PCCI
Marine and Environmental Engineering

Aquantis C-Plane
Tidal Bladed Mooring Input

Rev. 2
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Per the statement of work (SOW) agreed upon September 10, 2013, PCCI has been tasked with providing data as input to the mooring stiffness, damping and inertia matrices for the Tidal Bladed software.

To complete this task a model was built in Orcaflex using the net horizontal and vertical forces acting on the C-Plane (drag and buoyancy), and the mooring line properties provided in the mooring system specification spreadsheet for the prototype system. This spreadsheet is included as an attachment for reference. The static equilibrium position was determined for the design current speed of 1.6 m/s. This position was considered as the steady state position. Unit static displacements were applied from this steady state position and the resulting force recorded for determining the mooring line stiffness. Dynamic models were generated for determining the damping and mass matrices.

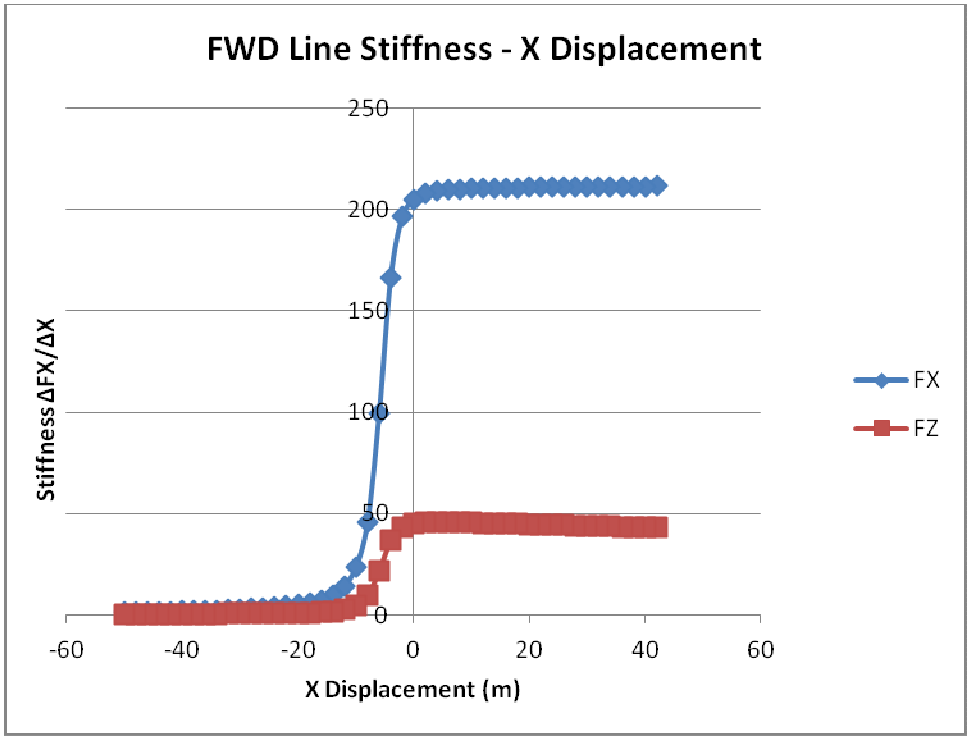
STIFFNESS

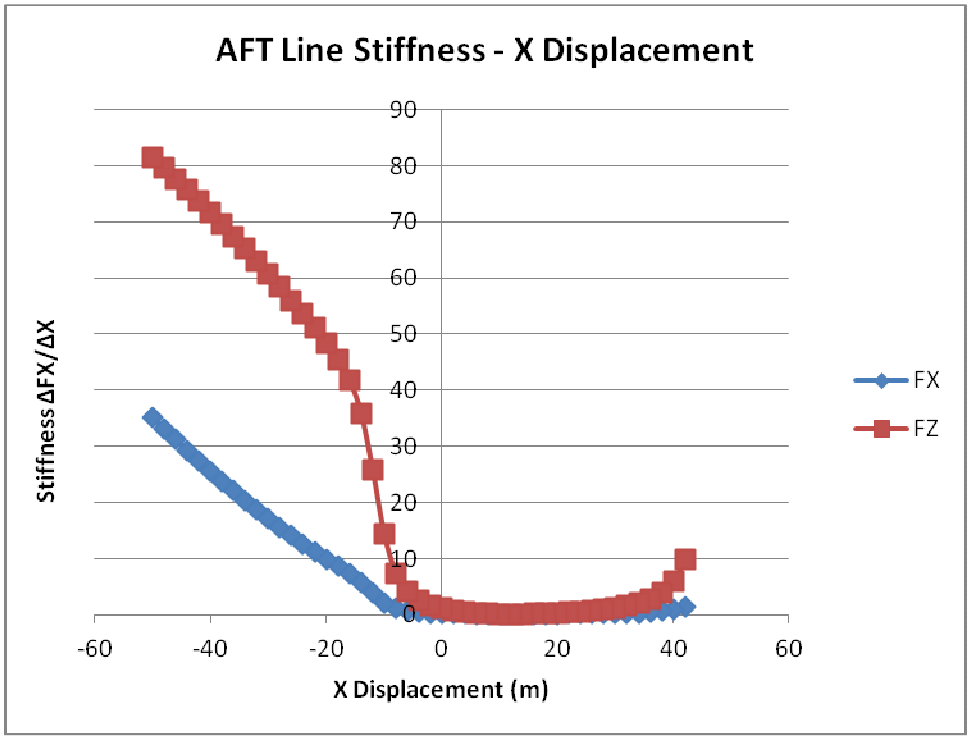
Line stiffness values for ΔFX-ΔX, ΔFX-ΔZ, ΔFZ-ΔX, ΔFZ-ΔZ are provided in the tables below. All other values in the stiffness matrix have been determined to be negligible and are assumed as approximately 0. Positive X displacement is defined as moving away from the anchor point in the plane of the mooring line. Positive Z displacement is defined as upward.

The tension in the mooring lines at the static position with a current speed of 1.6 m/s is shown in the table below.

Initial Line Tension

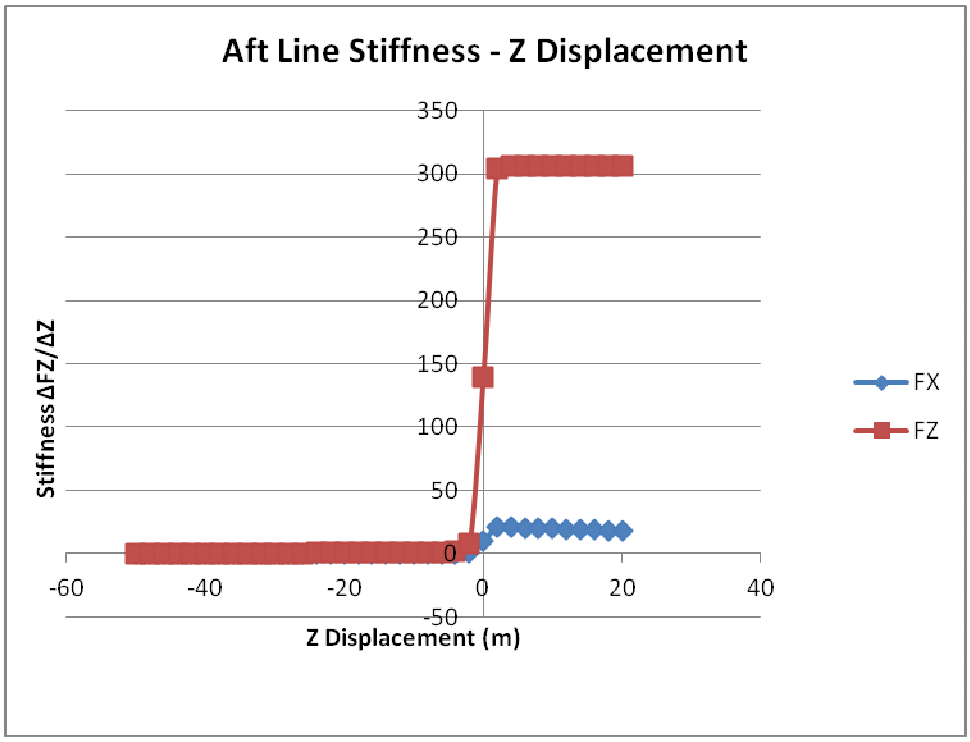
	Tension - X	Tension-Z
Forward Line	1660.6	404.1
Aft Line	14.5	66.1

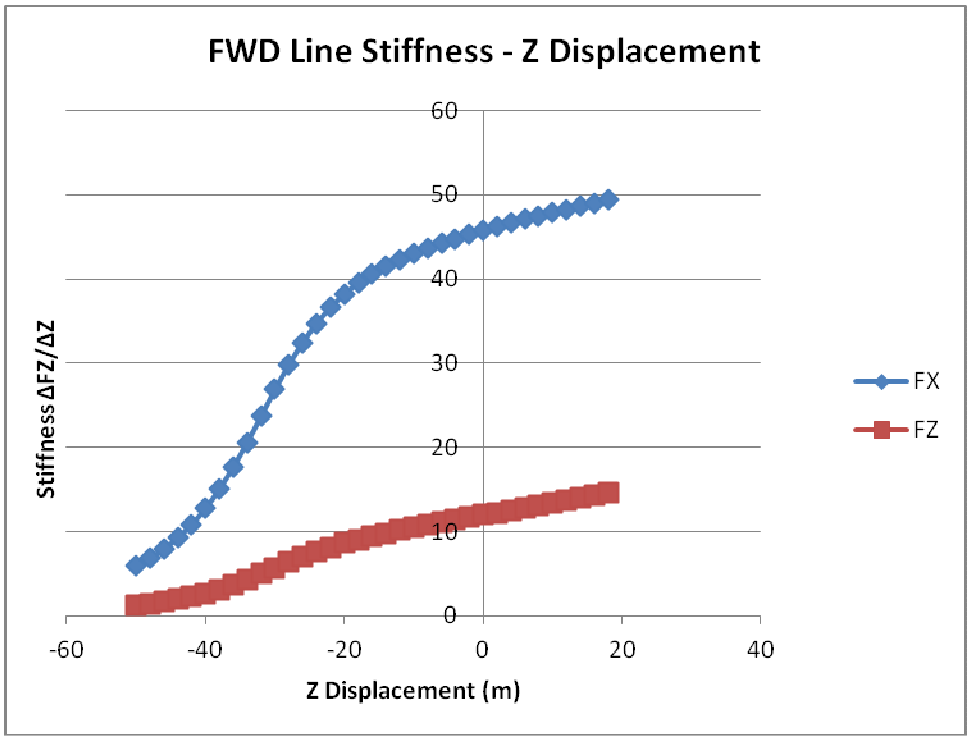

FWD Line Stiffness - X Displacement
Stiffness ΔFX/ΔX
250
200
150
100
50
0
-60
-40
-20
0
20
40
60
X Displacement (m)
FX
FZ


AFT Line Stiffness - X Displacement
Stiffness ΔFX/ΔX
90
80
70
60
50
40
30
20
10
0
-60
-40
-20
0
20
40
60
X Displacement (m)
FX
FZ

	X Displacement	FWD Mooring Line		Aft Mooring Line	
		ΔFX/ΔX	ΔFZ/ΔX	ΔFX/ΔX	ΔFZ/ΔX
	(m)	(kN/m)			
1	42.00	211.63	42.94	1.52	9.78
2	40.00	211.58	43.09	0.96	5.96
3	38.00	211.53	43.25	0.66	3.92
4	36.00	211.47	43.40	0.49	2.75
5	34.00	211.42	43.56	0.38	2.02
6	32.00	211.36	43.72	0.31	1.54
7	30.00	211.30	43.88	0.26	1.21
8	28.00	211.24	44.04	0.23	0.96
9	26.00	211.18	44.20	0.20	0.77
10	24.00	211.12	44.36	0.18	0.62
11	22.00	211.05	44.52	0.17	0.50
12	20.00	210.98	44.68	0.16	0.39
13	18.00	210.90	44.83	0.15	0.29
14	16.00	210.81	44.99	0.14	0.20
15	14.00	210.71	45.15	0.14	0.11
16	12.00	210.58	45.30	0.14	0.02
17	10.00	210.42	45.44	0.14	0.09
18	8.00	210.19	45.57	0.15	0.21
19	6.00	209.84	45.67	0.16	0.35
20	4.00	209.23	45.71	0.18	0.54
21	2.00	208.01	45.62	0.21	0.78
22	0.00	205.11	45.13	0.25	1.14
23	-2.00	196.46	43.33	0.32	1.67
24	-4.00	166.46	36.69	0.43	2.55
25	-6.00	99.48	21.70	0.65	4.14
26	-8.00	45.66	9.70	1.10	7.39
27	-10.00	23.42	4.79	2.10	14.39
28	-12.00	14.16	2.77	3.88	25.87
29	-14.00	9.68	1.81	5.78	35.95
30	-16.00	7.33	1.33	7.30	41.75
31	-18.00	6.22	1.15	8.64	45.45
32	-20.00	5.39	1.02	9.95	48.41
33	-22.00	4.70	0.91	11.29	51.07
34	-24.00	4.13	0.82	12.68	53.59
35	-26.00	3.66	0.74	14.11	56.02

36	-28.00	3.27	0.68	15.60	58.39
37	-30.00	2.93	0.62	17.14	60.71
38	-32.00	2.64	0.57	18.73	62.98
39	-34.00	2.40	0.53	20.37	65.20
40	-36.00	2.19	0.50	22.07	67.39
41	-38.00	2.01	0.47	23.80	69.52
42	-40.00	1.85	0.44	25.59	71.62
43	-42.00	1.70	0.42	27.42	73.66
44	-44.00	1.58	0.41	29.29	75.67
45	-46.00	1.47	0.39	31.20	77.62
46	-48.00	1.37	0.38	33.16	79.54
47	-50.00	1.28	0.37	35.14	81.40

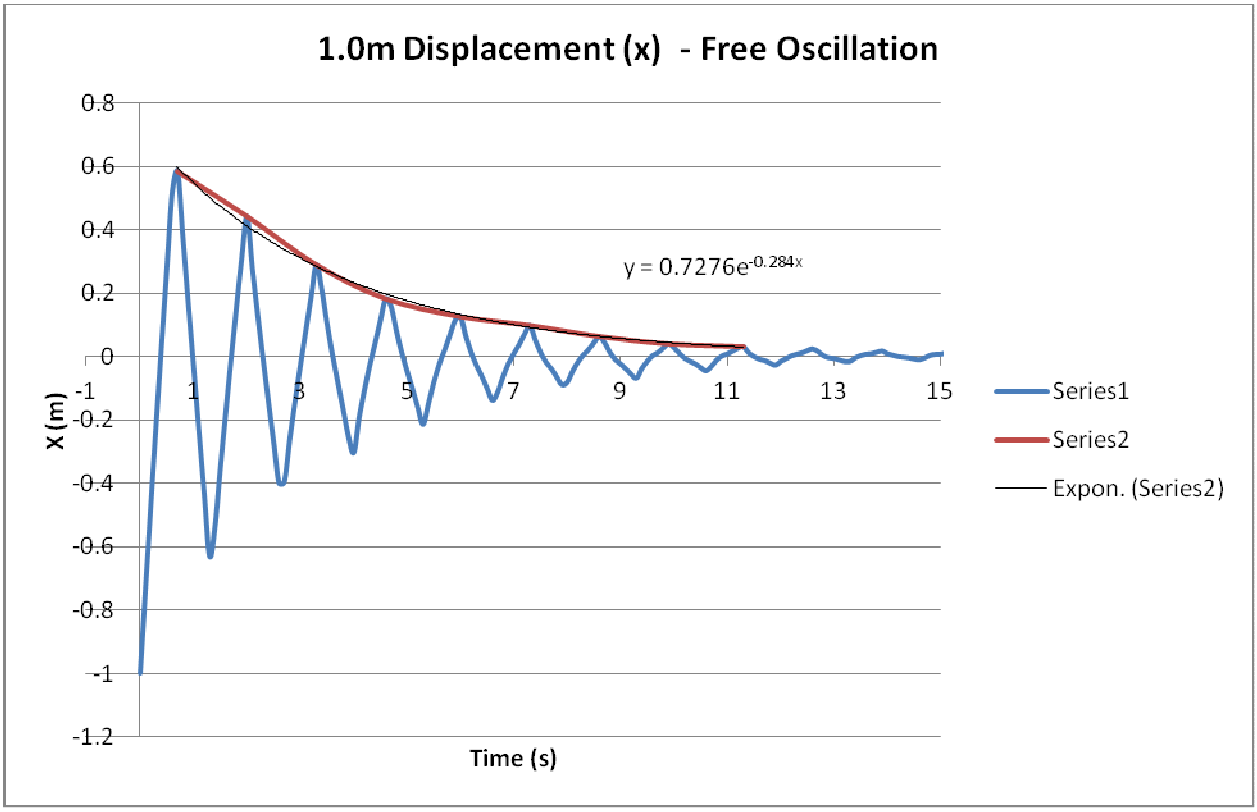

Aft Line Stiffness - Z Displacement
Stiffness ΔFZ/ΔZ
350
300
250
200
150
100
50
0
-50
-60
-40
-20
0
20
40
Z Displacement (m)
FX
FZ


FWD Line Stiffness - Z Displacement
Stiffness ΔFZ/ΔZ
60
50
40
30
20
10
0
-60
-40
-20
0
20
40
Z Displacement (m)
FX
FZ

	Z Displacement	FWD Mooring Line		Aft Mooring Line	
		ΔFX/ΔZ	ΔFZ/ΔZ	ΔFX/ΔZ	ΔFZ/ΔZ
	(m)	(kN/m)			
1	-50.00	6.01	1.28	0.08	0.07
2	-48.00	6.90	1.46	0.08	0.09
3	-46.00	7.97	1.68	0.09	0.10
4	-44.00	9.28	1.94	0.09	0.11
5	-42.00	10.87	2.27	0.10	0.13
6	-40.00	12.80	2.66	0.10	0.15
7	-38.00	15.09	3.14	0.11	0.17
8	-36.00	17.69	3.69	0.12	0.20
9	-34.00	20.61	4.31	0.12	0.23
10	-32.00	23.74	4.99	0.13	0.27
11	-30.00	26.87	5.70	0.14	0.31
12	-28.00	29.82	6.39	0.14	0.34
13	-26.00	32.47	7.04	0.15	0.39
14	-24.00	34.73	7.63	0.15	0.44
15	-22.00	36.63	8.15	0.15	0.49
16	-20.00	38.20	8.63	0.15	0.54
17	-18.00	39.51	9.05	0.15	0.60
18	-16.00	40.60	9.44	0.15	0.63
19	-14.00	41.53	9.80	0.14	0.68
20	-12.00	42.33	10.14	0.14	0.73
21	-10.00	43.04	10.47	0.13	0.76
22	-8.00	43.68	10.78	0.12	0.80
23	-6.00	44.26	11.09	0.12	0.91
24	-4.00	44.79	11.38	0.17	1.87
25	-2.00	45.30	11.68	0.60	7.71
26	0.00	45.77	11.97	9.74	139.59
27	2.00	46.23	12.26	20.97	303.74
28	4.00	46.66	12.54	20.78	306.18
29	6.00	47.09	12.83	20.44	306.38
30	8.00	47.50	13.12	20.09	306.45
31	10.00	47.90	13.40	19.76	306.50
32	12.00	48.29	13.69	19.43	306.54
33	14.00	48.67	13.98	19.11	306.57
34	16.00	49.05	14.26	18.79	306.60
35	18.00	49.42	14.55	18.49	306.63
36	20.00	49.79	14.84	18.19	306.66

DAMPING MATRIX

The figure below displays the results from the Orcaflex model for a 1-m displacement in the x-direction. The following table provides the damping due to a displacement in the x-direction is provided in the table below. All other values within the matrix are assumed to be negligible and close to zero. Values for the aft line are also assumed to be negligible.



Forward Line – Damping Matrix

	ΔX	ΔY	ΔZ	θX	θY	θZ
Fx	5200		~ 0	~ 0	~ 0	~ 0
Fy	~ 0		~ 0	~ 0	~ 0	~ 0
Fz	~ 0		~ 0	~ 0	~ 0	~ 0
Mx	~ 0		~ 0	~ 0	~ 0	~ 0
My	~ 0		~ 0	~ 0	~ 0	~ 0
Mz	~ 0		~ 0	~ 0	~ 0	~ 0

Values in N/m/s

MASS MATRIX

The following table is the mass matrix for the forward line.

Forward Line – Mass Matrix

	ΔX	ΔY	ΔZ	θX	θY	θZ
Fx	9160	~ 0	~ 0	~ 0	~ 0	~ 0
Fy		~ 0	~ 0	~ 0	~ 0	~ 0
Fz			~ 0	~ 0	~ 0	~ 0
Mx				~ 0	~ 0	~ 0
My					~ 0	~ 0
Mz						~ 0

Values in kg

Aft Line – Mass Matrix

	ΔX	ΔY	ΔZ	θX	θY	θZ
Fx	535	~ 0	~ 0	~ 0	~ 0	~ 0
Fy		~ 0	~ 0	~ 0	~ 0	~ 0
Fz			5746	~ 0	~ 0	~ 0
Mx				~ 0	~ 0	~ 0
My					~ 0	~ 0
Mz						~ 0

Values in kg