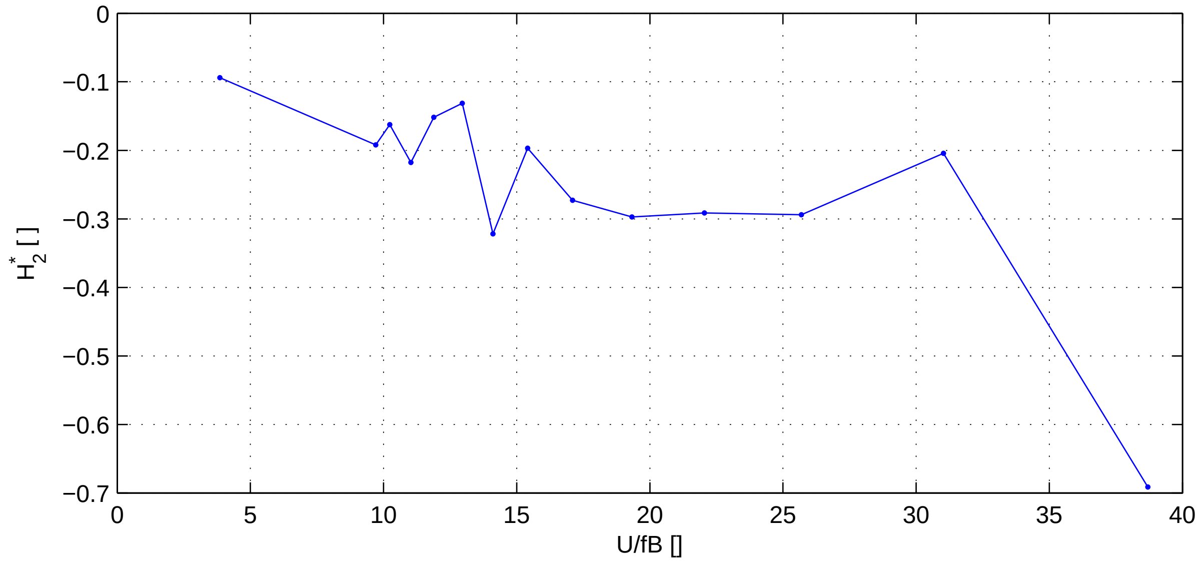


Figure M.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
11.65	25.13	4.00	1.63	3.86	−0.09
11.72	10.05	1.60	0.65	9.71	−0.19
11.62	9.45	1.50	0.61	10.23	−0.16
11.64	8.79	1.40	0.57	11.02	−0.22
11.65	8.16	1.30	0.53	11.88	−0.15
11.71	7.52	1.20	0.49	12.95	−0.13
11.70	6.90	1.10	0.45	14.11	−0.32
11.64	6.28	1.00	0.41	15.41	−0.20
11.63	5.66	0.90	0.37	17.10	−0.27
11.68	5.03	0.80	0.33	19.33	−0.30
11.64	4.39	0.70	0.28	22.05	−0.29
11.65	3.77	0.60	0.24	25.69	−0.29
11.71	3.14	0.50	0.20	31.03	−0.20
11.69	2.51	0.40	0.16	38.70	−0.69

Table M.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

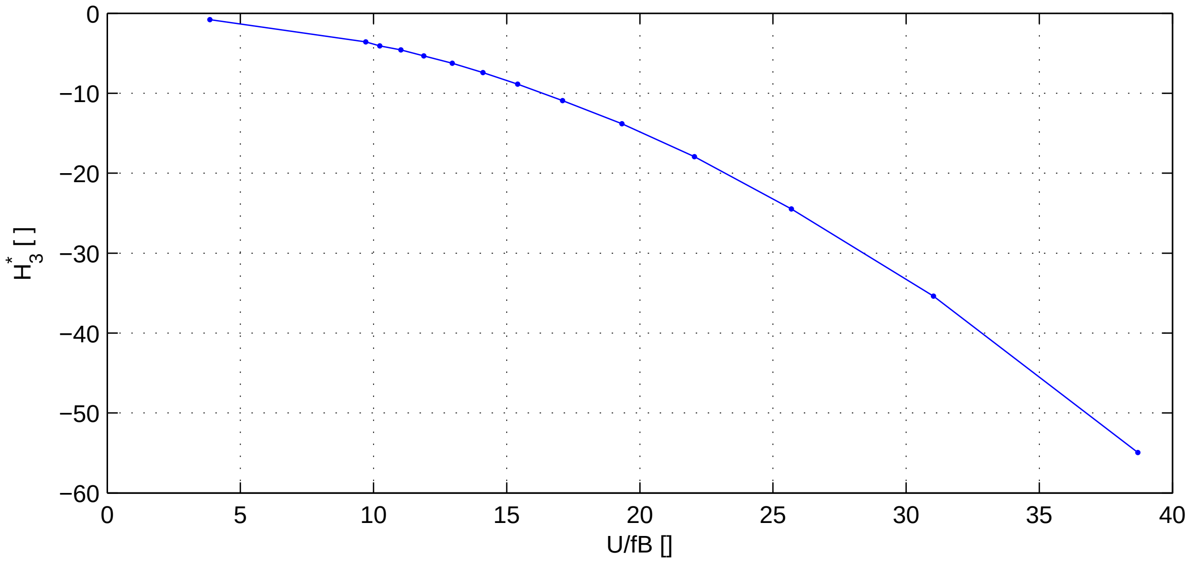


Figure M.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
11.65	25.13	4.00	1.63	3.86	−0.78
11.72	10.05	1.60	0.65	9.71	−3.58
11.62	9.45	1.50	0.61	10.23	−4.07
11.64	8.79	1.40	0.57	11.02	−4.59
11.65	8.16	1.30	0.53	11.88	−5.32
11.71	7.52	1.20	0.49	12.95	−6.26
11.70	6.90	1.10	0.45	14.11	−7.42
11.64	6.28	1.00	0.41	15.41	−8.87
11.63	5.66	0.90	0.37	17.10	−10.93
11.68	5.03	0.80	0.33	19.33	−13.82
11.64	4.39	0.70	0.28	22.05	−17.94
11.65	3.77	0.60	0.24	25.69	−24.49
11.71	3.14	0.50	0.20	31.03	−35.39
11.69	2.51	0.40	0.16	38.70	−54.96

Table M.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

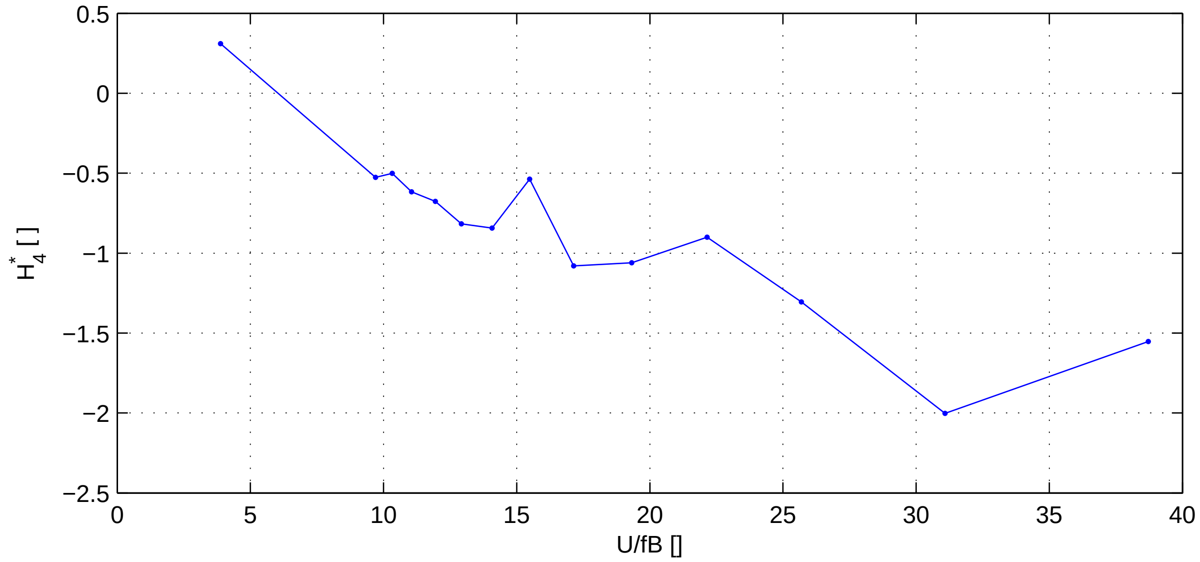


Figure M.4: H^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_4
11.70	25.13	4.00	1.62	3.87	0.31
11.71	10.05	1.60	0.65	9.70	−0.53
11.72	9.45	1.50	0.61	10.33	−0.50
11.67	8.79	1.40	0.57	11.06	−0.62
11.71	8.16	1.30	0.53	11.94	−0.68
11.69	7.52	1.20	0.49	12.92	−0.82
11.68	6.90	1.10	0.45	14.07	−0.84
11.70	6.28	1.00	0.41	15.49	−0.54
11.66	5.66	0.90	0.37	17.14	−1.08
11.67	5.03	0.80	0.33	19.32	−1.06
11.70	4.39	0.70	0.28	22.15	−0.90
11.65	3.77	0.60	0.24	25.69	−1.31
11.74	3.14	0.50	0.20	31.09	−2.00
11.69	2.51	0.40	0.16	38.72	−1.55

Table M.6: H^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

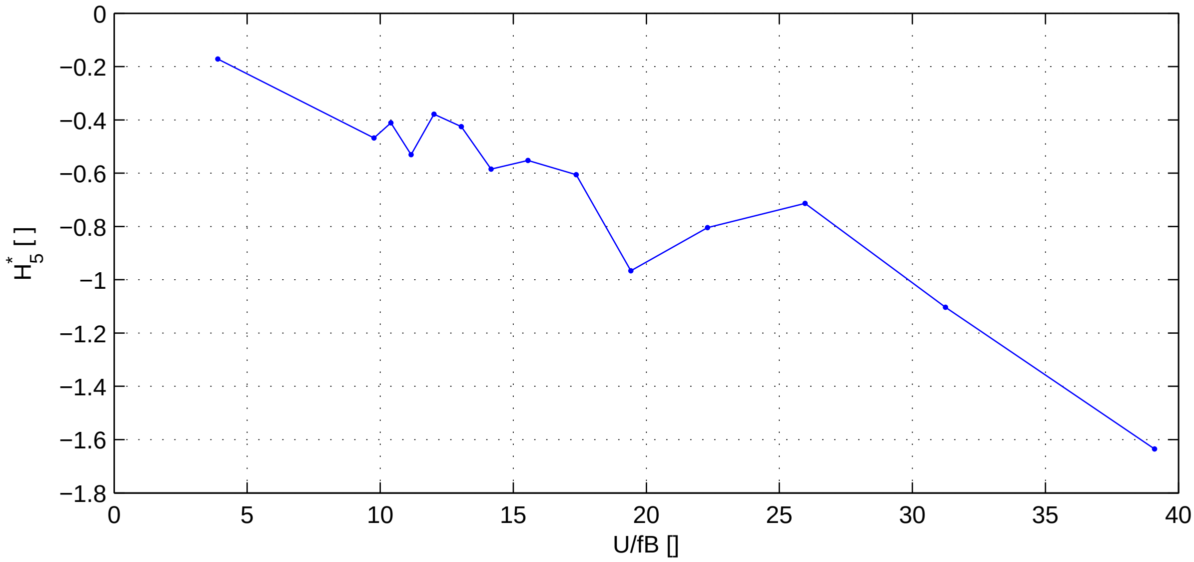


Figure M.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
11.76	25.13	4.00	1.61	3.89	−0.17
11.80	10.05	1.60	0.64	9.77	−0.47
11.81	9.45	1.50	0.60	10.40	−0.41
11.79	8.79	1.40	0.56	11.16	−0.53
11.79	8.16	1.30	0.52	12.02	−0.38
11.80	7.52	1.20	0.48	13.05	−0.43
11.76	6.90	1.10	0.44	14.17	−0.58
11.74	6.28	1.00	0.40	15.55	−0.55
11.81	5.66	0.90	0.36	17.36	−0.61
11.73	5.03	0.80	0.32	19.42	−0.97
11.78	4.39	0.70	0.28	22.30	−0.80
11.77	3.77	0.60	0.24	25.96	−0.71
11.80	3.14	0.50	0.20	31.25	−1.10
11.81	2.51	0.40	0.16	39.11	−1.64

Table M.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

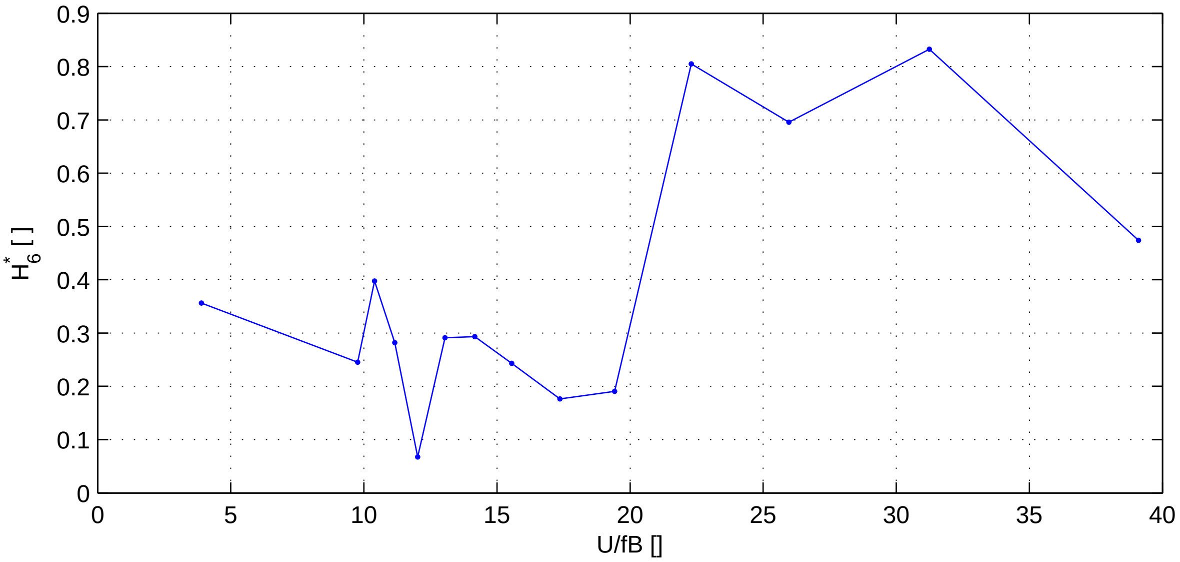


Figure M.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
11.76	25.13	4.00	1.61	3.89	0.36
11.80	10.05	1.60	0.64	9.77	0.25
11.81	9.45	1.50	0.60	10.40	0.40
11.79	8.79	1.40	0.56	11.16	0.28
11.79	8.16	1.30	0.52	12.02	0.07
11.80	7.52	1.20	0.48	13.05	0.29
11.76	6.90	1.10	0.44	14.17	0.29
11.74	6.28	1.00	0.40	15.55	0.24
11.81	5.66	0.90	0.36	17.36	0.18
11.73	5.03	0.80	0.32	19.42	0.19
11.78	4.39	0.70	0.28	22.30	0.80
11.77	3.77	0.60	0.24	25.96	0.70
11.80	3.14	0.50	0.20	31.25	0.83
11.81	2.51	0.40	0.16	39.11	0.47

Table M.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

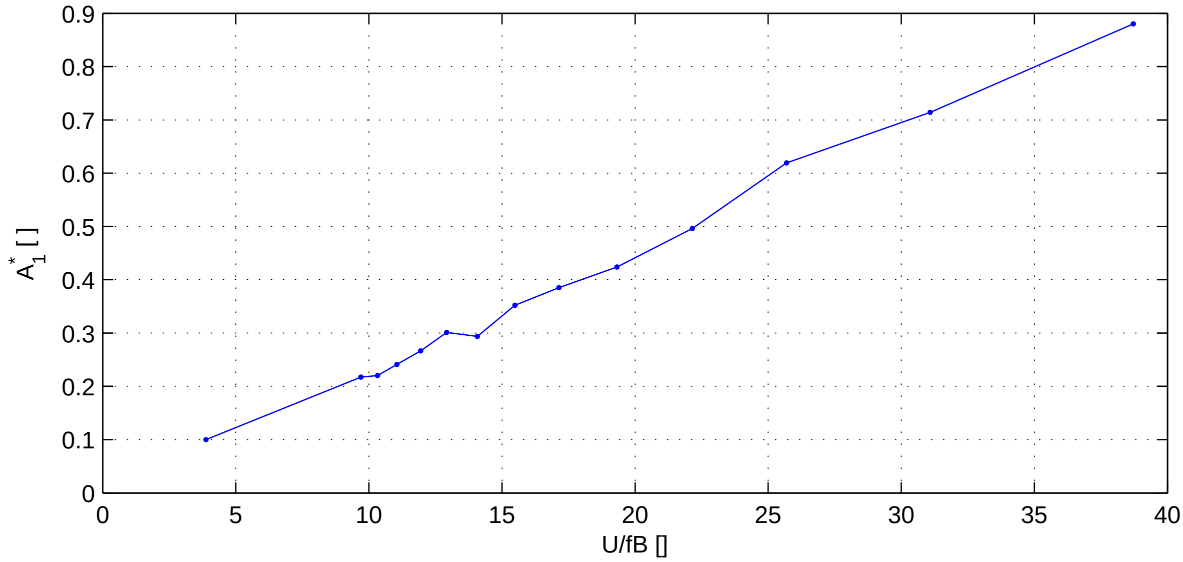


Figure M.7: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_1^*
11.70	25.13	4.00	1.62	3.87	0.10
11.71	10.05	1.60	0.65	9.70	0.22
11.72	9.45	1.50	0.61	10.33	0.22
11.67	8.79	1.40	0.57	11.06	0.24
11.71	8.16	1.30	0.53	11.94	0.27
11.69	7.52	1.20	0.49	12.92	0.30
11.68	6.90	1.10	0.45	14.07	0.29
11.70	6.28	1.00	0.41	15.49	0.35
11.66	5.66	0.90	0.37	17.14	0.39
11.67	5.03	0.80	0.33	19.32	0.42
11.70	4.39	0.70	0.28	22.15	0.50
11.65	3.77	0.60	0.24	25.69	0.62
11.74	3.14	0.50	0.20	31.09	0.71
11.69	2.51	0.40	0.16	38.72	0.88

Table M.9: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

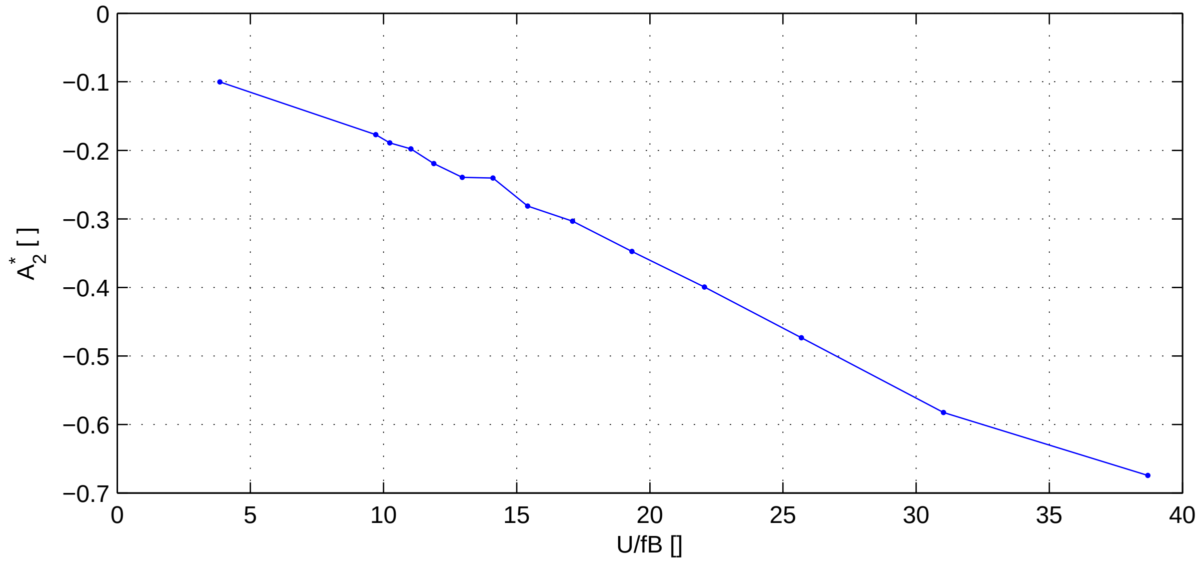


Figure M.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
11.65	25.13	4.00	1.63	3.86	−0.10
11.72	10.05	1.60	0.65	9.71	−0.18
11.62	9.45	1.50	0.61	10.23	−0.19
11.64	8.79	1.40	0.57	11.02	−0.20
11.65	8.16	1.30	0.53	11.88	−0.22
11.71	7.52	1.20	0.49	12.95	−0.24
11.70	6.90	1.10	0.45	14.11	−0.24
11.64	6.28	1.00	0.41	15.41	−0.28
11.63	5.66	0.90	0.37	17.10	−0.30
11.68	5.03	0.80	0.33	19.33	−0.35
11.64	4.39	0.70	0.28	22.05	−0.40
11.65	3.77	0.60	0.24	25.69	−0.47
11.71	3.14	0.50	0.20	31.03	−0.58
11.69	2.51	0.40	0.16	38.70	−0.67

Table M.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

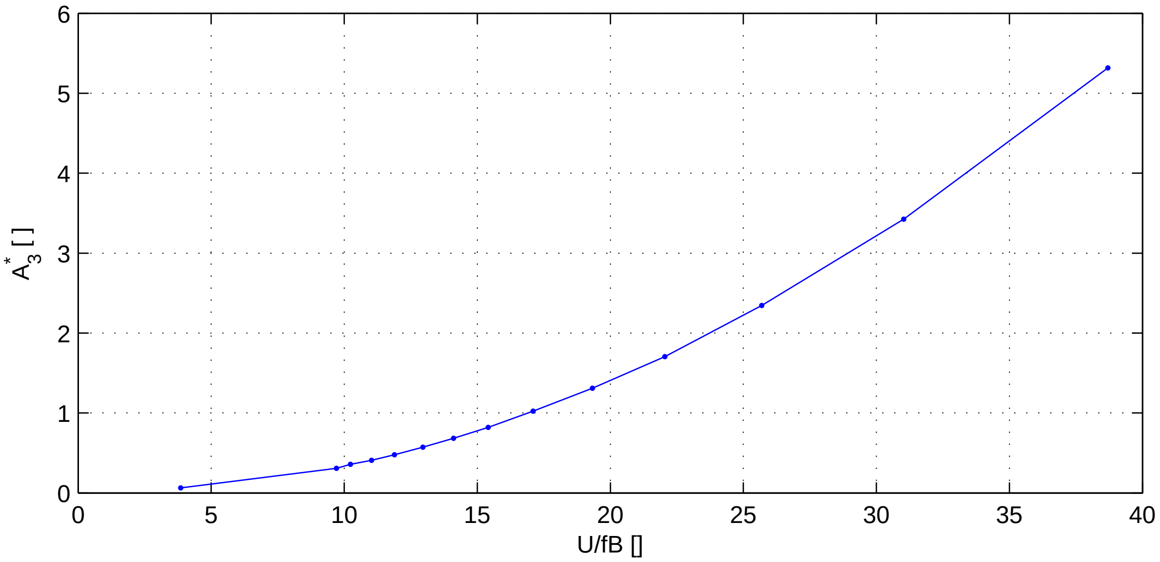


Figure M.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
11.65	25.13	4.00	1.63	3.86	0.06
11.72	10.05	1.60	0.65	9.71	0.31
11.62	9.45	1.50	0.61	10.23	0.36
11.64	8.79	1.40	0.57	11.02	0.41
11.65	8.16	1.30	0.53	11.88	0.48
11.71	7.52	1.20	0.49	12.95	0.57
11.70	6.90	1.10	0.45	14.11	0.68
11.64	6.28	1.00	0.41	15.41	0.82
11.63	5.66	0.90	0.37	17.10	1.02
11.68	5.03	0.80	0.33	19.33	1.31
11.64	4.39	0.70	0.28	22.05	1.71
11.65	3.77	0.60	0.24	25.69	2.34
11.71	3.14	0.50	0.20	31.03	3.42
11.69	2.51	0.40	0.16	38.70	5.32

Table M.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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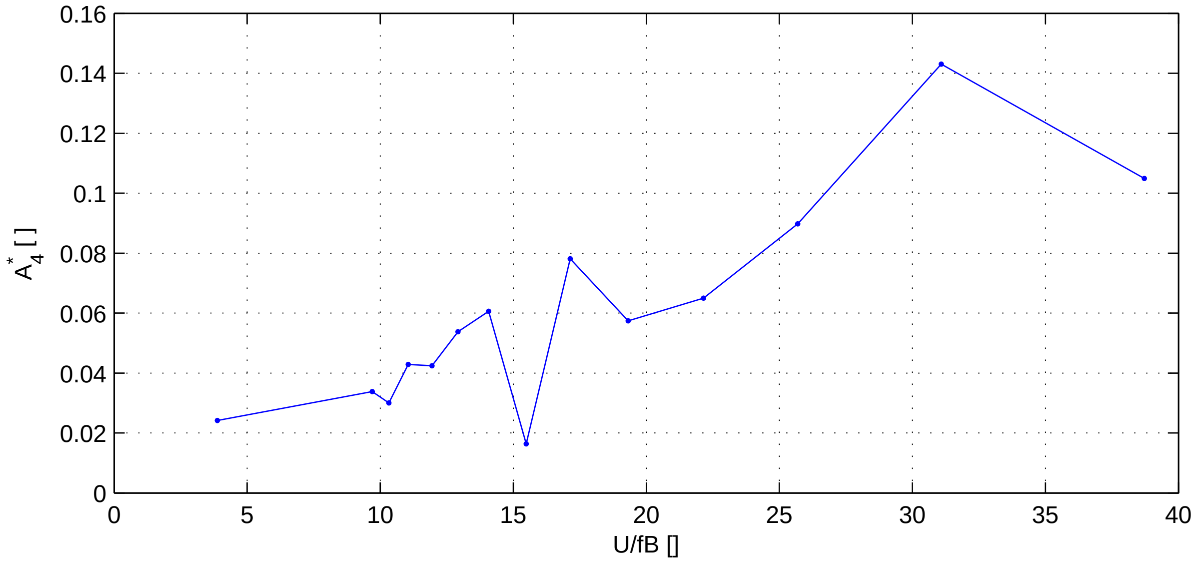

Figure M.10: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_4^*
11.70	25.13	4.00	1.62	3.87	0.02
11.71	10.05	1.60	0.65	9.70	0.03
11.72	9.45	1.50	0.61	10.33	0.03
11.67	8.79	1.40	0.57	11.06	0.04
11.71	8.16	1.30	0.53	11.94	0.04
11.69	7.52	1.20	0.49	12.92	0.05
11.68	6.90	1.10	0.45	14.07	0.06
11.70	6.28	1.00	0.41	15.49	0.02
11.66	5.66	0.90	0.37	17.14	0.08
11.67	5.03	0.80	0.33	19.32	0.06
11.70	4.39	0.70	0.28	22.15	0.06
11.65	3.77	0.60	0.24	25.69	0.09
11.74	3.14	0.50	0.20	31.09	0.14
11.69	2.51	0.40	0.16	38.72	0.10

Table M.12: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

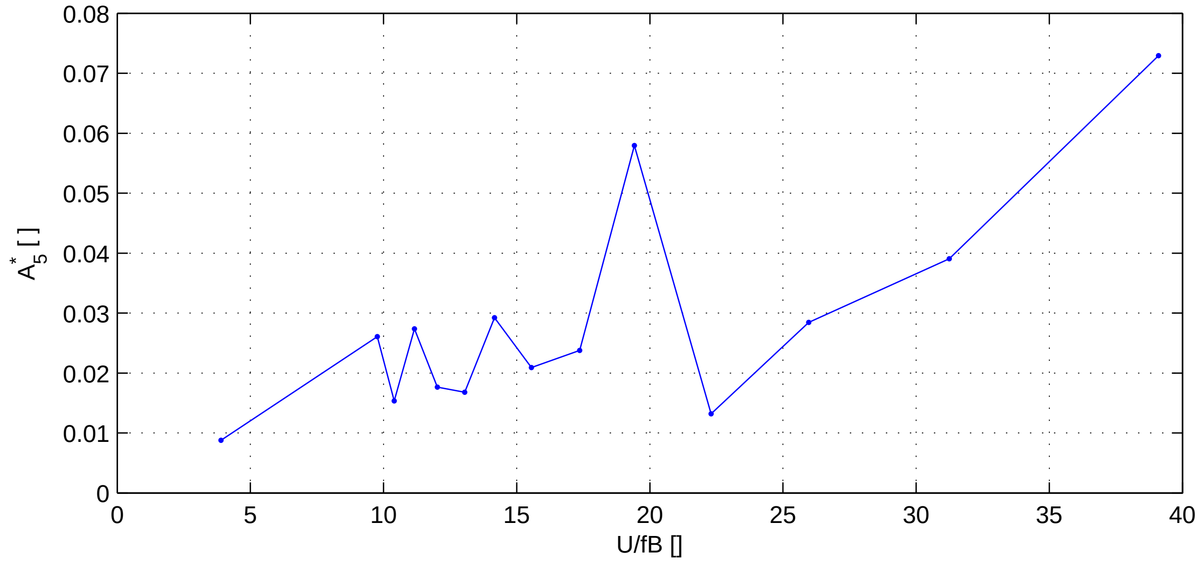

Figure M.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
11.76	25.13	4.00	1.61	3.89	0.01
11.80	10.05	1.60	0.64	9.77	0.03
11.81	9.45	1.50	0.60	10.40	0.02
11.79	8.79	1.40	0.56	11.16	0.03
11.79	8.16	1.30	0.52	12.02	0.02
11.80	7.52	1.20	0.48	13.05	0.02
11.76	6.90	1.10	0.44	14.17	0.03
11.74	6.28	1.00	0.40	15.55	0.02
11.81	5.66	0.90	0.36	17.36	0.02
11.73	5.03	0.80	0.32	19.42	0.06
11.78	4.39	0.70	0.28	22.30	0.01
11.77	3.77	0.60	0.24	25.96	0.03
11.80	3.14	0.50	0.20	31.25	0.04
11.81	2.51	0.40	0.16	39.11	0.07

Table M.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

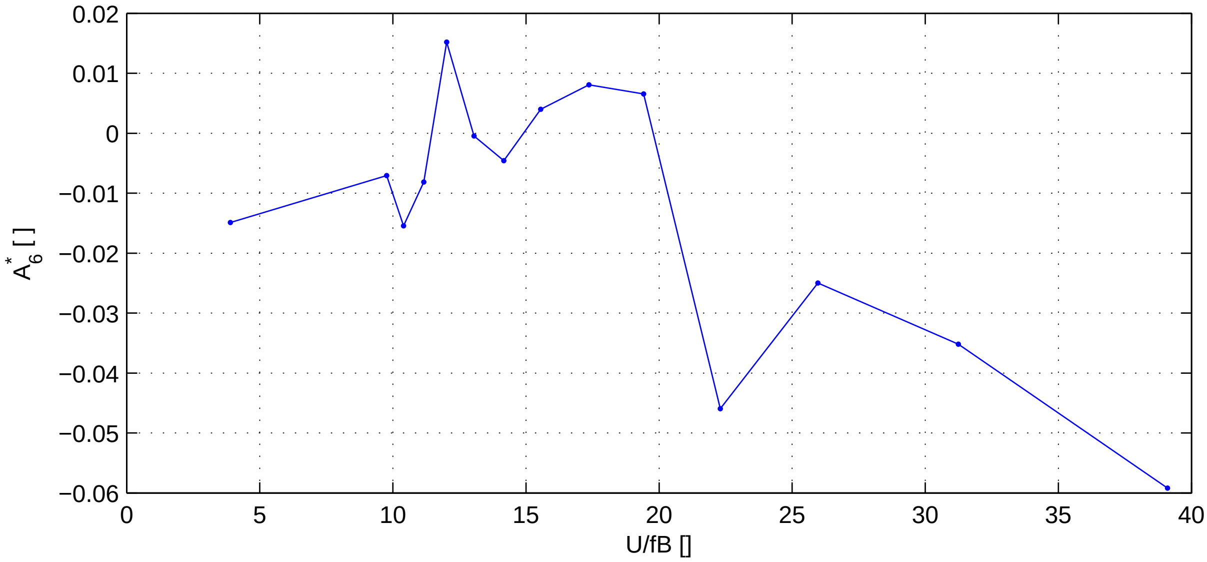

Figure M.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
11.76	25.13	4.00	1.61	3.89	−0.01
11.80	10.05	1.60	0.64	9.77	−0.01
11.81	9.45	1.50	0.60	10.40	−0.02
11.79	8.79	1.40	0.56	11.16	−0.01
11.79	8.16	1.30	0.52	12.02	0.02
11.80	7.52	1.20	0.48	13.05	−0.00
11.76	6.90	1.10	0.44	14.17	−0.00
11.74	6.28	1.00	0.40	15.55	0.00
11.81	5.66	0.90	0.36	17.36	0.01
11.73	5.03	0.80	0.32	19.42	0.01
11.78	4.39	0.70	0.28	22.30	−0.05
11.77	3.77	0.60	0.24	25.96	−0.02
11.80	3.14	0.50	0.20	31.25	−0.04
11.81	2.51	0.40	0.16	39.11	−0.06

Table M.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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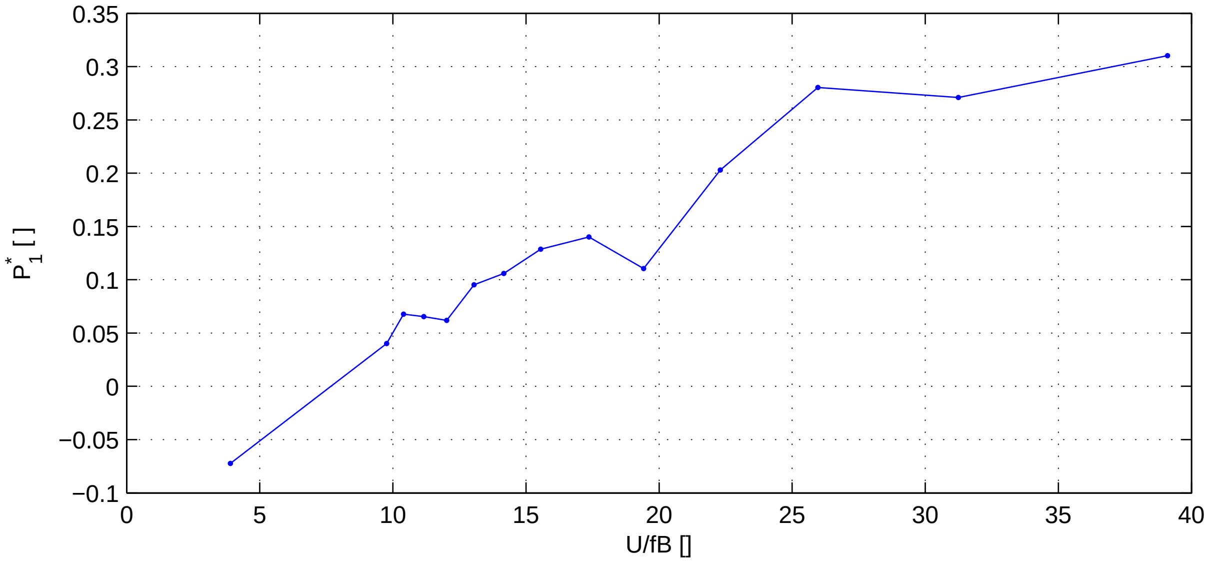

Figure M.13: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_1^*
11.76	25.13	4.00	1.61	3.89	−0.07
11.80	10.05	1.60	0.64	9.77	0.04
11.81	9.45	1.50	0.60	10.40	0.07
11.79	8.79	1.40	0.56	11.16	0.07
11.79	8.16	1.30	0.52	12.02	0.06
11.80	7.52	1.20	0.48	13.05	0.10
11.76	6.90	1.10	0.44	14.17	0.11
11.74	6.28	1.00	0.40	15.55	0.13
11.81	5.66	0.90	0.36	17.36	0.14
11.73	5.03	0.80	0.32	19.42	0.11
11.78	4.39	0.70	0.28	22.30	0.20
11.77	3.77	0.60	0.24	25.96	0.28
11.80	3.14	0.50	0.20	31.25	0.27
11.81	2.51	0.40	0.16	39.11	0.31

Table M.15: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

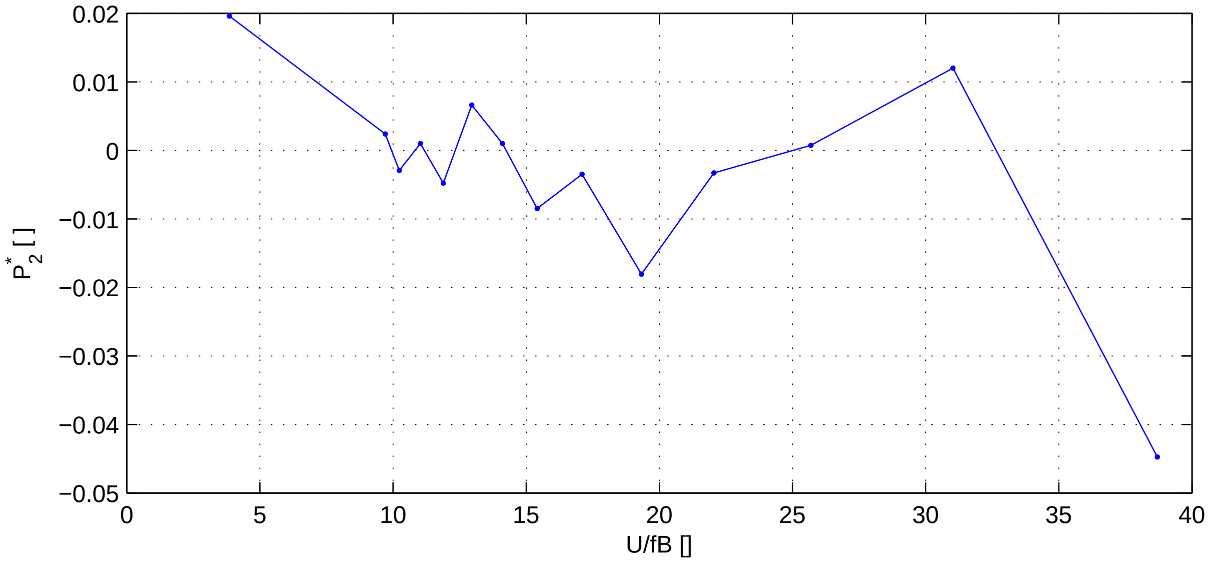

Figure M.14: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_2^*
11.65	25.13	4.00	1.63	3.86	0.02
11.72	10.05	1.60	0.65	9.71	0.00
11.62	9.45	1.50	0.61	10.23	−0.00
11.64	8.79	1.40	0.57	11.02	0.00
11.65	8.16	1.30	0.53	11.88	−0.00
11.71	7.52	1.20	0.49	12.95	0.01
11.70	6.90	1.10	0.45	14.11	0.00
11.64	6.28	1.00	0.41	15.41	−0.01
11.63	5.66	0.90	0.37	17.10	−0.00
11.68	5.03	0.80	0.33	19.33	−0.02
11.64	4.39	0.70	0.28	22.05	−0.00
11.65	3.77	0.60	0.24	25.69	0.00
11.71	3.14	0.50	0.20	31.03	0.01
11.69	2.51	0.40	0.16	38.70	−0.04

Table M.16: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

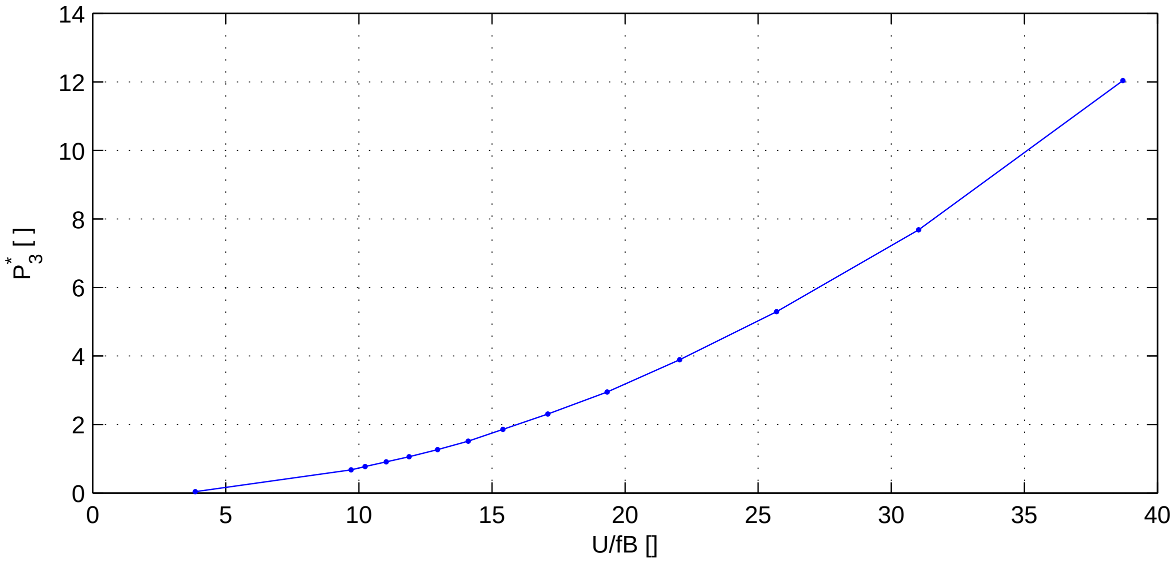

Figure M.15: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_3
11.65	25.13	4.00	1.63	3.86	0.03
11.72	10.05	1.60	0.65	9.71	0.67
11.62	9.45	1.50	0.61	10.23	0.77
11.64	8.79	1.40	0.57	11.02	0.91
11.65	8.16	1.30	0.53	11.88	1.05
11.71	7.52	1.20	0.49	12.95	1.26
11.70	6.90	1.10	0.45	14.11	1.51
11.64	6.28	1.00	0.41	15.41	1.85
11.63	5.66	0.90	0.37	17.10	2.30
11.68	5.03	0.80	0.33	19.33	2.95
11.64	4.39	0.70	0.28	22.05	3.89
11.65	3.77	0.60	0.24	25.69	5.29
11.71	3.14	0.50	0.20	31.03	7.68
11.69	2.51	0.40	0.16	38.70	12.04

Table M.17: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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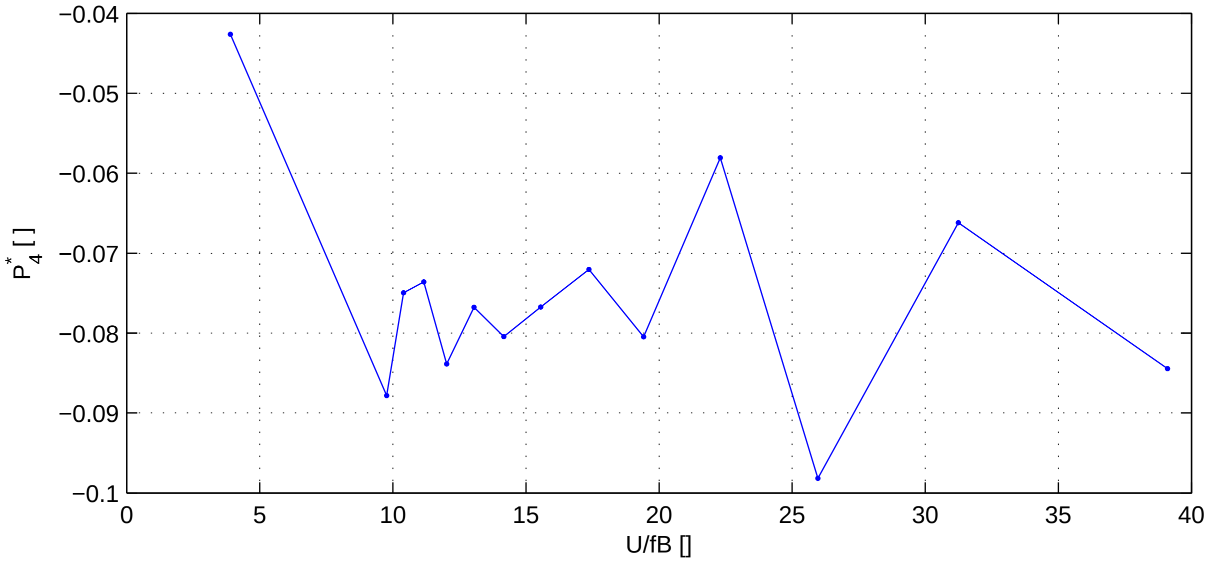

Figure M.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:24:03

U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
11.76	25.13	4.00	1.61	3.89	−0.04
11.80	10.05	1.60	0.64	9.77	−0.09
11.81	9.45	1.50	0.60	10.40	−0.07
11.79	8.79	1.40	0.56	11.16	−0.07
11.79	8.16	1.30	0.52	12.02	−0.08
11.80	7.52	1.20	0.48	13.05	−0.08
11.76	6.90	1.10	0.44	14.17	−0.08
11.74	6.28	1.00	0.40	15.55	−0.08
11.81	5.66	0.90	0.36	17.36	−0.07
11.73	5.03	0.80	0.32	19.42	−0.08
11.78	4.39	0.70	0.28	22.30	−0.06
11.77	3.77	0.60	0.24	25.96	−0.10
11.80	3.14	0.50	0.20	31.25	−0.07
11.81	2.51	0.40	0.16	39.11	−0.08

Table M.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

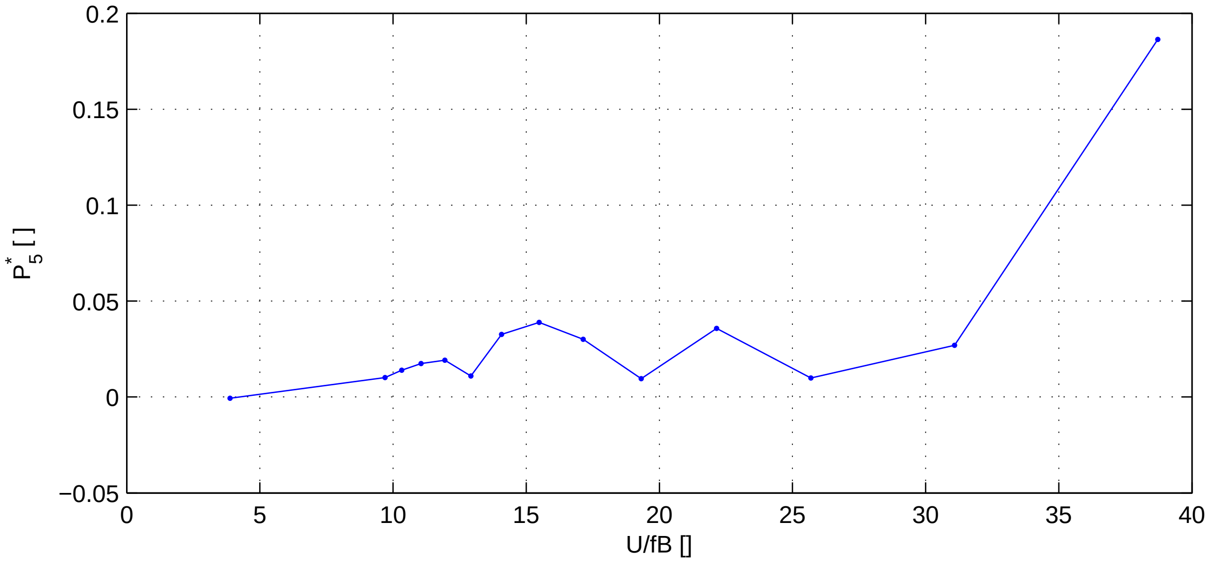

Figure M.17: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_5
11.70	25.13	4.00	1.62	3.87	−0.00
11.71	10.05	1.60	0.65	9.70	0.01
11.72	9.45	1.50	0.61	10.33	0.01
11.67	8.79	1.40	0.57	11.06	0.02
11.71	8.16	1.30	0.53	11.94	0.02
11.69	7.52	1.20	0.49	12.92	0.01
11.68	6.90	1.10	0.45	14.07	0.03
11.70	6.28	1.00	0.41	15.49	0.04
11.66	5.66	0.90	0.37	17.14	0.03
11.67	5.03	0.80	0.33	19.32	0.01
11.70	4.39	0.70	0.28	22.15	0.04
11.65	3.77	0.60	0.24	25.69	0.01
11.74	3.14	0.50	0.20	31.09	0.03
11.69	2.51	0.40	0.16	38.72	0.19

Table M.19: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:24:03

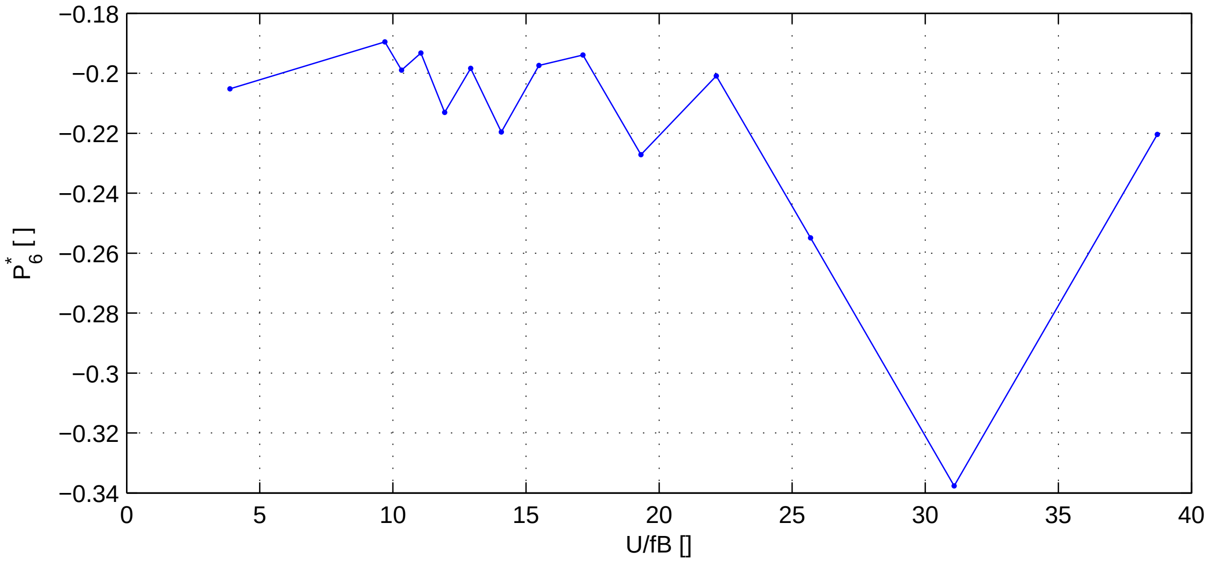

Figure M.18: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_6^*
11.70	25.13	4.00	1.62	3.87	−0.21
11.71	10.05	1.60	0.65	9.70	−0.19
11.72	9.45	1.50	0.61	10.33	−0.20
11.67	8.79	1.40	0.57	11.06	−0.19
11.71	8.16	1.30	0.53	11.94	−0.21
11.69	7.52	1.20	0.49	12.92	−0.20
11.68	6.90	1.10	0.45	14.07	−0.22
11.70	6.28	1.00	0.41	15.49	−0.20
11.66	5.66	0.90	0.37	17.14	−0.19
11.67	5.03	0.80	0.33	19.32	−0.23
11.70	4.39	0.70	0.28	22.15	−0.20
11.65	3.77	0.60	0.24	25.69	−0.25
11.74	3.14	0.50	0.20	31.09	−0.34
11.69	2.51	0.40	0.16	38.72	−0.22

Table M.20: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\,(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\,(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\,(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

Formula M.3: Equation of Motion (Stretto di Messina. Ref. [5].)

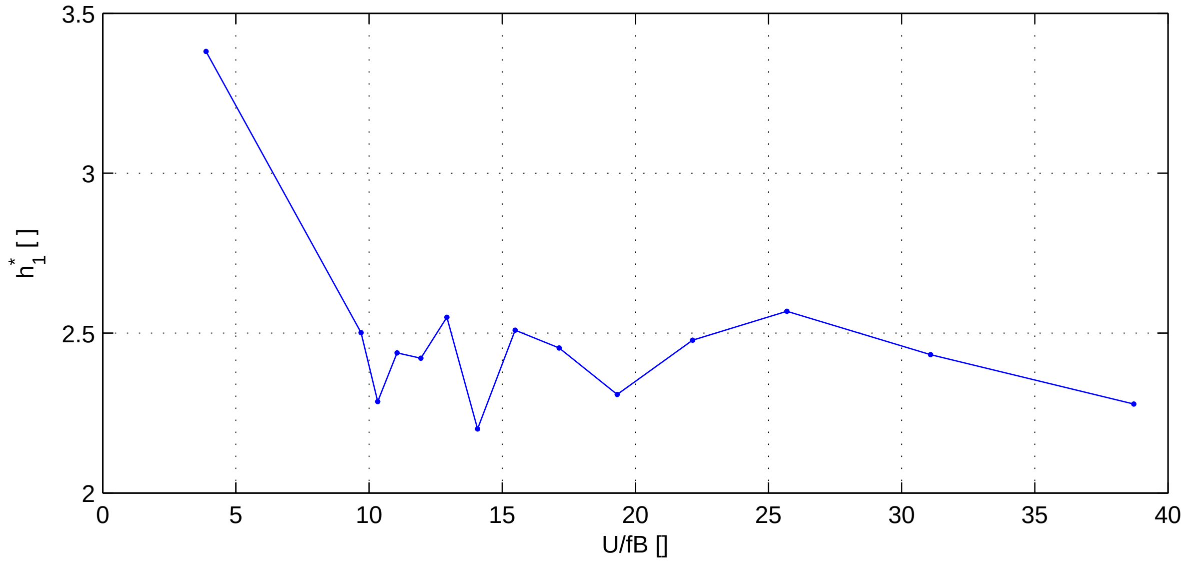

Figure M.19: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_1^*
11.70	25.13	4.00	1.62	3.87	3.38
11.71	10.05	1.60	0.65	9.70	2.50
11.72	9.45	1.50	0.61	10.33	2.29
11.67	8.79	1.40	0.57	11.06	2.44
11.71	8.16	1.30	0.53	11.94	2.42
11.69	7.52	1.20	0.49	12.92	2.55
11.68	6.90	1.10	0.45	14.07	2.20
11.70	6.28	1.00	0.41	15.49	2.51
11.66	5.66	0.90	0.37	17.14	2.45
11.67	5.03	0.80	0.33	19.32	2.31
11.70	4.39	0.70	0.28	22.15	2.48
11.65	3.77	0.60	0.24	25.69	2.57
11.74	3.14	0.50	0.20	31.09	2.43
11.69	2.51	0.40	0.16	38.72	2.28

Table M.21: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

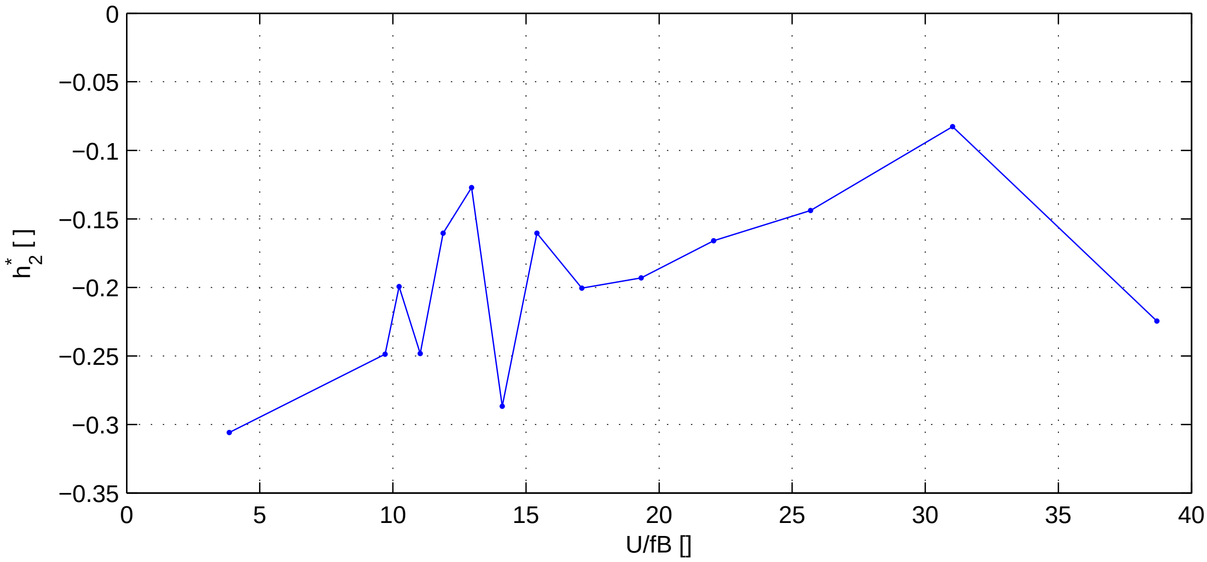

Figure M.20: h^*_2 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_2
11.65	25.13	4.00	1.63	3.86	−0.31
11.72	10.05	1.60	0.65	9.71	−0.25
11.62	9.45	1.50	0.61	10.23	−0.20
11.64	8.79	1.40	0.57	11.02	−0.25
11.65	8.16	1.30	0.53	11.88	−0.16
11.71	7.52	1.20	0.49	12.95	−0.13
11.70	6.90	1.10	0.45	14.11	−0.29
11.64	6.28	1.00	0.41	15.41	−0.16
11.63	5.66	0.90	0.37	17.10	−0.20
11.68	5.03	0.80	0.33	19.33	−0.19
11.64	4.39	0.70	0.28	22.05	−0.17
11.65	3.77	0.60	0.24	25.69	−0.14
11.71	3.14	0.50	0.20	31.03	−0.08
11.69	2.51	0.40	0.16	38.70	−0.22

Table M.22: h^*_2 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

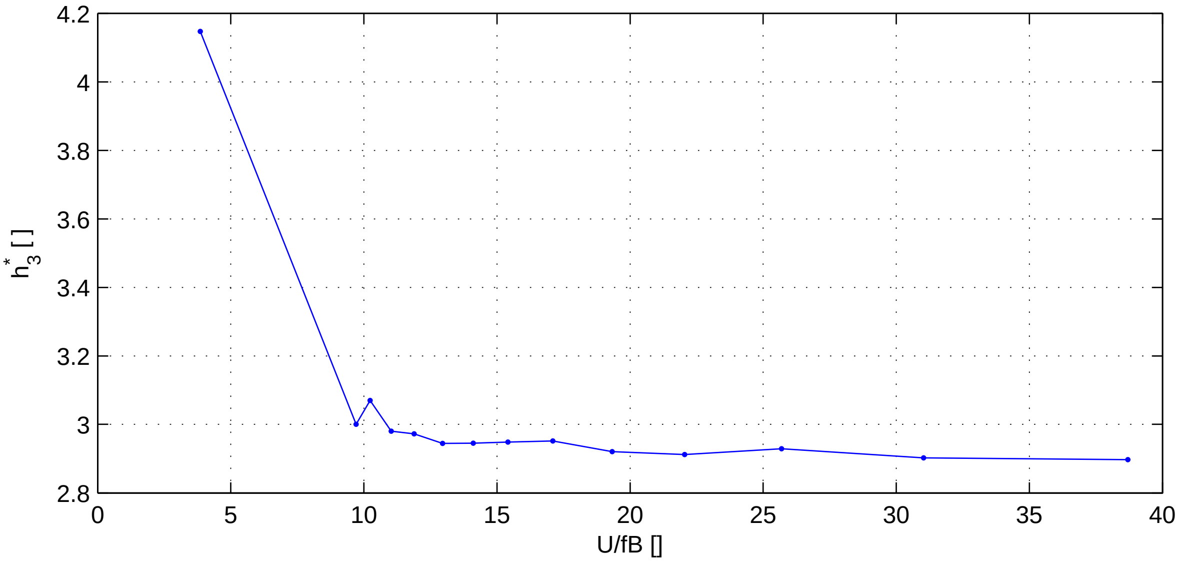

Figure M.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
11.65	25.13	4.00	1.63	3.86	4.15
11.72	10.05	1.60	0.65	9.71	3.00
11.62	9.45	1.50	0.61	10.23	3.07
11.64	8.79	1.40	0.57	11.02	2.98
11.65	8.16	1.30	0.53	11.88	2.97
11.71	7.52	1.20	0.49	12.95	2.94
11.70	6.90	1.10	0.45	14.11	2.95
11.64	6.28	1.00	0.41	15.41	2.95
11.63	5.66	0.90	0.37	17.10	2.95
11.68	5.03	0.80	0.33	19.33	2.92
11.64	4.39	0.70	0.28	22.05	2.91
11.65	3.77	0.60	0.24	25.69	2.93
11.71	3.14	0.50	0.20	31.03	2.90
11.69	2.51	0.40	0.16	38.70	2.90

Table M.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

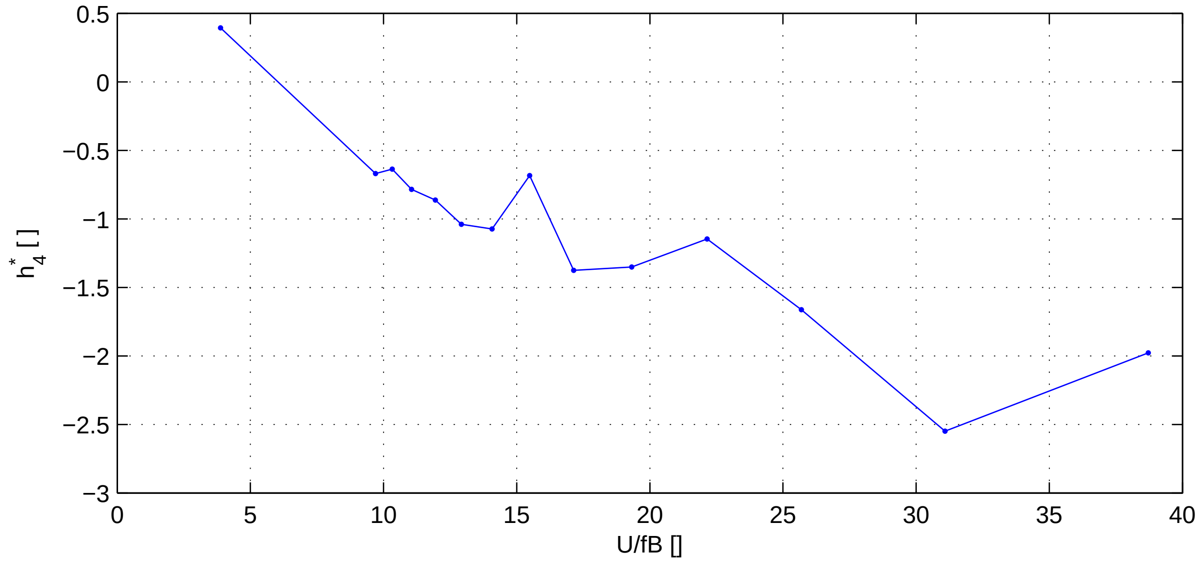

Figure M.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
11.70	25.13	4.00	1.62	3.87	0.39
11.71	10.05	1.60	0.65	9.70	−0.67
11.72	9.45	1.50	0.61	10.33	−0.64
11.67	8.79	1.40	0.57	11.06	−0.78
11.71	8.16	1.30	0.53	11.94	−0.86
11.69	7.52	1.20	0.49	12.92	−1.04
11.68	6.90	1.10	0.45	14.07	−1.07
11.70	6.28	1.00	0.41	15.49	−0.68
11.66	5.66	0.90	0.37	17.14	−1.38
11.67	5.03	0.80	0.33	19.32	−1.35
11.70	4.39	0.70	0.28	22.15	−1.15
11.65	3.77	0.60	0.24	25.69	−1.66
11.74	3.14	0.50	0.20	31.09	−2.55
11.69	2.51	0.40	0.16	38.72	−1.98

Table M.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

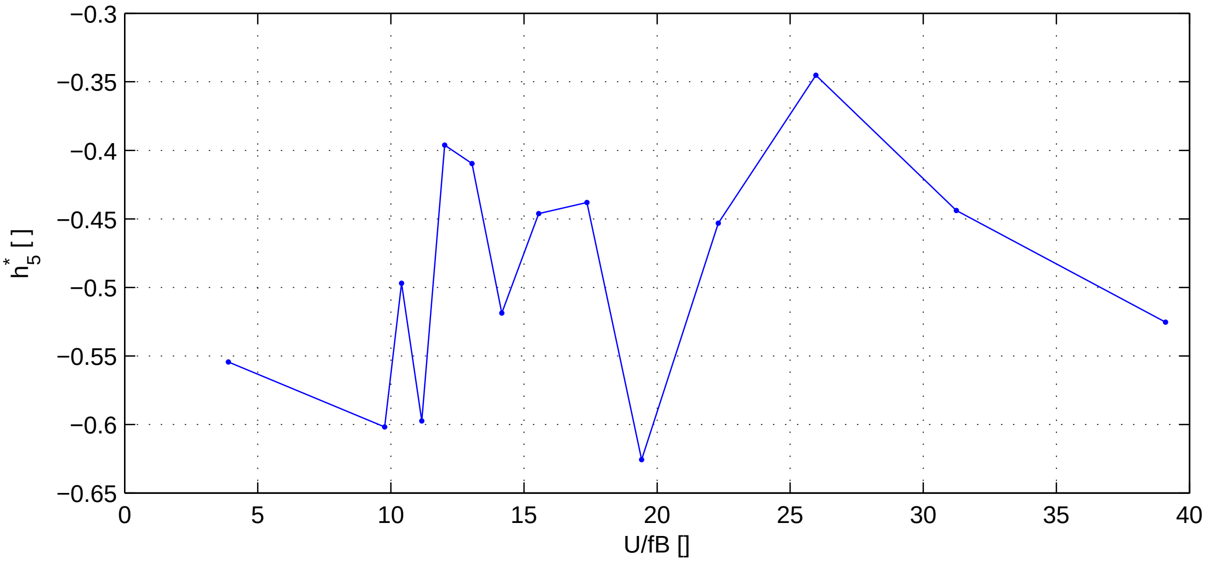

Figure M.23: h^*_5 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_5
11.76	25.13	4.00	1.61	3.89	−0.55
11.80	10.05	1.60	0.64	9.77	−0.60
11.81	9.45	1.50	0.60	10.40	−0.50
11.79	8.79	1.40	0.56	11.16	−0.60
11.79	8.16	1.30	0.52	12.02	−0.40
11.80	7.52	1.20	0.48	13.05	−0.41
11.76	6.90	1.10	0.44	14.17	−0.52
11.74	6.28	1.00	0.40	15.55	−0.45
11.81	5.66	0.90	0.36	17.36	−0.44
11.73	5.03	0.80	0.32	19.42	−0.63
11.78	4.39	0.70	0.28	22.30	−0.45
11.77	3.77	0.60	0.24	25.96	−0.35
11.80	3.14	0.50	0.20	31.25	−0.44
11.81	2.51	0.40	0.16	39.11	−0.53

Table M.25: h^*_5 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

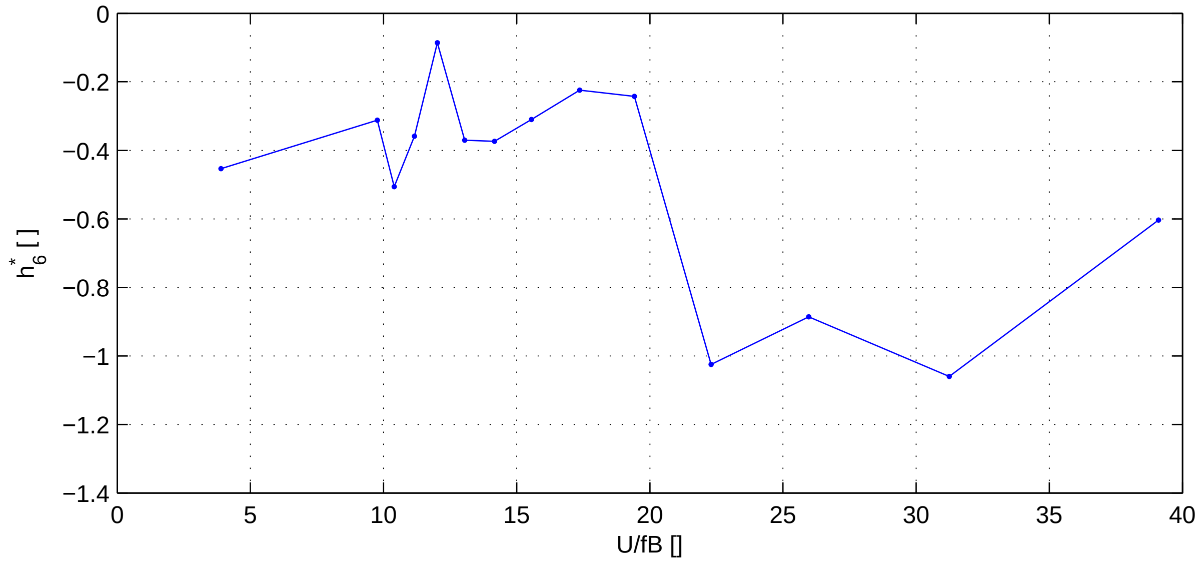

Figure M.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
11.76	25.13	4.00	1.61	3.89	−0.45
11.80	10.05	1.60	0.64	9.77	−0.31
11.81	9.45	1.50	0.60	10.40	−0.51
11.79	8.79	1.40	0.56	11.16	−0.36
11.79	8.16	1.30	0.52	12.02	−0.09
11.80	7.52	1.20	0.48	13.05	−0.37
11.76	6.90	1.10	0.44	14.17	−0.37
11.74	6.28	1.00	0.40	15.55	−0.31
11.81	5.66	0.90	0.36	17.36	−0.22
11.73	5.03	0.80	0.32	19.42	−0.24
11.78	4.39	0.70	0.28	22.30	−1.02
11.77	3.77	0.60	0.24	25.96	−0.89
11.80	3.14	0.50	0.20	31.25	−1.06
11.81	2.51	0.40	0.16	39.11	−0.60

Table M.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

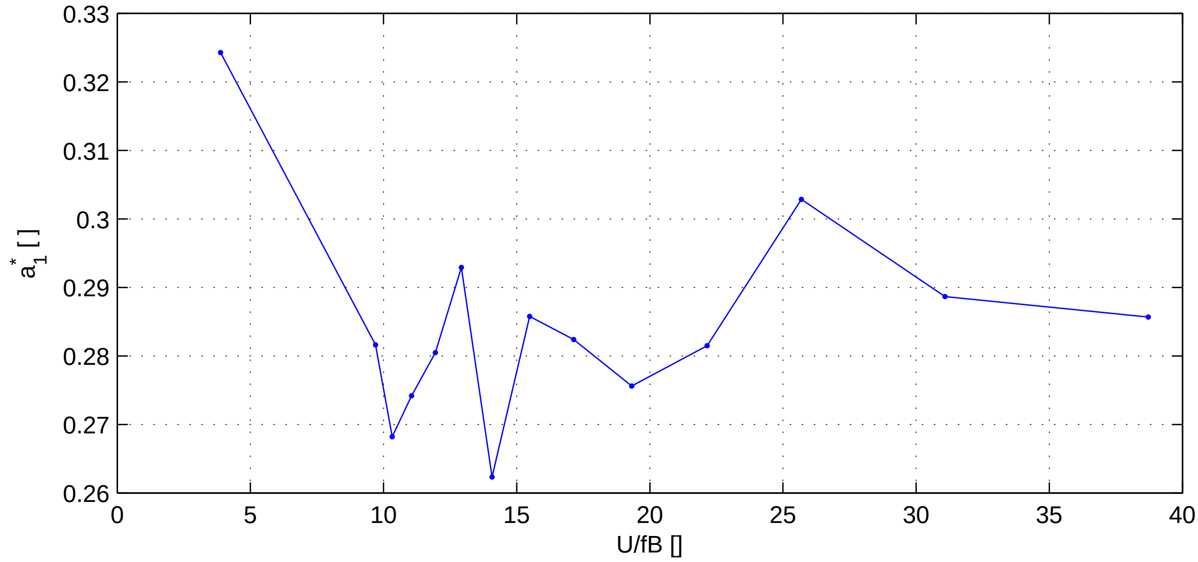

Figure M.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
11.70	25.13	4.00	1.62	3.87	0.32
11.71	10.05	1.60	0.65	9.70	0.28
11.72	9.45	1.50	0.61	10.33	0.27
11.67	8.79	1.40	0.57	11.06	0.27
11.71	8.16	1.30	0.53	11.94	0.28
11.69	7.52	1.20	0.49	12.92	0.29
11.68	6.90	1.10	0.45	14.07	0.26
11.70	6.28	1.00	0.41	15.49	0.29
11.66	5.66	0.90	0.37	17.14	0.28
11.67	5.03	0.80	0.33	19.32	0.28
11.70	4.39	0.70	0.28	22.15	0.28
11.65	3.77	0.60	0.24	25.69	0.30
11.74	3.14	0.50	0.20	31.09	0.29
11.69	2.51	0.40	0.16	38.72	0.29

Table M.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

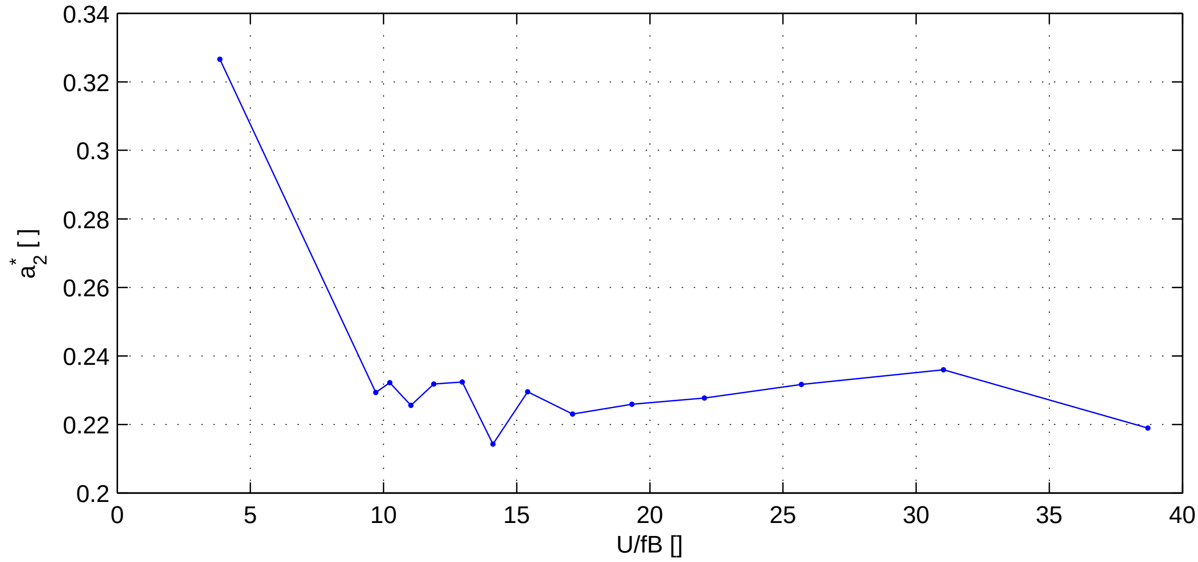

Figure M.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
11.65	25.13	4.00	1.63	3.86	0.33
11.72	10.05	1.60	0.65	9.71	0.23
11.62	9.45	1.50	0.61	10.23	0.23
11.64	8.79	1.40	0.57	11.02	0.23
11.65	8.16	1.30	0.53	11.88	0.23
11.71	7.52	1.20	0.49	12.95	0.23
11.70	6.90	1.10	0.45	14.11	0.21
11.64	6.28	1.00	0.41	15.41	0.23
11.63	5.66	0.90	0.37	17.10	0.22
11.68	5.03	0.80	0.33	19.33	0.23
11.64	4.39	0.70	0.28	22.05	0.23
11.65	3.77	0.60	0.24	25.69	0.23
11.71	3.14	0.50	0.20	31.03	0.24
11.69	2.51	0.40	0.16	38.70	0.22

Table M.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

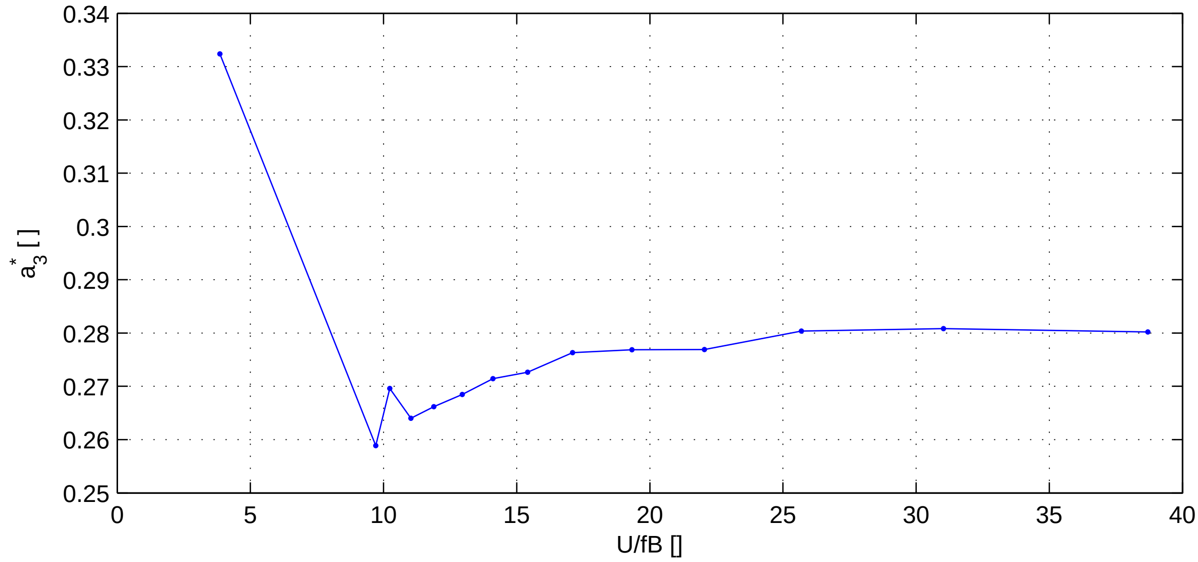

Figure M.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
11.65	25.13	4.00	1.63	3.86	0.33
11.72	10.05	1.60	0.65	9.71	0.26
11.62	9.45	1.50	0.61	10.23	0.27
11.64	8.79	1.40	0.57	11.02	0.26
11.65	8.16	1.30	0.53	11.88	0.27
11.71	7.52	1.20	0.49	12.95	0.27
11.70	6.90	1.10	0.45	14.11	0.27
11.64	6.28	1.00	0.41	15.41	0.27
11.63	5.66	0.90	0.37	17.10	0.28
11.68	5.03	0.80	0.33	19.33	0.28
11.64	4.39	0.70	0.28	22.05	0.28
11.65	3.77	0.60	0.24	25.69	0.28
11.71	3.14	0.50	0.20	31.03	0.28
11.69	2.51	0.40	0.16	38.70	0.28

Table M.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

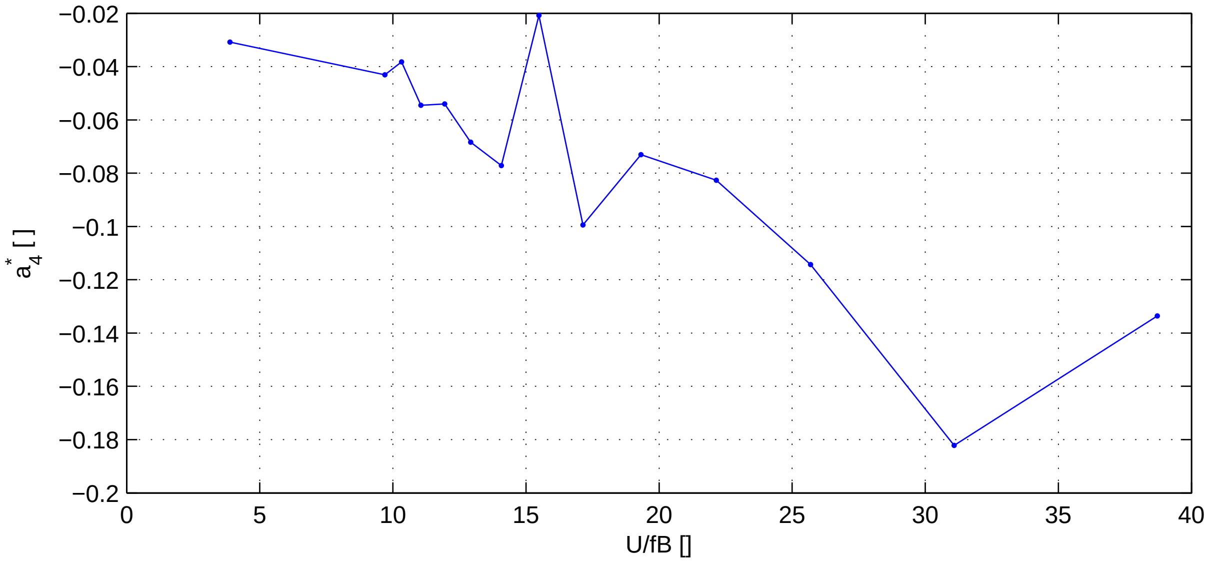

Figure M.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
11.70	25.13	4.00	1.62	3.87	−0.03
11.71	10.05	1.60	0.65	9.70	−0.04
11.72	9.45	1.50	0.61	10.33	−0.04
11.67	8.79	1.40	0.57	11.06	−0.05
11.71	8.16	1.30	0.53	11.94	−0.05
11.69	7.52	1.20	0.49	12.92	−0.07
11.68	6.90	1.10	0.45	14.07	−0.08
11.70	6.28	1.00	0.41	15.49	−0.02
11.66	5.66	0.90	0.37	17.14	−0.10
11.67	5.03	0.80	0.33	19.32	−0.07
11.70	4.39	0.70	0.28	22.15	−0.08
11.65	3.77	0.60	0.24	25.69	−0.11
11.74	3.14	0.50	0.20	31.09	−0.18
11.69	2.51	0.40	0.16	38.72	−0.13

Table M.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

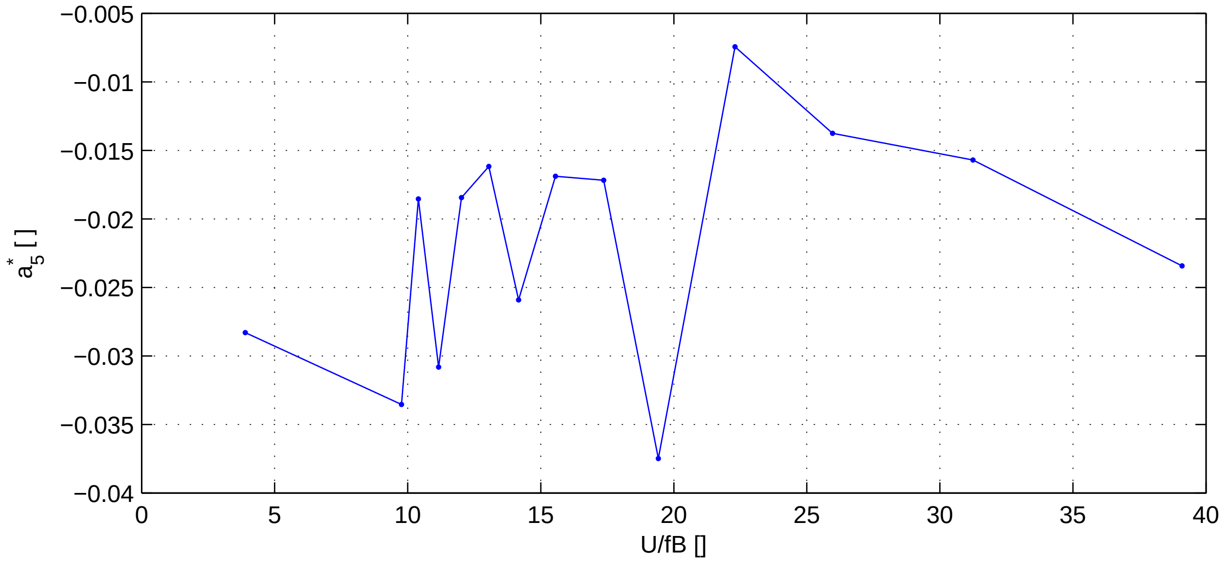

Figure M.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
11.76	25.13	4.00	1.61	3.89	−0.03
11.80	10.05	1.60	0.64	9.77	−0.03
11.81	9.45	1.50	0.60	10.40	−0.02
11.79	8.79	1.40	0.56	11.16	−0.03
11.79	8.16	1.30	0.52	12.02	−0.02
11.80	7.52	1.20	0.48	13.05	−0.02
11.76	6.90	1.10	0.44	14.17	−0.03
11.74	6.28	1.00	0.40	15.55	−0.02
11.81	5.66	0.90	0.36	17.36	−0.02
11.73	5.03	0.80	0.32	19.42	−0.04
11.78	4.39	0.70	0.28	22.30	−0.01
11.77	3.77	0.60	0.24	25.96	−0.01
11.80	3.14	0.50	0.20	31.25	−0.02
11.81	2.51	0.40	0.16	39.11	−0.02

Table M.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

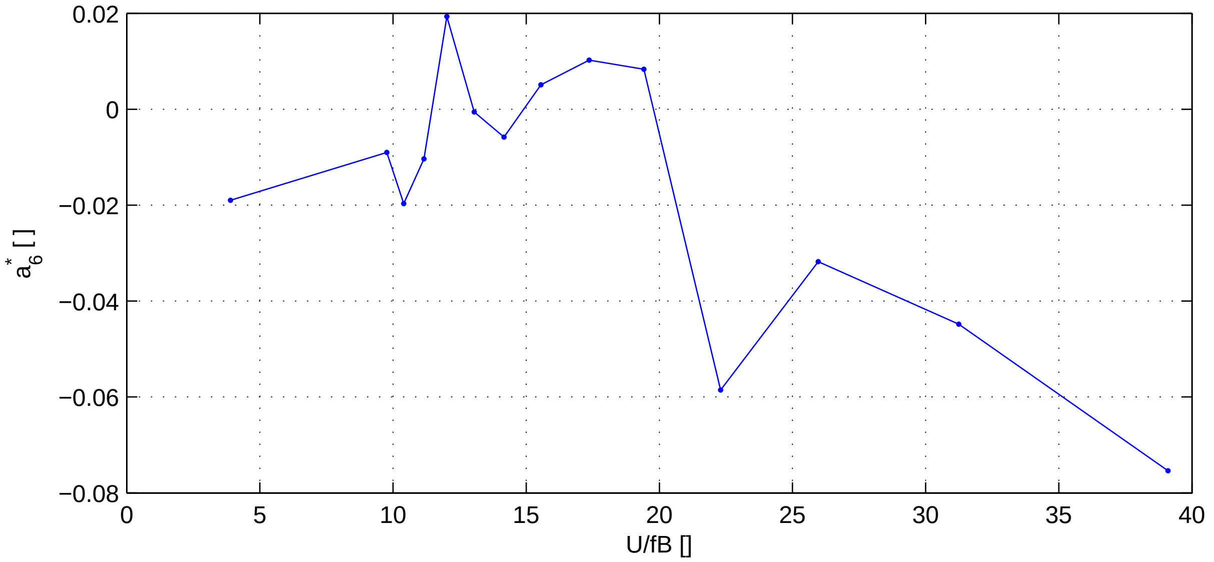

Figure M.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
11.76	25.13	4.00	1.61	3.89	−0.02
11.80	10.05	1.60	0.64	9.77	−0.01
11.81	9.45	1.50	0.60	10.40	−0.02
11.79	8.79	1.40	0.56	11.16	−0.01
11.79	8.16	1.30	0.52	12.02	0.02
11.80	7.52	1.20	0.48	13.05	−0.00
11.76	6.90	1.10	0.44	14.17	−0.01
11.74	6.28	1.00	0.40	15.55	0.01
11.81	5.66	0.90	0.36	17.36	0.01
11.73	5.03	0.80	0.32	19.42	0.01
11.78	4.39	0.70	0.28	22.30	−0.06
11.77	3.77	0.60	0.24	25.96	−0.03
11.80	3.14	0.50	0.20	31.25	−0.04
11.81	2.51	0.40	0.16	39.11	−0.08

Table M.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

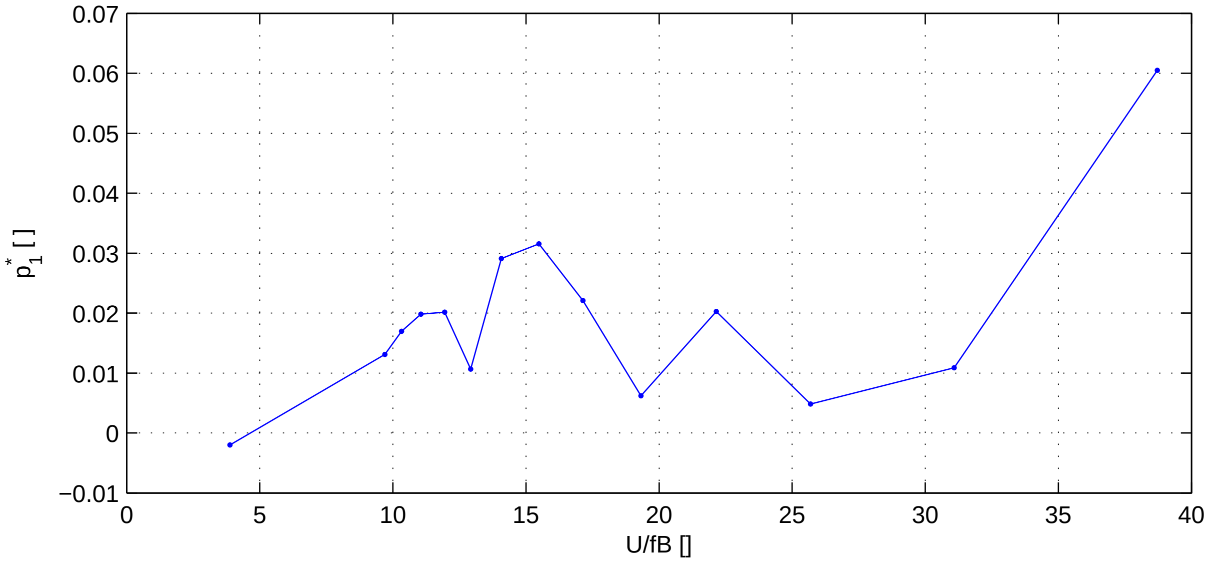

Figure M.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
11.70	25.13	4.00	1.62	3.87	−0.00
11.71	10.05	1.60	0.65	9.70	0.01
11.72	9.45	1.50	0.61	10.33	0.02
11.67	8.79	1.40	0.57	11.06	0.02
11.71	8.16	1.30	0.53	11.94	0.02
11.69	7.52	1.20	0.49	12.92	0.01
11.68	6.90	1.10	0.45	14.07	0.03
11.70	6.28	1.00	0.41	15.49	0.03
11.66	5.66	0.90	0.37	17.14	0.02
11.67	5.03	0.80	0.33	19.32	0.01
11.70	4.39	0.70	0.28	22.15	0.02
11.65	3.77	0.60	0.24	25.69	0.00
11.74	3.14	0.50	0.20	31.09	0.01
11.69	2.51	0.40	0.16	38.72	0.06

Table M.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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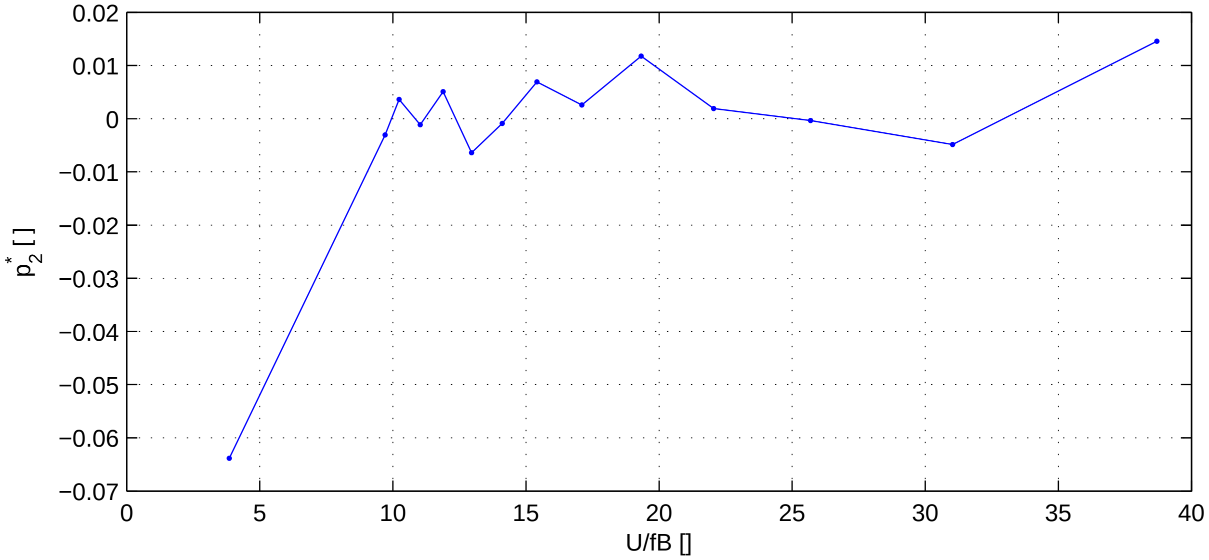

Figure M.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
11.65	25.13	4.00	1.63	3.86	−0.06
11.72	10.05	1.60	0.65	9.71	−0.00
11.62	9.45	1.50	0.61	10.23	0.00
11.64	8.79	1.40	0.57	11.02	−0.00
11.65	8.16	1.30	0.53	11.88	0.01
11.71	7.52	1.20	0.49	12.95	−0.01
11.70	6.90	1.10	0.45	14.11	−0.00
11.64	6.28	1.00	0.41	15.41	0.01
11.63	5.66	0.90	0.37	17.10	0.00
11.68	5.03	0.80	0.33	19.33	0.01
11.64	4.39	0.70	0.28	22.05	0.00
11.65	3.77	0.60	0.24	25.69	−0.00
11.71	3.14	0.50	0.20	31.03	−0.00
11.69	2.51	0.40	0.16	38.70	0.01

Table M.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

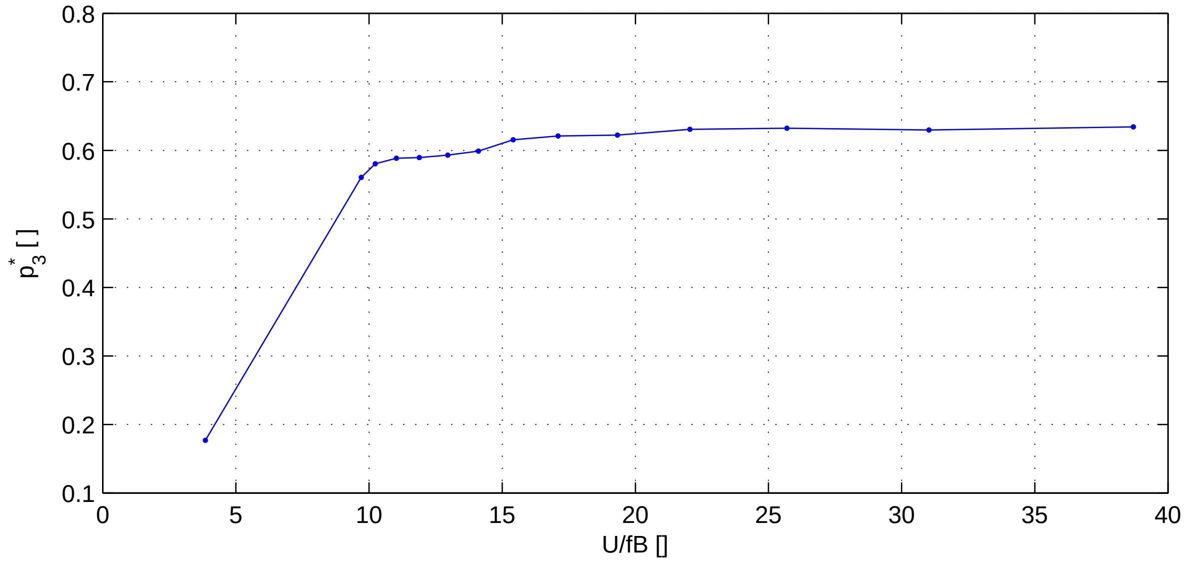

Figure M.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
11.65	25.13	4.00	1.63	3.86	0.18
11.72	10.05	1.60	0.65	9.71	0.56
11.62	9.45	1.50	0.61	10.23	0.58
11.64	8.79	1.40	0.57	11.02	0.59
11.65	8.16	1.30	0.53	11.88	0.59
11.71	7.52	1.20	0.49	12.95	0.59
11.70	6.90	1.10	0.45	14.11	0.60
11.64	6.28	1.00	0.41	15.41	0.62
11.63	5.66	0.90	0.37	17.10	0.62
11.68	5.03	0.80	0.33	19.33	0.62
11.64	4.39	0.70	0.28	22.05	0.63
11.65	3.77	0.60	0.24	25.69	0.63
11.71	3.14	0.50	0.20	31.03	0.63
11.69	2.51	0.40	0.16	38.70	0.63

Table M.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

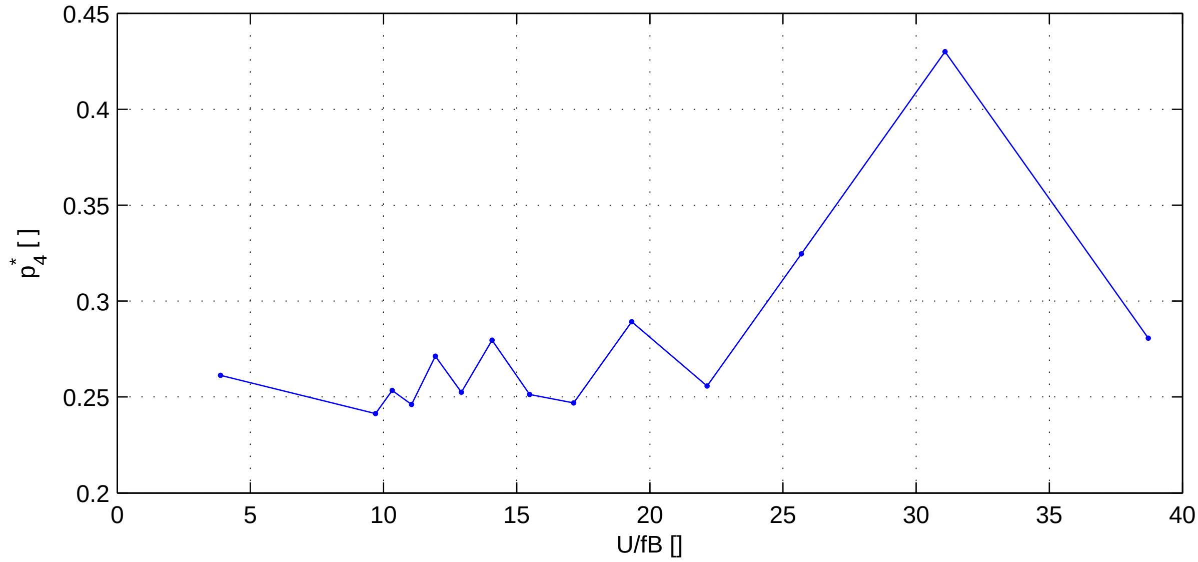

Figure M.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
11.70	25.13	4.00	1.62	3.87	0.26
11.71	10.05	1.60	0.65	9.70	0.24
11.72	9.45	1.50	0.61	10.33	0.25
11.67	8.79	1.40	0.57	11.06	0.25
11.71	8.16	1.30	0.53	11.94	0.27
11.69	7.52	1.20	0.49	12.92	0.25
11.68	6.90	1.10	0.45	14.07	0.28
11.70	6.28	1.00	0.41	15.49	0.25
11.66	5.66	0.90	0.37	17.14	0.25
11.67	5.03	0.80	0.33	19.32	0.29
11.70	4.39	0.70	0.28	22.15	0.26
11.65	3.77	0.60	0.24	25.69	0.32
11.74	3.14	0.50	0.20	31.09	0.43
11.69	2.51	0.40	0.16	38.72	0.28

Table M.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

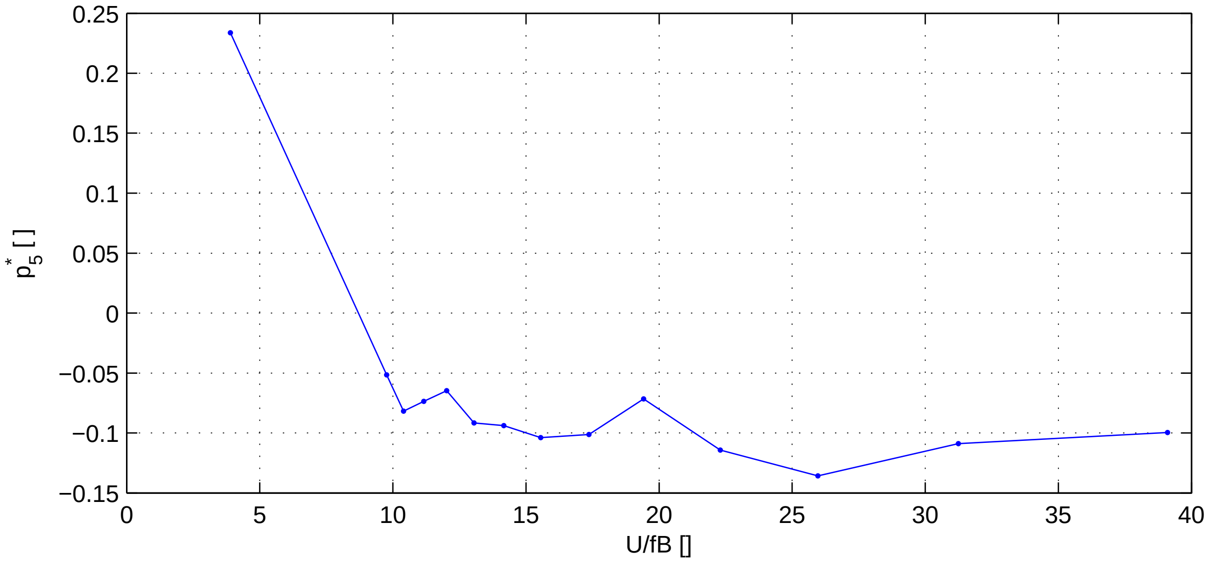

Figure M.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
11.76	25.13	4.00	1.61	3.89	0.23
11.80	10.05	1.60	0.64	9.77	−0.05
11.81	9.45	1.50	0.60	10.40	−0.08
11.79	8.79	1.40	0.56	11.16	−0.07
11.79	8.16	1.30	0.52	12.02	−0.06
11.80	7.52	1.20	0.48	13.05	−0.09
11.76	6.90	1.10	0.44	14.17	−0.09
11.74	6.28	1.00	0.40	15.55	−0.10
11.81	5.66	0.90	0.36	17.36	−0.10
11.73	5.03	0.80	0.32	19.42	−0.07
11.78	4.39	0.70	0.28	22.30	−0.11
11.77	3.77	0.60	0.24	25.96	−0.14
11.80	3.14	0.50	0.20	31.25	−0.11
11.81	2.51	0.40	0.16	39.11	−0.10

Table M.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

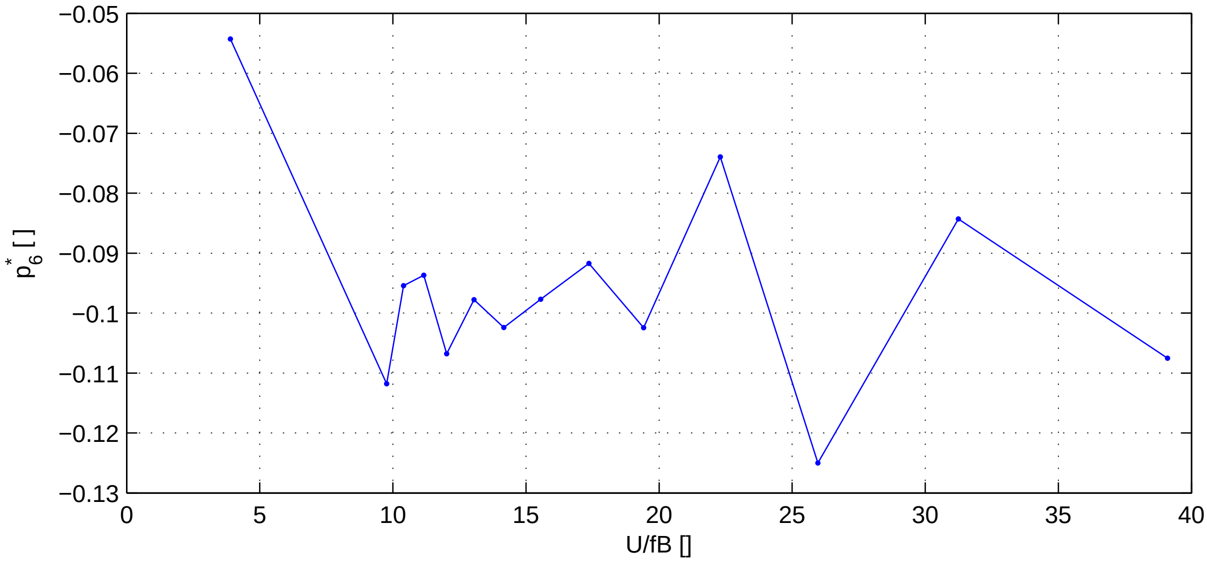

Figure M.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
11.76	25.13	4.00	1.61	3.89	−0.05
11.80	10.05	1.60	0.64	9.77	−0.11
11.81	9.45	1.50	0.60	10.40	−0.10
11.79	8.79	1.40	0.56	11.16	−0.09
11.79	8.16	1.30	0.52	12.02	−0.11
11.80	7.52	1.20	0.48	13.05	−0.10
11.76	6.90	1.10	0.44	14.17	−0.10
11.74	6.28	1.00	0.40	15.55	−0.10
11.81	5.66	0.90	0.36	17.36	−0.09
11.73	5.03	0.80	0.32	19.42	−0.10
11.78	4.39	0.70	0.28	22.30	−0.07
11.77	3.77	0.60	0.24	25.96	−0.12
11.80	3.14	0.50	0.20	31.25	−0.08
11.81	2.51	0.40	0.16	39.11	−0.11

Table M.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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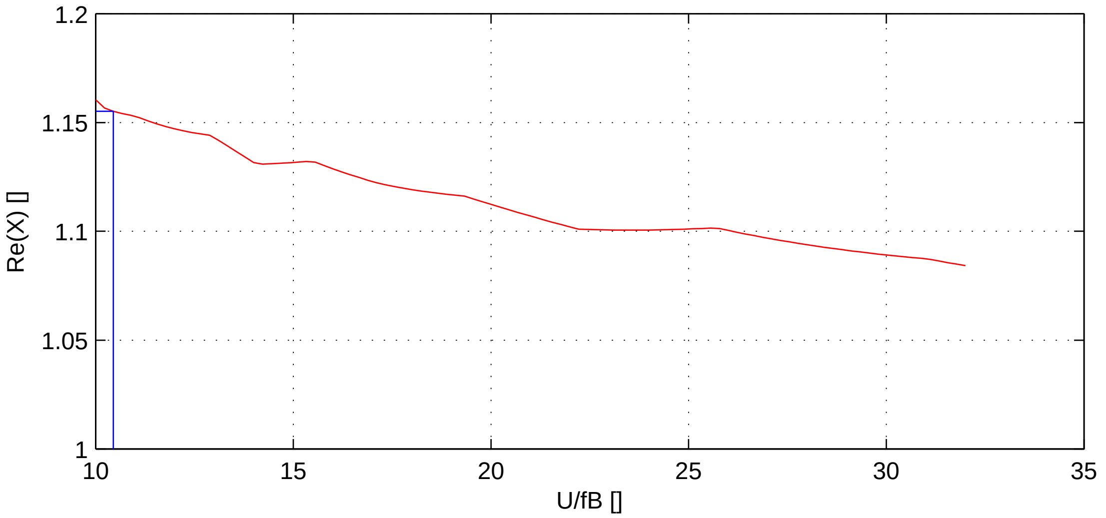


Figure M.37: Real part of the solution to stability equantion

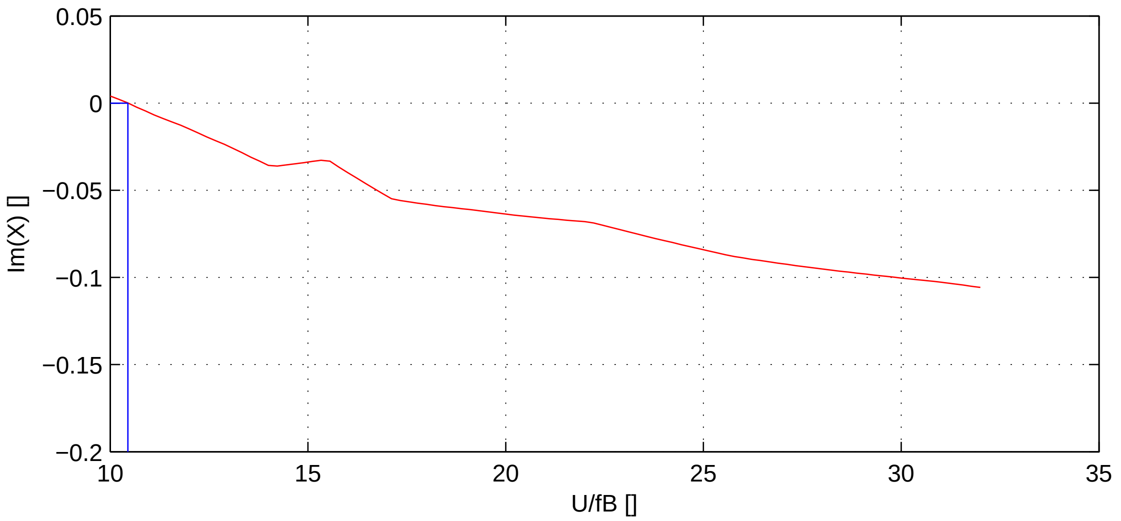


Figure M.38: Imaginary part of the solution to stability equantion

V_{Crit} = 10.4

f_{Crit} = 0.0747 Hz

U_{Crit} = 47.1 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.
[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.
[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.
[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.
[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix N

3D Flutter Tests

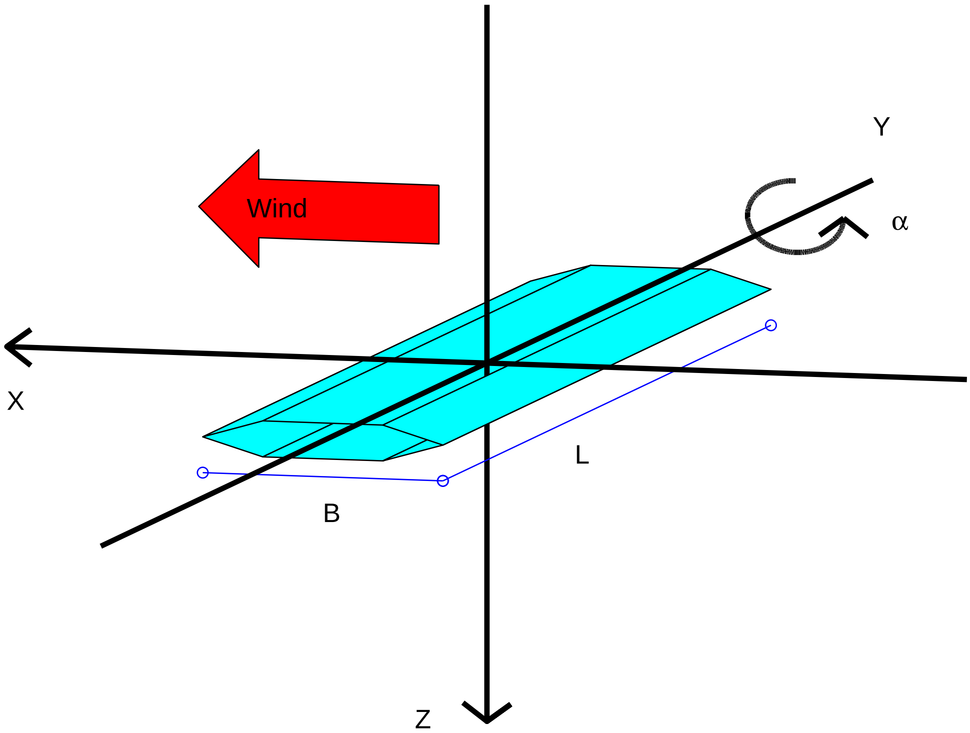
Flutter derivatives, Erection phase, Turbulent flow, Angle of incidence = 0 deg

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	9.700
Temperature	T	^{o}C	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1019.0

Table N.1: Project Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m g - m_{a,z}\ddot{h} - 2m\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$

$$I_y\ddot{\alpha} + m z_G\ddot{p} + m x_G\ddot{h}) = -I_{a,y}\ddot{\alpha} m g - 2m\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h	: Vertical displacement, displacement along z-axis, [m]
α	: Rotation around y-axis, nose up is positive, [rad]
p	: Horizontal displacement, displacement along the x-axis, [m]
m	: Mass per unit length, [kg/m]
I_y	: Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$	: Added mass in vertical direction, [kg/m]
$m_{a,x}$	: Added mass in horizontal direction, [kg/m]
$I_{a,y}$	: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G	: X-coordinate for centre of gravity, [m]
Z_G	: Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$	: Natural circular frequency for vertical motion, [/s]
ζ_h	: Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$	: Natural circular frequency for rotation around y axis, [/s]
ζ_α	: Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$	: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p	: Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$	: Force from rig per meter section, [N/m]
$M_{Y,external}$	: Moment from rig per meter section, [Nm/m]
$F_{X,external}$	: Force from rig per meter section, [N/m]

Formula N.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.093
Added mass in horizontal	$m_{a,x}$	kg/m	0.050
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.149
Horizontal centre of gravity	x_G	m	−0.001
Vertical centre of gravity	z_G	m	−0.005
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.225
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.146
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.079

Table N.2: Mechanical Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula N.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

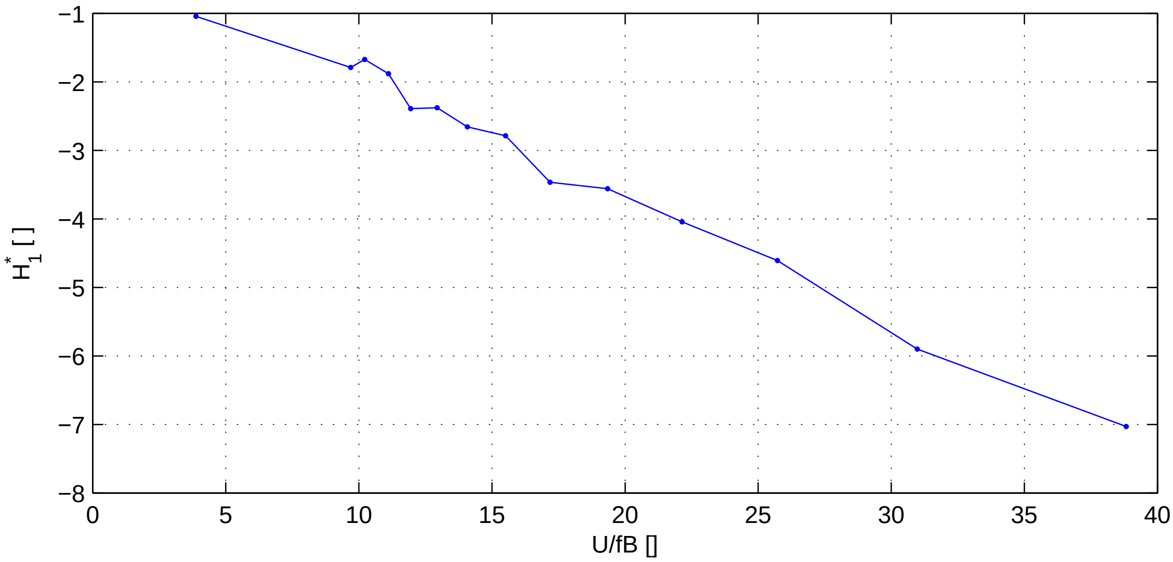


Figure N.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
11.71	25.13	4.00	1.62	3.88	−1.04
11.71	10.05	1.60	0.65	9.69	−1.79
11.60	9.45	1.50	0.61	10.22	−1.67
11.73	8.79	1.40	0.57	11.11	−1.88
11.71	8.16	1.30	0.53	11.94	−2.39
11.70	7.52	1.20	0.49	12.94	−2.38
11.68	6.90	1.10	0.45	14.08	−2.66
11.71	6.28	1.00	0.40	15.51	−2.79
11.69	5.66	0.90	0.37	17.18	−3.46
11.68	5.03	0.80	0.32	19.34	−3.56
11.69	4.39	0.70	0.28	22.14	−4.04
11.67	3.77	0.60	0.24	25.73	−4.61
11.69	3.14	0.50	0.20	30.98	−5.90
11.73	2.51	0.40	0.16	38.83	−7.03

Table N.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

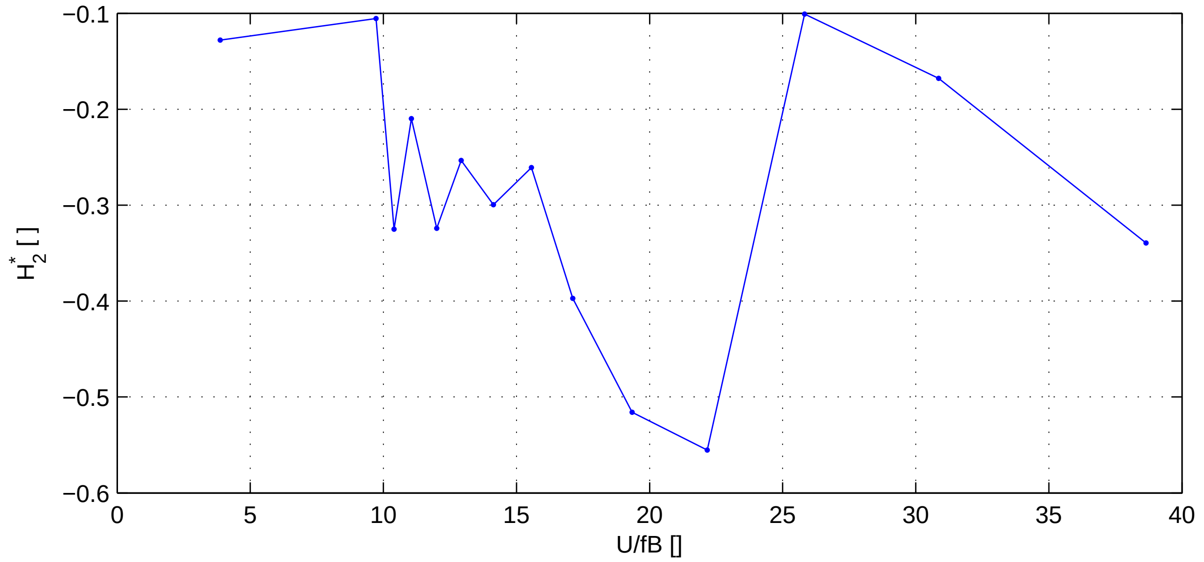


Figure N.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
11.68	25.13	4.00	1.62	3.87	−0.13
11.75	10.05	1.60	0.65	9.73	−0.11
11.81	9.45	1.50	0.60	10.40	−0.33
11.67	8.79	1.40	0.57	11.06	−0.21
11.77	8.16	1.30	0.52	12.01	−0.32
11.68	7.52	1.20	0.49	12.92	−0.25
11.72	6.90	1.10	0.44	14.13	−0.30
11.75	6.28	1.00	0.40	15.56	−0.26
11.64	5.66	0.90	0.37	17.12	−0.40
11.69	5.03	0.80	0.32	19.35	−0.52
11.71	4.39	0.70	0.28	22.17	−0.56
11.71	3.77	0.60	0.24	25.82	−0.10
11.65	3.14	0.50	0.20	30.86	−0.17
11.67	2.51	0.40	0.16	38.65	−0.34

Table N.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

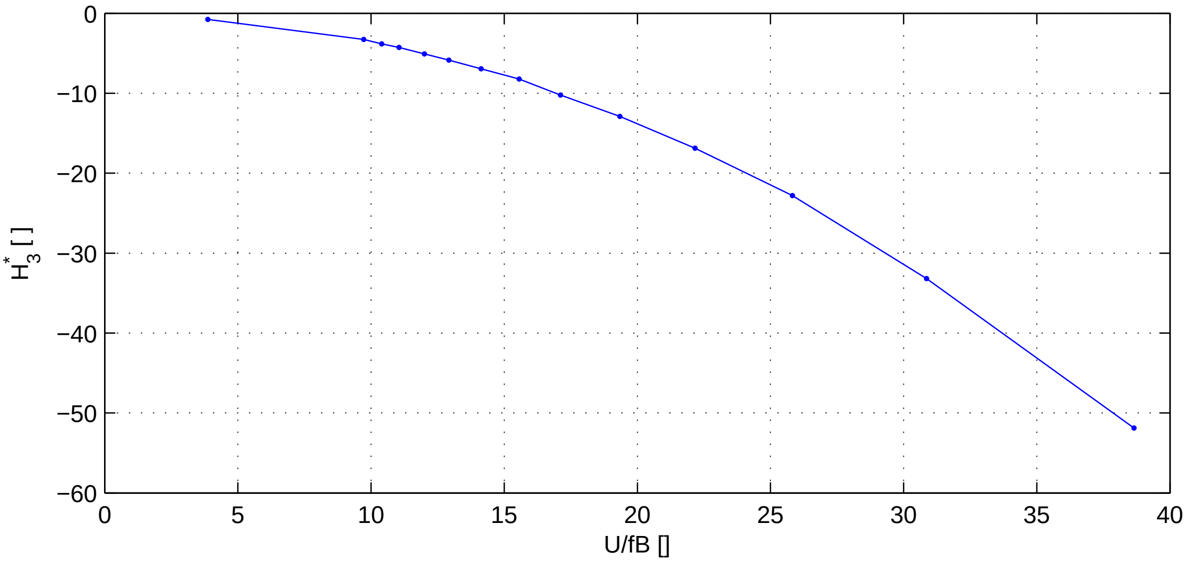


Figure N.3: H^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_3
11.68	25.13	4.00	1.62	3.87	−0.75
11.75	10.05	1.60	0.65	9.73	−3.26
11.81	9.45	1.50	0.60	10.40	−3.83
11.67	8.79	1.40	0.57	11.06	−4.27
11.77	8.16	1.30	0.52	12.01	−5.07
11.68	7.52	1.20	0.49	12.92	−5.85
11.72	6.90	1.10	0.44	14.13	−6.96
11.75	6.28	1.00	0.40	15.56	−8.24
11.64	5.66	0.90	0.37	17.12	−10.23
11.69	5.03	0.80	0.32	19.35	−12.89
11.71	4.39	0.70	0.28	22.17	−16.87
11.71	3.77	0.60	0.24	25.82	−22.81
11.65	3.14	0.50	0.20	30.86	−33.19
11.67	2.51	0.40	0.16	38.65	−51.89

Table N.5: H^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

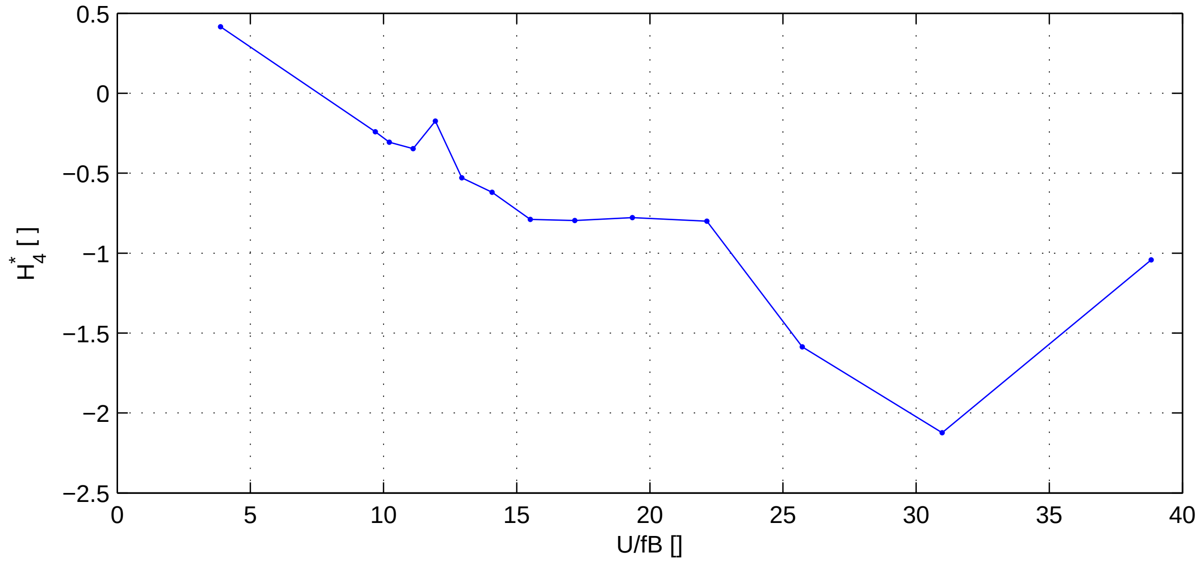


Figure N.4: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_4^*
11.71	25.13	4.00	1.62	3.88	0.42
11.71	10.05	1.60	0.65	9.69	−0.24
11.60	9.45	1.50	0.61	10.22	−0.31
11.73	8.79	1.40	0.57	11.11	−0.35
11.71	8.16	1.30	0.53	11.94	−0.17
11.70	7.52	1.20	0.49	12.94	−0.53
11.68	6.90	1.10	0.45	14.08	−0.62
11.71	6.28	1.00	0.40	15.51	−0.79
11.69	5.66	0.90	0.37	17.18	−0.80
11.68	5.03	0.80	0.32	19.34	−0.78
11.69	4.39	0.70	0.28	22.14	−0.80
11.67	3.77	0.60	0.24	25.73	−1.59
11.69	3.14	0.50	0.20	30.98	−2.12
11.73	2.51	0.40	0.16	38.83	−1.04

Table N.6: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

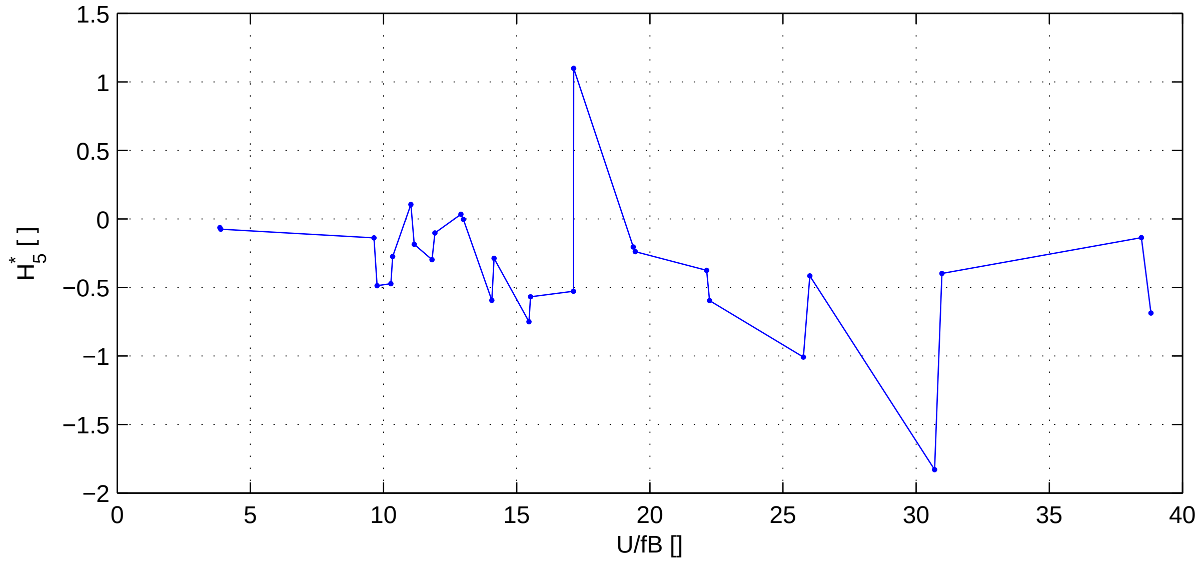


Figure N.5: H^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_5
11.63	25.13	4.00	1.63	3.85	−0.06
11.75	25.13	4.00	1.61	3.89	−0.08
11.65	10.05	1.60	0.65	9.64	−0.14
11.79	10.05	1.60	0.64	9.76	−0.49
11.66	9.45	1.50	0.61	10.27	−0.47
11.74	9.45	1.50	0.61	10.34	−0.27
11.64	8.79	1.40	0.57	11.02	0.10
11.78	8.79	1.40	0.56	11.15	−0.19
11.59	8.16	1.30	0.53	11.82	−0.30
11.70	8.16	1.30	0.53	11.93	−0.10
11.67	7.52	1.20	0.49	12.91	0.03
11.75	7.52	1.20	0.48	13.00	−0.00
11.67	6.90	1.10	0.45	14.06	−0.60
11.74	6.90	1.10	0.44	14.15	−0.29
11.67	6.28	1.00	0.41	15.46	−0.75
11.72	6.28	1.00	0.40	15.52	−0.57
11.65	5.66	0.90	0.37	17.13	−0.53
11.66	5.66	0.90	0.37	17.14	1.10
11.71	5.03	0.80	0.32	19.38	−0.20
11.75	5.03	0.80	0.32	19.45	−0.24
11.68	4.39	0.70	0.28	22.13	−0.38
11.74	4.39	0.70	0.28	22.25	−0.60
11.68	3.77	0.60	0.24	25.77	−1.01
11.79	3.77	0.60	0.24	26.01	−0.42
11.59	3.14	0.50	0.20	30.69	−1.83
11.69	3.14	0.50	0.20	30.97	−0.40
11.61	2.51	0.40	0.16	38.46	−0.14
11.72	2.51	0.40	0.16	38.82	−0.69

Table N.7: H^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

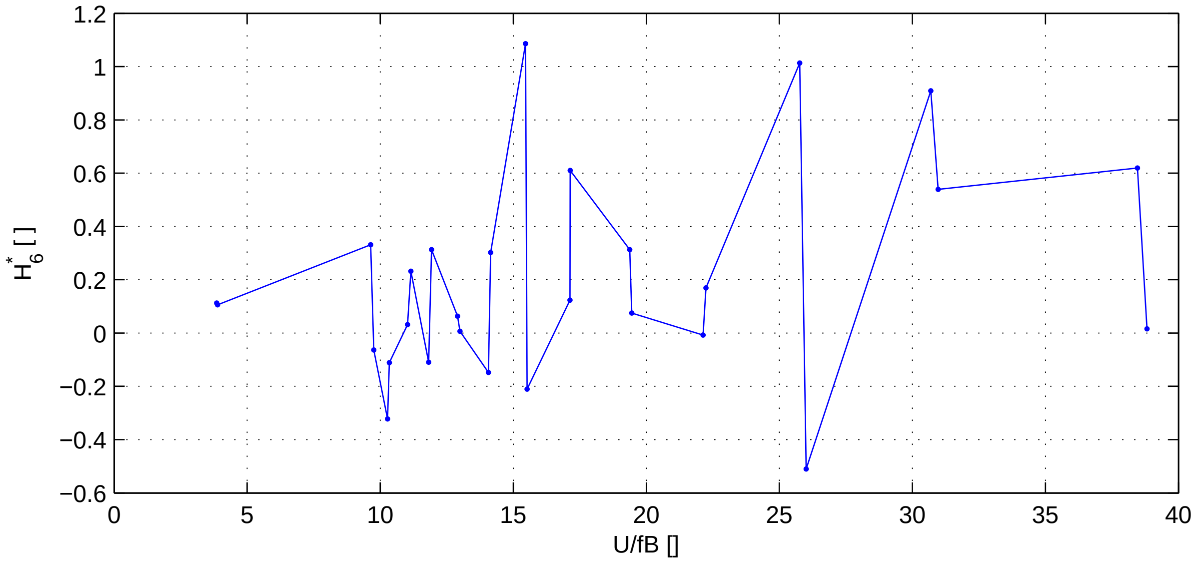


Figure N.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
11.63	25.13	4.00	1.63	3.85	0.11
11.75	25.13	4.00	1.61	3.89	0.11
11.65	10.05	1.60	0.65	9.64	0.33
11.79	10.05	1.60	0.64	9.76	−0.06
11.66	9.45	1.50	0.61	10.27	−0.32
11.74	9.45	1.50	0.61	10.34	−0.11
11.64	8.79	1.40	0.57	11.02	0.03
11.78	8.79	1.40	0.56	11.15	0.23
11.59	8.16	1.30	0.53	11.82	−0.11
11.70	8.16	1.30	0.53	11.93	0.31
11.67	7.52	1.20	0.49	12.91	0.06
11.75	7.52	1.20	0.48	13.00	0.01
11.67	6.90	1.10	0.45	14.06	−0.15
11.74	6.90	1.10	0.44	14.15	0.30
11.67	6.28	1.00	0.41	15.46	1.09
11.72	6.28	1.00	0.40	15.52	−0.21
11.65	5.66	0.90	0.37	17.13	0.12
11.66	5.66	0.90	0.37	17.14	0.61
11.71	5.03	0.80	0.32	19.38	0.31
11.75	5.03	0.80	0.32	19.45	0.08
11.68	4.39	0.70	0.28	22.13	−0.01
11.74	4.39	0.70	0.28	22.25	0.17
11.68	3.77	0.60	0.24	25.77	1.01
11.79	3.77	0.60	0.24	26.01	−0.51
11.59	3.14	0.50	0.20	30.69	0.91
11.69	3.14	0.50	0.20	30.97	0.54
11.61	2.51	0.40	0.16	38.46	0.62
11.72	2.51	0.40	0.16	38.82	0.02

Table N.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

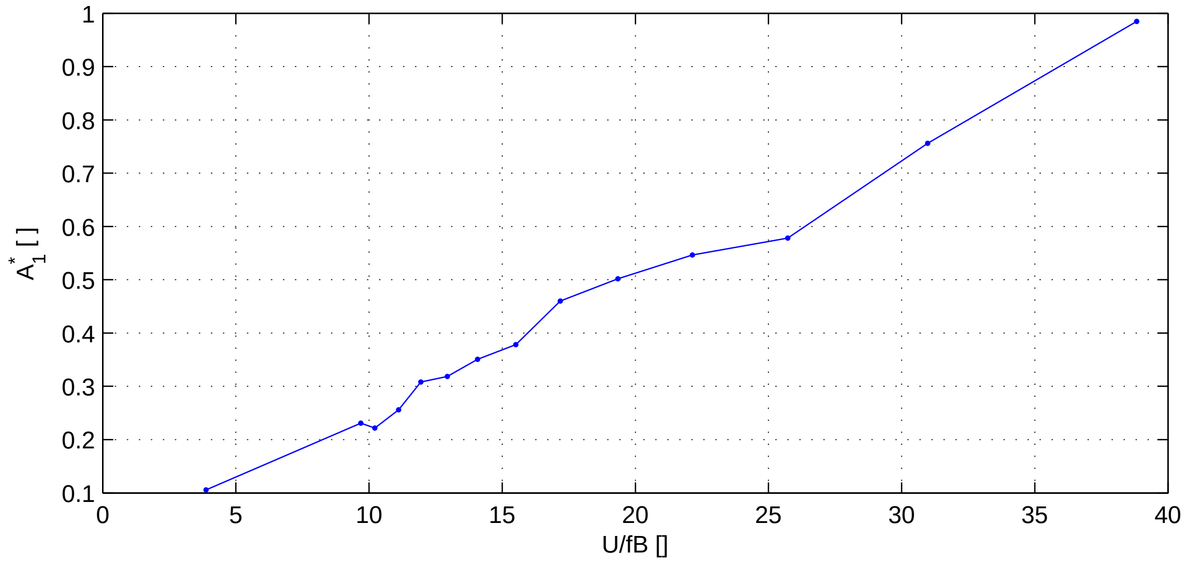


Figure N.7: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_1^*
11.71	25.13	4.00	1.62	3.88	0.11
11.71	10.05	1.60	0.65	9.69	0.23
11.60	9.45	1.50	0.61	10.22	0.22
11.73	8.79	1.40	0.57	11.11	0.26
11.71	8.16	1.30	0.53	11.94	0.31
11.70	7.52	1.20	0.49	12.94	0.32
11.68	6.90	1.10	0.45	14.08	0.35
11.71	6.28	1.00	0.40	15.51	0.38
11.69	5.66	0.90	0.37	17.18	0.46
11.68	5.03	0.80	0.32	19.34	0.50
11.69	4.39	0.70	0.28	22.14	0.55
11.67	3.77	0.60	0.24	25.73	0.58
11.69	3.14	0.50	0.20	30.98	0.76
11.73	2.51	0.40	0.16	38.83	0.98

Table N.9: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

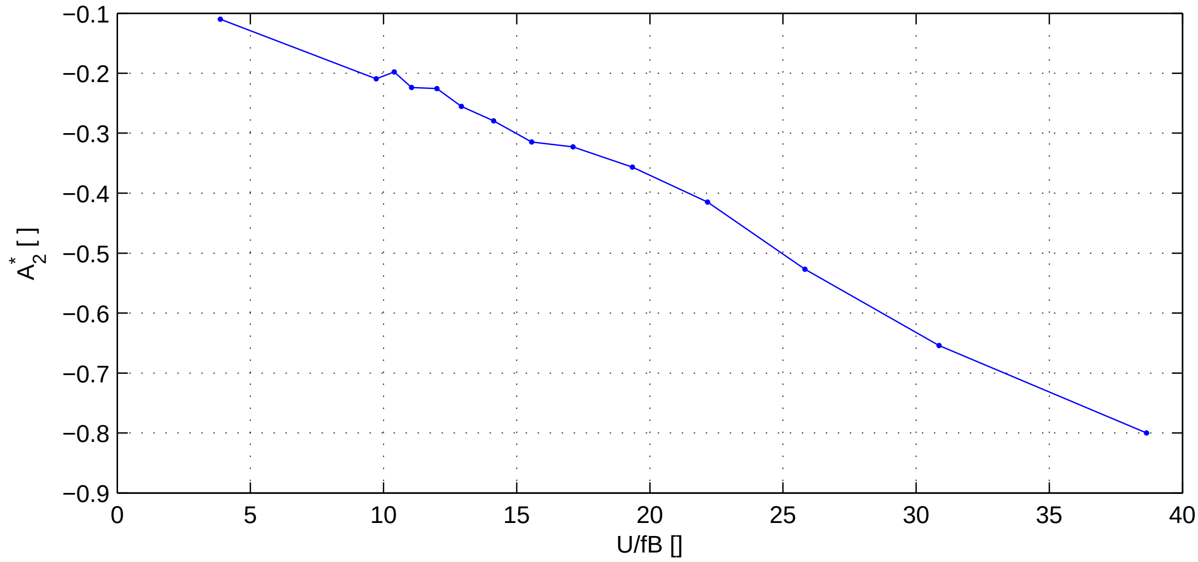


Figure N.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
11.68	25.13	4.00	1.62	3.87	−0.11
11.75	10.05	1.60	0.65	9.73	−0.21
11.81	9.45	1.50	0.60	10.40	−0.20
11.67	8.79	1.40	0.57	11.06	−0.22
11.77	8.16	1.30	0.52	12.01	−0.23
11.68	7.52	1.20	0.49	12.92	−0.26
11.72	6.90	1.10	0.44	14.13	−0.28
11.75	6.28	1.00	0.40	15.56	−0.31
11.64	5.66	0.90	0.37	17.12	−0.32
11.69	5.03	0.80	0.32	19.35	−0.36
11.71	4.39	0.70	0.28	22.17	−0.41
11.71	3.77	0.60	0.24	25.82	−0.53
11.65	3.14	0.50	0.20	30.86	−0.65
11.67	2.51	0.40	0.16	38.65	−0.80

Table N.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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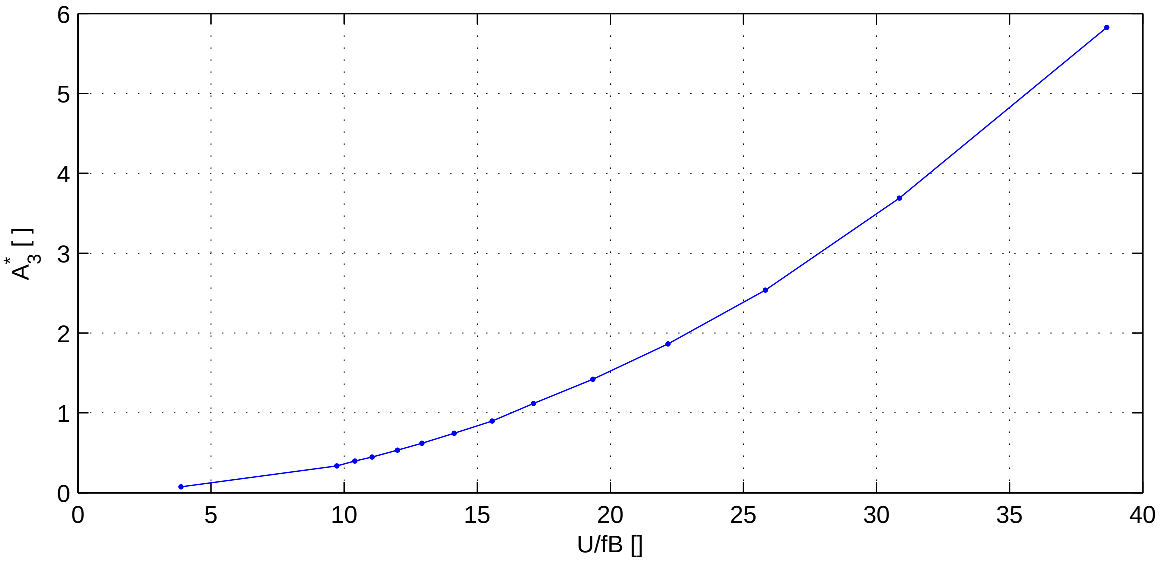

Figure N.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
11.68	25.13	4.00	1.62	3.87	0.07
11.75	10.05	1.60	0.65	9.73	0.33
11.81	9.45	1.50	0.60	10.40	0.40
11.67	8.79	1.40	0.57	11.06	0.45
11.77	8.16	1.30	0.52	12.01	0.53
11.68	7.52	1.20	0.49	12.92	0.62
11.72	6.90	1.10	0.44	14.13	0.74
11.75	6.28	1.00	0.40	15.56	0.90
11.64	5.66	0.90	0.37	17.12	1.12
11.69	5.03	0.80	0.32	19.35	1.42
11.71	4.39	0.70	0.28	22.17	1.86
11.71	3.77	0.60	0.24	25.82	2.54
11.65	3.14	0.50	0.20	30.86	3.69
11.67	2.51	0.40	0.16	38.65	5.82

Table N.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

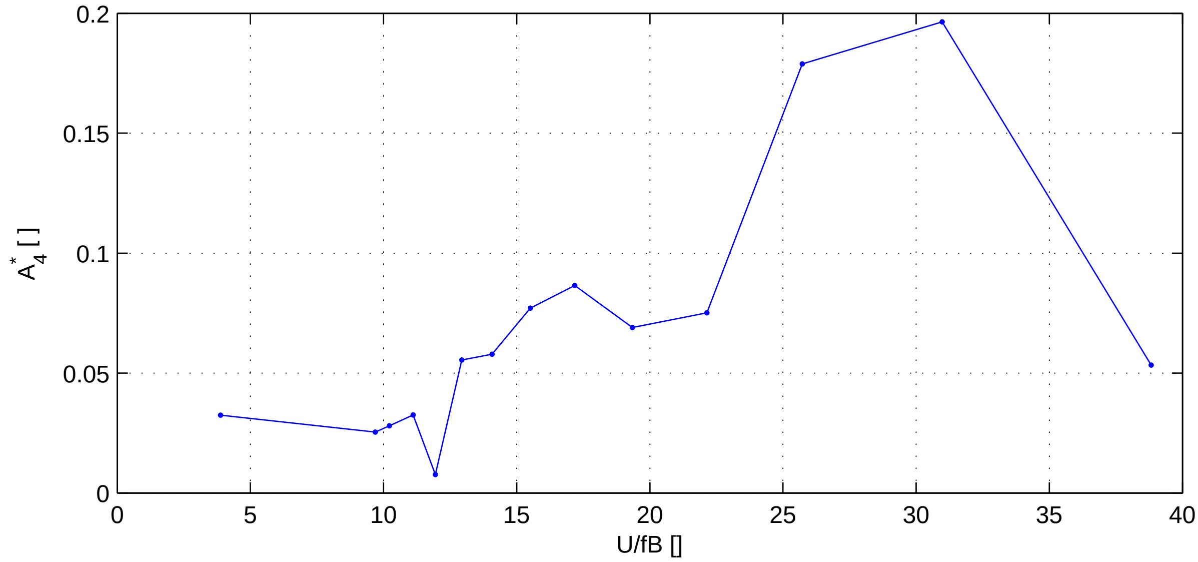

Figure N.10: A^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_4
11.71	25.13	4.00	1.62	3.88	0.03
11.71	10.05	1.60	0.65	9.69	0.03
11.60	9.45	1.50	0.61	10.22	0.03
11.73	8.79	1.40	0.57	11.11	0.03
11.71	8.16	1.30	0.53	11.94	0.01
11.70	7.52	1.20	0.49	12.94	0.06
11.68	6.90	1.10	0.45	14.08	0.06
11.71	6.28	1.00	0.40	15.51	0.08
11.69	5.66	0.90	0.37	17.18	0.09
11.68	5.03	0.80	0.32	19.34	0.07
11.69	4.39	0.70	0.28	22.14	0.08
11.67	3.77	0.60	0.24	25.73	0.18
11.69	3.14	0.50	0.20	30.98	0.20
11.73	2.51	0.40	0.16	38.83	0.05

Table N.12: A^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

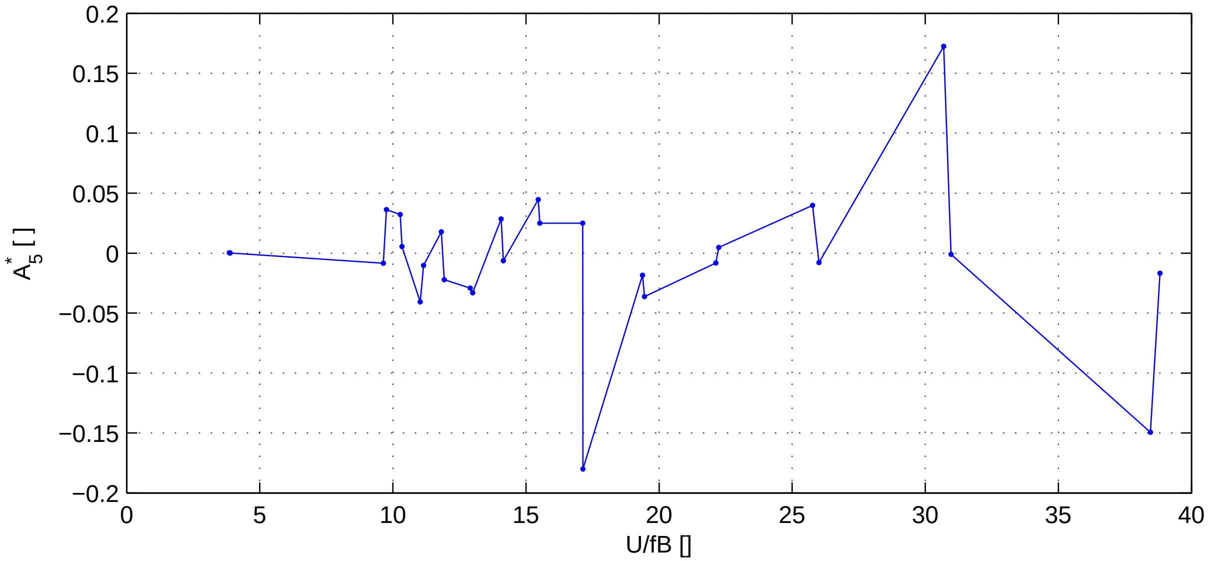

Figure N.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
11.63	25.13	4.00	1.63	3.85	0.00
11.75	25.13	4.00	1.61	3.89	0.00
11.65	10.05	1.60	0.65	9.64	−0.01
11.79	10.05	1.60	0.64	9.76	0.04
11.66	9.45	1.50	0.61	10.27	0.03
11.74	9.45	1.50	0.61	10.34	0.01
11.64	8.79	1.40	0.57	11.02	−0.04
11.78	8.79	1.40	0.56	11.15	−0.01
11.59	8.16	1.30	0.53	11.82	0.02
11.70	8.16	1.30	0.53	11.93	−0.02
11.67	7.52	1.20	0.49	12.91	−0.03
11.75	7.52	1.20	0.48	13.00	−0.03
11.67	6.90	1.10	0.45	14.06	0.03
11.74	6.90	1.10	0.44	14.15	−0.01
11.67	6.28	1.00	0.41	15.46	0.04
11.72	6.28	1.00	0.40	15.52	0.02
11.65	5.66	0.90	0.37	17.13	0.02
11.66	5.66	0.90	0.37	17.14	−0.18
11.71	5.03	0.80	0.32	19.38	−0.02
11.75	5.03	0.80	0.32	19.45	−0.04
11.68	4.39	0.70	0.28	22.13	−0.01
11.74	4.39	0.70	0.28	22.25	0.00
11.68	3.77	0.60	0.24	25.77	0.04
11.79	3.77	0.60	0.24	26.01	−0.01
11.59	3.14	0.50	0.20	30.69	0.17
11.69	3.14	0.50	0.20	30.97	−0.00
11.61	2.51	0.40	0.16	38.46	−0.15
11.72	2.51	0.40	0.16	38.82	−0.02

Table N.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

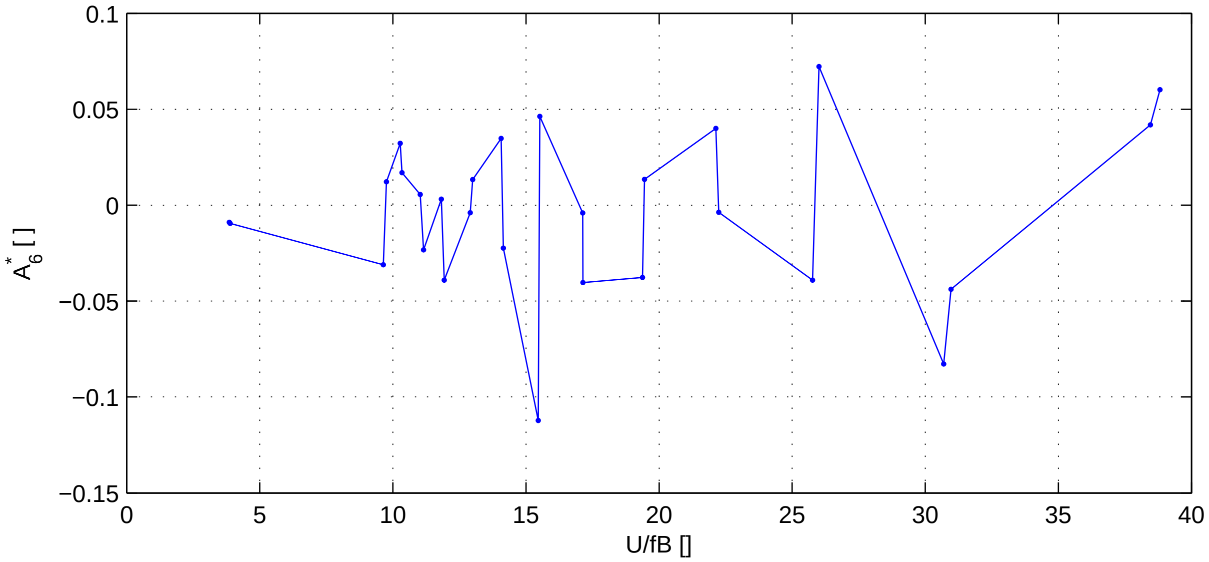

Figure N.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
11.63	25.13	4.00	1.63	3.85	−0.01
11.75	25.13	4.00	1.61	3.89	−0.01
11.65	10.05	1.60	0.65	9.64	−0.03
11.79	10.05	1.60	0.64	9.76	0.01
11.66	9.45	1.50	0.61	10.27	0.03
11.74	9.45	1.50	0.61	10.34	0.02
11.64	8.79	1.40	0.57	11.02	0.01
11.78	8.79	1.40	0.56	11.15	−0.02
11.59	8.16	1.30	0.53	11.82	0.00
11.70	8.16	1.30	0.53	11.93	−0.04
11.67	7.52	1.20	0.49	12.91	−0.00
11.75	7.52	1.20	0.48	13.00	0.01
11.67	6.90	1.10	0.45	14.06	0.03
11.74	6.90	1.10	0.44	14.15	−0.02
11.67	6.28	1.00	0.41	15.46	−0.11
11.72	6.28	1.00	0.40	15.52	0.05
11.65	5.66	0.90	0.37	17.13	−0.00
11.66	5.66	0.90	0.37	17.14	−0.04
11.71	5.03	0.80	0.32	19.38	−0.04
11.75	5.03	0.80	0.32	19.45	0.01
11.68	4.39	0.70	0.28	22.13	0.04
11.74	4.39	0.70	0.28	22.25	−0.00
11.68	3.77	0.60	0.24	25.77	−0.04
11.79	3.77	0.60	0.24	26.01	0.07
11.59	3.14	0.50	0.20	30.69	−0.08
11.69	3.14	0.50	0.20	30.97	−0.04
11.61	2.51	0.40	0.16	38.46	0.04
11.72	2.51	0.40	0.16	38.82	0.06

Table N.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

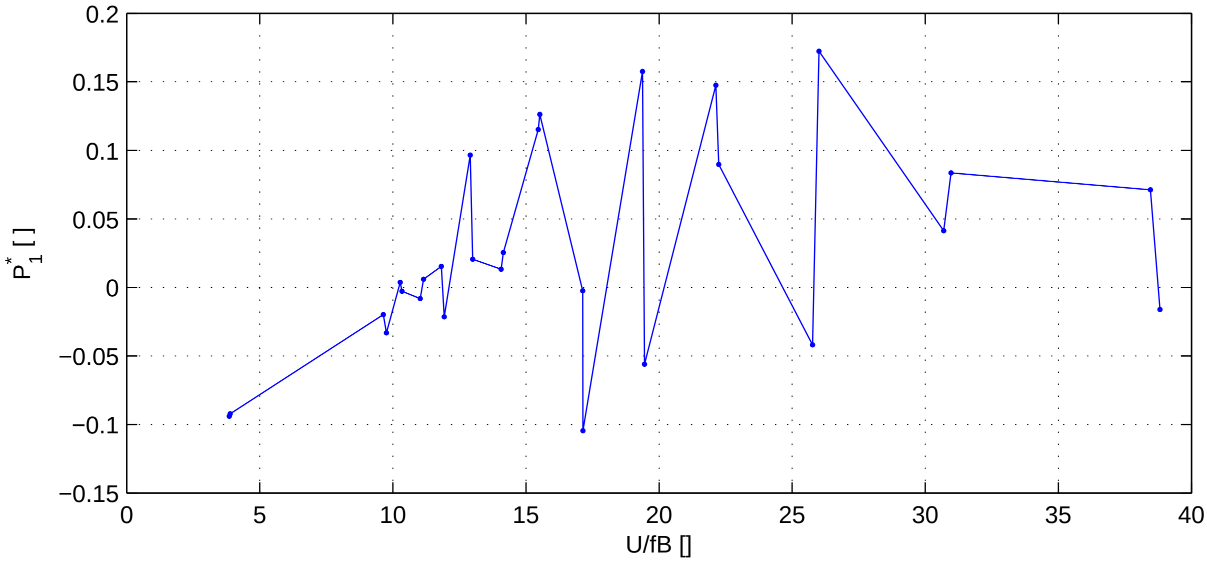

Figure N.13: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_1^*
11.63	25.13	4.00	1.63	3.85	−0.09
11.75	25.13	4.00	1.61	3.89	−0.09
11.65	10.05	1.60	0.65	9.64	−0.02
11.79	10.05	1.60	0.64	9.76	−0.03
11.66	9.45	1.50	0.61	10.27	0.00
11.74	9.45	1.50	0.61	10.34	−0.00
11.64	8.79	1.40	0.57	11.02	−0.01
11.78	8.79	1.40	0.56	11.15	0.01
11.59	8.16	1.30	0.53	11.82	0.02
11.70	8.16	1.30	0.53	11.93	−0.02
11.67	7.52	1.20	0.49	12.91	0.10
11.75	7.52	1.20	0.48	13.00	0.02
11.67	6.90	1.10	0.45	14.06	0.01
11.74	6.90	1.10	0.44	14.15	0.03
11.67	6.28	1.00	0.41	15.46	0.12
11.72	6.28	1.00	0.40	15.52	0.13
11.65	5.66	0.90	0.37	17.13	−0.00
11.66	5.66	0.90	0.37	17.14	−0.10
11.71	5.03	0.80	0.32	19.38	0.16
11.75	5.03	0.80	0.32	19.45	−0.06
11.68	4.39	0.70	0.28	22.13	0.15
11.74	4.39	0.70	0.28	22.25	0.09
11.68	3.77	0.60	0.24	25.77	−0.04
11.79	3.77	0.60	0.24	26.01	0.17
11.59	3.14	0.50	0.20	30.69	0.04
11.69	3.14	0.50	0.20	30.97	0.08
11.61	2.51	0.40	0.16	38.46	0.07
11.72	2.51	0.40	0.16	38.82	−0.02

Table N.15: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

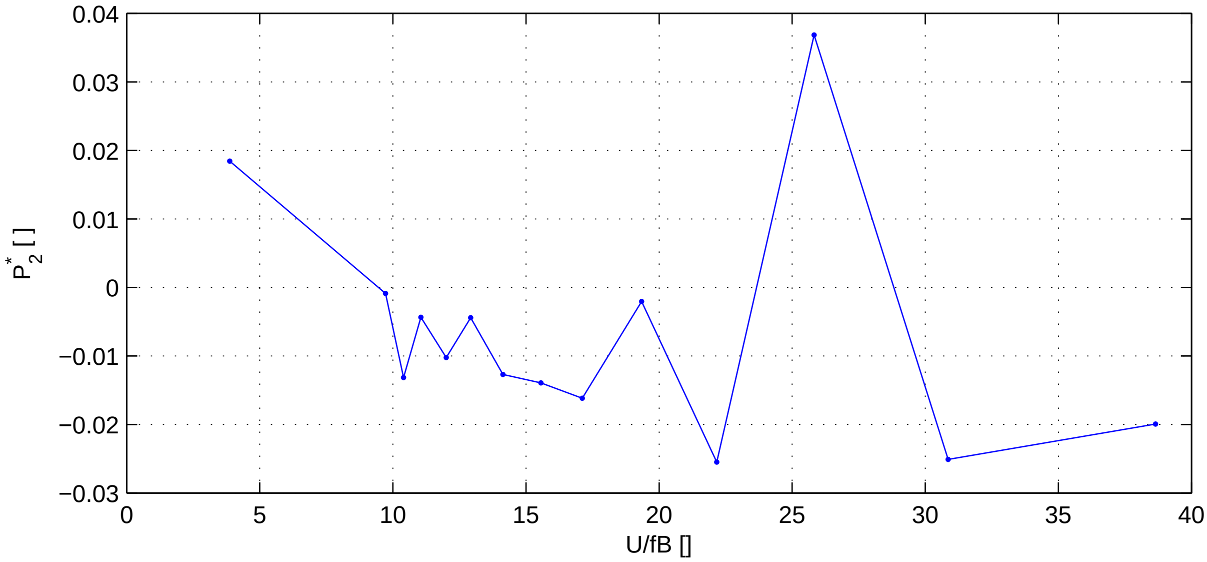

Figure N.14: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_2
11.68	25.13	4.00	1.62	3.87	0.02
11.75	10.05	1.60	0.65	9.73	−0.00
11.81	9.45	1.50	0.60	10.40	−0.01
11.67	8.79	1.40	0.57	11.06	−0.00
11.77	8.16	1.30	0.52	12.01	−0.01
11.68	7.52	1.20	0.49	12.92	−0.00
11.72	6.90	1.10	0.44	14.13	−0.01
11.75	6.28	1.00	0.40	15.56	−0.01
11.64	5.66	0.90	0.37	17.12	−0.02
11.69	5.03	0.80	0.32	19.35	−0.00
11.71	4.39	0.70	0.28	22.17	−0.03
11.71	3.77	0.60	0.24	25.82	0.04
11.65	3.14	0.50	0.20	30.86	−0.03
11.67	2.51	0.40	0.16	38.65	−0.02

Table N.16: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

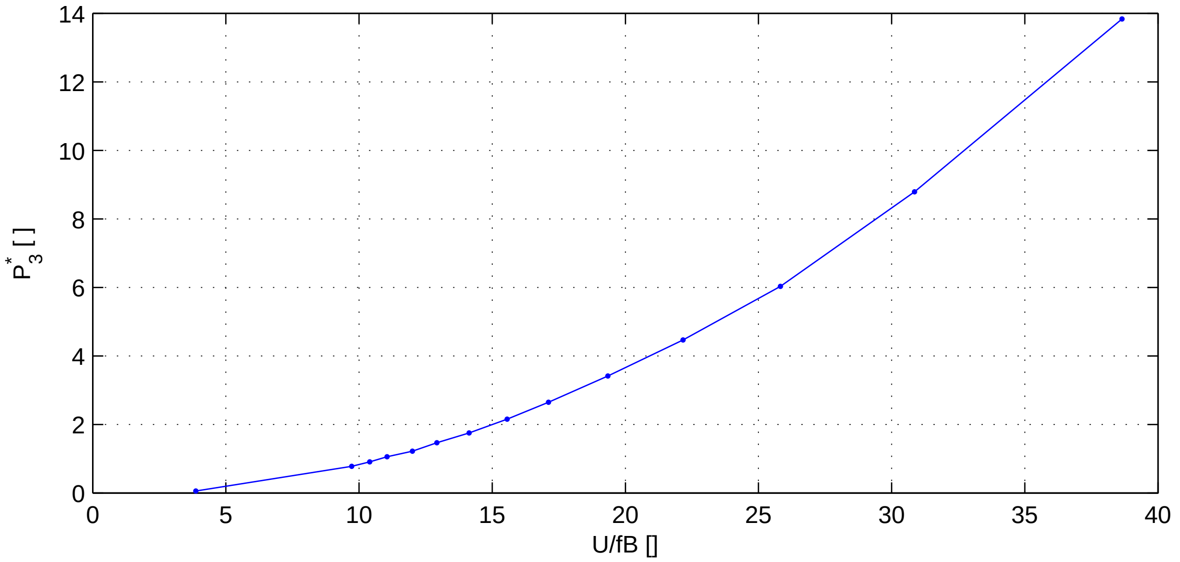

Figure N.15: P_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_3^*
11.68	25.13	4.00	1.62	3.87	0.06
11.75	10.05	1.60	0.65	9.73	0.78
11.81	9.45	1.50	0.60	10.40	0.90
11.67	8.79	1.40	0.57	11.06	1.06
11.77	8.16	1.30	0.52	12.01	1.22
11.68	7.52	1.20	0.49	12.92	1.47
11.72	6.90	1.10	0.44	14.13	1.75
11.75	6.28	1.00	0.40	15.56	2.15
11.64	5.66	0.90	0.37	17.12	2.65
11.69	5.03	0.80	0.32	19.35	3.41
11.71	4.39	0.70	0.28	22.17	4.46
11.71	3.77	0.60	0.24	25.82	6.03
11.65	3.14	0.50	0.20	30.86	8.79
11.67	2.51	0.40	0.16	38.65	13.83

Table N.17: P_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

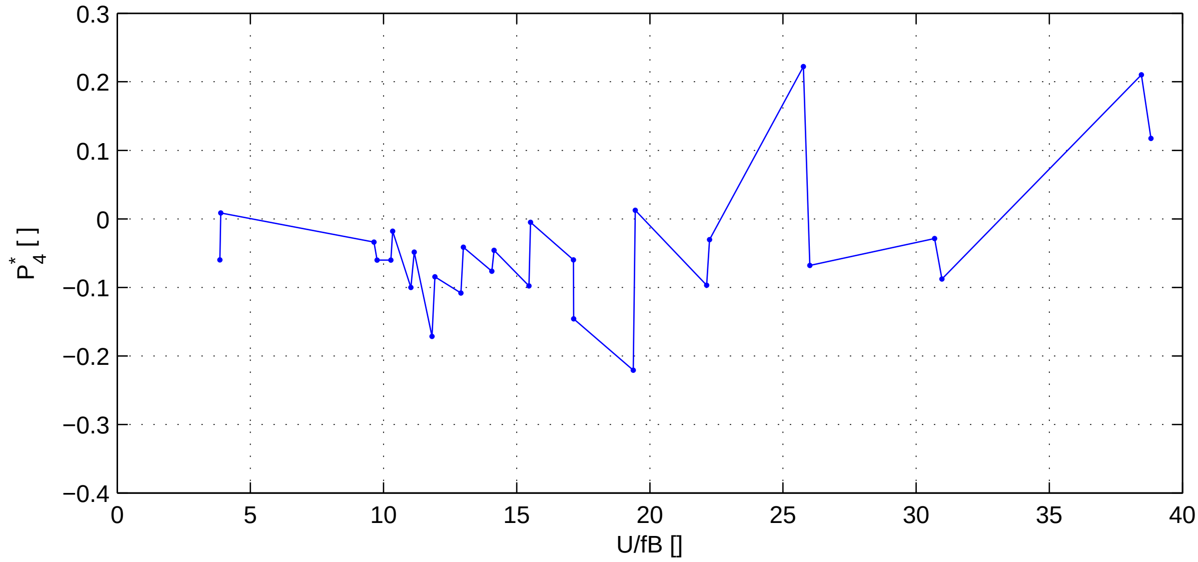

Figure N.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
11.63	25.13	4.00	1.63	3.85	−0.06
11.75	25.13	4.00	1.61	3.89	0.01
11.65	10.05	1.60	0.65	9.64	−0.03
11.79	10.05	1.60	0.64	9.76	−0.06
11.66	9.45	1.50	0.61	10.27	−0.06
11.74	9.45	1.50	0.61	10.34	−0.02
11.64	8.79	1.40	0.57	11.02	−0.10
11.78	8.79	1.40	0.56	11.15	−0.05
11.59	8.16	1.30	0.53	11.82	−0.17
11.70	8.16	1.30	0.53	11.93	−0.08
11.67	7.52	1.20	0.49	12.91	−0.11
11.75	7.52	1.20	0.48	13.00	−0.04
11.67	6.90	1.10	0.45	14.06	−0.08
11.74	6.90	1.10	0.44	14.15	−0.05
11.67	6.28	1.00	0.41	15.46	−0.10
11.72	6.28	1.00	0.40	15.52	−0.00
11.65	5.66	0.90	0.37	17.13	−0.06
11.66	5.66	0.90	0.37	17.14	−0.15
11.71	5.03	0.80	0.32	19.38	−0.22
11.75	5.03	0.80	0.32	19.45	0.01
11.68	4.39	0.70	0.28	22.13	−0.10
11.74	4.39	0.70	0.28	22.25	−0.03
11.68	3.77	0.60	0.24	25.77	0.22
11.79	3.77	0.60	0.24	26.01	−0.07
11.59	3.14	0.50	0.20	30.69	−0.03
11.69	3.14	0.50	0.20	30.97	−0.09
11.61	2.51	0.40	0.16	38.46	0.21
11.72	2.51	0.40	0.16	38.82	0.12

Table N.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

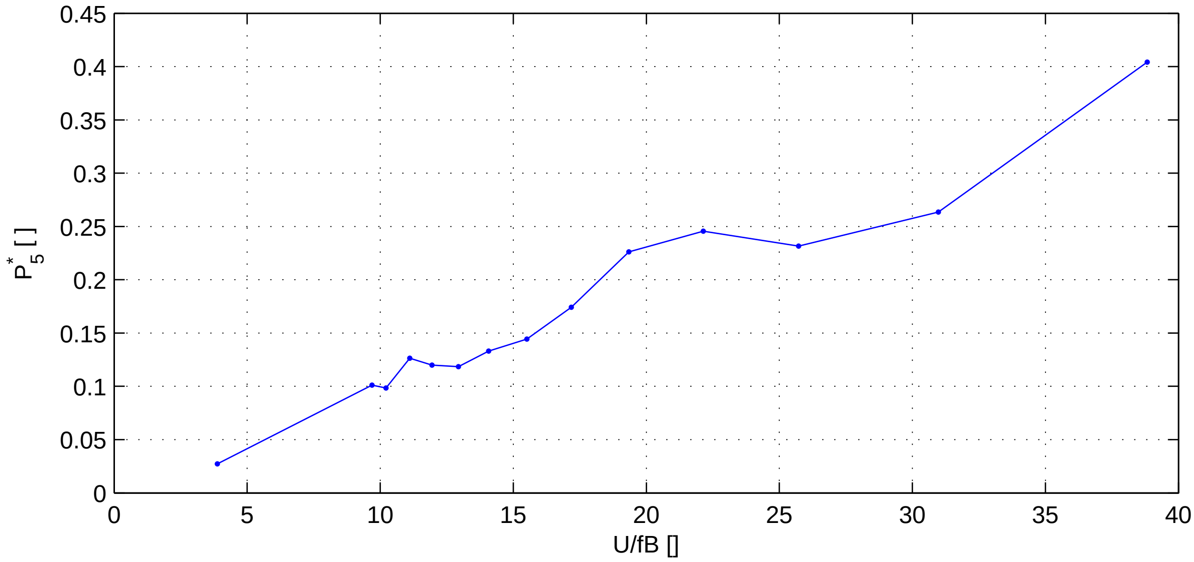

Figure N.17: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_5^*
11.71	25.13	4.00	1.62	3.88	0.03
11.71	10.05	1.60	0.65	9.69	0.10
11.60	9.45	1.50	0.61	10.22	0.10
11.73	8.79	1.40	0.57	11.11	0.13
11.71	8.16	1.30	0.53	11.94	0.12
11.70	7.52	1.20	0.49	12.94	0.12
11.68	6.90	1.10	0.45	14.08	0.13
11.71	6.28	1.00	0.40	15.51	0.14
11.69	5.66	0.90	0.37	17.18	0.17
11.68	5.03	0.80	0.32	19.34	0.23
11.69	4.39	0.70	0.28	22.14	0.25
11.67	3.77	0.60	0.24	25.73	0.23
11.69	3.14	0.50	0.20	30.98	0.26
11.73	2.51	0.40	0.16	38.83	0.40

Table N.19: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

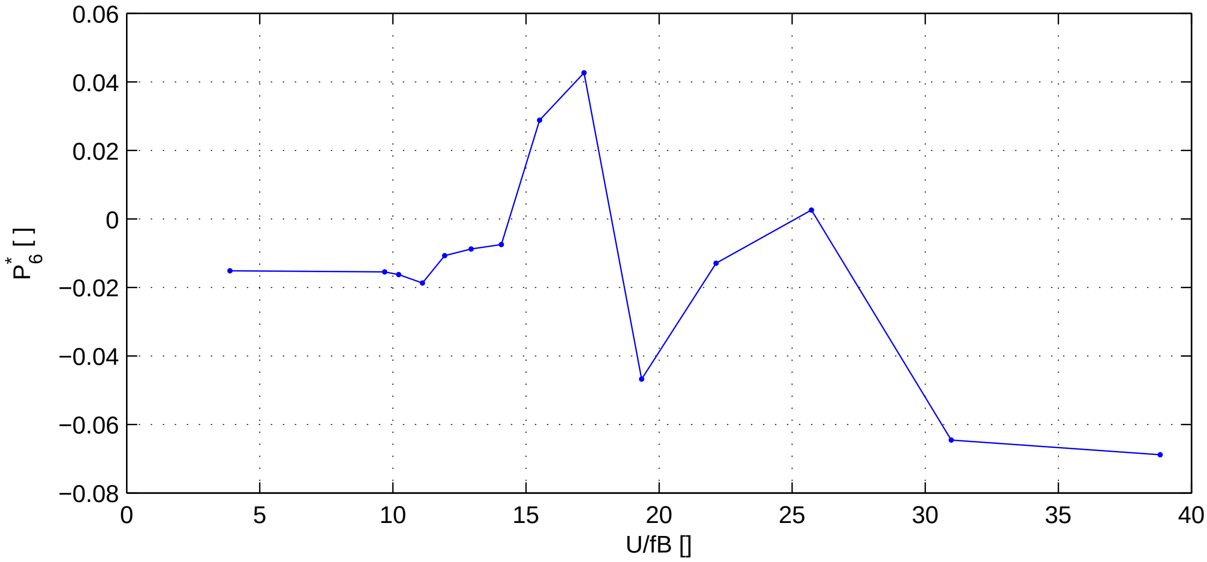

Figure N.18: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_6
11.71	25.13	4.00	1.62	3.88	−0.02
11.71	10.05	1.60	0.65	9.69	−0.02
11.60	9.45	1.50	0.61	10.22	−0.02
11.73	8.79	1.40	0.57	11.11	−0.02
11.71	8.16	1.30	0.53	11.94	−0.01
11.70	7.52	1.20	0.49	12.94	−0.01
11.68	6.90	1.10	0.45	14.08	−0.01
11.71	6.28	1.00	0.40	15.51	0.03
11.69	5.66	0.90	0.37	17.18	0.04
11.68	5.03	0.80	0.32	19.34	−0.05
11.69	4.39	0.70	0.28	22.14	−0.01
11.67	3.77	0.60	0.24	25.73	0.00
11.69	3.14	0.50	0.20	30.98	−0.06
11.73	2.51	0.40	0.16	38.83	−0.07

Table N.20: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\,(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\,\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\,(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\,\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\,(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\,\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

Formula N.3: Equation of Motion (Stretto di Messina. Ref. [5].)

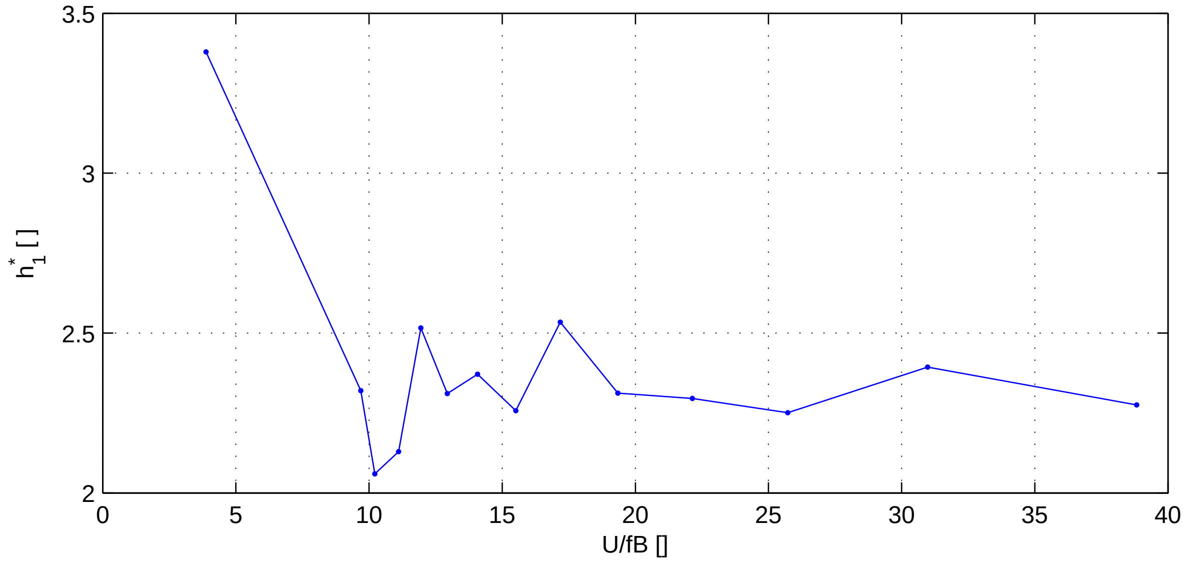

Figure N.19: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_1^*
11.71	25.13	4.00	1.62	3.88	3.38
11.71	10.05	1.60	0.65	9.69	2.32
11.60	9.45	1.50	0.61	10.22	2.06
11.73	8.79	1.40	0.57	11.11	2.13
11.71	8.16	1.30	0.53	11.94	2.52
11.70	7.52	1.20	0.49	12.94	2.31
11.68	6.90	1.10	0.45	14.08	2.37
11.71	6.28	1.00	0.40	15.51	2.26
11.69	5.66	0.90	0.37	17.18	2.53
11.68	5.03	0.80	0.32	19.34	2.31
11.69	4.39	0.70	0.28	22.14	2.30
11.67	3.77	0.60	0.24	25.73	2.25
11.69	3.14	0.50	0.20	30.98	2.39
11.73	2.51	0.40	0.16	38.83	2.28

Table N.21: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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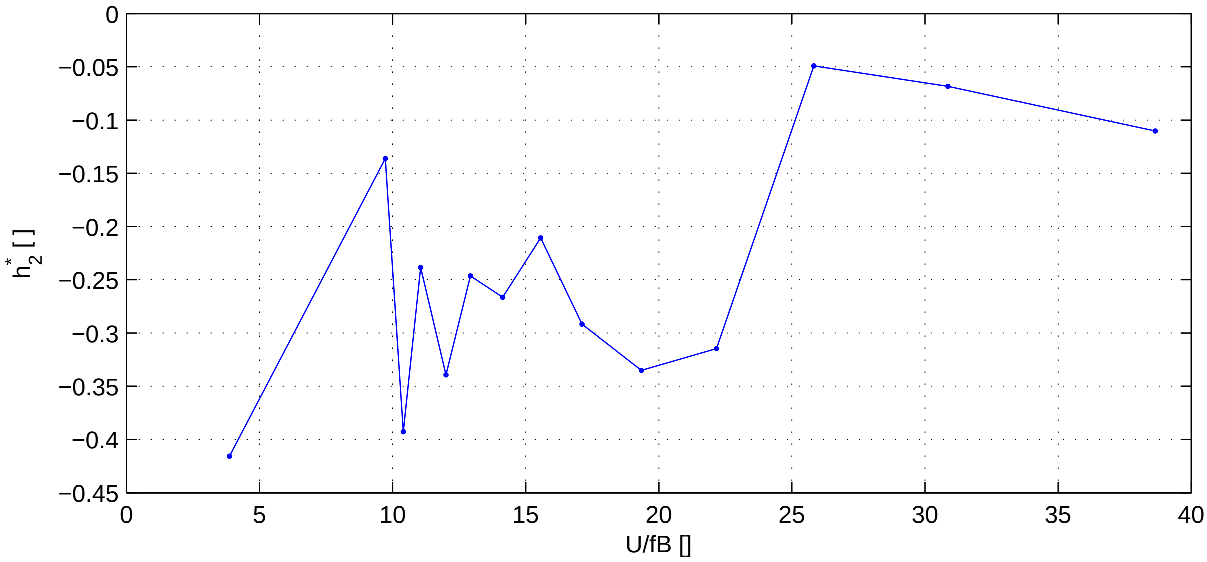

Figure N.20: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_2^*
11.68	25.13	4.00	1.62	3.87	−0.42
11.75	10.05	1.60	0.65	9.73	−0.14
11.81	9.45	1.50	0.60	10.40	−0.39
11.67	8.79	1.40	0.57	11.06	−0.24
11.77	8.16	1.30	0.52	12.01	−0.34
11.68	7.52	1.20	0.49	12.92	−0.25
11.72	6.90	1.10	0.44	14.13	−0.27
11.75	6.28	1.00	0.40	15.56	−0.21
11.64	5.66	0.90	0.37	17.12	−0.29
11.69	5.03	0.80	0.32	19.35	−0.34
11.71	4.39	0.70	0.28	22.17	−0.31
11.71	3.77	0.60	0.24	25.82	−0.05
11.65	3.14	0.50	0.20	30.86	−0.07
11.67	2.51	0.40	0.16	38.65	−0.11

Table N.22: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

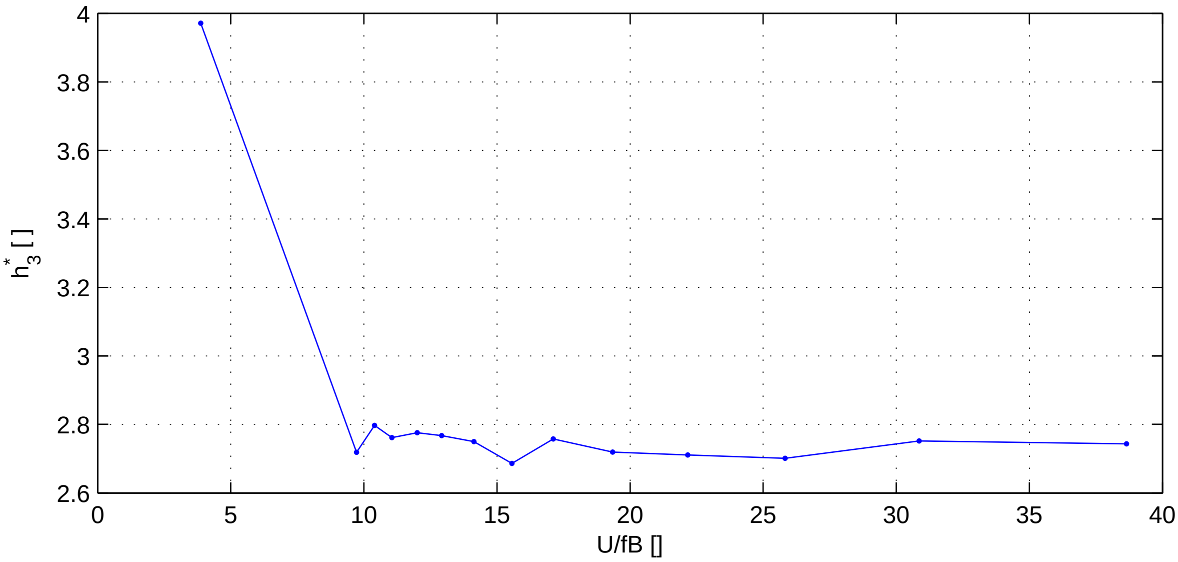

Figure N.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
11.68	25.13	4.00	1.62	3.87	3.97
11.75	10.05	1.60	0.65	9.73	2.72
11.81	9.45	1.50	0.60	10.40	2.80
11.67	8.79	1.40	0.57	11.06	2.76
11.77	8.16	1.30	0.52	12.01	2.78
11.68	7.52	1.20	0.49	12.92	2.77
11.72	6.90	1.10	0.44	14.13	2.75
11.75	6.28	1.00	0.40	15.56	2.69
11.64	5.66	0.90	0.37	17.12	2.76
11.69	5.03	0.80	0.32	19.35	2.72
11.71	4.39	0.70	0.28	22.17	2.71
11.71	3.77	0.60	0.24	25.82	2.70
11.65	3.14	0.50	0.20	30.86	2.75
11.67	2.51	0.40	0.16	38.65	2.74

Table N.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

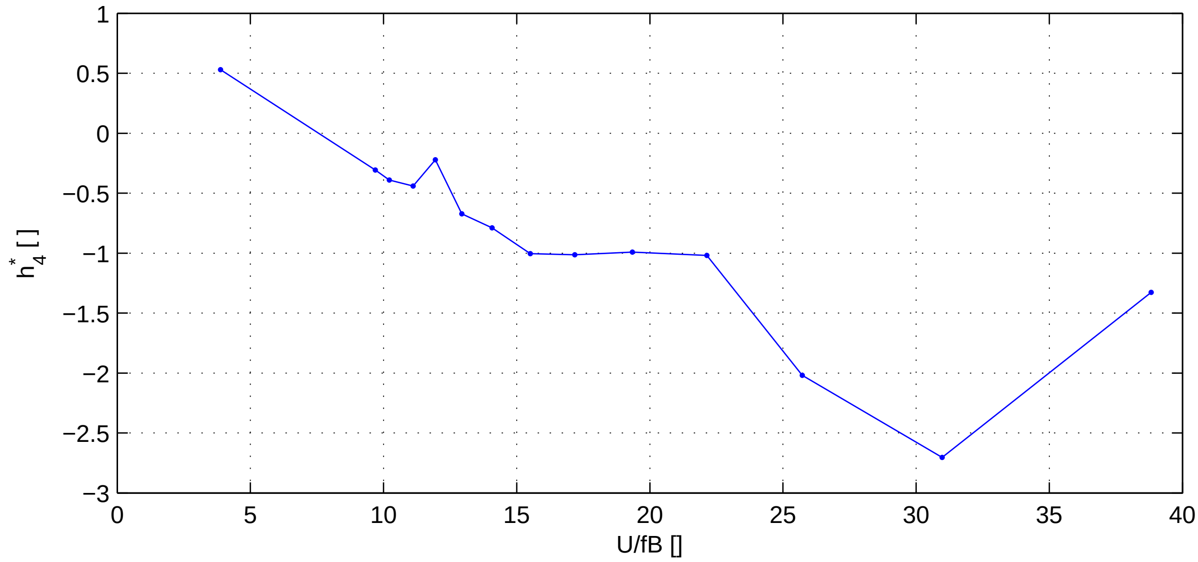

Figure N.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
11.71	25.13	4.00	1.62	3.88	0.53
11.71	10.05	1.60	0.65	9.69	−0.31
11.60	9.45	1.50	0.61	10.22	−0.39
11.73	8.79	1.40	0.57	11.11	−0.44
11.71	8.16	1.30	0.53	11.94	−0.22
11.70	7.52	1.20	0.49	12.94	−0.67
11.68	6.90	1.10	0.45	14.08	−0.79
11.71	6.28	1.00	0.40	15.51	−1.01
11.69	5.66	0.90	0.37	17.18	−1.01
11.68	5.03	0.80	0.32	19.34	−0.99
11.69	4.39	0.70	0.28	22.14	−1.02
11.67	3.77	0.60	0.24	25.73	−2.02
11.69	3.14	0.50	0.20	30.98	−2.70
11.73	2.51	0.40	0.16	38.83	−1.33

Table N.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

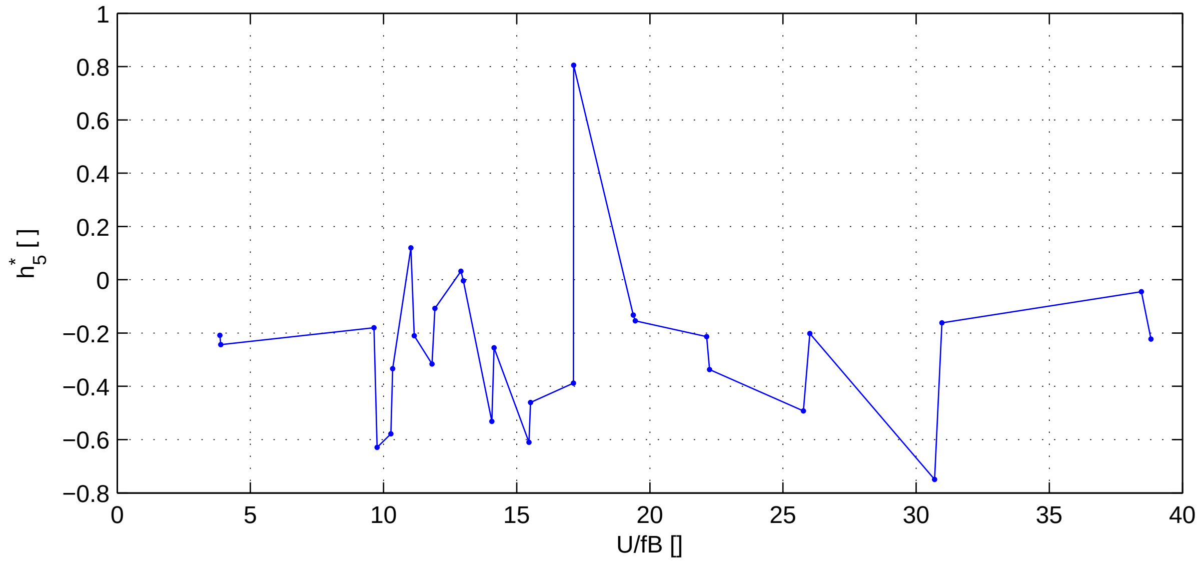

Figure N.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
11.63	25.13	4.00	1.63	3.85	−0.21
11.75	25.13	4.00	1.61	3.89	−0.24
11.65	10.05	1.60	0.65	9.64	−0.18
11.79	10.05	1.60	0.64	9.76	−0.63
11.66	9.45	1.50	0.61	10.27	−0.58
11.74	9.45	1.50	0.61	10.34	−0.33
11.64	8.79	1.40	0.57	11.02	0.12
11.78	8.79	1.40	0.56	11.15	−0.21
11.59	8.16	1.30	0.53	11.82	−0.32
11.70	8.16	1.30	0.53	11.93	−0.11
11.67	7.52	1.20	0.49	12.91	0.03
11.75	7.52	1.20	0.48	13.00	−0.00
11.67	6.90	1.10	0.45	14.06	−0.53
11.74	6.90	1.10	0.44	14.15	−0.26
11.67	6.28	1.00	0.41	15.46	−0.61
11.72	6.28	1.00	0.40	15.52	−0.46
11.65	5.66	0.90	0.37	17.13	−0.39
11.66	5.66	0.90	0.37	17.14	0.81
11.71	5.03	0.80	0.32	19.38	−0.13
11.75	5.03	0.80	0.32	19.45	−0.15
11.68	4.39	0.70	0.28	22.13	−0.21
11.74	4.39	0.70	0.28	22.25	−0.34
11.68	3.77	0.60	0.24	25.77	−0.49
11.79	3.77	0.60	0.24	26.01	−0.20
11.59	3.14	0.50	0.20	30.69	−0.75
11.69	3.14	0.50	0.20	30.97	−0.16
11.61	2.51	0.40	0.16	38.46	−0.04
11.72	2.51	0.40	0.16	38.82	−0.22

Table N.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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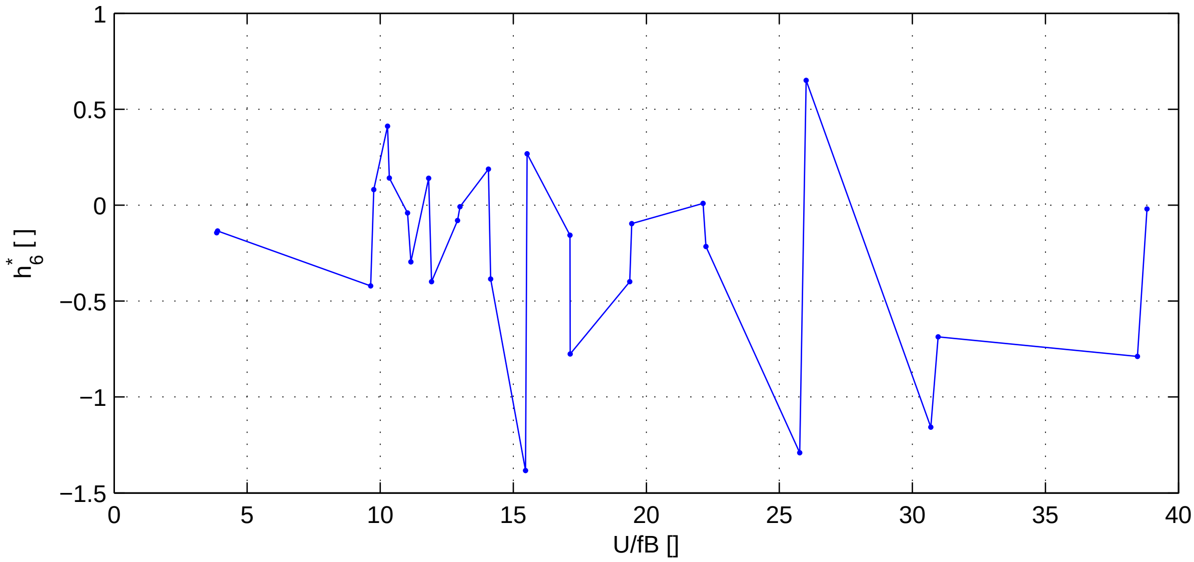


Figure N.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
11.63	25.13	4.00	1.63	3.85	−0.14
11.75	25.13	4.00	1.61	3.89	−0.13
11.65	10.05	1.60	0.65	9.64	−0.42
11.79	10.05	1.60	0.64	9.76	0.08
11.66	9.45	1.50	0.61	10.27	0.41
11.74	9.45	1.50	0.61	10.34	0.14
11.64	8.79	1.40	0.57	11.02	−0.04
11.78	8.79	1.40	0.56	11.15	−0.30
11.59	8.16	1.30	0.53	11.82	0.14
11.70	8.16	1.30	0.53	11.93	−0.40
11.67	7.52	1.20	0.49	12.91	−0.08
11.75	7.52	1.20	0.48	13.00	−0.01
11.67	6.90	1.10	0.45	14.06	0.19
11.74	6.90	1.10	0.44	14.15	−0.39
11.67	6.28	1.00	0.41	15.46	−1.38
11.72	6.28	1.00	0.40	15.52	0.27
11.65	5.66	0.90	0.37	17.13	−0.16
11.66	5.66	0.90	0.37	17.14	−0.78
11.71	5.03	0.80	0.32	19.38	−0.40
11.75	5.03	0.80	0.32	19.45	−0.10
11.68	4.39	0.70	0.28	22.13	0.01
11.74	4.39	0.70	0.28	22.25	−0.22
11.68	3.77	0.60	0.24	25.77	−1.29
11.79	3.77	0.60	0.24	26.01	0.65
11.59	3.14	0.50	0.20	30.69	−1.16
11.69	3.14	0.50	0.20	30.97	−0.69
11.61	2.51	0.40	0.16	38.46	−0.79
11.72	2.51	0.40	0.16	38.82	−0.02

Table N.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

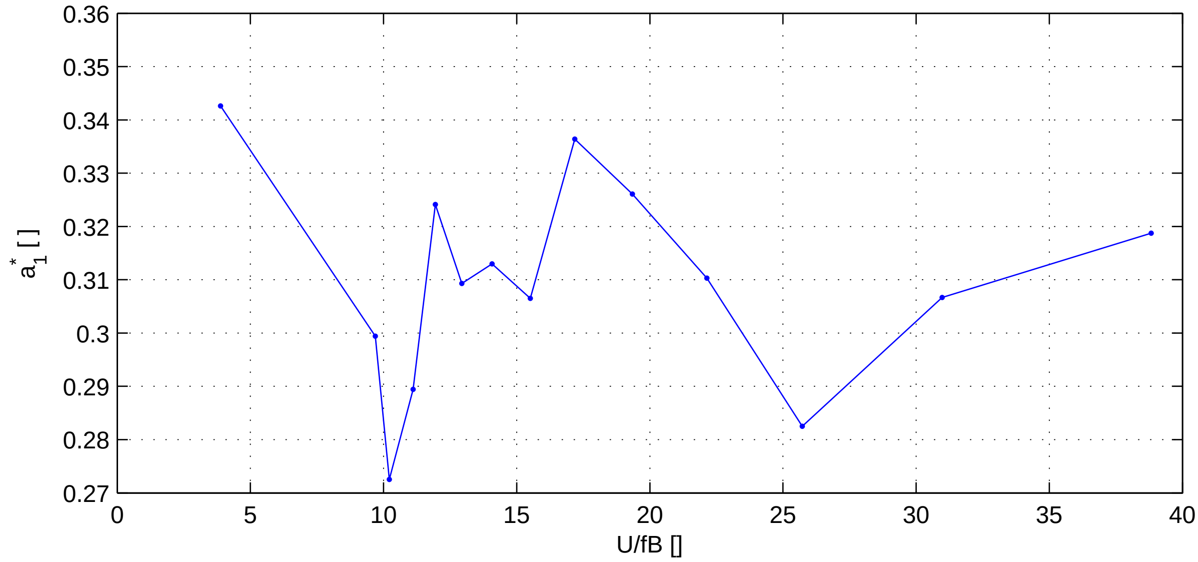


Figure N.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
11.71	25.13	4.00	1.62	3.88	0.34
11.71	10.05	1.60	0.65	9.69	0.30
11.60	9.45	1.50	0.61	10.22	0.27
11.73	8.79	1.40	0.57	11.11	0.29
11.71	8.16	1.30	0.53	11.94	0.32
11.70	7.52	1.20	0.49	12.94	0.31
11.68	6.90	1.10	0.45	14.08	0.31
11.71	6.28	1.00	0.40	15.51	0.31
11.69	5.66	0.90	0.37	17.18	0.34
11.68	5.03	0.80	0.32	19.34	0.33
11.69	4.39	0.70	0.28	22.14	0.31
11.67	3.77	0.60	0.24	25.73	0.28
11.69	3.14	0.50	0.20	30.98	0.31
11.73	2.51	0.40	0.16	38.83	0.32

Table N.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

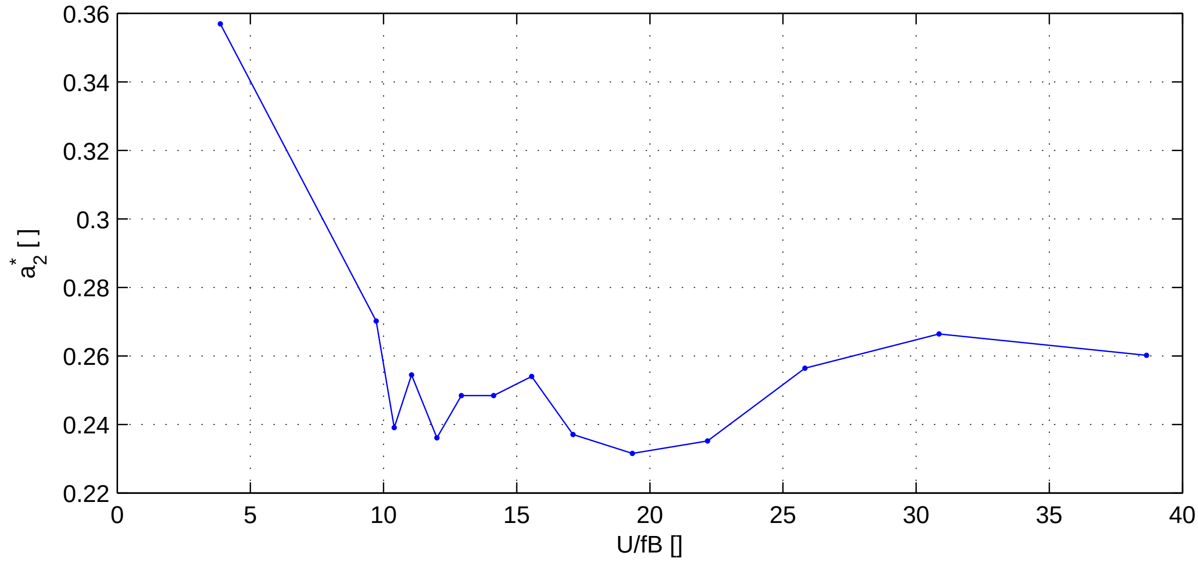


Figure N.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
11.68	25.13	4.00	1.62	3.87	0.36
11.75	10.05	1.60	0.65	9.73	0.27
11.81	9.45	1.50	0.60	10.40	0.24
11.67	8.79	1.40	0.57	11.06	0.25
11.77	8.16	1.30	0.52	12.01	0.24
11.68	7.52	1.20	0.49	12.92	0.25
11.72	6.90	1.10	0.44	14.13	0.25
11.75	6.28	1.00	0.40	15.56	0.25
11.64	5.66	0.90	0.37	17.12	0.24
11.69	5.03	0.80	0.32	19.35	0.23
11.71	4.39	0.70	0.28	22.17	0.24
11.71	3.77	0.60	0.24	25.82	0.26
11.65	3.14	0.50	0.20	30.86	0.27
11.67	2.51	0.40	0.16	38.65	0.26

Table N.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

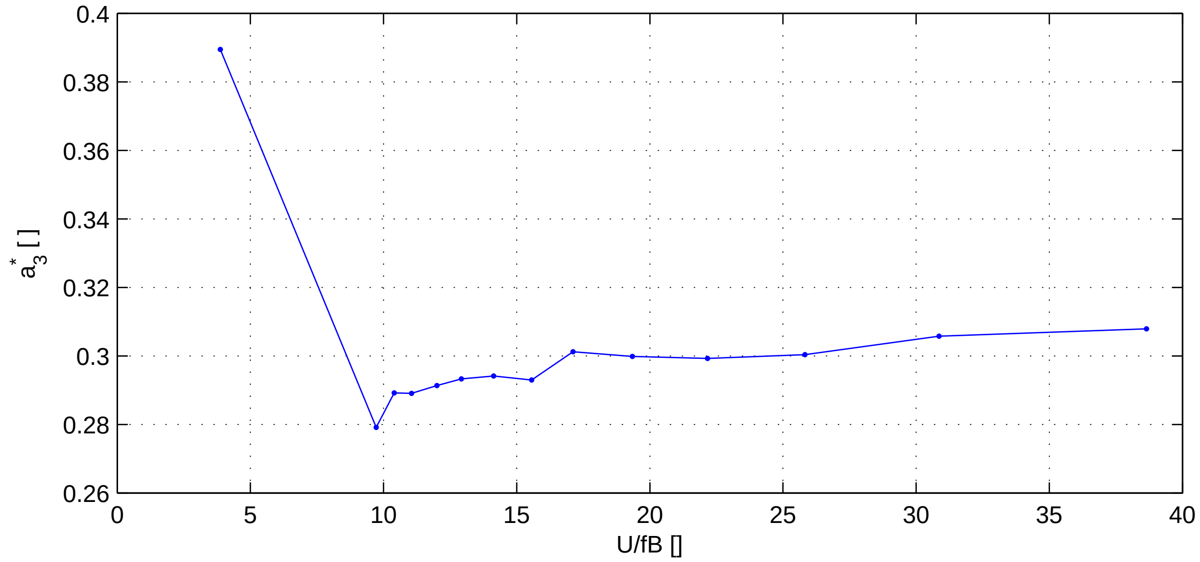


Figure N.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
11.68	25.13	4.00	1.62	3.87	0.39
11.75	10.05	1.60	0.65	9.73	0.28
11.81	9.45	1.50	0.60	10.40	0.29
11.67	8.79	1.40	0.57	11.06	0.29
11.77	8.16	1.30	0.52	12.01	0.29
11.68	7.52	1.20	0.49	12.92	0.29
11.72	6.90	1.10	0.44	14.13	0.29
11.75	6.28	1.00	0.40	15.56	0.29
11.64	5.66	0.90	0.37	17.12	0.30
11.69	5.03	0.80	0.32	19.35	0.30
11.71	4.39	0.70	0.28	22.17	0.30
11.71	3.77	0.60	0.24	25.82	0.30
11.65	3.14	0.50	0.20	30.86	0.31
11.67	2.51	0.40	0.16	38.65	0.31

Table N.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

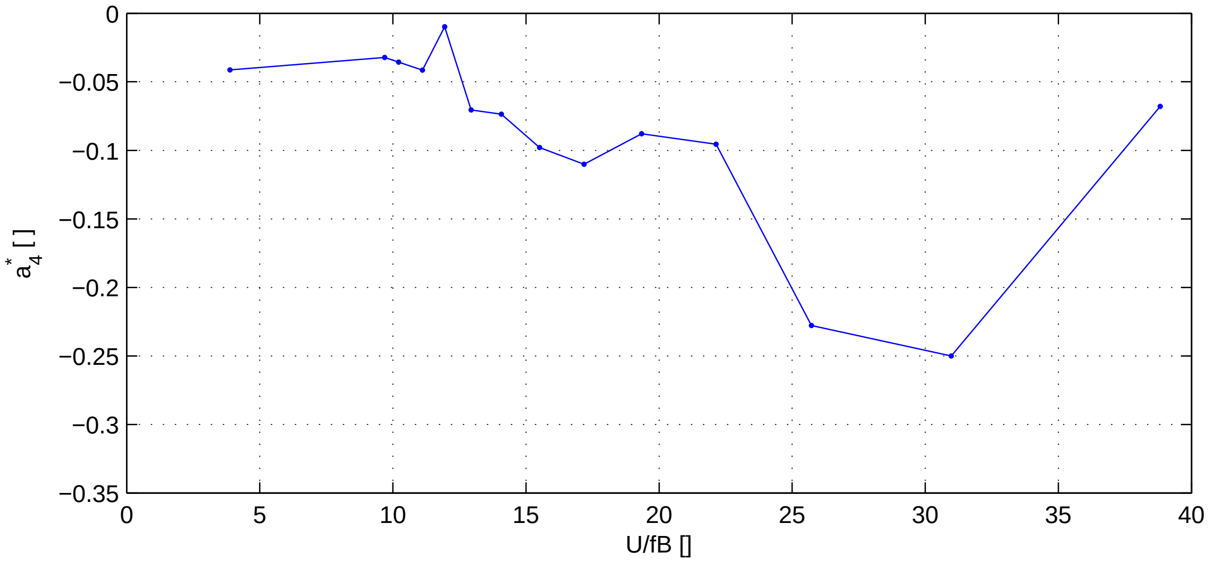


Figure N.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
11.71	25.13	4.00	1.62	3.88	−0.04
11.71	10.05	1.60	0.65	9.69	−0.03
11.60	9.45	1.50	0.61	10.22	−0.04
11.73	8.79	1.40	0.57	11.11	−0.04
11.71	8.16	1.30	0.53	11.94	−0.01
11.70	7.52	1.20	0.49	12.94	−0.07
11.68	6.90	1.10	0.45	14.08	−0.07
11.71	6.28	1.00	0.40	15.51	−0.10
11.69	5.66	0.90	0.37	17.18	−0.11
11.68	5.03	0.80	0.32	19.34	−0.09
11.69	4.39	0.70	0.28	22.14	−0.10
11.67	3.77	0.60	0.24	25.73	−0.23
11.69	3.14	0.50	0.20	30.98	−0.25
11.73	2.51	0.40	0.16	38.83	−0.07

Table N.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

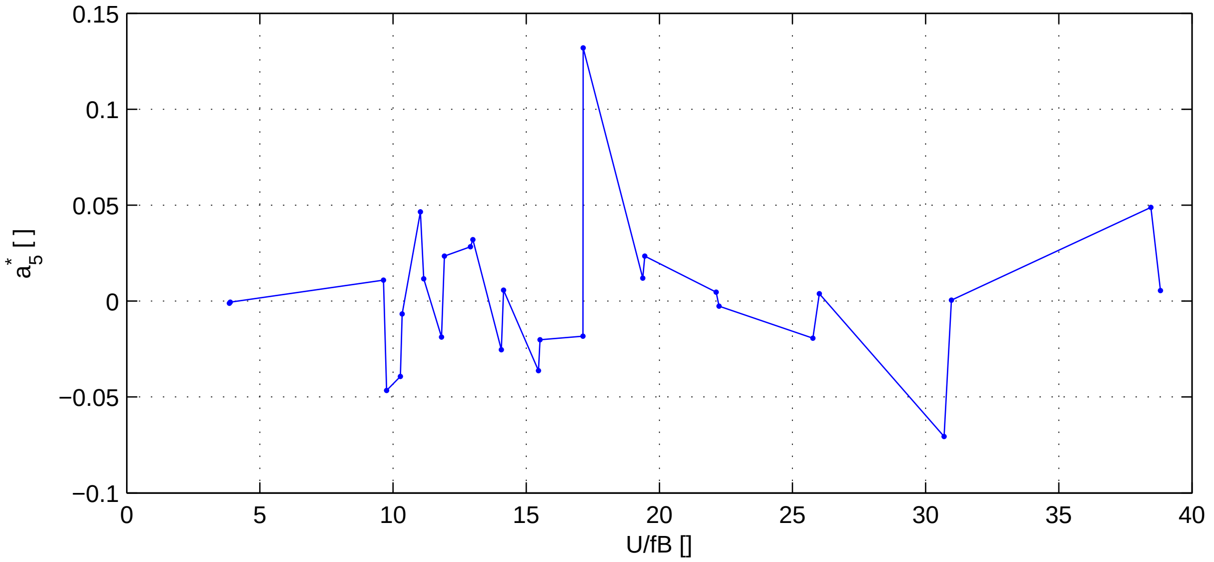


Figure N.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
11.63	25.13	4.00	1.63	3.85	−0.00
11.75	25.13	4.00	1.61	3.89	−0.00
11.65	10.05	1.60	0.65	9.64	0.01
11.79	10.05	1.60	0.64	9.76	−0.05
11.66	9.45	1.50	0.61	10.27	−0.04
11.74	9.45	1.50	0.61	10.34	−0.01
11.64	8.79	1.40	0.57	11.02	0.05
11.78	8.79	1.40	0.56	11.15	0.01
11.59	8.16	1.30	0.53	11.82	−0.02
11.70	8.16	1.30	0.53	11.93	0.02
11.67	7.52	1.20	0.49	12.91	0.03
11.75	7.52	1.20	0.48	13.00	0.03
11.67	6.90	1.10	0.45	14.06	−0.03
11.74	6.90	1.10	0.44	14.15	0.01
11.67	6.28	1.00	0.41	15.46	−0.04
11.72	6.28	1.00	0.40	15.52	−0.02
11.65	5.66	0.90	0.37	17.13	−0.02
11.66	5.66	0.90	0.37	17.14	0.13
11.71	5.03	0.80	0.32	19.38	0.01
11.75	5.03	0.80	0.32	19.45	0.02
11.68	4.39	0.70	0.28	22.13	0.00
11.74	4.39	0.70	0.28	22.25	−0.00
11.68	3.77	0.60	0.24	25.77	−0.02
11.79	3.77	0.60	0.24	26.01	0.00
11.59	3.14	0.50	0.20	30.69	−0.07
11.69	3.14	0.50	0.20	30.97	0.00
11.61	2.51	0.40	0.16	38.46	0.05
11.72	2.51	0.40	0.16	38.82	0.01

Table N.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:25:10

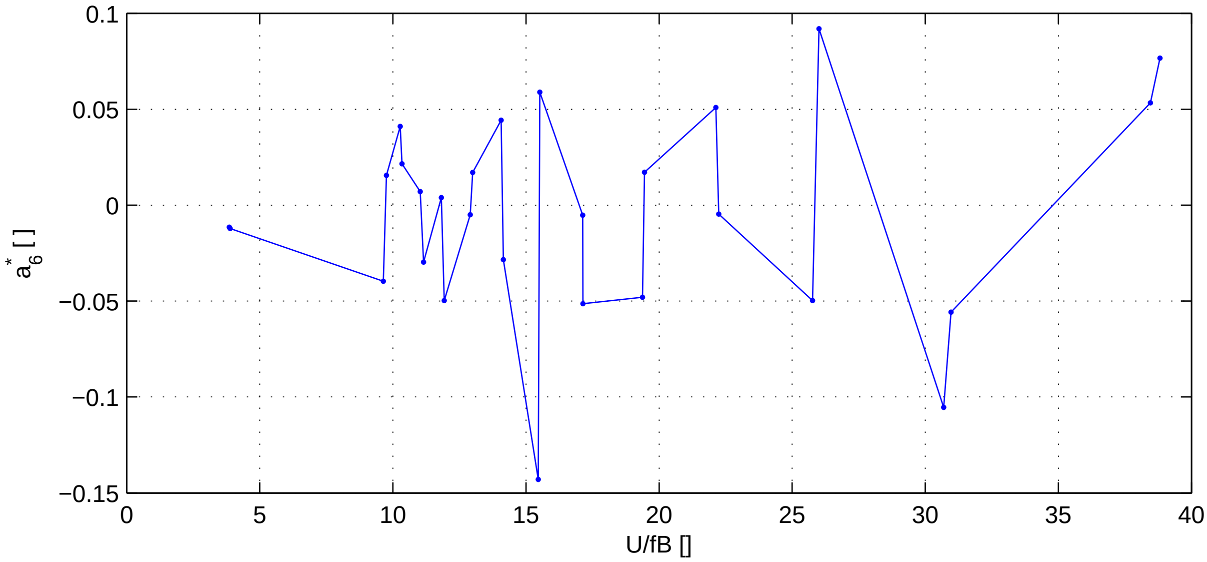


Figure N.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
11.63	25.13	4.00	1.63	3.85	−0.01
11.75	25.13	4.00	1.61	3.89	−0.01
11.65	10.05	1.60	0.65	9.64	−0.04
11.79	10.05	1.60	0.64	9.76	0.02
11.66	9.45	1.50	0.61	10.27	0.04
11.74	9.45	1.50	0.61	10.34	0.02
11.64	8.79	1.40	0.57	11.02	0.01
11.78	8.79	1.40	0.56	11.15	−0.03
11.59	8.16	1.30	0.53	11.82	0.00
11.70	8.16	1.30	0.53	11.93	−0.05
11.67	7.52	1.20	0.49	12.91	−0.01
11.75	7.52	1.20	0.48	13.00	0.02
11.67	6.90	1.10	0.45	14.06	0.04
11.74	6.90	1.10	0.44	14.15	−0.03
11.67	6.28	1.00	0.41	15.46	−0.14
11.72	6.28	1.00	0.40	15.52	0.06
11.65	5.66	0.90	0.37	17.13	−0.01
11.66	5.66	0.90	0.37	17.14	−0.05
11.71	5.03	0.80	0.32	19.38	−0.05
11.75	5.03	0.80	0.32	19.45	0.02
11.68	4.39	0.70	0.28	22.13	0.05
11.74	4.39	0.70	0.28	22.25	−0.00
11.68	3.77	0.60	0.24	25.77	−0.05
11.79	3.77	0.60	0.24	26.01	0.09
11.59	3.14	0.50	0.20	30.69	−0.11
11.69	3.14	0.50	0.20	30.97	−0.06
11.61	2.51	0.40	0.16	38.46	0.05
11.72	2.51	0.40	0.16	38.82	0.08

Table N.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

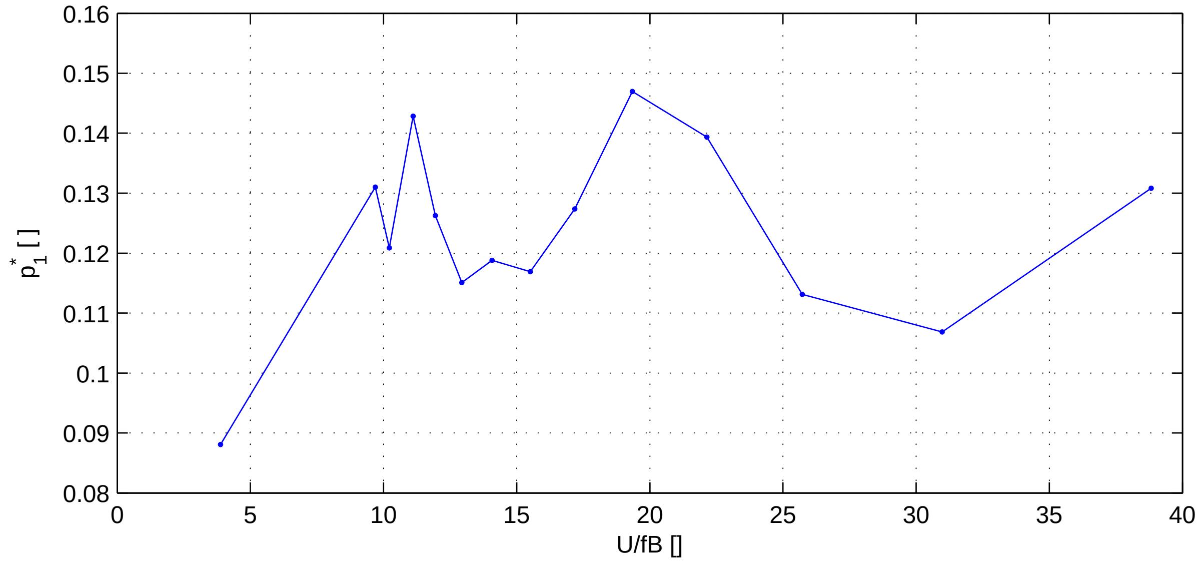


Figure N.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
11.71	25.13	4.00	1.62	3.88	0.09
11.71	10.05	1.60	0.65	9.69	0.13
11.60	9.45	1.50	0.61	10.22	0.12
11.73	8.79	1.40	0.57	11.11	0.14
11.71	8.16	1.30	0.53	11.94	0.13
11.70	7.52	1.20	0.49	12.94	0.12
11.68	6.90	1.10	0.45	14.08	0.12
11.71	6.28	1.00	0.40	15.51	0.12
11.69	5.66	0.90	0.37	17.18	0.13
11.68	5.03	0.80	0.32	19.34	0.15
11.69	4.39	0.70	0.28	22.14	0.14
11.67	3.77	0.60	0.24	25.73	0.11
11.69	3.14	0.50	0.20	30.98	0.11
11.73	2.51	0.40	0.16	38.83	0.13

Table N.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

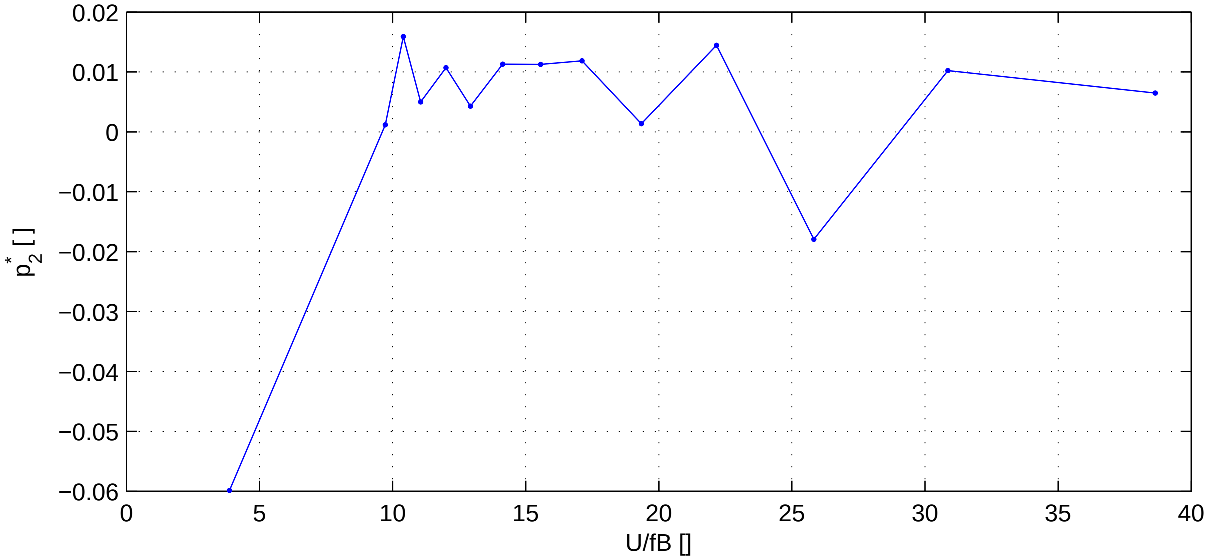


Figure N.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
11.68	25.13	4.00	1.62	3.87	−0.06
11.75	10.05	1.60	0.65	9.73	0.00
11.81	9.45	1.50	0.60	10.40	0.02
11.67	8.79	1.40	0.57	11.06	0.00
11.77	8.16	1.30	0.52	12.01	0.01
11.68	7.52	1.20	0.49	12.92	0.00
11.72	6.90	1.10	0.44	14.13	0.01
11.75	6.28	1.00	0.40	15.56	0.01
11.64	5.66	0.90	0.37	17.12	0.01
11.69	5.03	0.80	0.32	19.35	0.00
11.71	4.39	0.70	0.28	22.17	0.01
11.71	3.77	0.60	0.24	25.82	−0.02
11.65	3.14	0.50	0.20	30.86	0.01
11.67	2.51	0.40	0.16	38.65	0.01

Table N.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

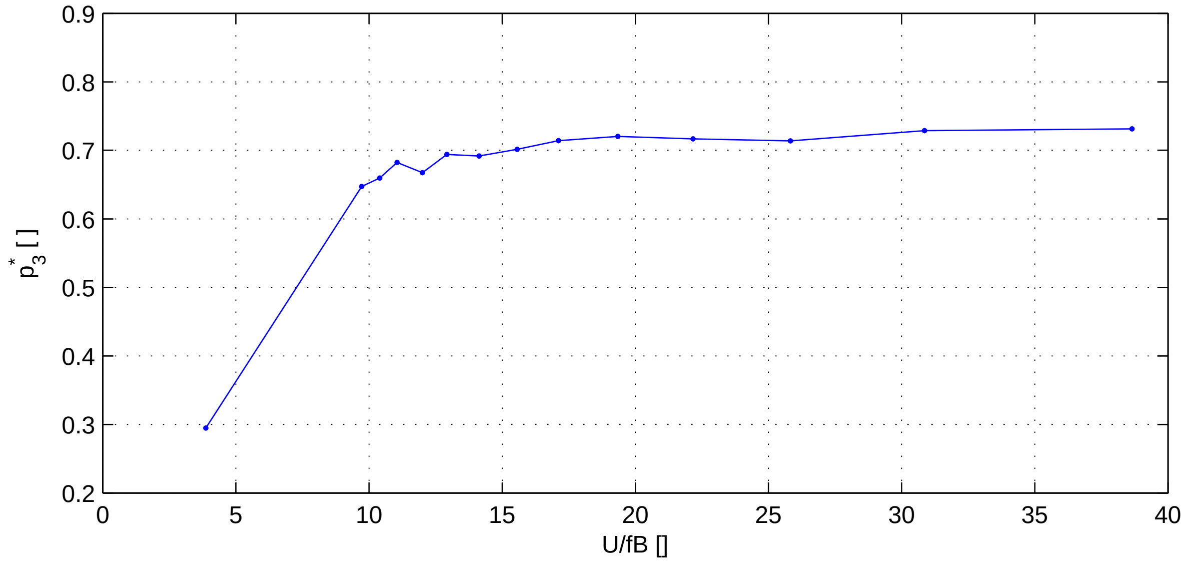


Figure N.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
11.68	25.13	4.00	1.62	3.87	0.29
11.75	10.05	1.60	0.65	9.73	0.65
11.81	9.45	1.50	0.60	10.40	0.66
11.67	8.79	1.40	0.57	11.06	0.68
11.77	8.16	1.30	0.52	12.01	0.67
11.68	7.52	1.20	0.49	12.92	0.69
11.72	6.90	1.10	0.44	14.13	0.69
11.75	6.28	1.00	0.40	15.56	0.70
11.64	5.66	0.90	0.37	17.12	0.71
11.69	5.03	0.80	0.32	19.35	0.72
11.71	4.39	0.70	0.28	22.17	0.72
11.71	3.77	0.60	0.24	25.82	0.71
11.65	3.14	0.50	0.20	30.86	0.73
11.67	2.51	0.40	0.16	38.65	0.73

Table N.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

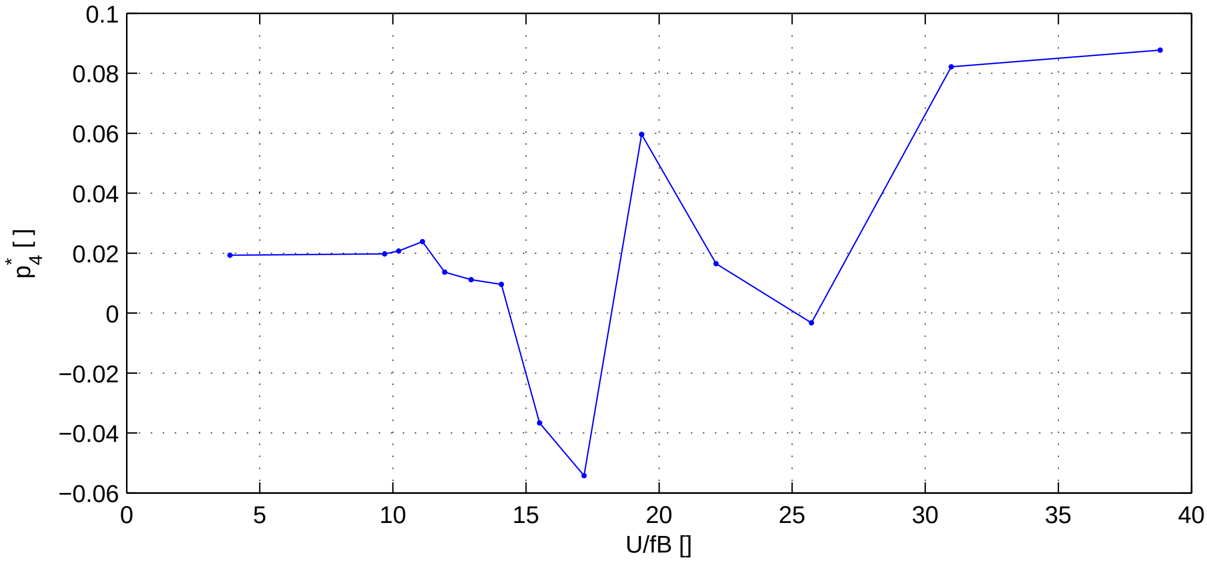


Figure N.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
11.71	25.13	4.00	1.62	3.88	0.02
11.71	10.05	1.60	0.65	9.69	0.02
11.60	9.45	1.50	0.61	10.22	0.02
11.73	8.79	1.40	0.57	11.11	0.02
11.71	8.16	1.30	0.53	11.94	0.01
11.70	7.52	1.20	0.49	12.94	0.01
11.68	6.90	1.10	0.45	14.08	0.01
11.71	6.28	1.00	0.40	15.51	−0.04
11.69	5.66	0.90	0.37	17.18	−0.05
11.68	5.03	0.80	0.32	19.34	0.06
11.69	4.39	0.70	0.28	22.14	0.02
11.67	3.77	0.60	0.24	25.73	−0.00
11.69	3.14	0.50	0.20	30.98	0.08
11.73	2.51	0.40	0.16	38.83	0.09

Table N.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

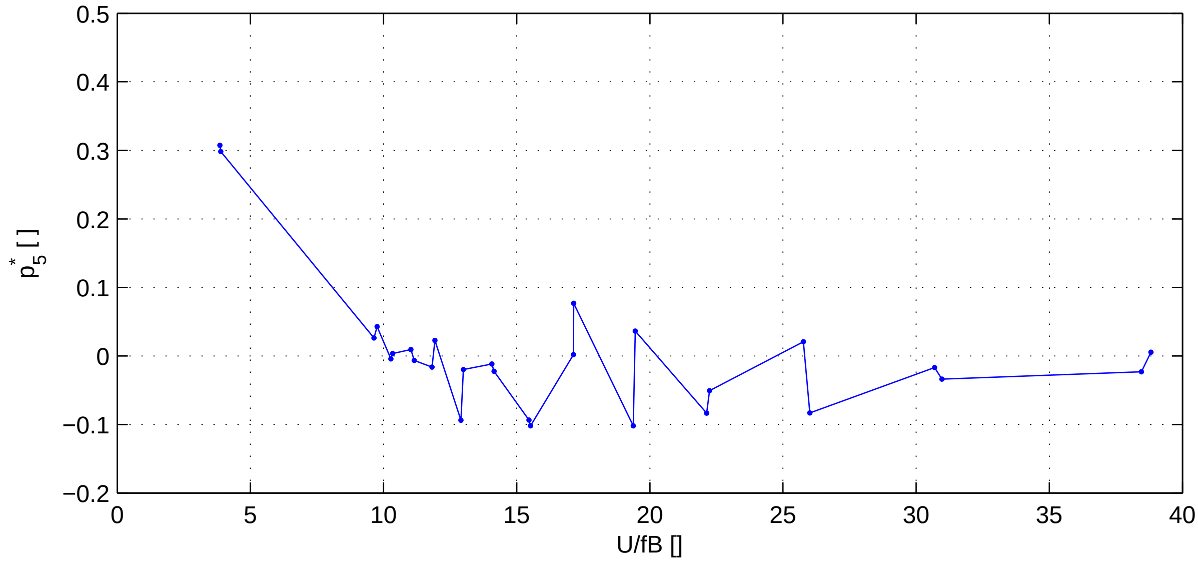


Figure N.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
11.63	25.13	4.00	1.63	3.85	0.31
11.75	25.13	4.00	1.61	3.89	0.30
11.65	10.05	1.60	0.65	9.64	0.03
11.79	10.05	1.60	0.64	9.76	0.04
11.66	9.45	1.50	0.61	10.27	−0.00
11.74	9.45	1.50	0.61	10.34	0.00
11.64	8.79	1.40	0.57	11.02	0.01
11.78	8.79	1.40	0.56	11.15	−0.01
11.59	8.16	1.30	0.53	11.82	−0.02
11.70	8.16	1.30	0.53	11.93	0.02
11.67	7.52	1.20	0.49	12.91	−0.09
11.75	7.52	1.20	0.48	13.00	−0.02
11.67	6.90	1.10	0.45	14.06	−0.01
11.74	6.90	1.10	0.44	14.15	−0.02
11.67	6.28	1.00	0.41	15.46	−0.09
11.72	6.28	1.00	0.40	15.52	−0.10
11.65	5.66	0.90	0.37	17.13	0.00
11.66	5.66	0.90	0.37	17.14	0.08
11.71	5.03	0.80	0.32	19.38	−0.10
11.75	5.03	0.80	0.32	19.45	0.04
11.68	4.39	0.70	0.28	22.13	−0.08
11.74	4.39	0.70	0.28	22.25	−0.05
11.68	3.77	0.60	0.24	25.77	0.02
11.79	3.77	0.60	0.24	26.01	−0.08
11.59	3.14	0.50	0.20	30.69	−0.02
11.69	3.14	0.50	0.20	30.97	−0.03
11.61	2.51	0.40	0.16	38.46	−0.02
11.72	2.51	0.40	0.16	38.82	0.01

Table N.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

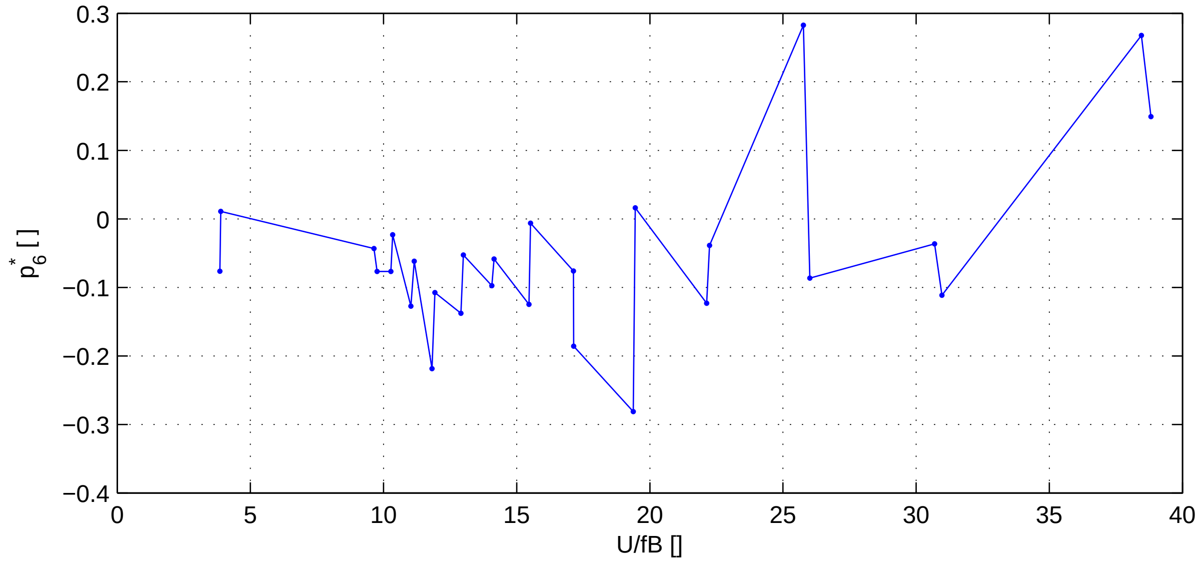


Figure N.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
11.63	25.13	4.00	1.63	3.85	−0.08
11.75	25.13	4.00	1.61	3.89	0.01
11.65	10.05	1.60	0.65	9.64	−0.04
11.79	10.05	1.60	0.64	9.76	−0.08
11.66	9.45	1.50	0.61	10.27	−0.08
11.74	9.45	1.50	0.61	10.34	−0.02
11.64	8.79	1.40	0.57	11.02	−0.13
11.78	8.79	1.40	0.56	11.15	−0.06
11.59	8.16	1.30	0.53	11.82	−0.22
11.70	8.16	1.30	0.53	11.93	−0.11
11.67	7.52	1.20	0.49	12.91	−0.14
11.75	7.52	1.20	0.48	13.00	−0.05
11.67	6.90	1.10	0.45	14.06	−0.10
11.74	6.90	1.10	0.44	14.15	−0.06
11.67	6.28	1.00	0.41	15.46	−0.12
11.72	6.28	1.00	0.40	15.52	−0.01
11.65	5.66	0.90	0.37	17.13	−0.08
11.66	5.66	0.90	0.37	17.14	−0.19
11.71	5.03	0.80	0.32	19.38	−0.28
11.75	5.03	0.80	0.32	19.45	0.02
11.68	4.39	0.70	0.28	22.13	−0.12
11.74	4.39	0.70	0.28	22.25	−0.04
11.68	3.77	0.60	0.24	25.77	0.28
11.79	3.77	0.60	0.24	26.01	−0.09
11.59	3.14	0.50	0.20	30.69	−0.04
11.69	3.14	0.50	0.20	30.97	−0.11
11.61	2.51	0.40	0.16	38.46	0.27
11.72	2.51	0.40	0.16	38.82	0.15

Table N.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

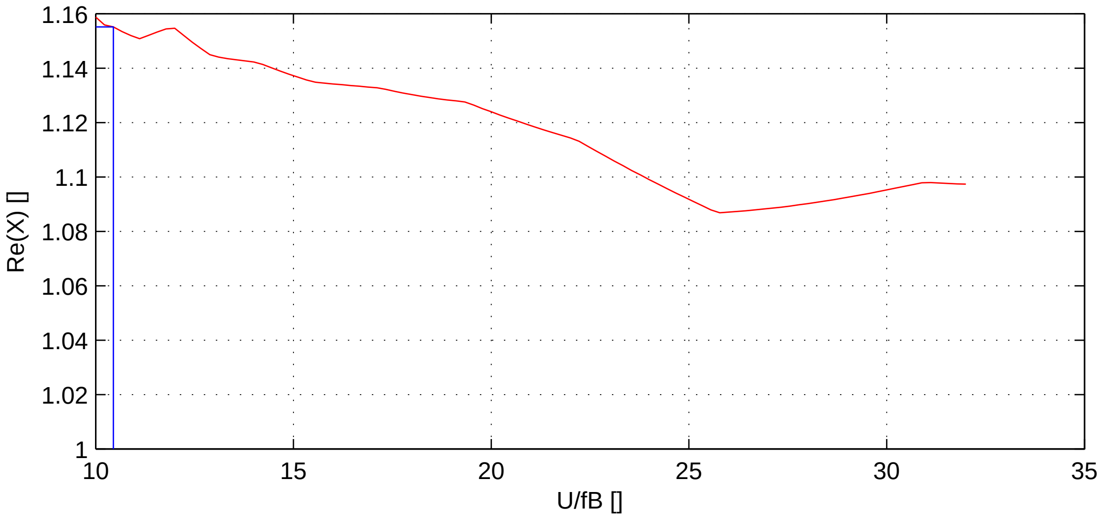


Figure N.37: Real part of the solution to stability equantion

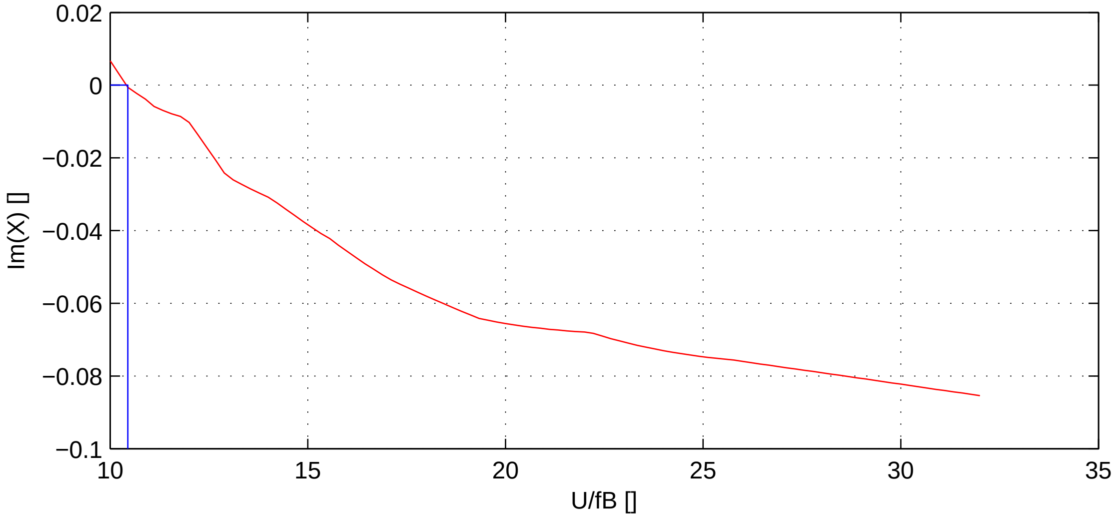


Figure N.38: Imaginary part of the solution to stability equantion

V_{Crit} = 10.4

f_{Crit} = 0.0747 Hz

U_{Crit} = 47.1 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.
[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.
[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.
[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.
[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix O

3D Flutter Tests

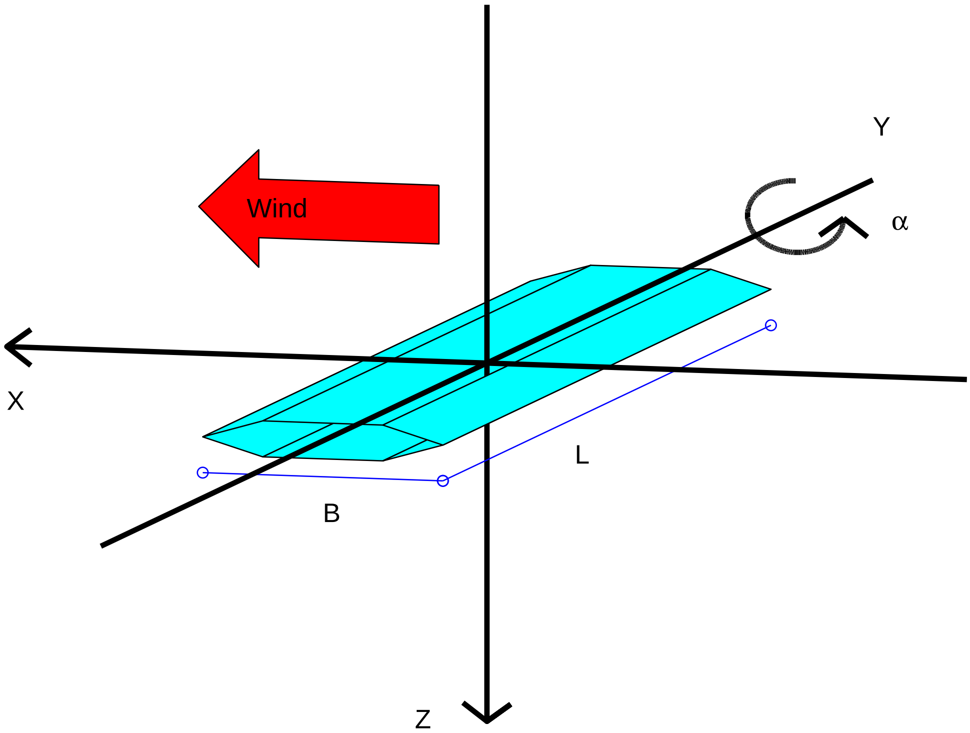
Flutter derivatives, Erection stage, Turbulent flow, Angle of incidence = 2 deg

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^oC	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1019.0

Table O.1: Project Data

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha} m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h : Vertical displacement, displacement along z-axis, [m]
α : Rotation around y-axis, nose up is positive, [rad]
p : Horizontal displacement, displacement along the x-axis, [m]
m : Mass per unit length, [kg/m]
I_y : Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$: Added mass in vertical direction, [kg/m]
$m_{a,x}$: Added mass in horizontal direction, [kg/m]
$I_{a,y}$: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G : X-coordinate for centre of gravity, [m]
Z_G : Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$: Natural circular frequency for vertical motion, [/s]
ζ_h : Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$: Natural circular frequency for rotation around y axis, [/s]
ζ_α : Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p : Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$: Force from rig per meter section, [N/m]
$M_{Y,external}$: Moment from rig per meter section, [Nm/m]
$F_{X,external}$: Force from rig per meter section, [N/m]

Formula O.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.639
Added mass in horizontal	$m_{a,x}$	kg/m	0.586
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.150
Horizontal centre of gravity	x_G	m	−0.001
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.294
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.162
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.125

Table O.2: Mechanical Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula O.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

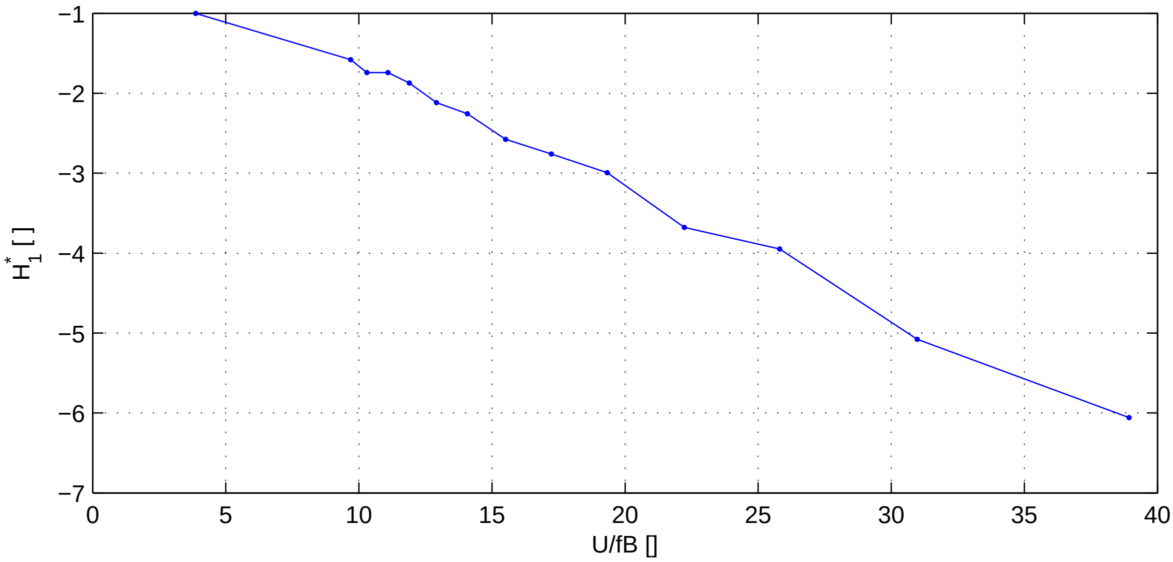


Figure O.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
11.68	25.13	4.00	1.62	3.87	−1.00
11.70	10.05	1.60	0.65	9.69	−1.58
11.69	9.45	1.50	0.61	10.30	−1.74
11.72	8.79	1.40	0.57	11.10	−1.74
11.67	8.16	1.30	0.53	11.90	−1.87
11.68	7.52	1.20	0.49	12.92	−2.12
11.67	6.90	1.10	0.45	14.07	−2.26
11.71	6.28	1.00	0.41	15.51	−2.58
11.72	5.66	0.90	0.36	17.23	−2.76
11.67	5.03	0.80	0.33	19.32	−2.99
11.74	4.39	0.70	0.28	22.23	−3.68
11.70	3.77	0.60	0.24	25.81	−3.95
11.69	3.14	0.50	0.20	30.98	−5.08
11.76	2.51	0.40	0.16	38.94	−6.06

Table O.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

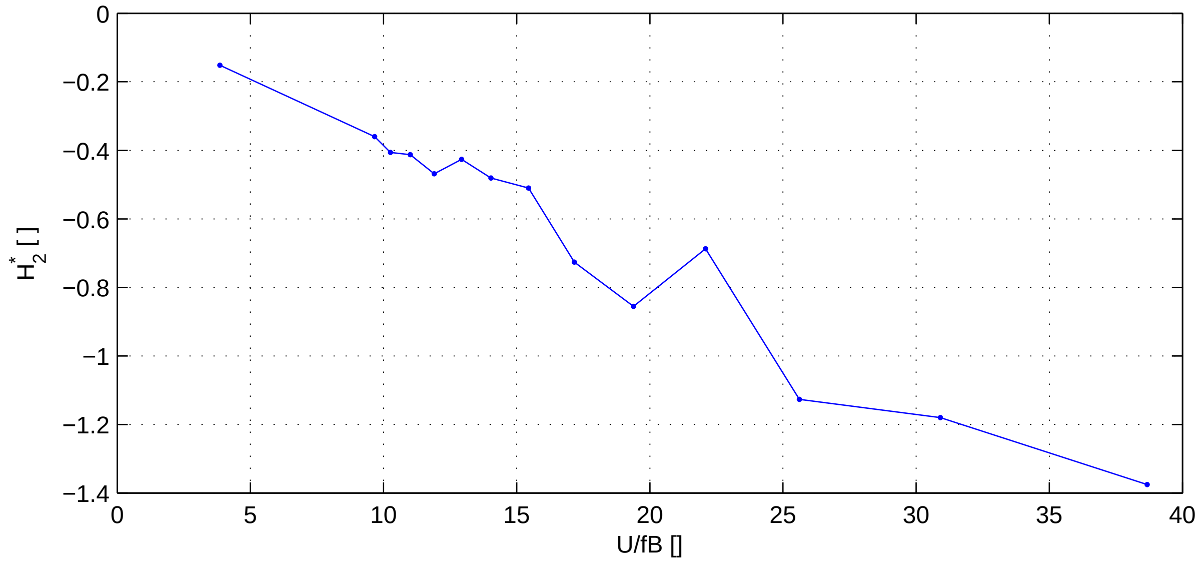


Figure O.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
11.64	25.13	4.00	1.63	3.85	−0.15
11.67	10.05	1.60	0.65	9.66	−0.36
11.64	9.45	1.50	0.61	10.26	−0.41
11.62	8.79	1.40	0.57	11.00	−0.41
11.67	8.16	1.30	0.53	11.91	−0.47
11.69	7.52	1.20	0.49	12.93	−0.43
11.64	6.90	1.10	0.45	14.03	−0.48
11.66	6.28	1.00	0.41	15.44	−0.51
11.67	5.66	0.90	0.37	17.16	−0.73
11.71	5.03	0.80	0.32	19.38	−0.86
11.66	4.39	0.70	0.28	22.09	−0.69
11.62	3.77	0.60	0.25	25.62	−1.13
11.67	3.14	0.50	0.20	30.91	−1.18
11.68	2.51	0.40	0.16	38.68	−1.38

Table O.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

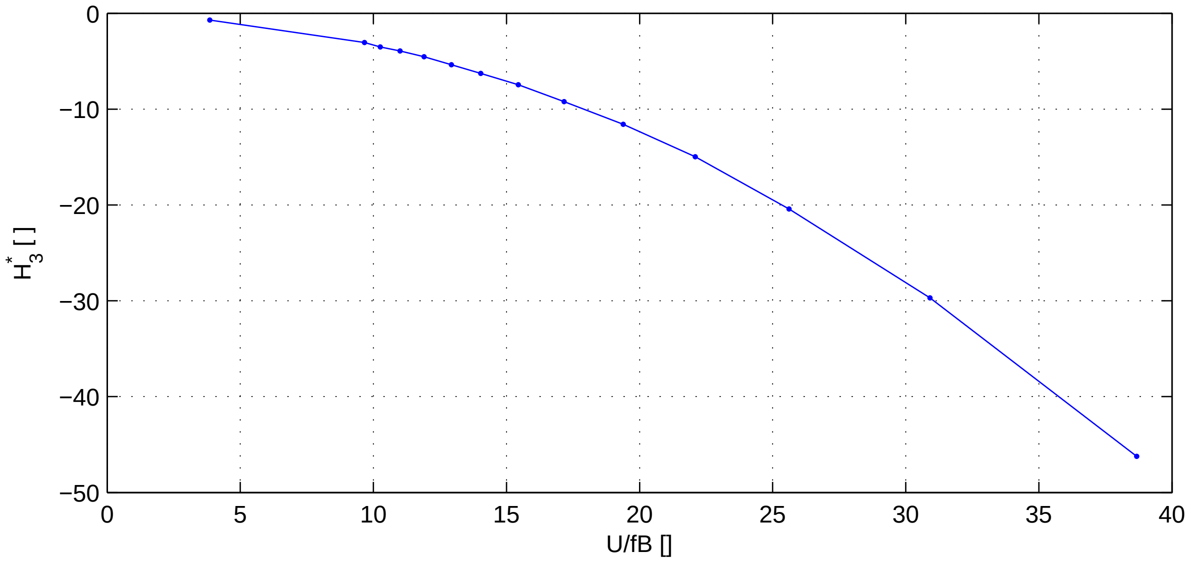


Figure O.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
11.64	25.13	4.00	1.63	3.85	−0.71
11.67	10.05	1.60	0.65	9.66	−3.06
11.64	9.45	1.50	0.61	10.26	−3.51
11.62	8.79	1.40	0.57	11.00	−3.93
11.67	8.16	1.30	0.53	11.91	−4.54
11.69	7.52	1.20	0.49	12.93	−5.37
11.64	6.90	1.10	0.45	14.03	−6.27
11.66	6.28	1.00	0.41	15.44	−7.46
11.67	5.66	0.90	0.37	17.16	−9.22
11.71	5.03	0.80	0.32	19.38	−11.58
11.66	4.39	0.70	0.28	22.09	−14.96
11.62	3.77	0.60	0.25	25.62	−20.43
11.67	3.14	0.50	0.20	30.91	−29.71
11.68	2.51	0.40	0.16	38.68	−46.23

Table O.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

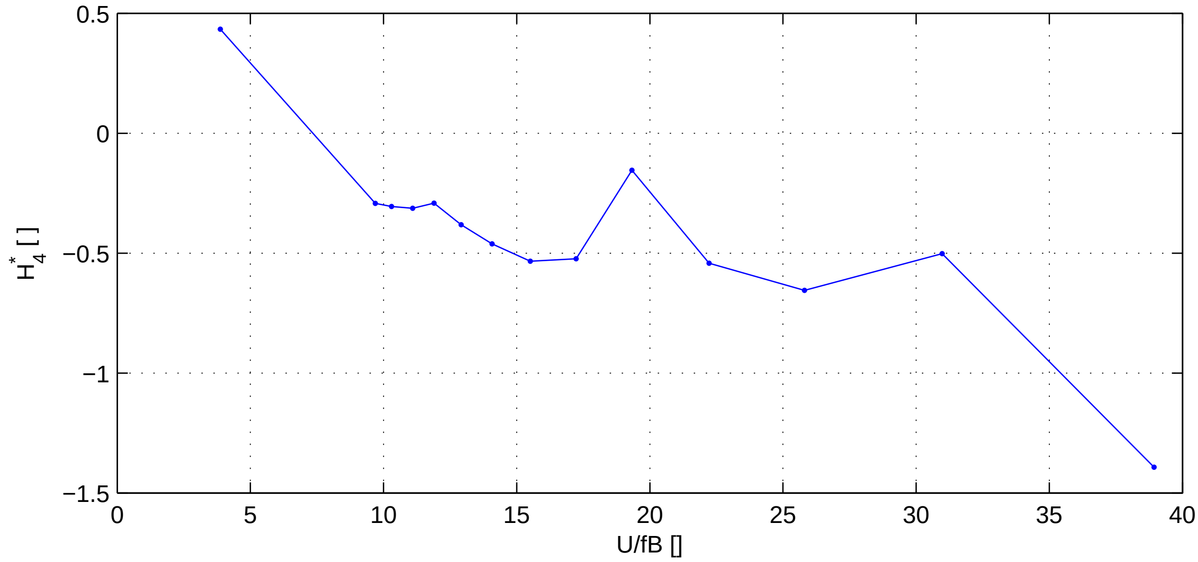


Figure O.4: H^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H^*_4
11.68	25.13	4.00	1.62	3.87	0.43
11.70	10.05	1.60	0.65	9.69	−0.29
11.69	9.45	1.50	0.61	10.30	−0.31
11.72	8.79	1.40	0.57	11.10	−0.31
11.67	8.16	1.30	0.53	11.90	−0.29
11.68	7.52	1.20	0.49	12.92	−0.38
11.67	6.90	1.10	0.45	14.07	−0.46
11.71	6.28	1.00	0.41	15.51	−0.53
11.72	5.66	0.90	0.36	17.23	−0.52
11.67	5.03	0.80	0.33	19.32	−0.15
11.74	4.39	0.70	0.28	22.23	−0.54
11.70	3.77	0.60	0.24	25.81	−0.66
11.69	3.14	0.50	0.20	30.98	−0.50
11.76	2.51	0.40	0.16	38.94	−1.39

Table O.6: H^*_4 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

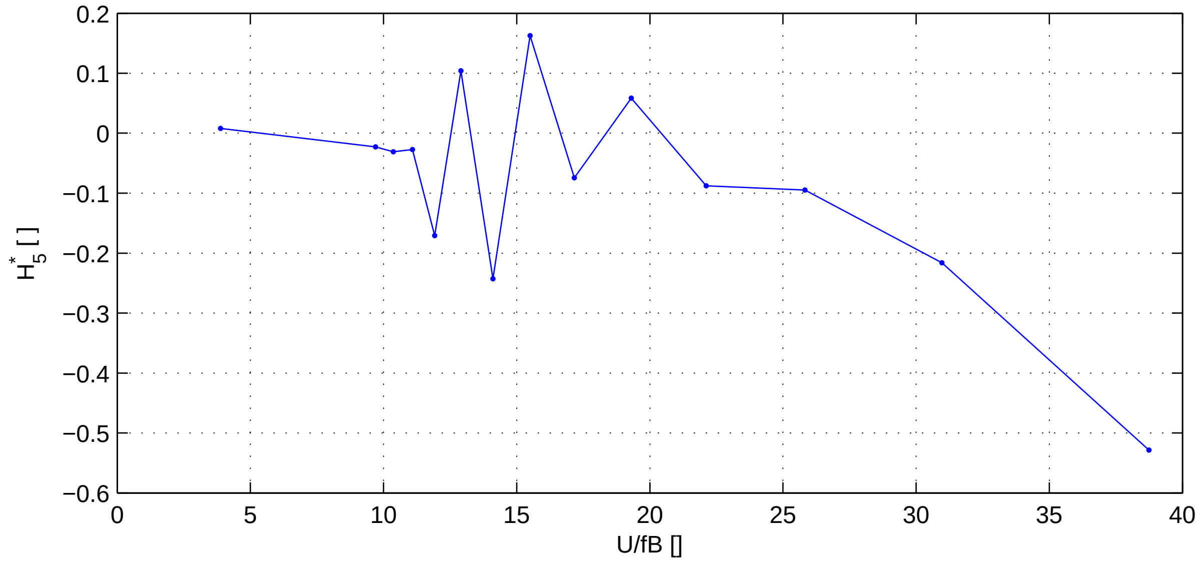


Figure O.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
11.70	25.13	4.00	1.62	3.87	0.01
11.72	10.05	1.60	0.65	9.70	−0.02
11.77	9.45	1.50	0.61	10.37	−0.03
11.70	8.79	1.40	0.57	11.08	−0.03
11.69	8.16	1.30	0.53	11.92	−0.17
11.67	7.52	1.20	0.49	12.91	0.10
11.71	6.90	1.10	0.45	14.11	−0.24
11.70	6.28	1.00	0.41	15.50	0.16
11.68	5.66	0.90	0.37	17.17	−0.07
11.66	5.03	0.80	0.33	19.30	0.06
11.68	4.39	0.70	0.28	22.12	−0.09
11.71	3.77	0.60	0.24	25.82	−0.09
11.69	3.14	0.50	0.20	30.96	−0.22
11.70	2.51	0.40	0.16	38.74	−0.53

Table O.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

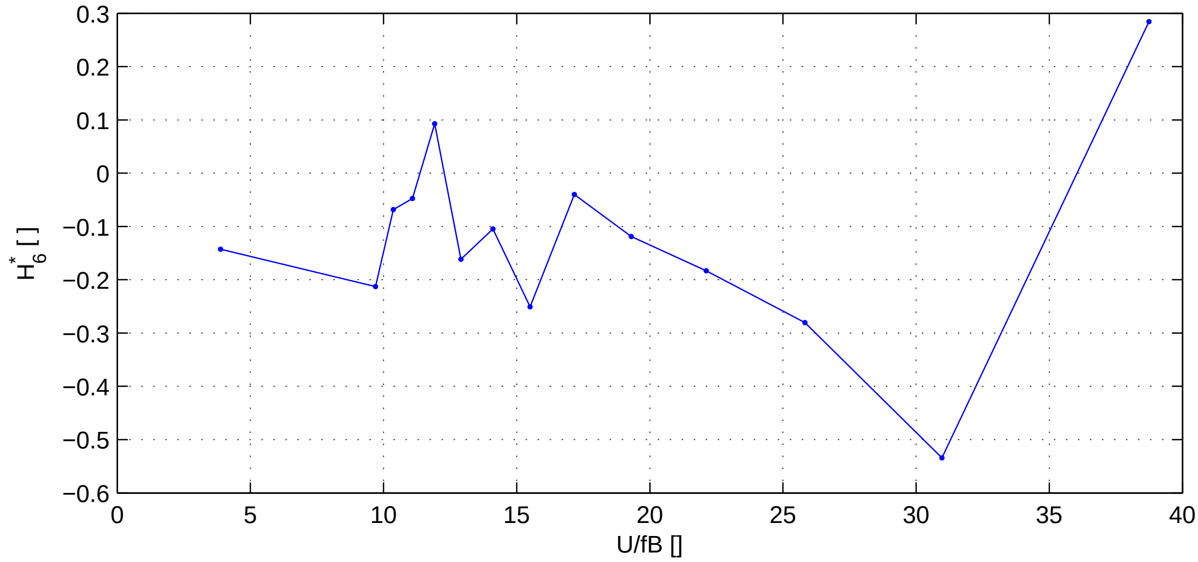


Figure O.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
11.70	25.13	4.00	1.62	3.87	−0.14
11.72	10.05	1.60	0.65	9.70	−0.21
11.77	9.45	1.50	0.61	10.37	−0.07
11.70	8.79	1.40	0.57	11.08	−0.05
11.69	8.16	1.30	0.53	11.92	0.09
11.67	7.52	1.20	0.49	12.91	−0.16
11.71	6.90	1.10	0.45	14.11	−0.10
11.70	6.28	1.00	0.41	15.50	−0.25
11.68	5.66	0.90	0.37	17.17	−0.04
11.66	5.03	0.80	0.33	19.30	−0.12
11.68	4.39	0.70	0.28	22.12	−0.18
11.71	3.77	0.60	0.24	25.82	−0.28
11.69	3.14	0.50	0.20	30.96	−0.53
11.70	2.51	0.40	0.16	38.74	0.28

Table O.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

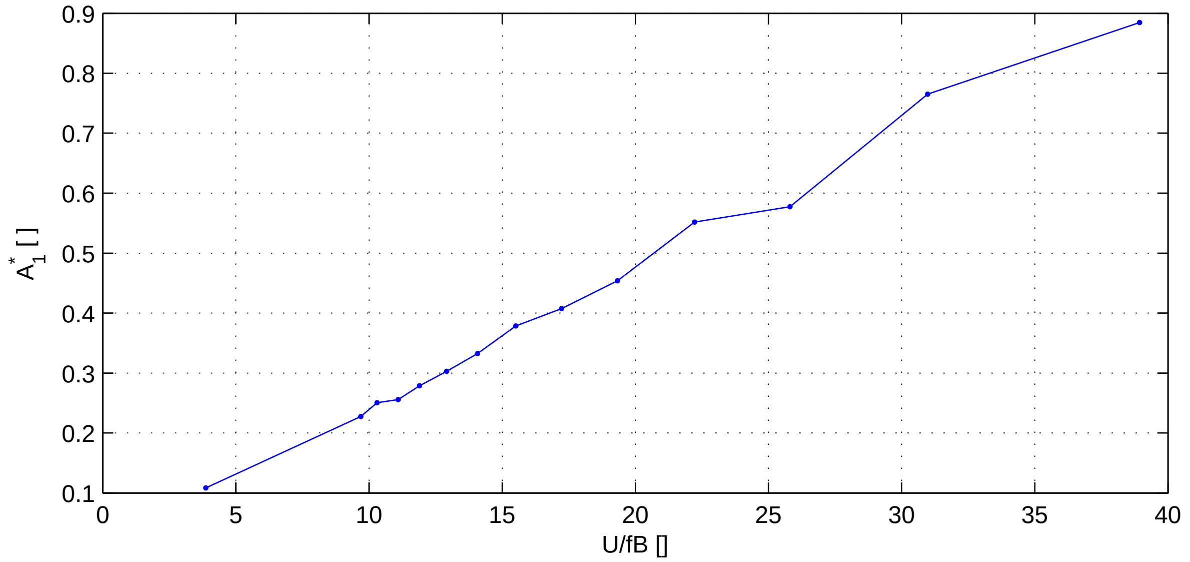


Figure O.7: A^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_1
11.68	25.13	4.00	1.62	3.87	0.11
11.70	10.05	1.60	0.65	9.69	0.23
11.69	9.45	1.50	0.61	10.30	0.25
11.72	8.79	1.40	0.57	11.10	0.26
11.67	8.16	1.30	0.53	11.90	0.28
11.68	7.52	1.20	0.49	12.92	0.30
11.67	6.90	1.10	0.45	14.07	0.33
11.71	6.28	1.00	0.41	15.51	0.38
11.72	5.66	0.90	0.36	17.23	0.41
11.67	5.03	0.80	0.33	19.32	0.45
11.74	4.39	0.70	0.28	22.23	0.55
11.70	3.77	0.60	0.24	25.81	0.58
11.69	3.14	0.50	0.20	30.98	0.77
11.76	2.51	0.40	0.16	38.94	0.88

Table O.9: A^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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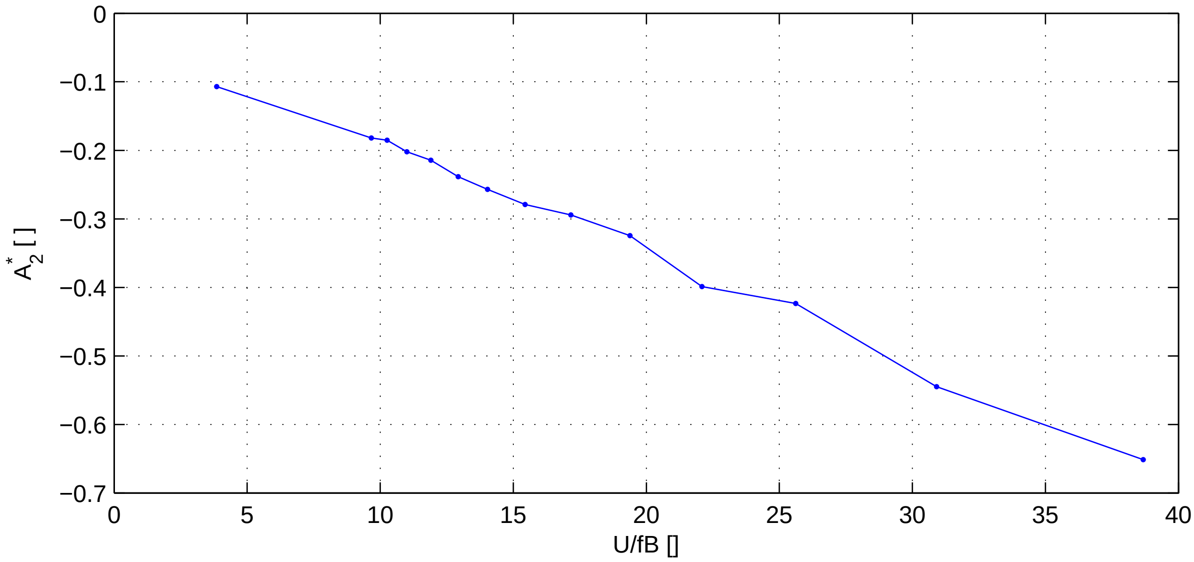

Figure O.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
11.64	25.13	4.00	1.63	3.85	−0.11
11.67	10.05	1.60	0.65	9.66	−0.18
11.64	9.45	1.50	0.61	10.26	−0.19
11.62	8.79	1.40	0.57	11.00	−0.20
11.67	8.16	1.30	0.53	11.91	−0.21
11.69	7.52	1.20	0.49	12.93	−0.24
11.64	6.90	1.10	0.45	14.03	−0.26
11.66	6.28	1.00	0.41	15.44	−0.28
11.67	5.66	0.90	0.37	17.16	−0.29
11.71	5.03	0.80	0.32	19.38	−0.32
11.66	4.39	0.70	0.28	22.09	−0.40
11.62	3.77	0.60	0.25	25.62	−0.42
11.67	3.14	0.50	0.20	30.91	−0.55
11.68	2.51	0.40	0.16	38.68	−0.65

Table O.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

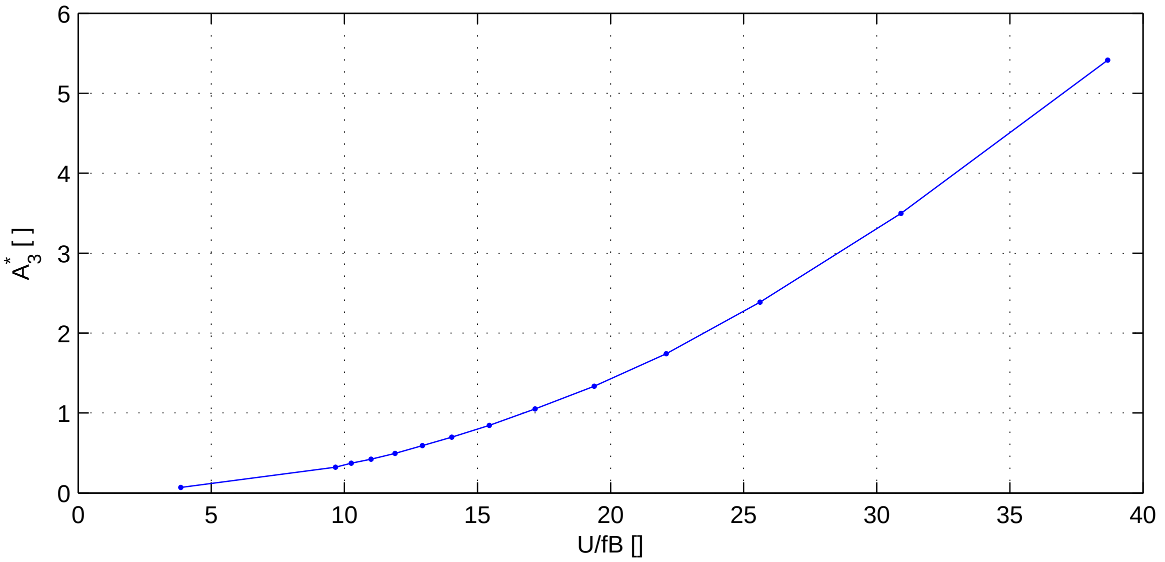

Figure O.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
11.64	25.13	4.00	1.63	3.85	0.07
11.67	10.05	1.60	0.65	9.66	0.32
11.64	9.45	1.50	0.61	10.26	0.37
11.62	8.79	1.40	0.57	11.00	0.42
11.67	8.16	1.30	0.53	11.91	0.50
11.69	7.52	1.20	0.49	12.93	0.59
11.64	6.90	1.10	0.45	14.03	0.70
11.66	6.28	1.00	0.41	15.44	0.85
11.67	5.66	0.90	0.37	17.16	1.05
11.71	5.03	0.80	0.32	19.38	1.33
11.66	4.39	0.70	0.28	22.09	1.74
11.62	3.77	0.60	0.25	25.62	2.39
11.67	3.14	0.50	0.20	30.91	3.50
11.68	2.51	0.40	0.16	38.68	5.42

Table O.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

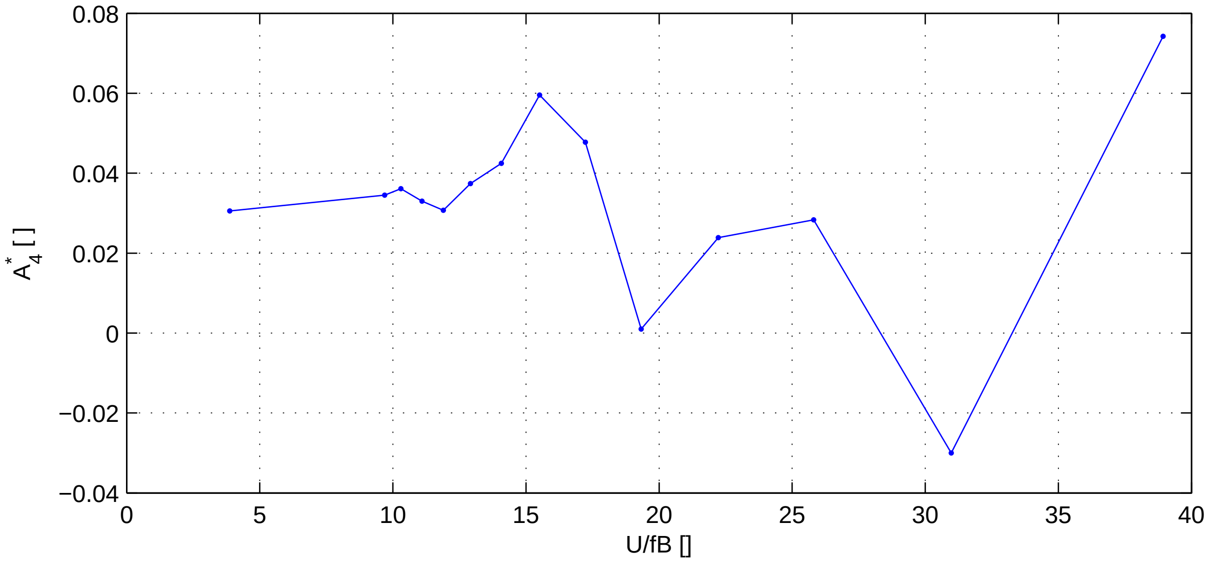

Figure O.10: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_4^*
11.68	25.13	4.00	1.62	3.87	0.03
11.70	10.05	1.60	0.65	9.69	0.03
11.69	9.45	1.50	0.61	10.30	0.04
11.72	8.79	1.40	0.57	11.10	0.03
11.67	8.16	1.30	0.53	11.90	0.03
11.68	7.52	1.20	0.49	12.92	0.04
11.67	6.90	1.10	0.45	14.07	0.04
11.71	6.28	1.00	0.41	15.51	0.06
11.72	5.66	0.90	0.36	17.23	0.05
11.67	5.03	0.80	0.33	19.32	0.00
11.74	4.39	0.70	0.28	22.23	0.02
11.70	3.77	0.60	0.24	25.81	0.03
11.69	3.14	0.50	0.20	30.98	−0.03
11.76	2.51	0.40	0.16	38.94	0.07

Table O.12: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

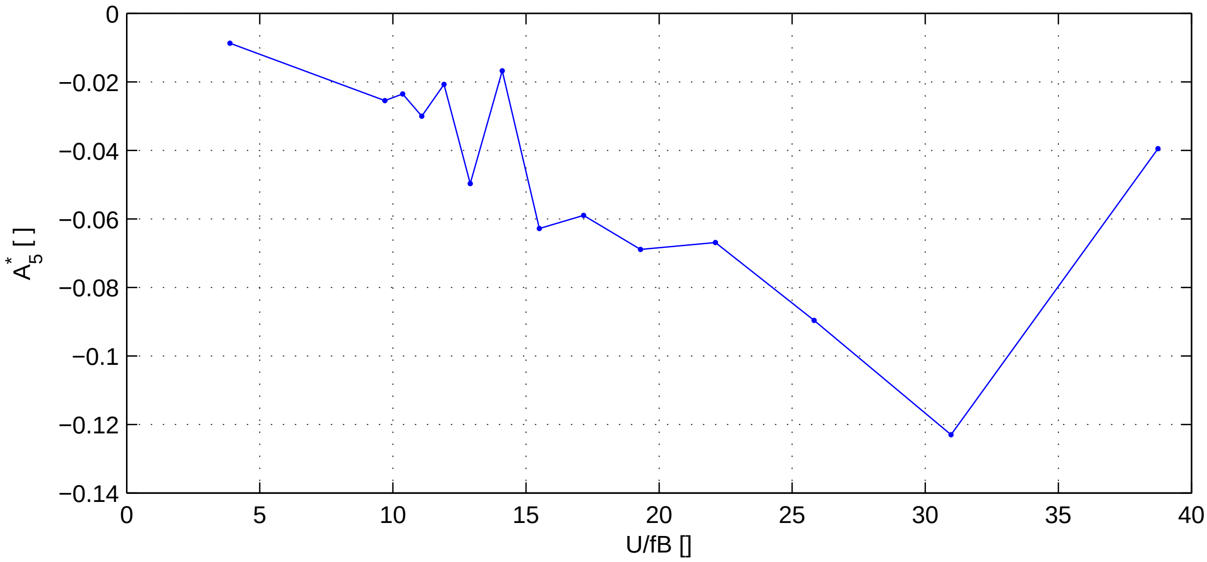

Figure O.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
11.70	25.13	4.00	1.62	3.87	−0.01
11.72	10.05	1.60	0.65	9.70	−0.03
11.77	9.45	1.50	0.61	10.37	−0.02
11.70	8.79	1.40	0.57	11.08	−0.03
11.69	8.16	1.30	0.53	11.92	−0.02
11.67	7.52	1.20	0.49	12.91	−0.05
11.71	6.90	1.10	0.45	14.11	−0.02
11.70	6.28	1.00	0.41	15.50	−0.06
11.68	5.66	0.90	0.37	17.17	−0.06
11.66	5.03	0.80	0.33	19.30	−0.07
11.68	4.39	0.70	0.28	22.12	−0.07
11.71	3.77	0.60	0.24	25.82	−0.09
11.69	3.14	0.50	0.20	30.96	−0.12
11.70	2.51	0.40	0.16	38.74	−0.04

Table O.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

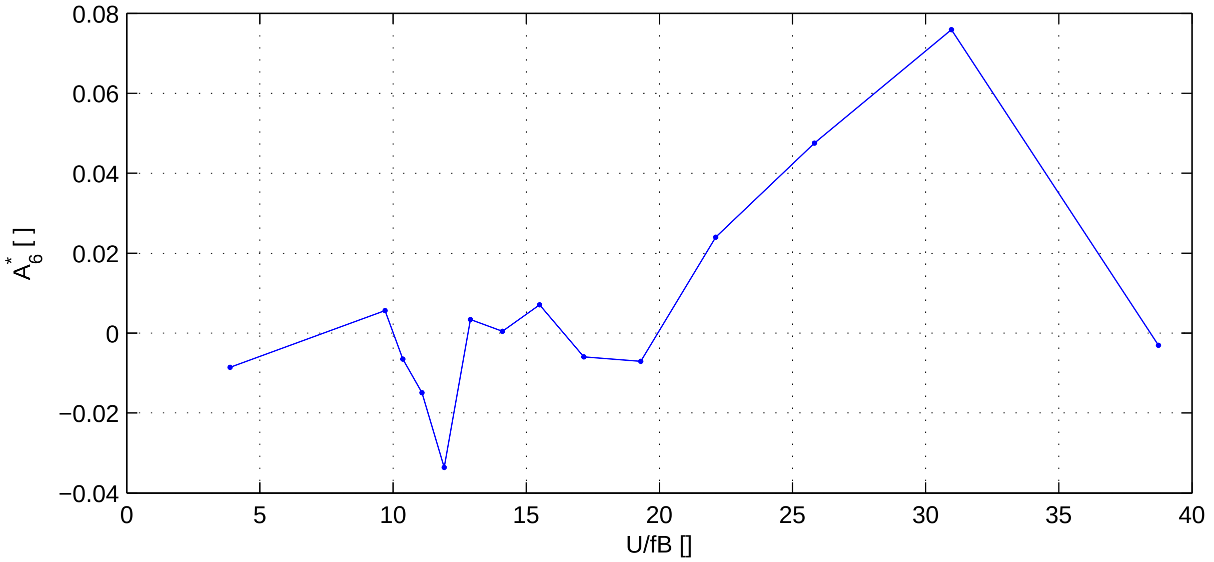

Figure O.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
11.70	25.13	4.00	1.62	3.87	−0.01
11.72	10.05	1.60	0.65	9.70	0.01
11.77	9.45	1.50	0.61	10.37	−0.01
11.70	8.79	1.40	0.57	11.08	−0.01
11.69	8.16	1.30	0.53	11.92	−0.03
11.67	7.52	1.20	0.49	12.91	0.00
11.71	6.90	1.10	0.45	14.11	0.00
11.70	6.28	1.00	0.41	15.50	0.01
11.68	5.66	0.90	0.37	17.17	−0.01
11.66	5.03	0.80	0.33	19.30	−0.01
11.68	4.39	0.70	0.28	22.12	0.02
11.71	3.77	0.60	0.24	25.82	0.05
11.69	3.14	0.50	0.20	30.96	0.08
11.70	2.51	0.40	0.16	38.74	−0.00

Table O.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

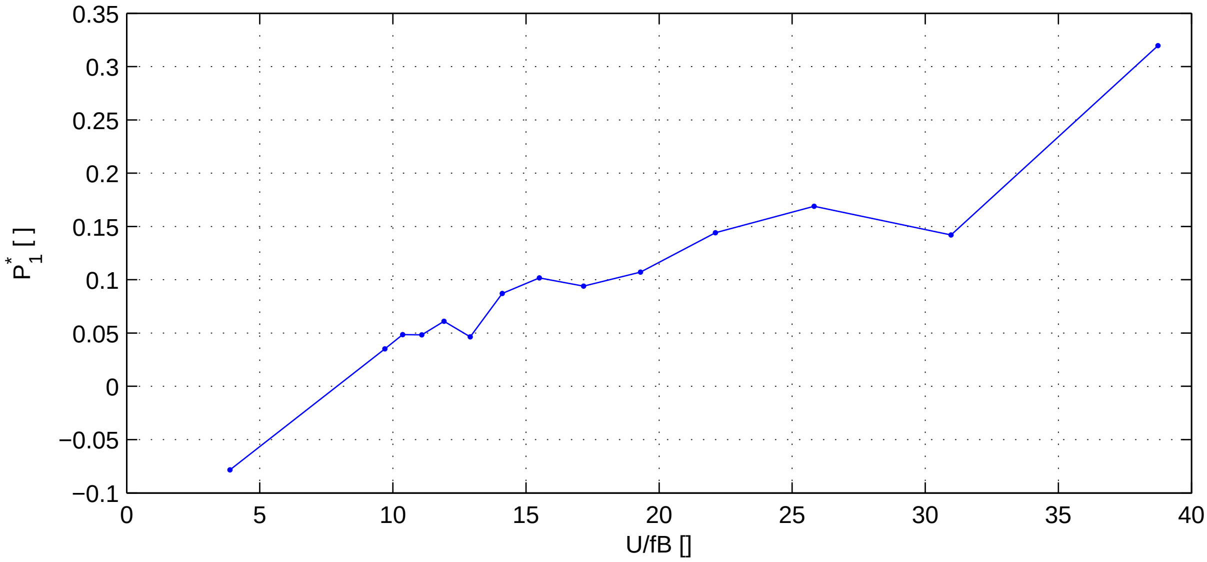

Figure O.13: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_1^*
11.70	25.13	4.00	1.62	3.87	−0.08
11.72	10.05	1.60	0.65	9.70	0.04
11.77	9.45	1.50	0.61	10.37	0.05
11.70	8.79	1.40	0.57	11.08	0.05
11.69	8.16	1.30	0.53	11.92	0.06
11.67	7.52	1.20	0.49	12.91	0.05
11.71	6.90	1.10	0.45	14.11	0.09
11.70	6.28	1.00	0.41	15.50	0.10
11.68	5.66	0.90	0.37	17.17	0.09
11.66	5.03	0.80	0.33	19.30	0.11
11.68	4.39	0.70	0.28	22.12	0.14
11.71	3.77	0.60	0.24	25.82	0.17
11.69	3.14	0.50	0.20	30.96	0.14
11.70	2.51	0.40	0.16	38.74	0.32

Table O.15: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

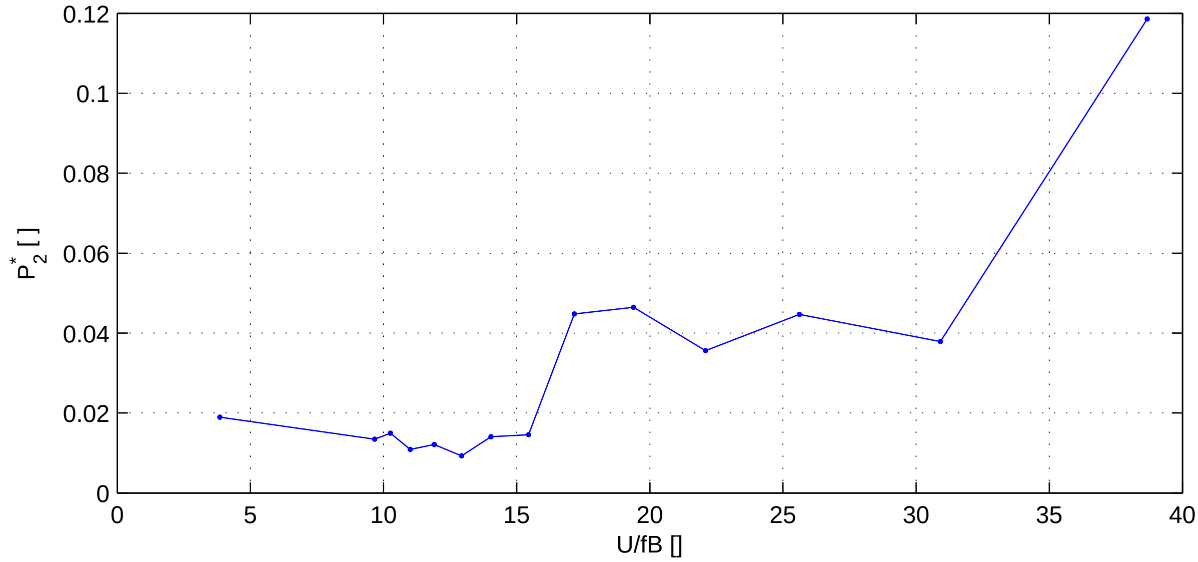

Figure O.14: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_2
11.64	25.13	4.00	1.63	3.85	0.02
11.67	10.05	1.60	0.65	9.66	0.01
11.64	9.45	1.50	0.61	10.26	0.01
11.62	8.79	1.40	0.57	11.00	0.01
11.67	8.16	1.30	0.53	11.91	0.01
11.69	7.52	1.20	0.49	12.93	0.01
11.64	6.90	1.10	0.45	14.03	0.01
11.66	6.28	1.00	0.41	15.44	0.01
11.67	5.66	0.90	0.37	17.16	0.04
11.71	5.03	0.80	0.32	19.38	0.05
11.66	4.39	0.70	0.28	22.09	0.04
11.62	3.77	0.60	0.25	25.62	0.04
11.67	3.14	0.50	0.20	30.91	0.04
11.68	2.51	0.40	0.16	38.68	0.12

Table O.16: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

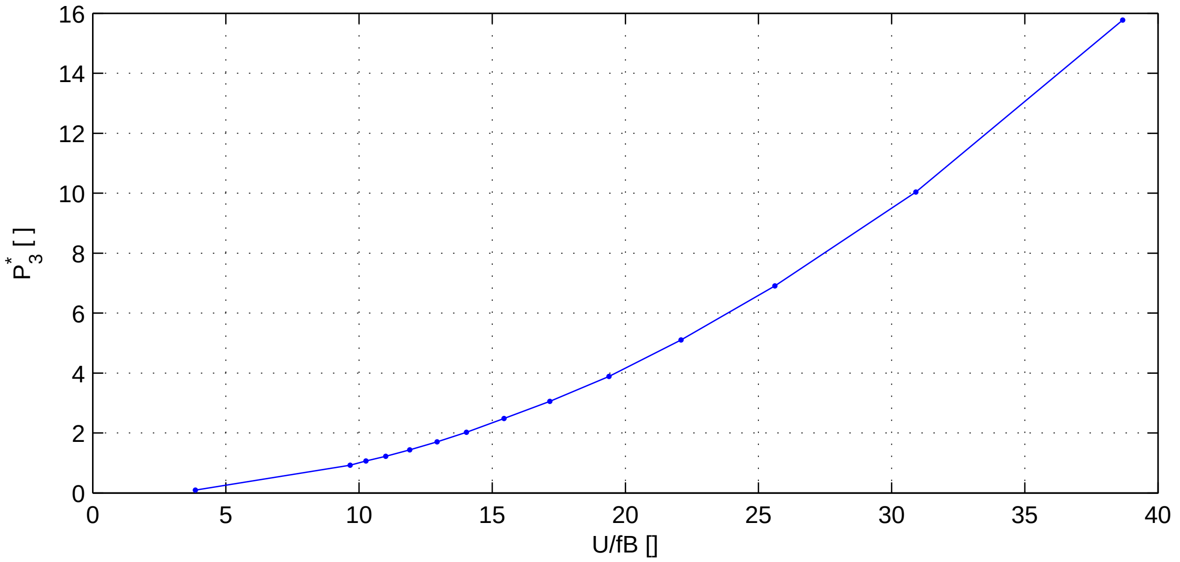

Figure O.15: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_3
11.64	25.13	4.00	1.63	3.85	0.09
11.67	10.05	1.60	0.65	9.66	0.93
11.64	9.45	1.50	0.61	10.26	1.06
11.62	8.79	1.40	0.57	11.00	1.22
11.67	8.16	1.30	0.53	11.91	1.44
11.69	7.52	1.20	0.49	12.93	1.70
11.64	6.90	1.10	0.45	14.03	2.02
11.66	6.28	1.00	0.41	15.44	2.48
11.67	5.66	0.90	0.37	17.16	3.05
11.71	5.03	0.80	0.32	19.38	3.89
11.66	4.39	0.70	0.28	22.09	5.10
11.62	3.77	0.60	0.25	25.62	6.91
11.67	3.14	0.50	0.20	30.91	10.04
11.68	2.51	0.40	0.16	38.68	15.78

Table O.17: P^*_3 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

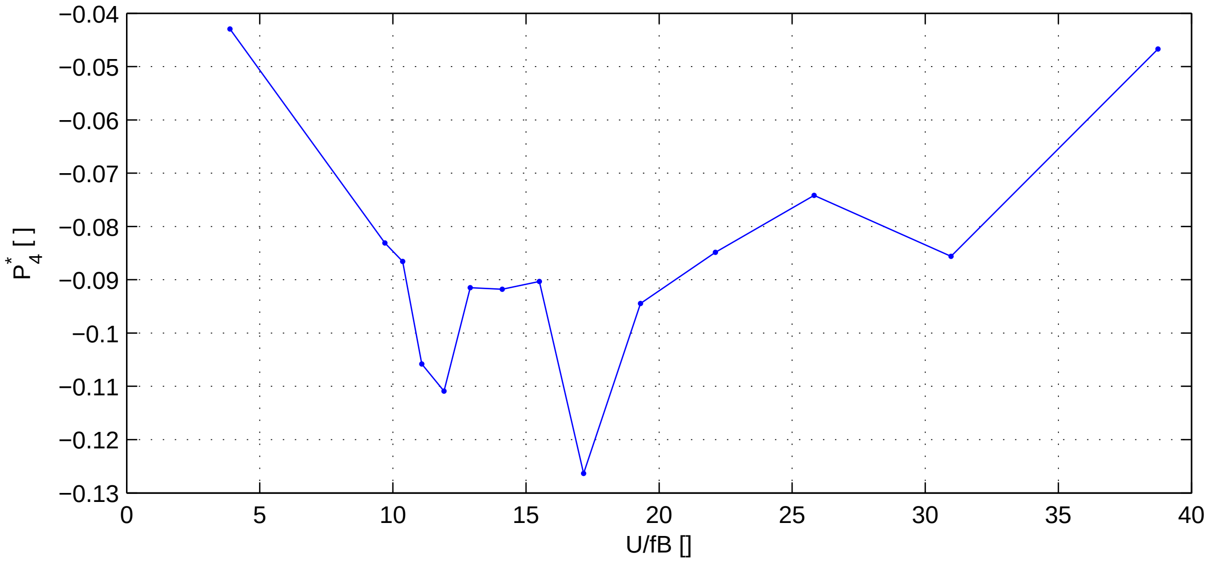

Figure O.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
11.70	25.13	4.00	1.62	3.87	−0.04
11.72	10.05	1.60	0.65	9.70	−0.08
11.77	9.45	1.50	0.61	10.37	−0.09
11.70	8.79	1.40	0.57	11.08	−0.11
11.69	8.16	1.30	0.53	11.92	−0.11
11.67	7.52	1.20	0.49	12.91	−0.09
11.71	6.90	1.10	0.45	14.11	−0.09
11.70	6.28	1.00	0.41	15.50	−0.09
11.68	5.66	0.90	0.37	17.17	−0.13
11.66	5.03	0.80	0.33	19.30	−0.09
11.68	4.39	0.70	0.28	22.12	−0.08
11.71	3.77	0.60	0.24	25.82	−0.07
11.69	3.14	0.50	0.20	30.96	−0.09
11.70	2.51	0.40	0.16	38.74	−0.05

Table O.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

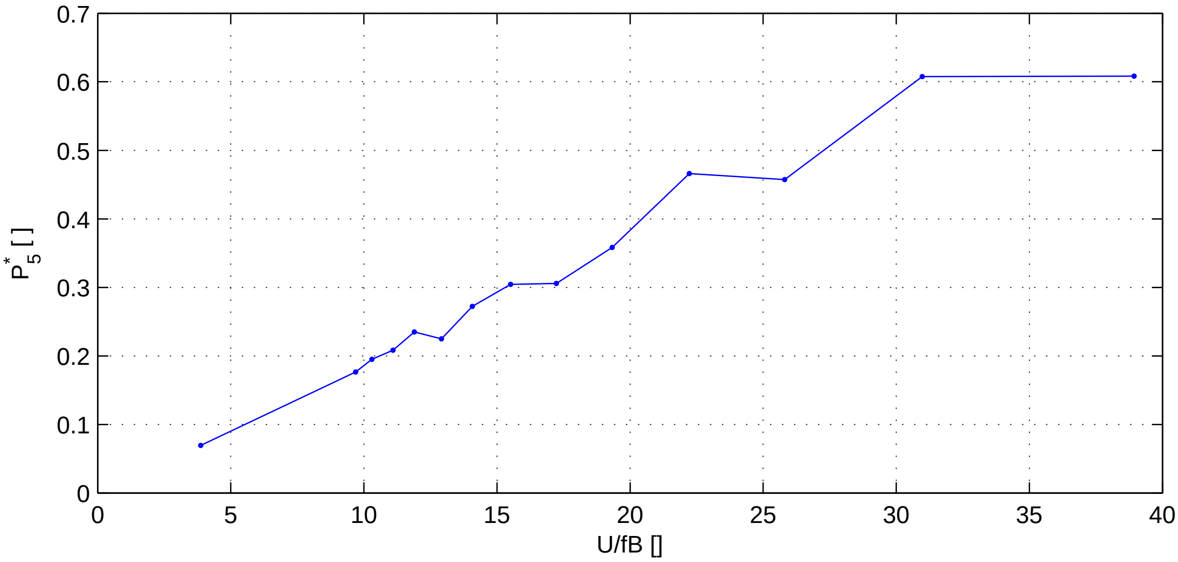

Figure O.17: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_5^*
11.68	25.13	4.00	1.62	3.87	0.07
11.70	10.05	1.60	0.65	9.69	0.18
11.69	9.45	1.50	0.61	10.30	0.19
11.72	8.79	1.40	0.57	11.10	0.21
11.67	8.16	1.30	0.53	11.90	0.23
11.68	7.52	1.20	0.49	12.92	0.22
11.67	6.90	1.10	0.45	14.07	0.27
11.71	6.28	1.00	0.41	15.51	0.30
11.72	5.66	0.90	0.36	17.23	0.31
11.67	5.03	0.80	0.33	19.32	0.36
11.74	4.39	0.70	0.28	22.23	0.47
11.70	3.77	0.60	0.24	25.81	0.46
11.69	3.14	0.50	0.20	30.98	0.61
11.76	2.51	0.40	0.16	38.94	0.61

Table O.19: P_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

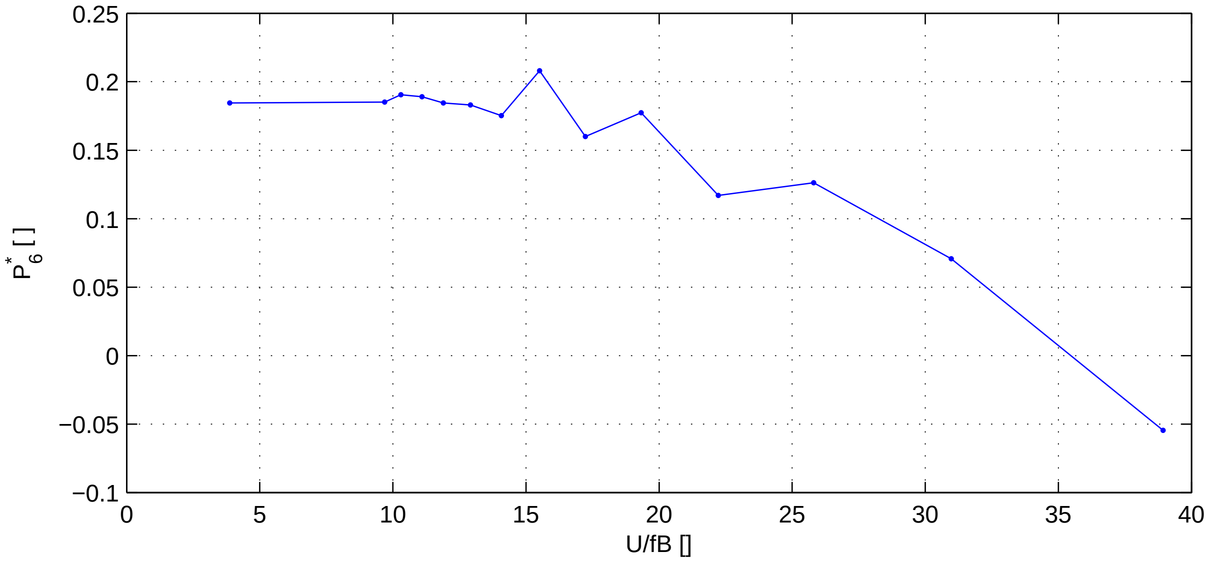

Figure O.18: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_6
11.68	25.13	4.00	1.62	3.87	0.18
11.70	10.05	1.60	0.65	9.69	0.19
11.69	9.45	1.50	0.61	10.30	0.19
11.72	8.79	1.40	0.57	11.10	0.19
11.67	8.16	1.30	0.53	11.90	0.18
11.68	7.52	1.20	0.49	12.92	0.18
11.67	6.90	1.10	0.45	14.07	0.18
11.71	6.28	1.00	0.41	15.51	0.21
11.72	5.66	0.90	0.36	17.23	0.16
11.67	5.03	0.80	0.33	19.32	0.18
11.74	4.39	0.70	0.28	22.23	0.12
11.70	3.77	0.60	0.24	25.81	0.13
11.69	3.14	0.50	0.20	30.98	0.07
11.76	2.51	0.40	0.16	38.94	−0.05

Table O.20: P^*_6 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\,(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\,(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\,(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

Formula O.3: Equation of Motion (Stretto di Messina. Ref. [5].)

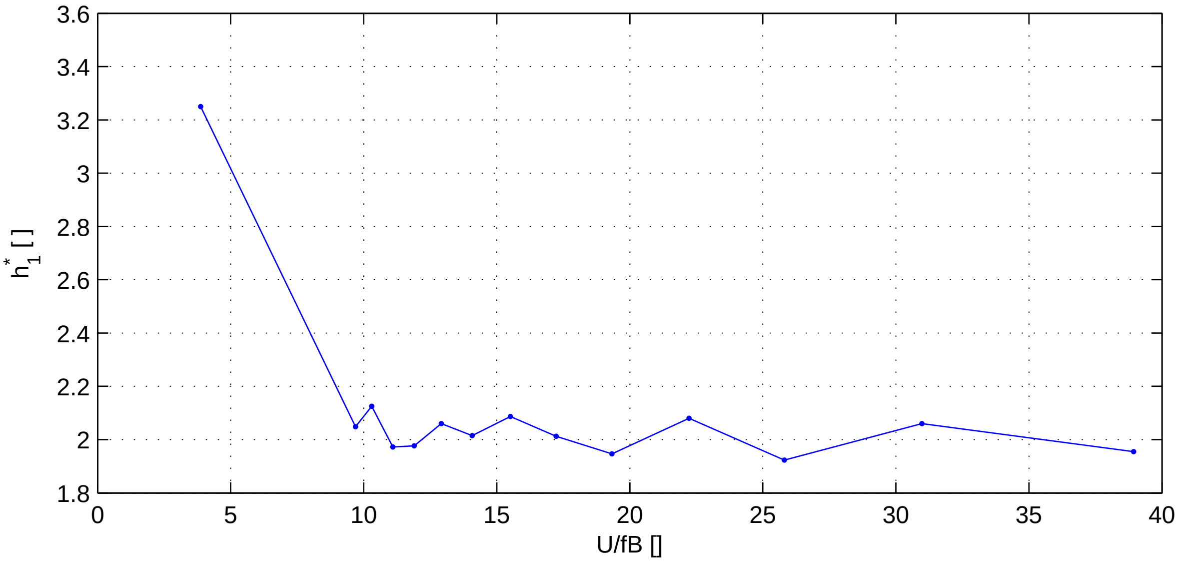

Figure O.19: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_1^*
11.68	25.13	4.00	1.62	3.87	3.25
11.70	10.05	1.60	0.65	9.69	2.05
11.69	9.45	1.50	0.61	10.30	2.13
11.72	8.79	1.40	0.57	11.10	1.97
11.67	8.16	1.30	0.53	11.90	1.98
11.68	7.52	1.20	0.49	12.92	2.06
11.67	6.90	1.10	0.45	14.07	2.01
11.71	6.28	1.00	0.41	15.51	2.09
11.72	5.66	0.90	0.36	17.23	2.01
11.67	5.03	0.80	0.33	19.32	1.95
11.74	4.39	0.70	0.28	22.23	2.08
11.70	3.77	0.60	0.24	25.81	1.92
11.69	3.14	0.50	0.20	30.98	2.06
11.76	2.51	0.40	0.16	38.94	1.95

Table O.21: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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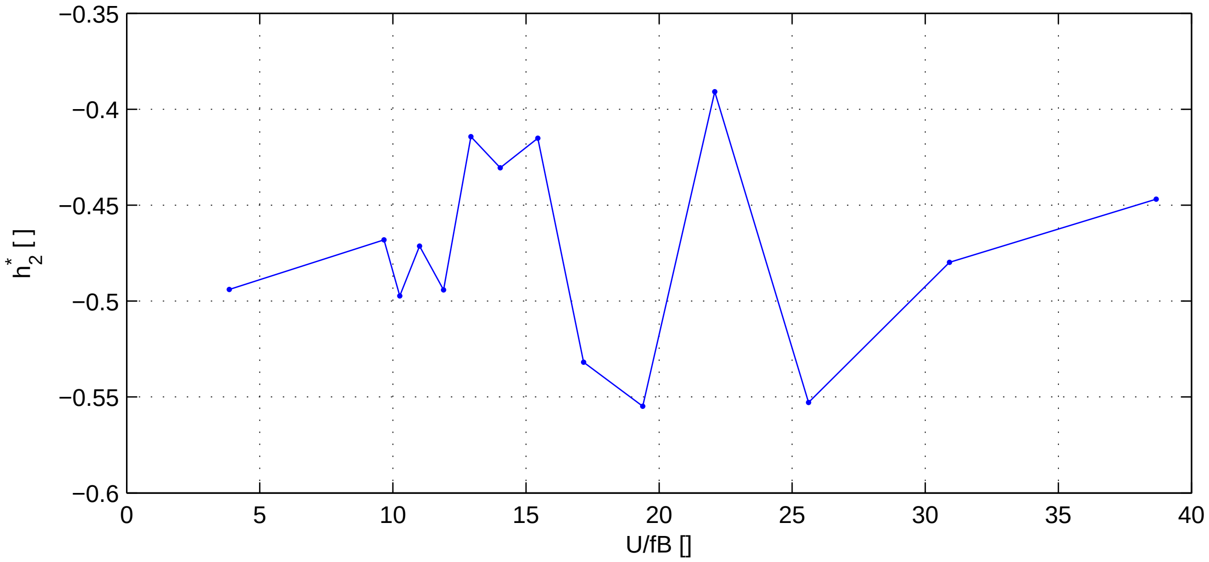

Figure O.20: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_2^*
11.64	25.13	4.00	1.63	3.85	−0.49
11.67	10.05	1.60	0.65	9.66	−0.47
11.64	9.45	1.50	0.61	10.26	−0.50
11.62	8.79	1.40	0.57	11.00	−0.47
11.67	8.16	1.30	0.53	11.91	−0.49
11.69	7.52	1.20	0.49	12.93	−0.41
11.64	6.90	1.10	0.45	14.03	−0.43
11.66	6.28	1.00	0.41	15.44	−0.42
11.67	5.66	0.90	0.37	17.16	−0.53
11.71	5.03	0.80	0.32	19.38	−0.55
11.66	4.39	0.70	0.28	22.09	−0.39
11.62	3.77	0.60	0.25	25.62	−0.55
11.67	3.14	0.50	0.20	30.91	−0.48
11.68	2.51	0.40	0.16	38.68	−0.45

Table O.22: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

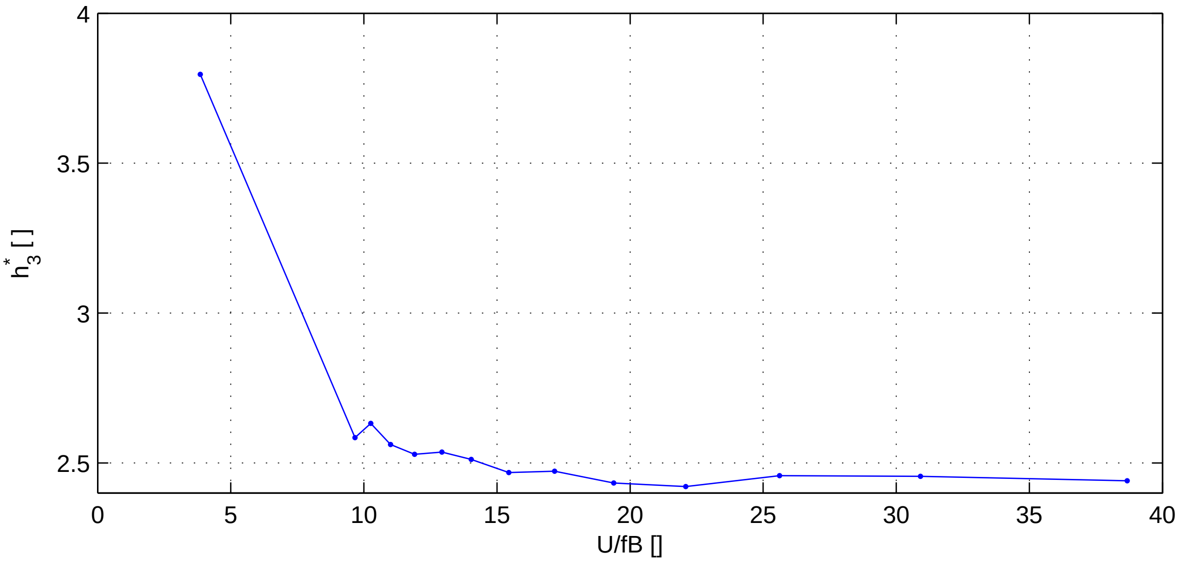

Figure O.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
11.64	25.13	4.00	1.63	3.85	3.80
11.67	10.05	1.60	0.65	9.66	2.58
11.64	9.45	1.50	0.61	10.26	2.63
11.62	8.79	1.40	0.57	11.00	2.56
11.67	8.16	1.30	0.53	11.91	2.53
11.69	7.52	1.20	0.49	12.93	2.54
11.64	6.90	1.10	0.45	14.03	2.51
11.66	6.28	1.00	0.41	15.44	2.47
11.67	5.66	0.90	0.37	17.16	2.47
11.71	5.03	0.80	0.32	19.38	2.43
11.66	4.39	0.70	0.28	22.09	2.42
11.62	3.77	0.60	0.25	25.62	2.46
11.67	3.14	0.50	0.20	30.91	2.46
11.68	2.51	0.40	0.16	38.68	2.44

Table O.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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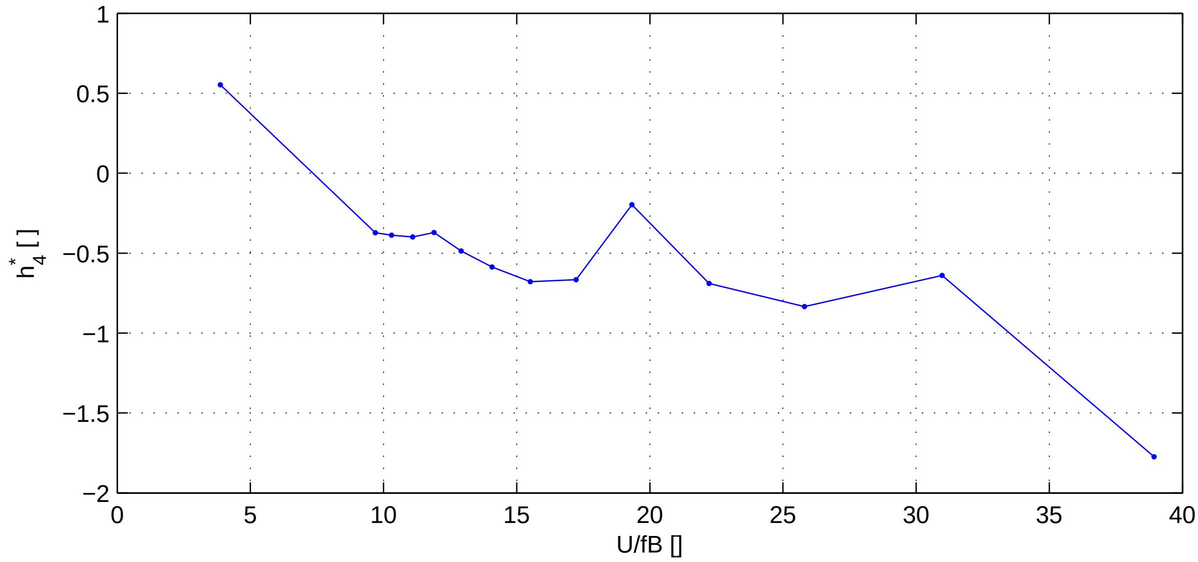

Figure O.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
11.68	25.13	4.00	1.62	3.87	0.55
11.70	10.05	1.60	0.65	9.69	−0.37
11.69	9.45	1.50	0.61	10.30	−0.39
11.72	8.79	1.40	0.57	11.10	−0.40
11.67	8.16	1.30	0.53	11.90	−0.37
11.68	7.52	1.20	0.49	12.92	−0.49
11.67	6.90	1.10	0.45	14.07	−0.59
11.71	6.28	1.00	0.41	15.51	−0.68
11.72	5.66	0.90	0.36	17.23	−0.67
11.67	5.03	0.80	0.33	19.32	−0.20
11.74	4.39	0.70	0.28	22.23	−0.69
11.70	3.77	0.60	0.24	25.81	−0.83
11.69	3.14	0.50	0.20	30.98	−0.64
11.76	2.51	0.40	0.16	38.94	−1.77

Table O.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

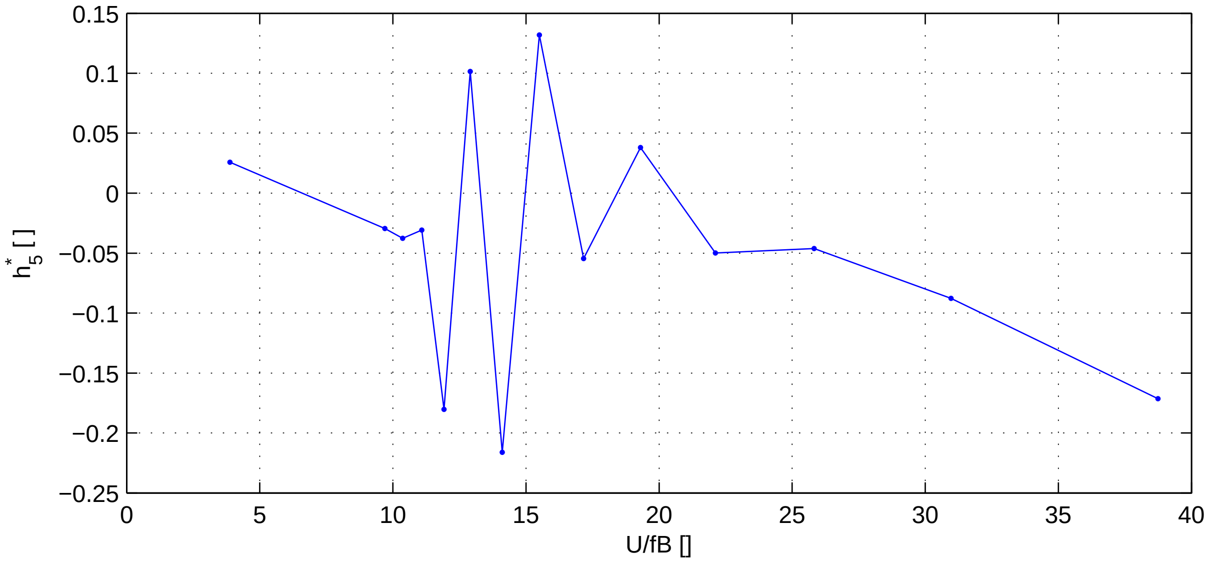

Figure O.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
11.70	25.13	4.00	1.62	3.87	0.03
11.72	10.05	1.60	0.65	9.70	−0.03
11.77	9.45	1.50	0.61	10.37	−0.04
11.70	8.79	1.40	0.57	11.08	−0.03
11.69	8.16	1.30	0.53	11.92	−0.18
11.67	7.52	1.20	0.49	12.91	0.10
11.71	6.90	1.10	0.45	14.11	−0.22
11.70	6.28	1.00	0.41	15.50	0.13
11.68	5.66	0.90	0.37	17.17	−0.05
11.66	5.03	0.80	0.33	19.30	0.04
11.68	4.39	0.70	0.28	22.12	−0.05
11.71	3.77	0.60	0.24	25.82	−0.05
11.69	3.14	0.50	0.20	30.96	−0.09
11.70	2.51	0.40	0.16	38.74	−0.17

Table O.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

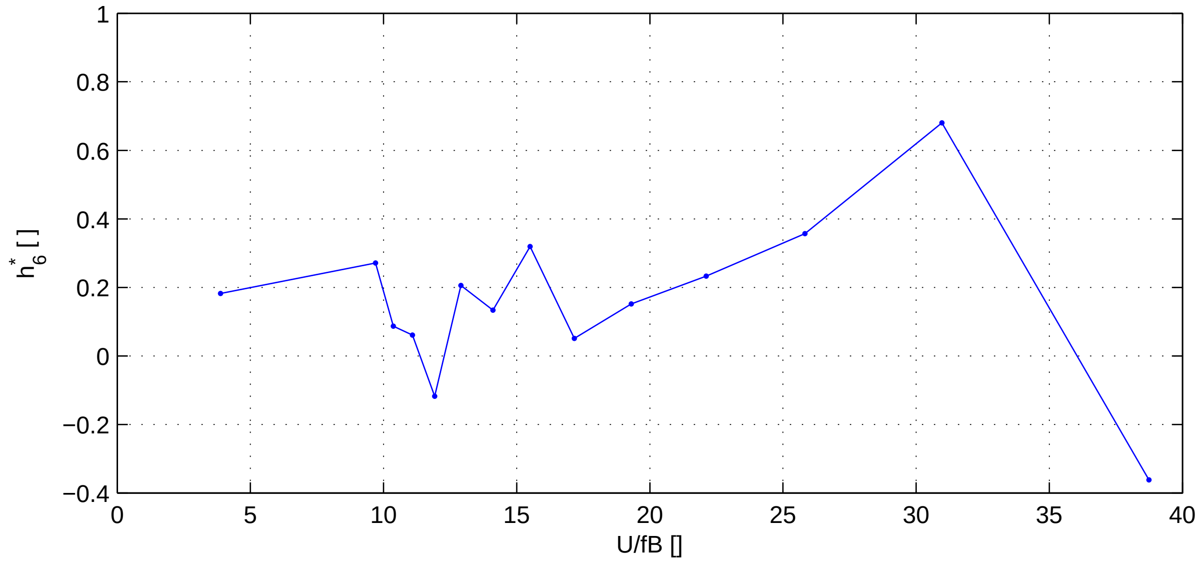

Figure O.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
11.70	25.13	4.00	1.62	3.87	0.18
11.72	10.05	1.60	0.65	9.70	0.27
11.77	9.45	1.50	0.61	10.37	0.09
11.70	8.79	1.40	0.57	11.08	0.06
11.69	8.16	1.30	0.53	11.92	−0.12
11.67	7.52	1.20	0.49	12.91	0.21
11.71	6.90	1.10	0.45	14.11	0.13
11.70	6.28	1.00	0.41	15.50	0.32
11.68	5.66	0.90	0.37	17.17	0.05
11.66	5.03	0.80	0.33	19.30	0.15
11.68	4.39	0.70	0.28	22.12	0.23
11.71	3.77	0.60	0.24	25.82	0.36
11.69	3.14	0.50	0.20	30.96	0.68
11.70	2.51	0.40	0.16	38.74	−0.36

Table O.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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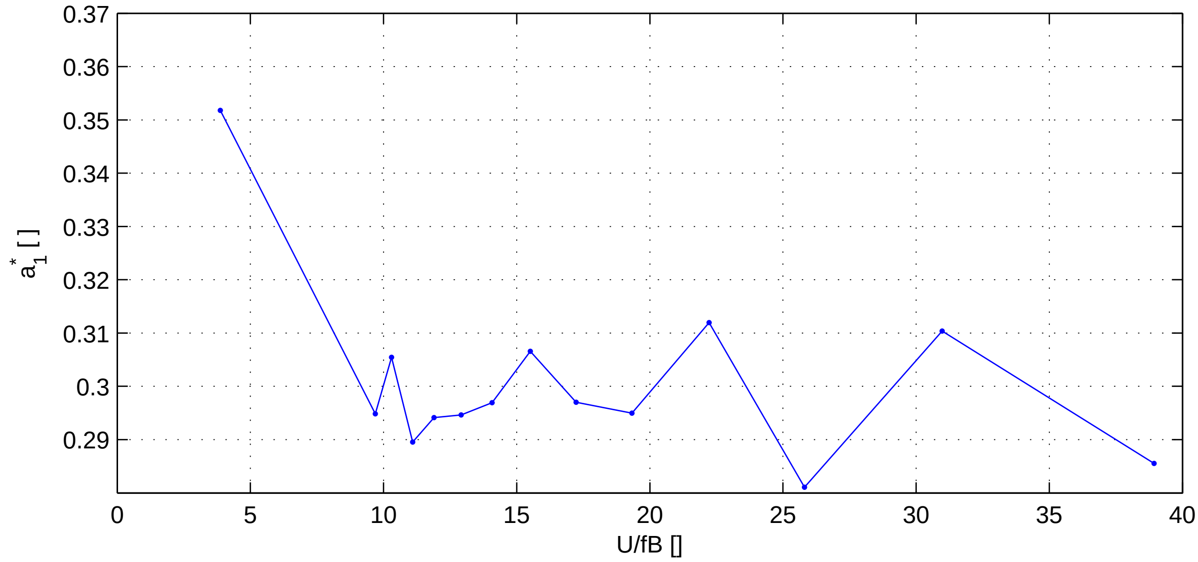

Figure O.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
11.68	25.13	4.00	1.62	3.87	0.35
11.70	10.05	1.60	0.65	9.69	0.29
11.69	9.45	1.50	0.61	10.30	0.31
11.72	8.79	1.40	0.57	11.10	0.29
11.67	8.16	1.30	0.53	11.90	0.29
11.68	7.52	1.20	0.49	12.92	0.29
11.67	6.90	1.10	0.45	14.07	0.30
11.71	6.28	1.00	0.41	15.51	0.31
11.72	5.66	0.90	0.36	17.23	0.30
11.67	5.03	0.80	0.33	19.32	0.29
11.74	4.39	0.70	0.28	22.23	0.31
11.70	3.77	0.60	0.24	25.81	0.28
11.69	3.14	0.50	0.20	30.98	0.31
11.76	2.51	0.40	0.16	38.94	0.29

Table O.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

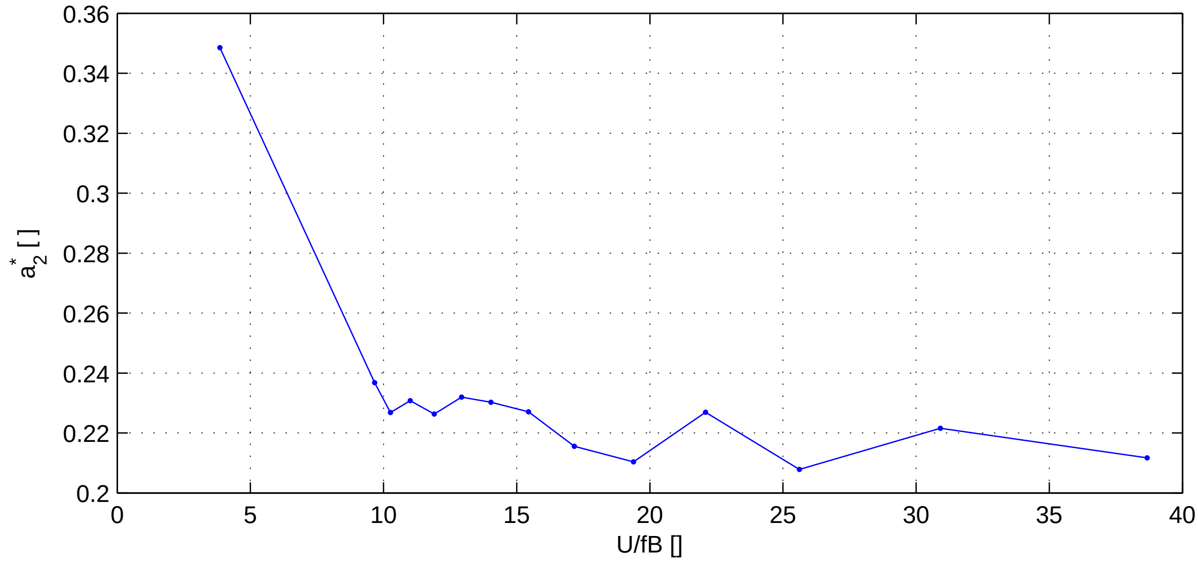

Figure O.26: a^*_2 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a^*_2
11.64	25.13	4.00	1.63	3.85	0.35
11.67	10.05	1.60	0.65	9.66	0.24
11.64	9.45	1.50	0.61	10.26	0.23
11.62	8.79	1.40	0.57	11.00	0.23
11.67	8.16	1.30	0.53	11.91	0.23
11.69	7.52	1.20	0.49	12.93	0.23
11.64	6.90	1.10	0.45	14.03	0.23
11.66	6.28	1.00	0.41	15.44	0.23
11.67	5.66	0.90	0.37	17.16	0.22
11.71	5.03	0.80	0.32	19.38	0.21
11.66	4.39	0.70	0.28	22.09	0.23
11.62	3.77	0.60	0.25	25.62	0.21
11.67	3.14	0.50	0.20	30.91	0.22
11.68	2.51	0.40	0.16	38.68	0.21

Table O.28: a^*_2 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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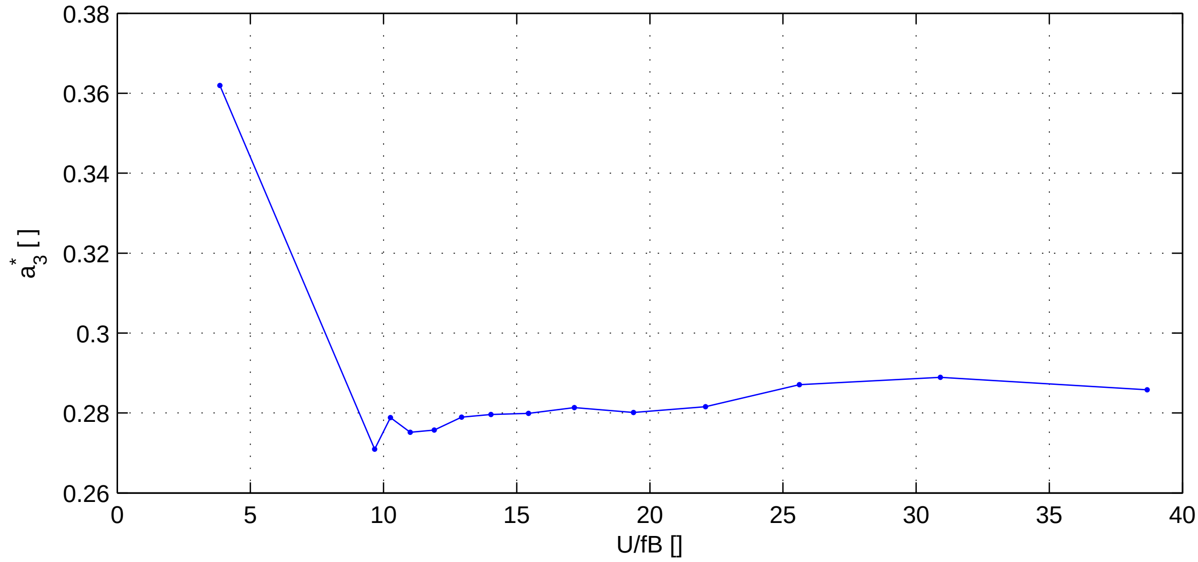

Figure O.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
11.64	25.13	4.00	1.63	3.85	0.36
11.67	10.05	1.60	0.65	9.66	0.27
11.64	9.45	1.50	0.61	10.26	0.28
11.62	8.79	1.40	0.57	11.00	0.28
11.67	8.16	1.30	0.53	11.91	0.28
11.69	7.52	1.20	0.49	12.93	0.28
11.64	6.90	1.10	0.45	14.03	0.28
11.66	6.28	1.00	0.41	15.44	0.28
11.67	5.66	0.90	0.37	17.16	0.28
11.71	5.03	0.80	0.32	19.38	0.28
11.66	4.39	0.70	0.28	22.09	0.28
11.62	3.77	0.60	0.25	25.62	0.29
11.67	3.14	0.50	0.20	30.91	0.29
11.68	2.51	0.40	0.16	38.68	0.29

Table O.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

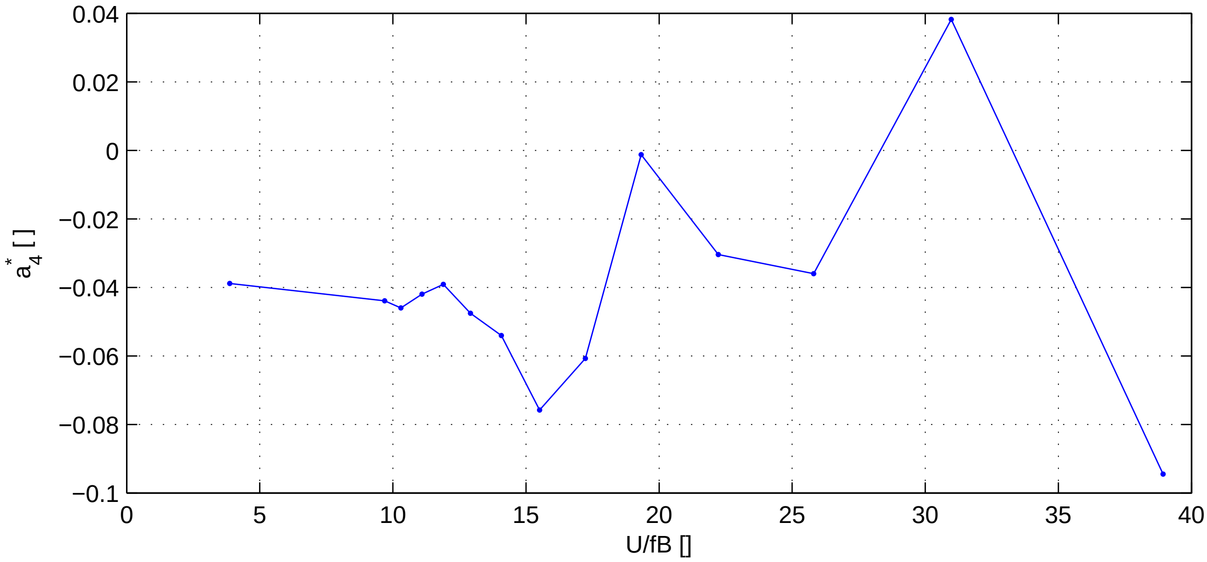

Figure O.28: a^*_4 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a^*_4
11.68	25.13	4.00	1.62	3.87	−0.04
11.70	10.05	1.60	0.65	9.69	−0.04
11.69	9.45	1.50	0.61	10.30	−0.05
11.72	8.79	1.40	0.57	11.10	−0.04
11.67	8.16	1.30	0.53	11.90	−0.04
11.68	7.52	1.20	0.49	12.92	−0.05
11.67	6.90	1.10	0.45	14.07	−0.05
11.71	6.28	1.00	0.41	15.51	−0.08
11.72	5.66	0.90	0.36	17.23	−0.06
11.67	5.03	0.80	0.33	19.32	−0.00
11.74	4.39	0.70	0.28	22.23	−0.03
11.70	3.77	0.60	0.24	25.81	−0.04
11.69	3.14	0.50	0.20	30.98	0.04
11.76	2.51	0.40	0.16	38.94	−0.09

Table O.30: a^*_4 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

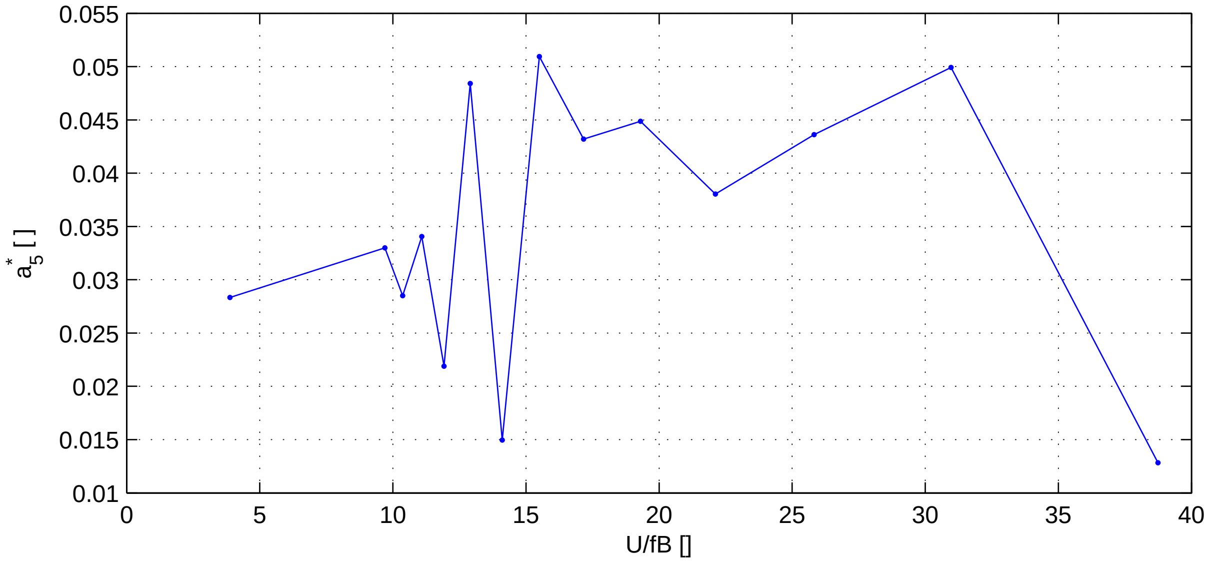

Figure O.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
11.70	25.13	4.00	1.62	3.87	0.03
11.72	10.05	1.60	0.65	9.70	0.03
11.77	9.45	1.50	0.61	10.37	0.03
11.70	8.79	1.40	0.57	11.08	0.03
11.69	8.16	1.30	0.53	11.92	0.02
11.67	7.52	1.20	0.49	12.91	0.05
11.71	6.90	1.10	0.45	14.11	0.01
11.70	6.28	1.00	0.41	15.50	0.05
11.68	5.66	0.90	0.37	17.17	0.04
11.66	5.03	0.80	0.33	19.30	0.04
11.68	4.39	0.70	0.28	22.12	0.04
11.71	3.77	0.60	0.24	25.82	0.04
11.69	3.14	0.50	0.20	30.96	0.05
11.70	2.51	0.40	0.16	38.74	0.01

Table O.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

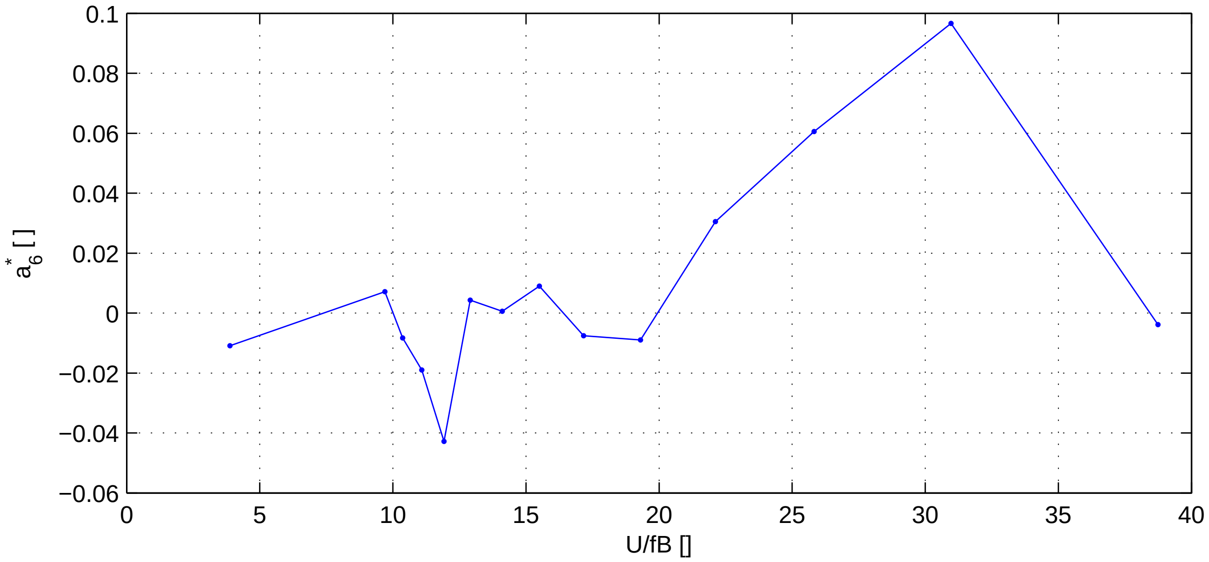

Figure O.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
11.70	25.13	4.00	1.62	3.87	−0.01
11.72	10.05	1.60	0.65	9.70	0.01
11.77	9.45	1.50	0.61	10.37	−0.01
11.70	8.79	1.40	0.57	11.08	−0.02
11.69	8.16	1.30	0.53	11.92	−0.04
11.67	7.52	1.20	0.49	12.91	0.00
11.71	6.90	1.10	0.45	14.11	0.00
11.70	6.28	1.00	0.41	15.50	0.01
11.68	5.66	0.90	0.37	17.17	−0.01
11.66	5.03	0.80	0.33	19.30	−0.01
11.68	4.39	0.70	0.28	22.12	0.03
11.71	3.77	0.60	0.24	25.82	0.06
11.69	3.14	0.50	0.20	30.96	0.10
11.70	2.51	0.40	0.16	38.74	−0.00

Table O.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:26:20

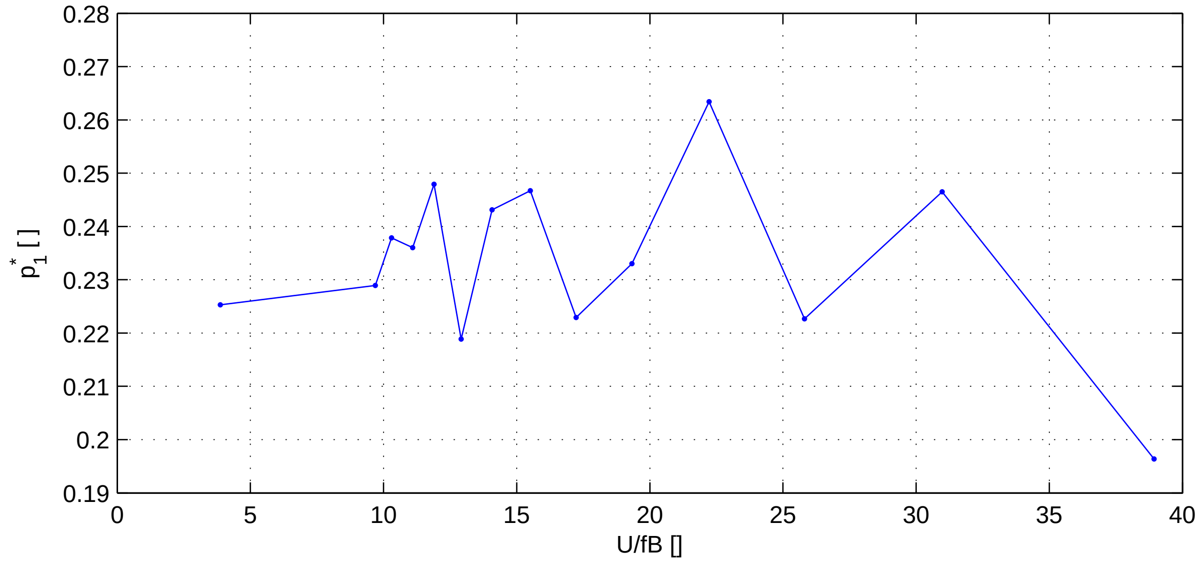

Figure O.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
11.68	25.13	4.00	1.62	3.87	0.23
11.70	10.05	1.60	0.65	9.69	0.23
11.69	9.45	1.50	0.61	10.30	0.24
11.72	8.79	1.40	0.57	11.10	0.24
11.67	8.16	1.30	0.53	11.90	0.25
11.68	7.52	1.20	0.49	12.92	0.22
11.67	6.90	1.10	0.45	14.07	0.24
11.71	6.28	1.00	0.41	15.51	0.25
11.72	5.66	0.90	0.36	17.23	0.22
11.67	5.03	0.80	0.33	19.32	0.23
11.74	4.39	0.70	0.28	22.23	0.26
11.70	3.77	0.60	0.24	25.81	0.22
11.69	3.14	0.50	0.20	30.98	0.25
11.76	2.51	0.40	0.16	38.94	0.20

Table O.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

ProgID: FlutterLab, Version: 1.00, Report generated: 18−Jan−2011 09:26:20

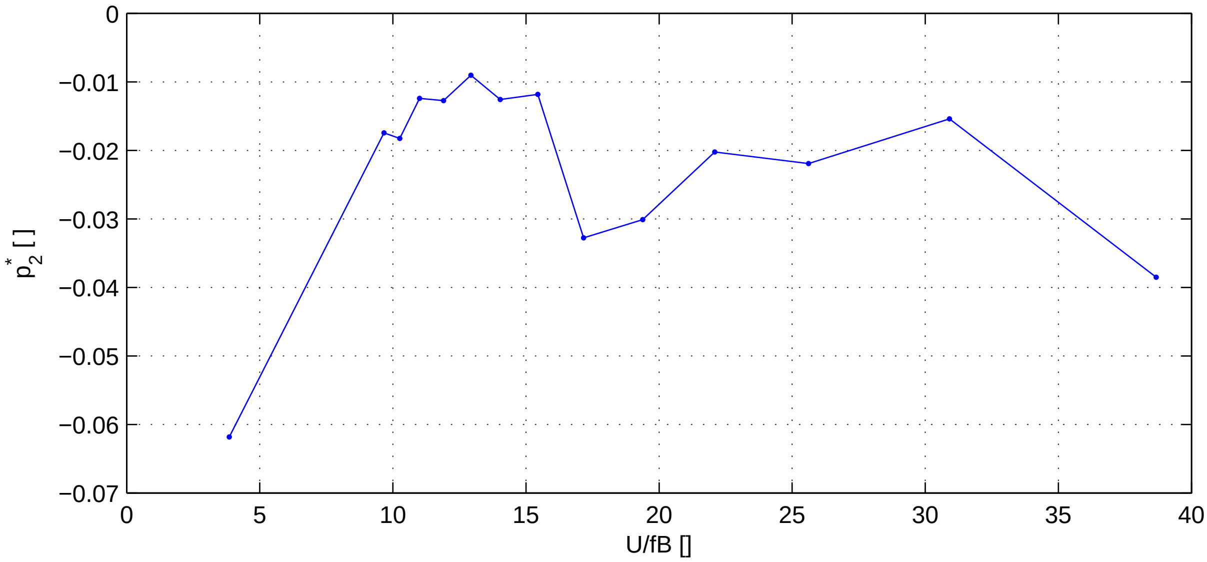

Figure O.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
11.64	25.13	4.00	1.63	3.85	−0.06
11.67	10.05	1.60	0.65	9.66	−0.02
11.64	9.45	1.50	0.61	10.26	−0.02
11.62	8.79	1.40	0.57	11.00	−0.01
11.67	8.16	1.30	0.53	11.91	−0.01
11.69	7.52	1.20	0.49	12.93	−0.01
11.64	6.90	1.10	0.45	14.03	−0.01
11.66	6.28	1.00	0.41	15.44	−0.01
11.67	5.66	0.90	0.37	17.16	−0.03
11.71	5.03	0.80	0.32	19.38	−0.03
11.66	4.39	0.70	0.28	22.09	−0.02
11.62	3.77	0.60	0.25	25.62	−0.02
11.67	3.14	0.50	0.20	30.91	−0.02
11.68	2.51	0.40	0.16	38.68	−0.04

Table O.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

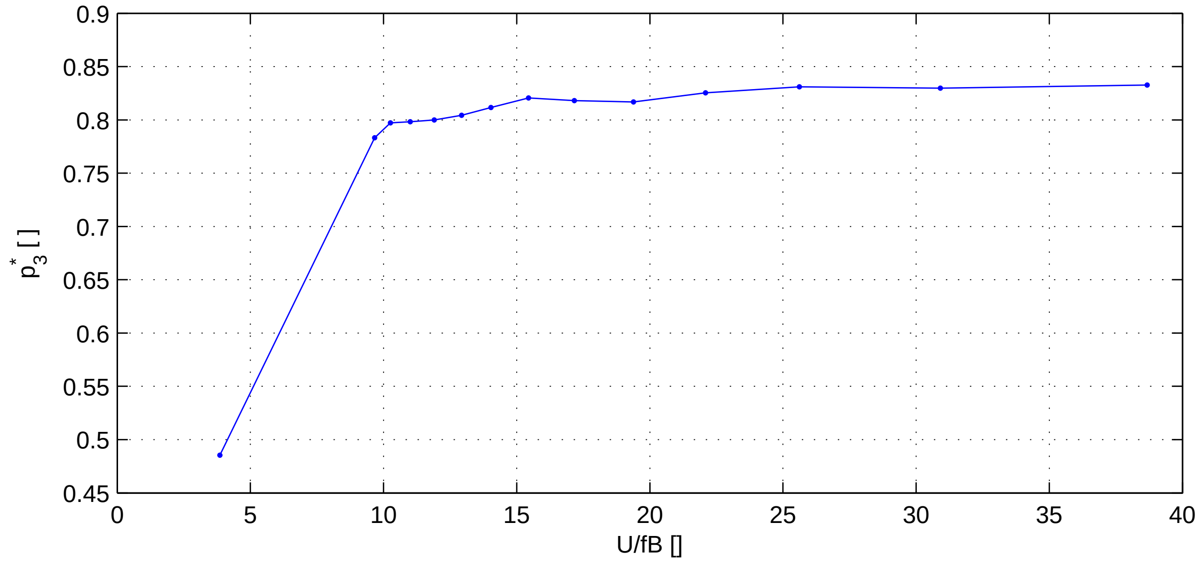

Figure O.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
11.64	25.13	4.00	1.63	3.85	0.49
11.67	10.05	1.60	0.65	9.66	0.78
11.64	9.45	1.50	0.61	10.26	0.80
11.62	8.79	1.40	0.57	11.00	0.80
11.67	8.16	1.30	0.53	11.91	0.80
11.69	7.52	1.20	0.49	12.93	0.80
11.64	6.90	1.10	0.45	14.03	0.81
11.66	6.28	1.00	0.41	15.44	0.82
11.67	5.66	0.90	0.37	17.16	0.82
11.71	5.03	0.80	0.32	19.38	0.82
11.66	4.39	0.70	0.28	22.09	0.83
11.62	3.77	0.60	0.25	25.62	0.83
11.67	3.14	0.50	0.20	30.91	0.83
11.68	2.51	0.40	0.16	38.68	0.83

Table O.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

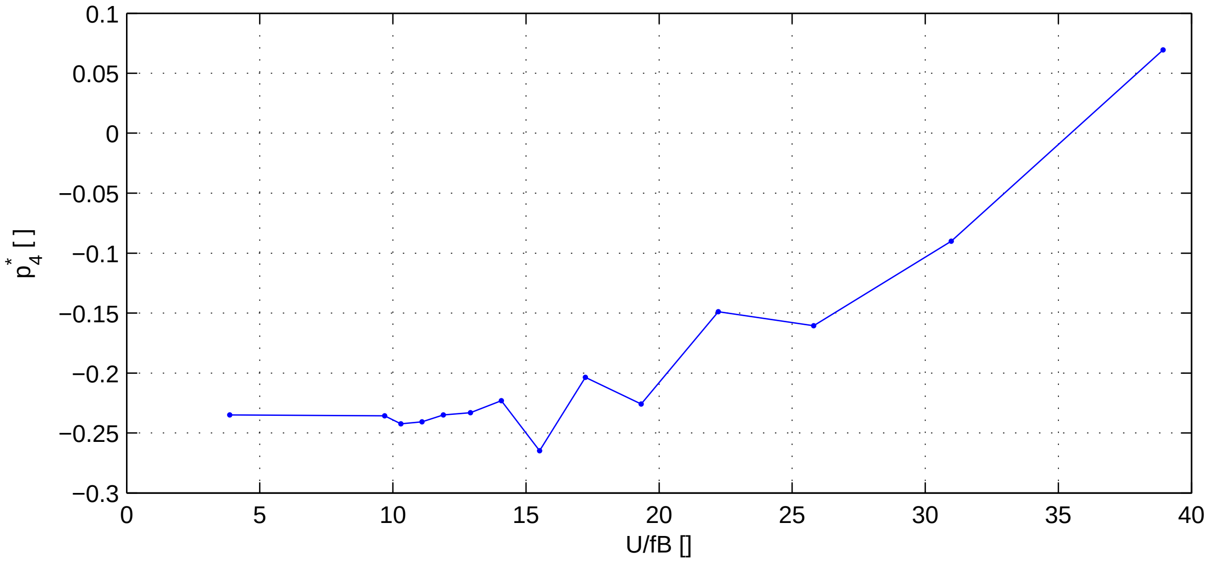

Figure O.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
11.68	25.13	4.00	1.62	3.87	−0.23
11.70	10.05	1.60	0.65	9.69	−0.24
11.69	9.45	1.50	0.61	10.30	−0.24
11.72	8.79	1.40	0.57	11.10	−0.24
11.67	8.16	1.30	0.53	11.90	−0.23
11.68	7.52	1.20	0.49	12.92	−0.23
11.67	6.90	1.10	0.45	14.07	−0.22
11.71	6.28	1.00	0.41	15.51	−0.26
11.72	5.66	0.90	0.36	17.23	−0.20
11.67	5.03	0.80	0.33	19.32	−0.23
11.74	4.39	0.70	0.28	22.23	−0.15
11.70	3.77	0.60	0.24	25.81	−0.16
11.69	3.14	0.50	0.20	30.98	−0.09
11.76	2.51	0.40	0.16	38.94	0.07

Table O.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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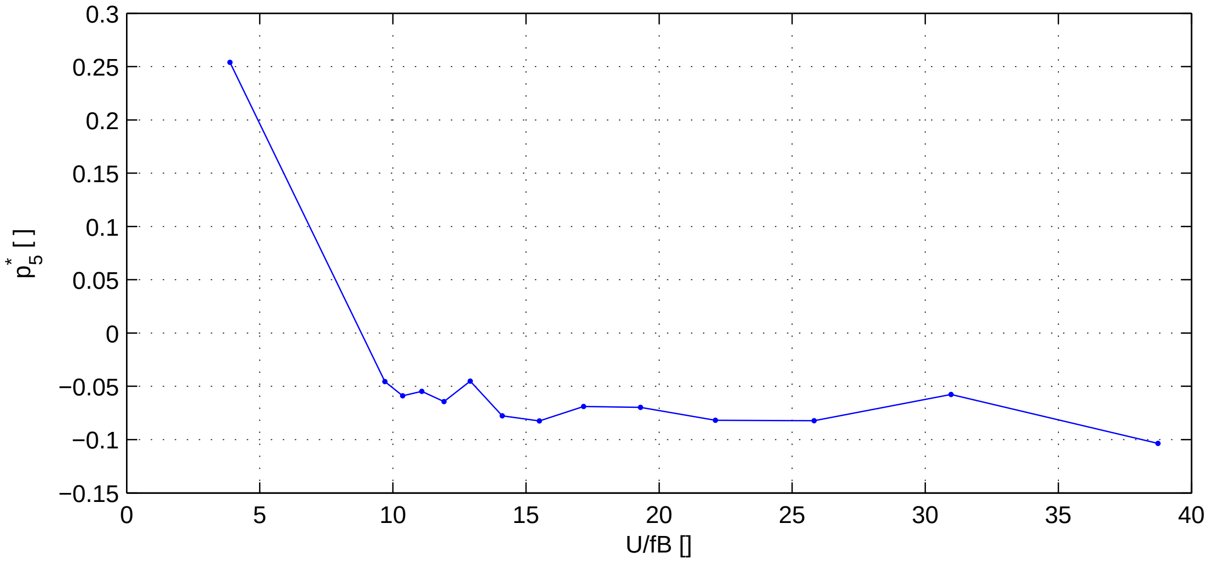


Figure O.35: p^*_5 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p^*_5
11.70	25.13	4.00	1.62	3.87	0.25
11.72	10.05	1.60	0.65	9.70	−0.05
11.77	9.45	1.50	0.61	10.37	−0.06
11.70	8.79	1.40	0.57	11.08	−0.05
11.69	8.16	1.30	0.53	11.92	−0.06
11.67	7.52	1.20	0.49	12.91	−0.05
11.71	6.90	1.10	0.45	14.11	−0.08
11.70	6.28	1.00	0.41	15.50	−0.08
11.68	5.66	0.90	0.37	17.17	−0.07
11.66	5.03	0.80	0.33	19.30	−0.07
11.68	4.39	0.70	0.28	22.12	−0.08
11.71	3.77	0.60	0.24	25.82	−0.08
11.69	3.14	0.50	0.20	30.96	−0.06
11.70	2.51	0.40	0.16	38.74	−0.10

Table O.37: p^*_5 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

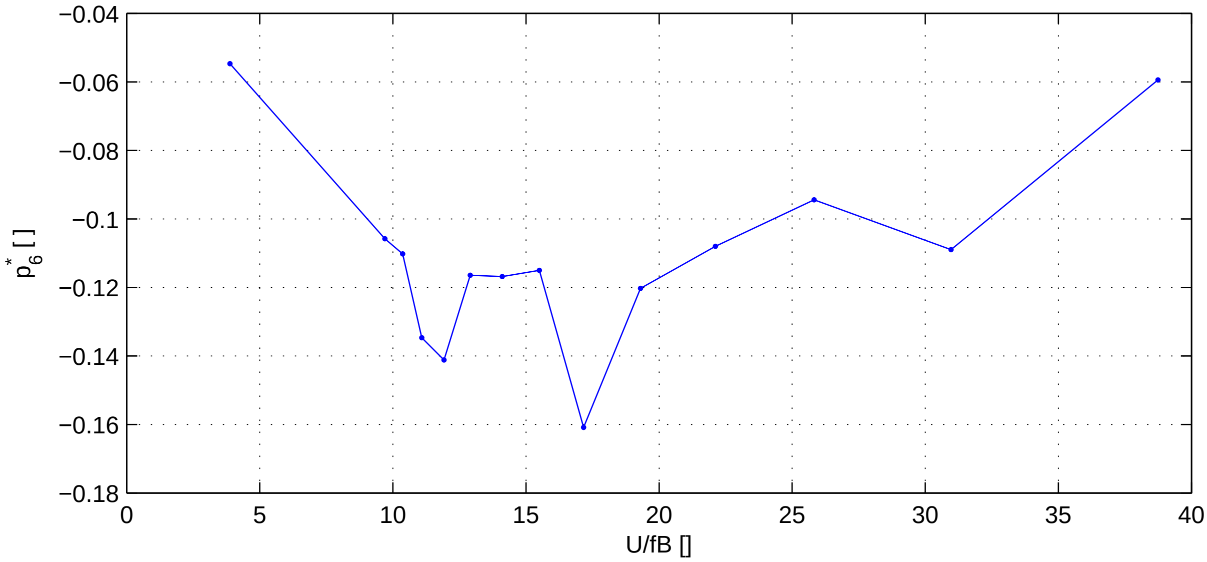


Figure O.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
11.70	25.13	4.00	1.62	3.87	−0.05
11.72	10.05	1.60	0.65	9.70	−0.11
11.77	9.45	1.50	0.61	10.37	−0.11
11.70	8.79	1.40	0.57	11.08	−0.13
11.69	8.16	1.30	0.53	11.92	−0.14
11.67	7.52	1.20	0.49	12.91	−0.12
11.71	6.90	1.10	0.45	14.11	−0.12
11.70	6.28	1.00	0.41	15.50	−0.12
11.68	5.66	0.90	0.37	17.17	−0.16
11.66	5.03	0.80	0.33	19.30	−0.12
11.68	4.39	0.70	0.28	22.12	−0.11
11.71	3.77	0.60	0.24	25.82	−0.09
11.69	3.14	0.50	0.20	30.96	−0.11
11.70	2.51	0.40	0.16	38.74	−0.06

Table O.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

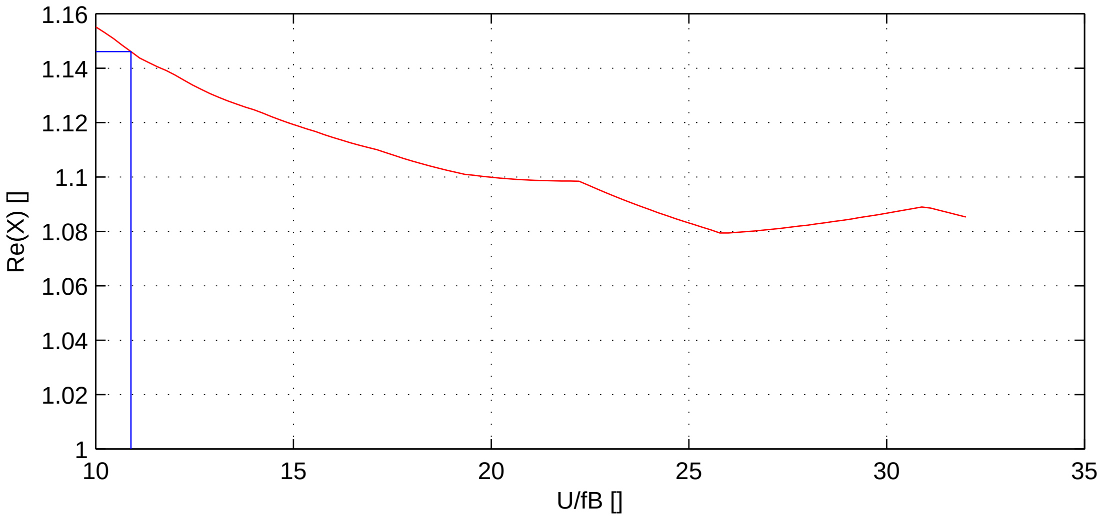


Figure O.37: Real part of the solution to stability equantion

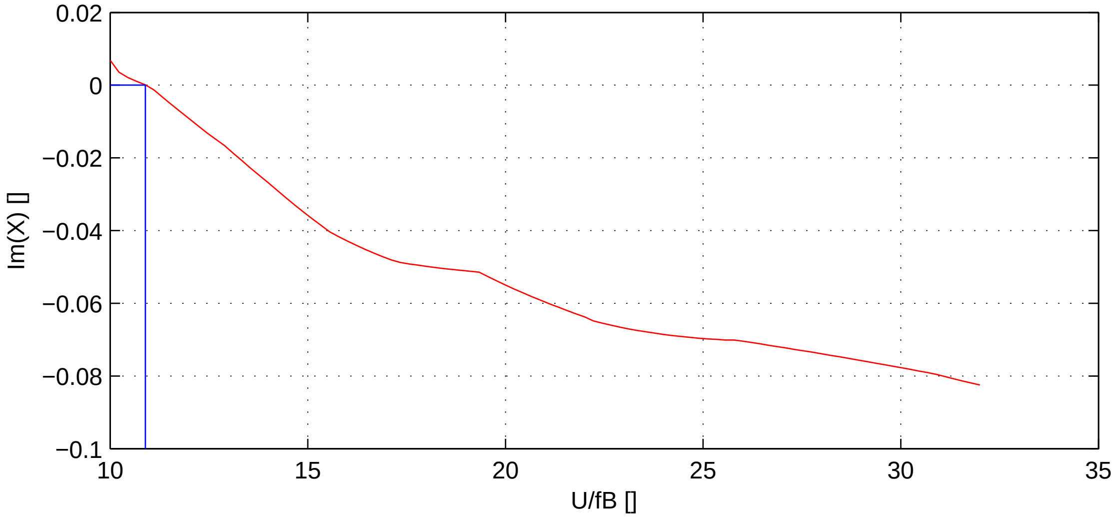


Figure O.38: Imaginary part of the solution to stability equantion

$V_{Crit} = 10.9$

$f_{Crit} = 0.0742$ Hz

$U_{Crit} = 48.8$ m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.
[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.
[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.
[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.
[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix P

3D Flutter Tests

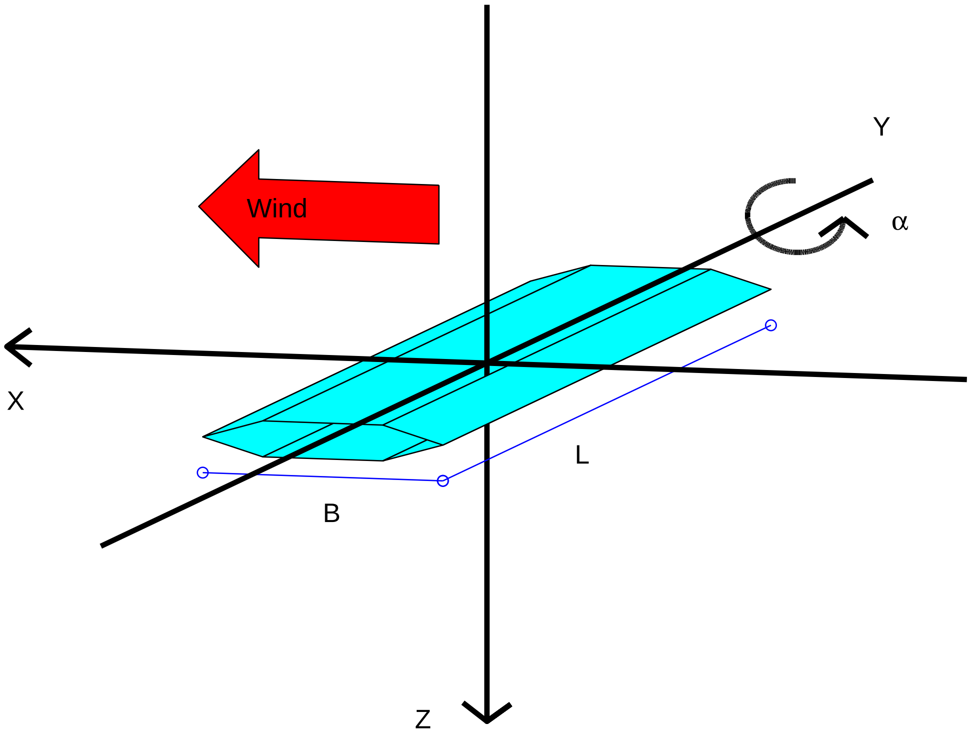
Flutter derivatives, Erection stage, Turbulent flow, Angle of incidence = 4 deg

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^{o}C	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1019.0

Table P.1: Project Data

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Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h : Vertical displacement, displacement along z-axis, [m]
α : Rotation around y-axis, nose up is positive, [rad]
p : Horizontal displacement, displacement along the x-axis, [m]
m : Mass per unit length, [kg/m]
I_y : Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$: Added mass in vertical direction, [kg/m]
$m_{a,x}$: Added mass in horizontal direction, [kg/m]
$I_{a,y}$: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G : X-coordinate for centre of gravity, [m]
Z_G : Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$: Natural circular frequency for vertical motion, [/s]
ζ_h : Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$: Natural circular frequency for rotation around y axis, [/s]
ζ_α : Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p : Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$: Force from rig per meter section, [N/m]
$M_{Y,external}$: Moment from rig per meter section, [Nm/m]
$F_{X,external}$: Force from rig per meter section, [N/m]

Formula P.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.640
Added mass in horizontal	$m_{a,x}$	kg/m	0.564
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.149
Horizontal centre of gravity	x_G	m	−0.001
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.293
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.157
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.117

Table P.2: Mechanical Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b: buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b: buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b: buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula P.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

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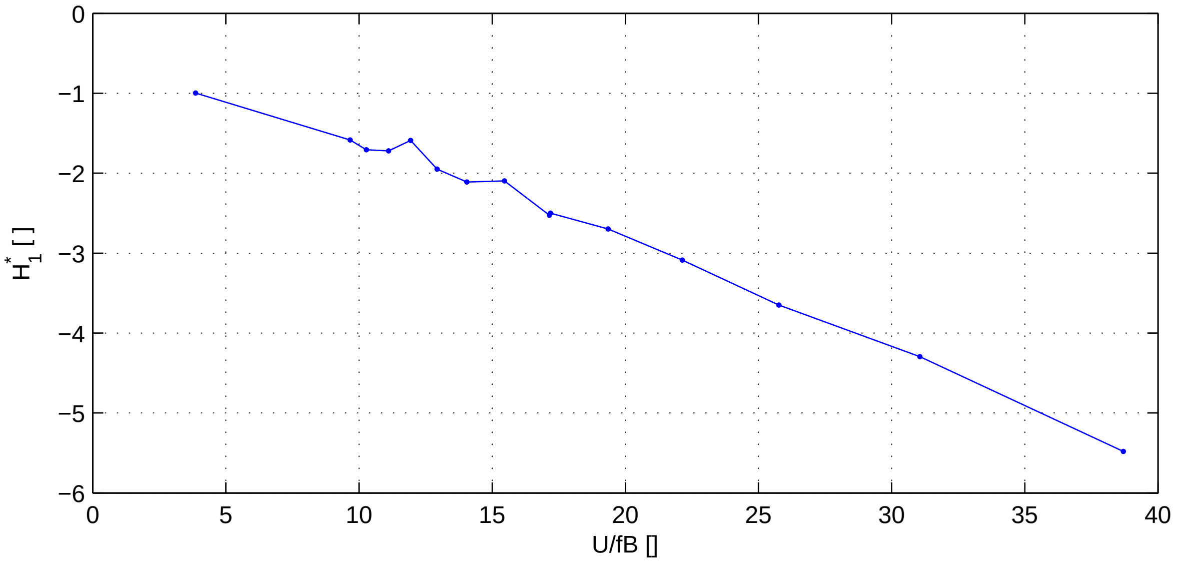

Figure P.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
11.67	25.13	4.00	1.63	3.86	−1.00
11.68	10.05	1.60	0.65	9.67	−1.59
11.66	9.45	1.50	0.61	10.27	−1.71
11.73	8.79	1.40	0.57	11.11	−1.72
11.71	8.16	1.30	0.53	11.94	−1.59
11.69	7.52	1.20	0.49	12.93	−1.95
11.65	6.90	1.10	0.45	14.05	−2.11
11.67	6.28	1.00	0.41	15.46	−2.10
11.66	5.66	0.90	0.37	17.15	−2.53
11.69	5.66	0.90	0.37	17.19	−2.50
11.69	5.03	0.80	0.32	19.35	−2.70
11.69	4.39	0.70	0.28	22.15	−3.09
11.68	3.77	0.60	0.24	25.76	−3.65
11.72	3.14	0.50	0.20	31.06	−4.30
11.69	2.51	0.40	0.16	38.70	−5.48

Table P.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

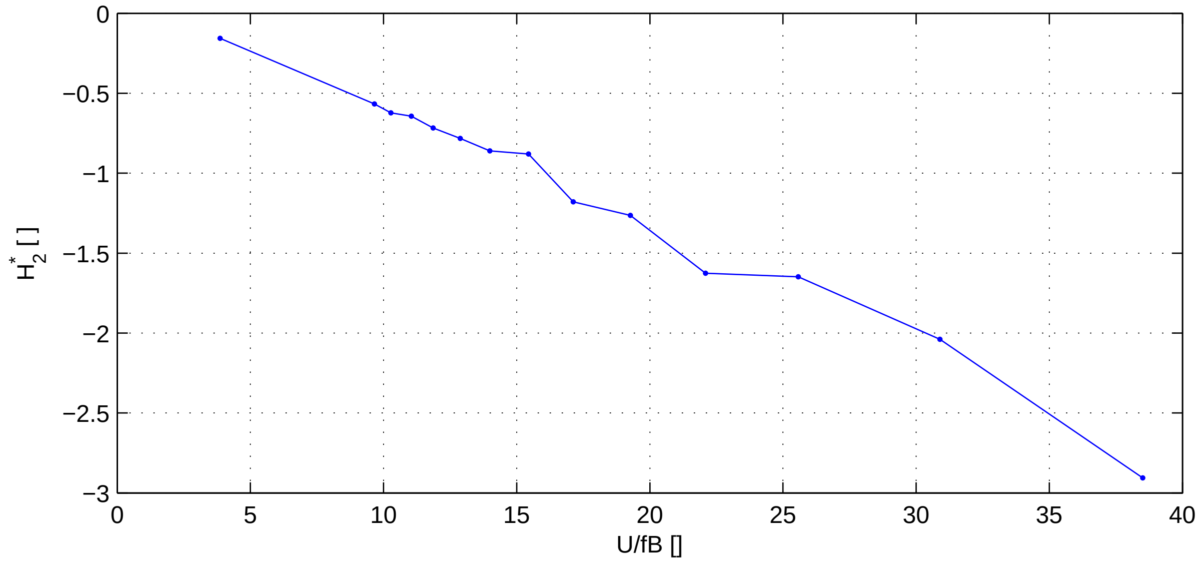

Figure P.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
11.67	25.13	4.00	1.63	3.86	−0.16
11.67	10.05	1.60	0.65	9.66	−0.57
11.67	9.45	1.50	0.61	10.28	−0.62
11.66	8.79	1.40	0.57	11.04	−0.64
11.63	8.16	1.30	0.53	11.86	−0.72
11.65	7.52	1.20	0.49	12.88	−0.78
11.61	6.90	1.10	0.45	13.99	−0.86
11.66	6.28	1.00	0.41	15.45	−0.88
11.65	5.66	0.90	0.37	17.12	−1.18
11.64	5.03	0.80	0.33	19.27	−1.26
11.67	4.39	0.70	0.28	22.10	−1.63
11.60	3.77	0.60	0.25	25.58	−1.65
11.66	3.14	0.50	0.20	30.89	−2.04
11.63	2.51	0.40	0.16	38.51	−2.91

Table P.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

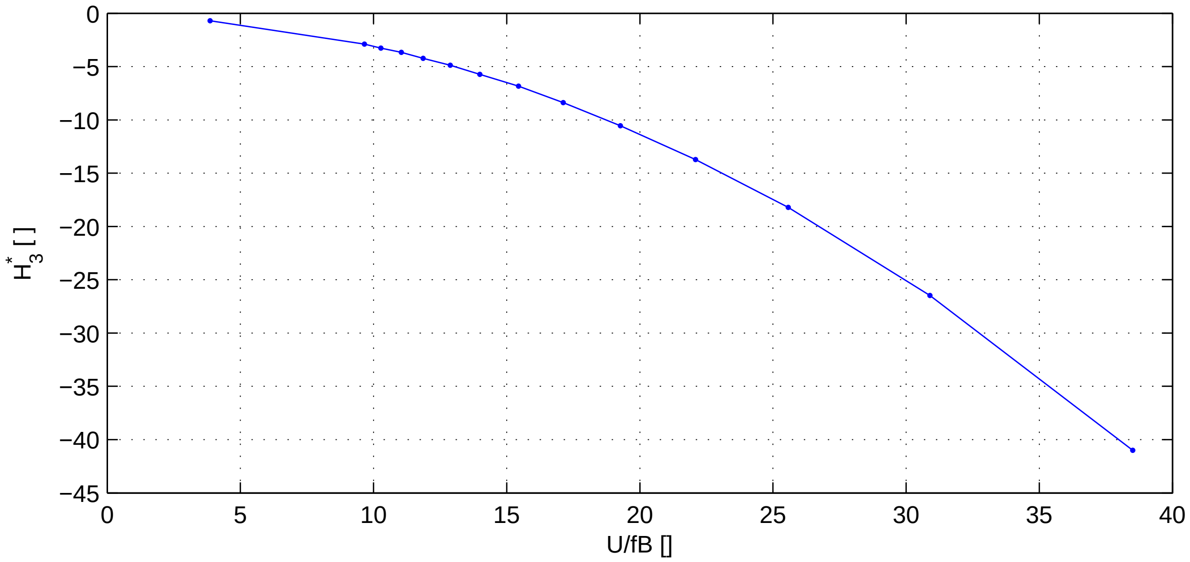

Figure P.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
11.67	25.13	4.00	1.63	3.86	−0.71
11.67	10.05	1.60	0.65	9.66	−2.89
11.67	9.45	1.50	0.61	10.28	−3.27
11.66	8.79	1.40	0.57	11.04	−3.67
11.63	8.16	1.30	0.53	11.86	−4.23
11.65	7.52	1.20	0.49	12.88	−4.87
11.61	6.90	1.10	0.45	13.99	−5.73
11.66	6.28	1.00	0.41	15.45	−6.84
11.65	5.66	0.90	0.37	17.12	−8.39
11.64	5.03	0.80	0.33	19.27	−10.55
11.67	4.39	0.70	0.28	22.10	−13.72
11.60	3.77	0.60	0.25	25.58	−18.20
11.66	3.14	0.50	0.20	30.89	−26.47
11.63	2.51	0.40	0.16	38.51	−41.01

Table P.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

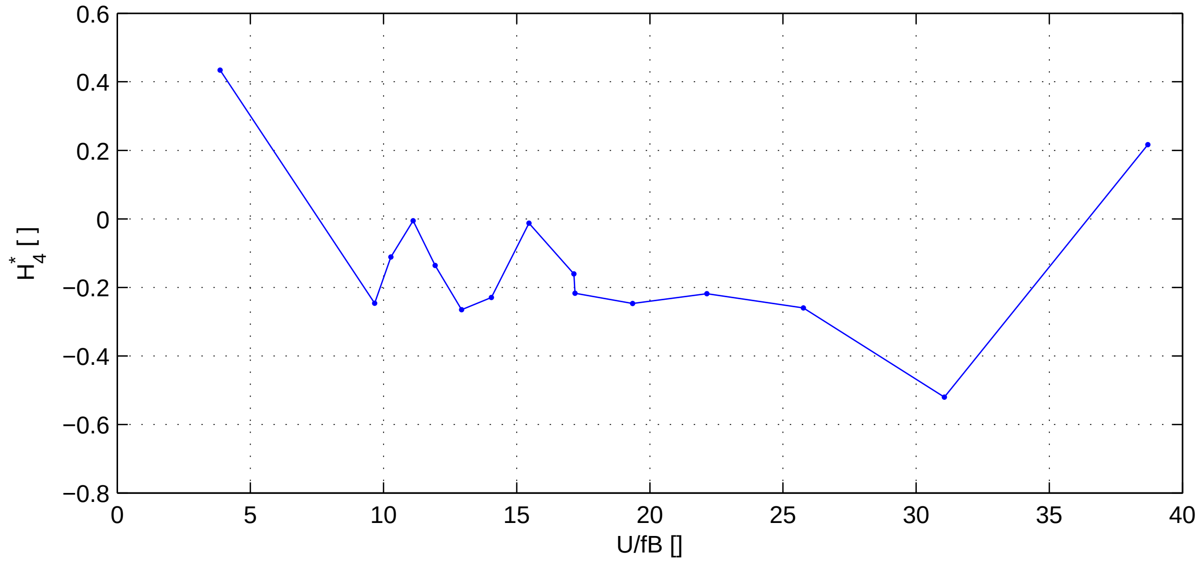

Figure P.4: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_4^*
11.67	25.13	4.00	1.63	3.86	0.43
11.68	10.05	1.60	0.65	9.67	−0.25
11.66	9.45	1.50	0.61	10.27	−0.11
11.73	8.79	1.40	0.57	11.11	−0.01
11.71	8.16	1.30	0.53	11.94	−0.14
11.69	7.52	1.20	0.49	12.93	−0.27
11.65	6.90	1.10	0.45	14.05	−0.23
11.67	6.28	1.00	0.41	15.46	−0.01
11.66	5.66	0.90	0.37	17.15	−0.16
11.69	5.66	0.90	0.37	17.19	−0.22
11.69	5.03	0.80	0.32	19.35	−0.25
11.69	4.39	0.70	0.28	22.15	−0.22
11.68	3.77	0.60	0.24	25.76	−0.26
11.72	3.14	0.50	0.20	31.06	−0.52
11.69	2.51	0.40	0.16	38.70	0.22

Table P.6: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

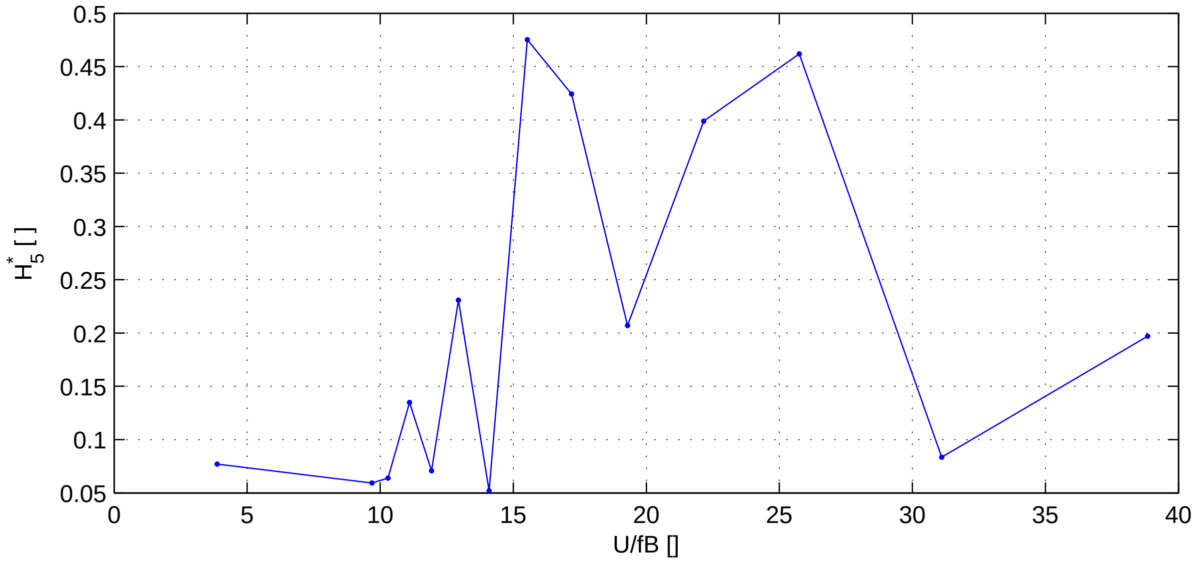

Figure P.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
11.68	25.13	4.00	1.62	3.87	0.08
11.71	10.05	1.60	0.65	9.69	0.06
11.69	9.45	1.50	0.61	10.29	0.06
11.72	8.79	1.40	0.57	11.10	0.13
11.70	8.16	1.30	0.53	11.93	0.07
11.70	7.52	1.20	0.49	12.94	0.23
11.69	6.90	1.10	0.45	14.09	0.05
11.72	6.28	1.00	0.40	15.53	0.48
11.69	5.66	0.90	0.37	17.19	0.42
11.65	5.03	0.80	0.33	19.29	0.21
11.70	4.39	0.70	0.28	22.16	0.40
11.68	3.77	0.60	0.24	25.75	0.46
11.74	3.14	0.50	0.20	31.10	0.08
11.73	2.51	0.40	0.16	38.85	0.20

Table P.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

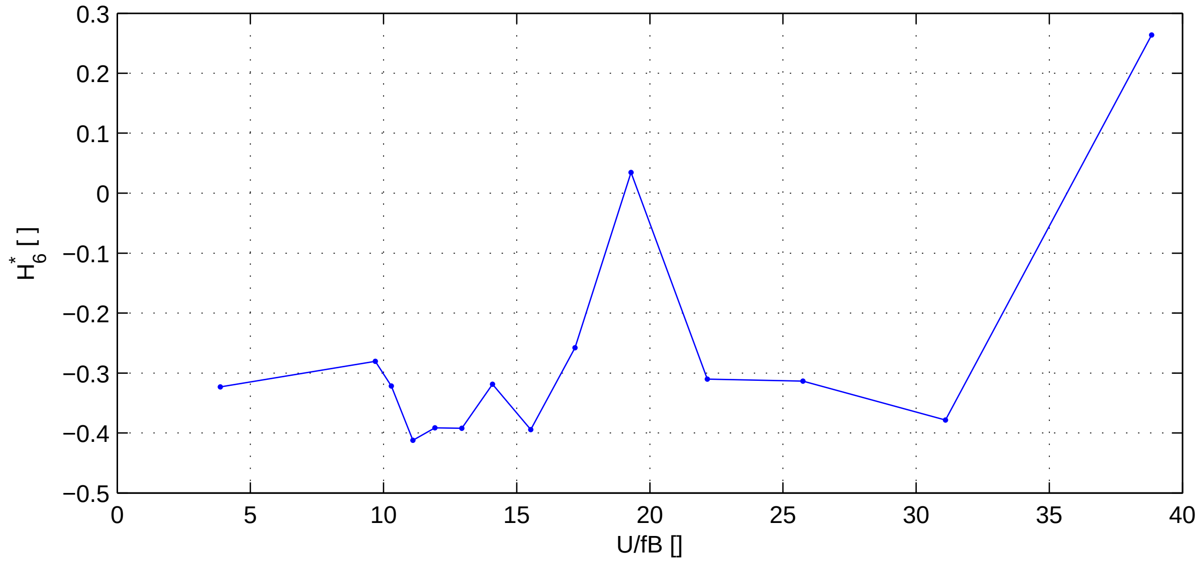

Figure P.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
11.68	25.13	4.00	1.62	3.87	−0.32
11.71	10.05	1.60	0.65	9.69	−0.28
11.69	9.45	1.50	0.61	10.29	−0.32
11.72	8.79	1.40	0.57	11.10	−0.41
11.70	8.16	1.30	0.53	11.93	−0.39
11.70	7.52	1.20	0.49	12.94	−0.39
11.69	6.90	1.10	0.45	14.09	−0.32
11.72	6.28	1.00	0.40	15.53	−0.39
11.69	5.66	0.90	0.37	17.19	−0.26
11.65	5.03	0.80	0.33	19.29	0.03
11.70	4.39	0.70	0.28	22.16	−0.31
11.68	3.77	0.60	0.24	25.75	−0.31
11.74	3.14	0.50	0.20	31.10	−0.38
11.73	2.51	0.40	0.16	38.85	0.26

Table P.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

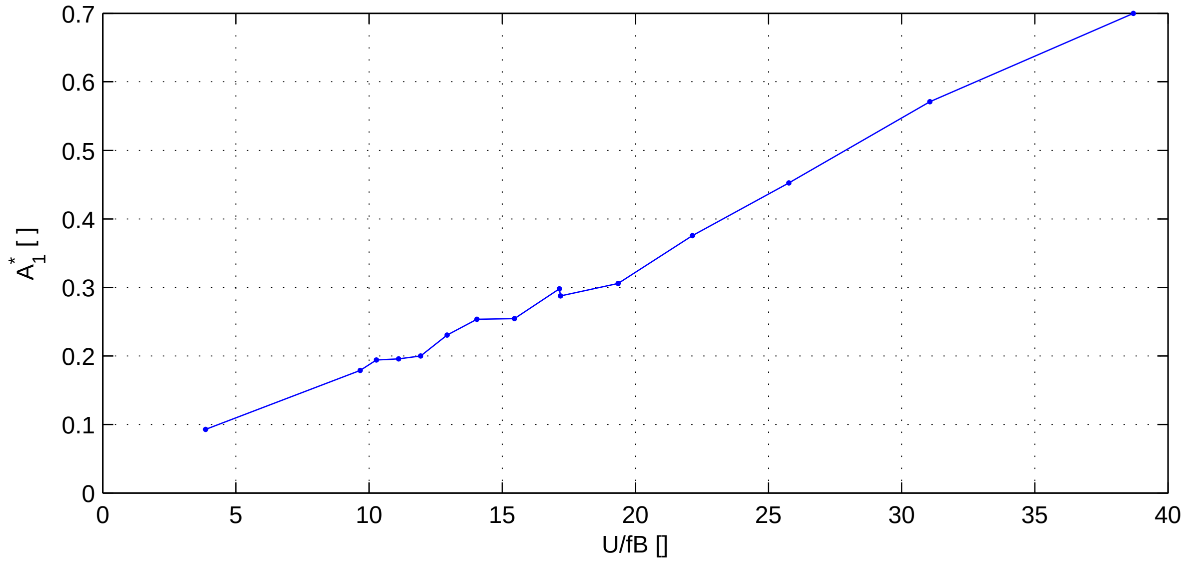

Figure P.7: A^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A^*_1
11.67	25.13	4.00	1.63	3.86	0.09
11.68	10.05	1.60	0.65	9.67	0.18
11.66	9.45	1.50	0.61	10.27	0.19
11.73	8.79	1.40	0.57	11.11	0.20
11.71	8.16	1.30	0.53	11.94	0.20
11.69	7.52	1.20	0.49	12.93	0.23
11.65	6.90	1.10	0.45	14.05	0.25
11.67	6.28	1.00	0.41	15.46	0.25
11.66	5.66	0.90	0.37	17.15	0.30
11.69	5.66	0.90	0.37	17.19	0.29
11.69	5.03	0.80	0.32	19.35	0.31
11.69	4.39	0.70	0.28	22.15	0.38
11.68	3.77	0.60	0.24	25.76	0.45
11.72	3.14	0.50	0.20	31.06	0.57
11.69	2.51	0.40	0.16	38.70	0.70

Table P.9: A^*_1 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

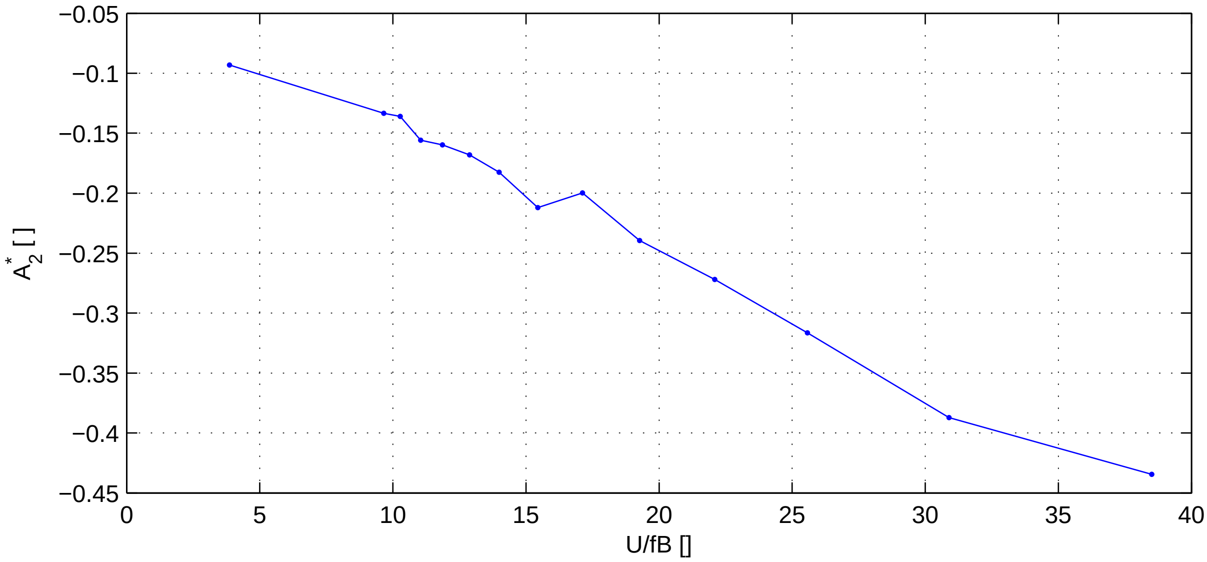

Figure P.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
11.67	25.13	4.00	1.63	3.86	−0.09
11.67	10.05	1.60	0.65	9.66	−0.13
11.67	9.45	1.50	0.61	10.28	−0.14
11.66	8.79	1.40	0.57	11.04	−0.16
11.63	8.16	1.30	0.53	11.86	−0.16
11.65	7.52	1.20	0.49	12.88	−0.17
11.61	6.90	1.10	0.45	13.99	−0.18
11.66	6.28	1.00	0.41	15.45	−0.21
11.65	5.66	0.90	0.37	17.12	−0.20
11.64	5.03	0.80	0.33	19.27	−0.24
11.67	4.39	0.70	0.28	22.10	−0.27
11.60	3.77	0.60	0.25	25.58	−0.32
11.66	3.14	0.50	0.20	30.89	−0.39
11.63	2.51	0.40	0.16	38.51	−0.43

Table P.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

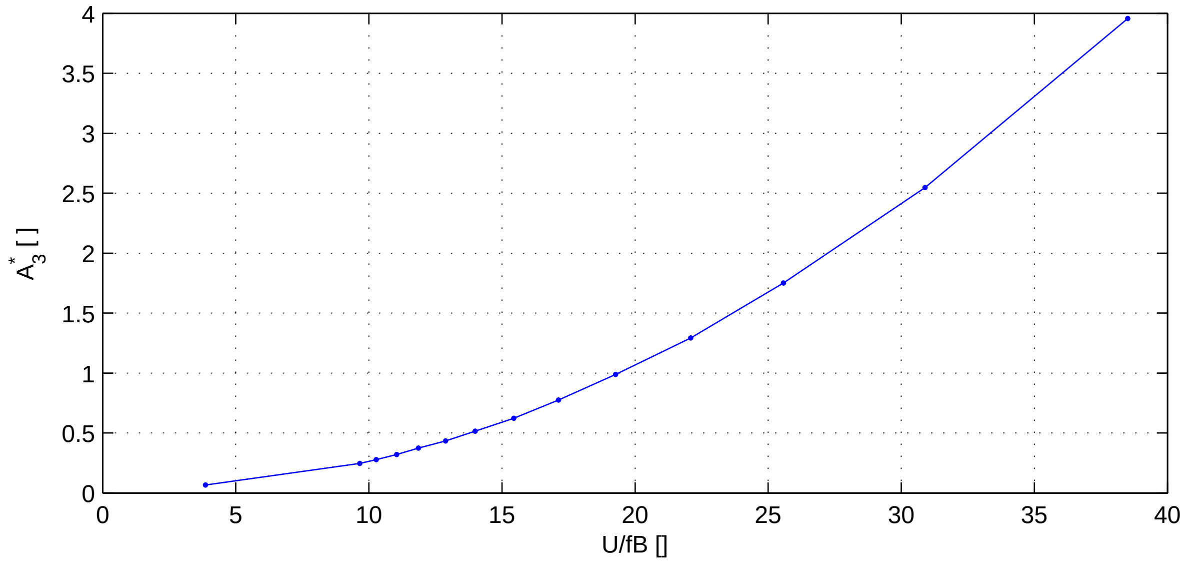

Figure P.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
11.67	25.13	4.00	1.63	3.86	0.07
11.67	10.05	1.60	0.65	9.66	0.25
11.67	9.45	1.50	0.61	10.28	0.28
11.66	8.79	1.40	0.57	11.04	0.32
11.63	8.16	1.30	0.53	11.86	0.37
11.65	7.52	1.20	0.49	12.88	0.43
11.61	6.90	1.10	0.45	13.99	0.52
11.66	6.28	1.00	0.41	15.45	0.62
11.65	5.66	0.90	0.37	17.12	0.77
11.64	5.03	0.80	0.33	19.27	0.99
11.67	4.39	0.70	0.28	22.10	1.29
11.60	3.77	0.60	0.25	25.58	1.75
11.66	3.14	0.50	0.20	30.89	2.55
11.63	2.51	0.40	0.16	38.51	3.96

Table P.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

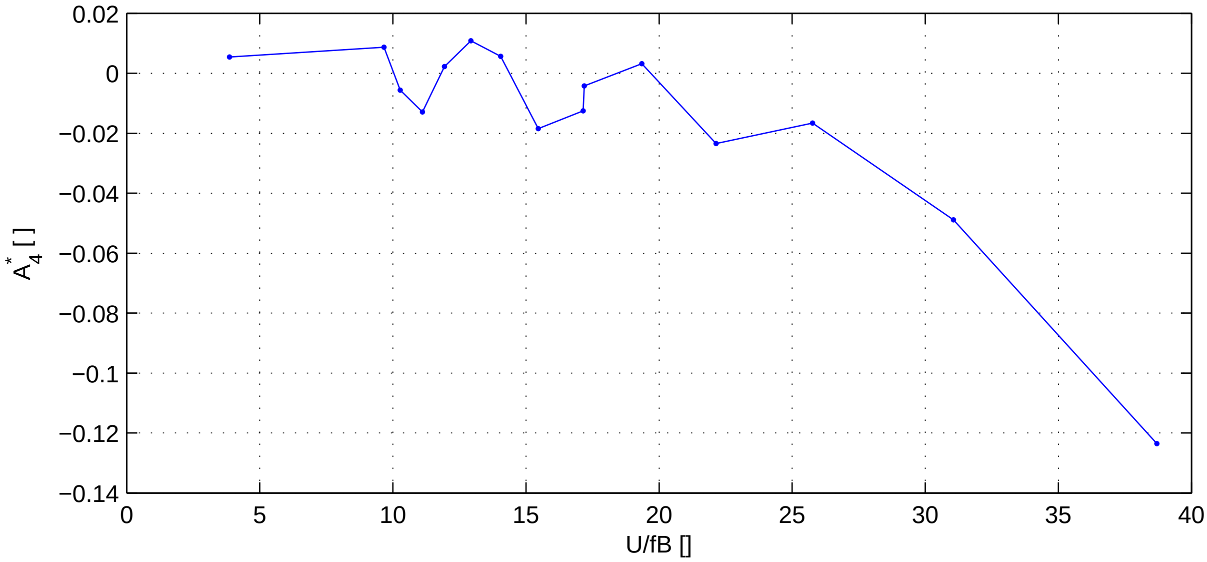

Figure P.10: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_4^*
11.67	25.13	4.00	1.63	3.86	0.01
11.68	10.05	1.60	0.65	9.67	0.01
11.66	9.45	1.50	0.61	10.27	−0.01
11.73	8.79	1.40	0.57	11.11	−0.01
11.71	8.16	1.30	0.53	11.94	0.00
11.69	7.52	1.20	0.49	12.93	0.01
11.65	6.90	1.10	0.45	14.05	0.01
11.67	6.28	1.00	0.41	15.46	−0.02
11.66	5.66	0.90	0.37	17.15	−0.01
11.69	5.66	0.90	0.37	17.19	−0.00
11.69	5.03	0.80	0.32	19.35	0.00
11.69	4.39	0.70	0.28	22.15	−0.02
11.68	3.77	0.60	0.24	25.76	−0.02
11.72	3.14	0.50	0.20	31.06	−0.05
11.69	2.51	0.40	0.16	38.70	−0.12

Table P.12: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

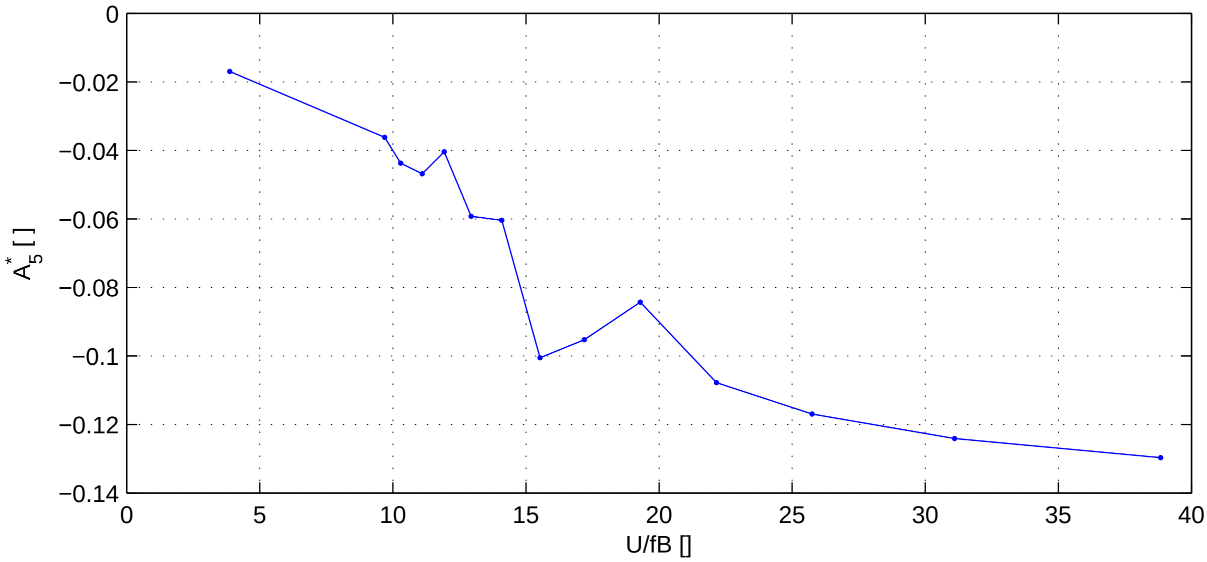

Figure P.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
11.68	25.13	4.00	1.62	3.87	−0.02
11.71	10.05	1.60	0.65	9.69	−0.04
11.69	9.45	1.50	0.61	10.29	−0.04
11.72	8.79	1.40	0.57	11.10	−0.05
11.70	8.16	1.30	0.53	11.93	−0.04
11.70	7.52	1.20	0.49	12.94	−0.06
11.69	6.90	1.10	0.45	14.09	−0.06
11.72	6.28	1.00	0.40	15.53	−0.10
11.69	5.66	0.90	0.37	17.19	−0.10
11.65	5.03	0.80	0.33	19.29	−0.08
11.70	4.39	0.70	0.28	22.16	−0.11
11.68	3.77	0.60	0.24	25.75	−0.12
11.74	3.14	0.50	0.20	31.10	−0.12
11.73	2.51	0.40	0.16	38.85	−0.13

Table P.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

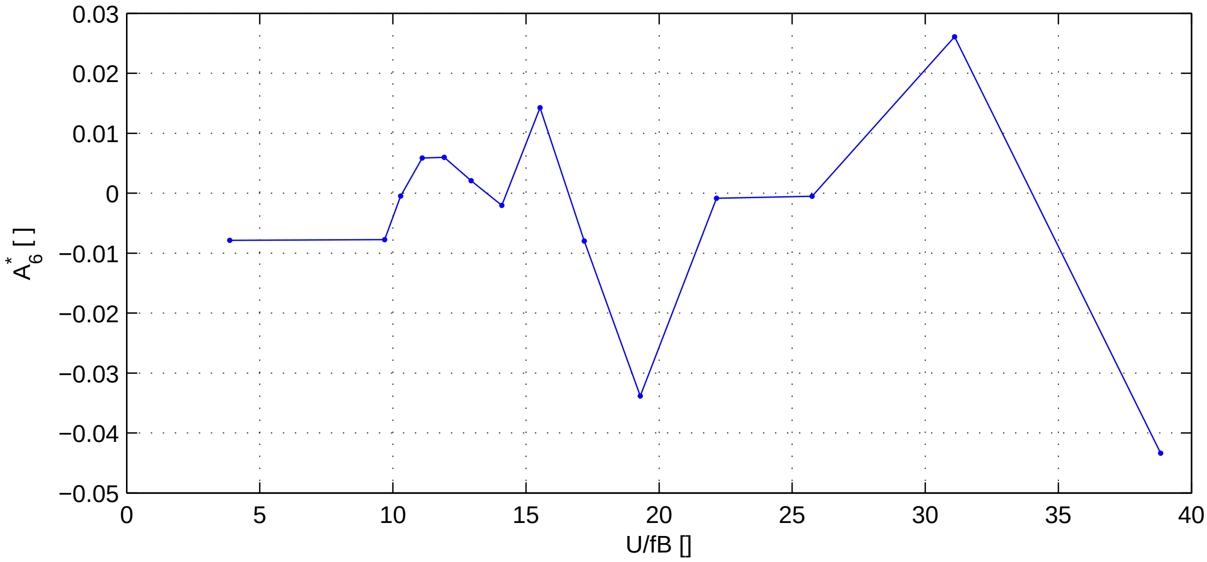

Figure P.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
11.68	25.13	4.00	1.62	3.87	−0.01
11.71	10.05	1.60	0.65	9.69	−0.01
11.69	9.45	1.50	0.61	10.29	−0.00
11.72	8.79	1.40	0.57	11.10	0.01
11.70	8.16	1.30	0.53	11.93	0.01
11.70	7.52	1.20	0.49	12.94	0.00
11.69	6.90	1.10	0.45	14.09	−0.00
11.72	6.28	1.00	0.40	15.53	0.01
11.69	5.66	0.90	0.37	17.19	−0.01
11.65	5.03	0.80	0.33	19.29	−0.03
11.70	4.39	0.70	0.28	22.16	−0.00
11.68	3.77	0.60	0.24	25.75	−0.00
11.74	3.14	0.50	0.20	31.10	0.03
11.73	2.51	0.40	0.16	38.85	−0.04

Table P.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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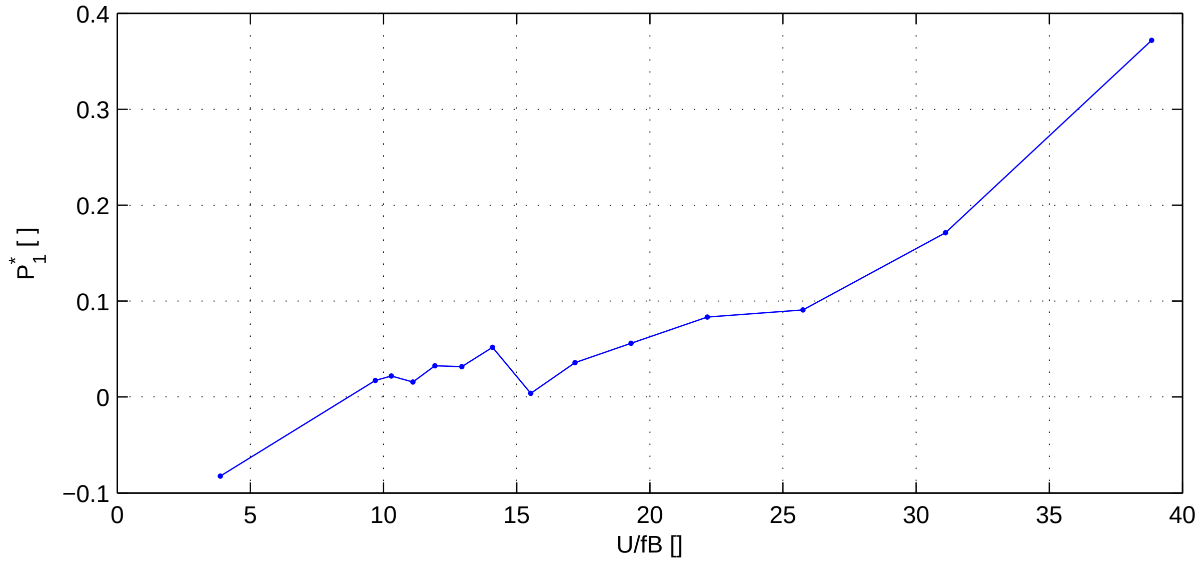

Figure P.13: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_1
11.68	25.13	4.00	1.62	3.87	−0.08
11.71	10.05	1.60	0.65	9.69	0.02
11.69	9.45	1.50	0.61	10.29	0.02
11.72	8.79	1.40	0.57	11.10	0.02
11.70	8.16	1.30	0.53	11.93	0.03
11.70	7.52	1.20	0.49	12.94	0.03
11.69	6.90	1.10	0.45	14.09	0.05
11.72	6.28	1.00	0.40	15.53	0.00
11.69	5.66	0.90	0.37	17.19	0.04
11.65	5.03	0.80	0.33	19.29	0.06
11.70	4.39	0.70	0.28	22.16	0.08
11.68	3.77	0.60	0.24	25.75	0.09
11.74	3.14	0.50	0.20	31.10	0.17
11.73	2.51	0.40	0.16	38.85	0.37

Table P.15: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

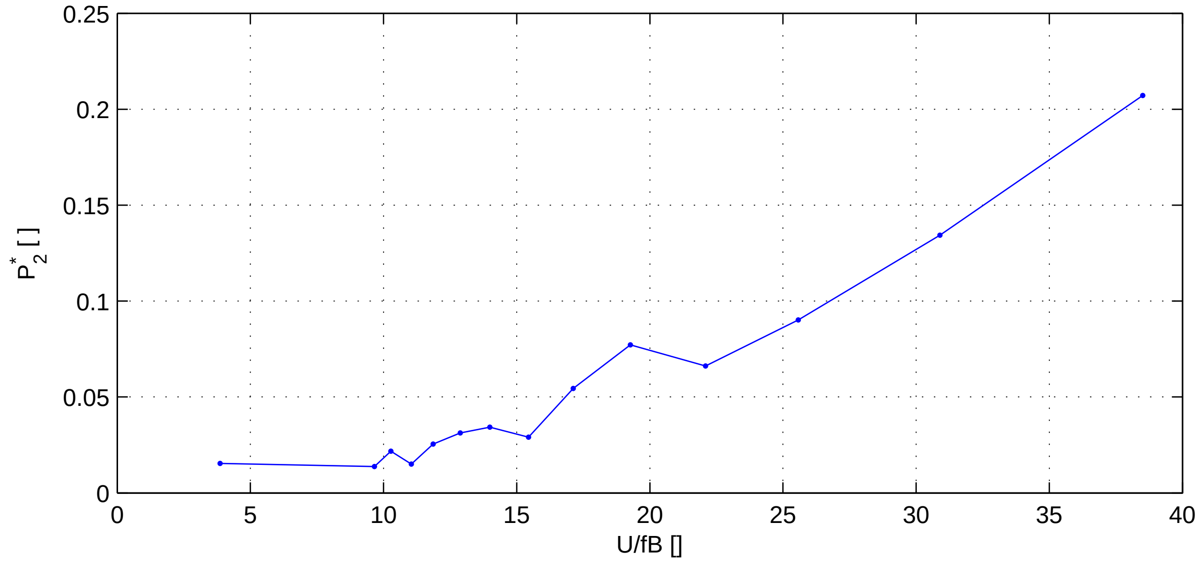

Figure P.14: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_2^*
11.67	25.13	4.00	1.63	3.86	0.02
11.67	10.05	1.60	0.65	9.66	0.01
11.67	9.45	1.50	0.61	10.28	0.02
11.66	8.79	1.40	0.57	11.04	0.02
11.63	8.16	1.30	0.53	11.86	0.03
11.65	7.52	1.20	0.49	12.88	0.03
11.61	6.90	1.10	0.45	13.99	0.03
11.66	6.28	1.00	0.41	15.45	0.03
11.65	5.66	0.90	0.37	17.12	0.05
11.64	5.03	0.80	0.33	19.27	0.08
11.67	4.39	0.70	0.28	22.10	0.07
11.60	3.77	0.60	0.25	25.58	0.09
11.66	3.14	0.50	0.20	30.89	0.13
11.63	2.51	0.40	0.16	38.51	0.21

Table P.16: P_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

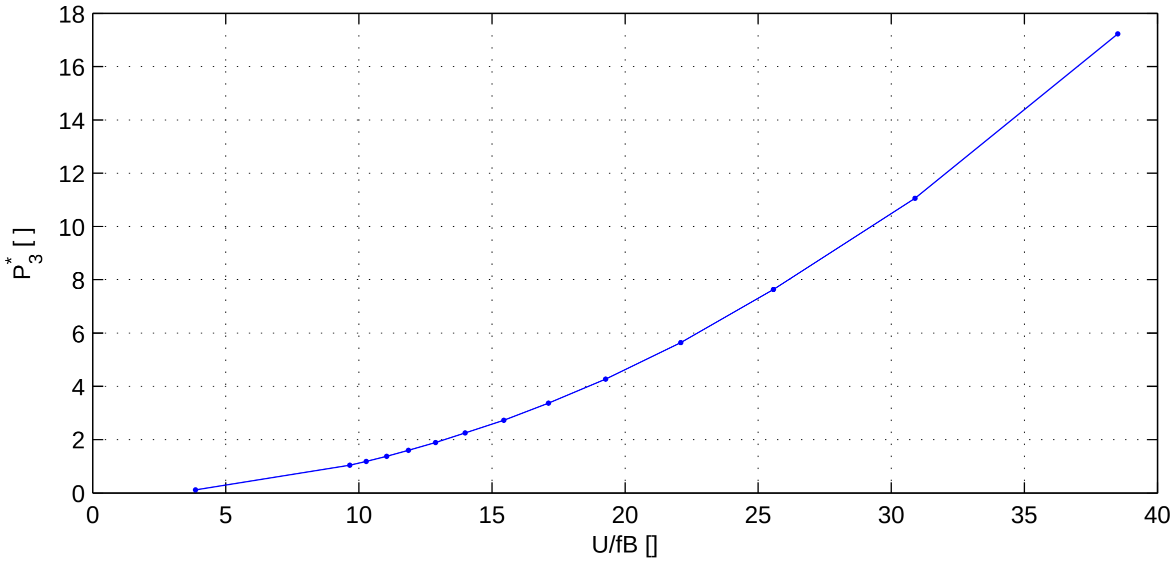

Figure P.15: P_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_3^*
11.67	25.13	4.00	1.63	3.86	0.11
11.67	10.05	1.60	0.65	9.66	1.04
11.67	9.45	1.50	0.61	10.28	1.18
11.66	8.79	1.40	0.57	11.04	1.38
11.63	8.16	1.30	0.53	11.86	1.60
11.65	7.52	1.20	0.49	12.88	1.89
11.61	6.90	1.10	0.45	13.99	2.25
11.66	6.28	1.00	0.41	15.45	2.72
11.65	5.66	0.90	0.37	17.12	3.37
11.64	5.03	0.80	0.33	19.27	4.27
11.67	4.39	0.70	0.28	22.10	5.64
11.60	3.77	0.60	0.25	25.58	7.64
11.66	3.14	0.50	0.20	30.89	11.06
11.63	2.51	0.40	0.16	38.51	17.23

Table P.17: P_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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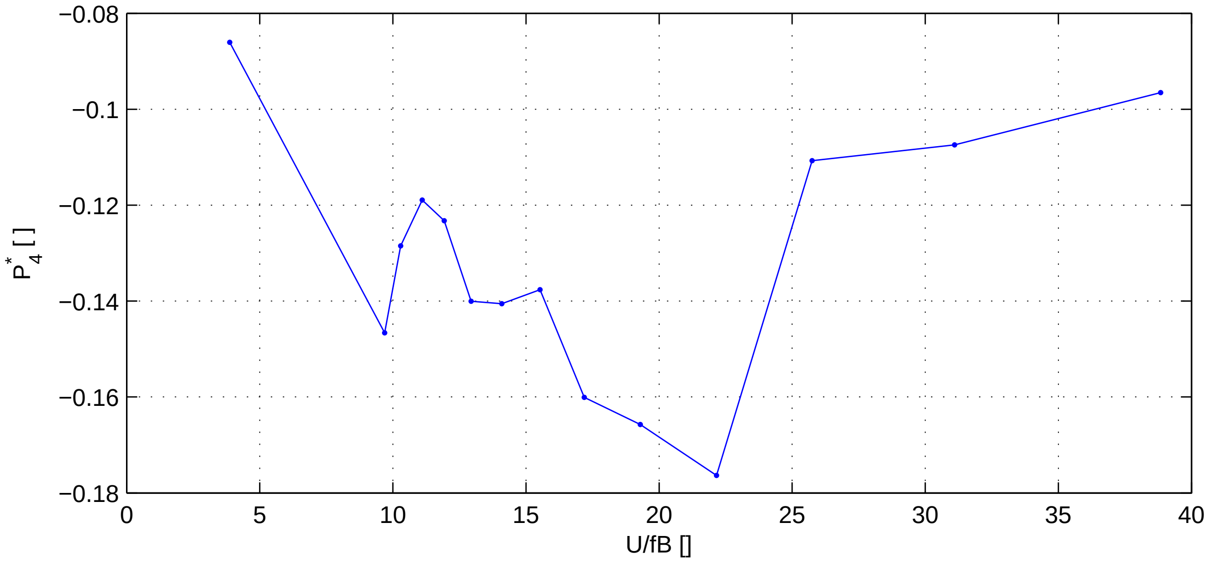

Figure P.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
11.68	25.13	4.00	1.62	3.87	−0.09
11.71	10.05	1.60	0.65	9.69	−0.15
11.69	9.45	1.50	0.61	10.29	−0.13
11.72	8.79	1.40	0.57	11.10	−0.12
11.70	8.16	1.30	0.53	11.93	−0.12
11.70	7.52	1.20	0.49	12.94	−0.14
11.69	6.90	1.10	0.45	14.09	−0.14
11.72	6.28	1.00	0.40	15.53	−0.14
11.69	5.66	0.90	0.37	17.19	−0.16
11.65	5.03	0.80	0.33	19.29	−0.17
11.70	4.39	0.70	0.28	22.16	−0.18
11.68	3.77	0.60	0.24	25.75	−0.11
11.74	3.14	0.50	0.20	31.10	−0.11
11.73	2.51	0.40	0.16	38.85	−0.10

Table P.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

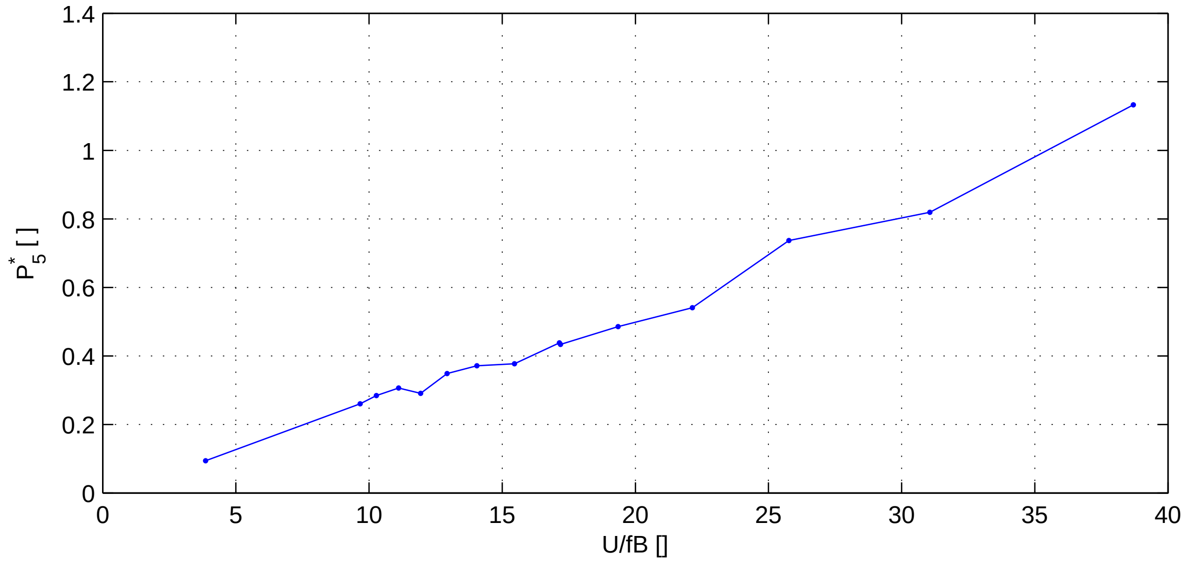

Figure P.17: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_5
11.67	25.13	4.00	1.63	3.86	0.09
11.68	10.05	1.60	0.65	9.67	0.26
11.66	9.45	1.50	0.61	10.27	0.28
11.73	8.79	1.40	0.57	11.11	0.31
11.71	8.16	1.30	0.53	11.94	0.29
11.69	7.52	1.20	0.49	12.93	0.35
11.65	6.90	1.10	0.45	14.05	0.37
11.67	6.28	1.00	0.41	15.46	0.38
11.66	5.66	0.90	0.37	17.15	0.44
11.69	5.66	0.90	0.37	17.19	0.43
11.69	5.03	0.80	0.32	19.35	0.49
11.69	4.39	0.70	0.28	22.15	0.54
11.68	3.77	0.60	0.24	25.76	0.74
11.72	3.14	0.50	0.20	31.06	0.82
11.69	2.51	0.40	0.16	38.70	1.13

Table P.19: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

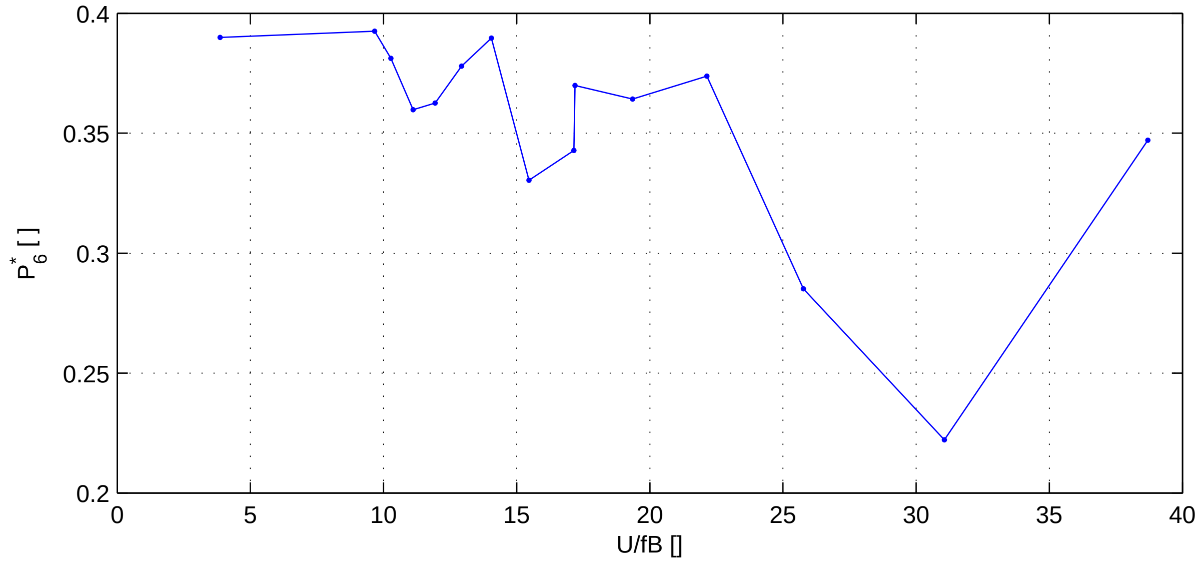

Figure P.18: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_6^*
11.67	25.13	4.00	1.63	3.86	0.39
11.68	10.05	1.60	0.65	9.67	0.39
11.66	9.45	1.50	0.61	10.27	0.38
11.73	8.79	1.40	0.57	11.11	0.36
11.71	8.16	1.30	0.53	11.94	0.36
11.69	7.52	1.20	0.49	12.93	0.38
11.65	6.90	1.10	0.45	14.05	0.39
11.67	6.28	1.00	0.41	15.46	0.33
11.66	5.66	0.90	0.37	17.15	0.34
11.69	5.66	0.90	0.37	17.19	0.37
11.69	5.03	0.80	0.32	19.35	0.36
11.69	4.39	0.70	0.28	22.15	0.37
11.68	3.77	0.60	0.24	25.76	0.29
11.72	3.14	0.50	0.20	31.06	0.22
11.69	2.51	0.40	0.16	38.70	0.35

Table P.20: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\left(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\,\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\left(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\,\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\left(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\,\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B}\right)$$

Formula P.3: Equation of Motion (Stretto di Messina. Ref. [5].)

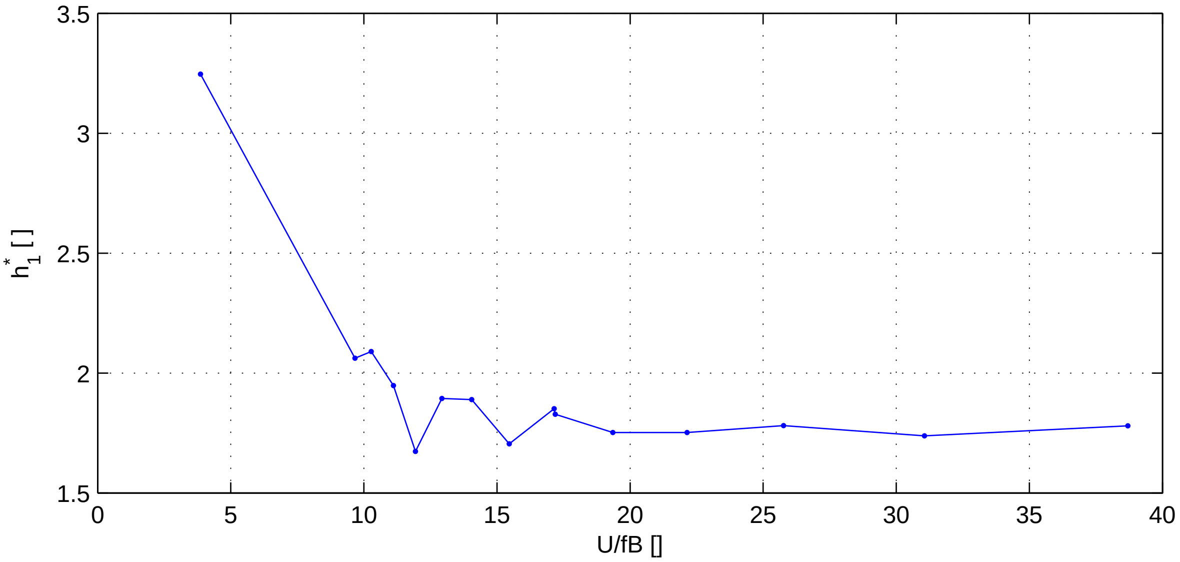

Figure P.19: h^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_1
11.67	25.13	4.00	1.63	3.86	3.25
11.68	10.05	1.60	0.65	9.67	2.06
11.66	9.45	1.50	0.61	10.27	2.09
11.73	8.79	1.40	0.57	11.11	1.95
11.71	8.16	1.30	0.53	11.94	1.67
11.69	7.52	1.20	0.49	12.93	1.89
11.65	6.90	1.10	0.45	14.05	1.89
11.67	6.28	1.00	0.41	15.46	1.70
11.66	5.66	0.90	0.37	17.15	1.85
11.69	5.66	0.90	0.37	17.19	1.83
11.69	5.03	0.80	0.32	19.35	1.75
11.69	4.39	0.70	0.28	22.15	1.75
11.68	3.77	0.60	0.24	25.76	1.78
11.72	3.14	0.50	0.20	31.06	1.74
11.69	2.51	0.40	0.16	38.70	1.78

Table P.21: h^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

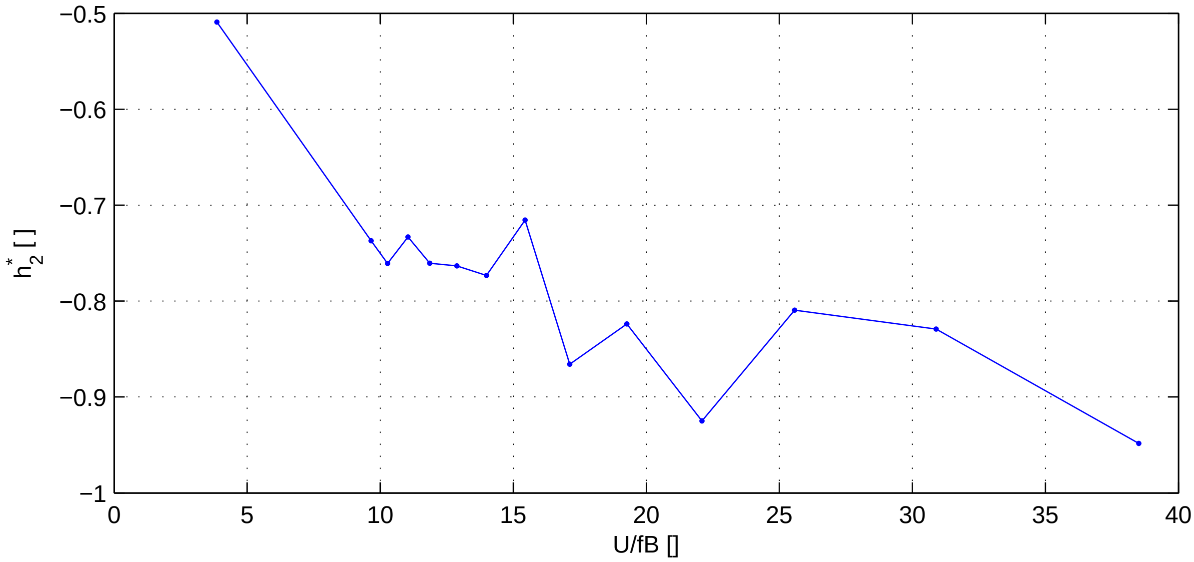

Figure P.20: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_2^*
11.67	25.13	4.00	1.63	3.86	−0.51
11.67	10.05	1.60	0.65	9.66	−0.74
11.67	9.45	1.50	0.61	10.28	−0.76
11.66	8.79	1.40	0.57	11.04	−0.73
11.63	8.16	1.30	0.53	11.86	−0.76
11.65	7.52	1.20	0.49	12.88	−0.76
11.61	6.90	1.10	0.45	13.99	−0.77
11.66	6.28	1.00	0.41	15.45	−0.72
11.65	5.66	0.90	0.37	17.12	−0.87
11.64	5.03	0.80	0.33	19.27	−0.82
11.67	4.39	0.70	0.28	22.10	−0.93
11.60	3.77	0.60	0.25	25.58	−0.81
11.66	3.14	0.50	0.20	30.89	−0.83
11.63	2.51	0.40	0.16	38.51	−0.95

Table P.22: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

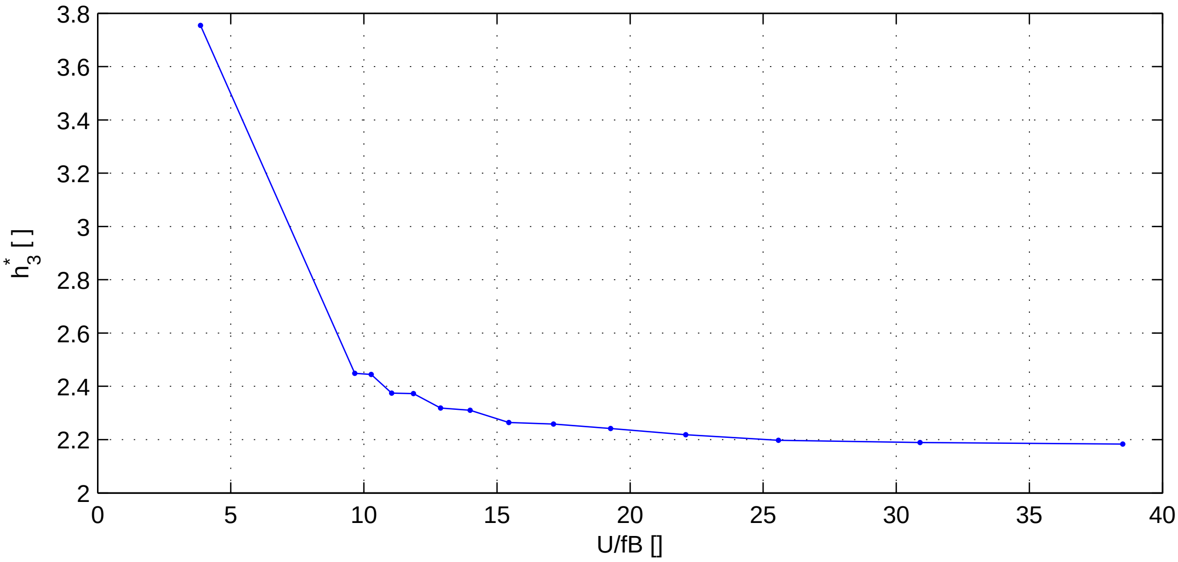

Figure P.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
11.67	25.13	4.00	1.63	3.86	3.75
11.67	10.05	1.60	0.65	9.66	2.45
11.67	9.45	1.50	0.61	10.28	2.44
11.66	8.79	1.40	0.57	11.04	2.37
11.63	8.16	1.30	0.53	11.86	2.37
11.65	7.52	1.20	0.49	12.88	2.32
11.61	6.90	1.10	0.45	13.99	2.31
11.66	6.28	1.00	0.41	15.45	2.26
11.65	5.66	0.90	0.37	17.12	2.26
11.64	5.03	0.80	0.33	19.27	2.24
11.67	4.39	0.70	0.28	22.10	2.22
11.60	3.77	0.60	0.25	25.58	2.20
11.66	3.14	0.50	0.20	30.89	2.19
11.63	2.51	0.40	0.16	38.51	2.18

Table P.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

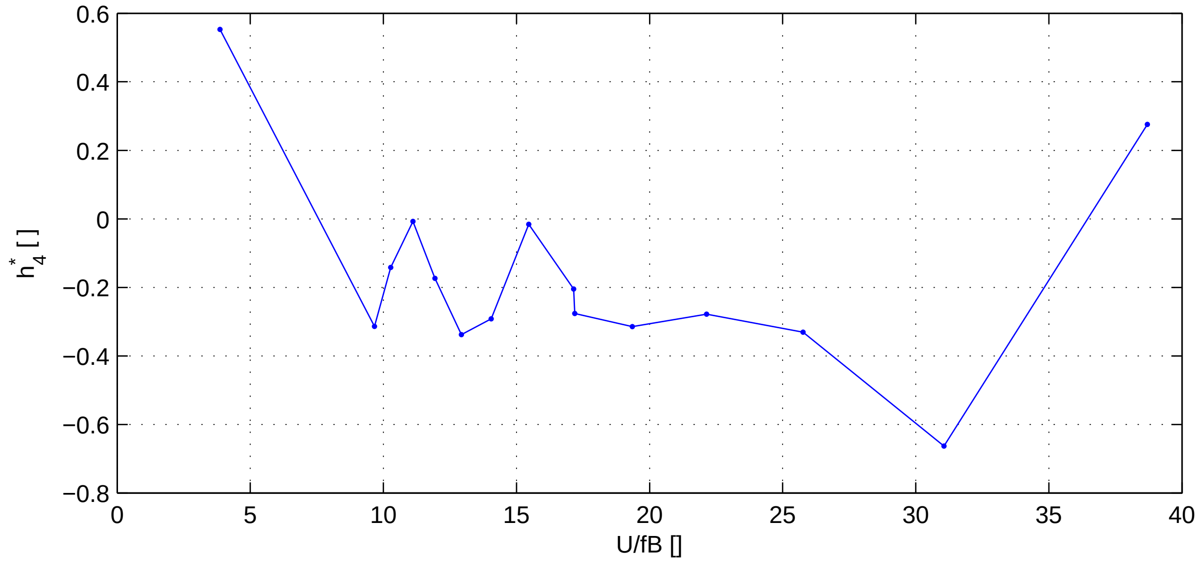

Figure P.22: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_4^*
11.67	25.13	4.00	1.63	3.86	0.55
11.68	10.05	1.60	0.65	9.67	−0.31
11.66	9.45	1.50	0.61	10.27	−0.14
11.73	8.79	1.40	0.57	11.11	−0.01
11.71	8.16	1.30	0.53	11.94	−0.17
11.69	7.52	1.20	0.49	12.93	−0.34
11.65	6.90	1.10	0.45	14.05	−0.29
11.67	6.28	1.00	0.41	15.46	−0.02
11.66	5.66	0.90	0.37	17.15	−0.20
11.69	5.66	0.90	0.37	17.19	−0.28
11.69	5.03	0.80	0.32	19.35	−0.31
11.69	4.39	0.70	0.28	22.15	−0.28
11.68	3.77	0.60	0.24	25.76	−0.33
11.72	3.14	0.50	0.20	31.06	−0.66
11.69	2.51	0.40	0.16	38.70	0.28

Table P.24: h_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

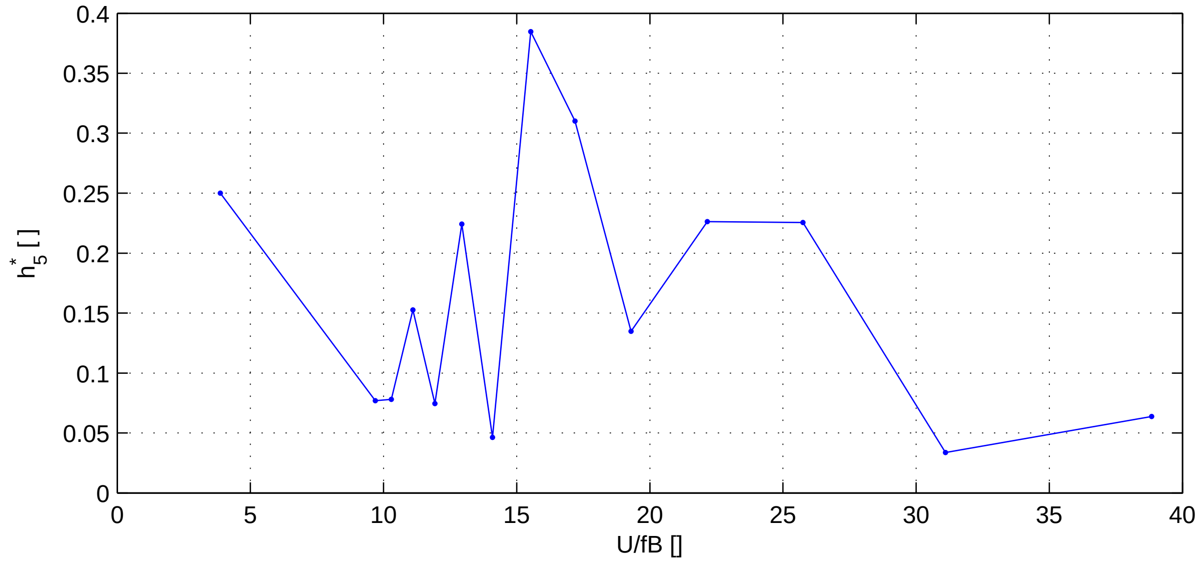

Figure P.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
11.68	25.13	4.00	1.62	3.87	0.25
11.71	10.05	1.60	0.65	9.69	0.08
11.69	9.45	1.50	0.61	10.29	0.08
11.72	8.79	1.40	0.57	11.10	0.15
11.70	8.16	1.30	0.53	11.93	0.07
11.70	7.52	1.20	0.49	12.94	0.22
11.69	6.90	1.10	0.45	14.09	0.05
11.72	6.28	1.00	0.40	15.53	0.38
11.69	5.66	0.90	0.37	17.19	0.31
11.65	5.03	0.80	0.33	19.29	0.13
11.70	4.39	0.70	0.28	22.16	0.23
11.68	3.77	0.60	0.24	25.75	0.23
11.74	3.14	0.50	0.20	31.10	0.03
11.73	2.51	0.40	0.16	38.85	0.06

Table P.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

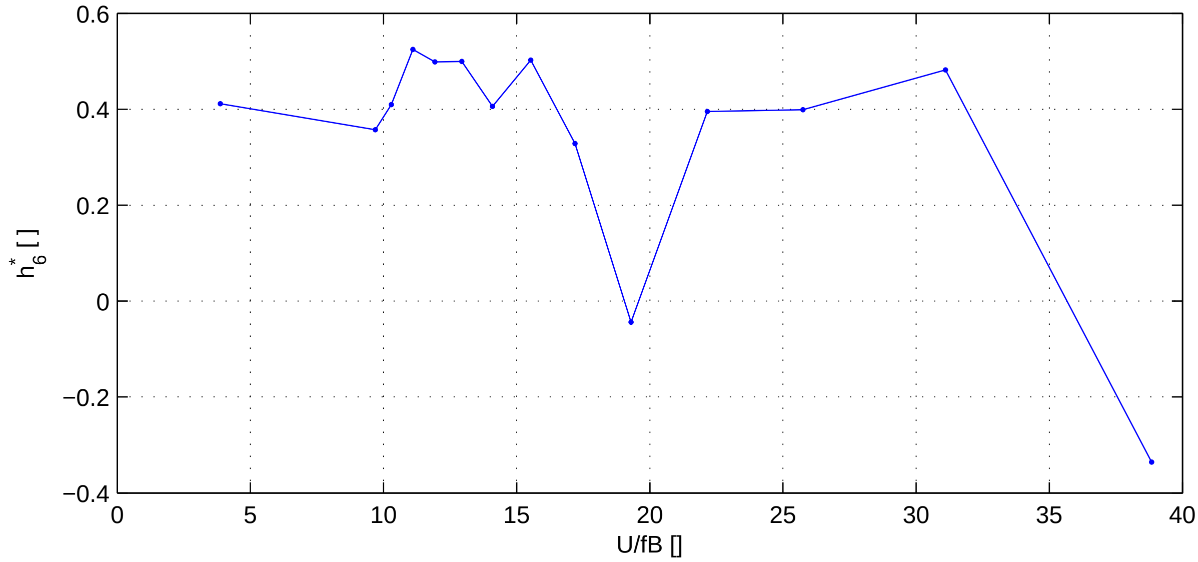

Figure P.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
11.68	25.13	4.00	1.62	3.87	0.41
11.71	10.05	1.60	0.65	9.69	0.36
11.69	9.45	1.50	0.61	10.29	0.41
11.72	8.79	1.40	0.57	11.10	0.52
11.70	8.16	1.30	0.53	11.93	0.50
11.70	7.52	1.20	0.49	12.94	0.50
11.69	6.90	1.10	0.45	14.09	0.41
11.72	6.28	1.00	0.40	15.53	0.50
11.69	5.66	0.90	0.37	17.19	0.33
11.65	5.03	0.80	0.33	19.29	−0.04
11.70	4.39	0.70	0.28	22.16	0.40
11.68	3.77	0.60	0.24	25.75	0.40
11.74	3.14	0.50	0.20	31.10	0.48
11.73	2.51	0.40	0.16	38.85	−0.34

Table P.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

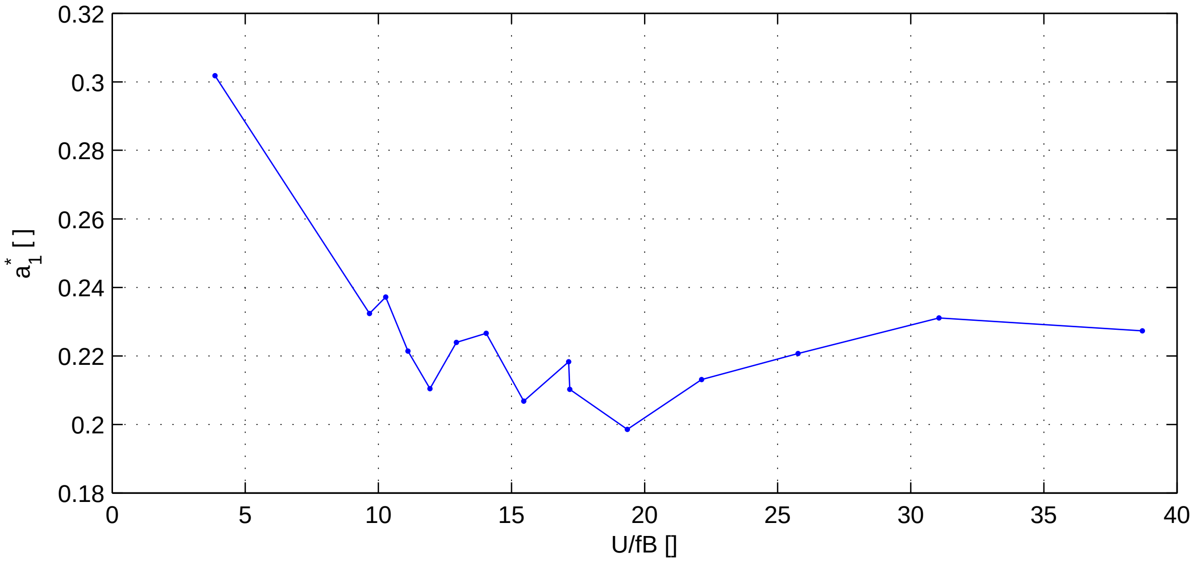

Figure P.25: a^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a^*_1
11.67	25.13	4.00	1.63	3.86	0.30
11.68	10.05	1.60	0.65	9.67	0.23
11.66	9.45	1.50	0.61	10.27	0.24
11.73	8.79	1.40	0.57	11.11	0.22
11.71	8.16	1.30	0.53	11.94	0.21
11.69	7.52	1.20	0.49	12.93	0.22
11.65	6.90	1.10	0.45	14.05	0.23
11.67	6.28	1.00	0.41	15.46	0.21
11.66	5.66	0.90	0.37	17.15	0.22
11.69	5.66	0.90	0.37	17.19	0.21
11.69	5.03	0.80	0.32	19.35	0.20
11.69	4.39	0.70	0.28	22.15	0.21
11.68	3.77	0.60	0.24	25.76	0.22
11.72	3.14	0.50	0.20	31.06	0.23
11.69	2.51	0.40	0.16	38.70	0.23

Table P.27: a^*_1 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

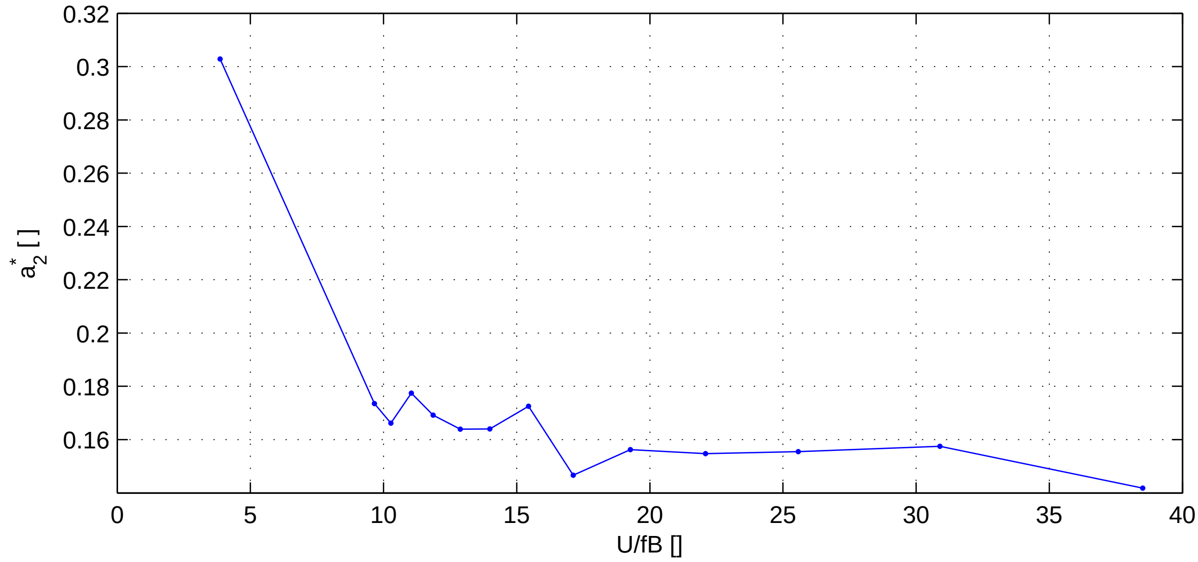

Figure P.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
11.67	25.13	4.00	1.63	3.86	0.30
11.67	10.05	1.60	0.65	9.66	0.17
11.67	9.45	1.50	0.61	10.28	0.17
11.66	8.79	1.40	0.57	11.04	0.18
11.63	8.16	1.30	0.53	11.86	0.17
11.65	7.52	1.20	0.49	12.88	0.16
11.61	6.90	1.10	0.45	13.99	0.16
11.66	6.28	1.00	0.41	15.45	0.17
11.65	5.66	0.90	0.37	17.12	0.15
11.64	5.03	0.80	0.33	19.27	0.16
11.67	4.39	0.70	0.28	22.10	0.15
11.60	3.77	0.60	0.25	25.58	0.16
11.66	3.14	0.50	0.20	30.89	0.16
11.63	2.51	0.40	0.16	38.51	0.14

Table P.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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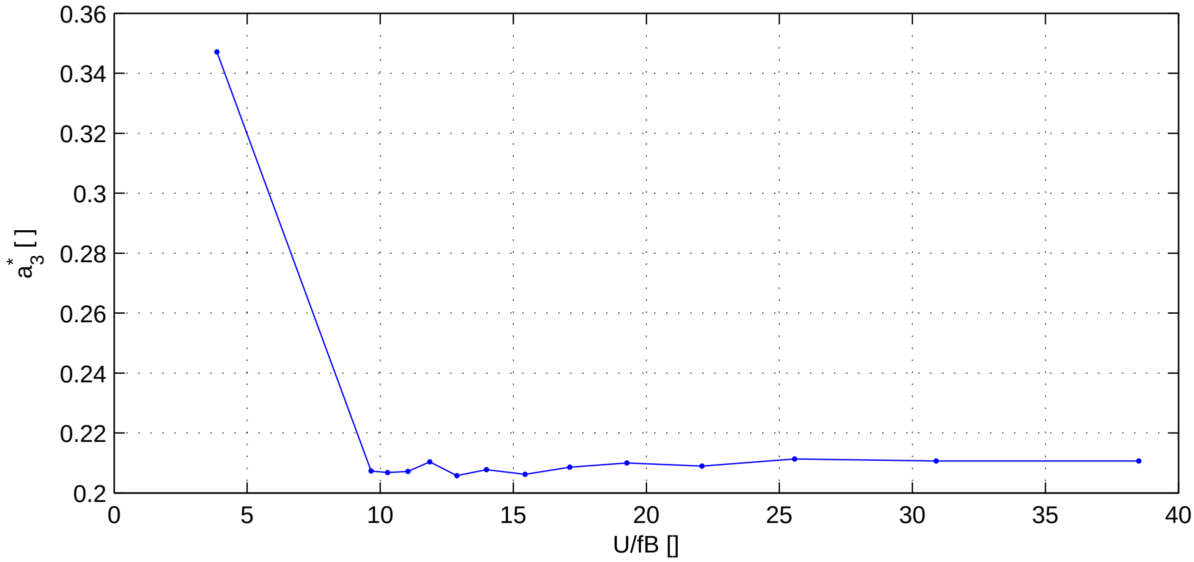

Figure P.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
11.67	25.13	4.00	1.63	3.86	0.35
11.67	10.05	1.60	0.65	9.66	0.21
11.67	9.45	1.50	0.61	10.28	0.21
11.66	8.79	1.40	0.57	11.04	0.21
11.63	8.16	1.30	0.53	11.86	0.21
11.65	7.52	1.20	0.49	12.88	0.21
11.61	6.90	1.10	0.45	13.99	0.21
11.66	6.28	1.00	0.41	15.45	0.21
11.65	5.66	0.90	0.37	17.12	0.21
11.64	5.03	0.80	0.33	19.27	0.21
11.67	4.39	0.70	0.28	22.10	0.21
11.60	3.77	0.60	0.25	25.58	0.21
11.66	3.14	0.50	0.20	30.89	0.21
11.63	2.51	0.40	0.16	38.51	0.21

Table P.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

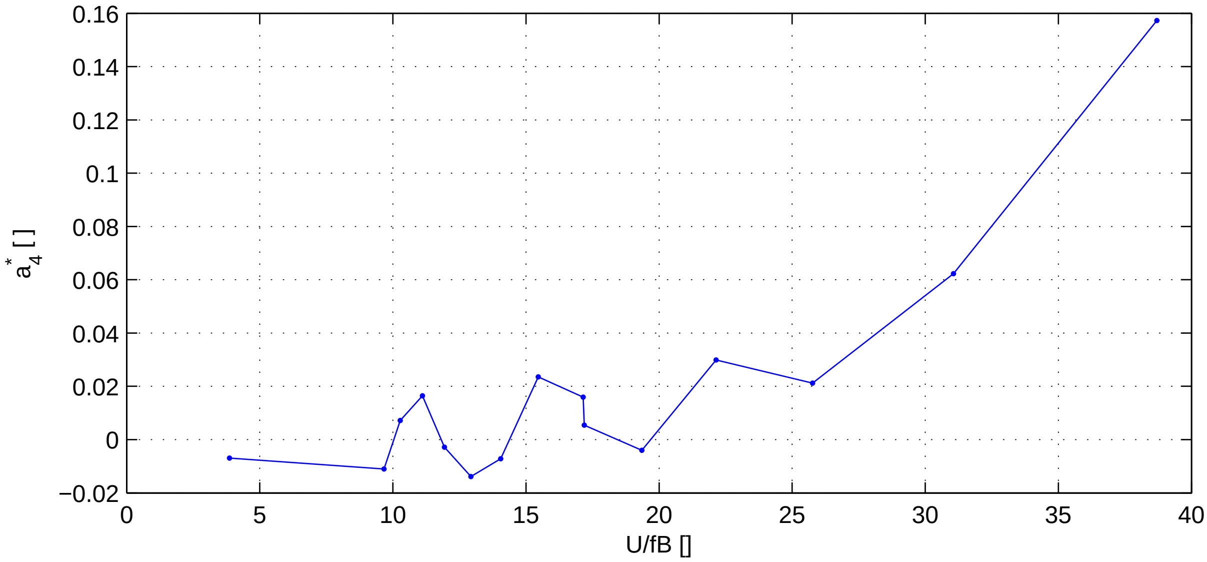

Figure P.28: a^*_4 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a^*_4
11.67	25.13	4.00	1.63	3.86	−0.01
11.68	10.05	1.60	0.65	9.67	−0.01
11.66	9.45	1.50	0.61	10.27	0.01
11.73	8.79	1.40	0.57	11.11	0.02
11.71	8.16	1.30	0.53	11.94	−0.00
11.69	7.52	1.20	0.49	12.93	−0.01
11.65	6.90	1.10	0.45	14.05	−0.01
11.67	6.28	1.00	0.41	15.46	0.02
11.66	5.66	0.90	0.37	17.15	0.02
11.69	5.66	0.90	0.37	17.19	0.01
11.69	5.03	0.80	0.32	19.35	−0.00
11.69	4.39	0.70	0.28	22.15	0.03
11.68	3.77	0.60	0.24	25.76	0.02
11.72	3.14	0.50	0.20	31.06	0.06
11.69	2.51	0.40	0.16	38.70	0.16

Table P.30: a^*_4 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

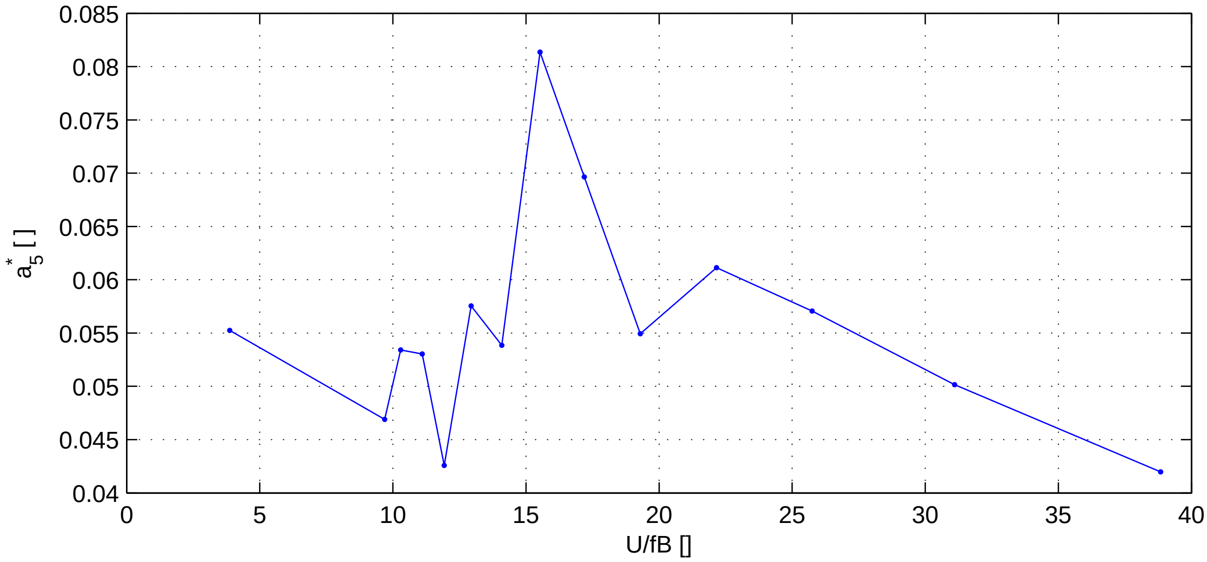

Figure P.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
11.68	25.13	4.00	1.62	3.87	0.06
11.71	10.05	1.60	0.65	9.69	0.05
11.69	9.45	1.50	0.61	10.29	0.05
11.72	8.79	1.40	0.57	11.10	0.05
11.70	8.16	1.30	0.53	11.93	0.04
11.70	7.52	1.20	0.49	12.94	0.06
11.69	6.90	1.10	0.45	14.09	0.05
11.72	6.28	1.00	0.40	15.53	0.08
11.69	5.66	0.90	0.37	17.19	0.07
11.65	5.03	0.80	0.33	19.29	0.05
11.70	4.39	0.70	0.28	22.16	0.06
11.68	3.77	0.60	0.24	25.75	0.06
11.74	3.14	0.50	0.20	31.10	0.05
11.73	2.51	0.40	0.16	38.85	0.04

Table P.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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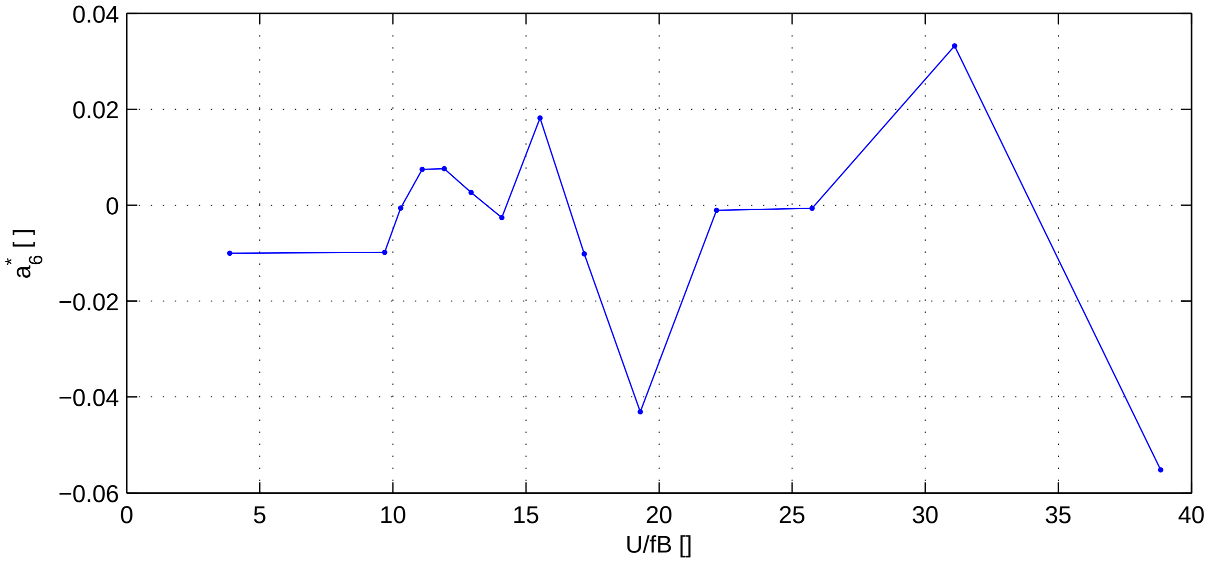


Figure P.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
11.68	25.13	4.00	1.62	3.87	−0.01
11.71	10.05	1.60	0.65	9.69	−0.01
11.69	9.45	1.50	0.61	10.29	−0.00
11.72	8.79	1.40	0.57	11.10	0.01
11.70	8.16	1.30	0.53	11.93	0.01
11.70	7.52	1.20	0.49	12.94	0.00
11.69	6.90	1.10	0.45	14.09	−0.00
11.72	6.28	1.00	0.40	15.53	0.02
11.69	5.66	0.90	0.37	17.19	−0.01
11.65	5.03	0.80	0.33	19.29	−0.04
11.70	4.39	0.70	0.28	22.16	−0.00
11.68	3.77	0.60	0.24	25.75	−0.00
11.74	3.14	0.50	0.20	31.10	0.03
11.73	2.51	0.40	0.16	38.85	−0.06

Table P.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

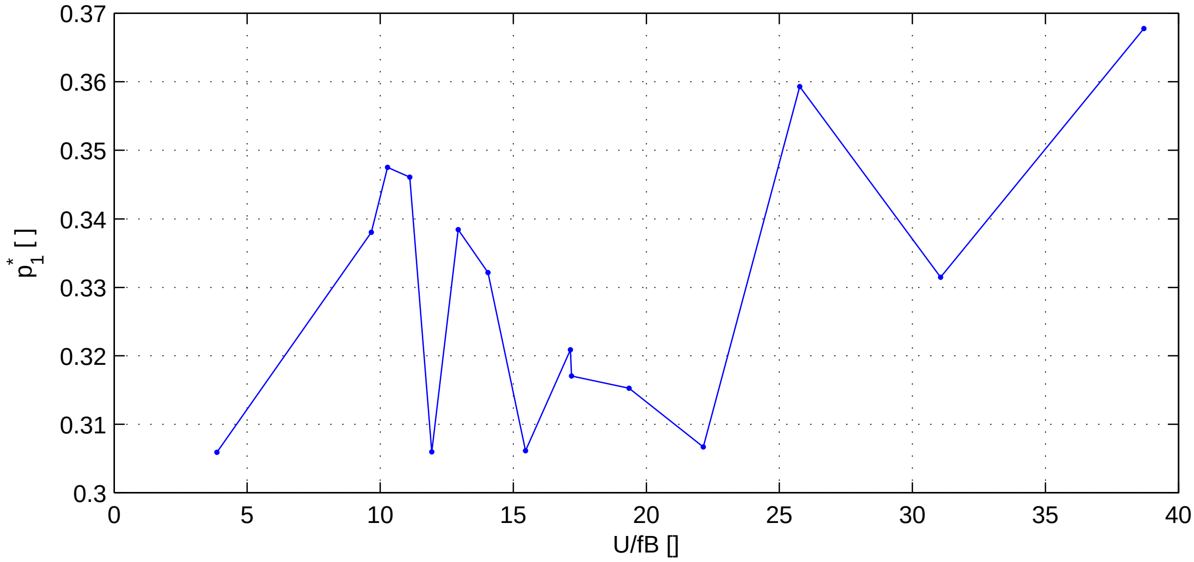


Figure P.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
11.67	25.13	4.00	1.63	3.86	0.31
11.68	10.05	1.60	0.65	9.67	0.34
11.66	9.45	1.50	0.61	10.27	0.35
11.73	8.79	1.40	0.57	11.11	0.35
11.71	8.16	1.30	0.53	11.94	0.31
11.69	7.52	1.20	0.49	12.93	0.34
11.65	6.90	1.10	0.45	14.05	0.33
11.67	6.28	1.00	0.41	15.46	0.31
11.66	5.66	0.90	0.37	17.15	0.32
11.69	5.66	0.90	0.37	17.19	0.32
11.69	5.03	0.80	0.32	19.35	0.32
11.69	4.39	0.70	0.28	22.15	0.31
11.68	3.77	0.60	0.24	25.76	0.36
11.72	3.14	0.50	0.20	31.06	0.33
11.69	2.51	0.40	0.16	38.70	0.37

Table P.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

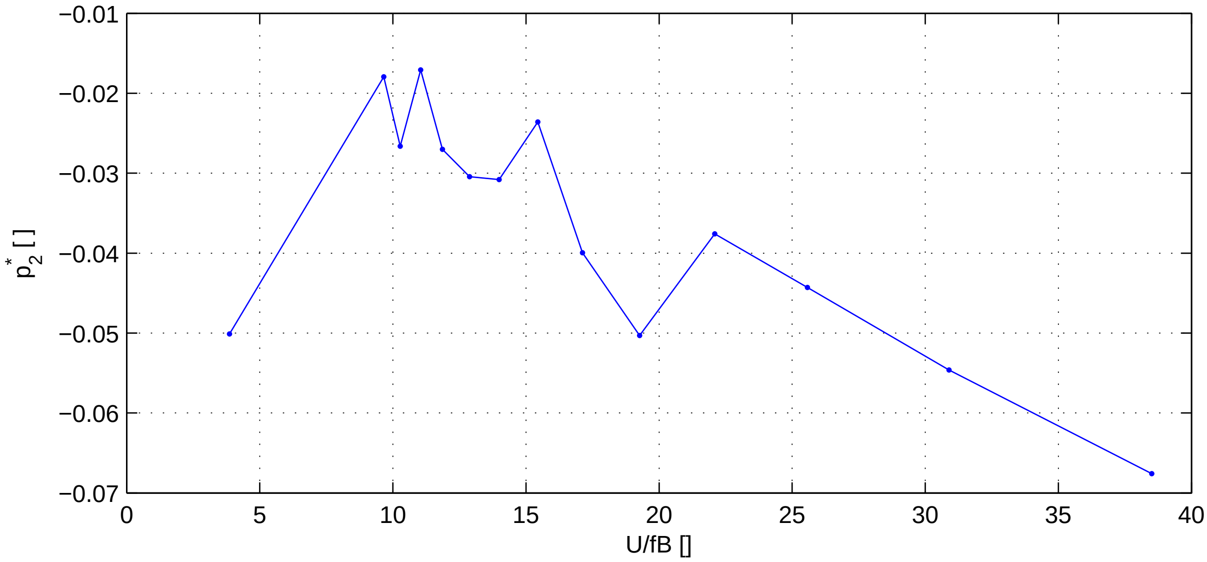


Figure P.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
11.67	25.13	4.00	1.63	3.86	−0.05
11.67	10.05	1.60	0.65	9.66	−0.02
11.67	9.45	1.50	0.61	10.28	−0.03
11.66	8.79	1.40	0.57	11.04	−0.02
11.63	8.16	1.30	0.53	11.86	−0.03
11.65	7.52	1.20	0.49	12.88	−0.03
11.61	6.90	1.10	0.45	13.99	−0.03
11.66	6.28	1.00	0.41	15.45	−0.02
11.65	5.66	0.90	0.37	17.12	−0.04
11.64	5.03	0.80	0.33	19.27	−0.05
11.67	4.39	0.70	0.28	22.10	−0.04
11.60	3.77	0.60	0.25	25.58	−0.04
11.66	3.14	0.50	0.20	30.89	−0.05
11.63	2.51	0.40	0.16	38.51	−0.07

Table P.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

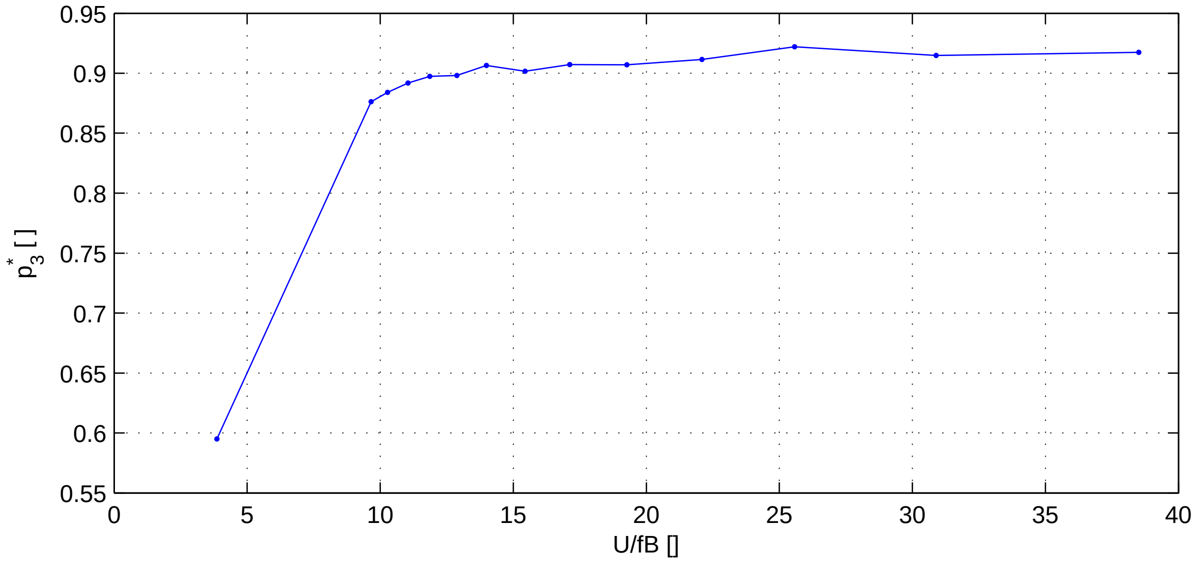


Figure P.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
11.67	25.13	4.00	1.63	3.86	0.59
11.67	10.05	1.60	0.65	9.66	0.88
11.67	9.45	1.50	0.61	10.28	0.88
11.66	8.79	1.40	0.57	11.04	0.89
11.63	8.16	1.30	0.53	11.86	0.90
11.65	7.52	1.20	0.49	12.88	0.90
11.61	6.90	1.10	0.45	13.99	0.91
11.66	6.28	1.00	0.41	15.45	0.90
11.65	5.66	0.90	0.37	17.12	0.91
11.64	5.03	0.80	0.33	19.27	0.91
11.67	4.39	0.70	0.28	22.10	0.91
11.60	3.77	0.60	0.25	25.58	0.92
11.66	3.14	0.50	0.20	30.89	0.91
11.63	2.51	0.40	0.16	38.51	0.92

Table P.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

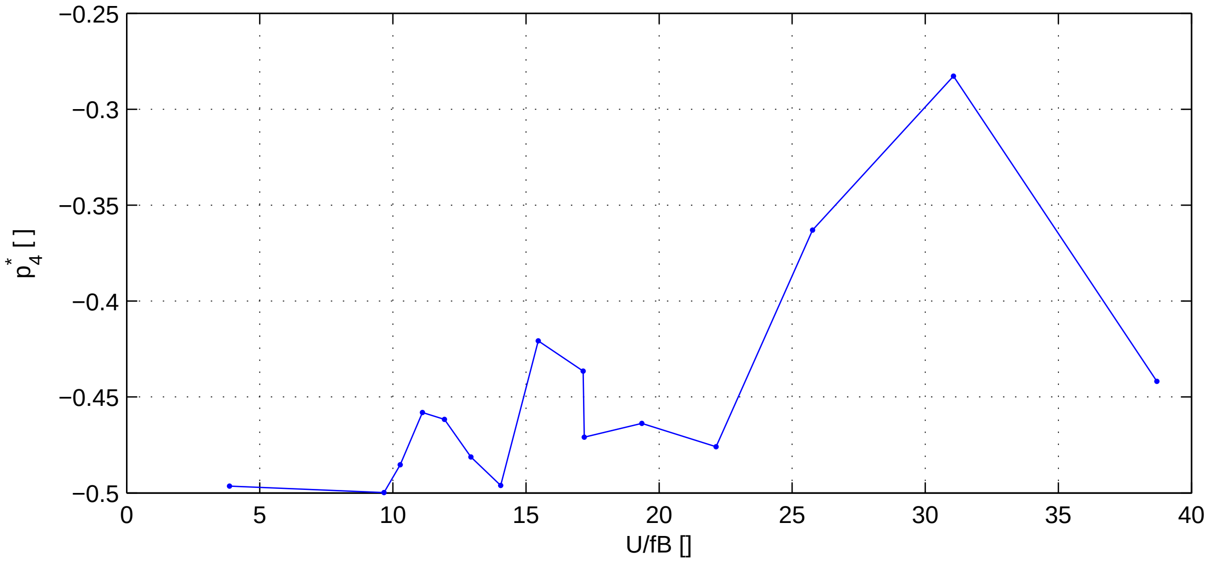


Figure P.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
11.67	25.13	4.00	1.63	3.86	−0.50
11.68	10.05	1.60	0.65	9.67	−0.50
11.66	9.45	1.50	0.61	10.27	−0.49
11.73	8.79	1.40	0.57	11.11	−0.46
11.71	8.16	1.30	0.53	11.94	−0.46
11.69	7.52	1.20	0.49	12.93	−0.48
11.65	6.90	1.10	0.45	14.05	−0.50
11.67	6.28	1.00	0.41	15.46	−0.42
11.66	5.66	0.90	0.37	17.15	−0.44
11.69	5.66	0.90	0.37	17.19	−0.47
11.69	5.03	0.80	0.32	19.35	−0.46
11.69	4.39	0.70	0.28	22.15	−0.48
11.68	3.77	0.60	0.24	25.76	−0.36
11.72	3.14	0.50	0.20	31.06	−0.28
11.69	2.51	0.40	0.16	38.70	−0.44

Table P.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

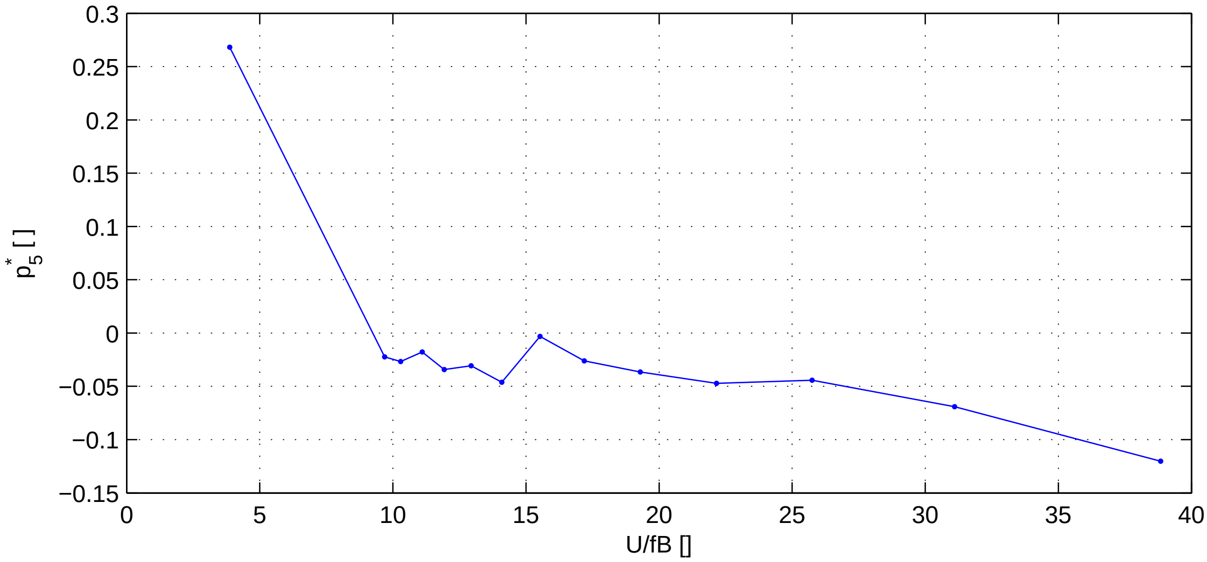


Figure P.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
11.68	25.13	4.00	1.62	3.87	0.27
11.71	10.05	1.60	0.65	9.69	−0.02
11.69	9.45	1.50	0.61	10.29	−0.03
11.72	8.79	1.40	0.57	11.10	−0.02
11.70	8.16	1.30	0.53	11.93	−0.03
11.70	7.52	1.20	0.49	12.94	−0.03
11.69	6.90	1.10	0.45	14.09	−0.05
11.72	6.28	1.00	0.40	15.53	−0.00
11.69	5.66	0.90	0.37	17.19	−0.03
11.65	5.03	0.80	0.33	19.29	−0.04
11.70	4.39	0.70	0.28	22.16	−0.05
11.68	3.77	0.60	0.24	25.75	−0.04
11.74	3.14	0.50	0.20	31.10	−0.07
11.73	2.51	0.40	0.16	38.85	−0.12

Table P.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

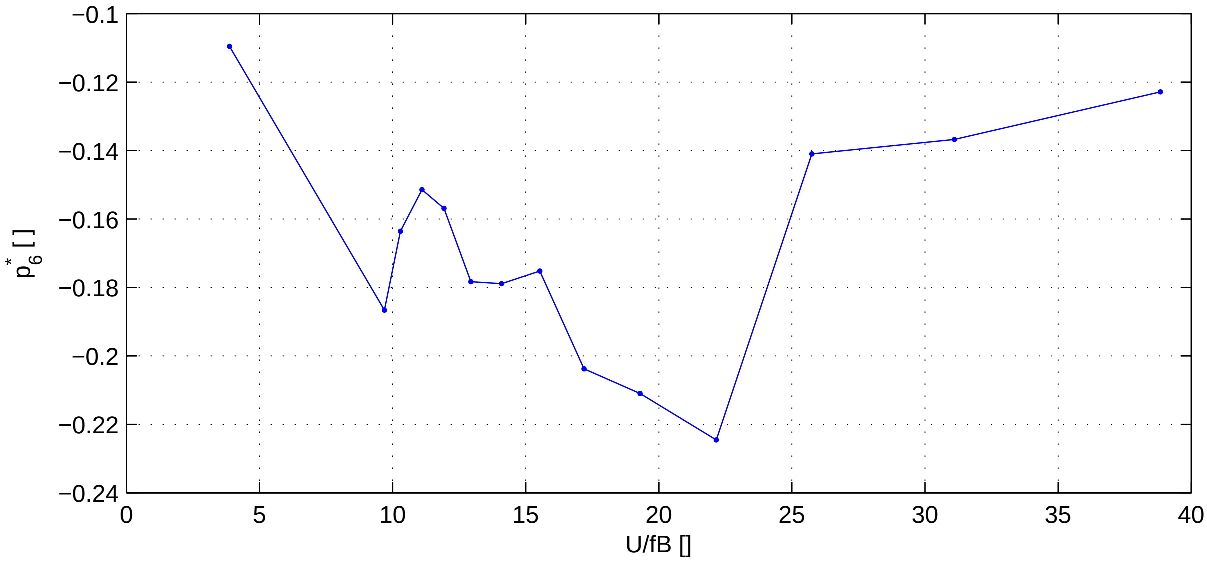


Figure P.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
11.68	25.13	4.00	1.62	3.87	−0.11
11.71	10.05	1.60	0.65	9.69	−0.19
11.69	9.45	1.50	0.61	10.29	−0.16
11.72	8.79	1.40	0.57	11.10	−0.15
11.70	8.16	1.30	0.53	11.93	−0.16
11.70	7.52	1.20	0.49	12.94	−0.18
11.69	6.90	1.10	0.45	14.09	−0.18
11.72	6.28	1.00	0.40	15.53	−0.18
11.69	5.66	0.90	0.37	17.19	−0.20
11.65	5.03	0.80	0.33	19.29	−0.21
11.70	4.39	0.70	0.28	22.16	−0.22
11.68	3.77	0.60	0.24	25.75	−0.14
11.74	3.14	0.50	0.20	31.10	−0.14
11.73	2.51	0.40	0.16	38.85	−0.12

Table P.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

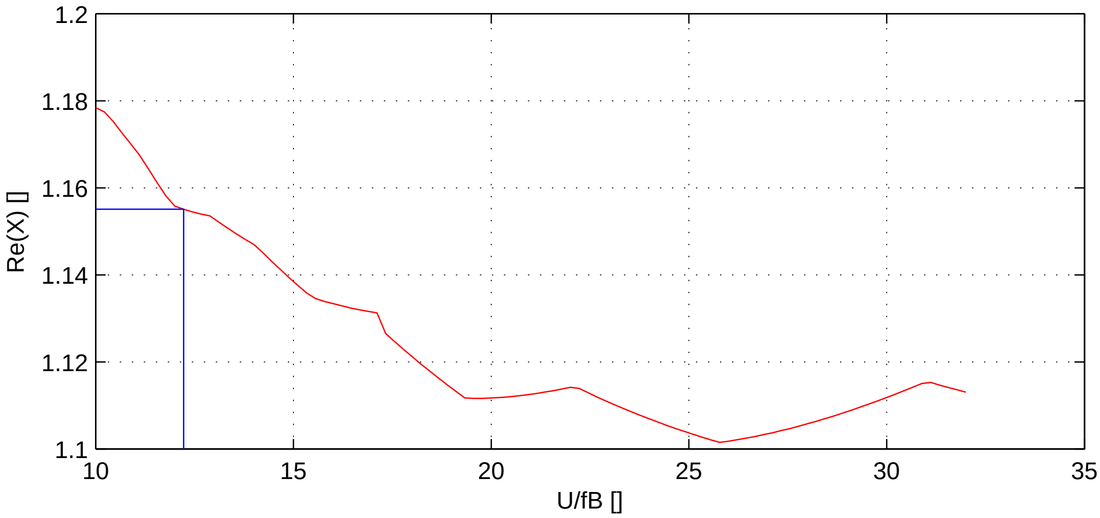


Figure P.37: Real part of the solution to stability equantion

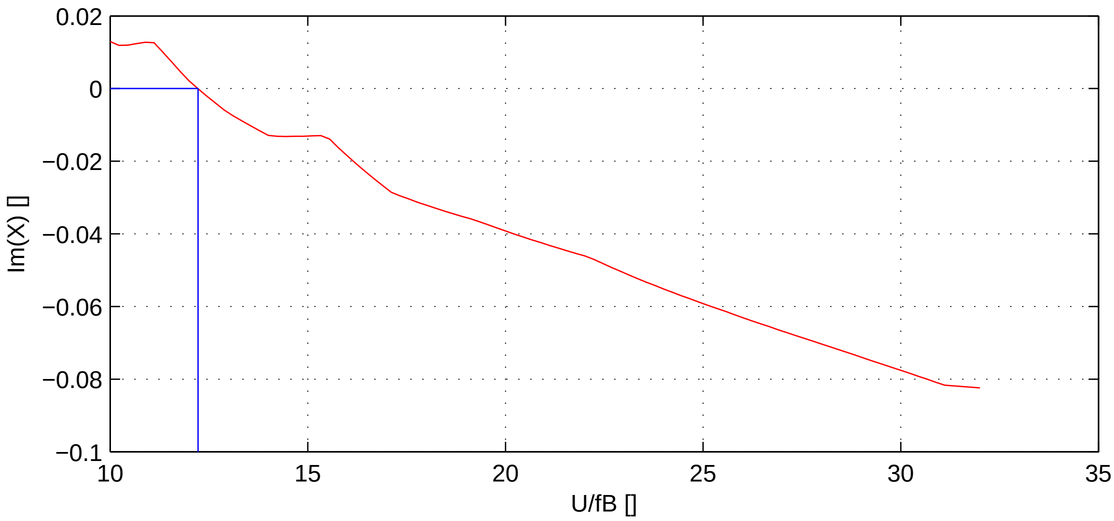


Figure P.38: Imaginary part of the solution to stability equantion

V_{Crit} = 12.2

f_{Crit} = 0.0747 Hz

U_{Crit} = 55.2 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.

[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.

[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.

[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.

[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix Q

3D Flutter Tests

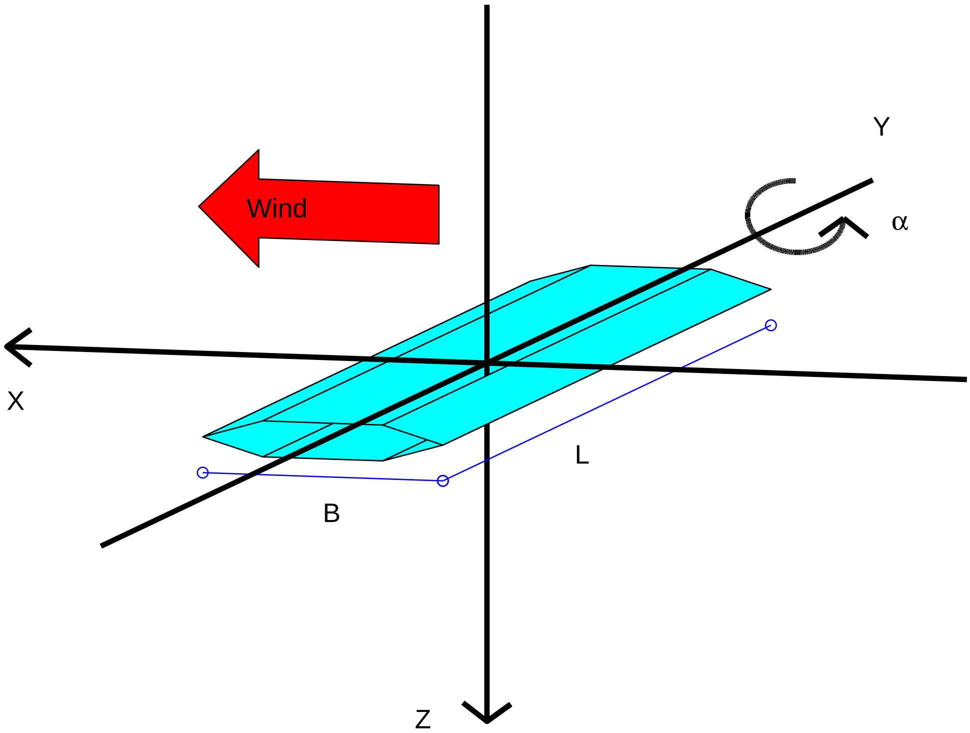
Flutter derivatives, Erection stage, Turbulent flow, Angle of incidence = 6 deg

3D Flutter Tests:

Determination of the dynamic response coefficients, the flutter derivatives, for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a mechanical response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arerodynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Section weight	m	kg	8.350
Temperature	T	^{o}C	26.0
Relative humidity	ϕ	%	30
Barometric pressure	p	mmBar	1019.0

Table Q.1: Project Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = mg - m_{a,z}\ddot{h} - 2m\omega_{h,0}\zeta_h\dot{h} + F_{Z,external}$$
$$I_y\ddot{\alpha} + mz_G\ddot{p} + mx_G\ddot{h}) = -I_{a,y}\ddot{\alpha} mg - 2m\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external}$$
$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\omega_{p,0}\zeta_p\dot{p} + F_{X,external}$$

where:

h	: Vertical displacement, displacement along z-axis, [m]
α	: Rotation around y-axis, nose up is positive, [rad]
p	: Horizontal displacement, displacement along the x-axis, [m]
m	: Mass per unit length, [kg/m]
I_y	: Mass moment of inertia per unit length around y-axis, [m*kg/m]
$m_{a,z}$	: Added mass in vertical direction, [kg/m]
$m_{a,x}$	: Added mass in horizontal direction, [kg/m]
$I_{a,y}$	: Added moment of inertia per unit length around y-axis, [m*kg/m]
X_G	: X-coordinate for centre of gravity, [m]
Z_G	: Z-coordinate for centre of gravity, [m]
$\omega_{h,0}$	: Natural circular frequency for vertical motion, [/s]
ζ_h	: Damping ratio-to-critical for vertical motion, []
$\omega_{\alpha,0}$	: Natural circular frequency for rotation around y axis, [/s]
ζ_α	: Damping ratio-to-critical for rotation around y axis, []
$\omega_{\alpha,0}$	: Natural circular frequency for horizontal motion along x-axis [/s]
ζ_p	: Damping ratio-to-critical for horizontal motion along x-axis, []
$F_{Z,external}$	: Force from rig per meter section, [N/m]
$M_{Y,external}$	: Moment from rig per meter section, [Nm/m]
$F_{X,external}$	: Force from rig per meter section, [N/m]

Formula Q.1: Equation of Motion

Quantity	Symbol	Unit	Value
Added mass in vertical	$m_{a,z}$	kg/m	0.651
Added mass in horizontal	$m_{a,x}$	kg/m	0.563
Mass moment and added mass moment	$I_y + I_{a,y}$	kg m^2/m	0.150
Horizontal centre of gravity	x_G	m	−0.002
Vertical centre of gravity	z_G	m	−0.006
Vertical damping	$\omega_{h,0}\zeta_h$	/s	0.288
Torsional damping	$\omega_{\alpha,0}\zeta_\alpha$	/s	0.156
Horizontal damping	$\omega_{p,0}\zeta_p$	/s	0.120

Table Q.2: Mechanical Data

Equation of Motion:

$$m(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N/m]

L_{ae}: aeroelastic lift, [N/m]

L_b : buffeting lift, [N/m]

M_{ad}: aero dynamic lift, [Nm/m]

M_{ae}: aeroelastic lift, [Nm/m]

M_b : buffeting lift, [Nm/m]

D_{ad}: aero dynamic lift, [N/m]

D_{ae}: aeroelastic lift, [N/m]

D_b : buffeting lift, [N/m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Old Scanlan. Ref. [1] and ref. [2].):

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2H_4^*\frac{h}{B} + K^2H_3^*\alpha + K^2H_6^*\frac{p}{B} + K\,H_1^*\frac{\dot{h}}{U} + K\,H_2^*\frac{B\,\dot{\alpha}}{U} + K\,H_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B^2)(K^2A_4^*\frac{h}{B} + K^2A_3^*\alpha + K^2A_6^*\frac{p}{B} + K\,A_1^*\frac{\dot{h}}{U} + K\,A_2^*\frac{B\,\dot{\alpha}}{U} + K\,A_5^*\frac{\dot{p}}{U})$$

$$L_{ae} = \frac{1}{2}\rho U^2(2B)(K^2P_6^*\frac{h}{B} + K^2P_3^*\alpha + K^2P_4^*\frac{p}{B} + K\,P_5^*\frac{\dot{h}}{U} + K\,P_2^*\frac{B\,\dot{\alpha}}{U} + K\,P_1^*\frac{\dot{p}}{U})$$

Formula Q.2: Equation of Motion (Old Scanlan. Ref. [1] and ref. [2].)

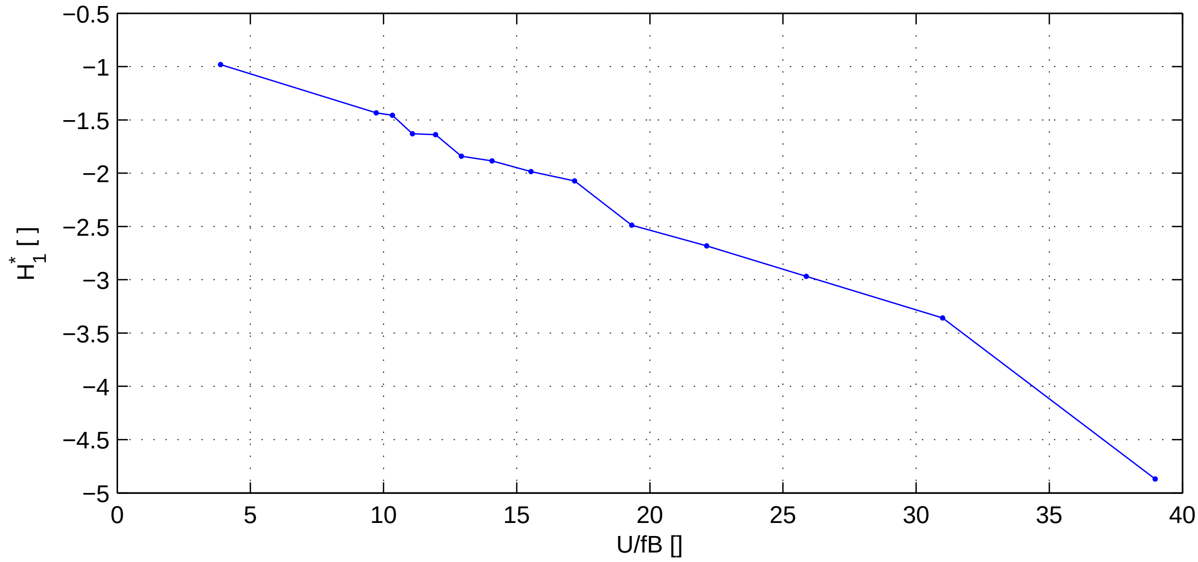


Figure Q.1: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_1^*
11.71	25.13	4.00	1.62	3.88	−0.98
11.74	10.05	1.60	0.65	9.72	−1.43
11.73	9.45	1.50	0.61	10.33	−1.46
11.71	8.79	1.40	0.57	11.09	−1.63
11.72	8.16	1.30	0.53	11.95	−1.64
11.68	7.52	1.20	0.49	12.92	−1.84
11.68	6.90	1.10	0.45	14.07	−1.89
11.73	6.28	1.00	0.40	15.54	−1.98
11.68	5.66	0.90	0.37	17.18	−2.07
11.67	5.03	0.80	0.33	19.32	−2.49
11.69	4.39	0.70	0.28	22.14	−2.68
11.73	3.77	0.60	0.24	25.88	−2.97
11.70	3.14	0.50	0.20	30.99	−3.36
11.77	2.51	0.40	0.16	38.98	−4.87

Table Q.3: H_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

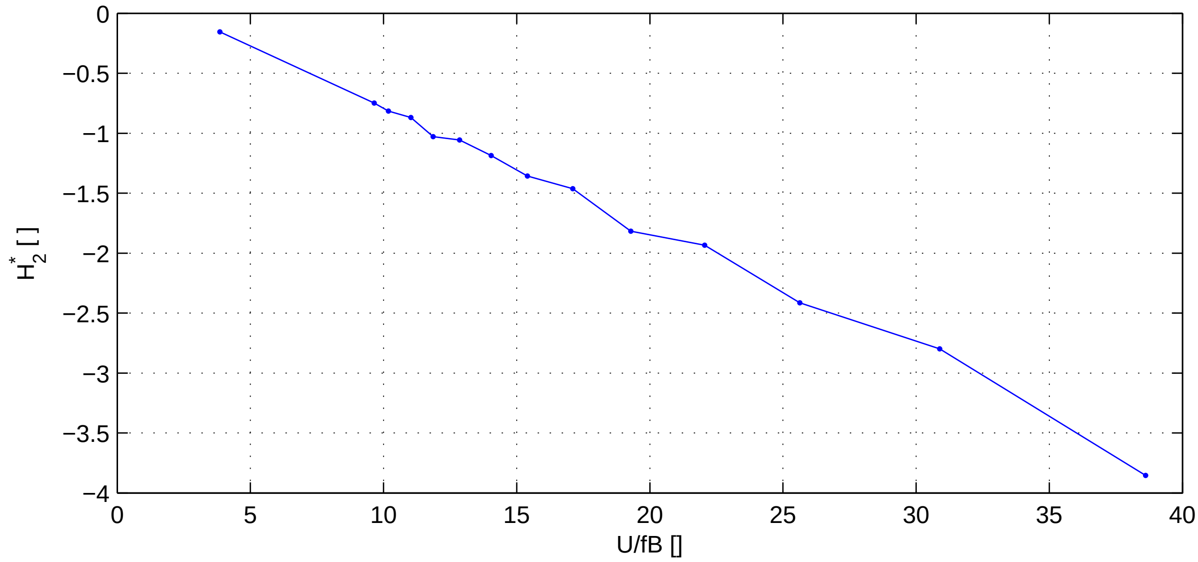


Figure Q.2: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_2^*
11.63	25.13	4.00	1.63	3.85	−0.15
11.66	10.05	1.60	0.65	9.65	−0.75
11.57	9.45	1.50	0.62	10.19	−0.82
11.64	8.79	1.40	0.57	11.03	−0.87
11.63	8.16	1.30	0.53	11.86	−1.03
11.62	7.52	1.20	0.49	12.85	−1.06
11.65	6.90	1.10	0.45	14.04	−1.19
11.63	6.28	1.00	0.41	15.40	−1.36
11.63	5.66	0.90	0.37	17.10	−1.46
11.65	5.03	0.80	0.33	19.28	−1.82
11.65	4.39	0.70	0.28	22.06	−1.93
11.62	3.77	0.60	0.25	25.64	−2.41
11.66	3.14	0.50	0.20	30.88	−2.80
11.66	2.51	0.40	0.16	38.61	−3.85

Table Q.4: H_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

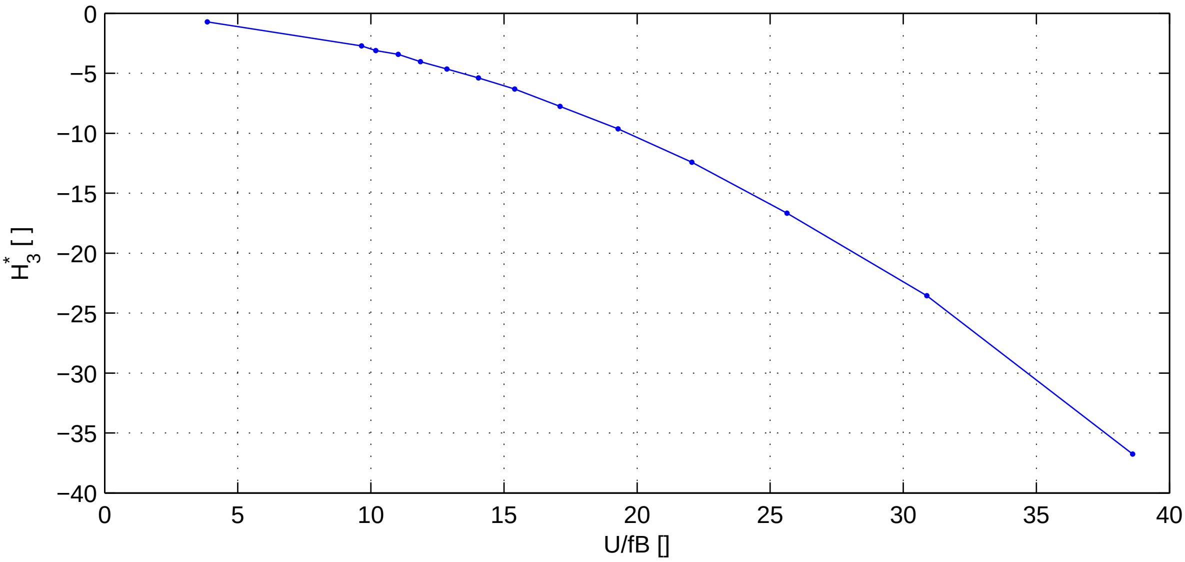


Figure Q.3: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_3^*
11.63	25.13	4.00	1.63	3.85	−0.71
11.66	10.05	1.60	0.65	9.65	−2.72
11.57	9.45	1.50	0.62	10.19	−3.10
11.64	8.79	1.40	0.57	11.03	−3.43
11.63	8.16	1.30	0.53	11.86	−4.03
11.62	7.52	1.20	0.49	12.85	−4.65
11.65	6.90	1.10	0.45	14.04	−5.39
11.63	6.28	1.00	0.41	15.40	−6.31
11.63	5.66	0.90	0.37	17.10	−7.77
11.65	5.03	0.80	0.33	19.28	−9.64
11.65	4.39	0.70	0.28	22.06	−12.43
11.62	3.77	0.60	0.25	25.64	−16.66
11.66	3.14	0.50	0.20	30.88	−23.55
11.66	2.51	0.40	0.16	38.61	−36.76

Table Q.5: H_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

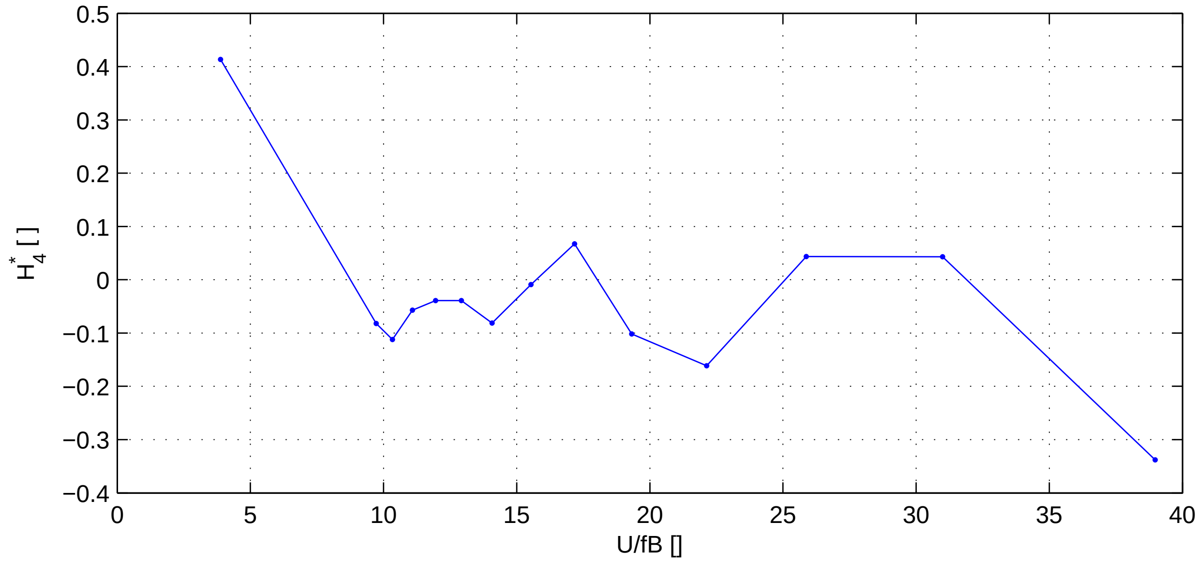


Figure Q.4: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_4^*
11.71	25.13	4.00	1.62	3.88	0.41
11.74	10.05	1.60	0.65	9.72	−0.08
11.73	9.45	1.50	0.61	10.33	−0.11
11.71	8.79	1.40	0.57	11.09	−0.06
11.72	8.16	1.30	0.53	11.95	−0.04
11.68	7.52	1.20	0.49	12.92	−0.04
11.68	6.90	1.10	0.45	14.07	−0.08
11.73	6.28	1.00	0.40	15.54	−0.01
11.68	5.66	0.90	0.37	17.18	0.07
11.67	5.03	0.80	0.33	19.32	−0.10
11.69	4.39	0.70	0.28	22.14	−0.16
11.73	3.77	0.60	0.24	25.88	0.04
11.70	3.14	0.50	0.20	30.99	0.04
11.77	2.51	0.40	0.16	38.98	−0.34

Table Q.6: H_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

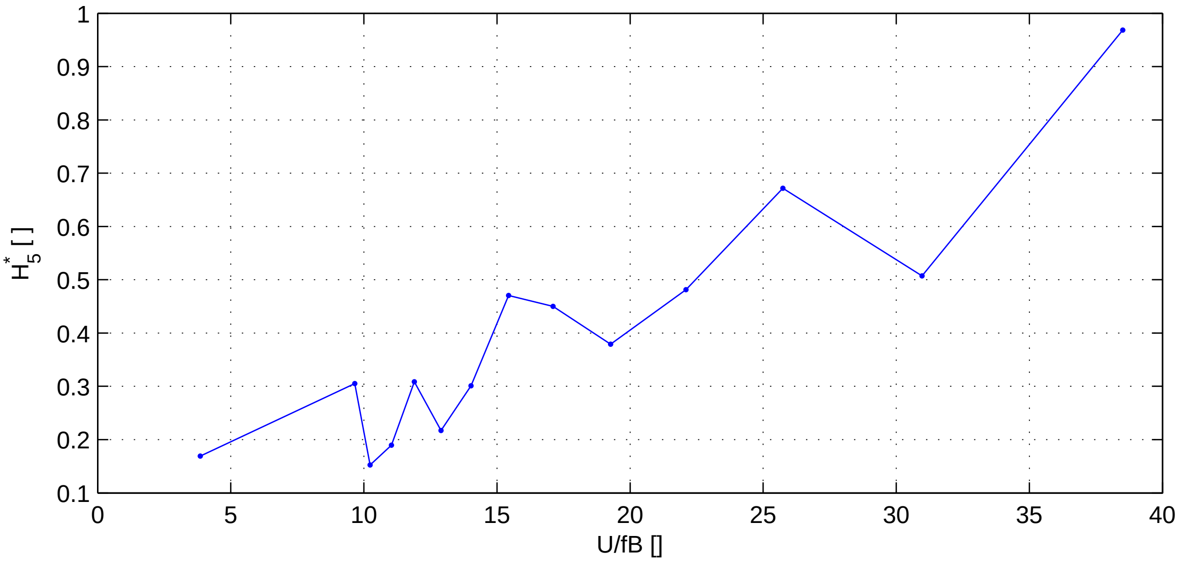


Figure Q.5: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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U m/s	Omega rad/s	f /s	K	U/fB	H_5^*
11.65	25.13	4.00	1.63	3.86	0.17
11.67	10.05	1.60	0.65	9.66	0.31
11.62	9.45	1.50	0.61	10.23	0.15
11.65	8.79	1.40	0.57	11.03	0.19
11.66	8.16	1.30	0.53	11.89	0.31
11.67	7.52	1.20	0.49	12.90	0.22
11.63	6.90	1.10	0.45	14.02	0.30
11.66	6.28	1.00	0.41	15.44	0.47
11.64	5.66	0.90	0.37	17.11	0.45
11.64	5.03	0.80	0.33	19.27	0.38
11.67	4.39	0.70	0.28	22.10	0.48
11.67	3.77	0.60	0.24	25.74	0.67
11.69	3.14	0.50	0.20	30.97	0.51
11.63	2.51	0.40	0.16	38.51	0.97

Table Q.7: H_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

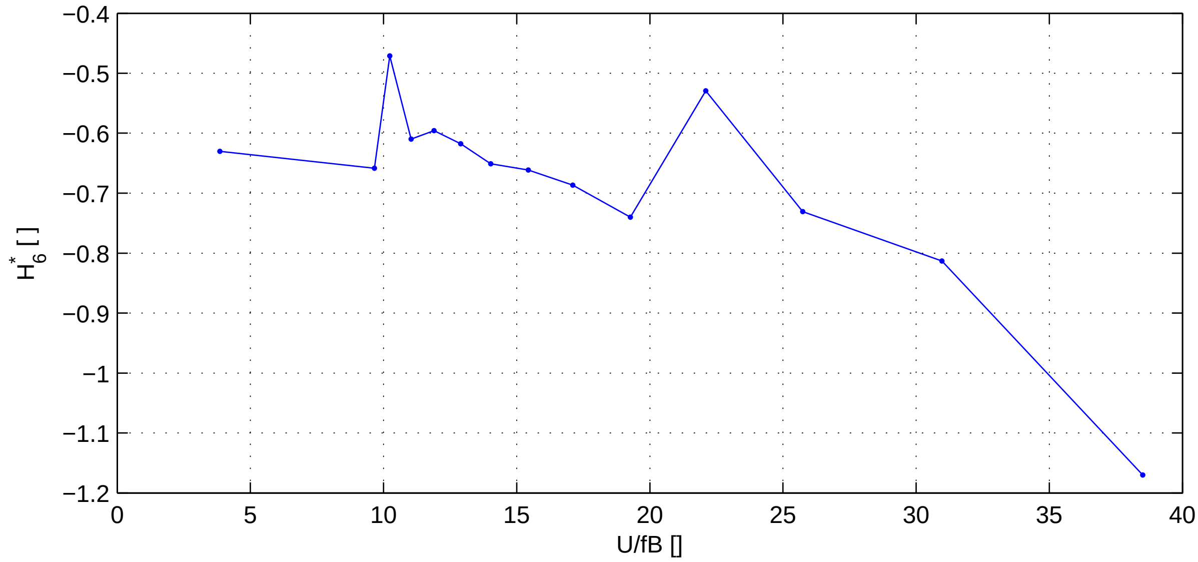

Figure Q.6: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	H_6^*
11.65	25.13	4.00	1.63	3.86	−0.63
11.67	10.05	1.60	0.65	9.66	−0.66
11.62	9.45	1.50	0.61	10.23	−0.47
11.65	8.79	1.40	0.57	11.03	−0.61
11.66	8.16	1.30	0.53	11.89	−0.60
11.67	7.52	1.20	0.49	12.90	−0.62
11.63	6.90	1.10	0.45	14.02	−0.65
11.66	6.28	1.00	0.41	15.44	−0.66
11.64	5.66	0.90	0.37	17.11	−0.69
11.64	5.03	0.80	0.33	19.27	−0.74
11.67	4.39	0.70	0.28	22.10	−0.53
11.67	3.77	0.60	0.24	25.74	−0.73
11.69	3.14	0.50	0.20	30.97	−0.81
11.63	2.51	0.40	0.16	38.51	−1.17

Table Q.8: H_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

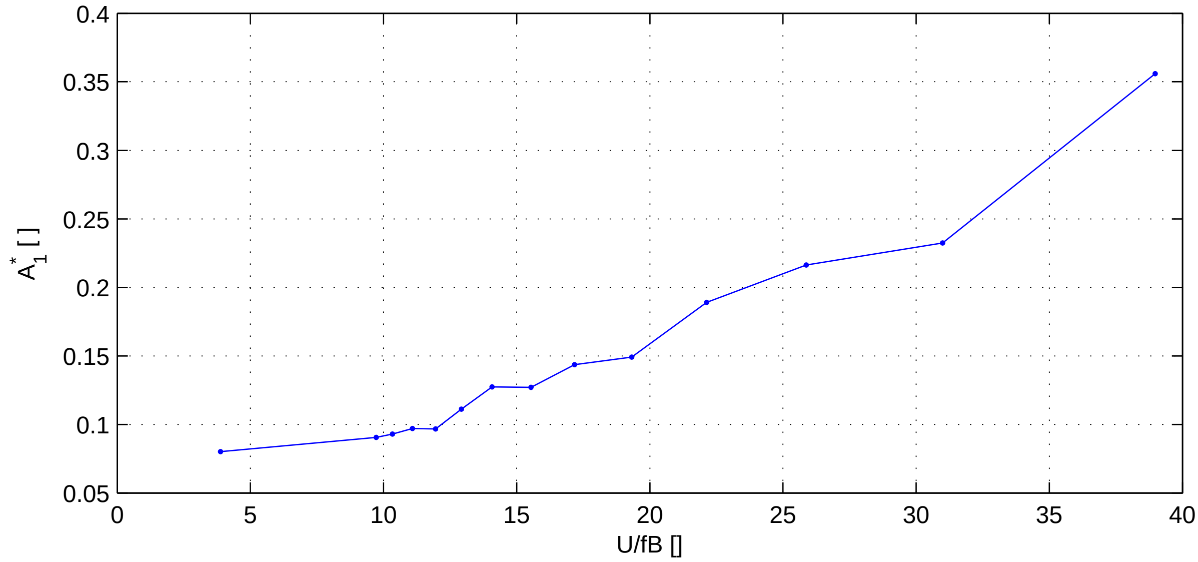

Figure Q.7: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_1^*
11.71	25.13	4.00	1.62	3.88	0.08
11.74	10.05	1.60	0.65	9.72	0.09
11.73	9.45	1.50	0.61	10.33	0.09
11.71	8.79	1.40	0.57	11.09	0.10
11.72	8.16	1.30	0.53	11.95	0.10
11.68	7.52	1.20	0.49	12.92	0.11
11.68	6.90	1.10	0.45	14.07	0.13
11.73	6.28	1.00	0.40	15.54	0.13
11.68	5.66	0.90	0.37	17.18	0.14
11.67	5.03	0.80	0.33	19.32	0.15
11.69	4.39	0.70	0.28	22.14	0.19
11.73	3.77	0.60	0.24	25.88	0.22
11.70	3.14	0.50	0.20	30.99	0.23
11.77	2.51	0.40	0.16	38.98	0.36

Table Q.9: A_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

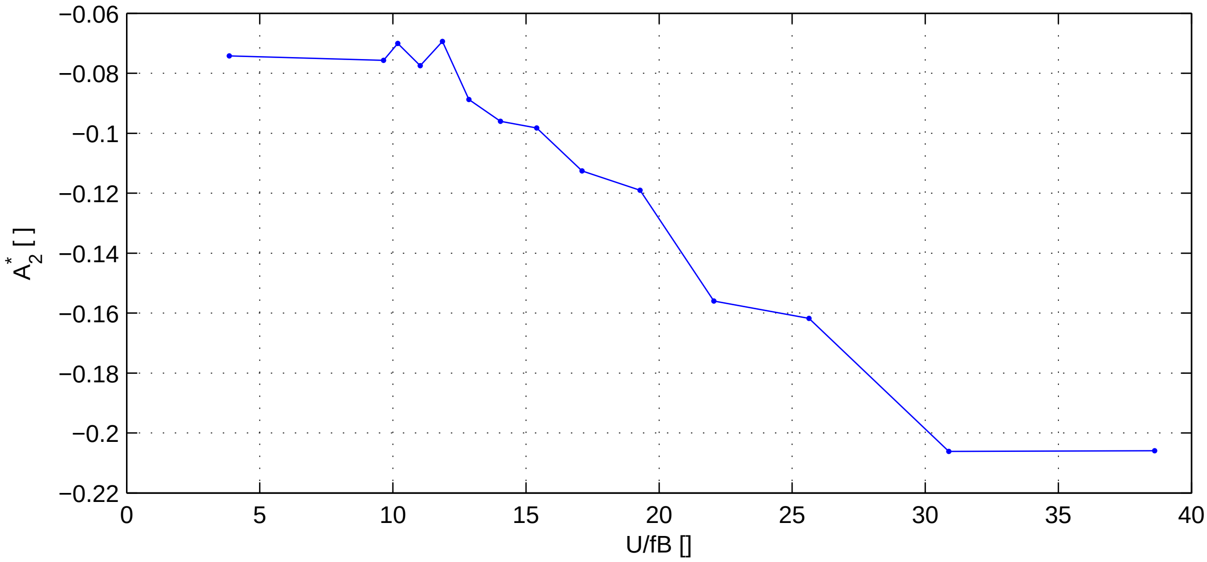

Figure Q.8: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_2^*
11.63	25.13	4.00	1.63	3.85	−0.07
11.66	10.05	1.60	0.65	9.65	−0.08
11.57	9.45	1.50	0.62	10.19	−0.07
11.64	8.79	1.40	0.57	11.03	−0.08
11.63	8.16	1.30	0.53	11.86	−0.07
11.62	7.52	1.20	0.49	12.85	−0.09
11.65	6.90	1.10	0.45	14.04	−0.10
11.63	6.28	1.00	0.41	15.40	−0.10
11.63	5.66	0.90	0.37	17.10	−0.11
11.65	5.03	0.80	0.33	19.28	−0.12
11.65	4.39	0.70	0.28	22.06	−0.16
11.62	3.77	0.60	0.25	25.64	−0.16
11.66	3.14	0.50	0.20	30.88	−0.21
11.66	2.51	0.40	0.16	38.61	−0.21

Table Q.10: A_2^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

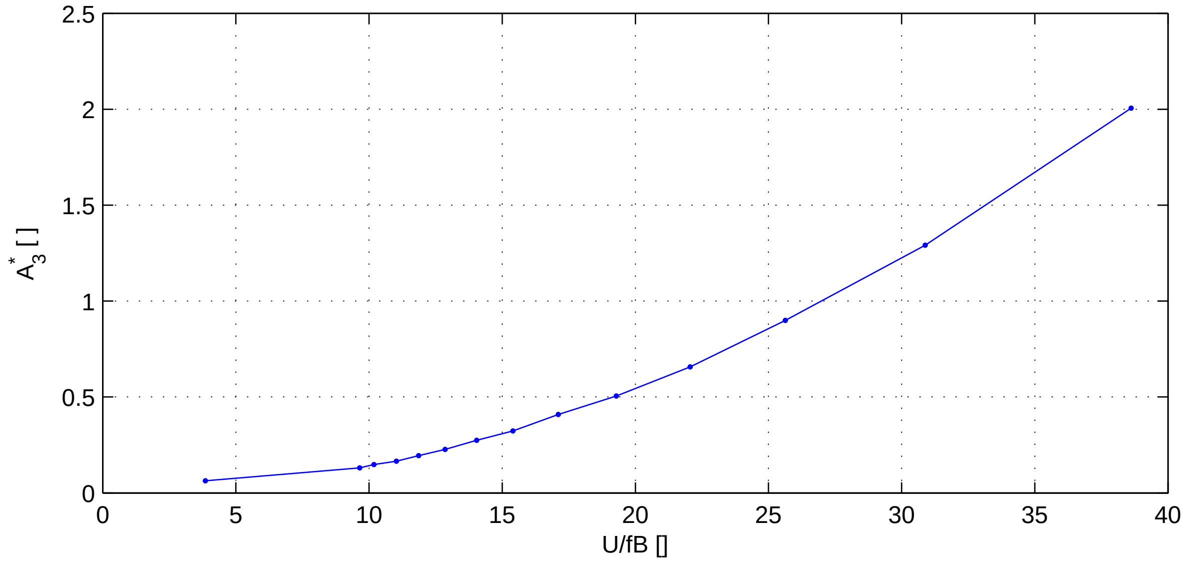

Figure Q.9: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

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U m/s	Omega rad/s	f /s	K	U/fB	A_3^*
11.63	25.13	4.00	1.63	3.85	0.06
11.66	10.05	1.60	0.65	9.65	0.13
11.57	9.45	1.50	0.62	10.19	0.15
11.64	8.79	1.40	0.57	11.03	0.17
11.63	8.16	1.30	0.53	11.86	0.19
11.62	7.52	1.20	0.49	12.85	0.23
11.65	6.90	1.10	0.45	14.04	0.27
11.63	6.28	1.00	0.41	15.40	0.32
11.63	5.66	0.90	0.37	17.10	0.41
11.65	5.03	0.80	0.33	19.28	0.50
11.65	4.39	0.70	0.28	22.06	0.66
11.62	3.77	0.60	0.25	25.64	0.90
11.66	3.14	0.50	0.20	30.88	1.29
11.66	2.51	0.40	0.16	38.61	2.01

Table Q.11: A_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

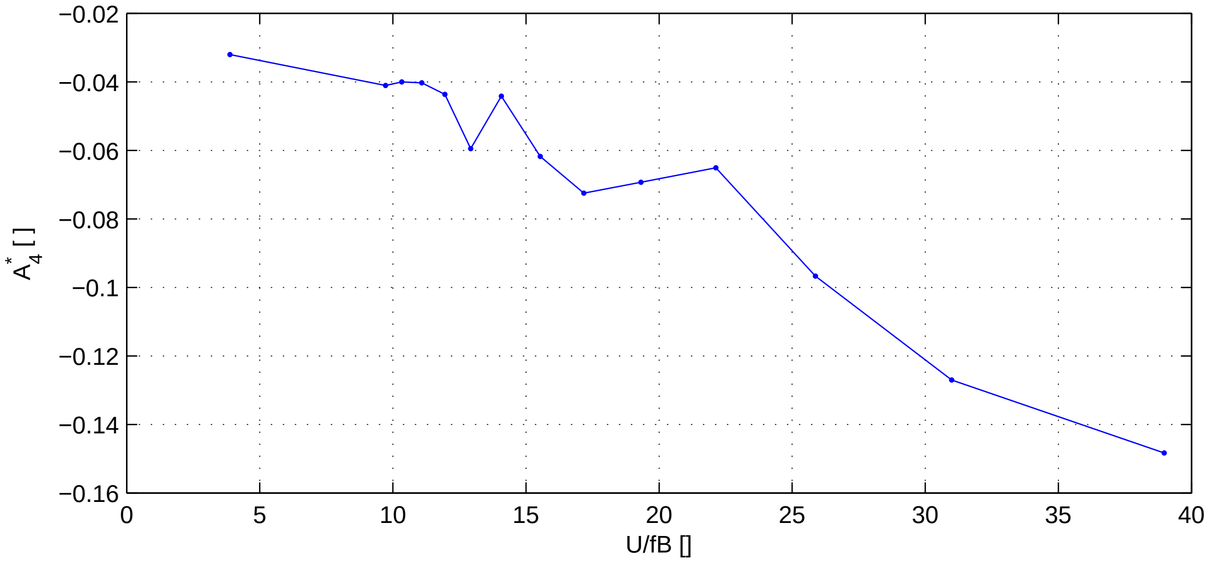

Figure Q.10: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_4^*
11.71	25.13	4.00	1.62	3.88	−0.03
11.74	10.05	1.60	0.65	9.72	−0.04
11.73	9.45	1.50	0.61	10.33	−0.04
11.71	8.79	1.40	0.57	11.09	−0.04
11.72	8.16	1.30	0.53	11.95	−0.04
11.68	7.52	1.20	0.49	12.92	−0.06
11.68	6.90	1.10	0.45	14.07	−0.04
11.73	6.28	1.00	0.40	15.54	−0.06
11.68	5.66	0.90	0.37	17.18	−0.07
11.67	5.03	0.80	0.33	19.32	−0.07
11.69	4.39	0.70	0.28	22.14	−0.07
11.73	3.77	0.60	0.24	25.88	−0.10
11.70	3.14	0.50	0.20	30.99	−0.13
11.77	2.51	0.40	0.16	38.98	−0.15

Table Q.12: A_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

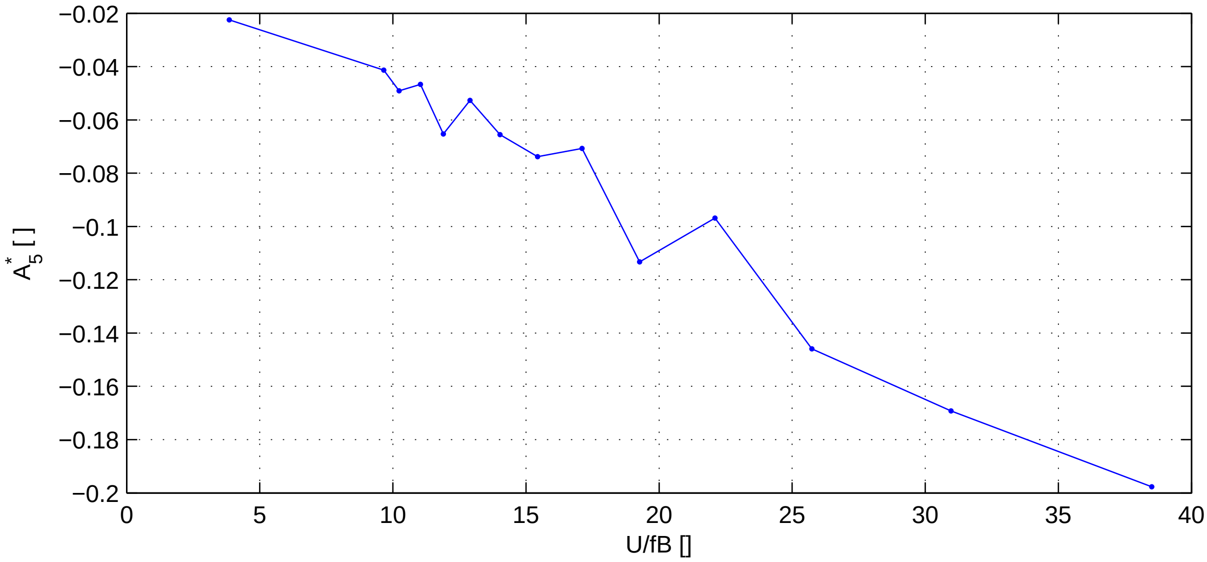

Figure Q.11: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_5^*
11.65	25.13	4.00	1.63	3.86	−0.02
11.67	10.05	1.60	0.65	9.66	−0.04
11.62	9.45	1.50	0.61	10.23	−0.05
11.65	8.79	1.40	0.57	11.03	−0.05
11.66	8.16	1.30	0.53	11.89	−0.07
11.67	7.52	1.20	0.49	12.90	−0.05
11.63	6.90	1.10	0.45	14.02	−0.07
11.66	6.28	1.00	0.41	15.44	−0.07
11.64	5.66	0.90	0.37	17.11	−0.07
11.64	5.03	0.80	0.33	19.27	−0.11
11.67	4.39	0.70	0.28	22.10	−0.10
11.67	3.77	0.60	0.24	25.74	−0.15
11.69	3.14	0.50	0.20	30.97	−0.17
11.63	2.51	0.40	0.16	38.51	−0.20

Table Q.13: A_5^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

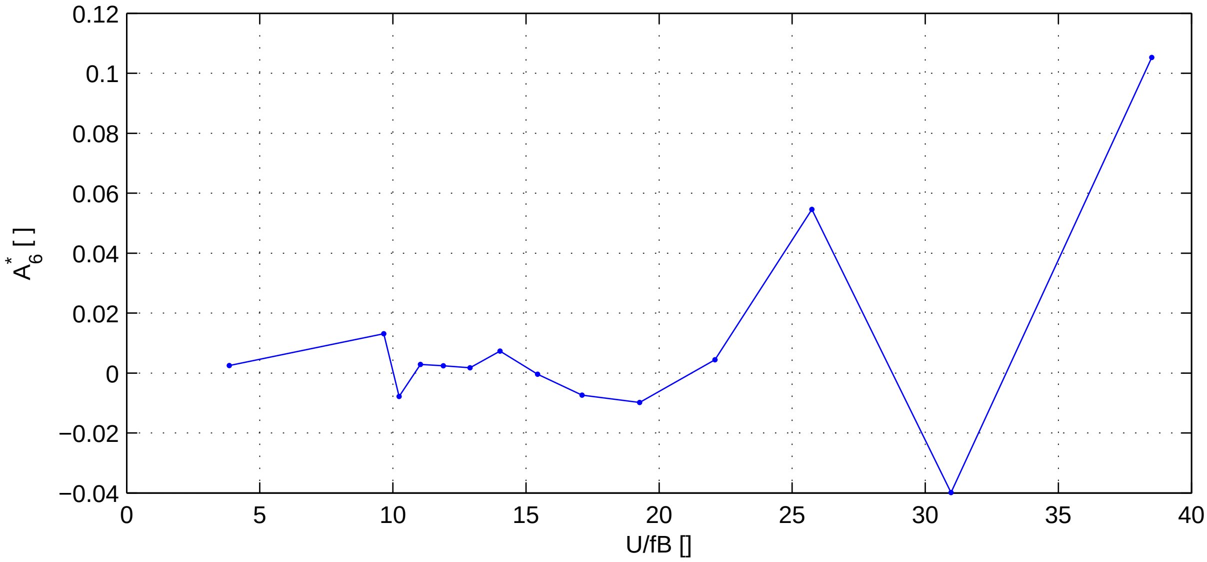

Figure Q.12: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	A_6^*
11.65	25.13	4.00	1.63	3.86	0.00
11.67	10.05	1.60	0.65	9.66	0.01
11.62	9.45	1.50	0.61	10.23	−0.01
11.65	8.79	1.40	0.57	11.03	0.00
11.66	8.16	1.30	0.53	11.89	0.00
11.67	7.52	1.20	0.49	12.90	0.00
11.63	6.90	1.10	0.45	14.02	0.01
11.66	6.28	1.00	0.41	15.44	−0.00
11.64	5.66	0.90	0.37	17.11	−0.01
11.64	5.03	0.80	0.33	19.27	−0.01
11.67	4.39	0.70	0.28	22.10	0.00
11.67	3.77	0.60	0.24	25.74	0.05
11.69	3.14	0.50	0.20	30.97	−0.04
11.63	2.51	0.40	0.16	38.51	0.11

Table Q.14: A_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

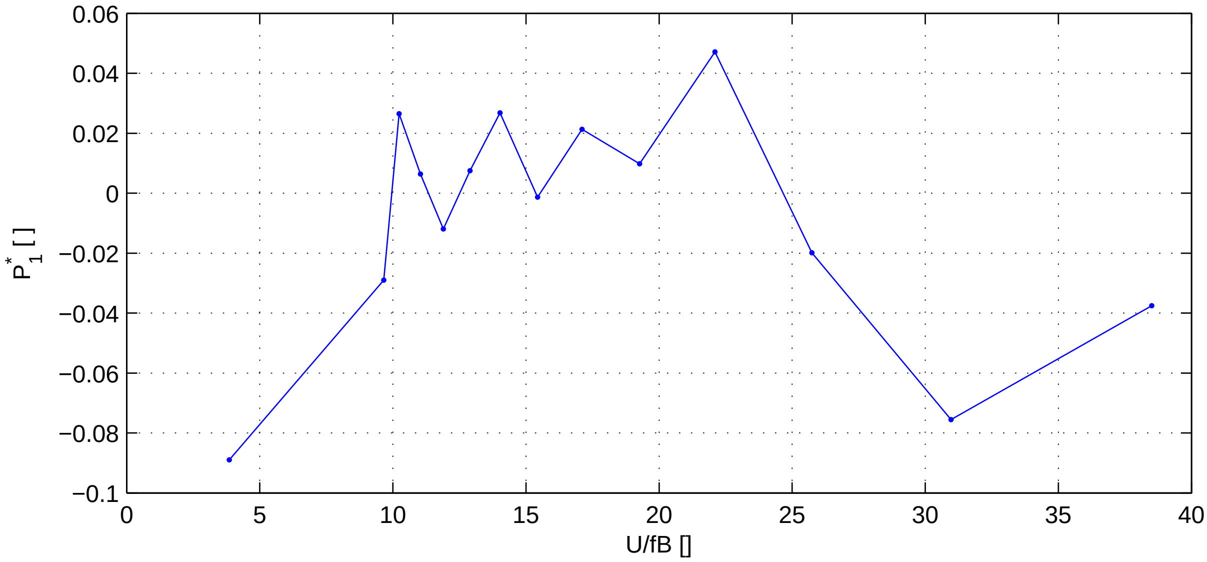

Figure Q.13: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_1^*
11.65	25.13	4.00	1.63	3.86	−0.09
11.67	10.05	1.60	0.65	9.66	−0.03
11.62	9.45	1.50	0.61	10.23	0.03
11.65	8.79	1.40	0.57	11.03	0.01
11.66	8.16	1.30	0.53	11.89	−0.01
11.67	7.52	1.20	0.49	12.90	0.01
11.63	6.90	1.10	0.45	14.02	0.03
11.66	6.28	1.00	0.41	15.44	−0.00
11.64	5.66	0.90	0.37	17.11	0.02
11.64	5.03	0.80	0.33	19.27	0.01
11.67	4.39	0.70	0.28	22.10	0.05
11.67	3.77	0.60	0.24	25.74	−0.02
11.69	3.14	0.50	0.20	30.97	−0.08
11.63	2.51	0.40	0.16	38.51	−0.04

Table Q.15: P_1^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

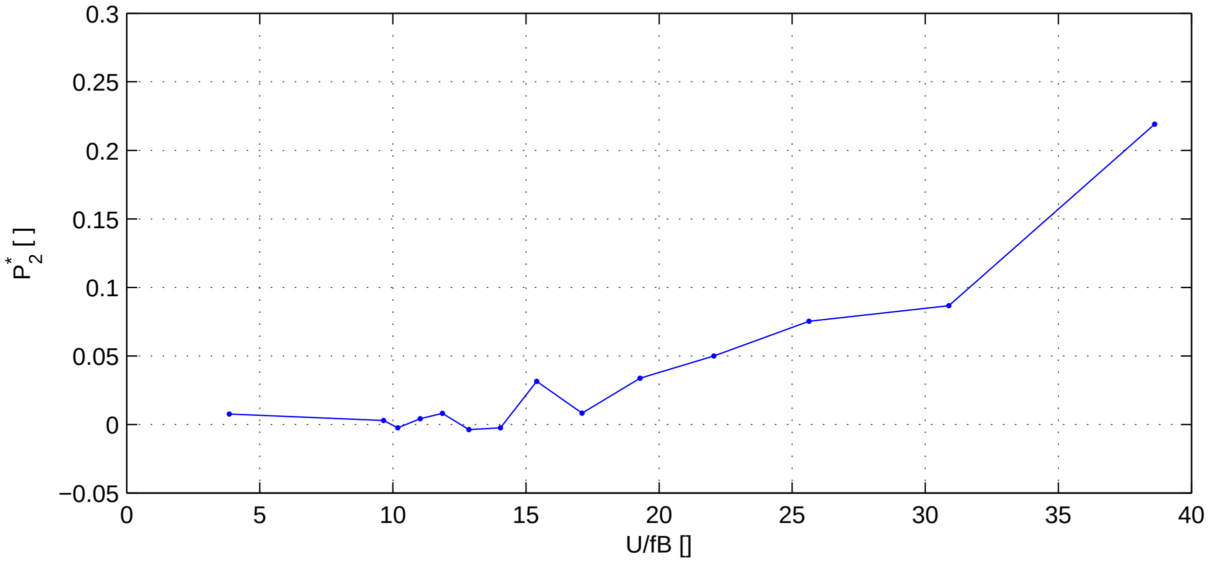

Figure Q.14: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_2
11.63	25.13	4.00	1.63	3.85	0.01
11.66	10.05	1.60	0.65	9.65	0.00
11.57	9.45	1.50	0.62	10.19	−0.00
11.64	8.79	1.40	0.57	11.03	0.00
11.63	8.16	1.30	0.53	11.86	0.01
11.62	7.52	1.20	0.49	12.85	−0.00
11.65	6.90	1.10	0.45	14.04	−0.00
11.63	6.28	1.00	0.41	15.40	0.03
11.63	5.66	0.90	0.37	17.10	0.01
11.65	5.03	0.80	0.33	19.28	0.03
11.65	4.39	0.70	0.28	22.06	0.05
11.62	3.77	0.60	0.25	25.64	0.08
11.66	3.14	0.50	0.20	30.88	0.09
11.66	2.51	0.40	0.16	38.61	0.22

Table Q.16: P^*_2 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

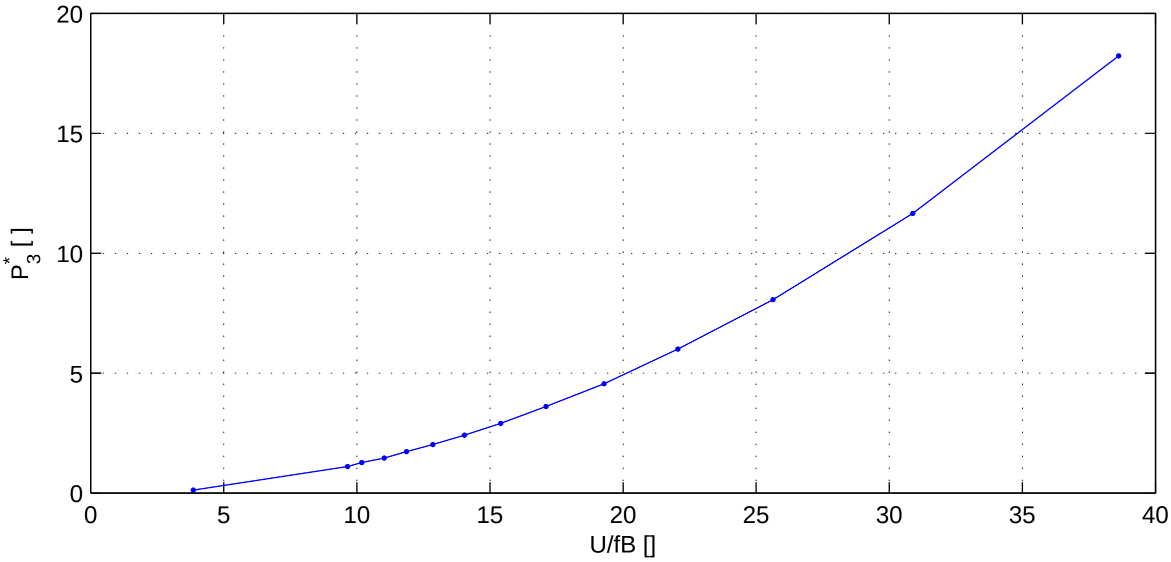

Figure Q.15: P_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_3^*
11.63	25.13	4.00	1.63	3.85	0.12
11.66	10.05	1.60	0.65	9.65	1.10
11.57	9.45	1.50	0.62	10.19	1.27
11.64	8.79	1.40	0.57	11.03	1.45
11.63	8.16	1.30	0.53	11.86	1.72
11.62	7.52	1.20	0.49	12.85	2.02
11.65	6.90	1.10	0.45	14.04	2.40
11.63	6.28	1.00	0.41	15.40	2.90
11.63	5.66	0.90	0.37	17.10	3.61
11.65	5.03	0.80	0.33	19.28	4.55
11.65	4.39	0.70	0.28	22.06	6.00
11.62	3.77	0.60	0.25	25.64	8.06
11.66	3.14	0.50	0.20	30.88	11.66
11.66	2.51	0.40	0.16	38.61	18.22

Table Q.17: P_3^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

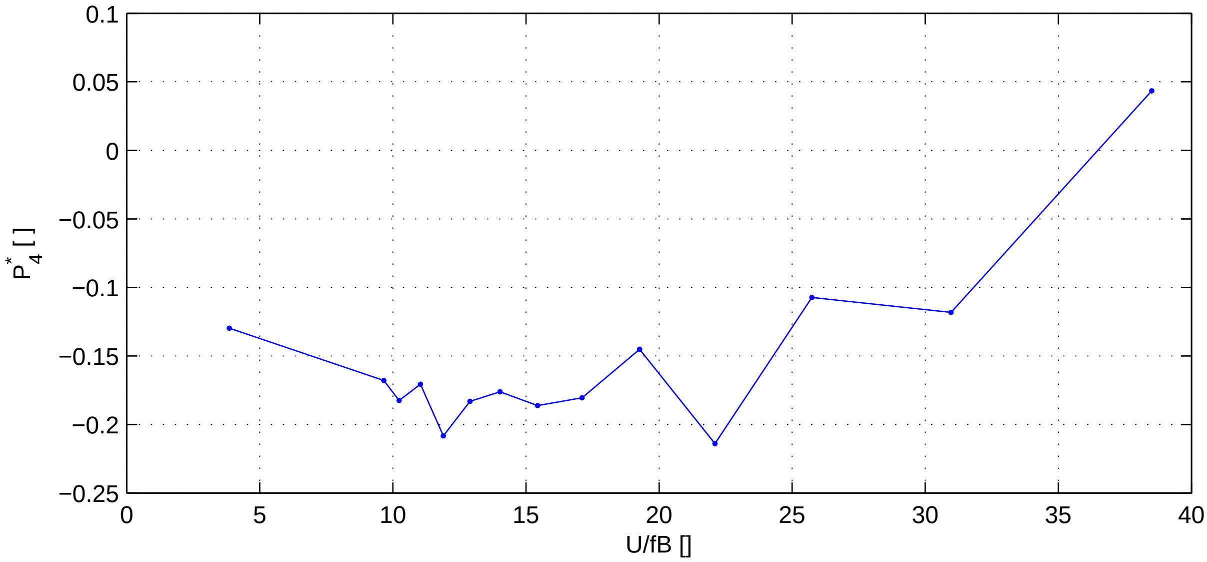

Figure Q.16: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_4^*
11.65	25.13	4.00	1.63	3.86	−0.13
11.67	10.05	1.60	0.65	9.66	−0.17
11.62	9.45	1.50	0.61	10.23	−0.18
11.65	8.79	1.40	0.57	11.03	−0.17
11.66	8.16	1.30	0.53	11.89	−0.21
11.67	7.52	1.20	0.49	12.90	−0.18
11.63	6.90	1.10	0.45	14.02	−0.18
11.66	6.28	1.00	0.41	15.44	−0.19
11.64	5.66	0.90	0.37	17.11	−0.18
11.64	5.03	0.80	0.33	19.27	−0.15
11.67	4.39	0.70	0.28	22.10	−0.21
11.67	3.77	0.60	0.24	25.74	−0.11
11.69	3.14	0.50	0.20	30.97	−0.12
11.63	2.51	0.40	0.16	38.51	0.04

Table Q.18: P_4^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

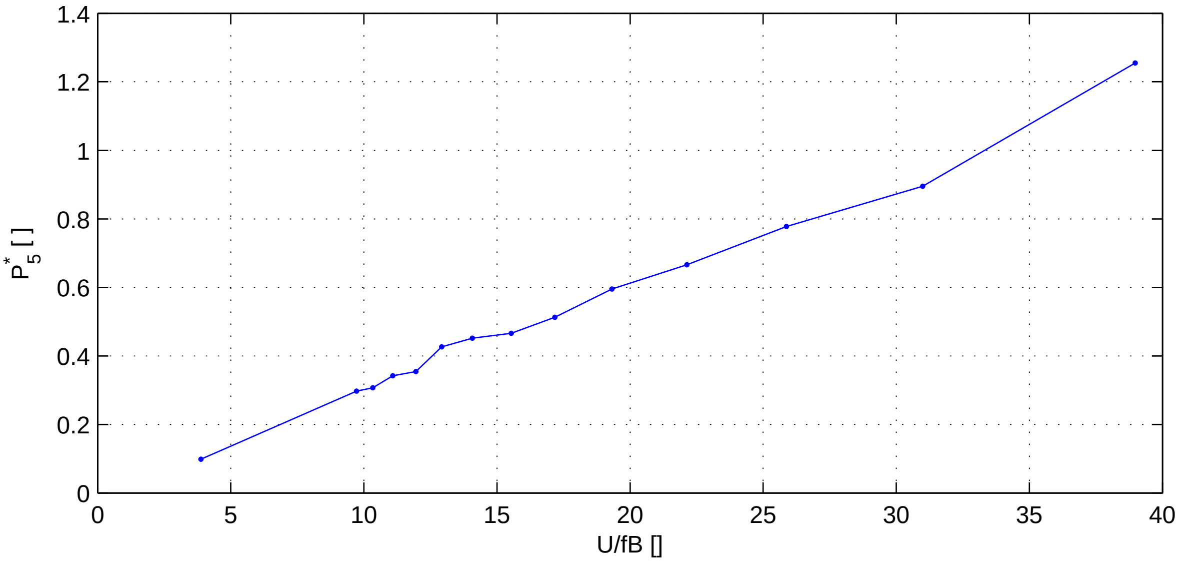

Figure Q.17: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P^*_5
11.71	25.13	4.00	1.62	3.88	0.10
11.74	10.05	1.60	0.65	9.72	0.30
11.73	9.45	1.50	0.61	10.33	0.31
11.71	8.79	1.40	0.57	11.09	0.34
11.72	8.16	1.30	0.53	11.95	0.35
11.68	7.52	1.20	0.49	12.92	0.43
11.68	6.90	1.10	0.45	14.07	0.45
11.73	6.28	1.00	0.40	15.54	0.47
11.68	5.66	0.90	0.37	17.18	0.51
11.67	5.03	0.80	0.33	19.32	0.60
11.69	4.39	0.70	0.28	22.14	0.67
11.73	3.77	0.60	0.24	25.88	0.78
11.70	3.14	0.50	0.20	30.99	0.90
11.77	2.51	0.40	0.16	38.98	1.25

Table Q.19: P^*_5 as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

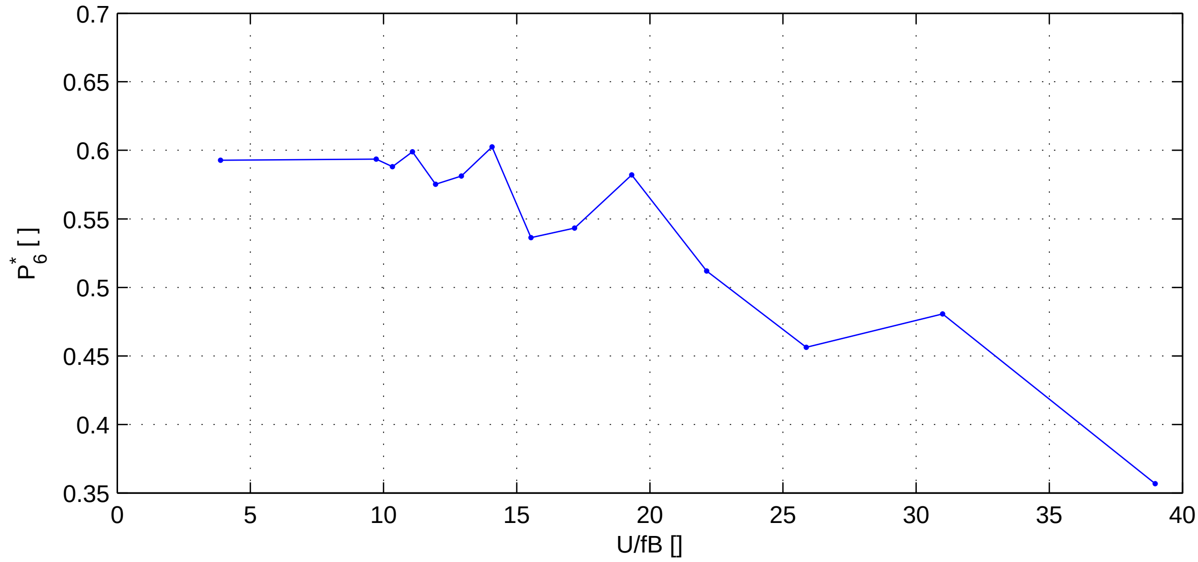

Figure Q.18: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	P_6^*
11.71	25.13	4.00	1.62	3.88	0.59
11.74	10.05	1.60	0.65	9.72	0.59
11.73	9.45	1.50	0.61	10.33	0.59
11.71	8.79	1.40	0.57	11.09	0.60
11.72	8.16	1.30	0.53	11.95	0.58
11.68	7.52	1.20	0.49	12.92	0.58
11.68	6.90	1.10	0.45	14.07	0.60
11.73	6.28	1.00	0.40	15.54	0.54
11.68	5.66	0.90	0.37	17.18	0.54
11.67	5.03	0.80	0.33	19.32	0.58
11.69	4.39	0.70	0.28	22.14	0.51
11.73	3.77	0.60	0.24	25.88	0.46
11.70	3.14	0.50	0.20	30.99	0.48
11.77	2.51	0.40	0.16	38.98	0.36

Table Q.20: P_6^* as function of reduced velocity. Old Scanlan. Ref. [1] and ref. [2]. formulation.

Equation of Motion:

$$m\,(\ddot{h} - z_G\dot{\alpha}^2 + x_G\ddot{\alpha}) = m\,g - m_{a,z}\ddot{h} - 2m\,\omega_{h,0}\zeta_h\dot{h} + F_{Z,external} + L_{ad} + L_{ae} + L_b$$

$$I_y\ddot{\alpha} + m\,z_G\ddot{p} + m\,x_G\ddot{h}) = -I_{a,y}\ddot{\alpha}m\,g - 2m\,\omega_{\alpha,0}\zeta_\alpha\dot{\alpha} + M_{Y,external} + M_{ad} + L_{ae} + M_b$$

$$m\,(\ddot{p} - z_G\ddot{\alpha} + x_G\dot{\alpha}^2) = -m_{a,x}\ddot{p} - 2m\,\omega_{p,0}\zeta_p\dot{p} + F_{X,external} + D_{ad} + D_{ae} + D_b$$

where:

L_{ad}: aero dynamic lift, [N / m]

L_{ae}: aeroelastic lift, [N / m]

L_b : buffeting lift, [N / m]

M_{ad}: aero dynamic lift, [N m / m]

M_{ae}: aeroelastic lift, [N m / m]

M_b : buffeting lift, [N m / m]

D_{ad}: aero dynamic lift, [N / m]

D_{ae}: aeroelastic lift, [N / m]

D_b : buffeting lift, [N / m]

The aerodynamic forces are described as follows:

$$L_{ad} = 1/2\,\rho U^2 B\,C_z$$

$$M_{ad} = 1/2\,\rho U^2 B^2 C_m$$

$$D_{ad} = 1/2\,\rho U^2 B\,C_x$$

The aero elastic forces are described as follows (Stretto di Messina. Ref. [5].):

$$L_{ae} = \frac{1}{2}\rho U^2 B\,(-h_1^*\frac{i\omega z}{U} + h_4^*\frac{\pi}{2U^2}\frac{z}{B} - h_2^*\frac{i\omega B\theta}{U} + h_3^*\theta - h_5^*\frac{i\omega y}{U} + h_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$M_{ae} = \frac{1}{2}\rho U^2 B\,(-a_1^*\frac{i\omega z}{U} + a_4^*\frac{\pi}{2U^2}\frac{z}{B} - a_2^*\frac{i\omega B\theta}{U} + a_3^*\theta - a_5^*\frac{i\omega y}{U} + a_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

$$D_{ae} = \frac{1}{2}\rho U^2 B\,(-p_1^*\frac{i\omega z}{U} + p_4^*\frac{\pi}{2U^2}\frac{z}{B} - p_2^*\frac{i\omega B\theta}{U} + p_3^*\theta - p_5^*\frac{i\omega y}{U} + p_6^*\frac{\pi}{2U^2}\frac{y}{B})$$

Formula Q.3: Equation of Motion (Stretto di Messina. Ref. [5].)

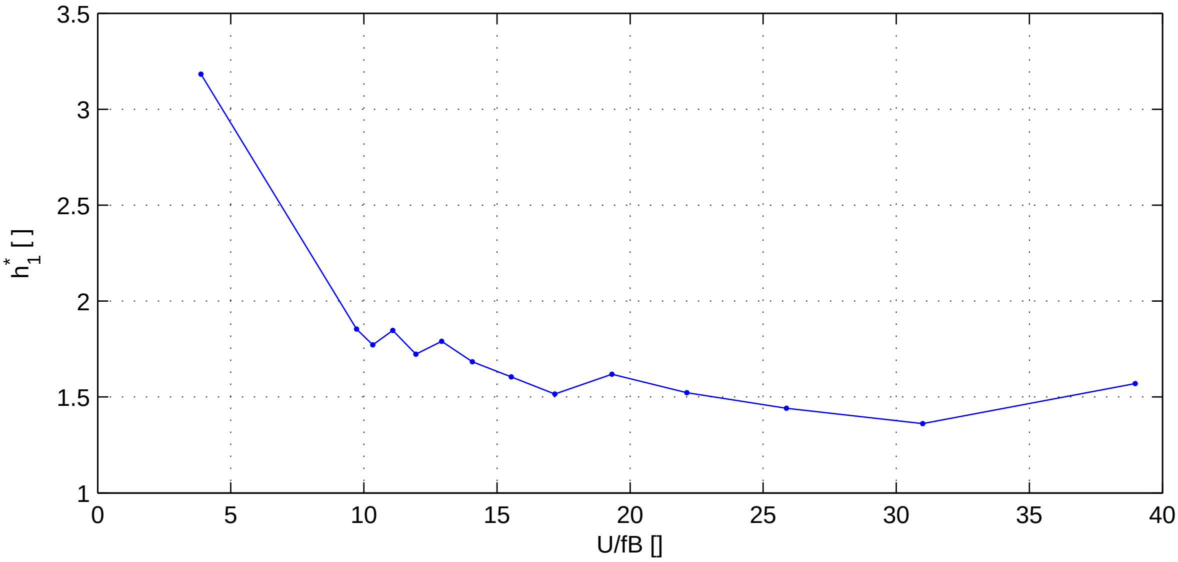

Figure Q.19: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_1^*
11.71	25.13	4.00	1.62	3.88	3.18
11.74	10.05	1.60	0.65	9.72	1.85
11.73	9.45	1.50	0.61	10.33	1.77
11.71	8.79	1.40	0.57	11.09	1.85
11.72	8.16	1.30	0.53	11.95	1.72
11.68	7.52	1.20	0.49	12.92	1.79
11.68	6.90	1.10	0.45	14.07	1.68
11.73	6.28	1.00	0.40	15.54	1.60
11.68	5.66	0.90	0.37	17.18	1.52
11.67	5.03	0.80	0.33	19.32	1.62
11.69	4.39	0.70	0.28	22.14	1.52
11.73	3.77	0.60	0.24	25.88	1.44
11.70	3.14	0.50	0.20	30.99	1.36
11.77	2.51	0.40	0.16	38.98	1.57

Table Q.21: h_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

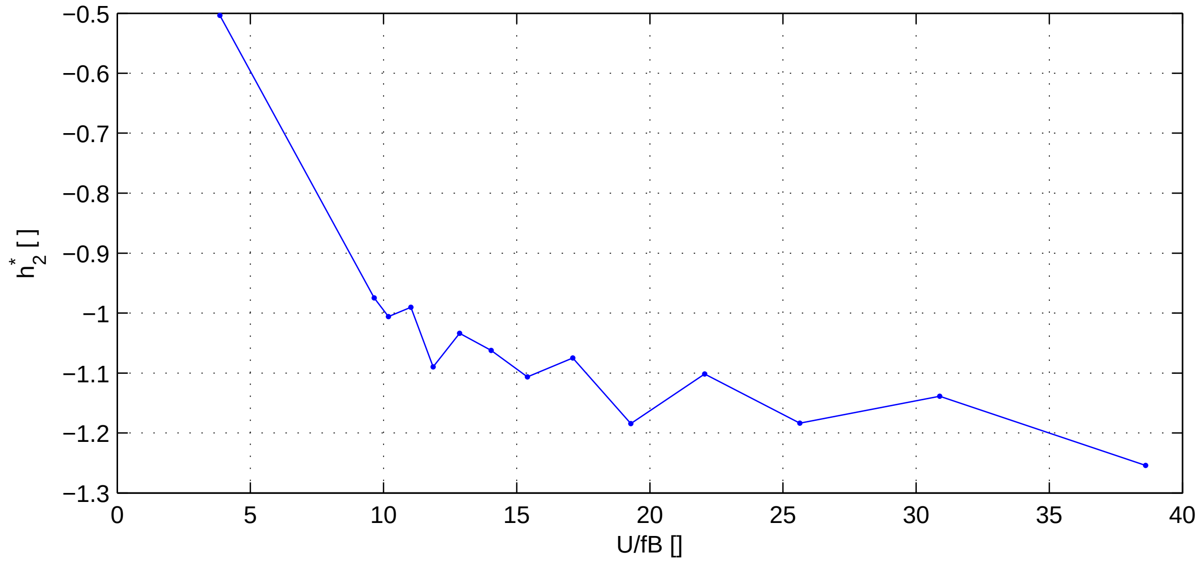

Figure Q.20: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_2^*
11.63	25.13	4.00	1.63	3.85	−0.50
11.66	10.05	1.60	0.65	9.65	−0.97
11.57	9.45	1.50	0.62	10.19	−1.01
11.64	8.79	1.40	0.57	11.03	−0.99
11.63	8.16	1.30	0.53	11.86	−1.09
11.62	7.52	1.20	0.49	12.85	−1.03
11.65	6.90	1.10	0.45	14.04	−1.06
11.63	6.28	1.00	0.41	15.40	−1.11
11.63	5.66	0.90	0.37	17.10	−1.07
11.65	5.03	0.80	0.33	19.28	−1.18
11.65	4.39	0.70	0.28	22.06	−1.10
11.62	3.77	0.60	0.25	25.64	−1.18
11.66	3.14	0.50	0.20	30.88	−1.14
11.66	2.51	0.40	0.16	38.61	−1.25

Table Q.22: h_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

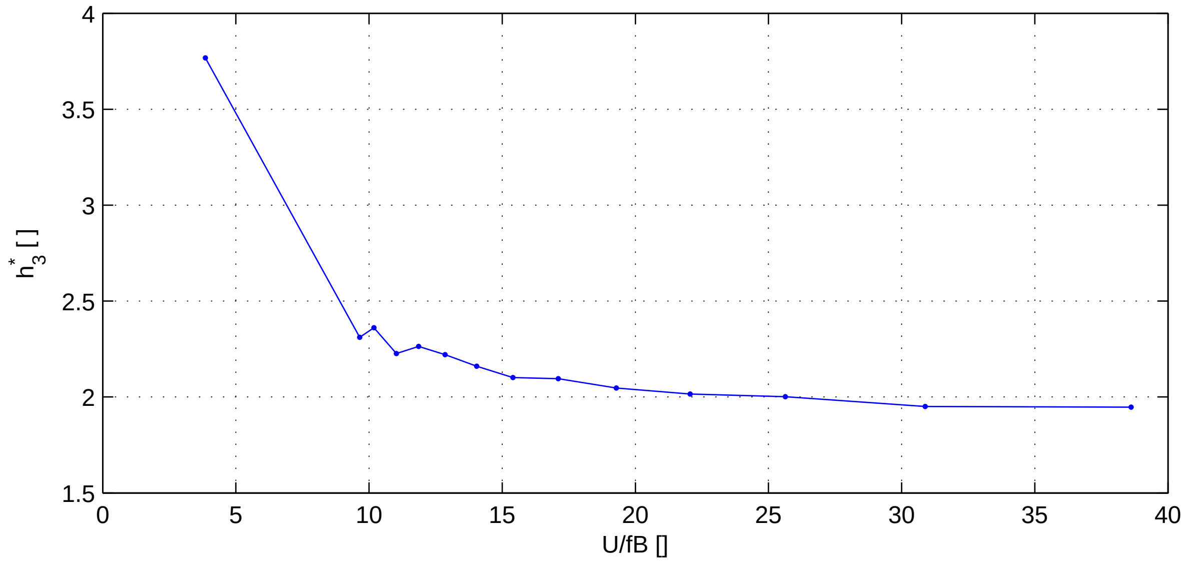

Figure Q.21: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_3^*
11.63	25.13	4.00	1.63	3.85	3.77
11.66	10.05	1.60	0.65	9.65	2.31
11.57	9.45	1.50	0.62	10.19	2.36
11.64	8.79	1.40	0.57	11.03	2.23
11.63	8.16	1.30	0.53	11.86	2.26
11.62	7.52	1.20	0.49	12.85	2.22
11.65	6.90	1.10	0.45	14.04	2.16
11.63	6.28	1.00	0.41	15.40	2.10
11.63	5.66	0.90	0.37	17.10	2.10
11.65	5.03	0.80	0.33	19.28	2.05
11.65	4.39	0.70	0.28	22.06	2.02
11.62	3.77	0.60	0.25	25.64	2.00
11.66	3.14	0.50	0.20	30.88	1.95
11.66	2.51	0.40	0.16	38.61	1.95

Table Q.23: h_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

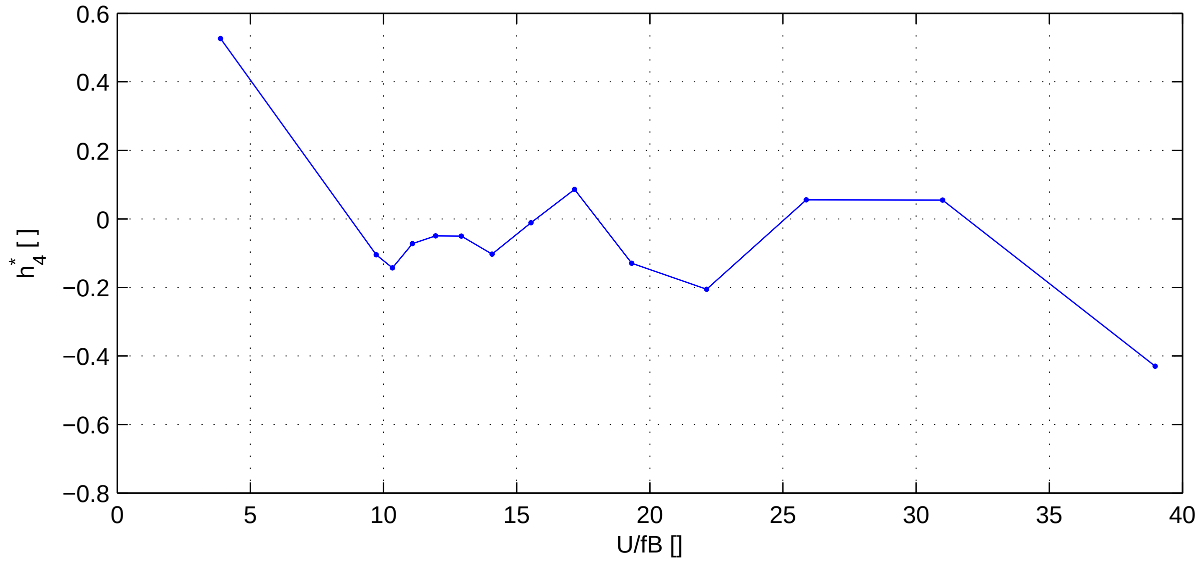

Figure Q.22: h^*_4 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h^*_4
11.71	25.13	4.00	1.62	3.88	0.53
11.74	10.05	1.60	0.65	9.72	−0.10
11.73	9.45	1.50	0.61	10.33	−0.14
11.71	8.79	1.40	0.57	11.09	−0.07
11.72	8.16	1.30	0.53	11.95	−0.05
11.68	7.52	1.20	0.49	12.92	−0.05
11.68	6.90	1.10	0.45	14.07	−0.10
11.73	6.28	1.00	0.40	15.54	−0.01
11.68	5.66	0.90	0.37	17.18	0.09
11.67	5.03	0.80	0.33	19.32	−0.13
11.69	4.39	0.70	0.28	22.14	−0.21
11.73	3.77	0.60	0.24	25.88	0.06
11.70	3.14	0.50	0.20	30.99	0.05
11.77	2.51	0.40	0.16	38.98	−0.43

Table Q.24: h^*_4 as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

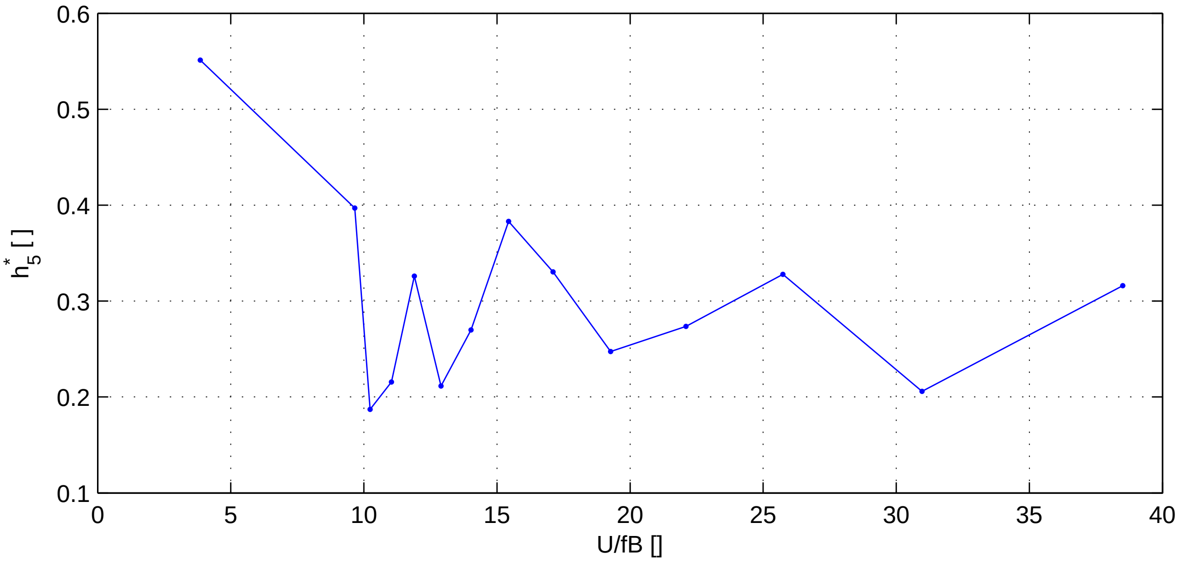

Figure Q.23: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_5^*
11.65	25.13	4.00	1.63	3.86	0.55
11.67	10.05	1.60	0.65	9.66	0.40
11.62	9.45	1.50	0.61	10.23	0.19
11.65	8.79	1.40	0.57	11.03	0.22
11.66	8.16	1.30	0.53	11.89	0.33
11.67	7.52	1.20	0.49	12.90	0.21
11.63	6.90	1.10	0.45	14.02	0.27
11.66	6.28	1.00	0.41	15.44	0.38
11.64	5.66	0.90	0.37	17.11	0.33
11.64	5.03	0.80	0.33	19.27	0.25
11.67	4.39	0.70	0.28	22.10	0.27
11.67	3.77	0.60	0.24	25.74	0.33
11.69	3.14	0.50	0.20	30.97	0.21
11.63	2.51	0.40	0.16	38.51	0.32

Table Q.25: h_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

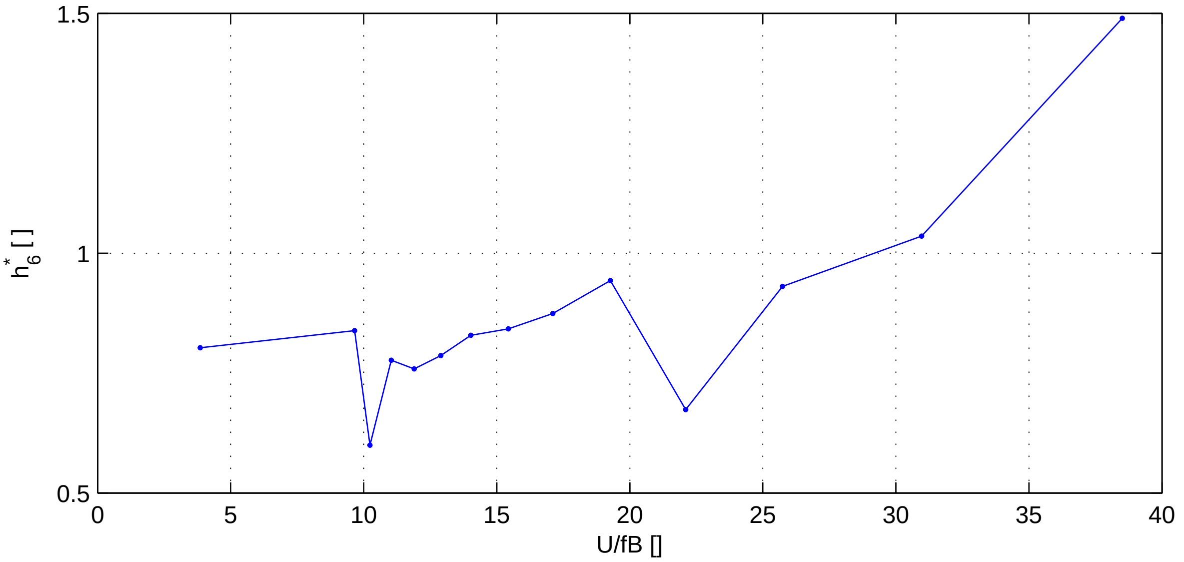

Figure Q.24: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	h_6^*
11.65	25.13	4.00	1.63	3.86	0.80
11.67	10.05	1.60	0.65	9.66	0.84
11.62	9.45	1.50	0.61	10.23	0.60
11.65	8.79	1.40	0.57	11.03	0.78
11.66	8.16	1.30	0.53	11.89	0.76
11.67	7.52	1.20	0.49	12.90	0.79
11.63	6.90	1.10	0.45	14.02	0.83
11.66	6.28	1.00	0.41	15.44	0.84
11.64	5.66	0.90	0.37	17.11	0.87
11.64	5.03	0.80	0.33	19.27	0.94
11.67	4.39	0.70	0.28	22.10	0.67
11.67	3.77	0.60	0.24	25.74	0.93
11.69	3.14	0.50	0.20	30.97	1.04
11.63	2.51	0.40	0.16	38.51	1.49

Table Q.26: h_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

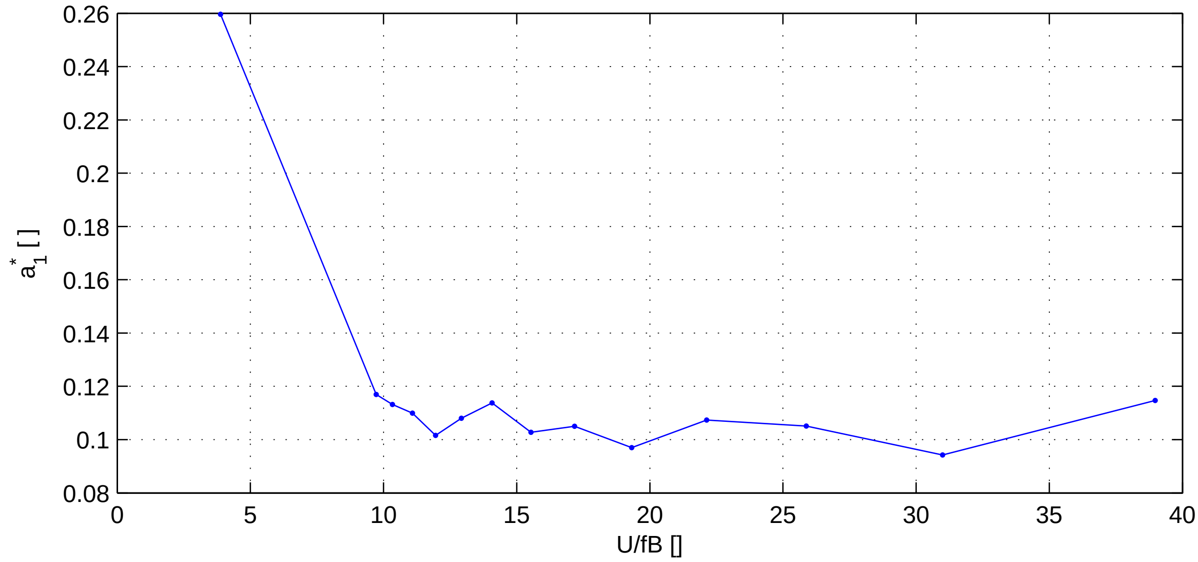

Figure Q.25: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_1^*
11.71	25.13	4.00	1.62	3.88	0.26
11.74	10.05	1.60	0.65	9.72	0.12
11.73	9.45	1.50	0.61	10.33	0.11
11.71	8.79	1.40	0.57	11.09	0.11
11.72	8.16	1.30	0.53	11.95	0.10
11.68	7.52	1.20	0.49	12.92	0.11
11.68	6.90	1.10	0.45	14.07	0.11
11.73	6.28	1.00	0.40	15.54	0.10
11.68	5.66	0.90	0.37	17.18	0.11
11.67	5.03	0.80	0.33	19.32	0.10
11.69	4.39	0.70	0.28	22.14	0.11
11.73	3.77	0.60	0.24	25.88	0.11
11.70	3.14	0.50	0.20	30.99	0.09
11.77	2.51	0.40	0.16	38.98	0.11

Table Q.27: a_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

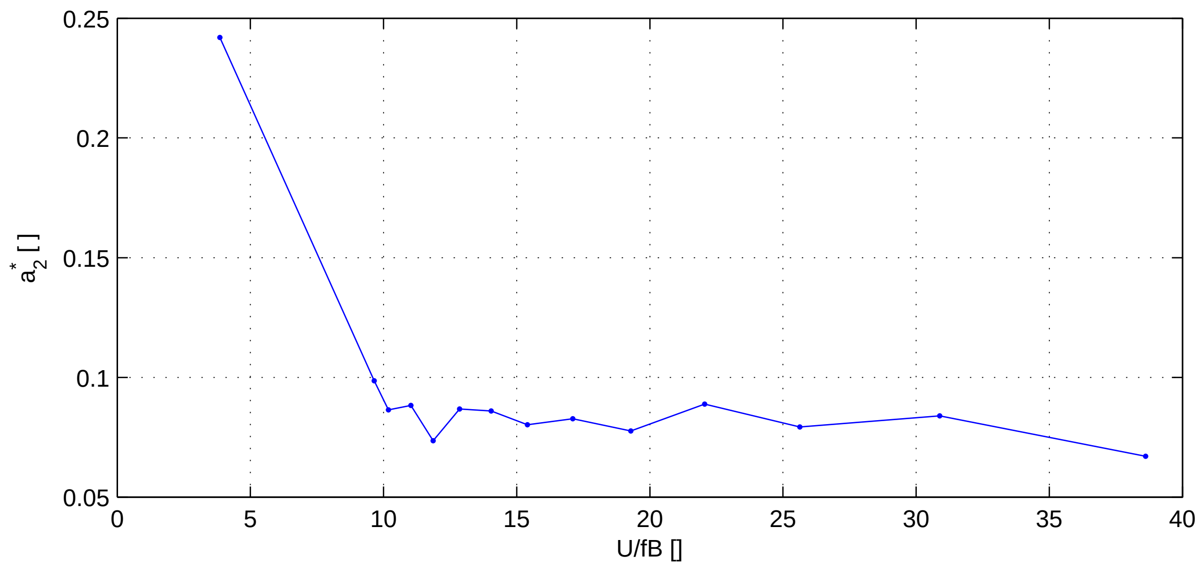

Figure Q.26: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_2^*
11.63	25.13	4.00	1.63	3.85	0.24
11.66	10.05	1.60	0.65	9.65	0.10
11.57	9.45	1.50	0.62	10.19	0.09
11.64	8.79	1.40	0.57	11.03	0.09
11.63	8.16	1.30	0.53	11.86	0.07
11.62	7.52	1.20	0.49	12.85	0.09
11.65	6.90	1.10	0.45	14.04	0.09
11.63	6.28	1.00	0.41	15.40	0.08
11.63	5.66	0.90	0.37	17.10	0.08
11.65	5.03	0.80	0.33	19.28	0.08
11.65	4.39	0.70	0.28	22.06	0.09
11.62	3.77	0.60	0.25	25.64	0.08
11.66	3.14	0.50	0.20	30.88	0.08
11.66	2.51	0.40	0.16	38.61	0.07

Table Q.28: a_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

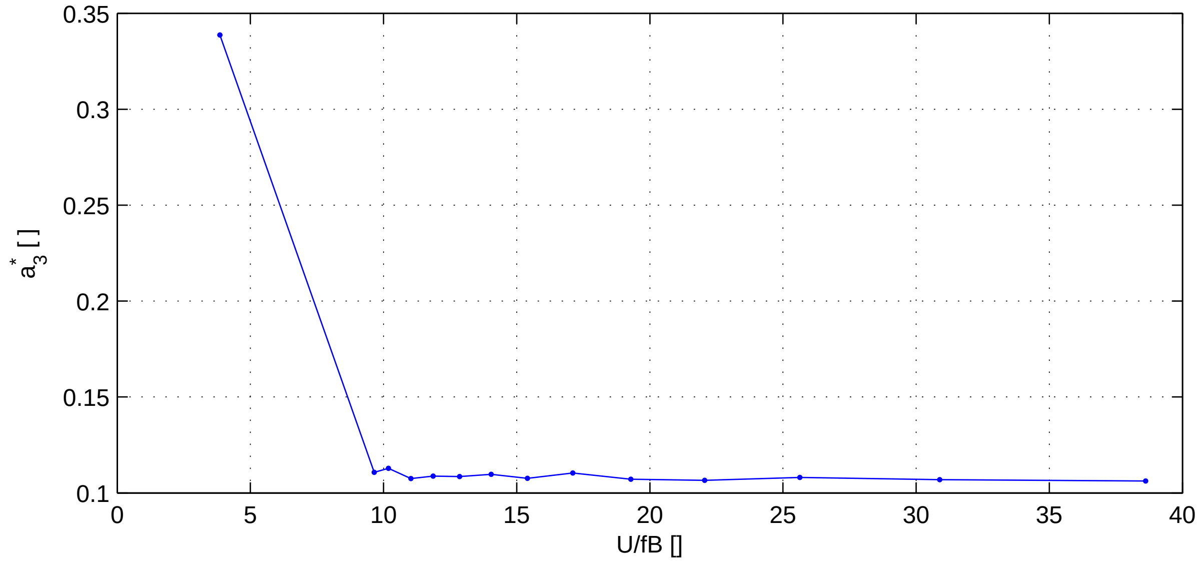

Figure Q.27: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_3^*
11.63	25.13	4.00	1.63	3.85	0.34
11.66	10.05	1.60	0.65	9.65	0.11
11.57	9.45	1.50	0.62	10.19	0.11
11.64	8.79	1.40	0.57	11.03	0.11
11.63	8.16	1.30	0.53	11.86	0.11
11.62	7.52	1.20	0.49	12.85	0.11
11.65	6.90	1.10	0.45	14.04	0.11
11.63	6.28	1.00	0.41	15.40	0.11
11.63	5.66	0.90	0.37	17.10	0.11
11.65	5.03	0.80	0.33	19.28	0.11
11.65	4.39	0.70	0.28	22.06	0.11
11.62	3.77	0.60	0.25	25.64	0.11
11.66	3.14	0.50	0.20	30.88	0.11
11.66	2.51	0.40	0.16	38.61	0.11

Table Q.29: a_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

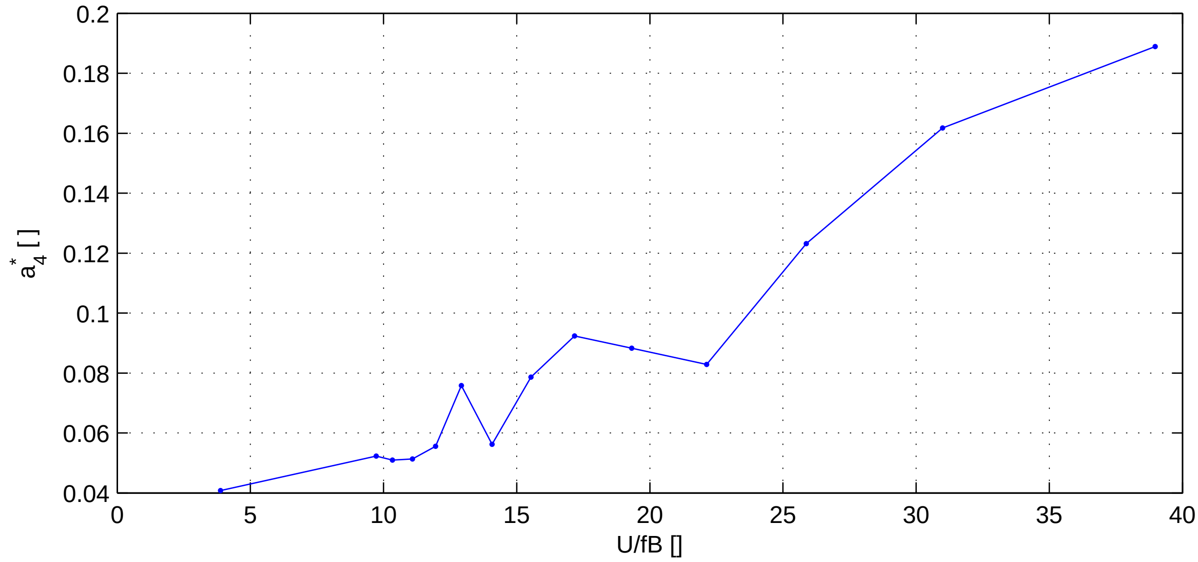

Figure Q.28: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_4^*
11.71	25.13	4.00	1.62	3.88	0.04
11.74	10.05	1.60	0.65	9.72	0.05
11.73	9.45	1.50	0.61	10.33	0.05
11.71	8.79	1.40	0.57	11.09	0.05
11.72	8.16	1.30	0.53	11.95	0.06
11.68	7.52	1.20	0.49	12.92	0.08
11.68	6.90	1.10	0.45	14.07	0.06
11.73	6.28	1.00	0.40	15.54	0.08
11.68	5.66	0.90	0.37	17.18	0.09
11.67	5.03	0.80	0.33	19.32	0.09
11.69	4.39	0.70	0.28	22.14	0.08
11.73	3.77	0.60	0.24	25.88	0.12
11.70	3.14	0.50	0.20	30.99	0.16
11.77	2.51	0.40	0.16	38.98	0.19

Table Q.30: a_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

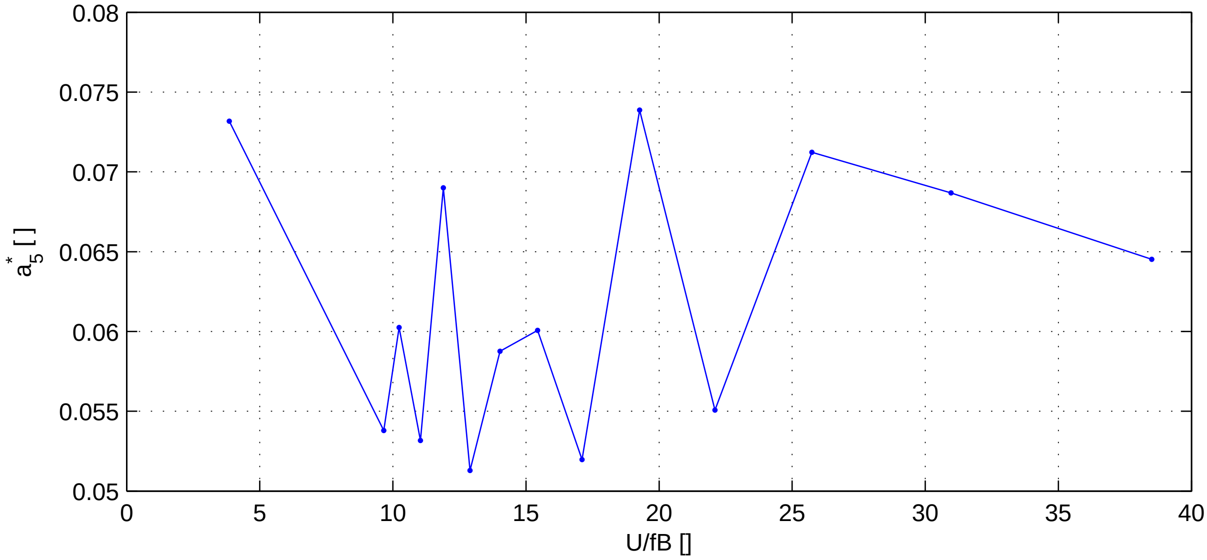

Figure Q.29: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_5^*
11.65	25.13	4.00	1.63	3.86	0.07
11.67	10.05	1.60	0.65	9.66	0.05
11.62	9.45	1.50	0.61	10.23	0.06
11.65	8.79	1.40	0.57	11.03	0.05
11.66	8.16	1.30	0.53	11.89	0.07
11.67	7.52	1.20	0.49	12.90	0.05
11.63	6.90	1.10	0.45	14.02	0.06
11.66	6.28	1.00	0.41	15.44	0.06
11.64	5.66	0.90	0.37	17.11	0.05
11.64	5.03	0.80	0.33	19.27	0.07
11.67	4.39	0.70	0.28	22.10	0.06
11.67	3.77	0.60	0.24	25.74	0.07
11.69	3.14	0.50	0.20	30.97	0.07
11.63	2.51	0.40	0.16	38.51	0.06

Table Q.31: a_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

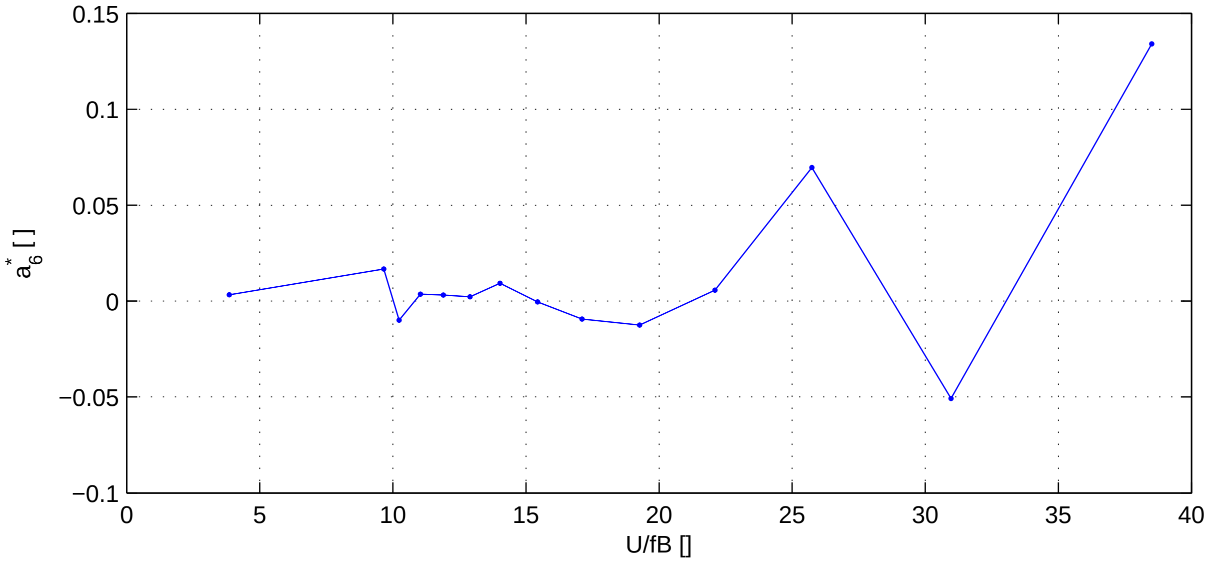

Figure Q.30: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	a_6^*
11.65	25.13	4.00	1.63	3.86	0.00
11.67	10.05	1.60	0.65	9.66	0.02
11.62	9.45	1.50	0.61	10.23	−0.01
11.65	8.79	1.40	0.57	11.03	0.00
11.66	8.16	1.30	0.53	11.89	0.00
11.67	7.52	1.20	0.49	12.90	0.00
11.63	6.90	1.10	0.45	14.02	0.01
11.66	6.28	1.00	0.41	15.44	−0.00
11.64	5.66	0.90	0.37	17.11	−0.01
11.64	5.03	0.80	0.33	19.27	−0.01
11.67	4.39	0.70	0.28	22.10	0.01
11.67	3.77	0.60	0.24	25.74	0.07
11.69	3.14	0.50	0.20	30.97	−0.05
11.63	2.51	0.40	0.16	38.51	0.13

Table Q.32: a_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

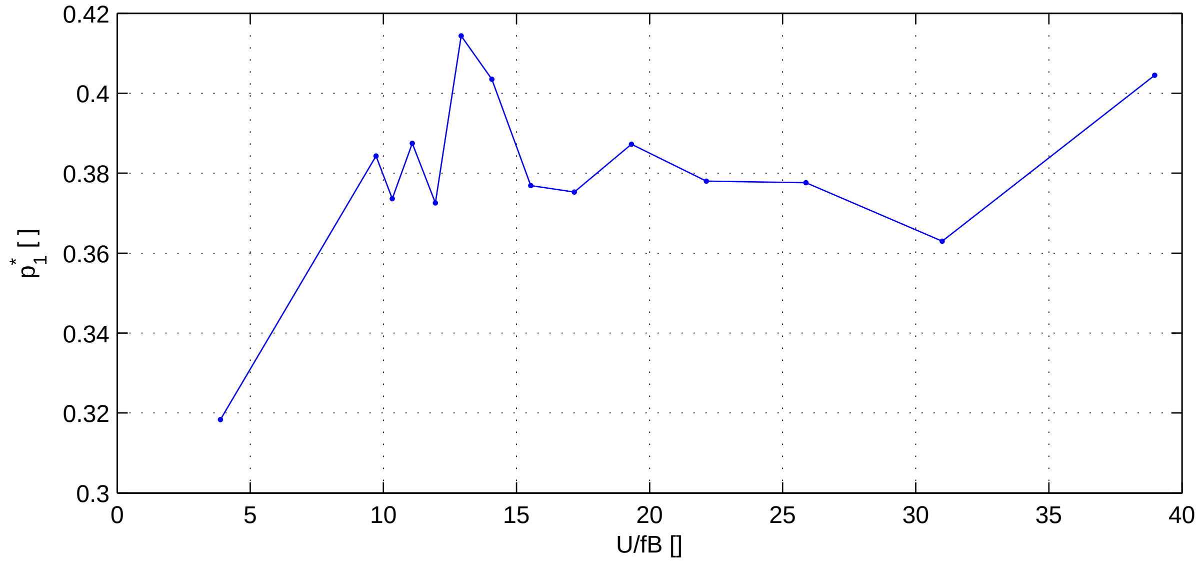

Figure Q.31: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

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U m/s	Omega rad/s	f /s	K	U/fB	p_1^*
11.71	25.13	4.00	1.62	3.88	0.32
11.74	10.05	1.60	0.65	9.72	0.38
11.73	9.45	1.50	0.61	10.33	0.37
11.71	8.79	1.40	0.57	11.09	0.39
11.72	8.16	1.30	0.53	11.95	0.37
11.68	7.52	1.20	0.49	12.92	0.41
11.68	6.90	1.10	0.45	14.07	0.40
11.73	6.28	1.00	0.40	15.54	0.38
11.68	5.66	0.90	0.37	17.18	0.38
11.67	5.03	0.80	0.33	19.32	0.39
11.69	4.39	0.70	0.28	22.14	0.38
11.73	3.77	0.60	0.24	25.88	0.38
11.70	3.14	0.50	0.20	30.99	0.36
11.77	2.51	0.40	0.16	38.98	0.40

Table Q.33: p_1^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

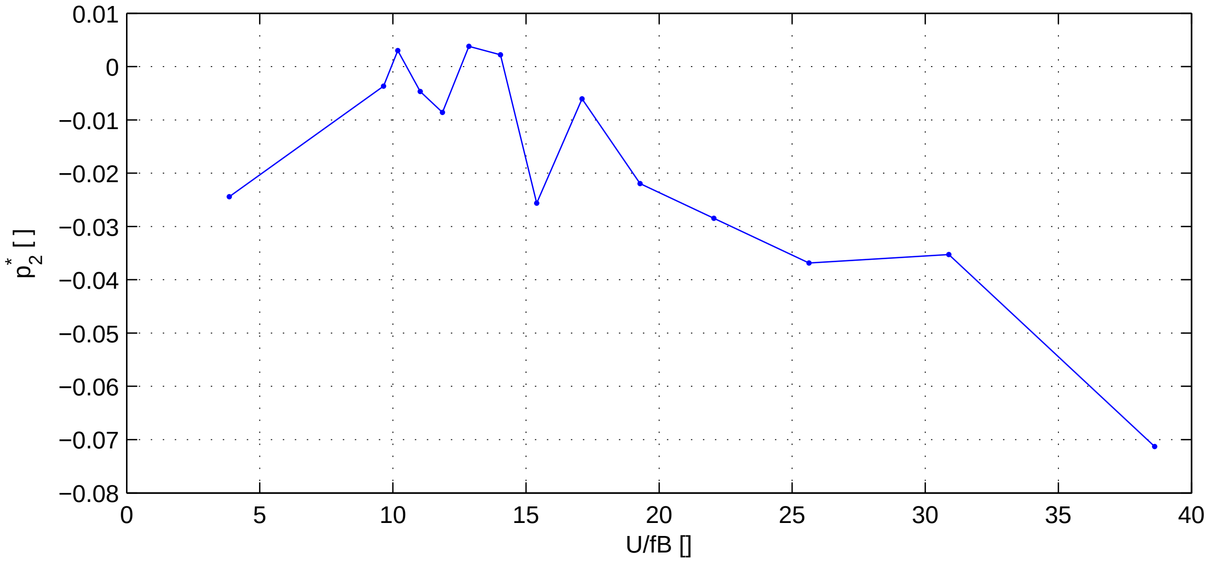

Figure Q.32: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_2^*
11.63	25.13	4.00	1.63	3.85	−0.02
11.66	10.05	1.60	0.65	9.65	−0.00
11.57	9.45	1.50	0.62	10.19	0.00
11.64	8.79	1.40	0.57	11.03	−0.00
11.63	8.16	1.30	0.53	11.86	−0.01
11.62	7.52	1.20	0.49	12.85	0.00
11.65	6.90	1.10	0.45	14.04	0.00
11.63	6.28	1.00	0.41	15.40	−0.03
11.63	5.66	0.90	0.37	17.10	−0.01
11.65	5.03	0.80	0.33	19.28	−0.02
11.65	4.39	0.70	0.28	22.06	−0.03
11.62	3.77	0.60	0.25	25.64	−0.04
11.66	3.14	0.50	0.20	30.88	−0.04
11.66	2.51	0.40	0.16	38.61	−0.07

Table Q.34: p_2^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

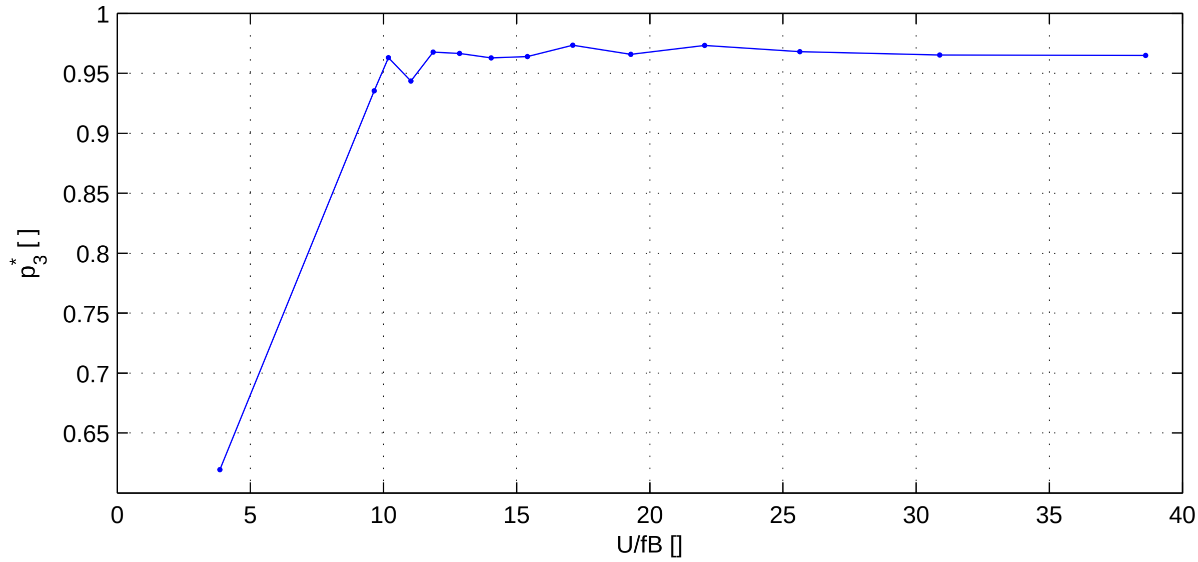

Figure Q.33: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_3^*
11.63	25.13	4.00	1.63	3.85	0.62
11.66	10.05	1.60	0.65	9.65	0.94
11.57	9.45	1.50	0.62	10.19	0.96
11.64	8.79	1.40	0.57	11.03	0.94
11.63	8.16	1.30	0.53	11.86	0.97
11.62	7.52	1.20	0.49	12.85	0.97
11.65	6.90	1.10	0.45	14.04	0.96
11.63	6.28	1.00	0.41	15.40	0.96
11.63	5.66	0.90	0.37	17.10	0.97
11.65	5.03	0.80	0.33	19.28	0.97
11.65	4.39	0.70	0.28	22.06	0.97
11.62	3.77	0.60	0.25	25.64	0.97
11.66	3.14	0.50	0.20	30.88	0.97
11.66	2.51	0.40	0.16	38.61	0.96

Table Q.35: p_3^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

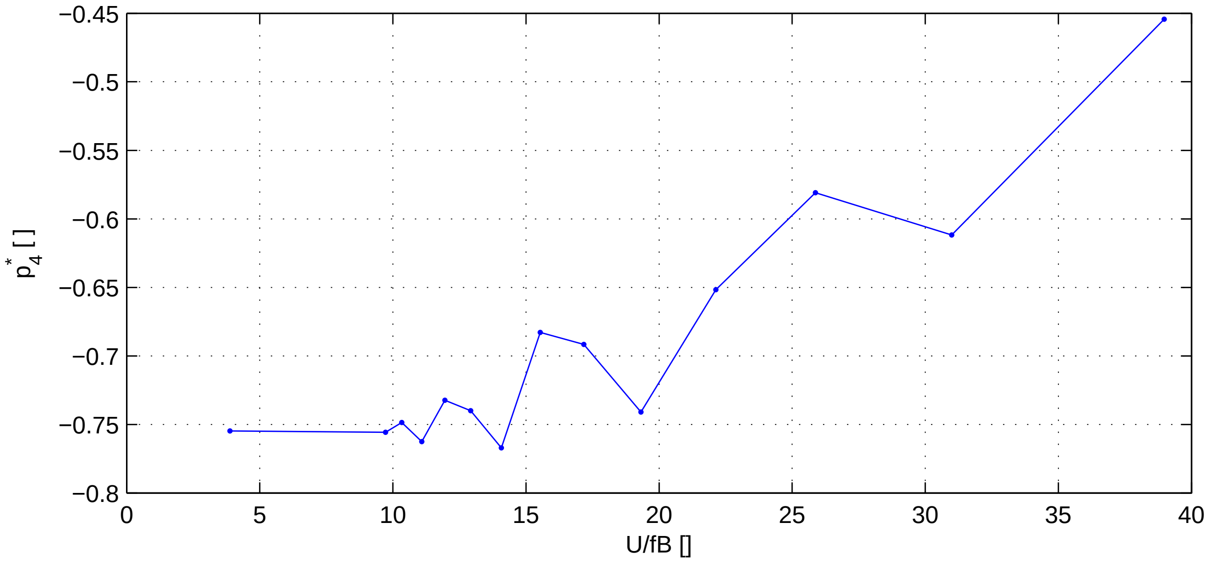

Figure Q.34: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_4^*
11.71	25.13	4.00	1.62	3.88	−0.75
11.74	10.05	1.60	0.65	9.72	−0.76
11.73	9.45	1.50	0.61	10.33	−0.75
11.71	8.79	1.40	0.57	11.09	−0.76
11.72	8.16	1.30	0.53	11.95	−0.73
11.68	7.52	1.20	0.49	12.92	−0.74
11.68	6.90	1.10	0.45	14.07	−0.77
11.73	6.28	1.00	0.40	15.54	−0.68
11.68	5.66	0.90	0.37	17.18	−0.69
11.67	5.03	0.80	0.33	19.32	−0.74
11.69	4.39	0.70	0.28	22.14	−0.65
11.73	3.77	0.60	0.24	25.88	−0.58
11.70	3.14	0.50	0.20	30.99	−0.61
11.77	2.51	0.40	0.16	38.98	−0.45

Table Q.36: p_4^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

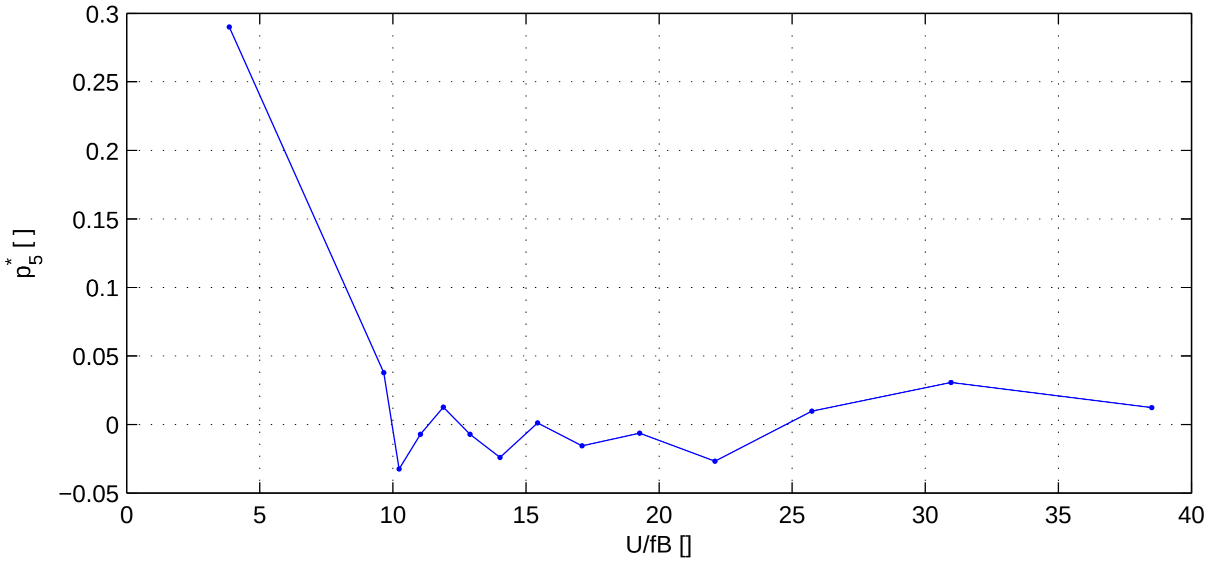

Figure Q.35: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_5^*
11.65	25.13	4.00	1.63	3.86	0.29
11.67	10.05	1.60	0.65	9.66	0.04
11.62	9.45	1.50	0.61	10.23	−0.03
11.65	8.79	1.40	0.57	11.03	−0.01
11.66	8.16	1.30	0.53	11.89	0.01
11.67	7.52	1.20	0.49	12.90	−0.01
11.63	6.90	1.10	0.45	14.02	−0.02
11.66	6.28	1.00	0.41	15.44	0.00
11.64	5.66	0.90	0.37	17.11	−0.02
11.64	5.03	0.80	0.33	19.27	−0.01
11.67	4.39	0.70	0.28	22.10	−0.03
11.67	3.77	0.60	0.24	25.74	0.01
11.69	3.14	0.50	0.20	30.97	0.03
11.63	2.51	0.40	0.16	38.51	0.01

Table Q.37: p_5^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

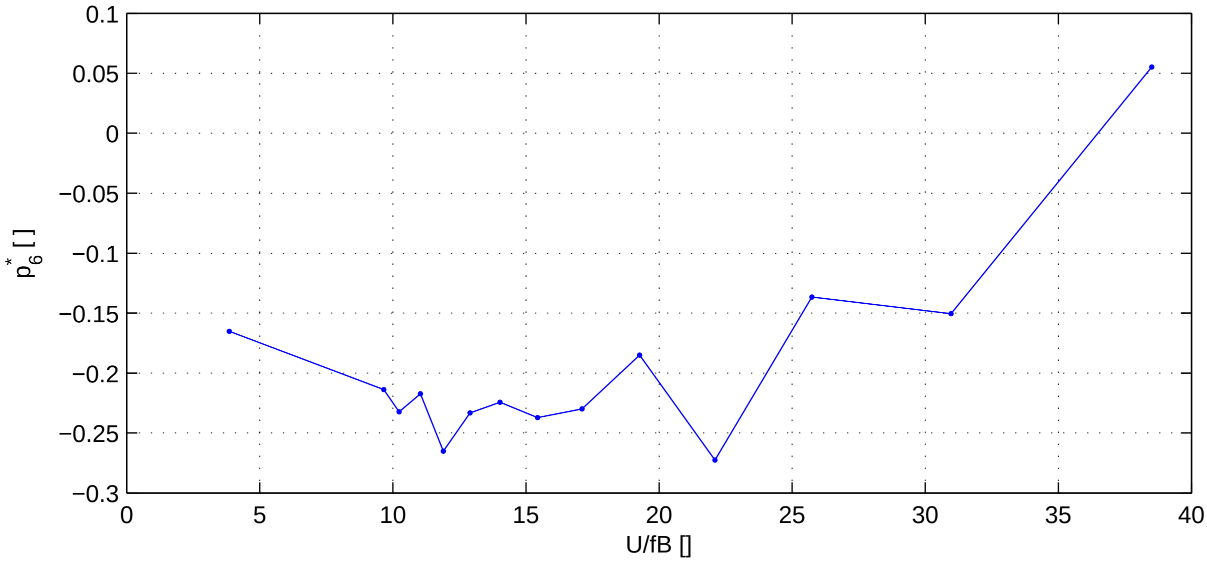

Figure Q.36: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

U m/s	Omega rad/s	f /s	K	U/fB	p_6^*
11.65	25.13	4.00	1.63	3.86	−0.17
11.67	10.05	1.60	0.65	9.66	−0.21
11.62	9.45	1.50	0.61	10.23	−0.23
11.65	8.79	1.40	0.57	11.03	−0.22
11.66	8.16	1.30	0.53	11.89	−0.27
11.67	7.52	1.20	0.49	12.90	−0.23
11.63	6.90	1.10	0.45	14.02	−0.22
11.66	6.28	1.00	0.41	15.44	−0.24
11.64	5.66	0.90	0.37	17.11	−0.23
11.64	5.03	0.80	0.33	19.27	−0.18
11.67	4.39	0.70	0.28	22.10	−0.27
11.67	3.77	0.60	0.24	25.74	−0.14
11.69	3.14	0.50	0.20	30.97	−0.15
11.63	2.51	0.40	0.16	38.51	0.06

Table Q.38: p_6^* as function of reduced velocity. Stretto di Messina. Ref. [5]. formulation.

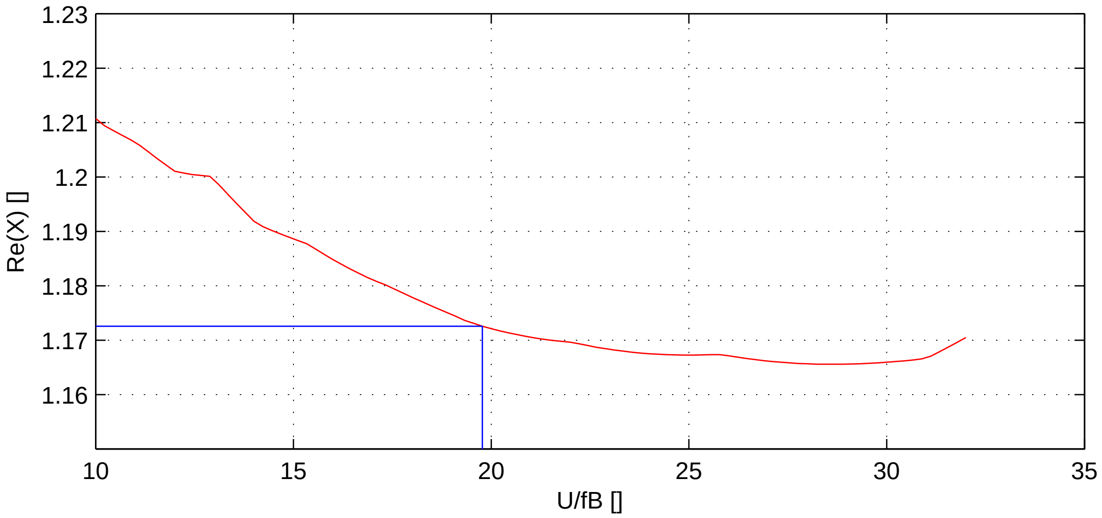

Figure Q.37: Real part of the solution to stability equantion

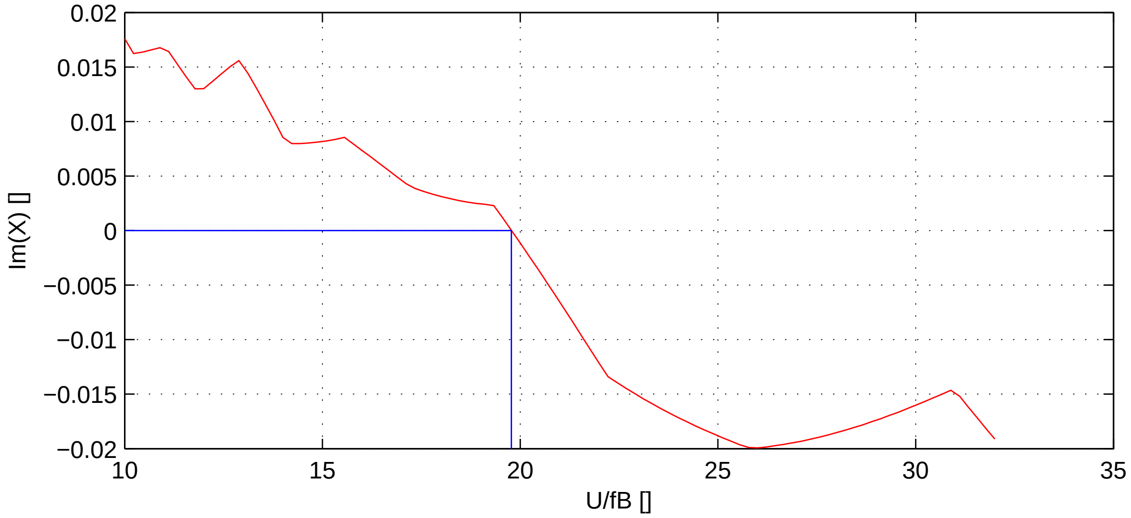

Figure Q.38: Imaginary part of the solution to stability equantion

V_{Crit} = 19.8

f_{Crit} = 0.0759 Hz

U_{Crit} = 90.6 m/s

References:

[1]: Scanlan, R.H. & Tomko, J.J., "Airfoil and Bridge Deck Flutter Derivatives". Proc.ASCE (97) EM6, 1971, pp. 1717−1737.
[2]: Scanlan, R.H., Béliveau, J.G. & Budlong, K.S., "Indicial Aerodynamic Functions for Bridge Decks". Proc.ASCE (100) EM4, 1974, pp.657−672.
[3]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Simultaneous Identification of 3−DOF Aeroelastic Parameters". ICWE, 1995, New Delhi, India.
[4]: Singh, L., Jones, N.P., Scanlan, R.H. and Lorendeaux, O, "Identification of Lateral Flutter Derivatives of Bridge Decks". Journal of Wind Engineering and Industrial Aerodynamics 60 (1996) 81−89.
[5]: Stretto di Messina, Technical specification for final and the executive plan for the bridge. Requirements and guidelines for the development of the project – Aerodynamic Design". Doc. Code. F.05.03, 22 Oct. 2004.

Appendix R

Result comparisons for different flow types

Smooth flow, Installation stage

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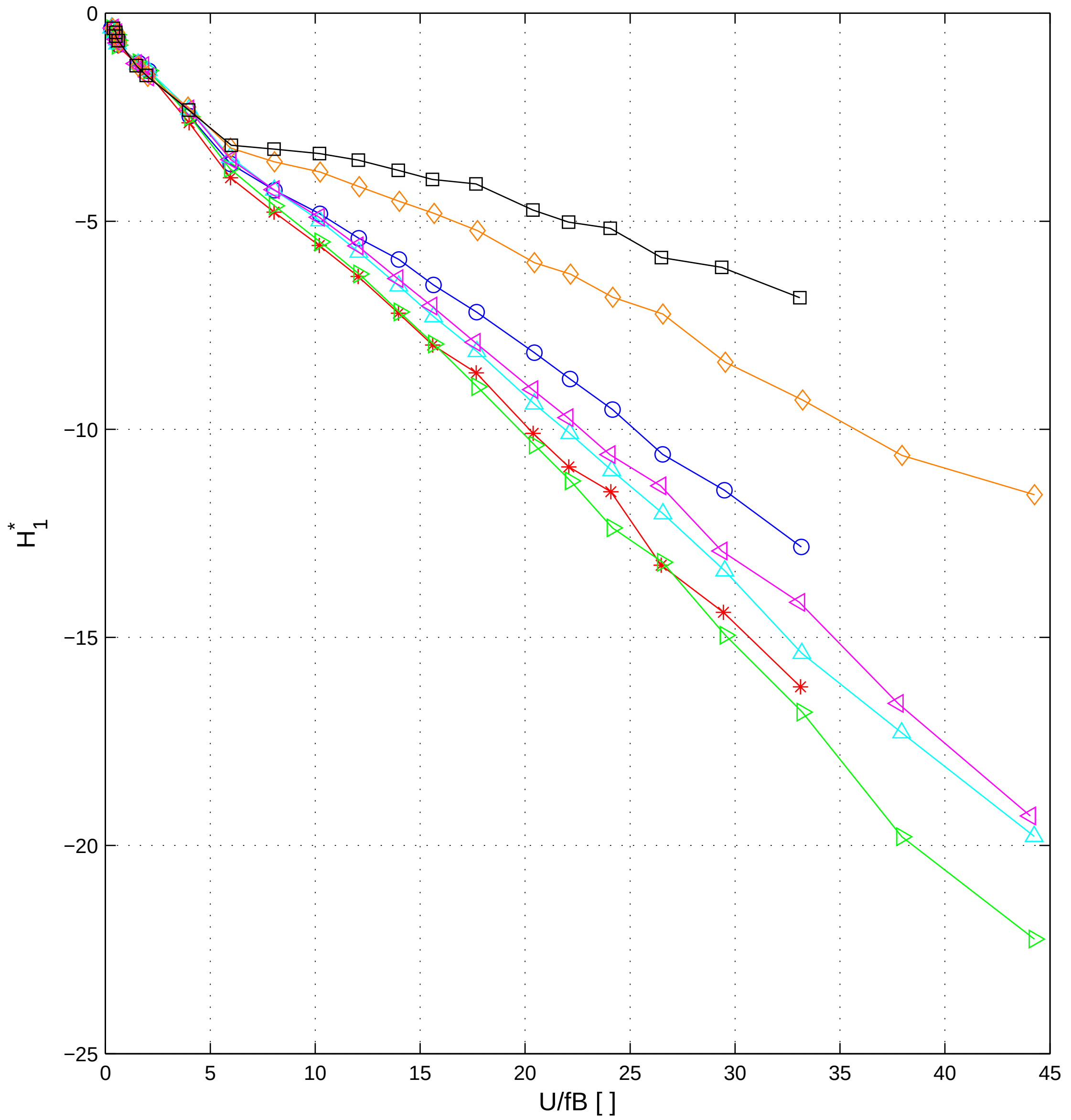
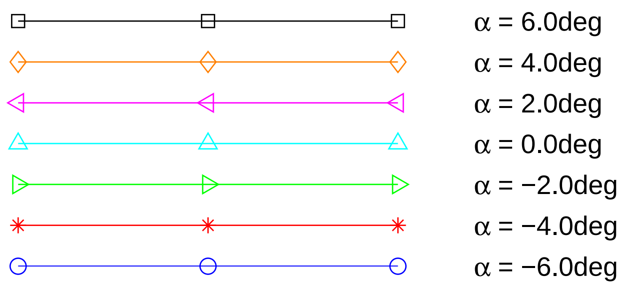


Figure R.1: Variation of coefficient H_1^* with angle of incidence



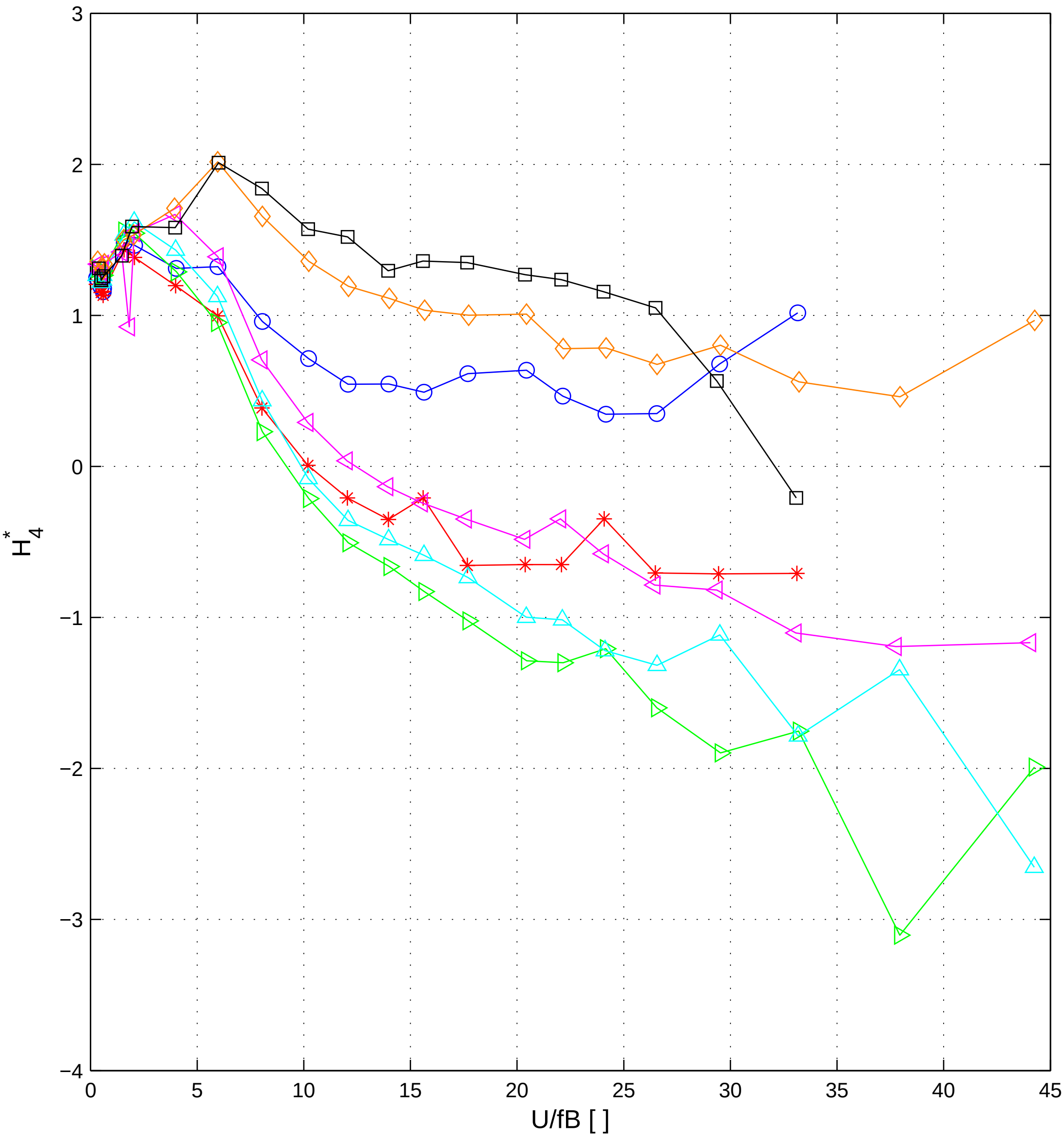
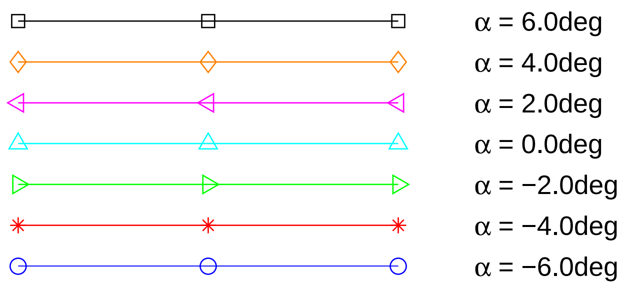


Figure R.2: Variation of coefficient H^*_4 with angle of incidence



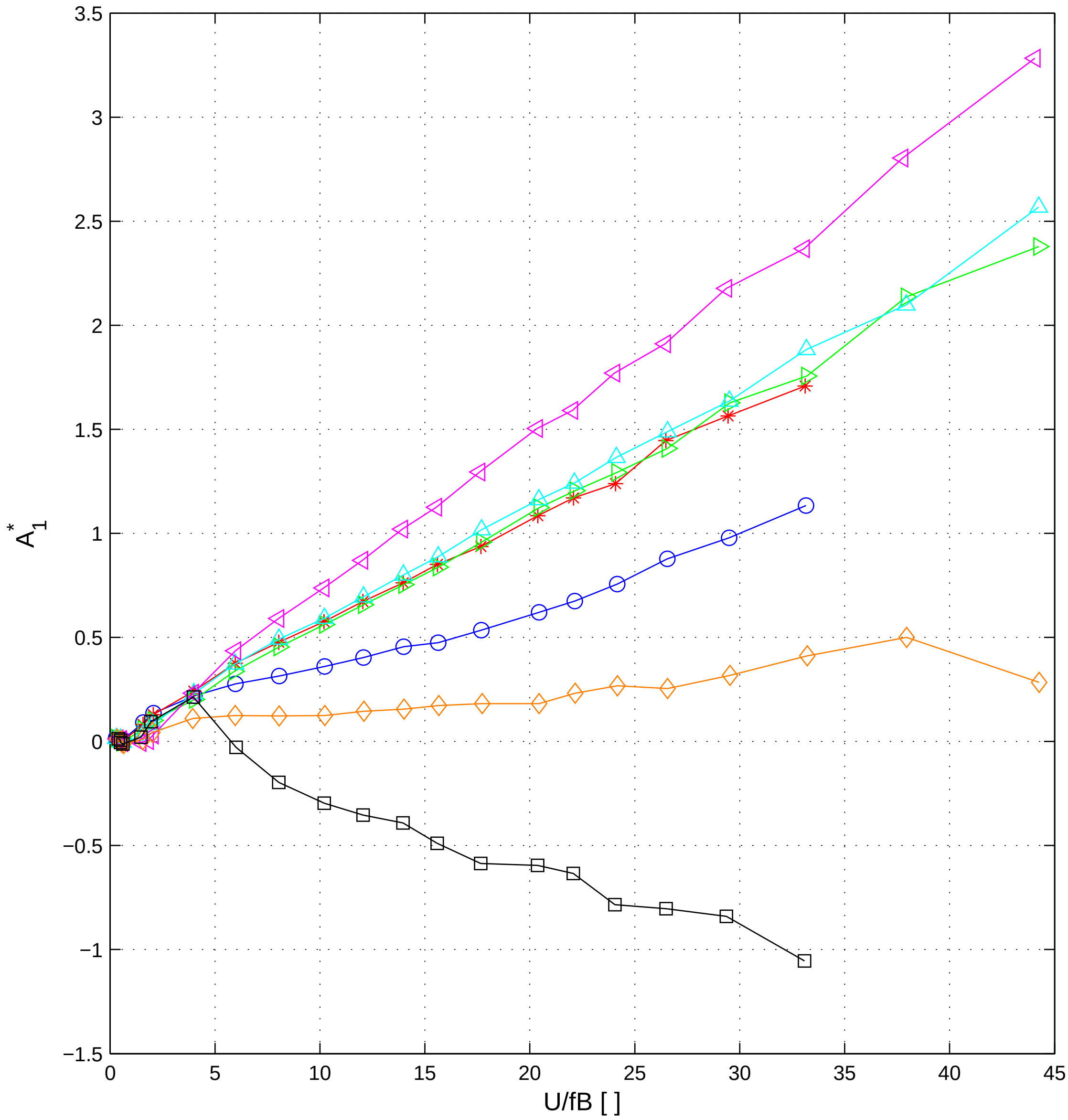
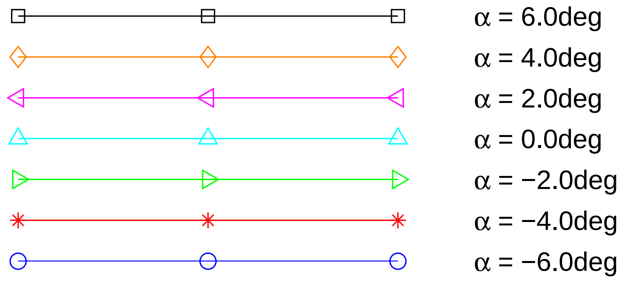


Figure R.3: Variation of coefficient A_1^* with angle of incidence



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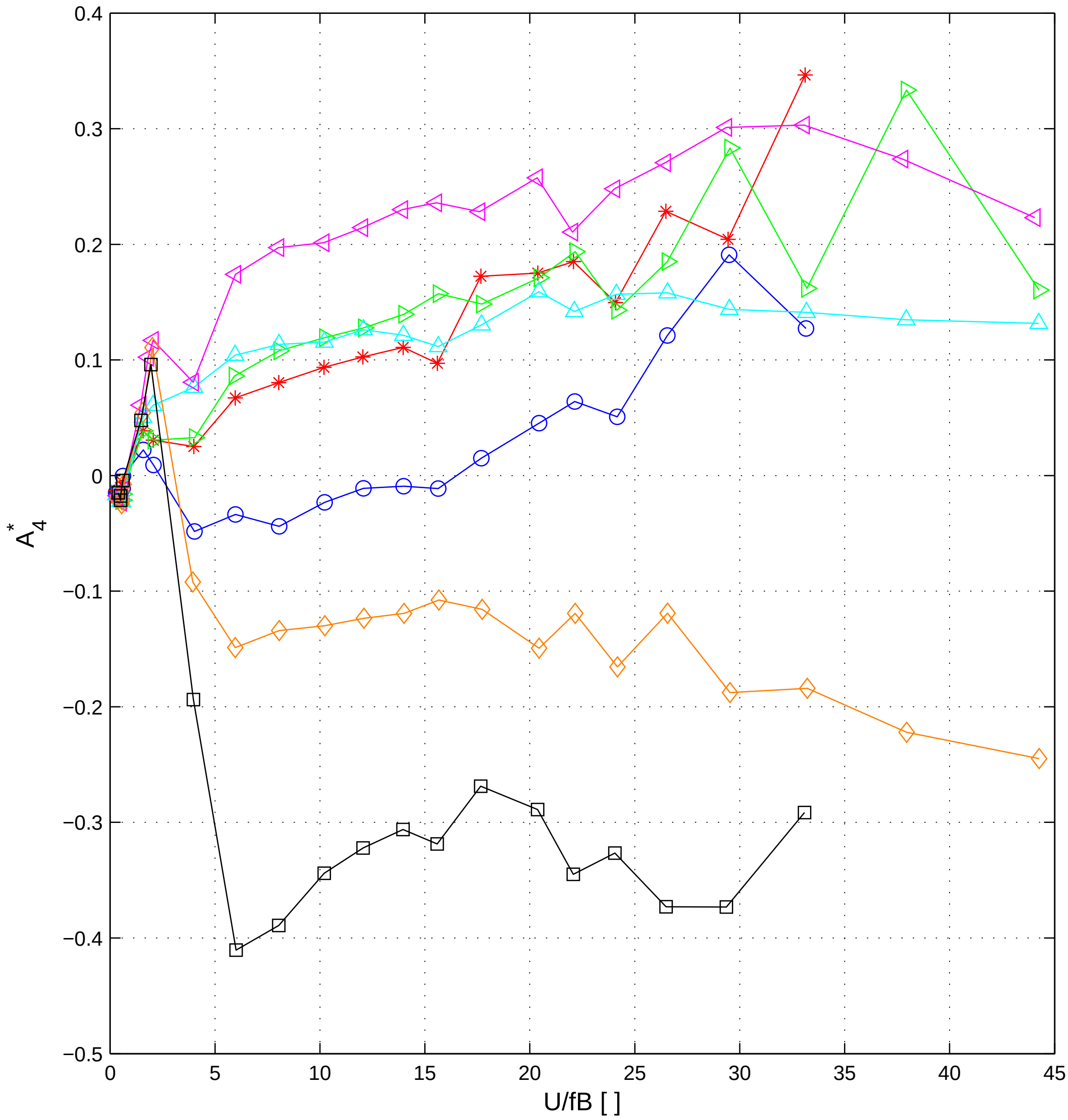
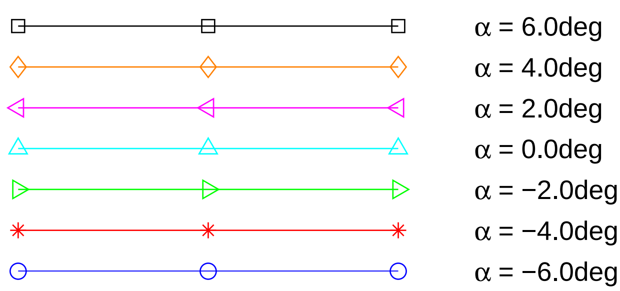


Figure R.4: Variation of coefficient A_4^* with angle of incidence



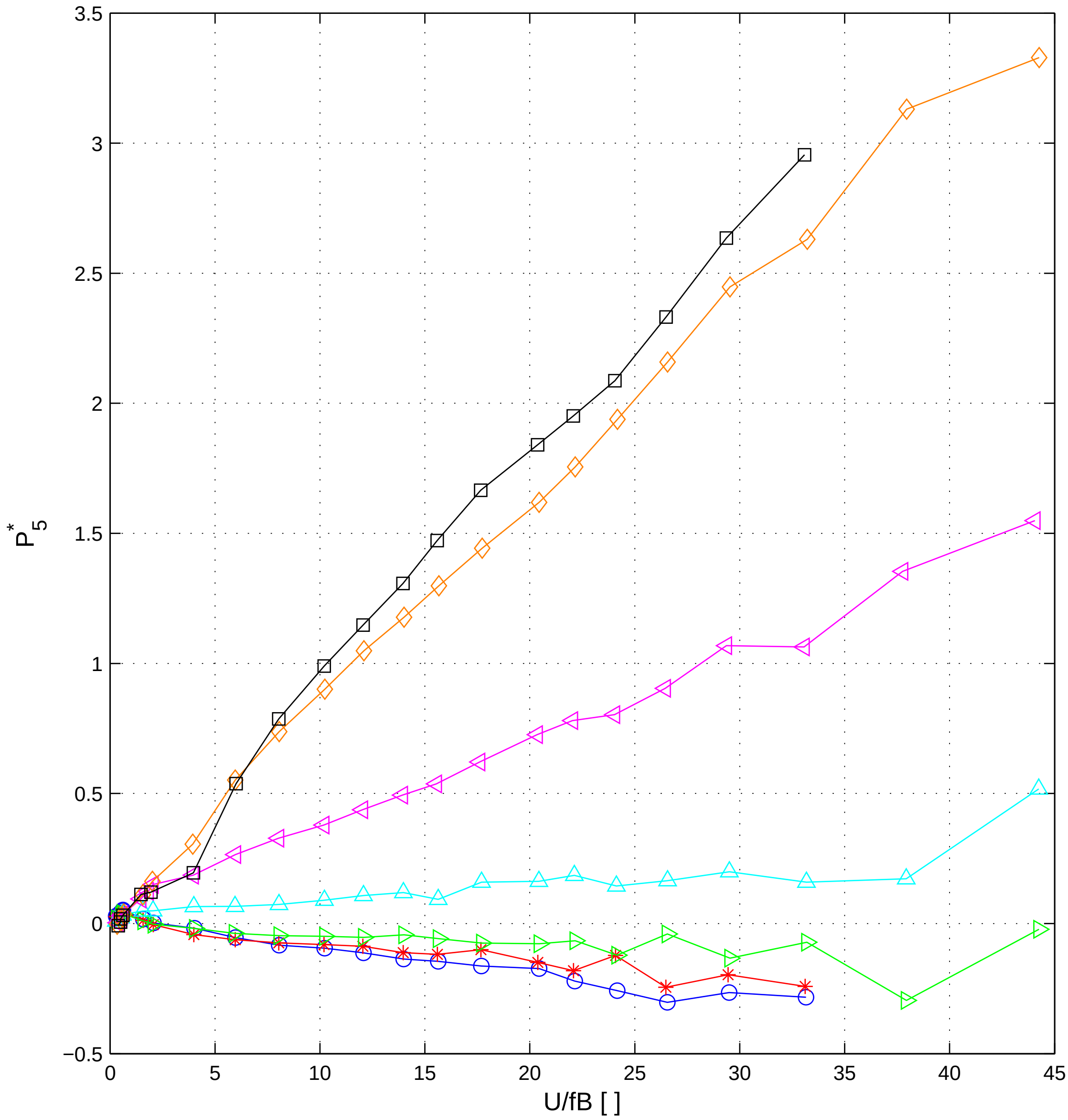
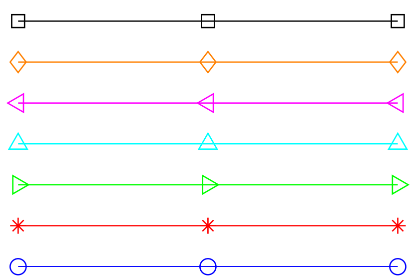


Figure R.5: Variation of coefficient P^*_5 with angle of incidence



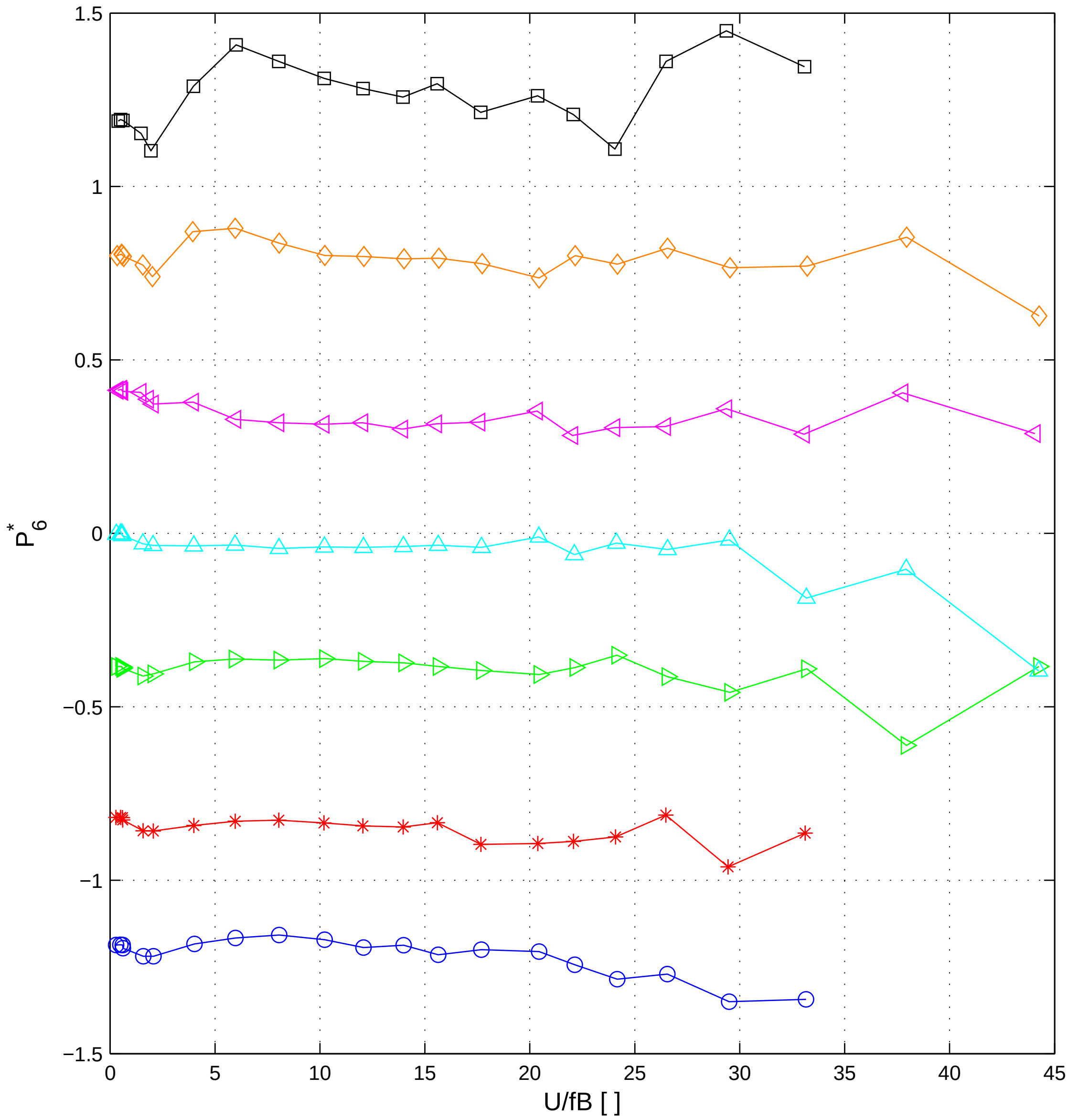
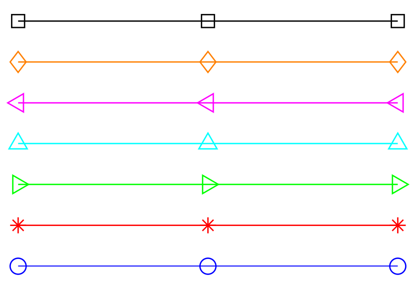


Figure R.6: Variation of coefficient P_6^* with angle of incidence



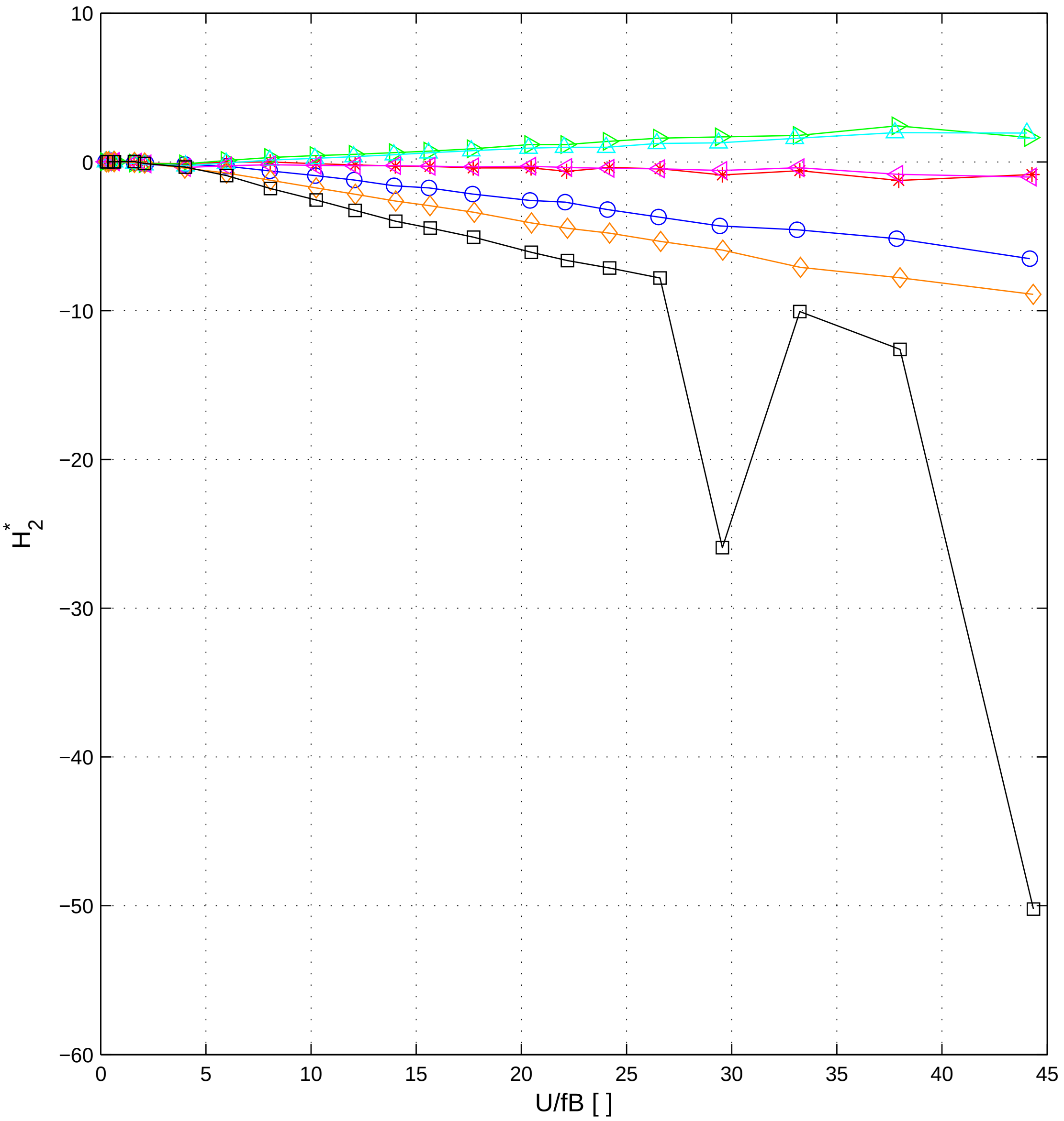
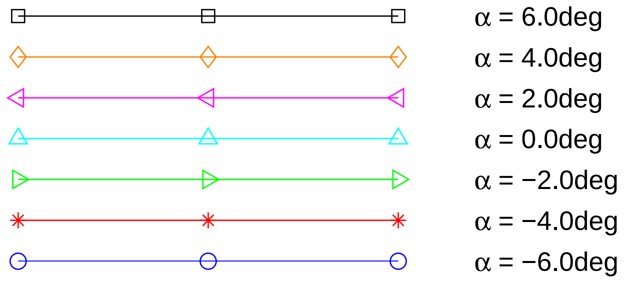


Figure R.7: Variation of coefficient H_2^* with angle of incidence



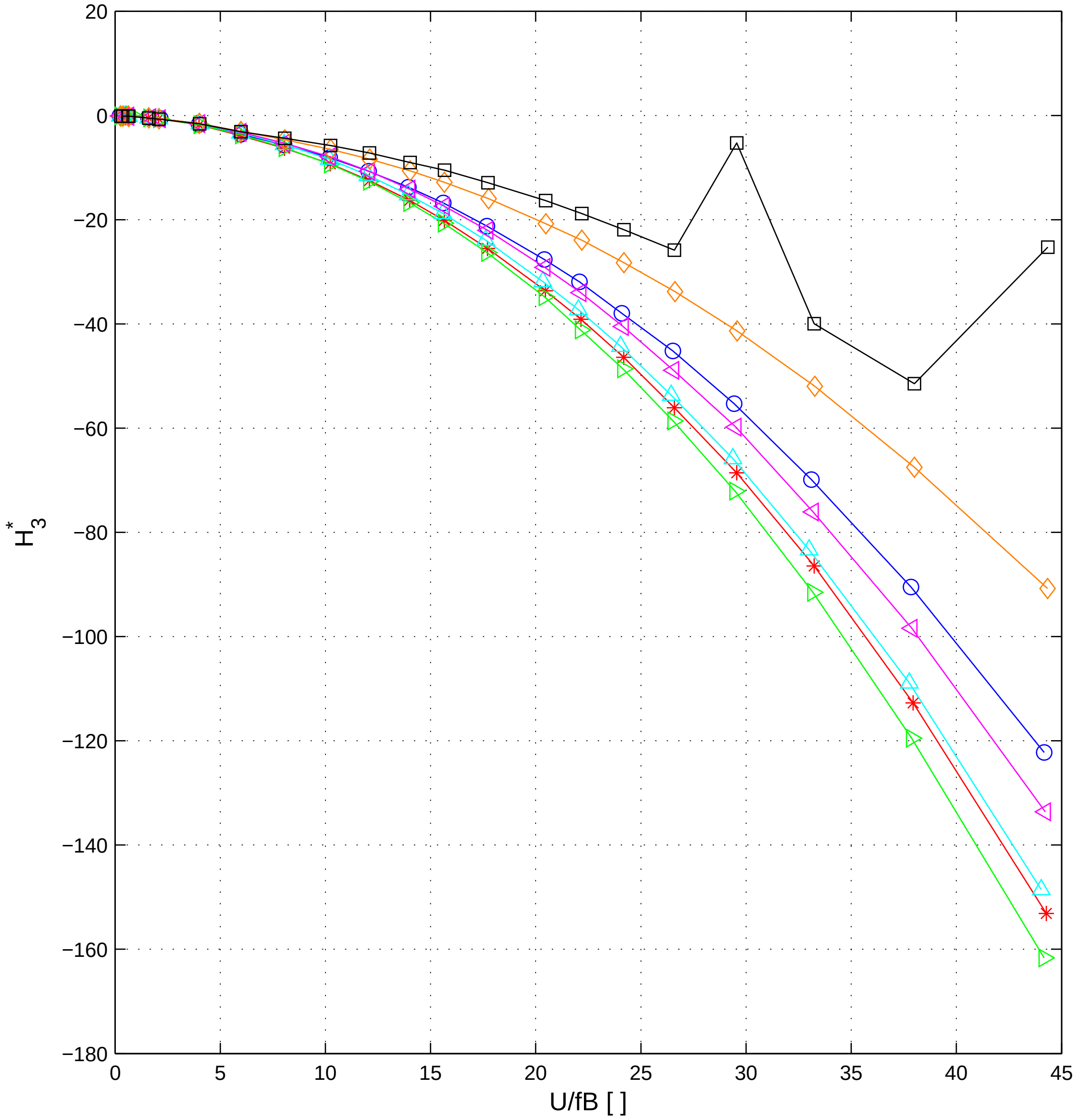
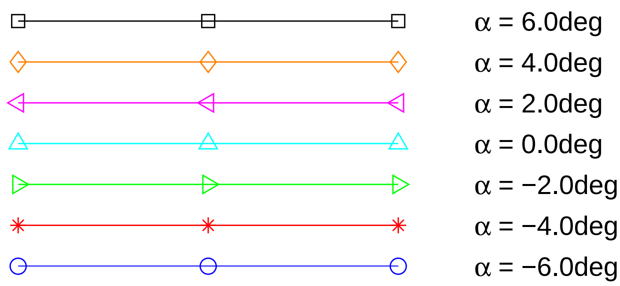


Figure R.8: Variation of coefficient H^*_3 with angle of incidence



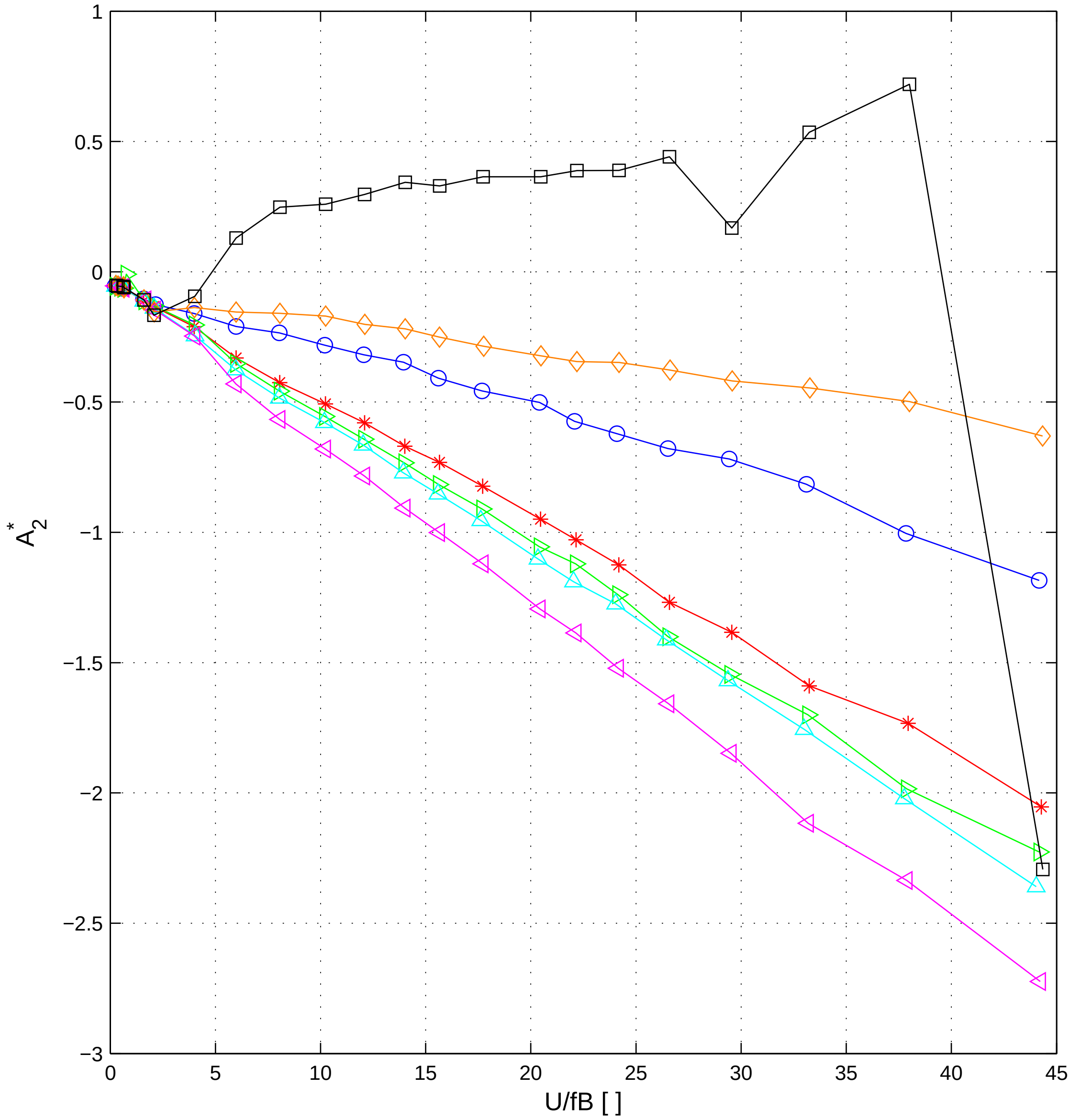
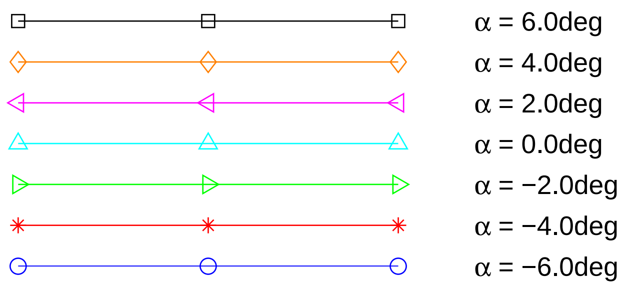


Figure R.9: Variation of coefficient A_2^* with angle of incidence



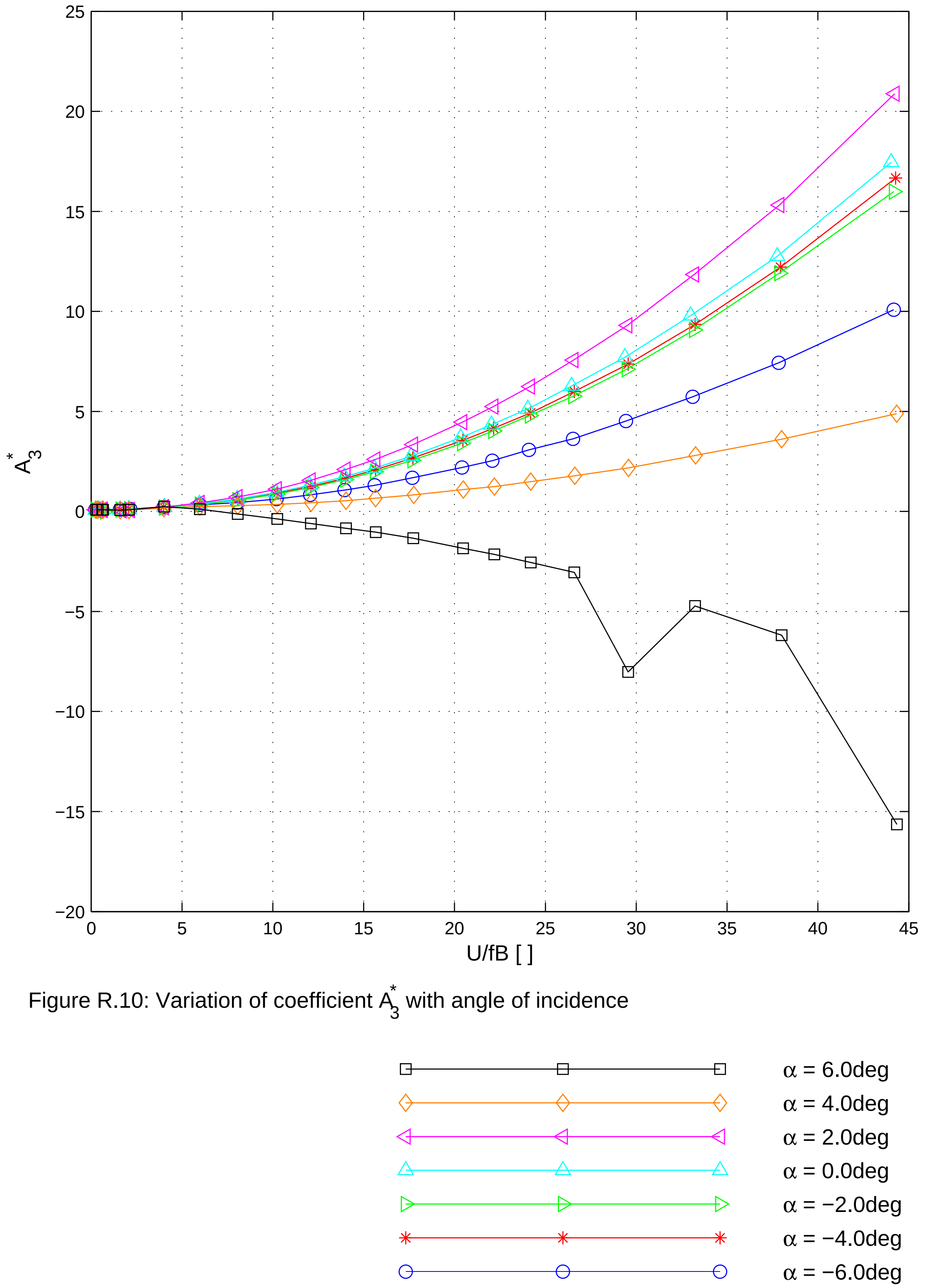


Figure R.10: Variation of coefficient A_3^* with angle of incidence

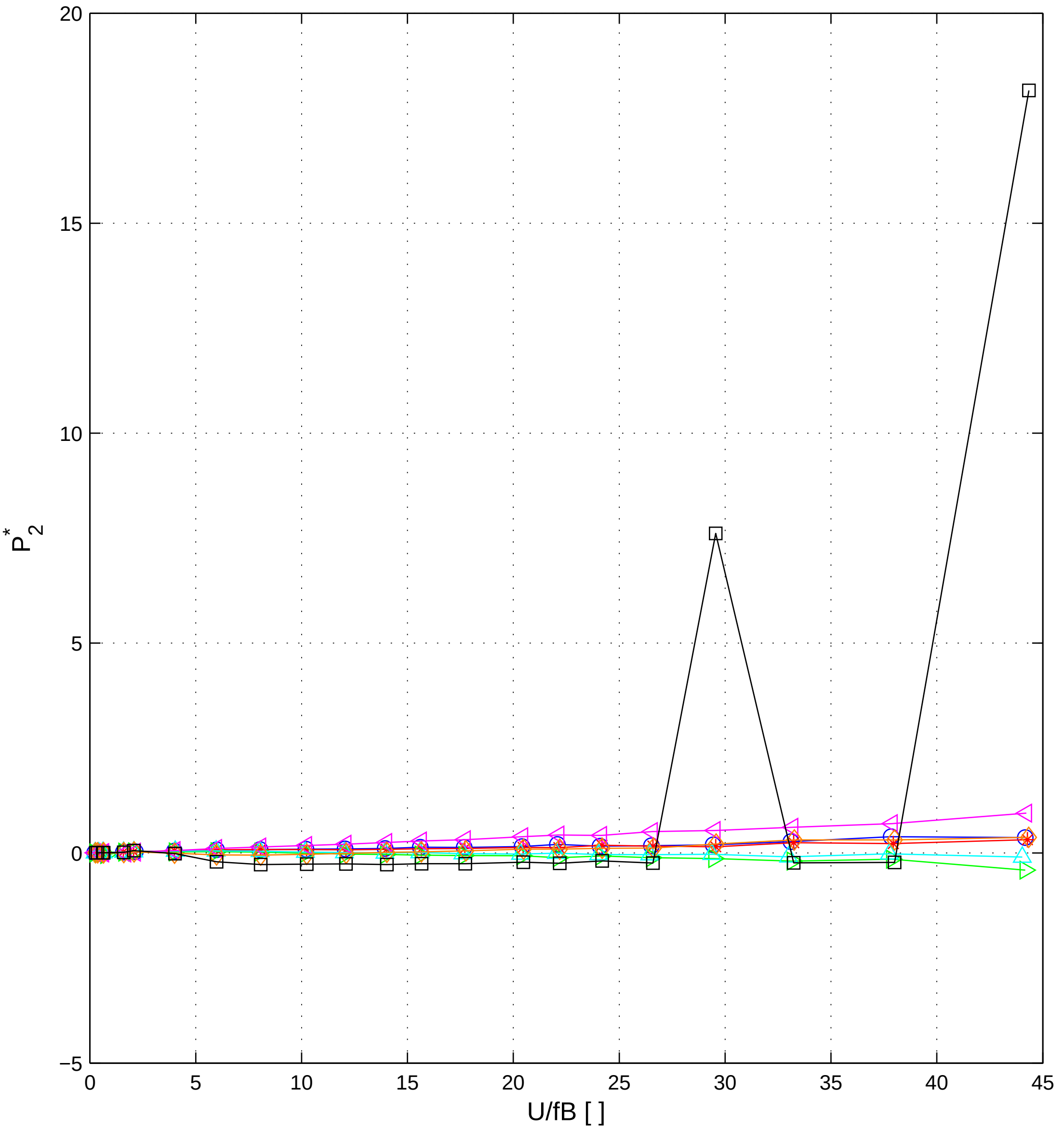
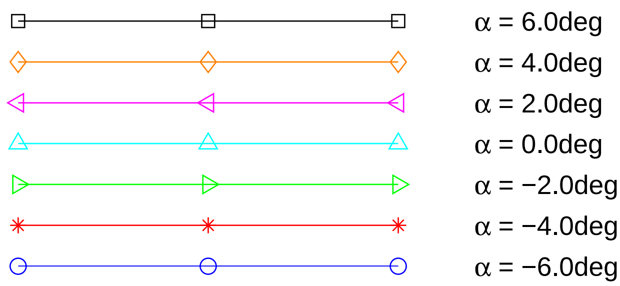


Figure R.11: Variation of coefficient P_2^* with angle of incidence



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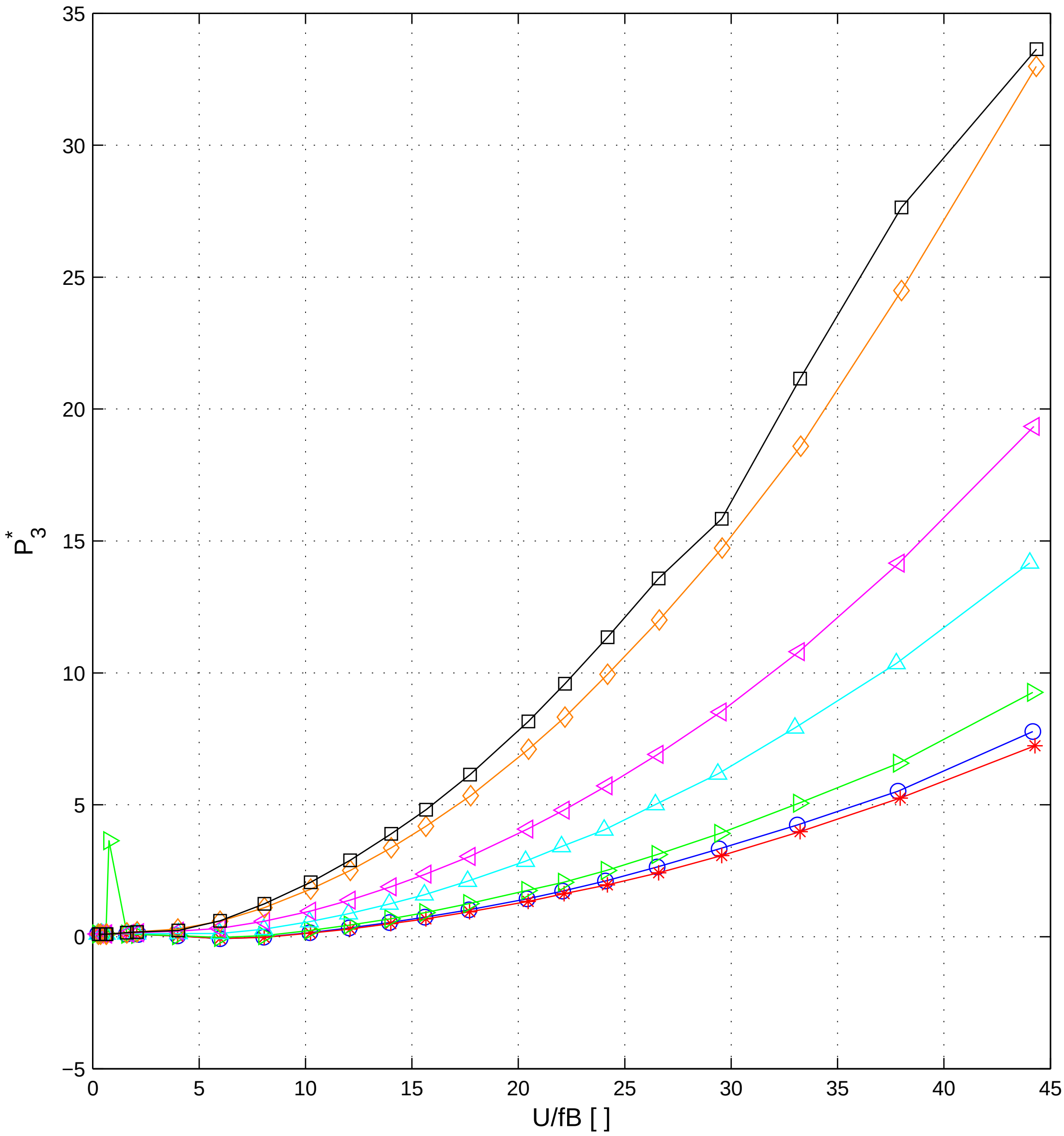
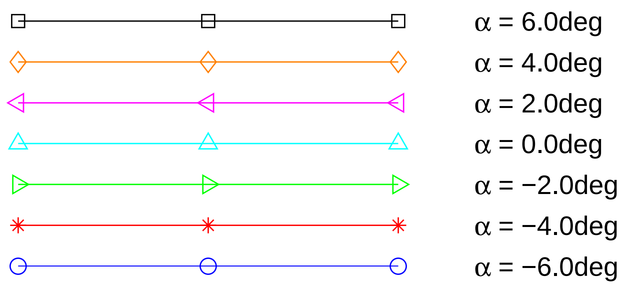


Figure R.12: Variation of coefficient P^*_3 with angle of incidence



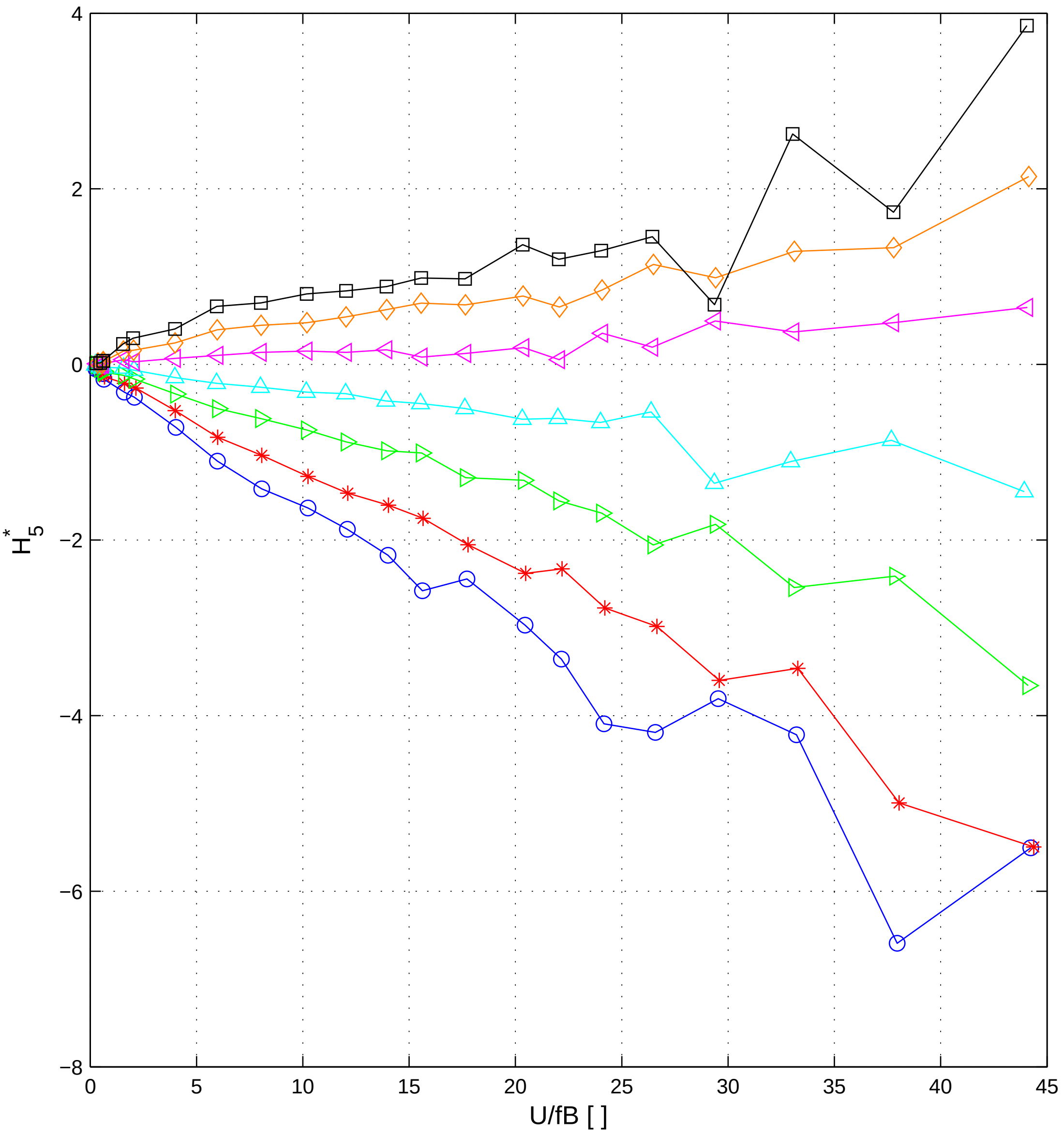
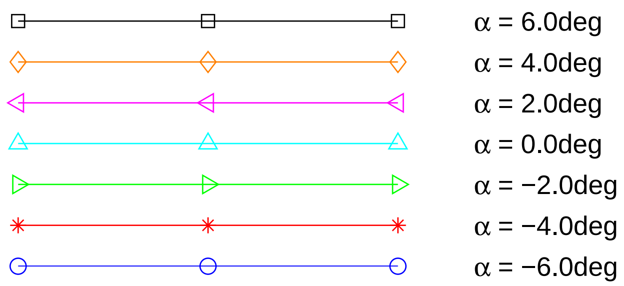


Figure R.13: Variation of coefficient H_5^* with angle of incidence



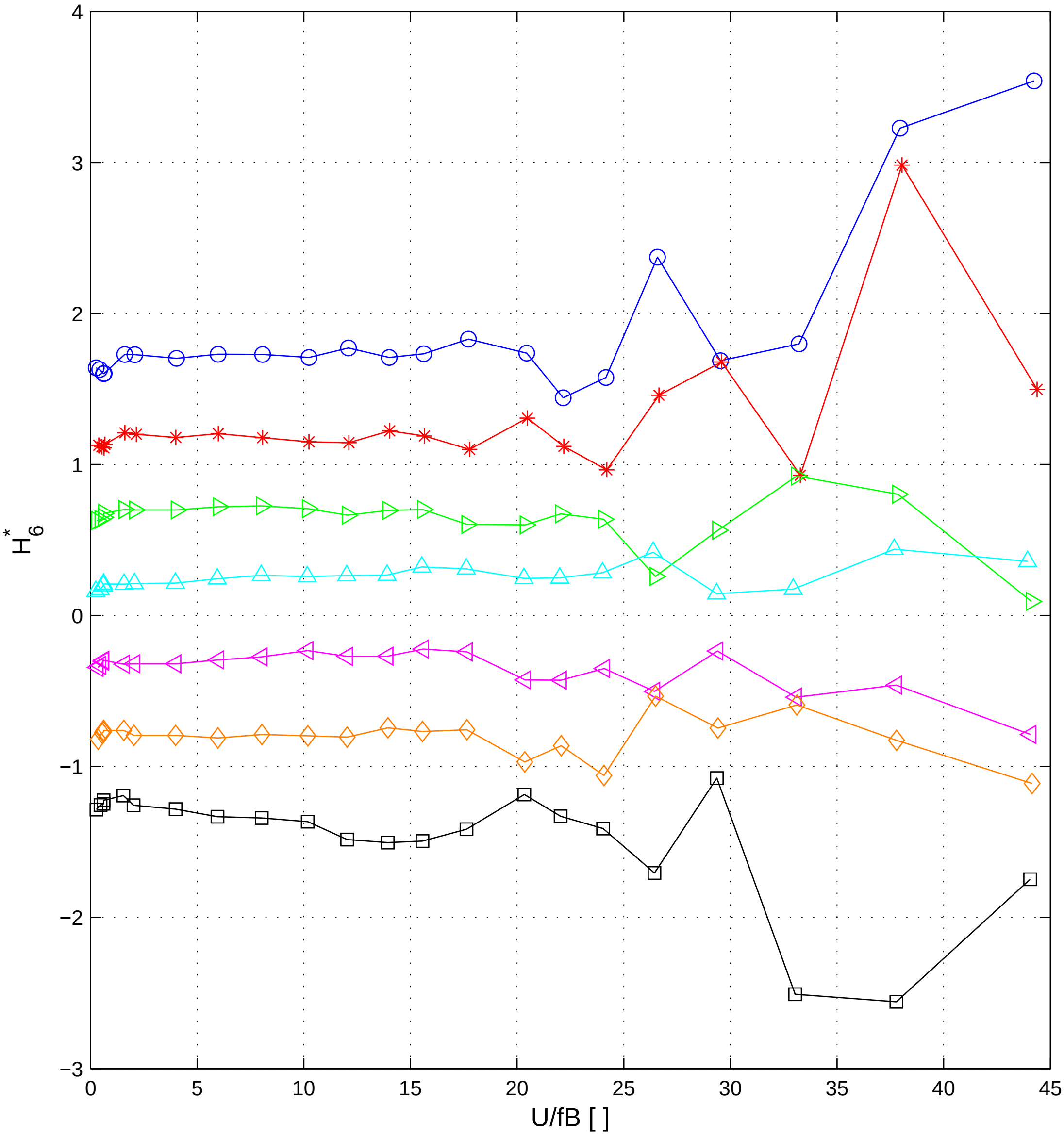
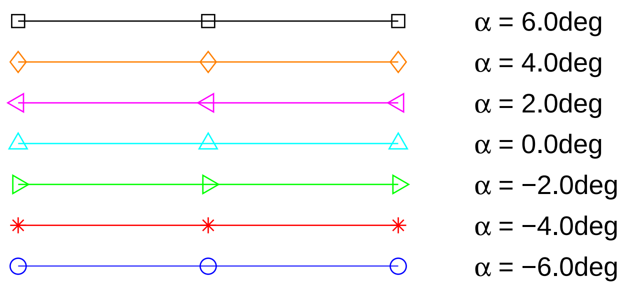


Figure R.14: Variation of coefficient H^*_6 with angle of incidence



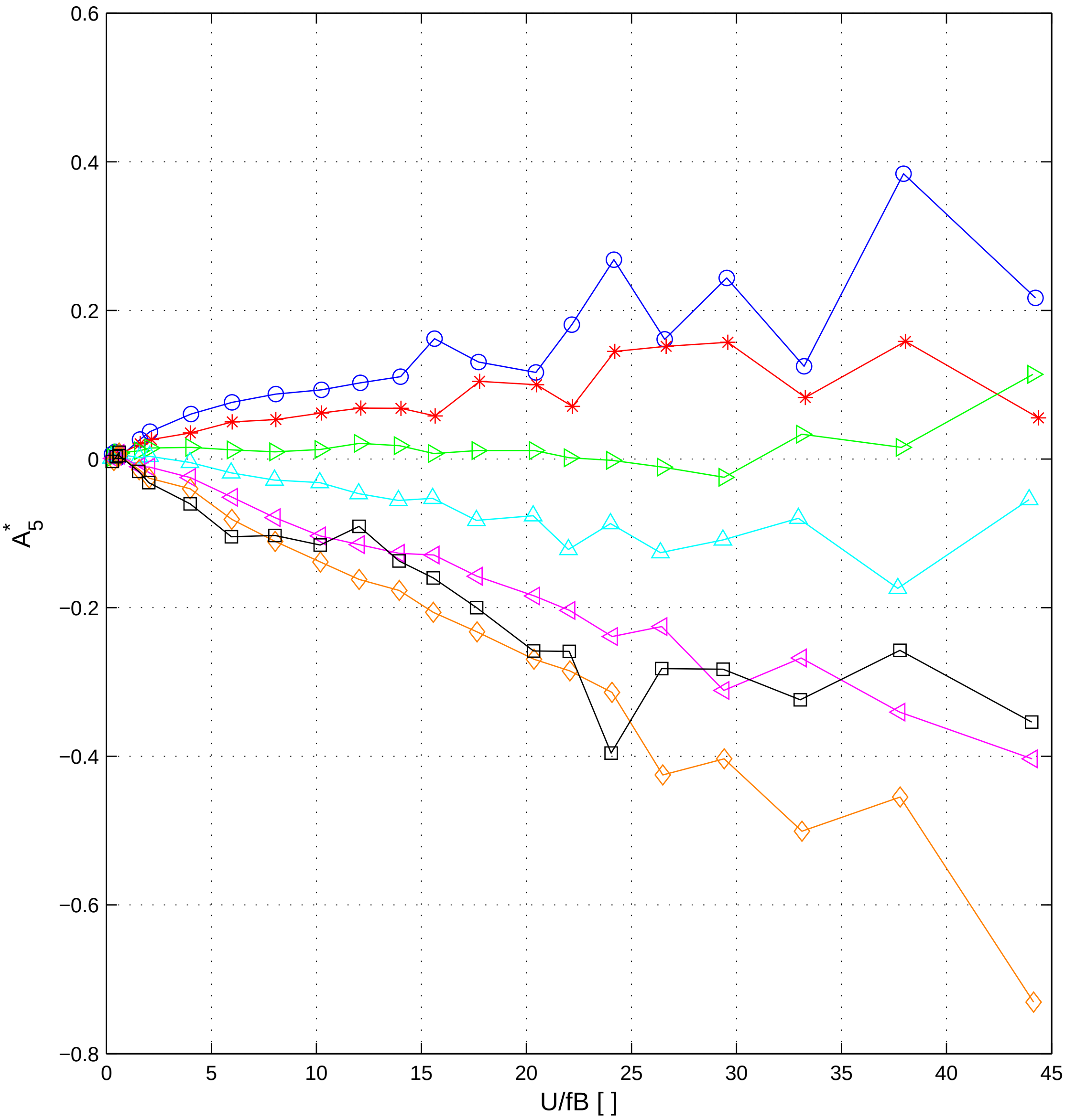
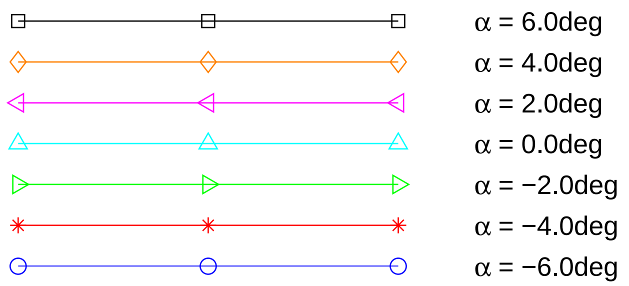


Figure R.15: Variation of coefficient A_5^* with angle of incidence



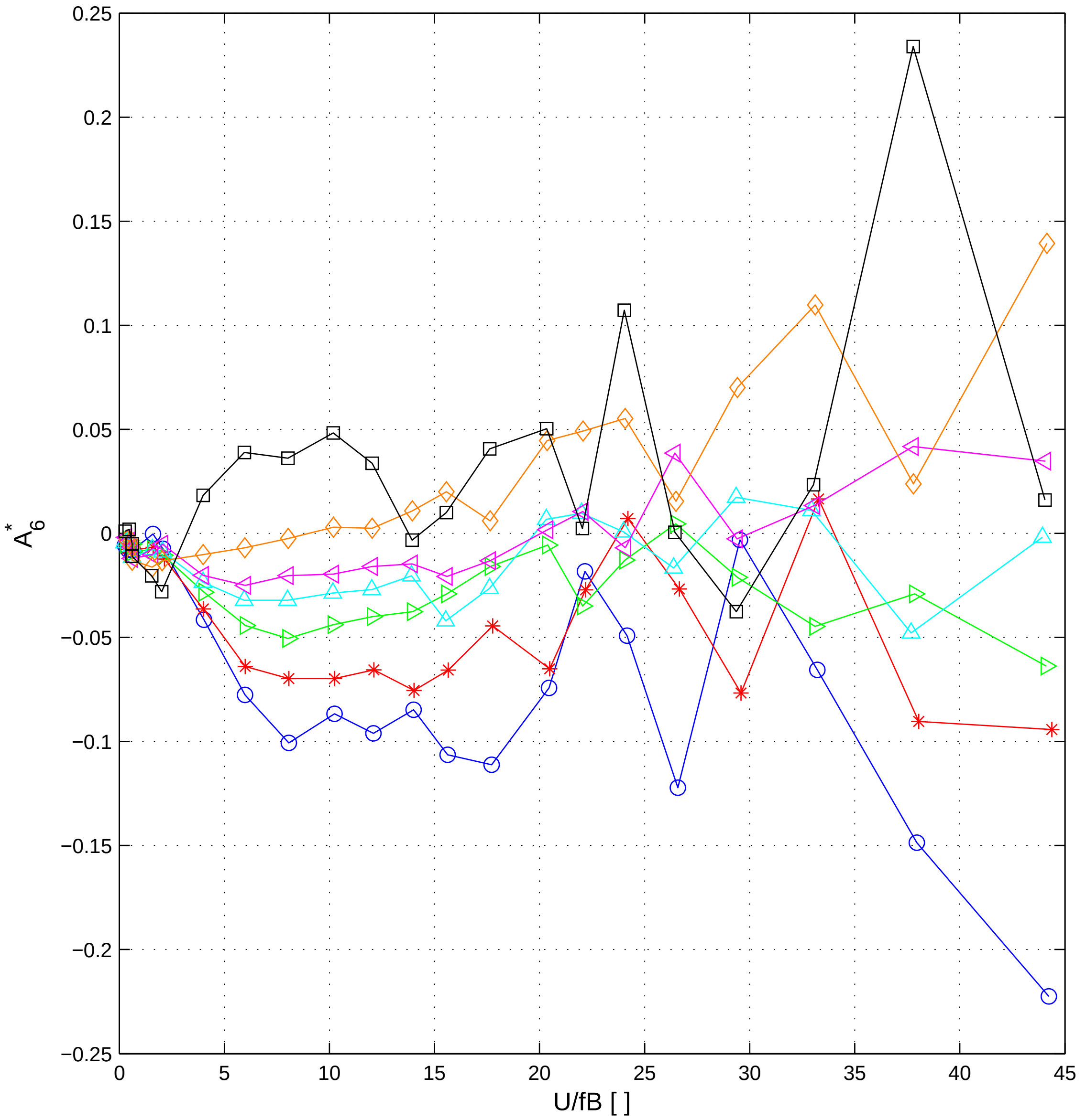
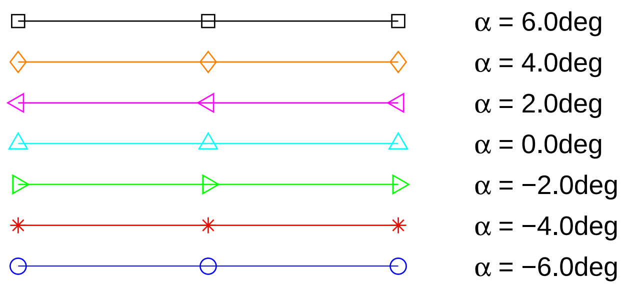


Figure R.16: Variation of coefficient A_6^* with angle of incidence



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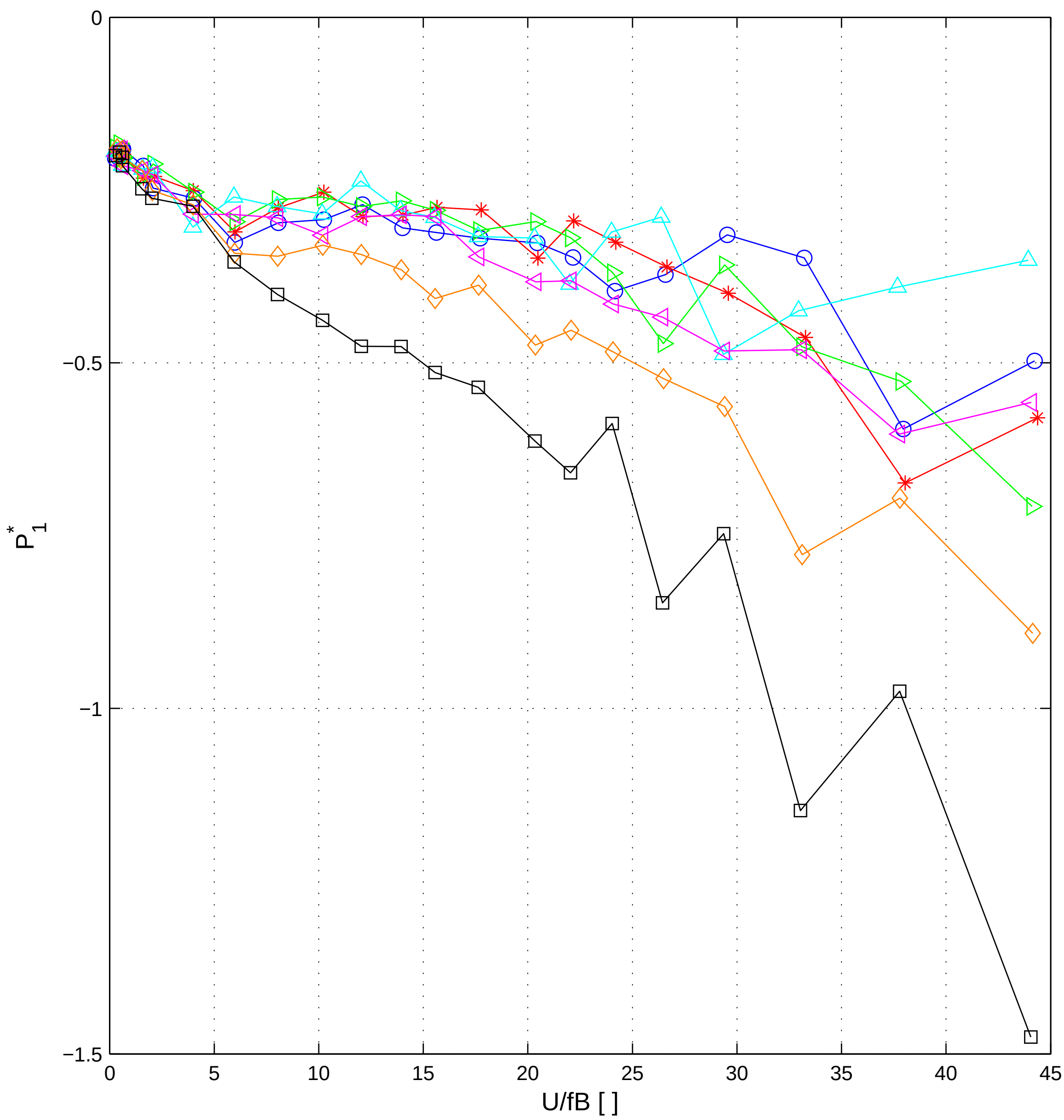
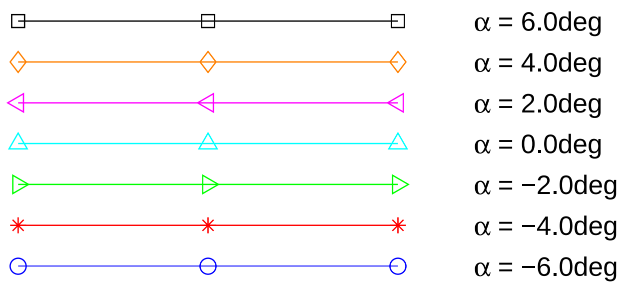


Figure R.17: Variation of coefficient P_1^* with angle of incidence



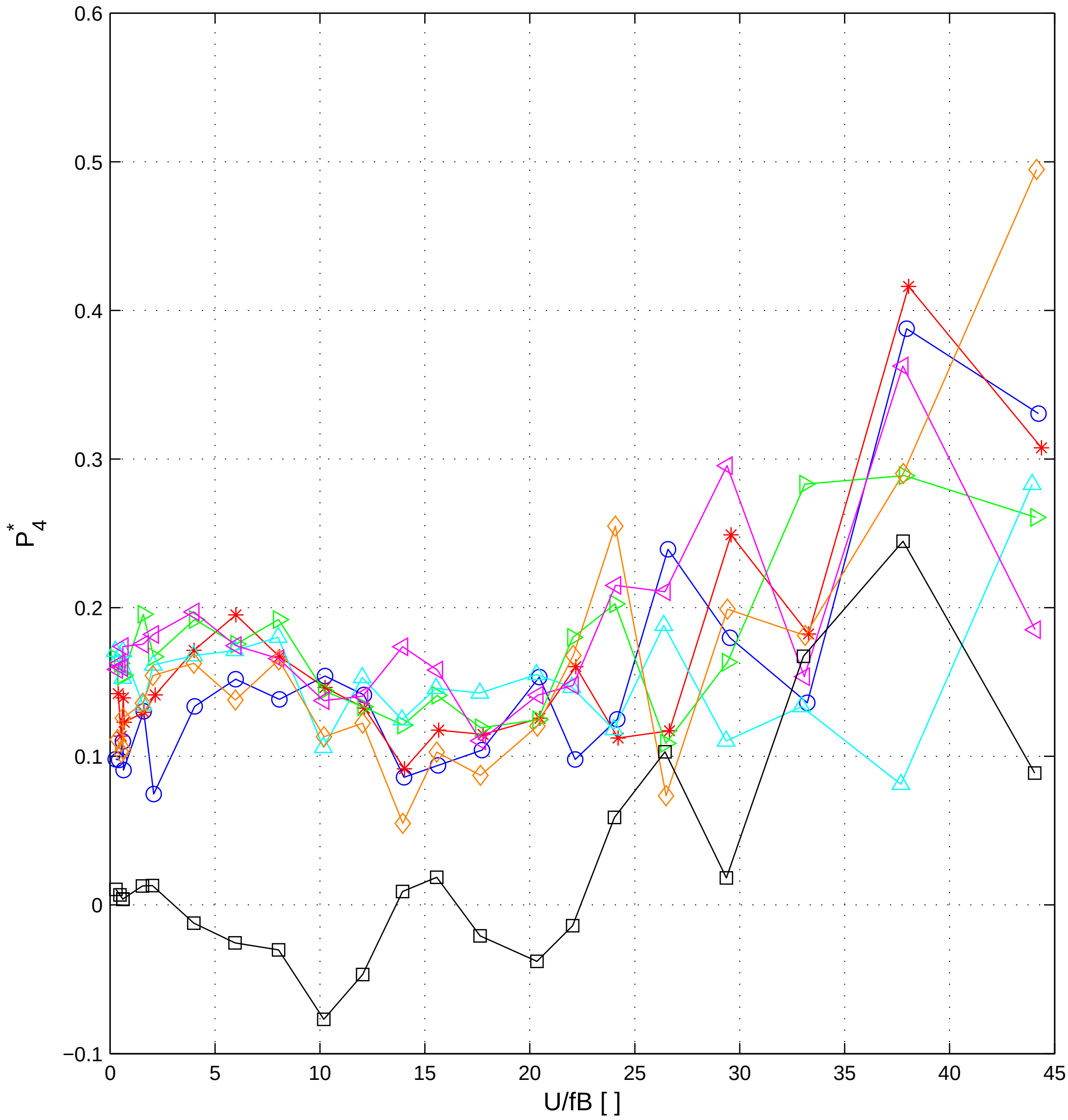
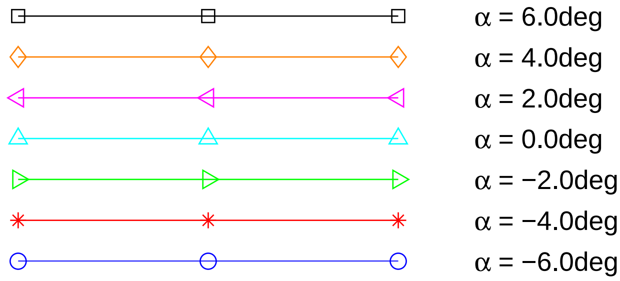


Figure R.18: Variation of coefficient P_4^* with angle of incidence



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Appendix S

Result comparisons for different flow types

Turbulent flow, Installation stage

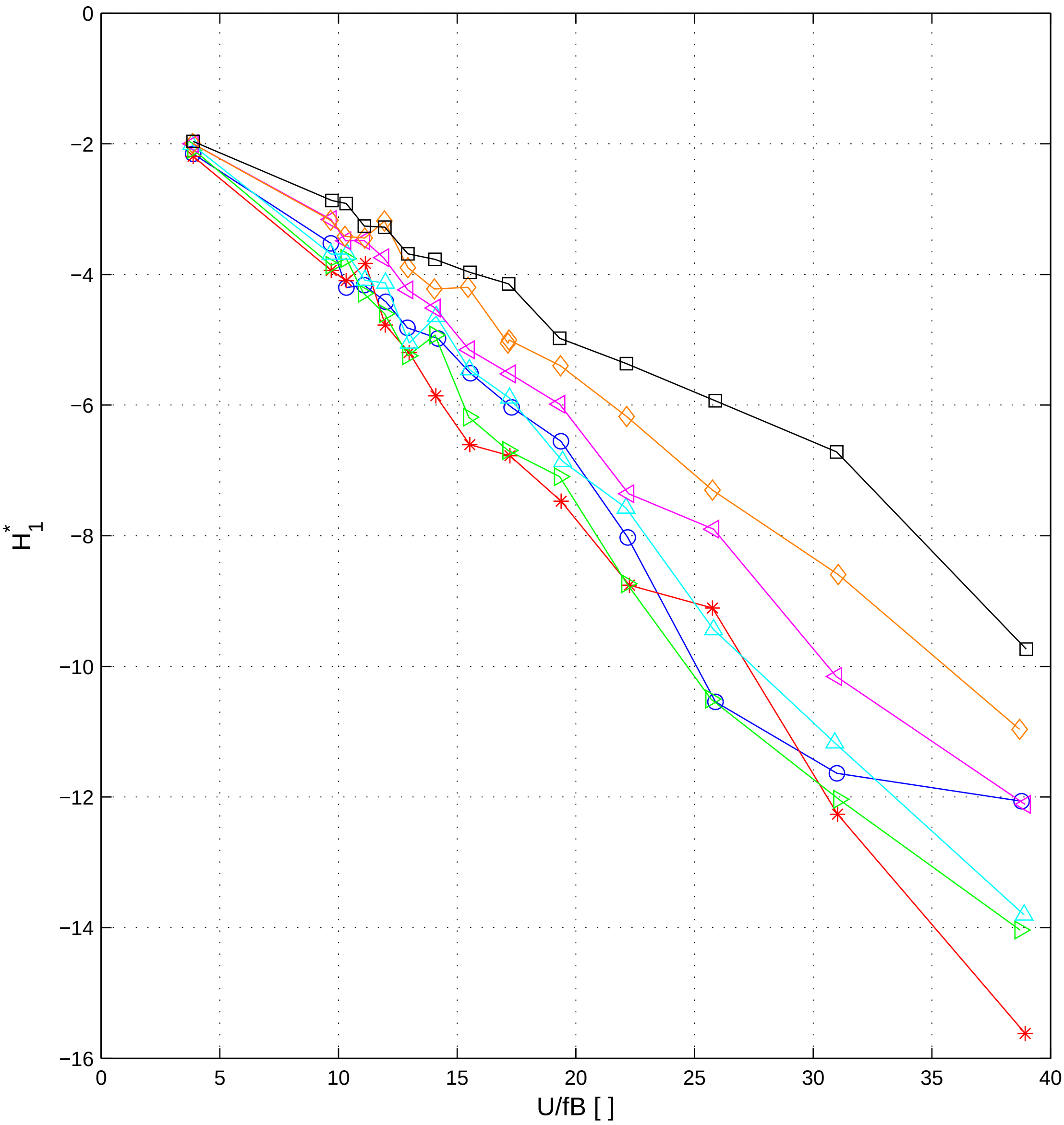
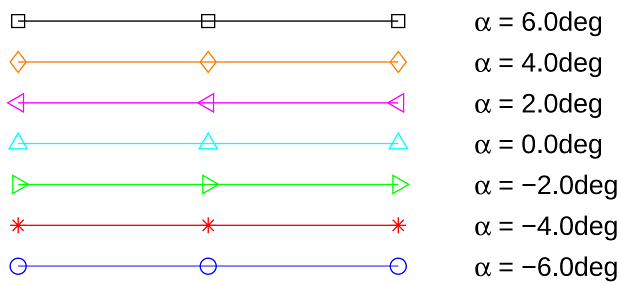


Figure S.1: Variation of coefficient H_1^* with angle of incidence



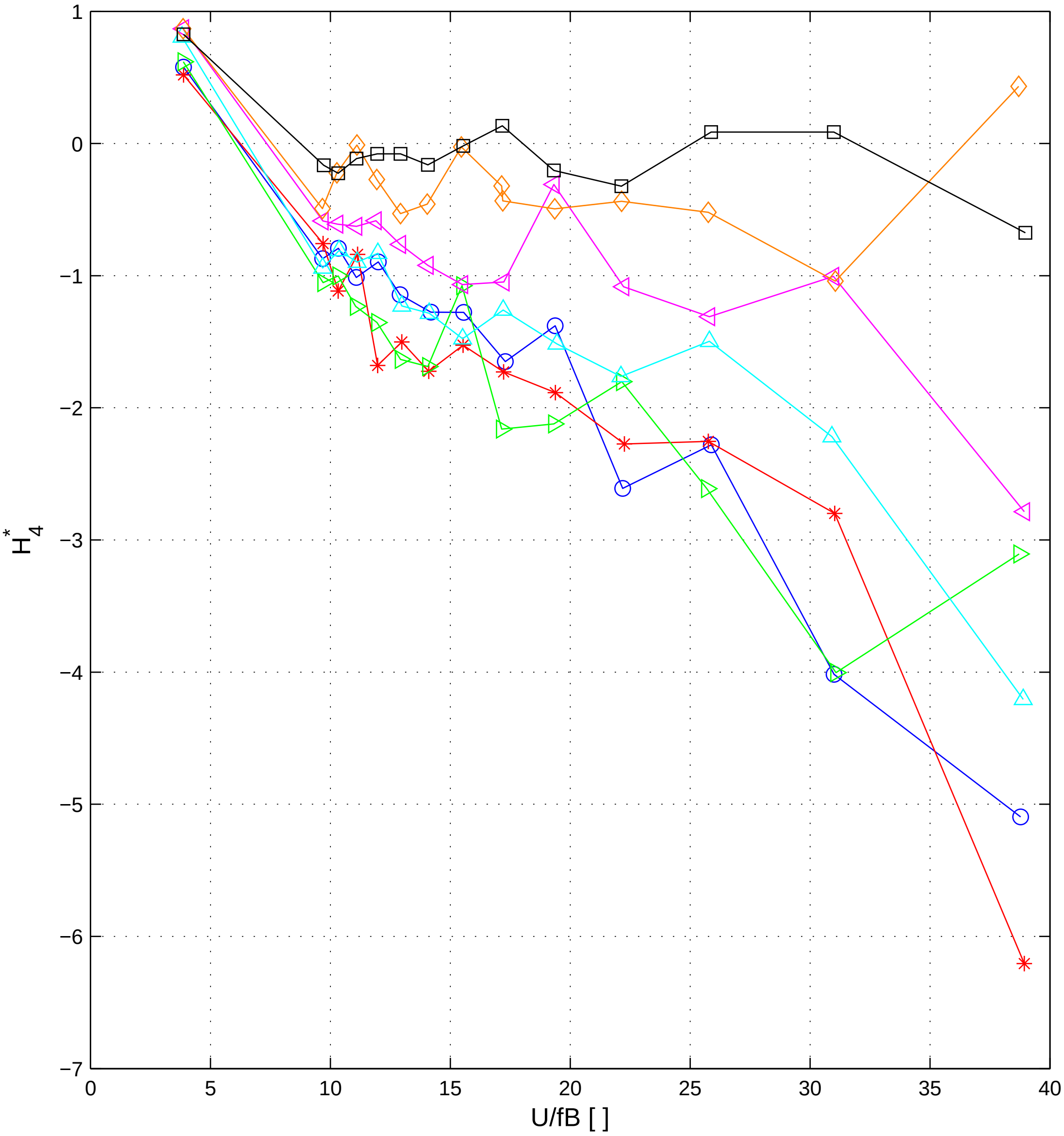
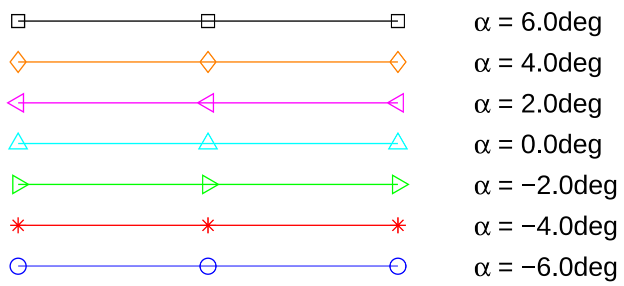


Figure S.2: Variation of coefficient H_4^* with angle of incidence



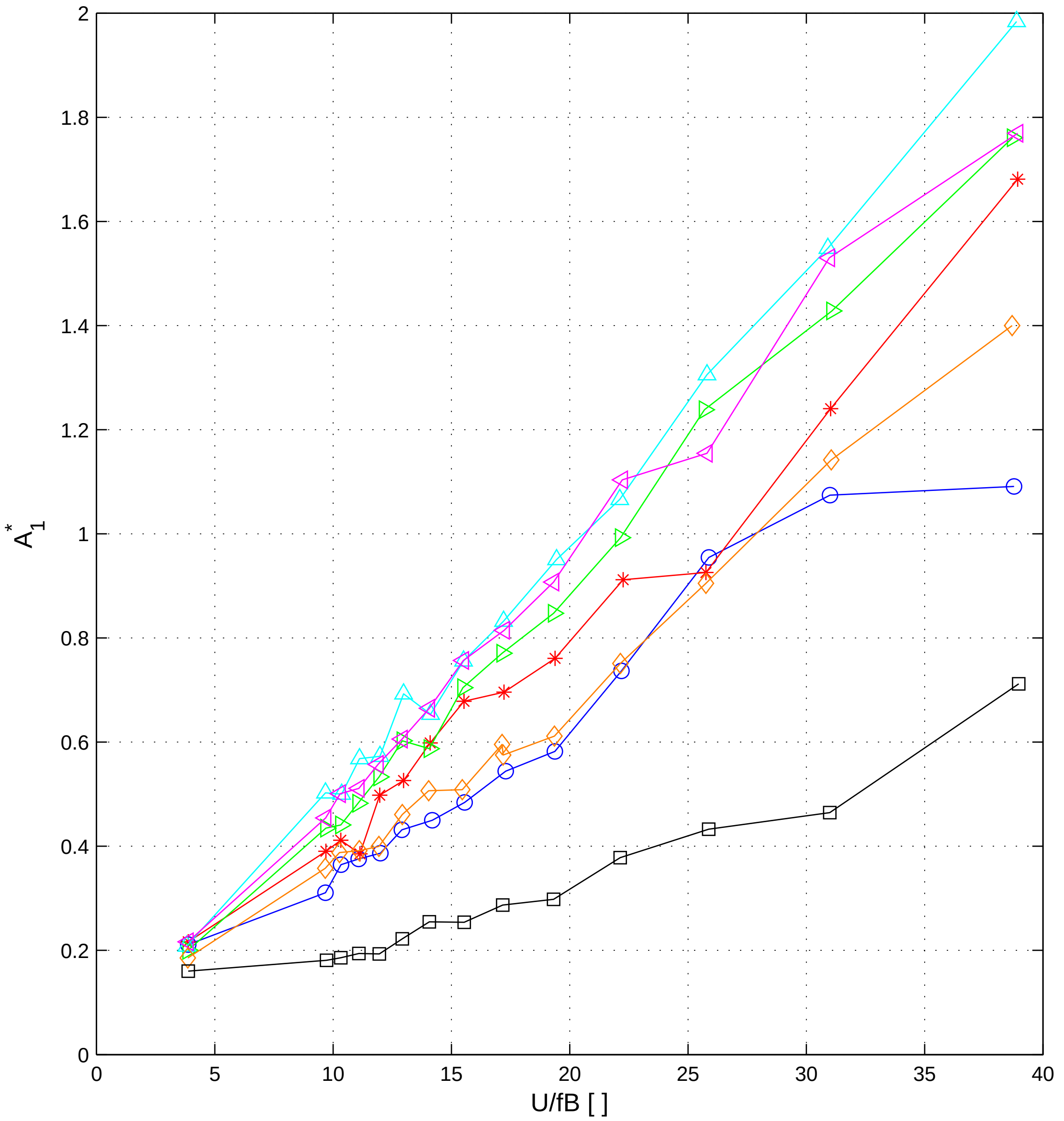
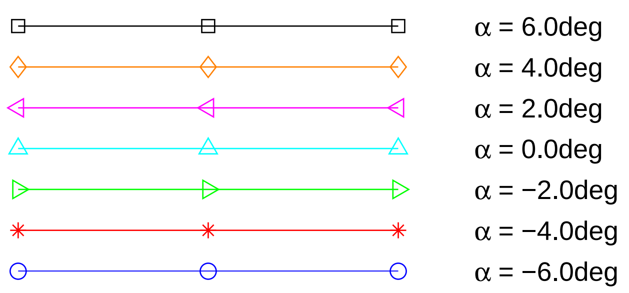


Figure S.3: Variation of coefficient A_1^* with angle of incidence



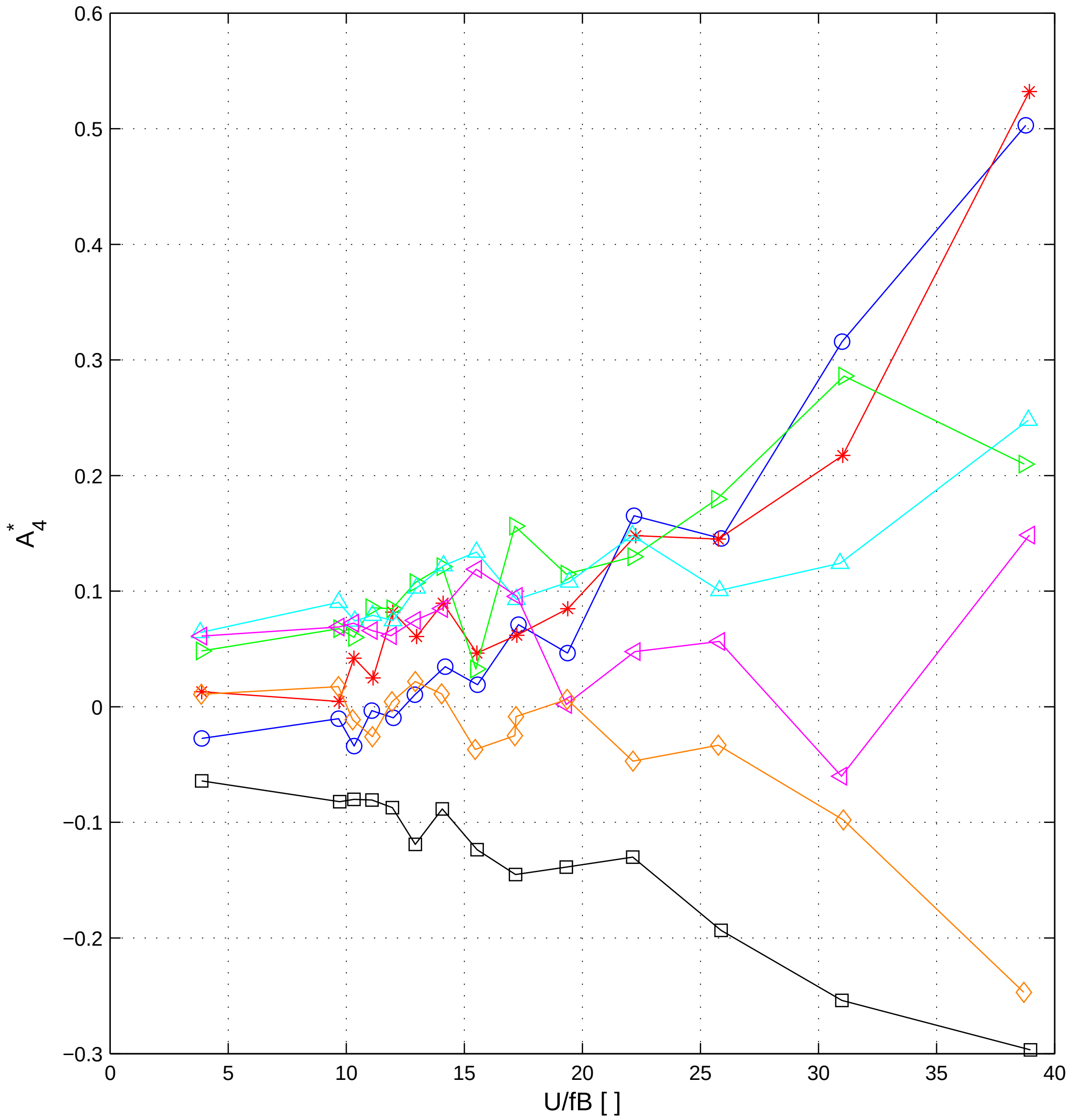
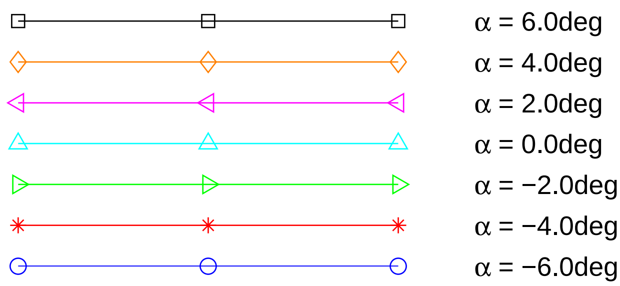


Figure S.4: Variation of coefficient A_4^* with angle of incidence



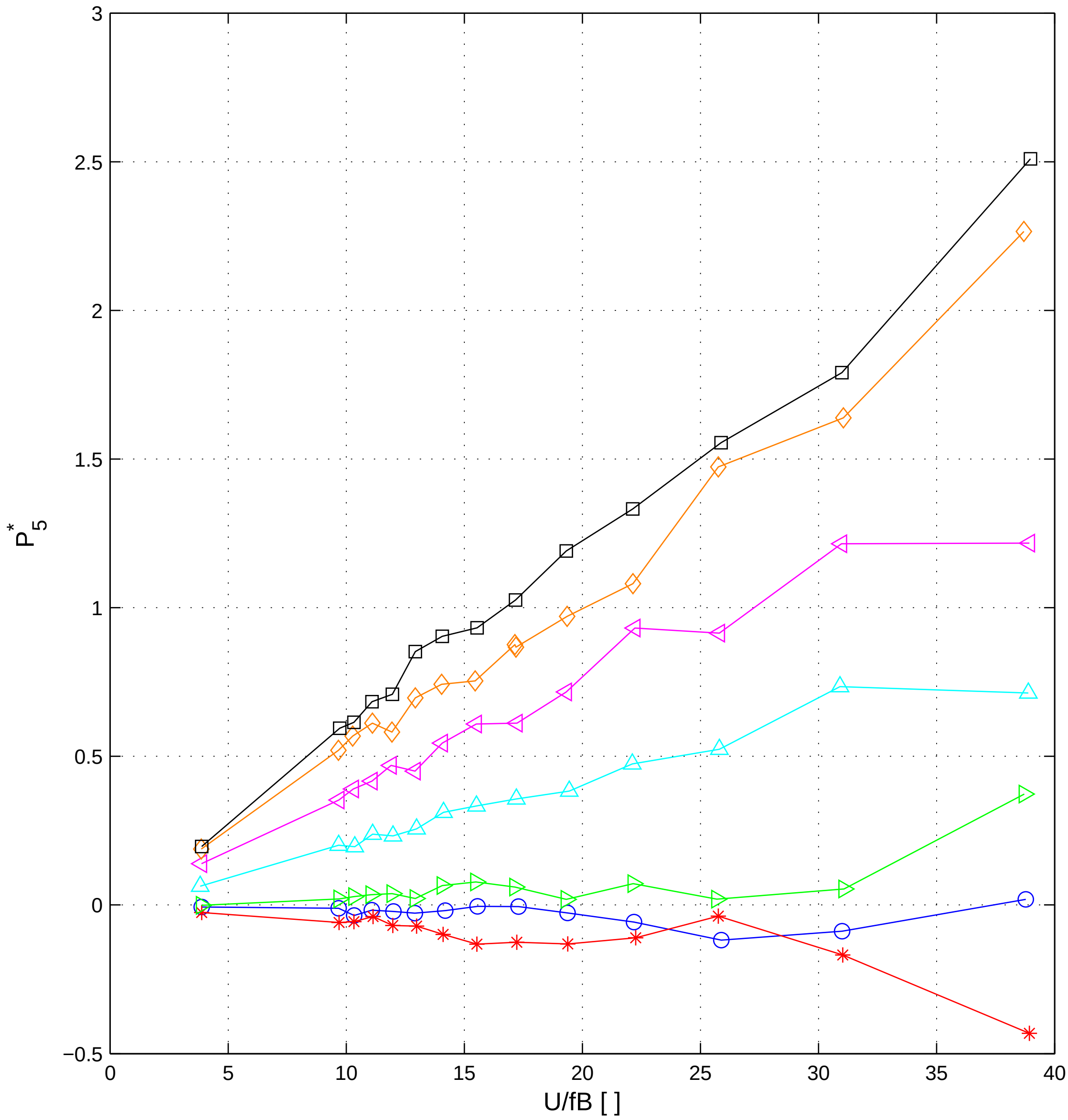
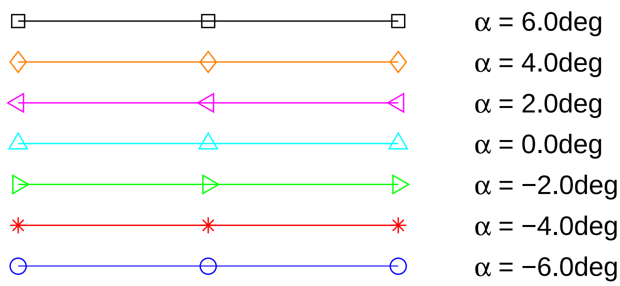


Figure S.5: Variation of coefficient P^*_5 with angle of incidence



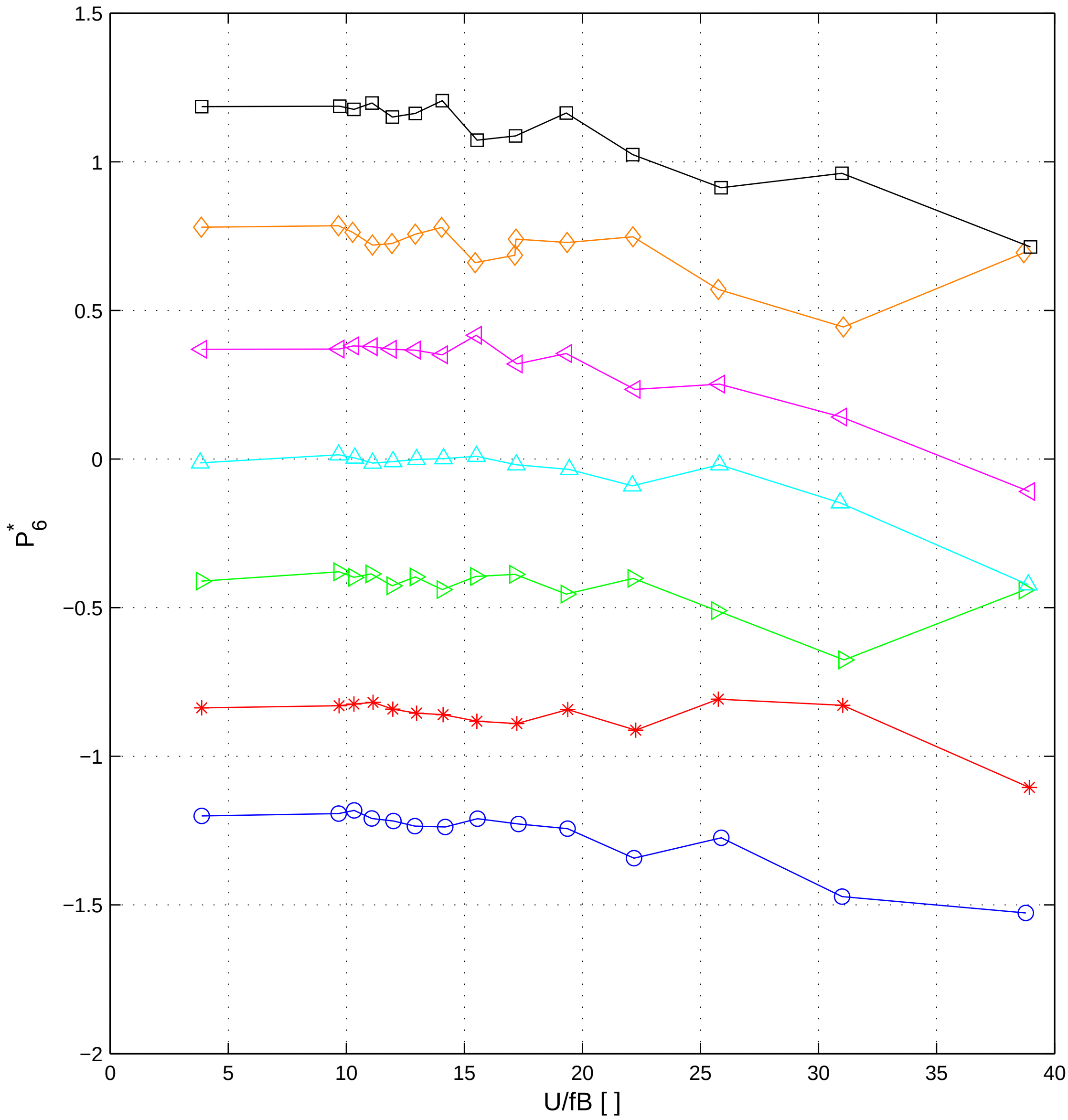
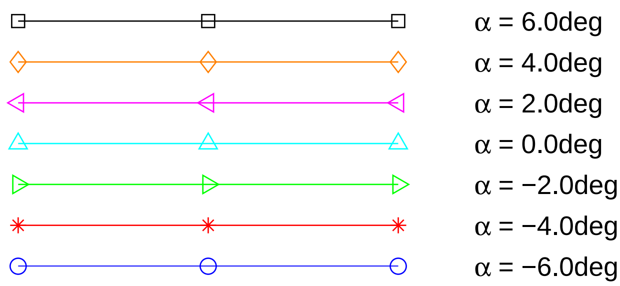


Figure S.6: Variation of coefficient P_6^* with angle of incidence



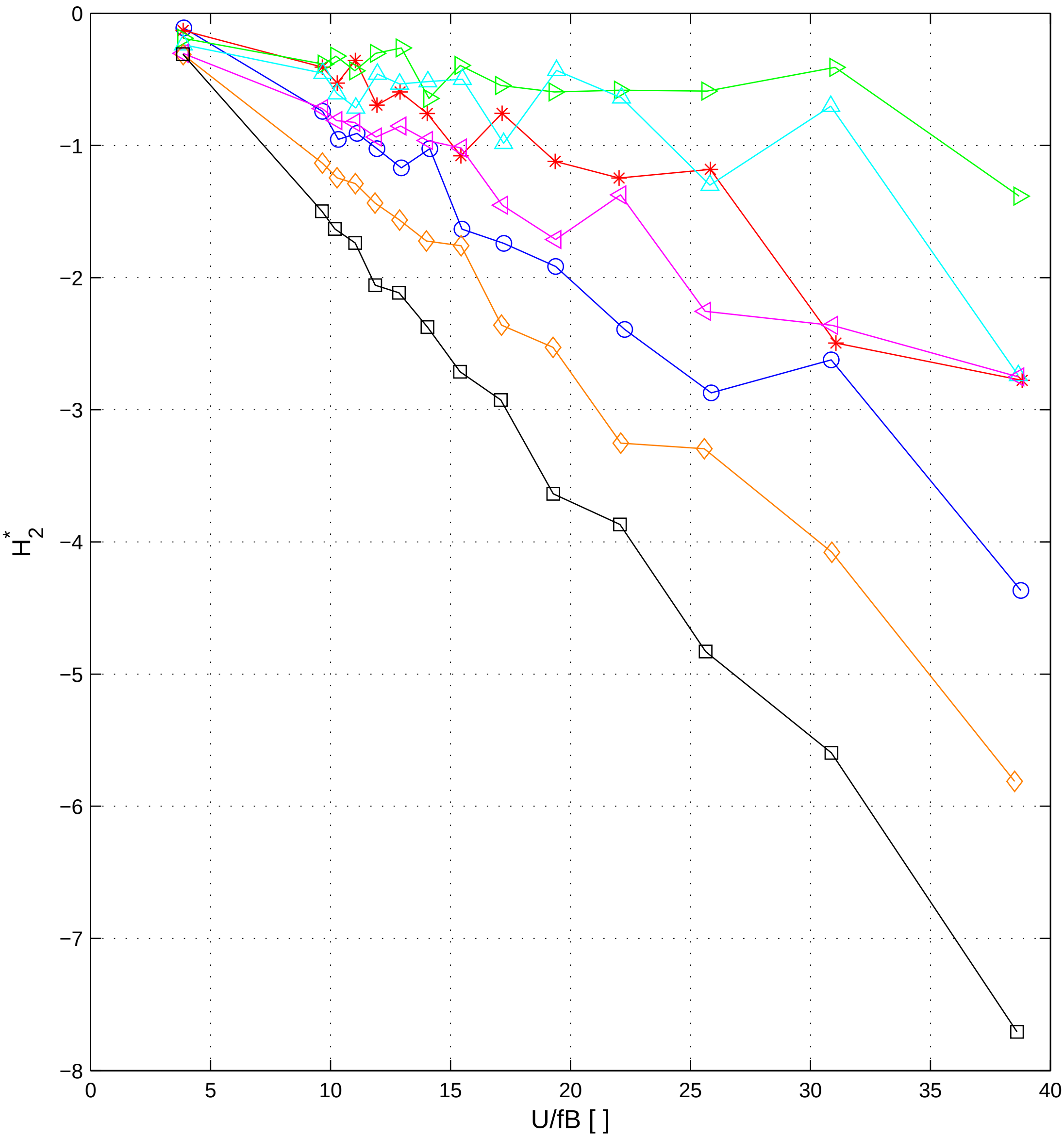
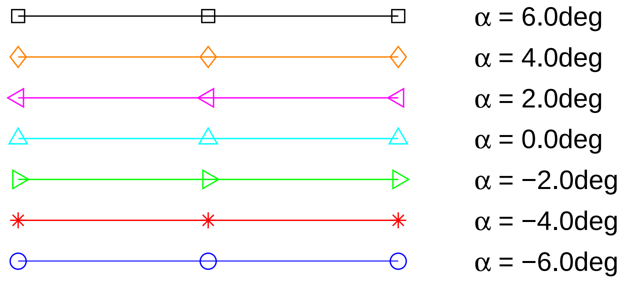


Figure S.7: Variation of coefficient H_2^* with angle of incidence



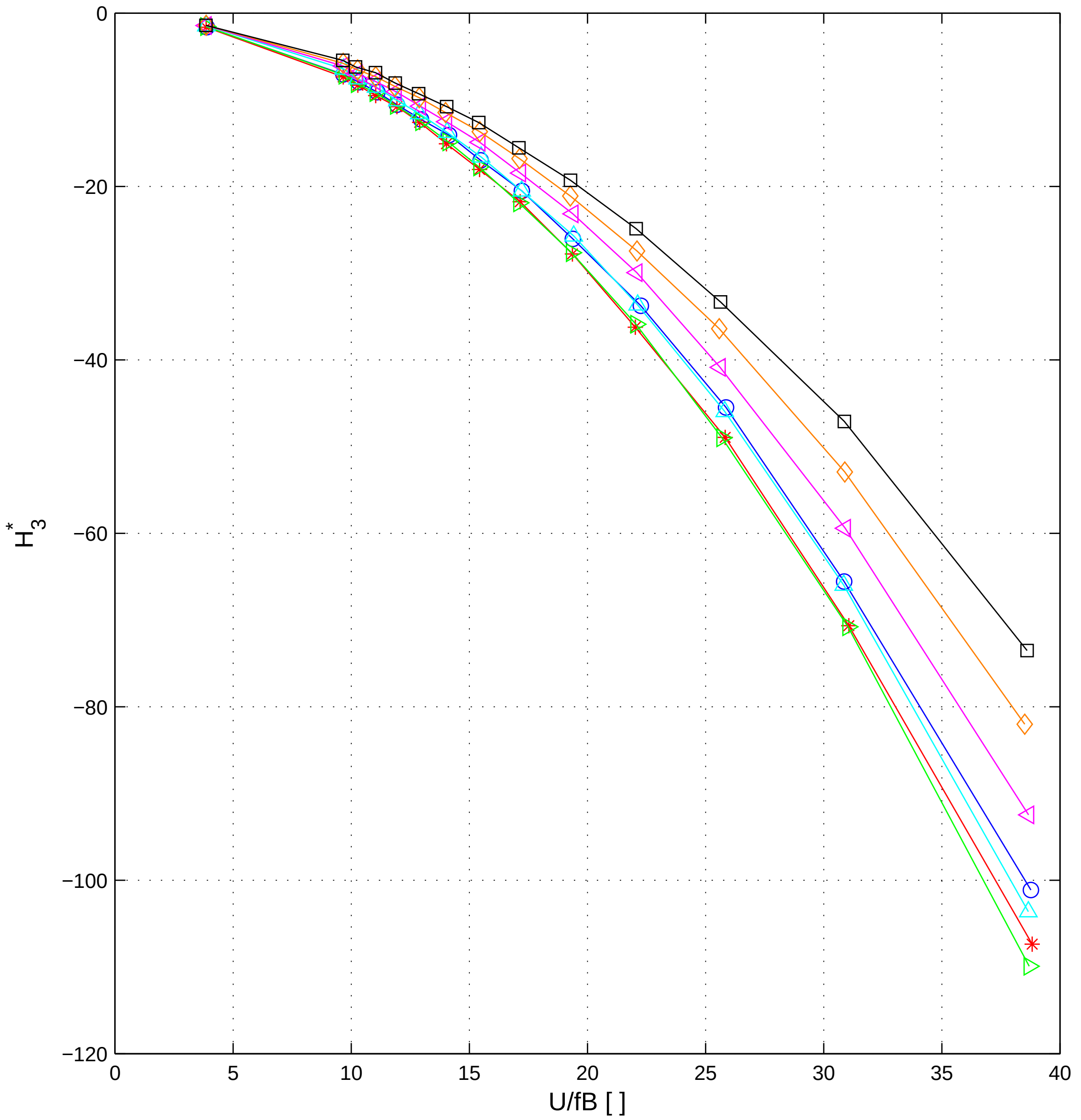
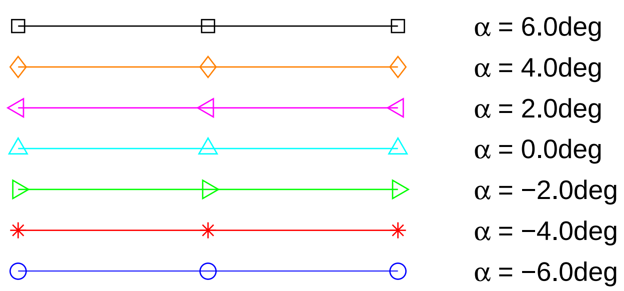


Figure S.8: Variation of coefficient H^*_3 with angle of incidence



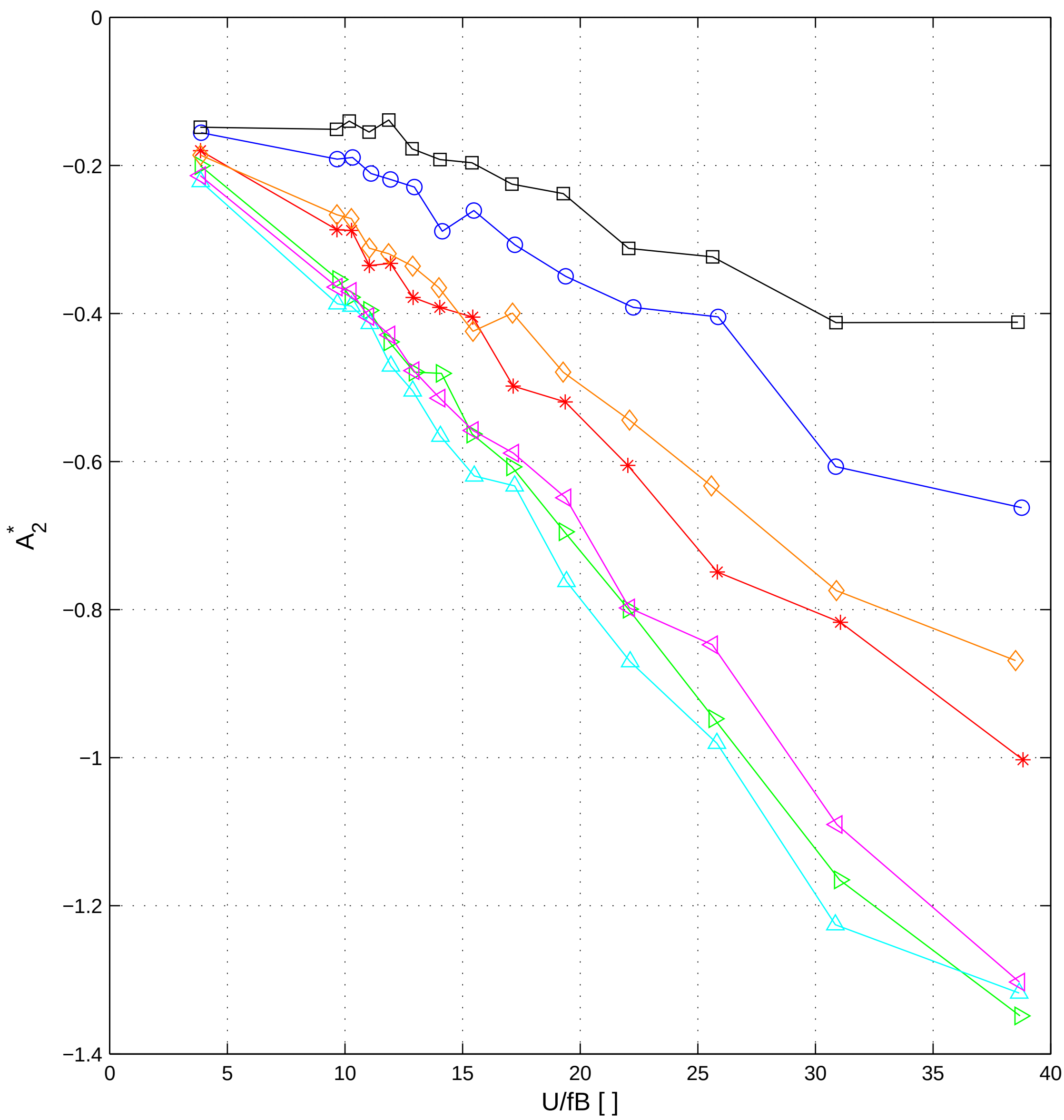
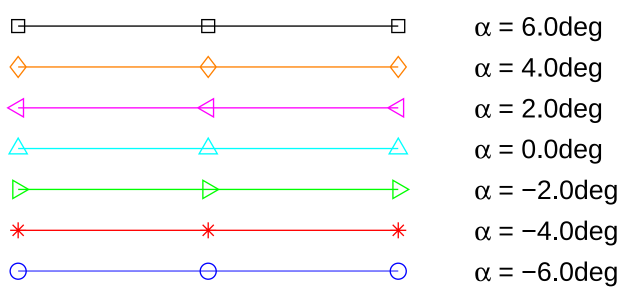


Figure S.9: Variation of coefficient A^*_2 with angle of incidence



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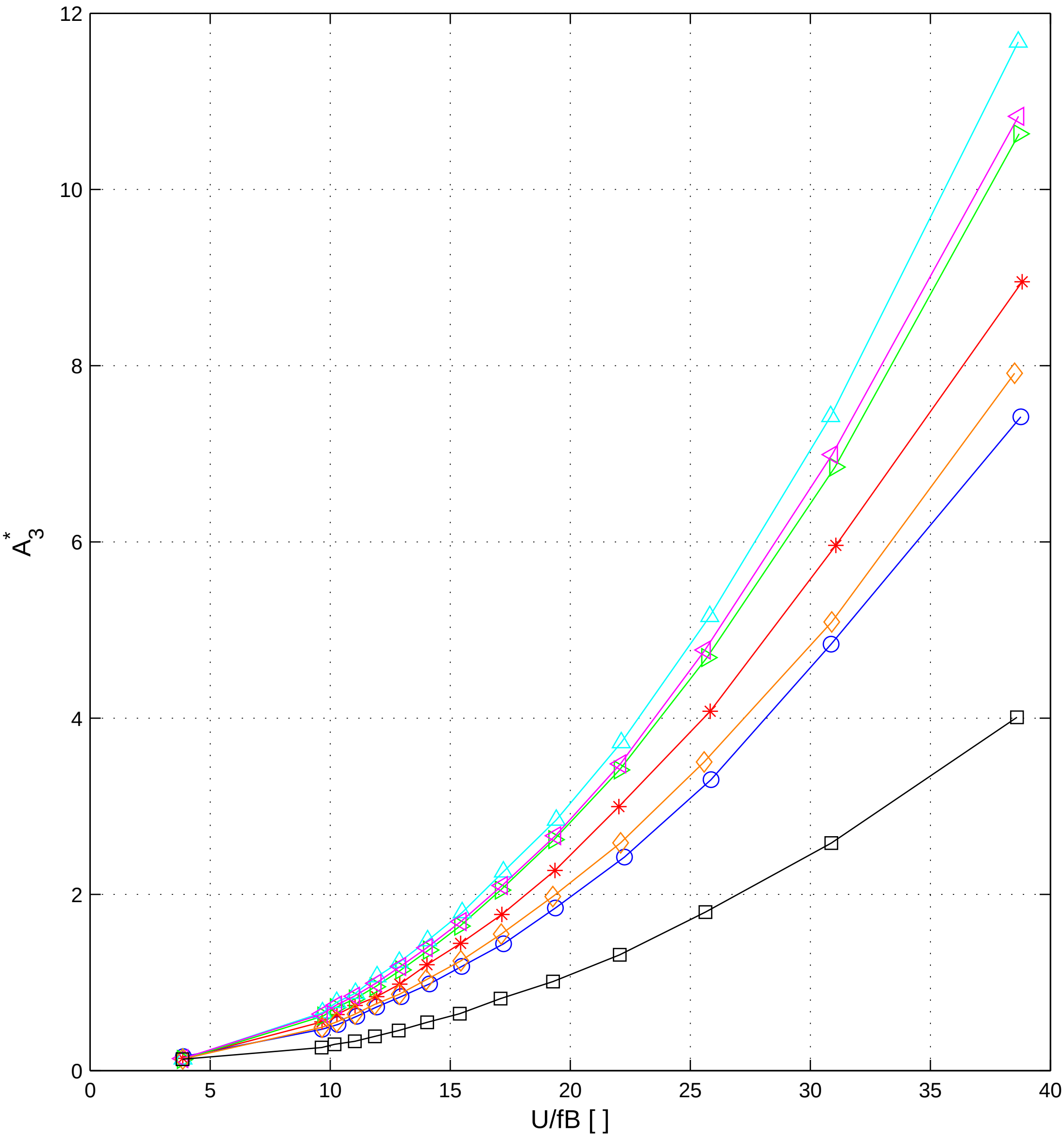
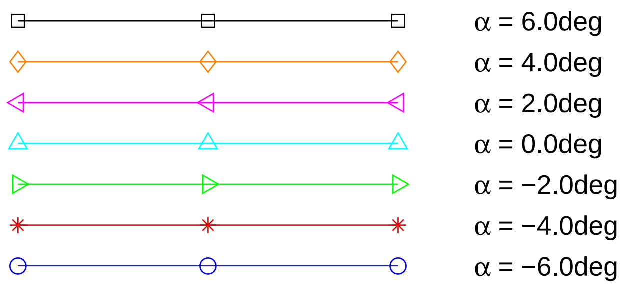


Figure S.10: Variation of coefficient A_3^* with angle of incidence



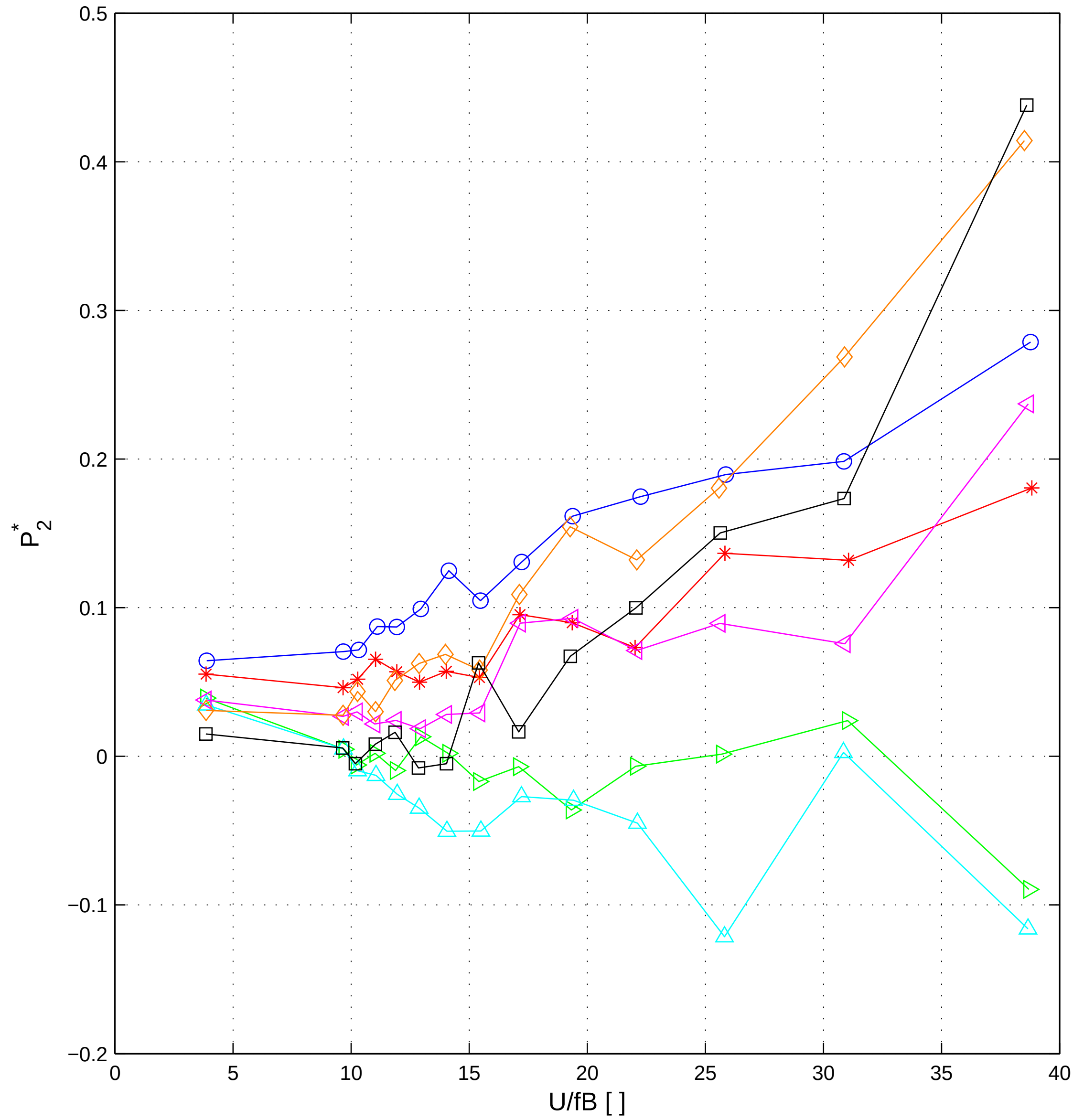


Figure S.11: Variation of coefficient P^*_2 with angle of incidence

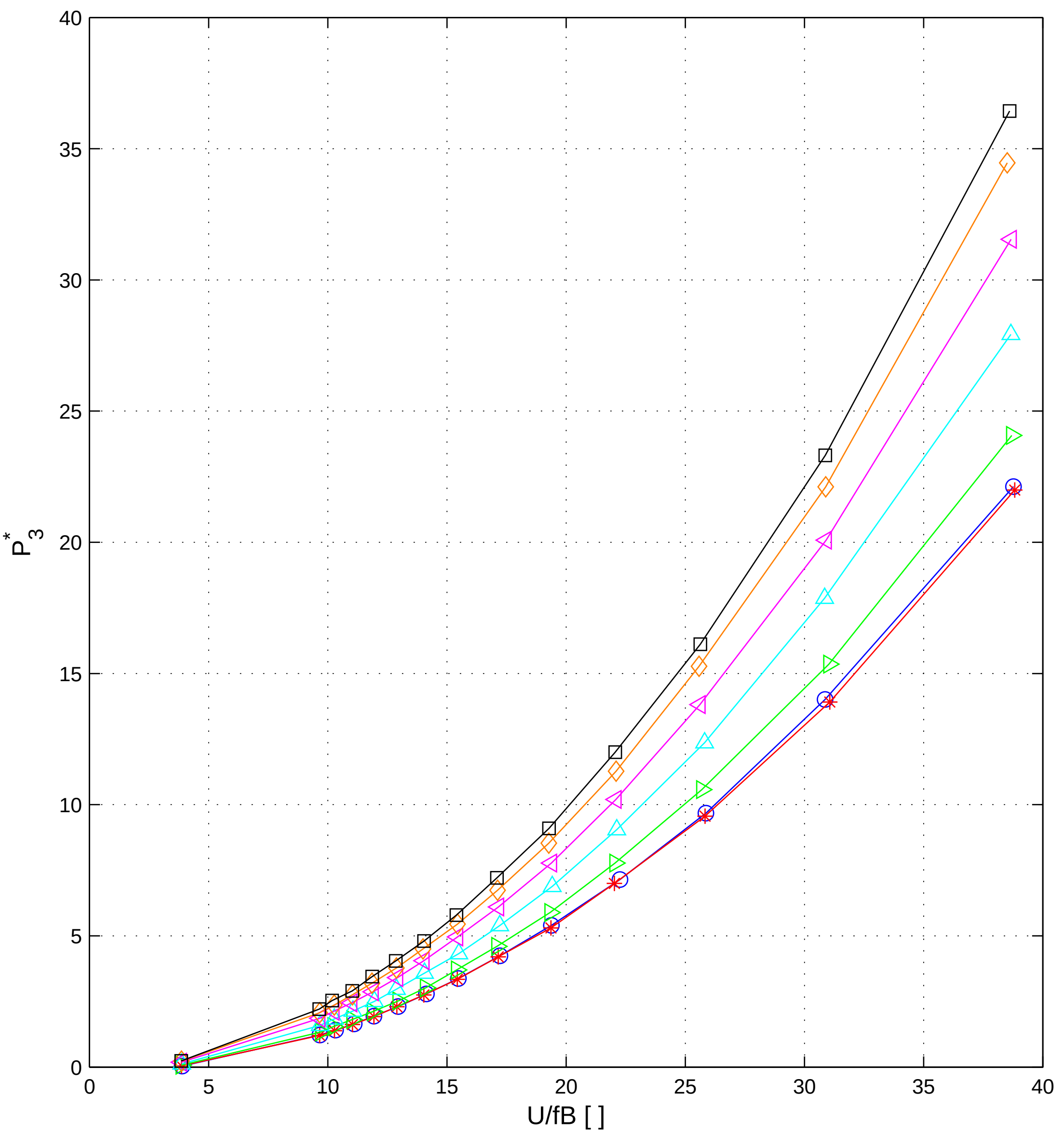
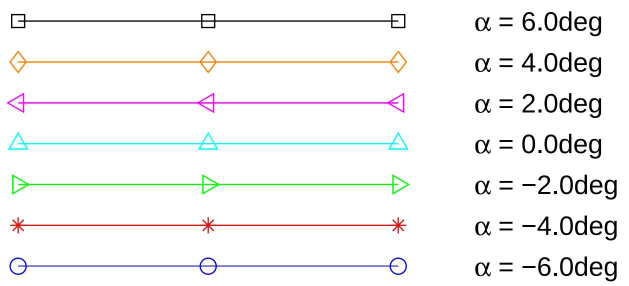


Figure S.12: Variation of coefficient P^*_3 with angle of incidence



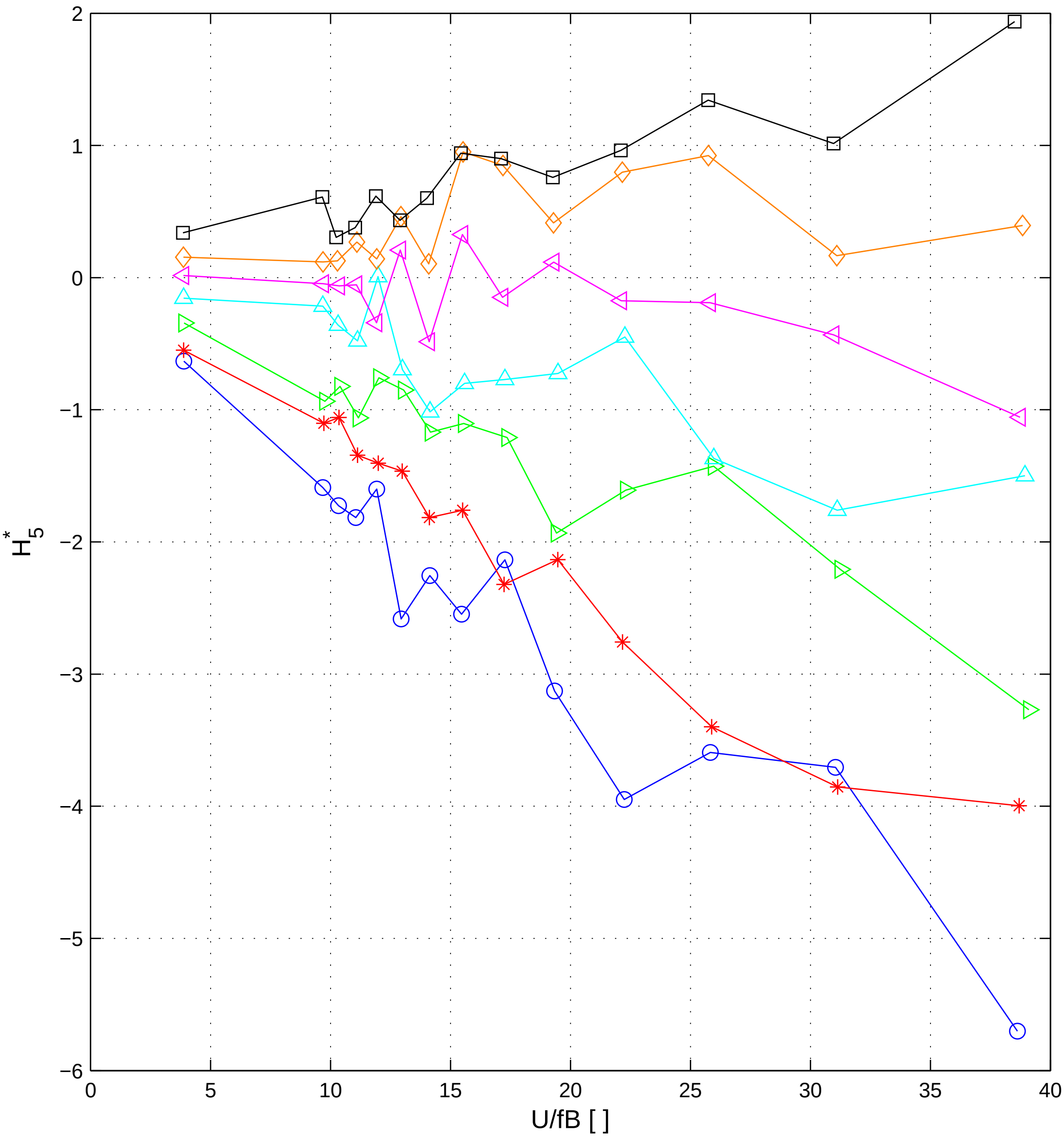
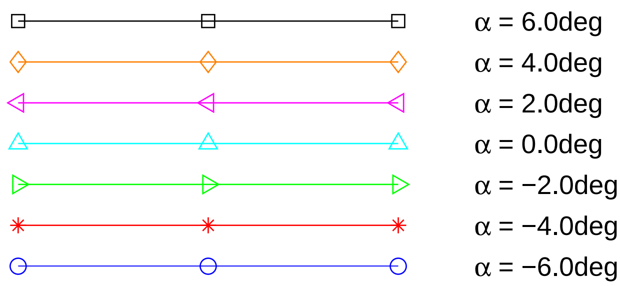


Figure S.13: Variation of coefficient H_5^* with angle of incidence



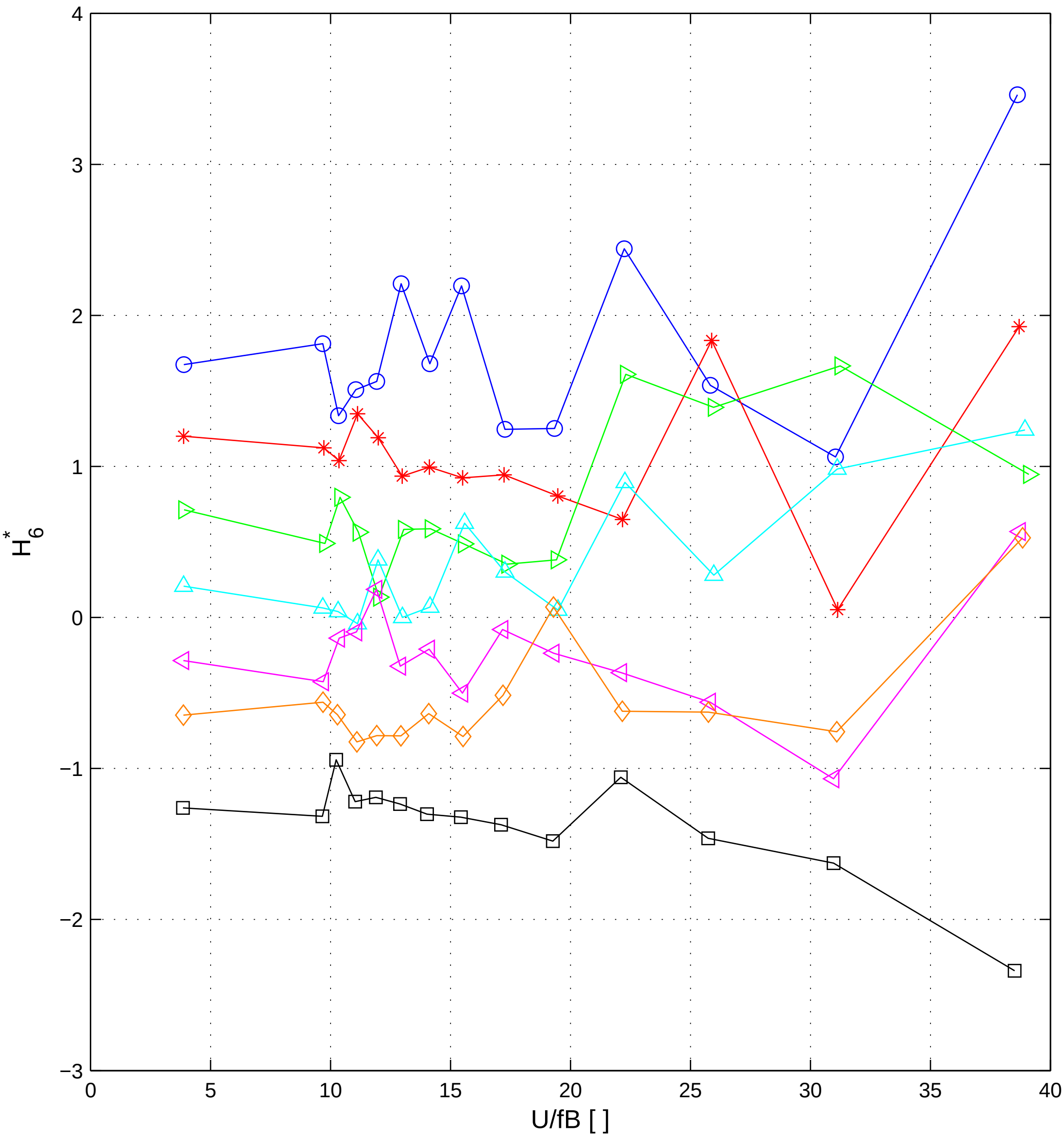
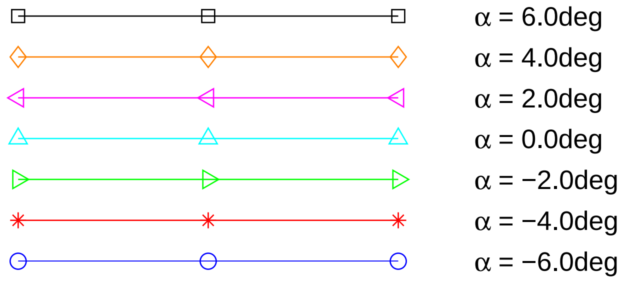


Figure S.14: Variation of coefficient H_6^* with angle of incidence



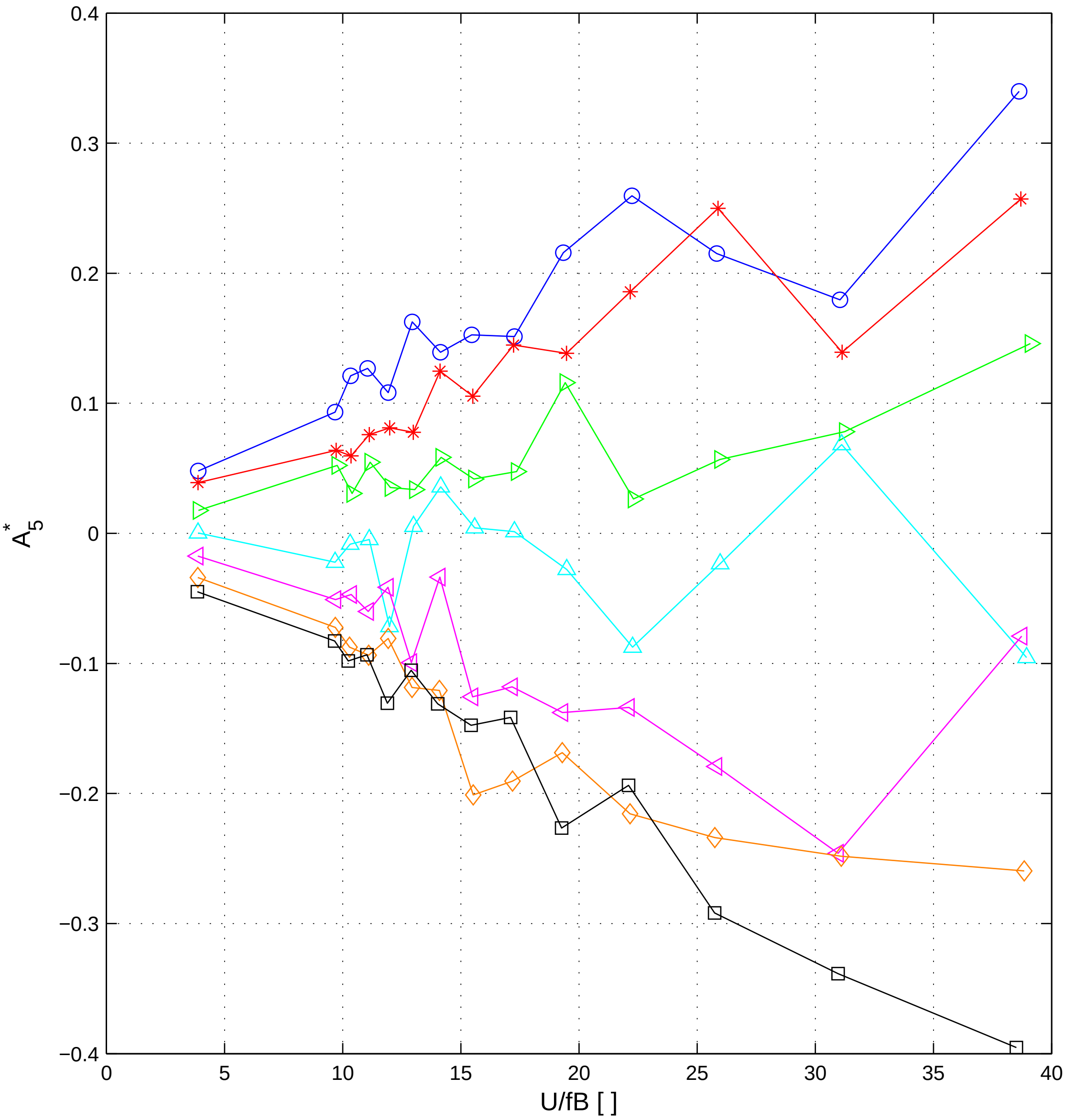
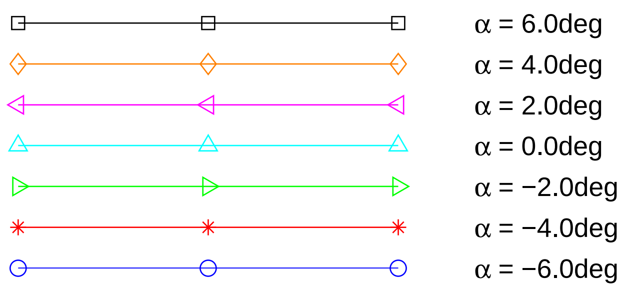


Figure S.15: Variation of coefficient A_5^* with angle of incidence



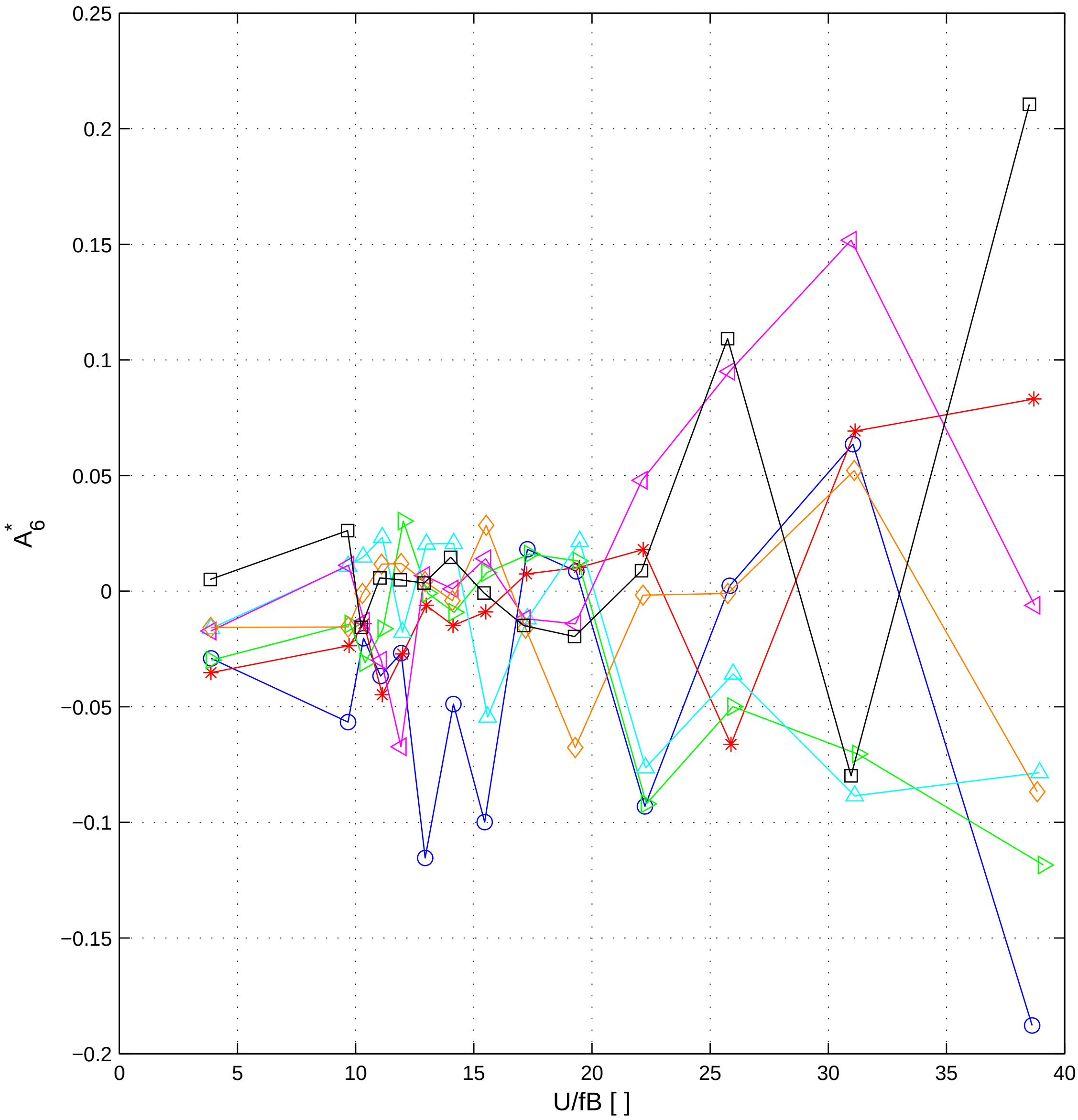
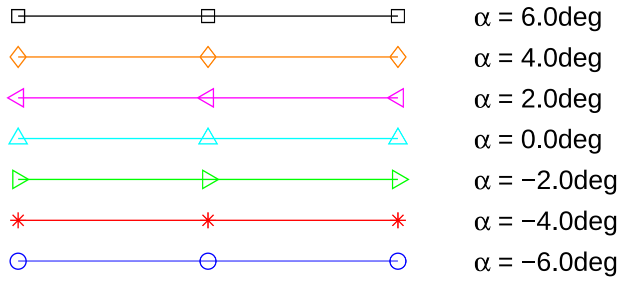


Figure S.16: Variation of coefficient A^*_6 with angle of incidence



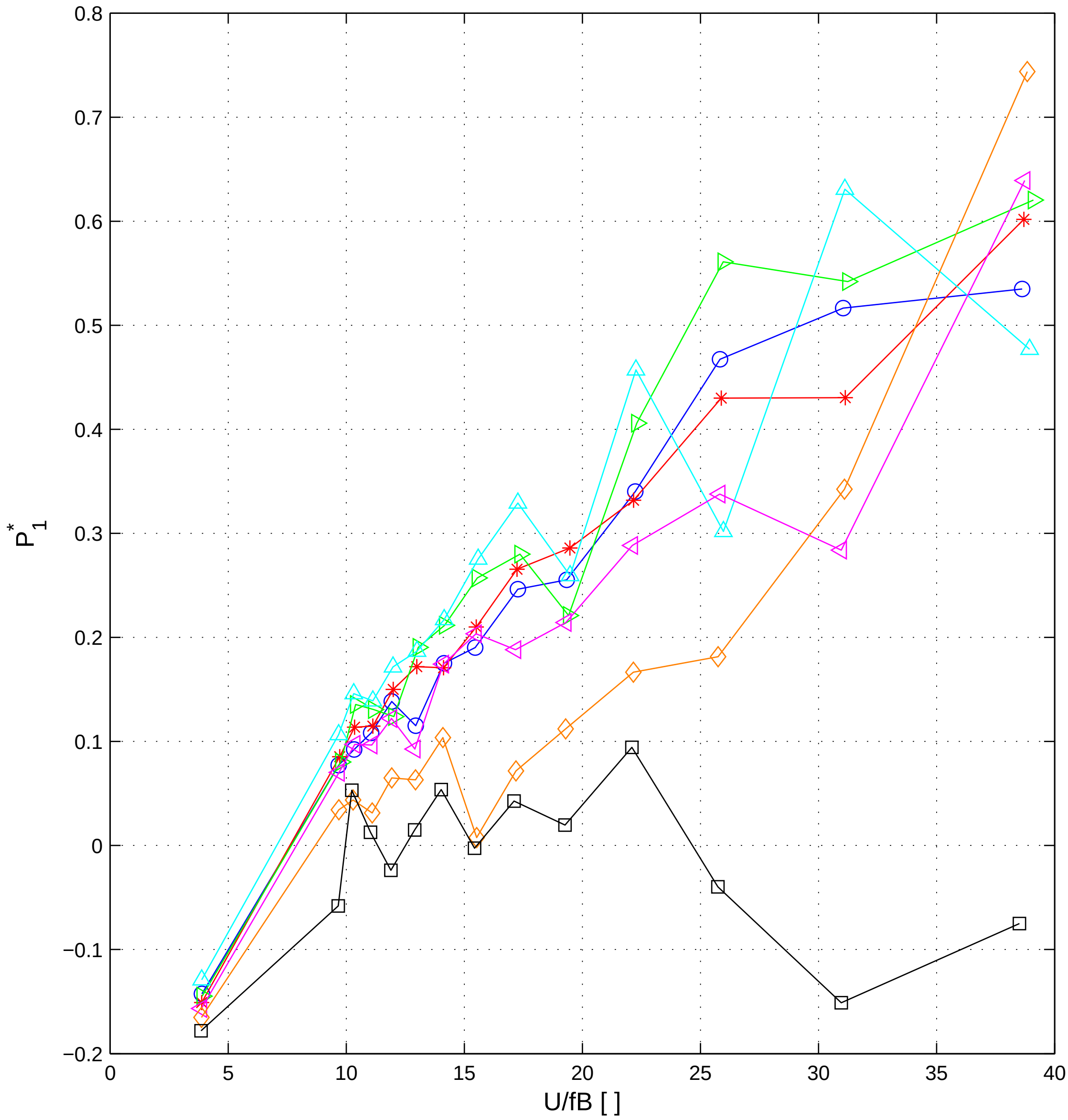
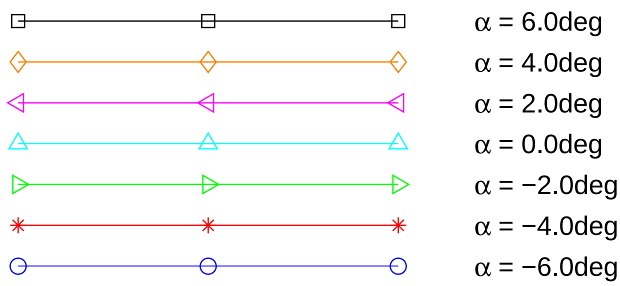


Figure S.17: Variation of coefficient P^*_1 with angle of incidence



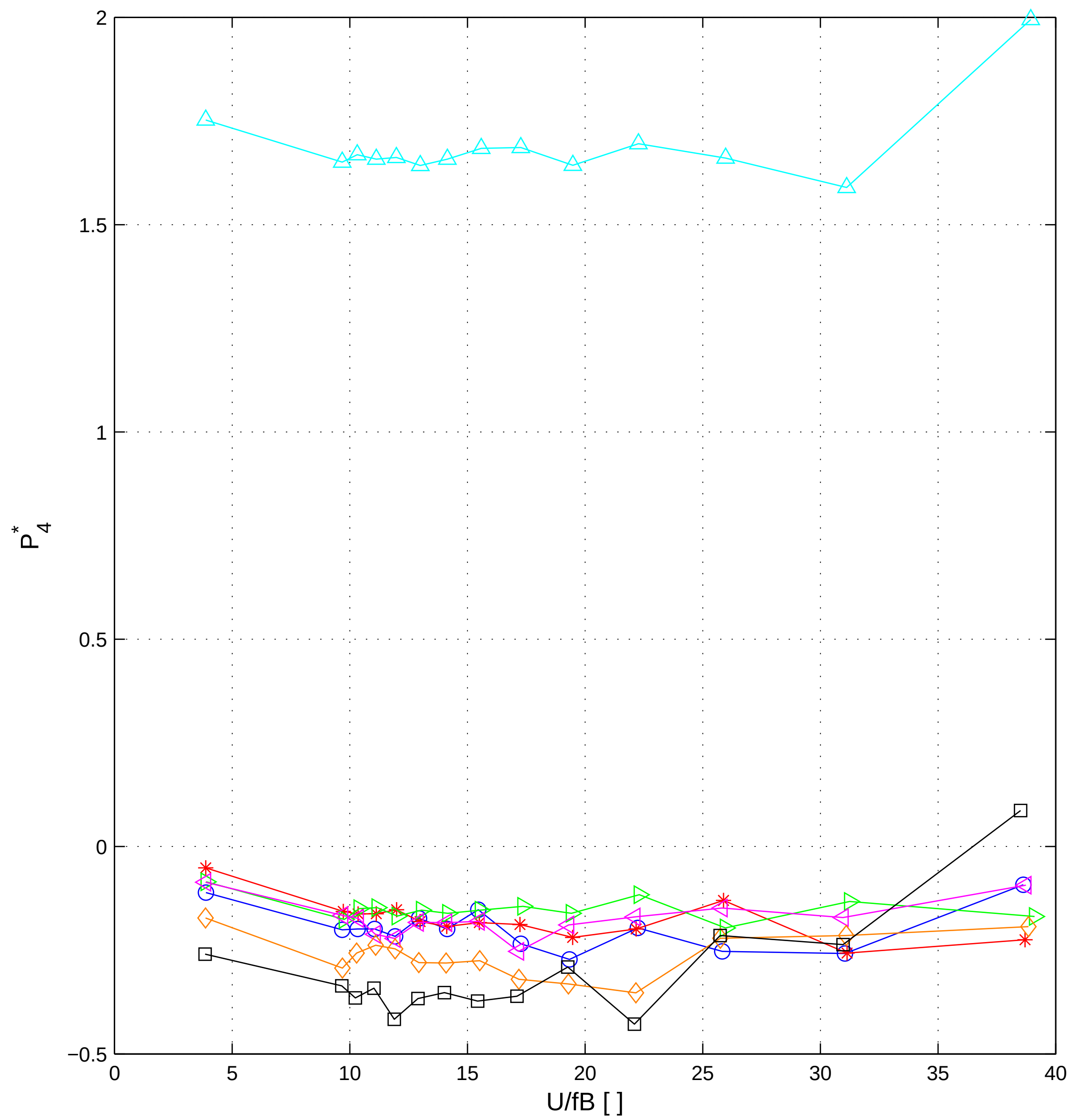
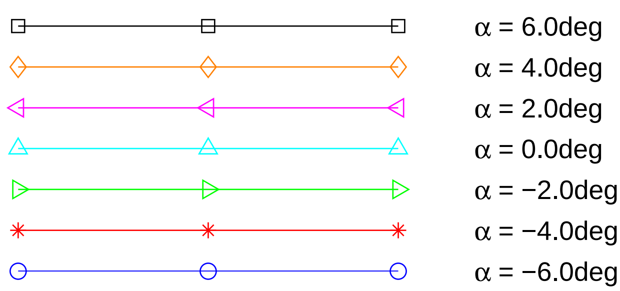


Figure S.18: Variation of coefficient P^*_4 with angle of incidence



Appendix T

Stability limit for different angles of incidence

Smooth flow, Erection stage

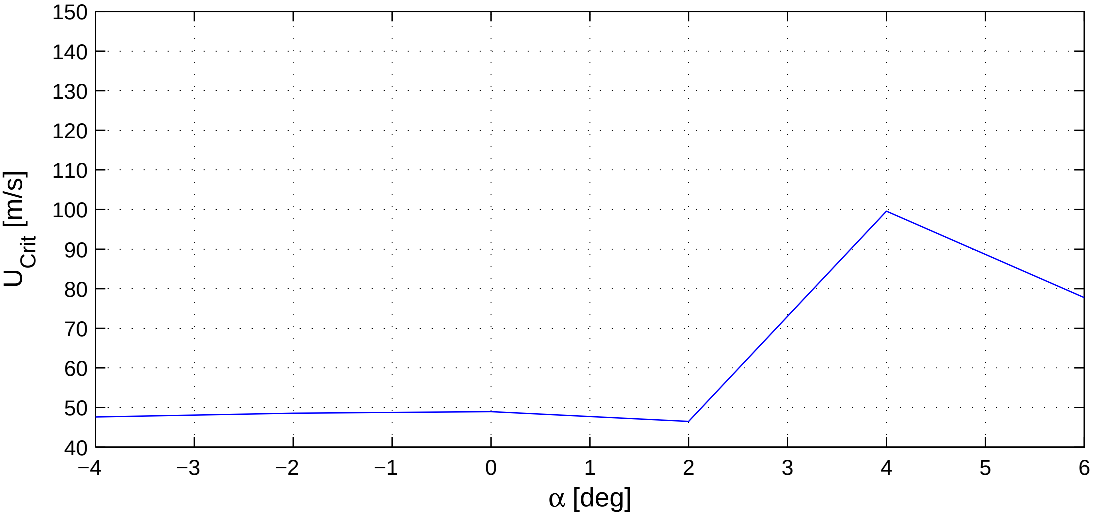


Figure T.1: Variation of stability limit with angle of incidence

α [deg.]	U_{Crit} [m/s]
−6	NaN
−4	48
−2	49
0	49
2	47
4	100
6	78

Table T.1: Variation of stability limit with angle of incidence

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Appendix U

Stability limit for different angles of incidence

Turbulent flow, Erection stage

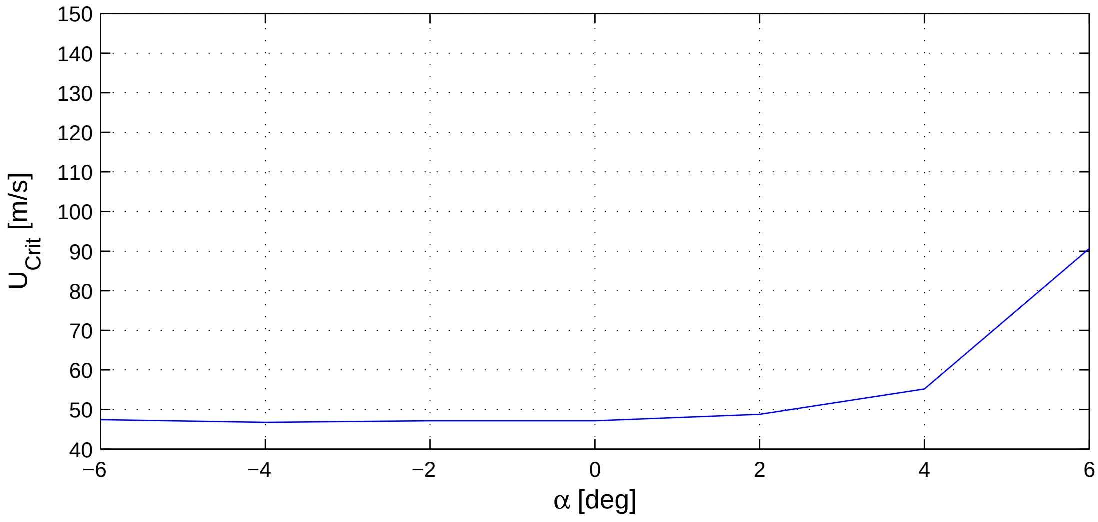

Figure U.1: Variation of stability limit with angle of incidence

α [deg.]	U_{Crit} [m/s]
−6	47
−4	47
−2	47
0	47
2	49
4	55
6	91

Table U.1: Variation of stability limit with angle of incidence

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Appendix V

Admittance Tests

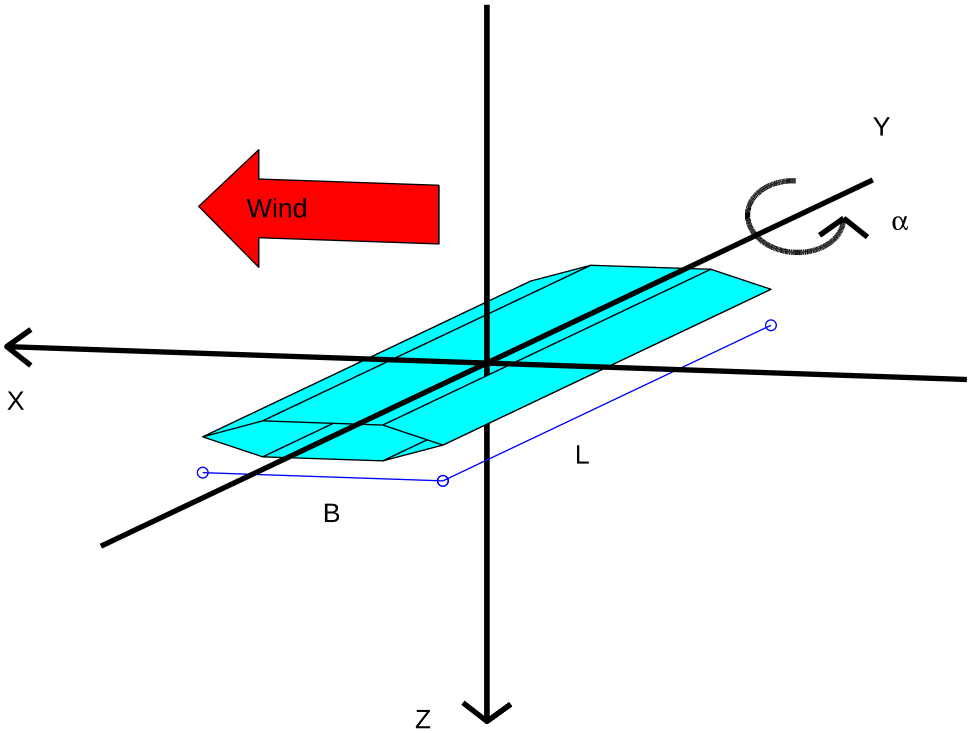
Admittance, Erection stage

Admittance Tests:

Determination of the admittance functions for vertical, lateral and torsoinal motions.

The response of a bridge section may be devided between a decay response originating from the mass, moment of intertia, mass midpoint and structural stiffness and a aerodynamic contribution from lift, drag and arero dynamic moment

Test sketch and co−ordinate system:



Project Data:

Quantity	Symbol	Unit	Value
Section width	B	m	0.755
Section length	L	m	2.550
Air density	ρ_{Air}	kg/m^3	1.1638

Table V.1: Project Data

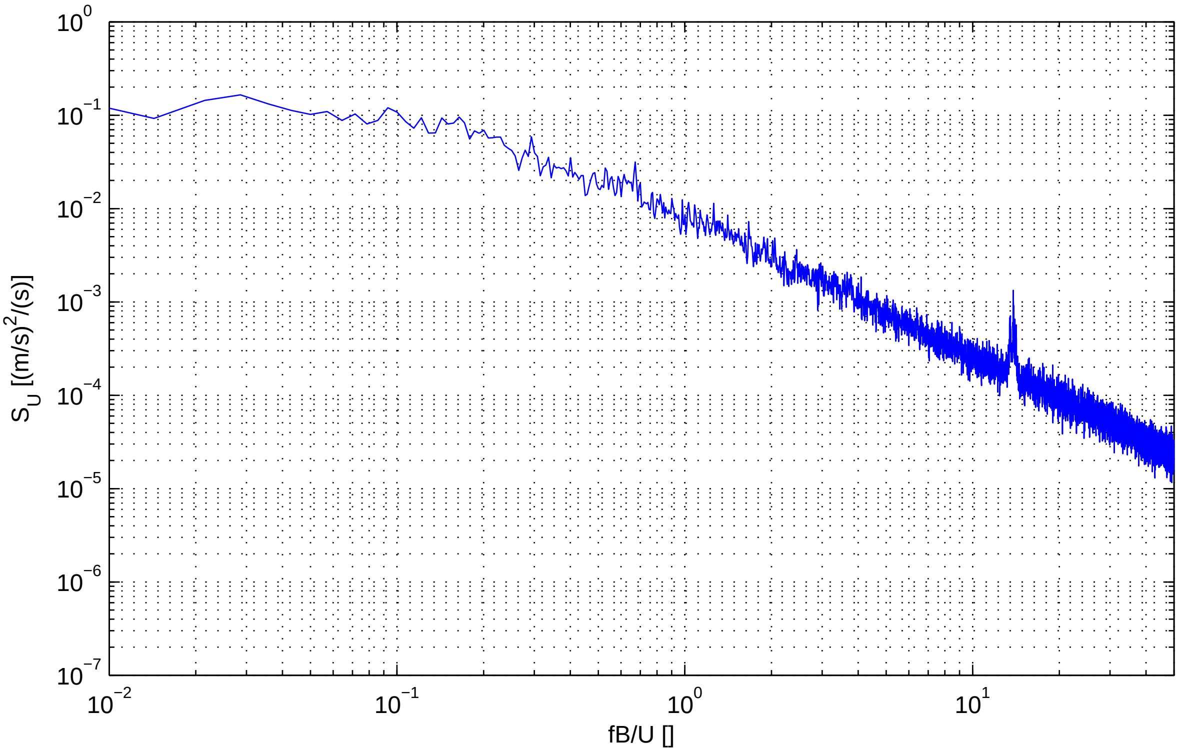


Figure V.1: Spectrum for u−velocity component

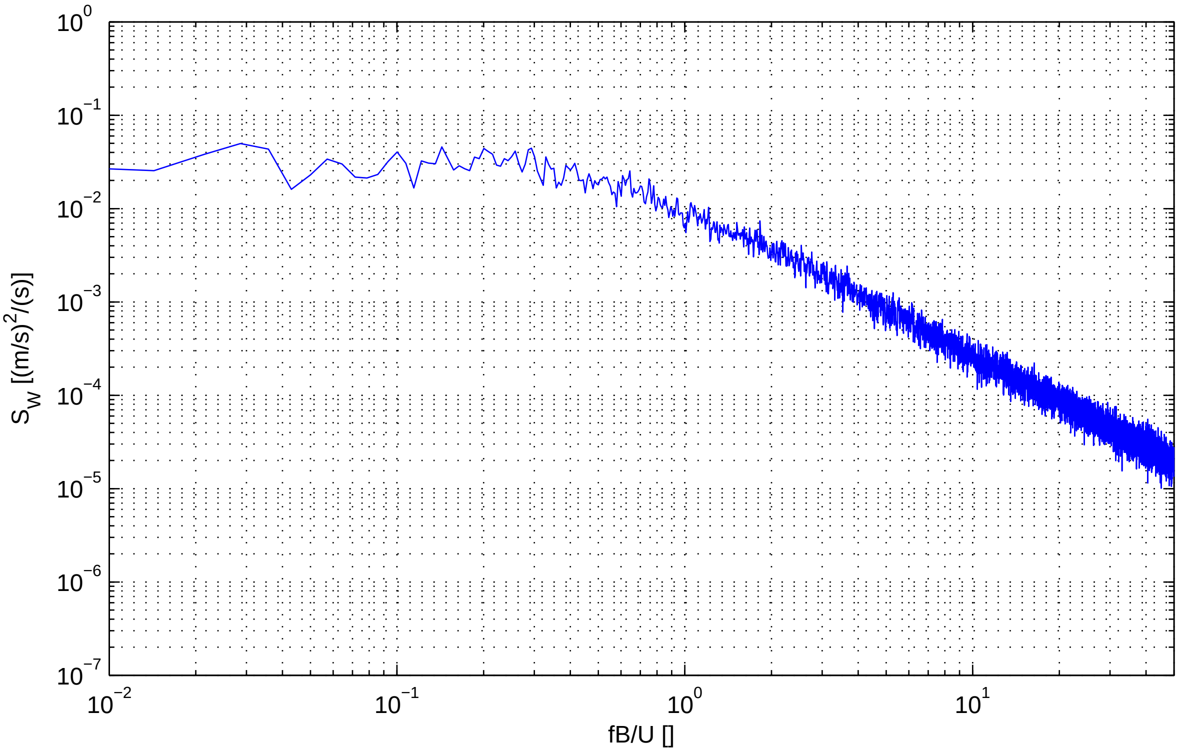


Figure V.2: Spectrum for w−velocity component

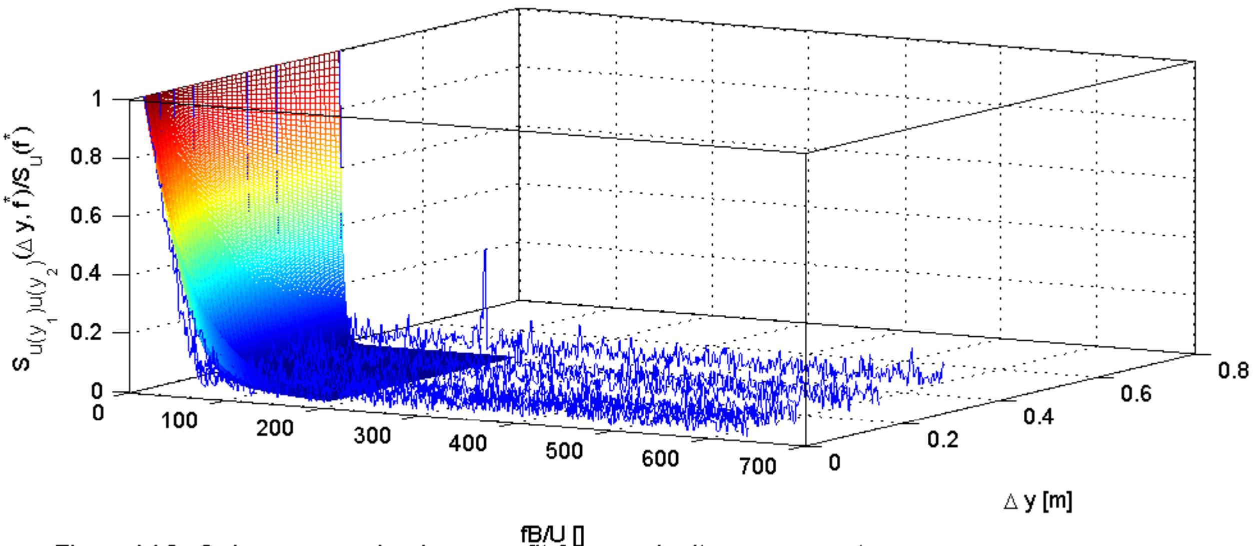


Figure V.3: Coherence and coherence fit for w-velocity component

$$S_{u(y_1)u(y_2)}(\Delta y, f^*)/S_u(f^*) = \exp(-C_{11} f\Delta y/V)\cos(C_{12} f\Delta y/V)\ ;\ \ C_{11} = 5.33\ ;\ \ C_{12} = 2.4284e\text{-}005$$

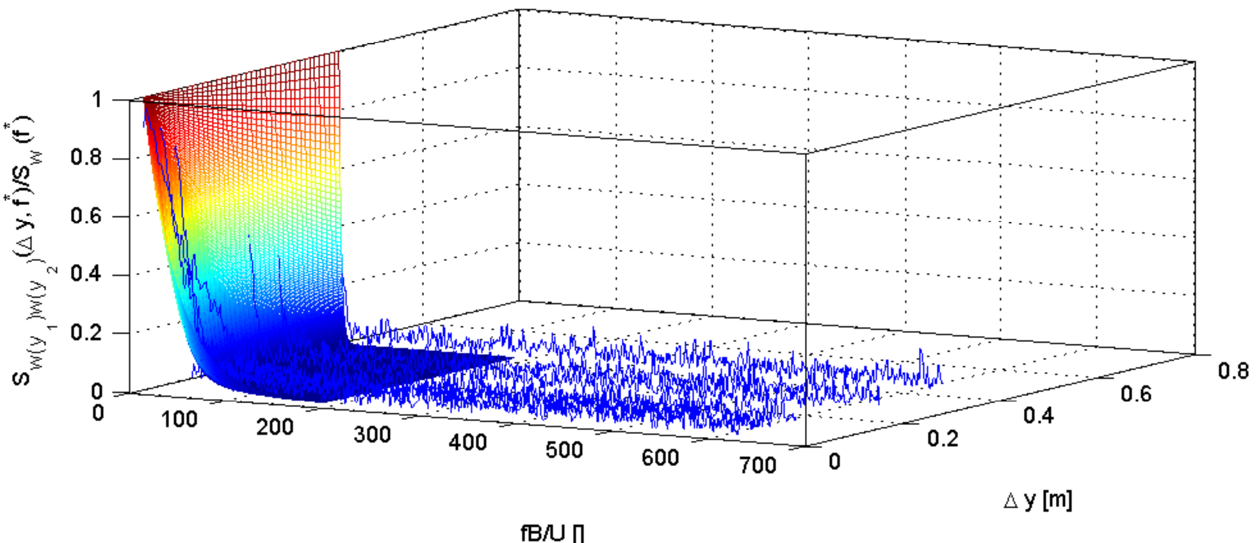


Figure V.4: Coherence and coherence fit for w-velocity component

$$S_{w(y_1)w(y_2)}(\Delta y, f^*)/S_w(f^*) = \exp(-C_{21} f\Delta y/V)\cos(C_{22} f\Delta y/V)\ ;\ \ C_{21} = 7.91\ ;\ \ C_{22} = 2.7766e\text{-}005$$

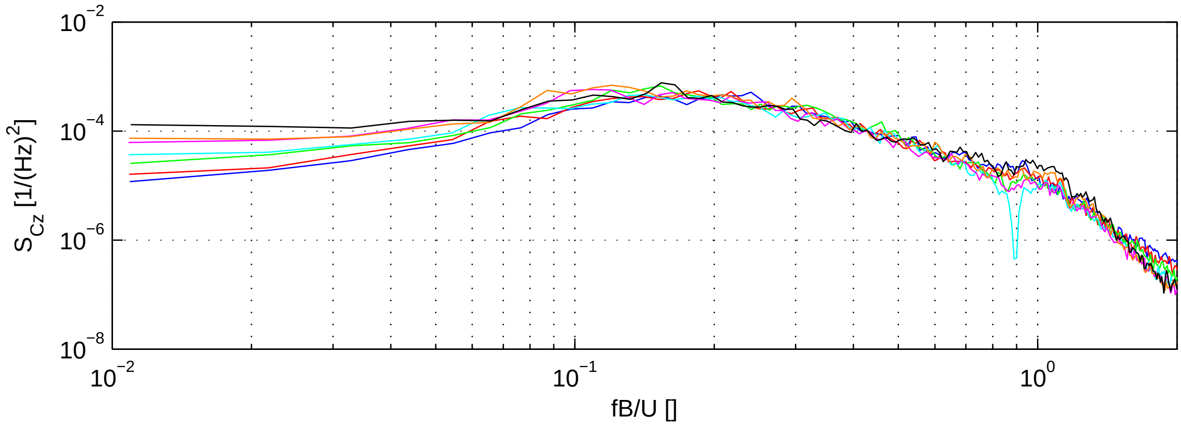


Figure V.5: Vertical force coefficient spectrum

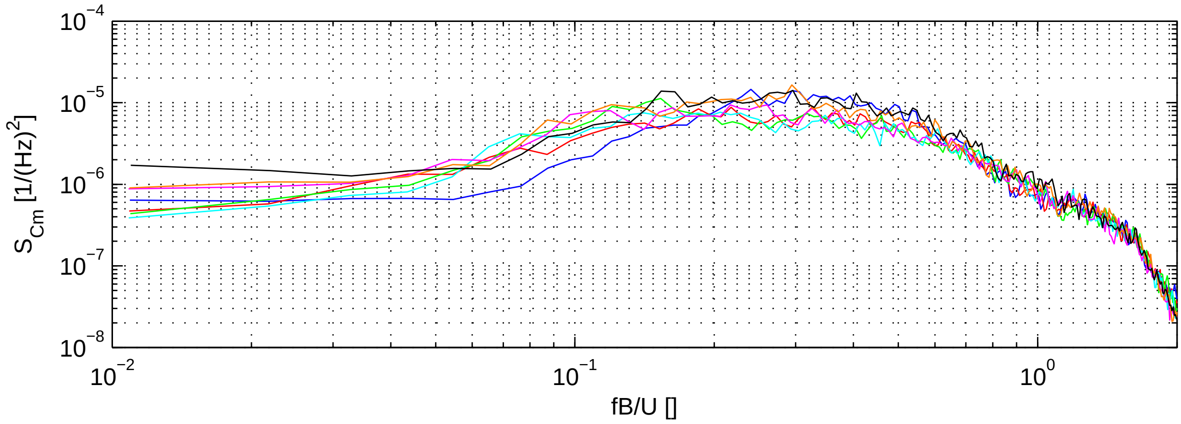


Figure V.6: Torsional moment coefficient spectrum

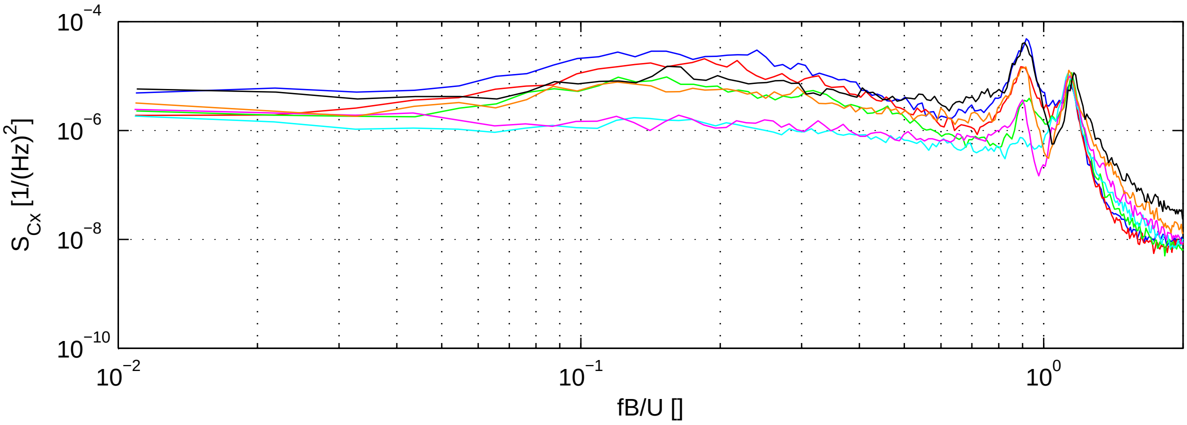
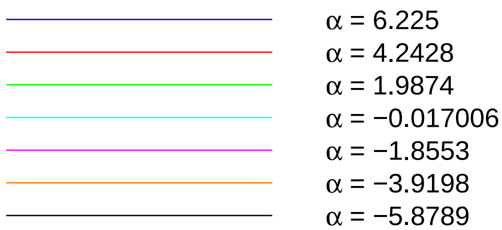


Figure V.7: Horizontal force coefficient spectrum



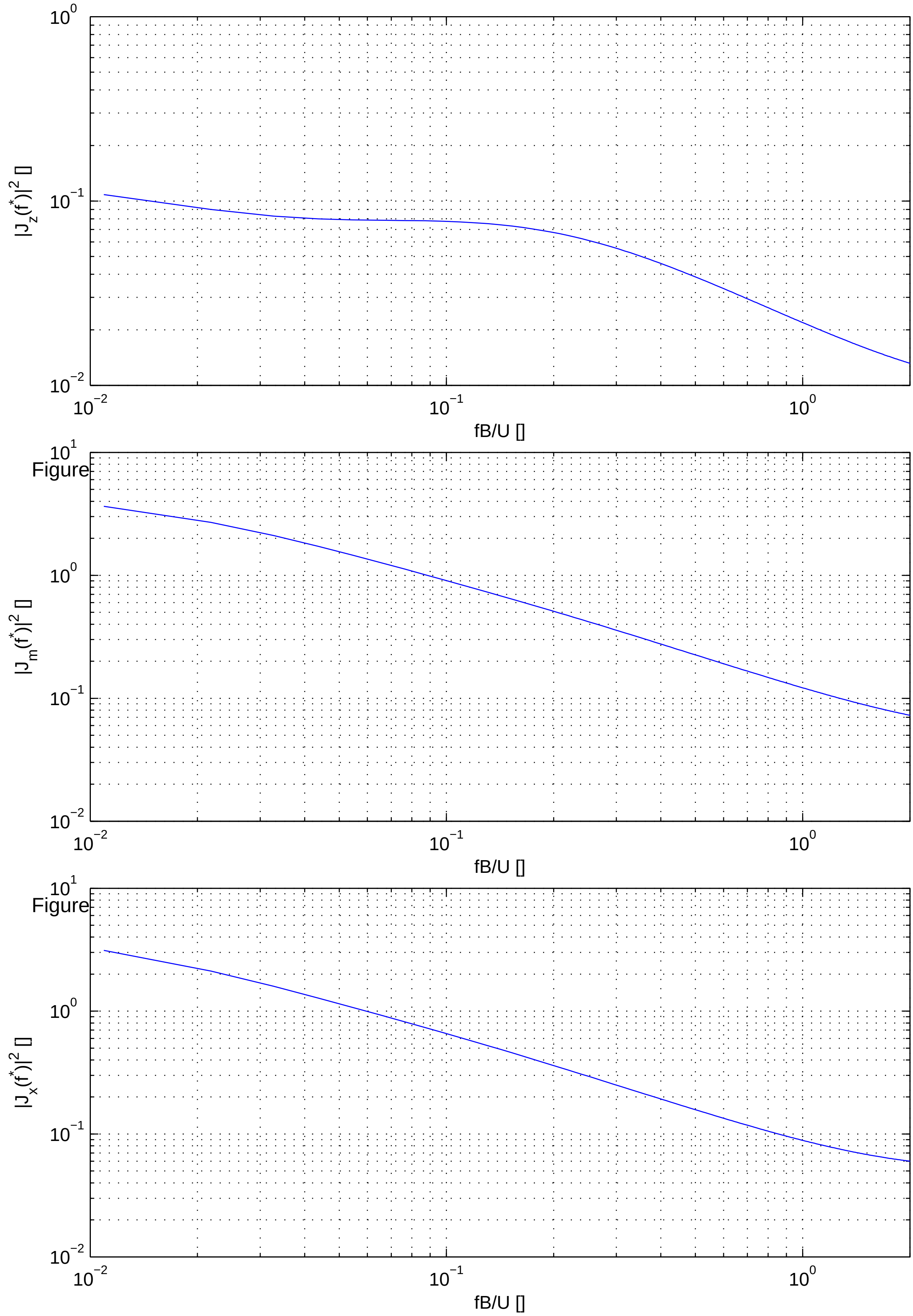


Figure V.10: Joint acceptance function for horizontal motion

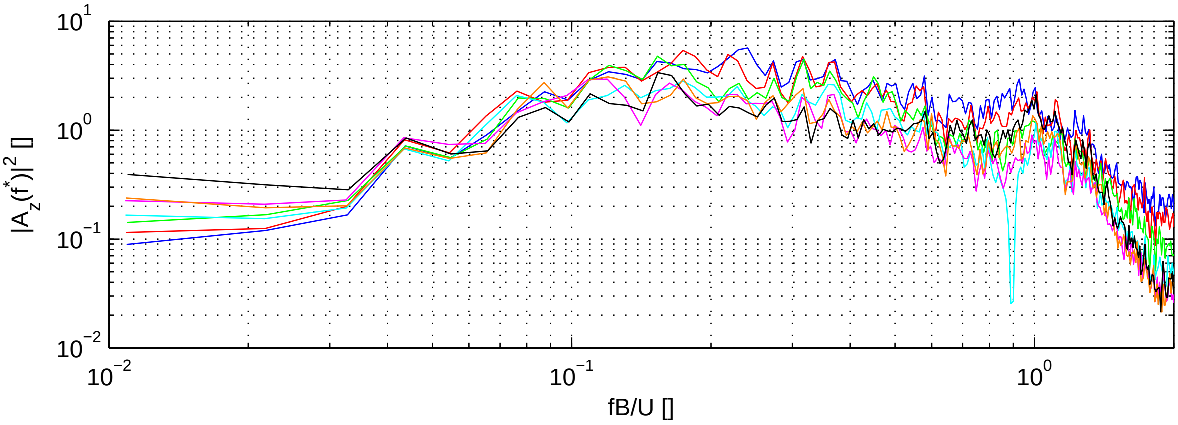


Figure V.11: Aerodynamic admittance for vertical motion

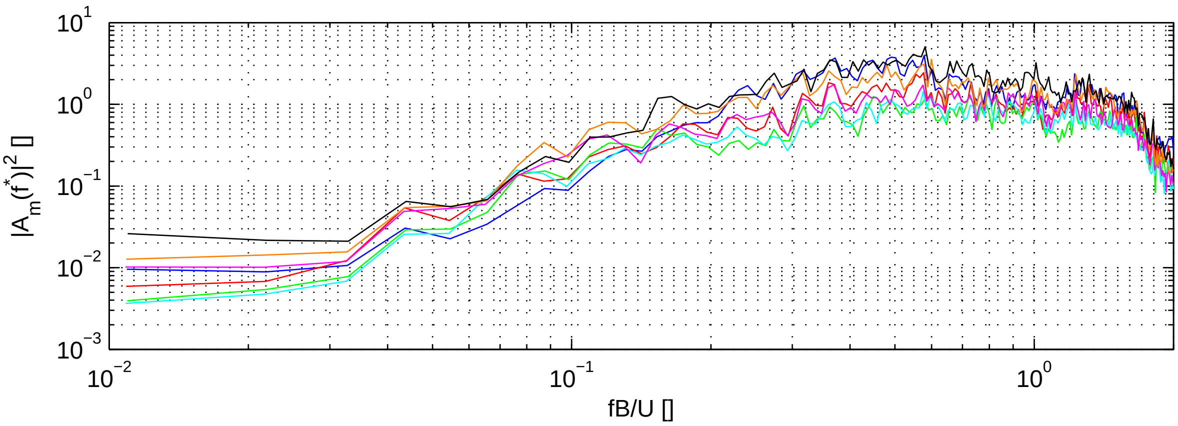


Figure V.12: Aerodynamic admittance for torsional motion

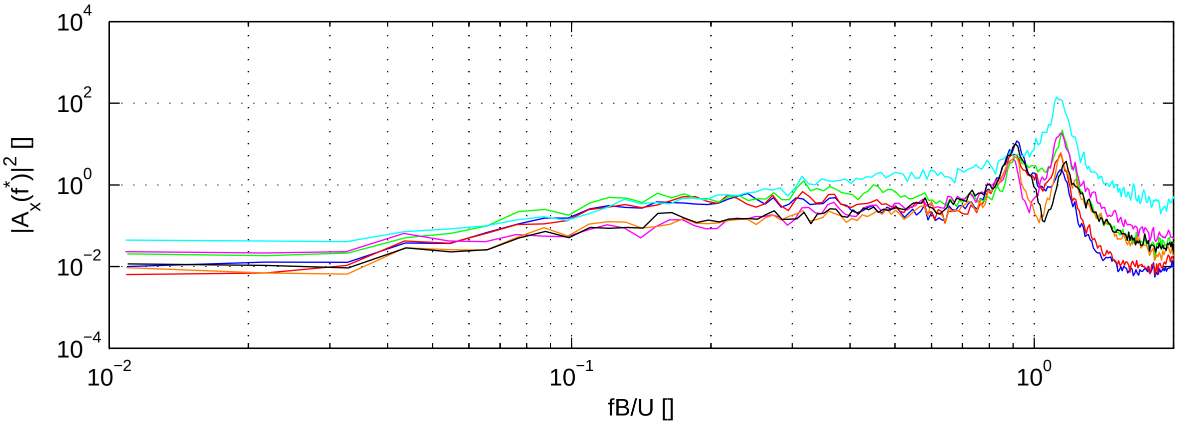
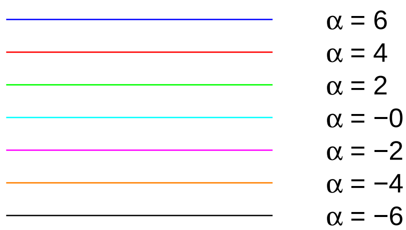


Figure V.13: Aerodynamic admittance for horizontal motion



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