LONGITUDE
Engineering

MARINE CONSULTING ENGINEERS

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Email

To:	TADEK Ltd	Email:	tadek@gmx.co.uk
Attn:	Rupert Raymond	Your ref:	-
From:	Roberto Longo	Date:	23rd February 2015
Our ref:	LGK-C192-P277-E02	No. of pages (inc cover)	1+10+58
Subject:	P277-103 - Review and Due Diligence of Designed Mooring System		

Dear Rupert

As requested, please find below a technical note reporting the results of our Review and Due Diligence of Designed Mooring System for Wello Penguin Wave Energy Device.

As agreed, a quasi-static analysis was carried out aimed verifying the proposed mooring system in terms of:

- Maximum tension on mooring lines;
- Maximum loads on anchor clumps;
- Maximum displacement of Penguin Wave Energy device.

Analysis was conducted considering the 10 years return storm.

In this note we have detailed the inputs used and assumptions made in generating such results.

Best regards,

Roberto Longo

1. Introduction

The Wello Ocean Wave Energy Converter system consists of a floater with an asymmetrical hull shape and a roll plate hanging from the port side of the vessel. The floater is designed to have large motions, which facilitates production of energy through a rotating flywheel inside the hull.

Longitude Consulting Engineers (LGK) were instructed to conduct a study to verify the proposed mooring system developed by TADEK Ltd [1], comprised of a 6 legged mooring system.

This is an evolution of the original mooring system used for the Wello Ocean Wave Energy Converter at EMEC in the Orkney Isles, which was comprised of the following components.

- Concrete clumps (54t/31t) are connected almost vertically via wires to 25t buoyancy floats;
- Wire leads from the floats to 14t suspended clump weights which have the function of tensioning the system and enabling movement.

As this previous design was suffering of high dynamic loads, leading to mooring system failure, the new design proposed by Tadek introduces the following principal modifications:

- Reduce Buoyancy from 25t to 12.5t and move (when tensioned) to approximately 5m below still water level. This was motivated to reduce the level of dynamic loading;
- Increase the length of risers in catenaries in order to reduce snatch loading;
- Make risers catenaries out of chain to increase life expectancy of the system as well as to enable greater contribution to the system stiffness than a wire catenary;
- Remove suspended concentrated clump weights and replace with length of 54mm chain to assist operations as well as to remove the significant dynamic and concentrated loading.

An Orcaflex screenshot of the supplied Tadek design is presented below.

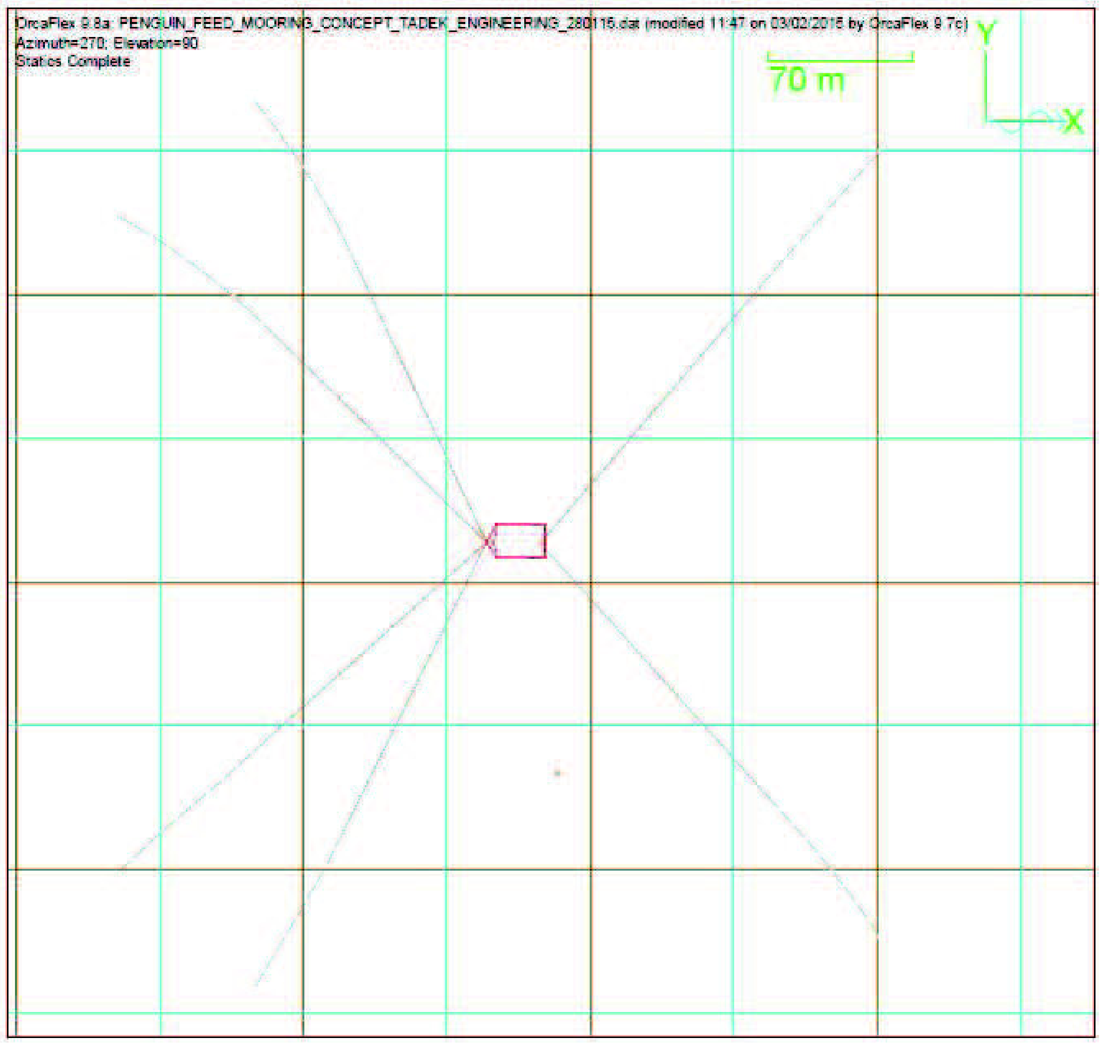


Figure 1 – Proposed Mooring System – Plan View

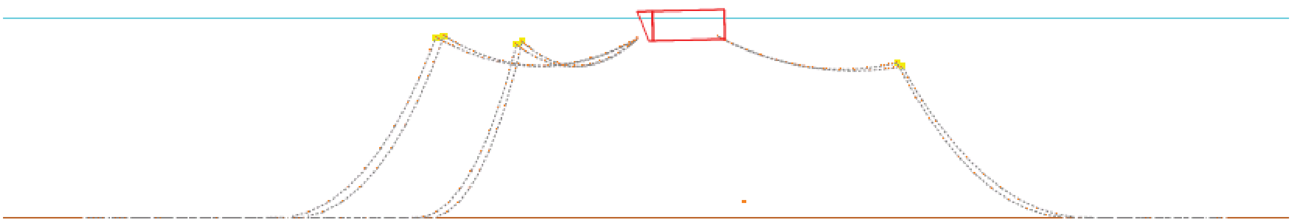


Figure 2 – Proposed Mooring System – Elevation View

2. References

[1] File: PENGUIN_FEED_MOORING_CONCEPT_TADEK_ENGINEERING_280115

[2] API RP 2SK, Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures, 3rd Edition.

[3] Report EX 4471, Marine Energy Test Centre, Stromness, Orkney, November 2001

[4] DNV Offshore Standard DNV-OS-E301 “Position Mooring”, October 2010

[5] BS 6349: Part 6: 1989 - British Standard Code Practice for Maritime Structures, Part 6 – Design of inshore moorings and floating structures

[6] DNV Reg. No. 13EJ2LJ-1: Report: "Wello Mooring Analysis" (Rev01, June 2011)

[7] AN-012-12-01: Drawing: “Unit 12, Converter – Lower Roll Flange New” (Rev F, February 2013)

[8] Tadek Memo Optimised Mooring Analysis 300914

[9] Penguin Mooring – Concept Decision

[10] Workshop with Tadek Ltd – Wednesday 28th January 2015, MOM - Email “MOORING DESIGN - REQUIREMENTS, OUTPUT, INPUTS”

[11] Fugro Report REP100-01-02 “Vessel Mounted ADCP Current Measurements”

3. Methodology

Analysis was conducted in frequency domain using the commercial 3D Diffraction software MOSES.

A quasi-static analysis was carried out aimed at verifying the proposed mooring system in terms of:

- Maximum tension on mooring lines;
- Maximum loads on anchor clumps;
- Maximum displacement of the floater.

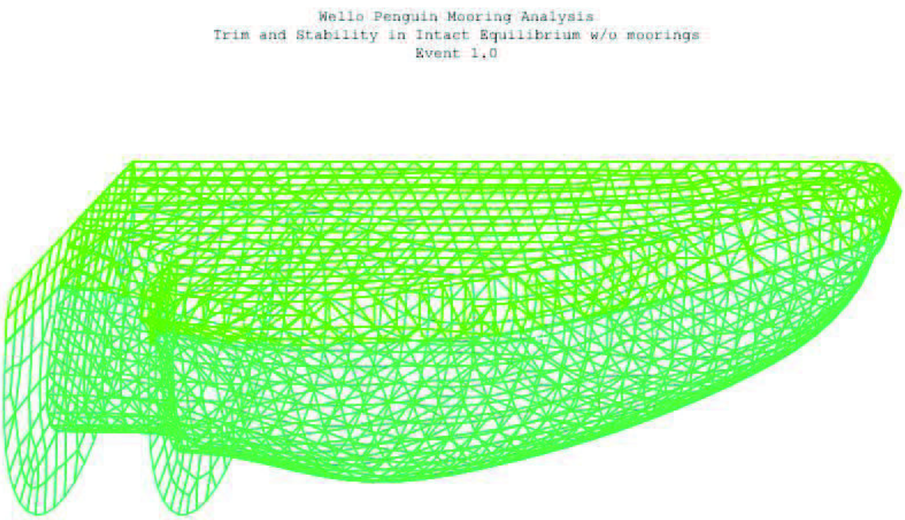


Figure 3 – MOSES: Floater model mesh

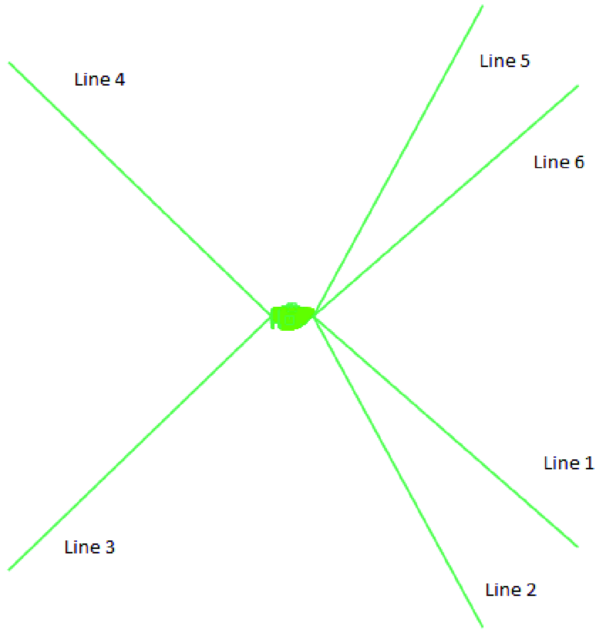


Figure 4 –Mooring System Layout (Plan View)

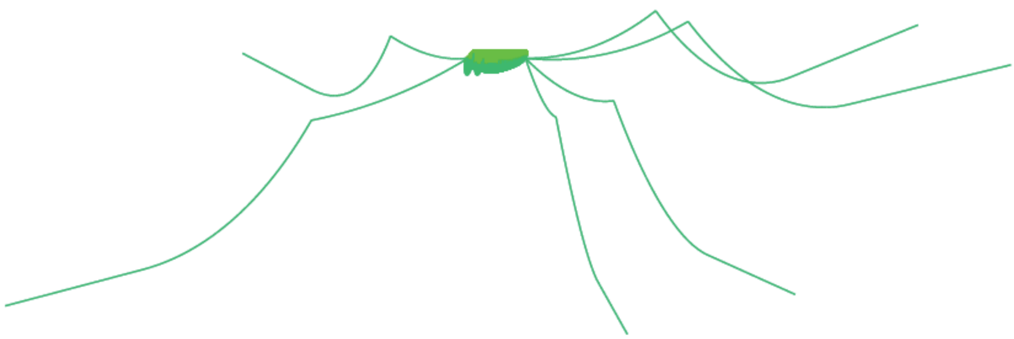


Figure 5 –Mooring System Layout (Iso View)

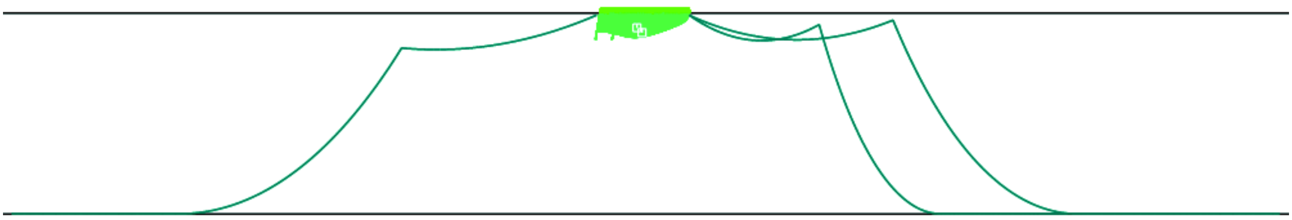


Figure 6 –Mooring System Layout (Side View)

4. Main Assumptions

Environmental Data

The proposed mooring system is designed for operating for one year and, therefore, can be considered as a “mobile mooring system”. According to [2], for this mooring system category a design environment with a return period of at least 5 years should be used.

In a conservative way, the proposed mooring system was verified considering the 10 years return storm. Different environmental conditions were considered in the analysis as detailed in the following table.

ENV NAME	Compass Direction (degs)	Waves			Wind	Current
		Hs metres	Tp min sec	Tp max sec	speed m/sec	speed m/sec
ENV_240	240	6.40	9.12	13.86	30	0.30
ENV_270	270	10.50	11.68	17.75	40	0.30
ENV_285	285	11.60	12.28	18.65	40	0.30
ENV_300	300	12.70	12.85	19.52	40	0.40
ENV_330	330	10.20	11.52	17.49	40	0.40

Table 1 – Environmental data analysed

Only direction between 240°N and 330°N where considered as representative of the worst cases in terms of wave height and covering 90% of occurrence of wave directions [3]. The floater heading is assumed to be 285°N predominantly head to the waves. .

The sea states are assumed to be represented by the JONSWAP wave spectrum. Since no detailed information is given it is assumed that the peak enhancement factor $\gamma = 3.3$ applies for all sea states as recommended in [4].

Wind and current were assumed collinear with wave direction.

The water depth at site is approximately 60 m. The seabed is simplified to a level plain in this analysis, it is considered small changes in bathymetry will have little influence on the analysis results.

Mooring System

Each mooring line was considered composed of:

- A first section of 82.50m connecting the Penguin to the mooring buoys (floats)
- A second section of 178.75m connecting the buoy to the anchor concrete block.

The first section was assumed made of 54mm studlink chain grade U3 (MBL = 231t) while the second section was assumed made of 76mm studlink chain grade U2 (MBL = 306t). The two section are connected through a buoy having a buoyancy capacity of 12.5t.

The anchor blocks were positioned approximately 240m away from the floater and assumed made of concrete and having a submerged weight of 30t. In a conservative way, it was considered a friction coefficient of 0.3 as indicated in [5] for deadweight anchors in poor soils (silt and soft clay)

Reference System

Moses reference system is reported in Figure 7. The following table is reporting conversion from heading in actual coordinate system to MOSES reference system.

Wave Direction	
Wello [deg]	MOSES [deg]
240	225
270	195
285	180
300	165
330	135

Table 2 – Wave Heading: Wello vs. Moses reference system

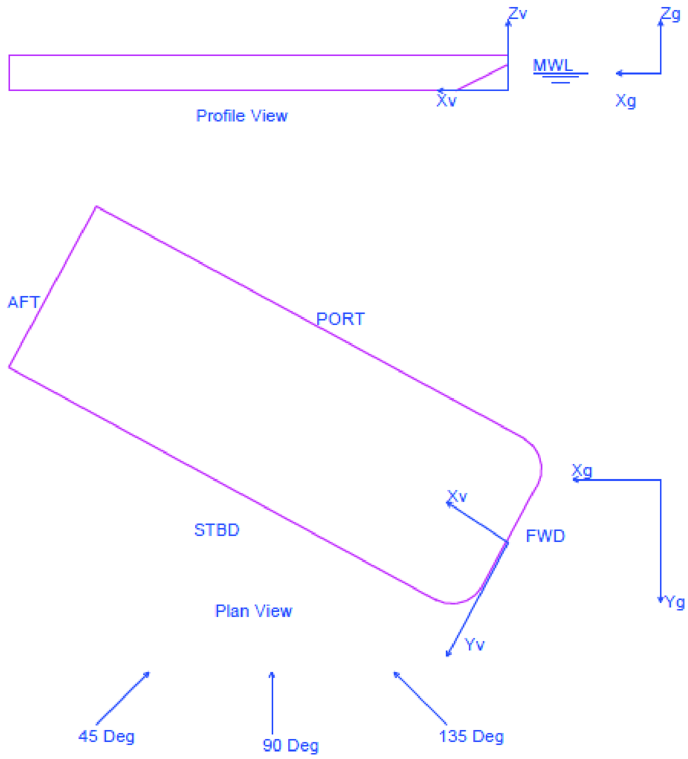


Figure 7 – Moses Reference System

5. Results

The following limits where considered for the purpose of the analysis:

- Line Safe Working Load: 1135 kN
- Maximum Allowable Tension @ Anchor: 128 kN

According to above figures, the following utilization factors were calculated:

LINE	Max Tension [kN]	Tension Utilization	Anchor Holding Utilization
L1	293	26%	**228%**
L2	333	29%	**259%**
L3	185	16%	**144%**
L4	136	12%	**106%**
L5	157	14%	**122%**
L6	179	16%	**139%**

Table 3 – Result Summary – Mooring Lines

For each environmental condition analysed, the maximum displacement was calculated. TADEK specified 30 m as the maximum allowable displacement on the as built configuration of the export cable from the device to the seabed box. Above this value there becomes a risk of the cable coming tight and breaking. This would obviously be as significant a failure as a mooring component failure. According to this, the following utilization factors were calculated.

ENV NAME	Max Displacement [m]	Utilization
ENV_240	13.9	46%
ENV_270	24.3	81%
ENV_285	27.4	91%
ENV_300	30.5	**102%**
ENV_330	26.5	88%

Table 4 – Results Summary – Maximum Displacement

The following figure is reporting the vertical position of the buoys respect to the sea-level as a function of the tension on the line.

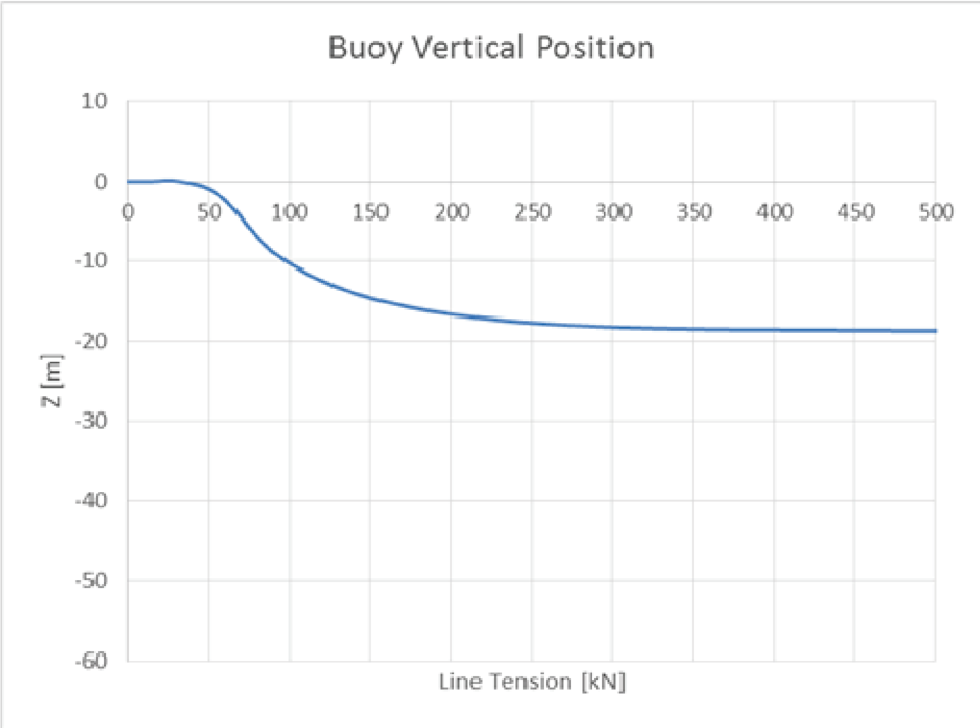


Figure 8 – Buoy vertical distance from sea-level Vs. tension on the line

Complete results are provided in APPENDIX C.

6. Conclusion

A quasi-static analysis was carried out in order to verify the proposed mooring system for the Wello Penguin Wave Energy Device. Analysis was conducted using the commercial software MOSES in the frequency domain and aimed assessing the maximum tension on the mooring lines, anchor holding capacity and maximum displacement of the floater.

Even if the proposed mooring system can be considered “temporary” as it is meant to be operating for one year only, to ensure conservatism it was verified considering the 10 years return storm

Results showed that lines’ utilization is within the maximum allowable values and therefore the proposed size is suitable.

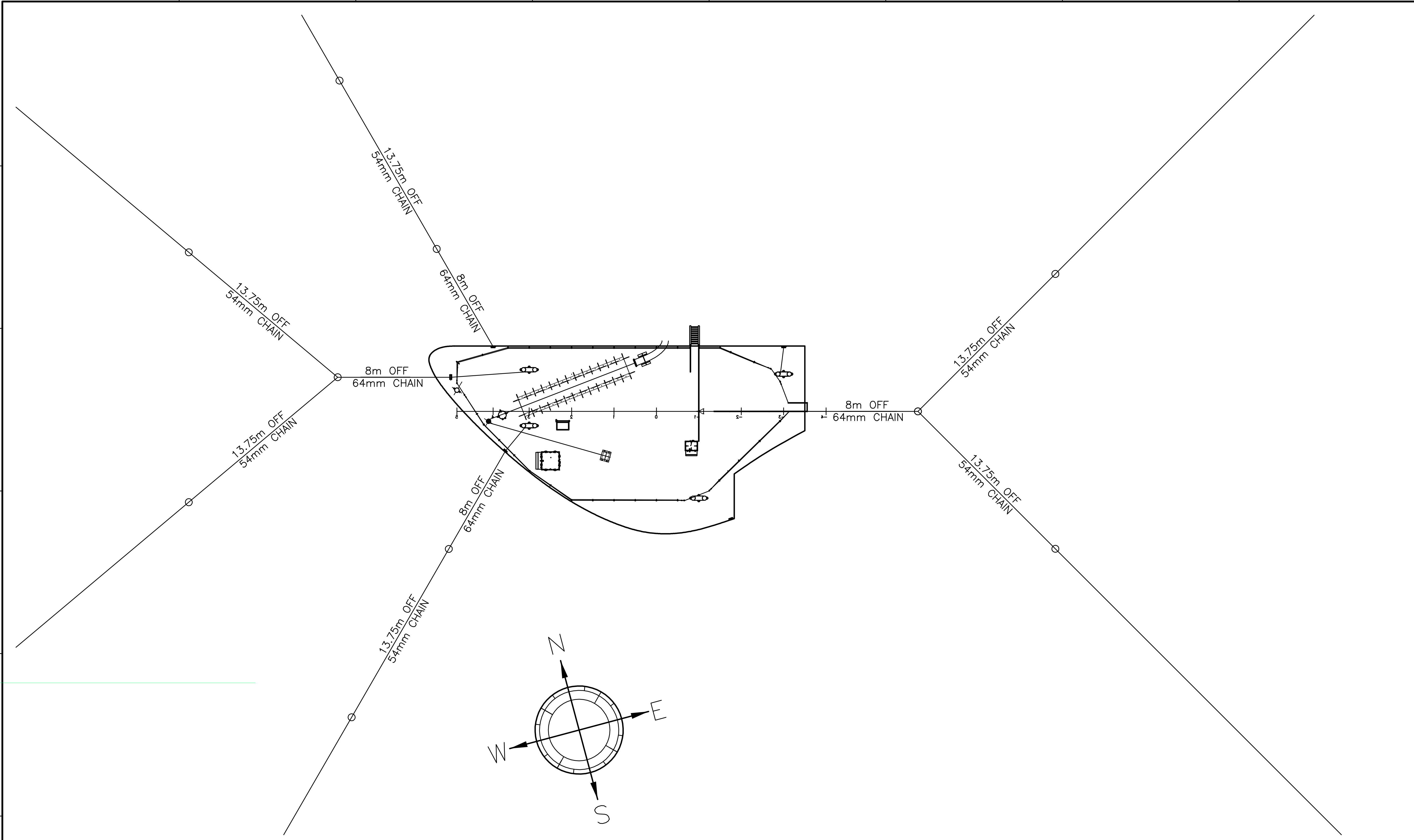
The anchor’s holding capacity results so these are not sufficient for withstanding the 10 years return storm induced loads and, therefore, clump weight size shall be increased. However it should be noted that the friction coefficient of 0.3 might be too conservative and this aspect should be better investigated.

In terms of maximum floater displacement, the only condition exceeding the limit of 30m is the “ENV_300”, for which an exceedance of less than 2% is highlighted. However it should be noted that maximum displacement is calculated in a conservative way considering maximum surge, maximum sway and maximum heave acting at the same time, condition which is quite unlikely.

This said the above, some optimization of the mooring system are possible working on different parameters such as line pre-tension (here not included), chain and anchor size and position. Also at a later stage damage condition shall be considered as well which is not included in the present study.

APPENDIX A

MOORING SYSTEM DRAWING



1	10/01/15	DJG	RL	RL	ISSUE FOR COMMENT
Rev	Date	Drawn	Checked	Approved	Issue Status

Client / Project

TADEK Ltd

MOORING DESIGN FOR WELLO OY

WAVE ENERGY CONVERTER MK. 1

Filename:	Drawing Number:	Sheet:	Rev.	Client Drawing Number.
–	TDK-WELLO-WEC-001-01	1 OF 4 / Scale: AS SHOWN	1 / Size: A3	–

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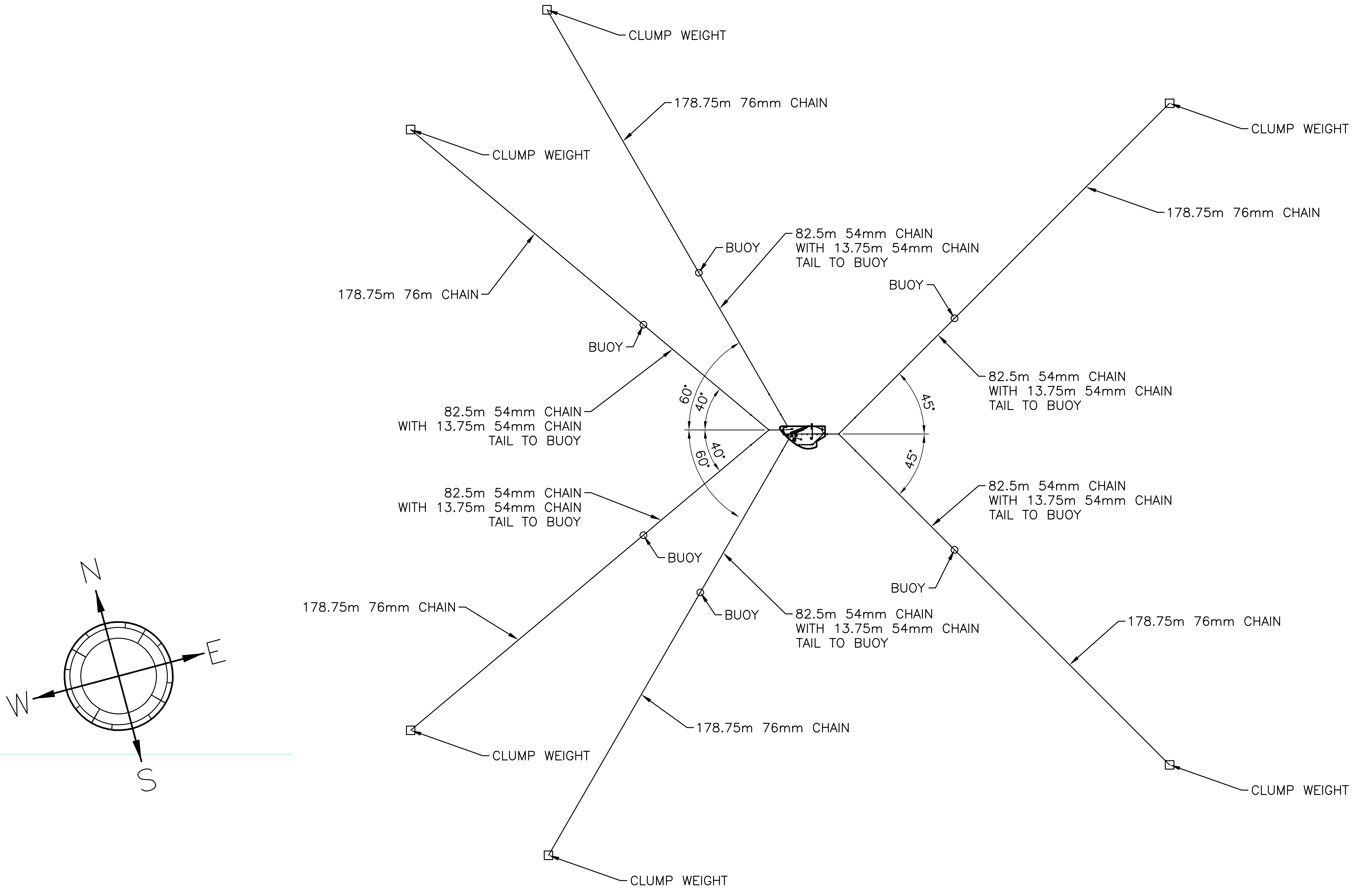

Rev	Date	Drawn	Checked	Approved	Issue Status
1	10/01/15	DJG	RL	RL	ISSUE FOR COMMENT

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MOORING DESIGN FOR WELLO OY WAVE ENERGY CONVERTER MK. 1

Filename:	Drawing Number:	Sheet: 2 OF 4	Rev. 1	Client Drawing Number.
–	TDK-WELLO-WEC-001-01	Scale: AS SHOWN	Size: A3	–

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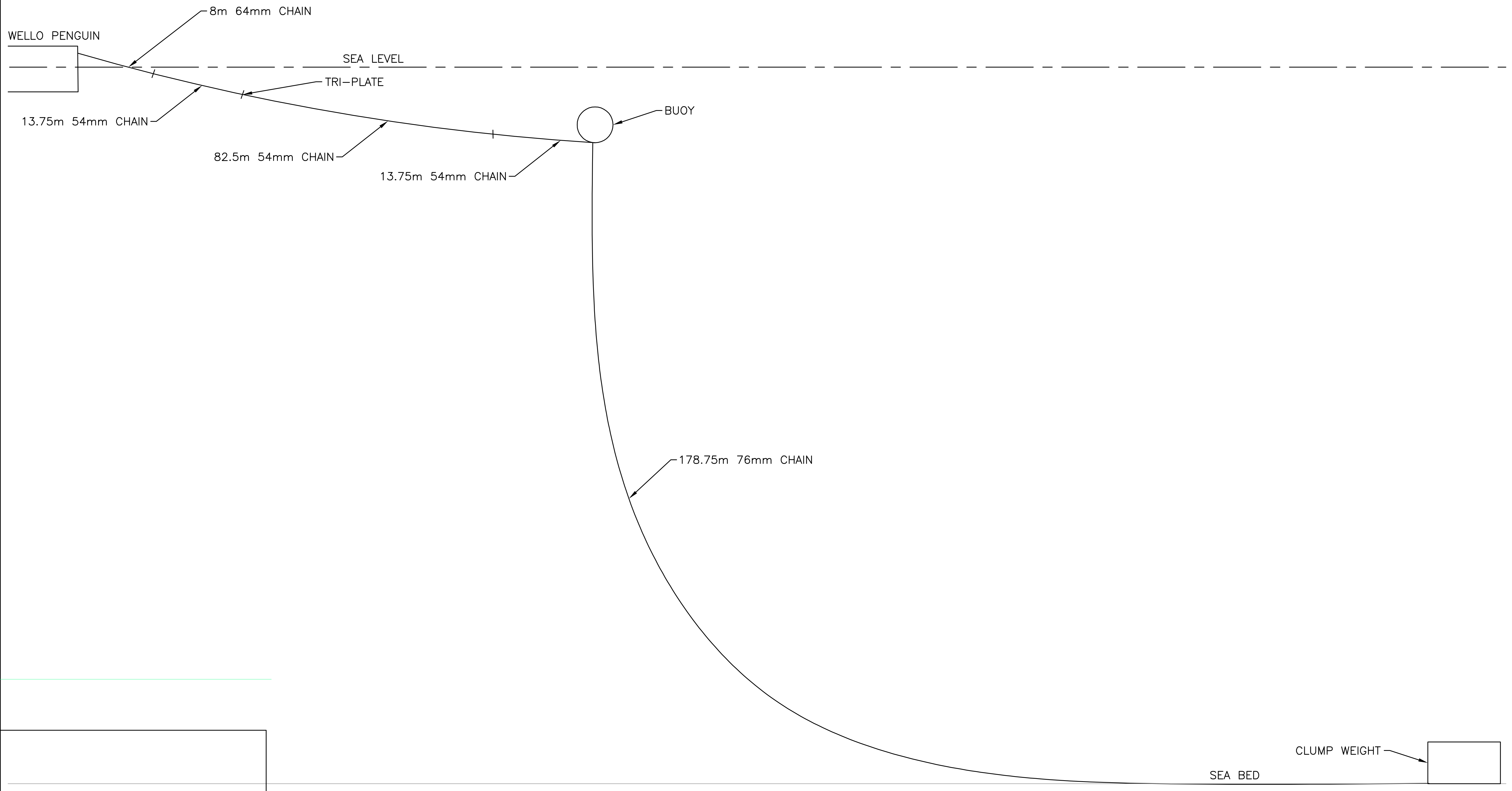

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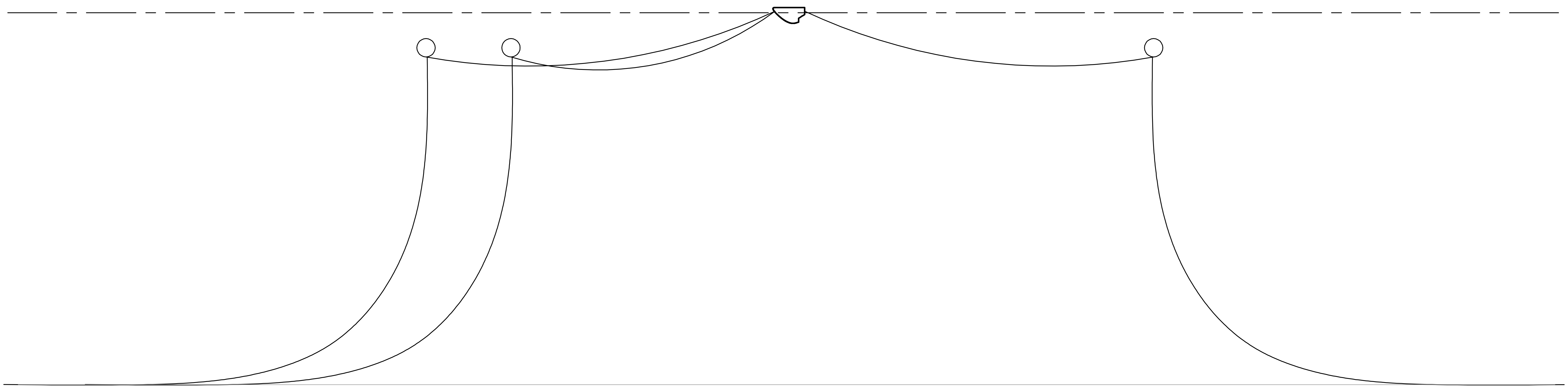

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1	10/01/15	DJG	RL	RL	ISSUE FOR COMMENT

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MOORING DESIGN FOR WELLO OY WAVE ENERGY CONVERTER MK. 1

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		Scale: AS SHOWN	Size: A3	

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APPENDIX B

MOORING ANALYSIS RESULTS SUMMARY

JOB: P277 - Wello Penguin Wave Energy Device	Sheet No. 1 of: 15
SUBJECT:	By: RL
P277 -103	Date: Feb-15
Review of Designed Mooring System	Checked: JA
10 yr Return Storm Result (intact Condition)	Date: Feb-15

LONGITUDE Engineering

Requirements

Min intact safety factor line tension	2.00	(API STAND OFF)
Min damaged safety factor line tension	1.43	(API STAND OFF)
Min intact safety factor anchor tension	1.00	
Min damaged safety factor anchor tension	0.00	
Max uplift for intact case	0.0	deg
Max uplift for damaged case	0.0	deg
Selected anchor efficiency for intact analysis	0.3	(Concrete Block Friction Coefficient)
Selected anchor efficiency for damage analysis	0.3	(Concrete Block Friction Coefficient)
Mooring Lines MBL	231	t

Mooring system particulars at equlibrium under no environment

Line number	L1	L2	L3	L4	L5	L6
Line MBL (kN)	2270	2270	2270	2270	2270	2270
Anchor weight (tonnes)	30.0	30.0	30.0	30.0	30.0	30.0
Winch break cap. (kN)	2270	2270	2270	2270	2270	2270
Intact SWL (kN)	1135	1135	1135	1135	1135	1135
Uplift load (kN)	370	370	370	370	370	370
Intact anchor (kN)	128	128	128	128	128	128
Abs intact limit (kN)	**128**	**128**	**128**	**128**	**128**	**128**

Summary of applied environments

Vessel Headi 180 S

Headings

Enviromt Degrees	Enviromt Degrees	Relative to vessel
000	N	Stbd Bow
045	NE	Stbd Beam
090	E	Port Stern
135	SE	Stern
180	S	Head Sea
225	SW	Stbd Bow
270	W	Stbd Beam
315	NW	Stbd Quarter

Environments

Env no.	Compass Direction (degs)	Waves Hs metres	Tp min sec	Tp max sec	Wind speed m/sec	Current speed m/sec
ENV_240	240	6.40	9.12	13.86	30	0.30
ENV_270	270	10.50	11.68	17.75	40	0.30
ENV_285	285	11.60	12.28	18.65	40	0.30
ENV_300	300	12.70	12.85	19.52	40	0.40
ENV_330	330	10.20	11.52	17.49	40	0.40

JOB:	P277 - Wello Penguin Wave Energy Device	Sheet No.	2 of: 15
SUBJECT:		By:	RL
P277 -103		Date:	Feb-15
Review of Designed Mooring System		Checked:	JA
10 yr Return Storm Result (intact Condition)		Date:	Feb-15

Mooring line fairlead tensions

5 6 7 8 9 10 11 12 13 14 15

Maximum intact line tensions (kN)

Env	L1	L2	L3	L4	L5	L6							Unity
ENV_240	75	78	99	136	124	114							**106%**
ENV_270	125	108	95	113	157	179							**139%**
ENV_285	178	139	107	97	132	168							**139%**
ENV_300	282	242	130	86	131	150							**220%**
ENV_330	293	333	185	76	97	100							**259%**
Max	293	333	185	136	157	179	0	0	0	0	0	0	
Line %	26%	29%	16%	12%	14%	16%							29%
Uplift %	79%	90%	50%	37%	42%	48%							90%
Anch %	**228%**	**259%**	**144%**	**106%**	**122%**	**139%**							**259%**
Winch %	13%	15%	8%	6%	7%	8%							15%

Excursions

Vessel heading (in MOSES) **0.0** deg

Maximum intact excursions (m)

Enviro/ head	Surge		Sway		Heave		Dynamic excursion		
	Max	Min	Max	Min	Max	Min	Surge	Sway	Heave
ENV_240	8.45	7.81	8.55	8.31	-6.94	-7.04	4.35	4.78	7.01
ENV_270	20.40	18.34	6.56	5.92	-11.36	-11.48	10.98	4.52	11.38
ENV_285	24.28	21.60	-1.25	-1.62	-12.53	-12.65	13.50	1.06	12.53
ENV_300	25.53	22.68	-8.43	-9.46	-13.71	-13.88	14.16	6.00	13.74
ENV_330	17.15	15.64	-15.38	-16.89	-11.01	-11.19	8.25	8.89	11.11
Max	25.53	7.81	8.55	-16.89	-6.94	-13.88	14.16	8.89	13.74

Table of line characteristics

Fairlead tension		Anchor tension				Line on	Distance
Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc
kN		kN	kN	kN	degrees	metres	metres
18.7	121.13	0.0	0.0	0.0	0.0	118.7	121.6
19.1	118.97	0.0	0.0	0.0	0.0	115.5	164.6
23.5	96.43	0.0	0.0	0.0	0.0	106.6	206.7
37.1	61.12	0.0	0.0	0.0	0.0	93.9	225.2
60.5	37.53	13.9	0.0	13.9	0.0	80.8	234.9
93.6	24.26	50.2	0.0	50.2	0.0	73.1	243.0
134.4	16.90	94.9	0.0	94.9	0.0	62.9	247.1
182.6	12.43	147.9	0.0	147.9	0.0	50.8	249.5
238.0	9.54	208.6	0.0	208.6	0.0	37.3	251.0
300.7	7.55	277.1	0.0	277.1	0.0	22.7	252.1
370.4	6.13	353.2	0.0	353.2	0.0	7.4	252.9
447.3	5.07	432.1	9.4	432.2	1.2	0.0	253.6
531.6	4.27	514.3	28.2	515.0	3.1	0.0	254.1
623.1	3.64	603.5	48.8	605.5	4.6	0.0	254.5
722.1	3.14	700.0	71.0	703.6	5.8	0.0	254.8
828.3	2.74	803.5	94.9	809.1	6.7	0.0	255.0
941.9	2.41	914.2	120.5	922.1	7.5	0.0	255.2
1062.9	2.14	1032.1	147.7	1042.6	8.1	0.0	255.4
1191.1	1.91	1157.1	176.5	1170.4	8.7	0.0	255.7
1326.7	1.71	1289.2	206.9	1305.7	9.1	0.0	255.9
1469.6	1.54	1428.5	239.0	1448.3	9.5	0.0	256.1
1619.9	1.40	1574.9	272.7	1598.3	9.8	0.0	256.3
1777.4	1.28	1728.5	307.9	1755.7	10.1	0.0	256.5
1942.3	1.17	1889.2	344.8	1920.4	10.3	0.0	256.7
2114.5	1.07	2057.0	383.2	2092.4	10.6	0.0	256.9
2294.0	0.99	2232.0	423.2	2271.8	10.7	0.0	257.1
2480.8	0.92	2414.1	464.8	2458.5	10.9	0.0	257.4
2674.9	0.85	2603.4	507.9	2652.5	11.0	0.0	257.6
2876.3	0.79	2799.8	552.6	2853.8	11.2	0.0	257.9
3085.1	0.74	3003.4	598.8	3062.5	11.3	0.0	258.2

L1 Minimum Break Load of line 2270.0 kN Paid out length 82.50 m

Table of line loads from analysis

Condition	Fairlead tension		Anchor tension				Line on	Distance	Offset
	Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc	in line
	kN		kN	kN	kN	degrees	metres	metres	metres
Pre-tension	61	37.3	14	0	14	0.0	80.7	235.1	-
Intact line load	293	7.8	269	0	269	0.0	24.5	251.9	16.9
Damage line load	-	-	-	-	-	-	-	-	-
Intact anchor limit	128	18.0	88	0	88	0.0	64.4	246.5	11.4
Damage anchor limi	-	-	-	-	-	-	-	-	-
Uplift intact limit	370	6.1	353	0	353	0.0	7.4	252.9	17.8
Uplift damage limit	-	-	-	-	-	-	-	-	-

Table of line characteristics

Fairlead tension		Anchor tension				Line on	Distance
Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc
kN		kN	kN	kN	degrees	metres	metres
18.7	121.13	0.0	0.0	0.0	0.0	118.7	121.6
19.1	118.97	0.0	0.0	0.0	0.0	115.5	164.6
23.5	96.43	0.0	0.0	0.0	0.0	106.6	206.7
37.1	61.12	0.0	0.0	0.0	0.0	93.9	225.2
60.5	37.53	13.9	0.0	13.9	0.0	80.8	234.9
93.6	24.26	50.2	0.0	50.2	0.0	73.1	243.0
134.4	16.90	94.9	0.0	94.9	0.0	62.9	247.1
182.6	12.43	147.9	0.0	147.9	0.0	50.8	249.5
238.0	9.54	208.6	0.0	208.6	0.0	37.3	251.0
300.7	7.55	277.1	0.0	277.1	0.0	22.7	252.1
370.4	6.13	353.2	0.0	353.2	0.0	7.4	252.9
447.3	5.07	432.1	9.4	432.2	1.2	0.0	253.6
531.6	4.27	514.3	28.2	515.0	3.1	0.0	254.1
623.1	3.64	603.5	48.8	605.5	4.6	0.0	254.5
722.1	3.14	700.0	71.0	703.6	5.8	0.0	254.8
828.3	2.74	803.5	94.9	809.1	6.7	0.0	255.0
941.9	2.41	914.2	120.5	922.1	7.5	0.0	255.2
1062.9	2.14	1032.1	147.7	1042.6	8.1	0.0	255.4
1191.1	1.91	1157.1	176.5	1170.4	8.7	0.0	255.7
1326.7	1.71	1289.2	206.9	1305.7	9.1	0.0	255.9
1469.6	1.54	1428.5	239.0	1448.3	9.5	0.0	256.1
1619.9	1.40	1574.9	272.7	1598.3	9.8	0.0	256.3
1777.4	1.28	1728.5	307.9	1755.7	10.1	0.0	256.5
1942.3	1.17	1889.2	344.8	1920.4	10.3	0.0	256.7
2114.5	1.07	2057.0	383.2	2092.4	10.6	0.0	256.9
2294.0	0.99	2232.0	423.2	2271.8	10.7	0.0	257.1
2480.8	0.92	2414.1	464.8	2458.5	10.9	0.0	257.4
2674.9	0.85	2603.4	507.9	2652.5	11.0	0.0	257.6
2876.3	0.79	2799.8	552.6	2853.8	11.2	0.0	257.9
3085.1	0.74	3003.4	598.8	3062.5	11.3	0.0	258.2

L2 Minimum Break Load of line 2270.0 kN Paid out length 82.50 m

Table of line loads from analysis

Condition	Fairlead tension		Anchor tension				Line on	Distance	Offset
	Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc	in line
	kN		kN	kN	kN	degrees	metres	metres	metres
Pre-tension	68	34.5	22	0	22	0.0	79.1	236.8	-
Maximum intact	333	6.9	312	0	312	0.0	15.6	252.5	15.7
Maximum damage	-	-	-	-	-	-	-	-	-
Intact anchor limit	128	18.0	88	0	88	0.0	64.4	246.5	9.7
Damage anchor limi	-	-	-	-	-	-	-	-	-
Uplift intact limit	370	6.1	353	0	353	0.0	7.4	252.9	16.1
Uplift damage limit	-	-	-	-	-	-	-	-	-

Table of line characteristics

Fairlead tension		Anchor tension				Line on	Distance
Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc
kN		kN	kN	kN	degrees	metres	metres
18.7	121.13	0.0	0.0	0.0	0.0	118.7	121.6
19.1	118.97	0.0	0.0	0.0	0.0	115.5	164.6
23.5	96.43	0.0	0.0	0.0	0.0	106.6	206.7
37.2	61.10	0.0	0.0	0.0	0.0	93.9	225.2
60.5	37.53	13.9	0.0	13.9	0.0	80.8	234.9
93.6	24.26	50.2	0.0	50.2	0.0	73.1	243.0
134.4	16.89	94.9	0.0	94.9	0.0	62.9	247.1
182.6	12.43	147.9	0.0	147.9	0.0	50.8	249.5
238.0	9.54	208.7	0.0	208.7	0.0	37.3	251.0
300.7	7.55	277.1	0.0	277.1	0.0	22.7	252.1
370.4	6.13	353.2	0.0	353.2	0.0	7.4	252.9
447.3	5.07	432.1	9.4	432.2	1.2	0.0	253.6
531.6	4.27	514.3	28.2	515.0	3.1	0.0	254.1
623.1	3.64	603.5	48.8	605.5	4.6	0.0	254.5
722.1	3.14	700.0	71.0	703.6	5.8	0.0	254.8
828.3	2.74	803.5	94.9	809.1	6.7	0.0	255.0
941.9	2.41	914.2	120.5	922.1	7.5	0.0	255.2
1062.9	2.14	1032.1	147.7	1042.6	8.1	0.0	255.4
1191.1	1.91	1157.1	176.5	1170.5	8.7	0.0	255.7
1326.7	1.71	1289.2	206.9	1305.7	9.1	0.0	255.9
1469.6	1.54	1428.5	239.0	1448.3	9.5	0.0	256.1
1619.9	1.40	1574.9	272.7	1598.3	9.8	0.0	256.3
1777.4	1.28	1728.5	308.0	1755.7	10.1	0.0	256.5
1942.3	1.17	1889.2	344.8	1920.4	10.3	0.0	256.7
2114.5	1.07	2057.0	383.3	2092.4	10.6	0.0	256.9
2294.0	0.99	2232.0	423.3	2271.8	10.7	0.0	257.1
2480.8	0.92	2414.1	464.9	2458.5	10.9	0.0	257.4
2674.9	0.85	2603.4	508.0	2652.5	11.0	0.0	257.6
2876.3	0.79	2799.8	552.7	2853.9	11.2	0.0	257.9
3085.1	0.74	3003.4	598.9	3062.5	11.3	0.0	258.2

L3 Minimum Break Load of line 2270.0 kN Paid out length 82.50 m

Table of line loads from analysis

Condition	Fairlead tension		Anchor tension				Line on	Distance	Offset
	Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc	in line
	kN		kN	kN	kN	degrees	metres	metres	metres
Pre-tension	109	21.5	67	0	67	0.0	69.3	244.5	-
Maximum intact	185	12.3	151	0	151	0.0	50.2	249.5	5.0
Maximum damage	-	-	-	-	-	-	-	-	-
Intact anchor limit	128	18.0	88	0	88	0.0	64.4	246.5	2.0
Damage anchor limi	-	-	-	-	-	-	-	-	-
Uplift intact limit	370	6.1	353	0	353	0.0	7.4	252.9	8.4
Uplift damage limit	-	-	-	-	-	-	-	-	-

JOB:	P277 - Wello Penguin Wave Energy Dev	Sheet No.	7 of: 15
SUBJECT:		By:	RL
P277 -103		Date:	Feb-15
Review of Designed Mooring System		Checked:	JA
10 yr Return Storm Result (intact Conditi	L4	Date:	Feb-15

Table of line characteristics

Fairlead tension		Anchor tension				Line on	Distance
Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc
kN		kN	kN	kN	degrees	metres	metres
18.7	121.13	0.0	0.0	0.0	0.0	118.7	121.6
19.1	118.97	0.0	0.0	0.0	0.0	115.5	164.6
23.5	96.43	0.0	0.0	0.0	0.0	106.6	206.7
37.2	61.10	0.0	0.0	0.0	0.0	93.9	225.2
60.5	37.53	13.9	0.0	13.9	0.0	80.8	234.9
93.6	24.26	50.2	0.0	50.2	0.0	73.1	243.0
134.4	16.89	94.9	0.0	94.9	0.0	62.9	247.1
182.6	12.43	147.9	0.0	147.9	0.0	50.8	249.5
238.0	9.54	208.7	0.0	208.7	0.0	37.3	251.0
300.7	7.55	277.1	0.0	277.1	0.0	22.7	252.1
370.4	6.13	353.2	0.0	353.2	0.0	7.4	252.9
447.3	5.07	432.1	9.4	432.2	1.2	0.0	253.6
531.6	4.27	514.3	28.2	515.0	3.1	0.0	254.1
623.1	3.64	603.5	48.8	605.5	4.6	0.0	254.5
722.1	3.14	700.0	71.0	703.6	5.8	0.0	254.8
828.3	2.74	803.5	94.9	809.1	6.7	0.0	255.0
941.9	2.41	914.2	120.5	922.1	7.5	0.0	255.2
1062.9	2.14	1032.1	147.7	1042.6	8.1	0.0	255.4
1191.1	1.91	1157.1	176.5	1170.5	8.7	0.0	255.7
1326.7	1.71	1289.2	206.9	1305.7	9.1	0.0	255.9
1469.6	1.54	1428.5	239.0	1448.3	9.5	0.0	256.1
1619.9	1.40	1574.9	272.7	1598.3	9.8	0.0	256.3
1777.4	1.28	1728.5	308.0	1755.7	10.1	0.0	256.5
1942.3	1.17	1889.2	344.8	1920.4	10.3	0.0	256.7
2114.5	1.07	2057.0	383.3	2092.4	10.6	0.0	256.9
2294.0	0.99	2232.0	423.3	2271.8	10.7	0.0	257.1
2480.8	0.92	2414.1	464.9	2458.5	10.9	0.0	257.4
2674.9	0.85	2603.4	508.0	2652.5	11.0	0.0	257.6
2876.3	0.79	2799.8	552.7	2853.9	11.2	0.0	257.9
3085.1	0.74	3003.4	598.9	3062.5	11.3	0.0	258.2

L4 Minimum Break Load of line 2270.0 kN Paid out length 82.50 m

Table of line loads from analysis

Condition	Fairlead tension		Anchor tension				Line on	Distance	Offset
	Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc	in line
	kN		kN	kN	kN	degrees	metres	metres	metres
Pre-tension	109	21.5	67	0	67	0.0	69.3	244.5	-
Maximum intact	136	16.8	97	0	97	0.0	62.5	247.2	2.7
Maximum damage	-	-	-	-	-	-	-	-	-
Intact anchor limit	128	18.0	88	0	88	0.0	64.4	246.5	2.0
Damage anchor limi	-	-	-	-	-	-	-	-	-
Uplift intact limit	370	6.1	353	0	353	0.0	7.4	252.9	8.4
Uplift damage limit	-	-	-	-	-	-	-	-	-

Table of line characteristics

Fairlead tension		Anchor tension				Line on	Distance
Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc
kN		kN	kN	kN	degrees	metres	metres
18.7	121.13	0.0	0.0	0.0	0.0	118.7	121.6
19.1	118.97	0.0	0.0	0.0	0.0	115.5	164.6
23.5	96.43	0.0	0.0	0.0	0.0	106.6	206.7
37.1	61.12	0.0	0.0	0.0	0.0	93.9	225.2
60.5	37.53	13.9	0.0	13.9	0.0	80.8	234.9
93.6	24.26	50.2	0.0	50.2	0.0	73.1	243.0
134.4	16.90	94.9	0.0	94.9	0.0	62.9	247.1
182.6	12.43	147.9	0.0	147.9	0.0	50.8	249.5
238.0	9.54	208.6	0.0	208.6	0.0	37.3	251.0
300.7	7.55	277.1	0.0	277.1	0.0	22.7	252.1
370.4	6.13	353.2	0.0	353.2	0.0	7.4	252.9
447.3	5.07	432.1	9.4	432.2	1.2	0.0	253.6
531.6	4.27	514.3	28.2	515.0	3.1	0.0	254.1
623.1	3.64	603.5	48.8	605.5	4.6	0.0	254.5
722.1	3.14	700.0	71.0	703.6	5.8	0.0	254.8
828.3	2.74	803.5	94.9	809.1	6.7	0.0	255.0
941.9	2.41	914.2	120.5	922.1	7.5	0.0	255.2
1062.9	2.14	1032.1	147.7	1042.6	8.1	0.0	255.4
1191.1	1.91	1157.1	176.5	1170.4	8.7	0.0	255.7
1326.7	1.71	1289.2	206.9	1305.7	9.1	0.0	255.9
1469.6	1.54	1428.5	239.0	1448.3	9.5	0.0	256.1
1619.9	1.40	1574.9	272.7	1598.3	9.8	0.0	256.3
1777.4	1.28	1728.5	307.9	1755.7	10.1	0.0	256.5
1942.3	1.17	1889.2	344.8	1920.4	10.3	0.0	256.7
2114.5	1.07	2057.0	383.2	2092.4	10.6	0.0	256.9
2294.0	0.99	2232.0	423.2	2271.8	10.7	0.0	257.1
2480.8	0.92	2414.1	464.8	2458.5	10.9	0.0	257.4
2674.9	0.85	2603.4	507.9	2652.5	11.0	0.0	257.6
2876.3	0.79	2799.8	552.6	2853.8	11.2	0.0	257.9
3085.1	0.74	3003.4	598.8	3062.5	11.3	0.0	258.2

L5 Minimum Break Load of line 2270.0 kN Paid out length 82.50 m

Table of line loads from analysis

Condition	Fairlead tension		Anchor tension				Line on	Distance	Offset
	Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc	in line
	kN		kN	kN	kN	degrees	metres	metres	metres
Pre-tension	68	34.5	22	0	22	0.0	79.1	236.8	-
Maximum intact	157	14.8	120	0	120	0.0	57.2	248.2	11.5
Maximum damage	-	-	-	-	-	-	-	-	-
Intact anchor limit	128	18.0	88	0	88	0.0	64.4	246.5	9.7
Damage anchor limi	-	-	-	-	-	-	-	-	-
Uplift intact limit	370	6.1	353	0	353	0.0	7.4	252.9	16.1
Uplift damage limit	-	-	-	-	-	-	-	-	-

Table of line characteristics

Fairlead tension		Anchor tension				Line on	Distance
Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc
kN		kN	kN	kN	degrees	metres	metres
18.7	121.13	0.0	0.0	0.0	0.0	118.7	121.6
19.1	118.97	0.0	0.0	0.0	0.0	115.5	164.6
23.5	96.43	0.0	0.0	0.0	0.0	106.6	206.7
37.1	61.12	0.0	0.0	0.0	0.0	93.9	225.2
60.5	37.53	13.9	0.0	13.9	0.0	80.8	234.9
93.6	24.26	50.2	0.0	50.2	0.0	73.1	243.0
134.4	16.90	94.9	0.0	94.9	0.0	62.9	247.1
182.6	12.43	147.9	0.0	147.9	0.0	50.8	249.5
238.0	9.54	208.6	0.0	208.6	0.0	37.3	251.0
300.7	7.55	277.1	0.0	277.1	0.0	22.7	252.1
370.4	6.13	353.2	0.0	353.2	0.0	7.4	252.9
447.3	5.07	432.1	9.4	432.2	1.2	0.0	253.6
531.6	4.27	514.3	28.2	515.0	3.1	0.0	254.1
623.1	3.64	603.5	48.8	605.5	4.6	0.0	254.5
722.1	3.14	700.0	71.0	703.6	5.8	0.0	254.8
828.3	2.74	803.5	94.9	809.1	6.7	0.0	255.0
941.9	2.41	914.2	120.5	922.1	7.5	0.0	255.2
1062.9	2.14	1032.1	147.7	1042.6	8.1	0.0	255.4
1191.1	1.91	1157.1	176.5	1170.4	8.7	0.0	255.7
1326.7	1.71	1289.2	206.9	1305.7	9.1	0.0	255.9
1469.6	1.54	1428.5	239.0	1448.3	9.5	0.0	256.1
1619.9	1.40	1574.9	272.7	1598.3	9.8	0.0	256.3
1777.4	1.28	1728.5	307.9	1755.7	10.1	0.0	256.5
1942.3	1.17	1889.2	344.8	1920.4	10.3	0.0	256.7
2114.5	1.07	2057.0	383.2	2092.4	10.6	0.0	256.9
2294.0	0.99	2232.0	423.2	2271.8	10.7	0.0	257.1
2480.8	0.92	2414.1	464.8	2458.5	10.9	0.0	257.4
2674.9	0.85	2603.4	507.9	2652.5	11.0	0.0	257.6
2876.3	0.79	2799.8	552.6	2853.8	11.2	0.0	257.9
3085.1	0.74	3003.4	598.8	3062.5	11.3	0.0	258.2

L6 Minimum Break Load of line 2270.0 kN Paid out length 82.50 m

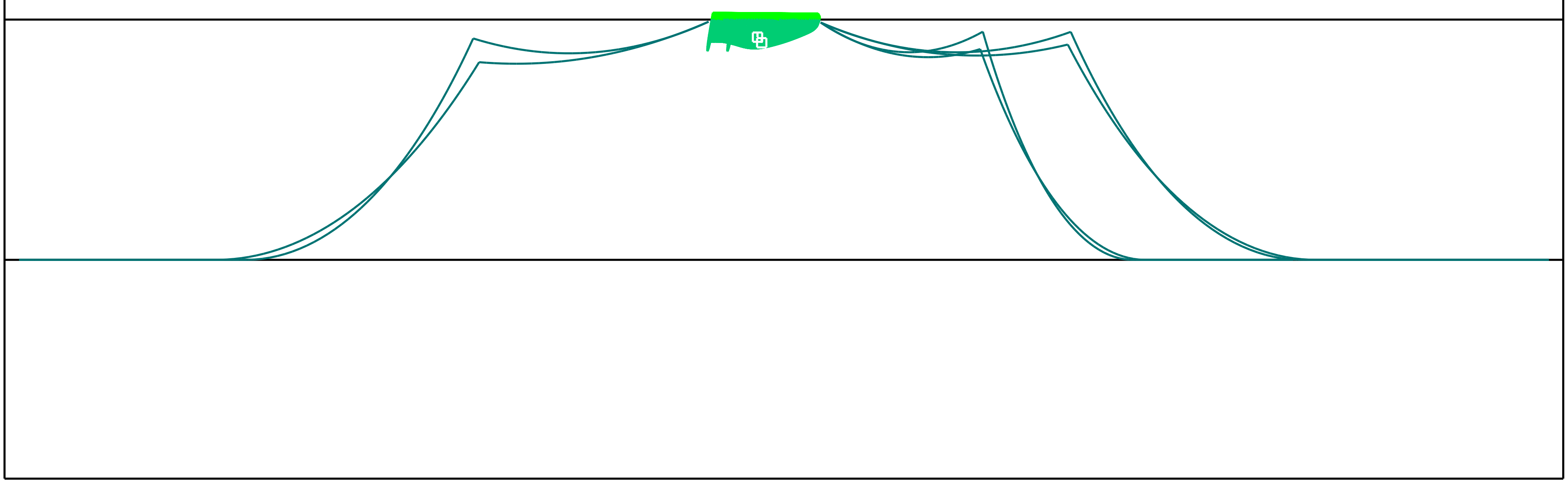
Table of line loads from analysis

Condition	Fairlead tension		Anchor tension				Line on	Distance	Offset
	Total	S.F.	Horiz.	Vert.	Total	Angle	bottom	Fair-Anc	in line
	kN		kN	kN	kN	degrees	metres	metres	metres
Pre-tension	61	37.3	14	0	14	0.0	80.7	235.1	-
Maximum intact	179	12.8	144	0	144	0.0	51.8	249.3	14.2
Maximum damage	-	-	-	-	-	-	-	-	-
Intact anchor limit	128	18.0	88	0	88	0.0	64.4	246.5	11.4
Damage anchor limi	-	-	-	-	-	-	-	-	-
Uplift intact limit	370	6.1	353	0	353	0.0	7.4	252.9	17.8
Uplift damage limit	-	-	-	-	-	-	-	-	-

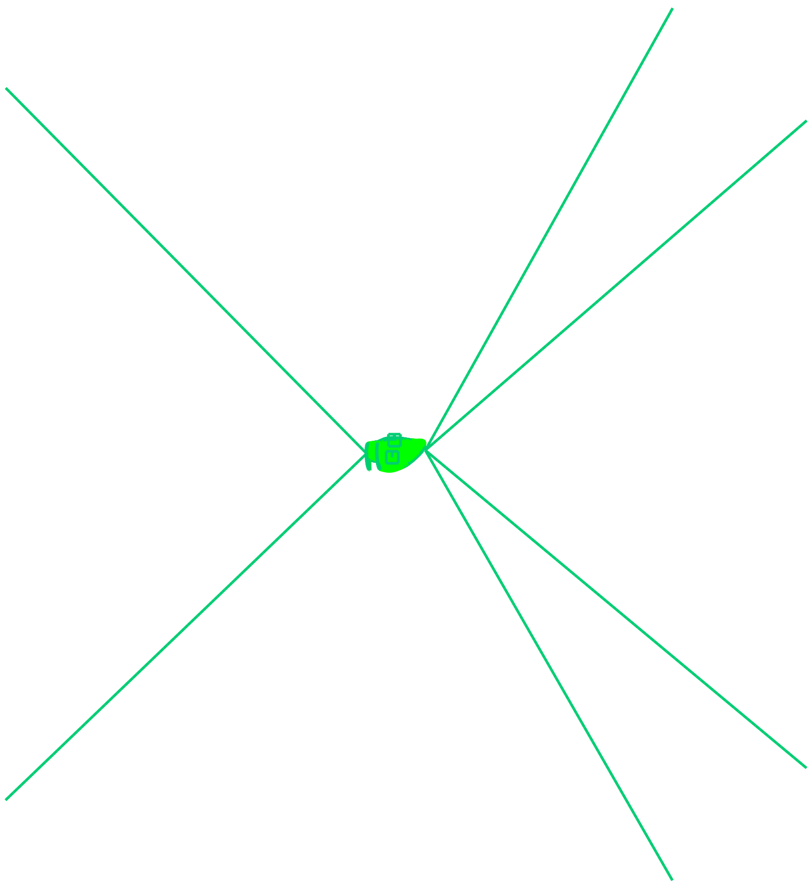
APPENDIX C

MOSES OUTPUT

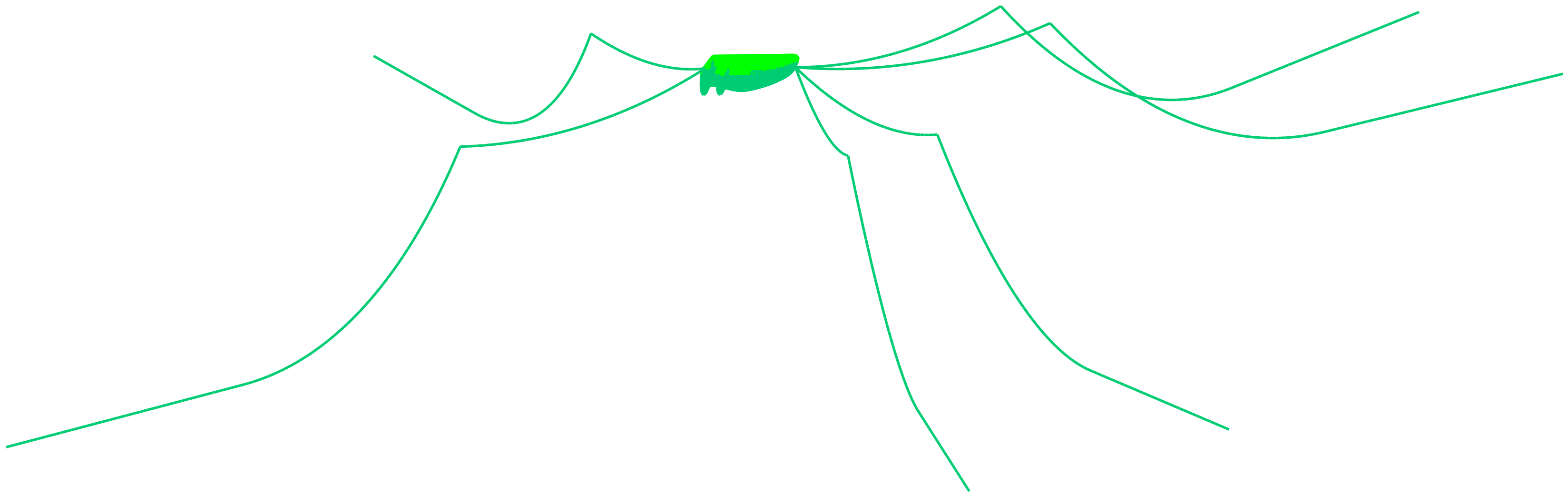
Wello Penguin Mooring Analysis
Environment ENam1 - Intact System
Event 1.0



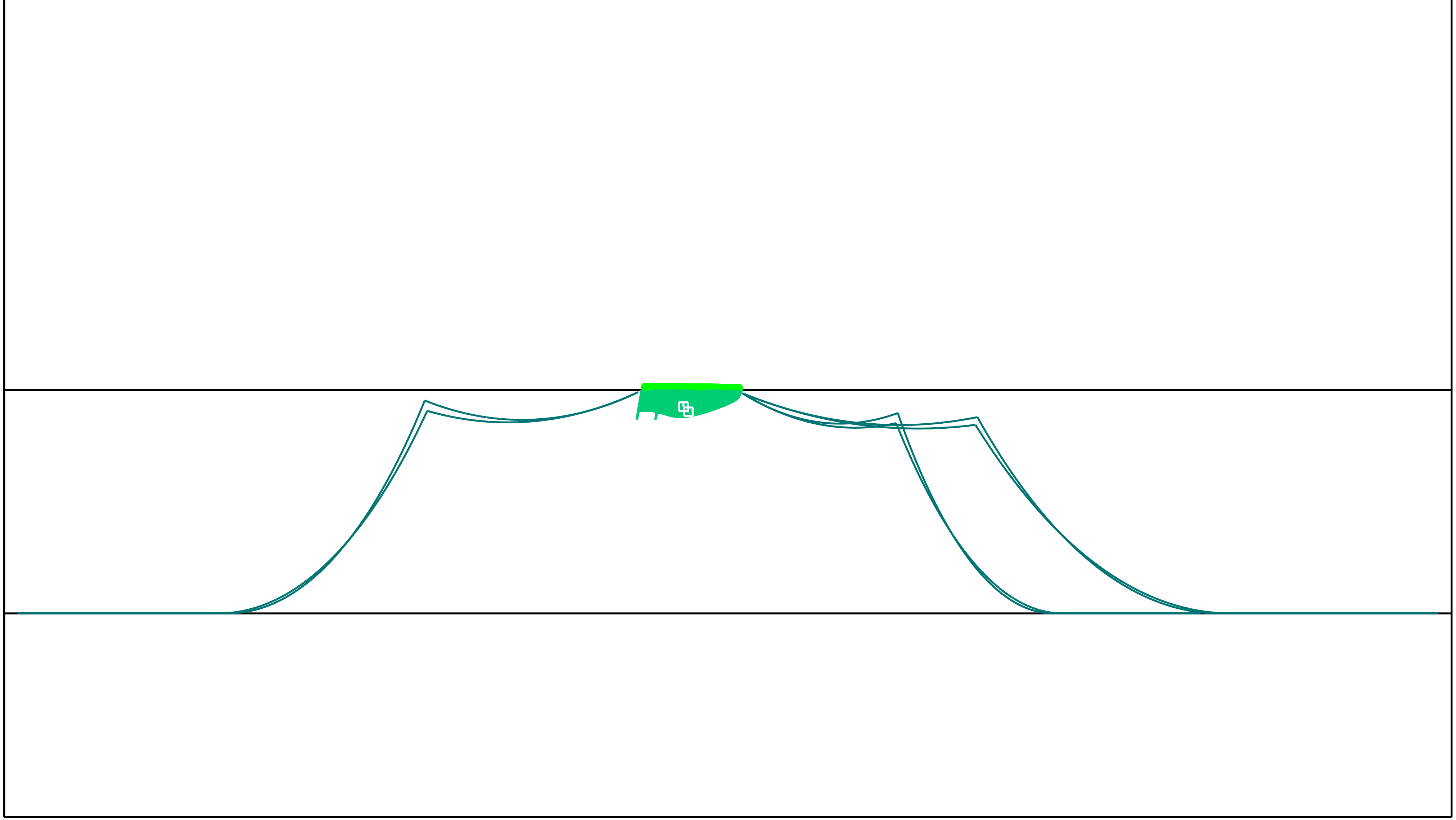
Wello Penguin Mooring Analysis
Environment ENam1 - Intact System
Event 1.0



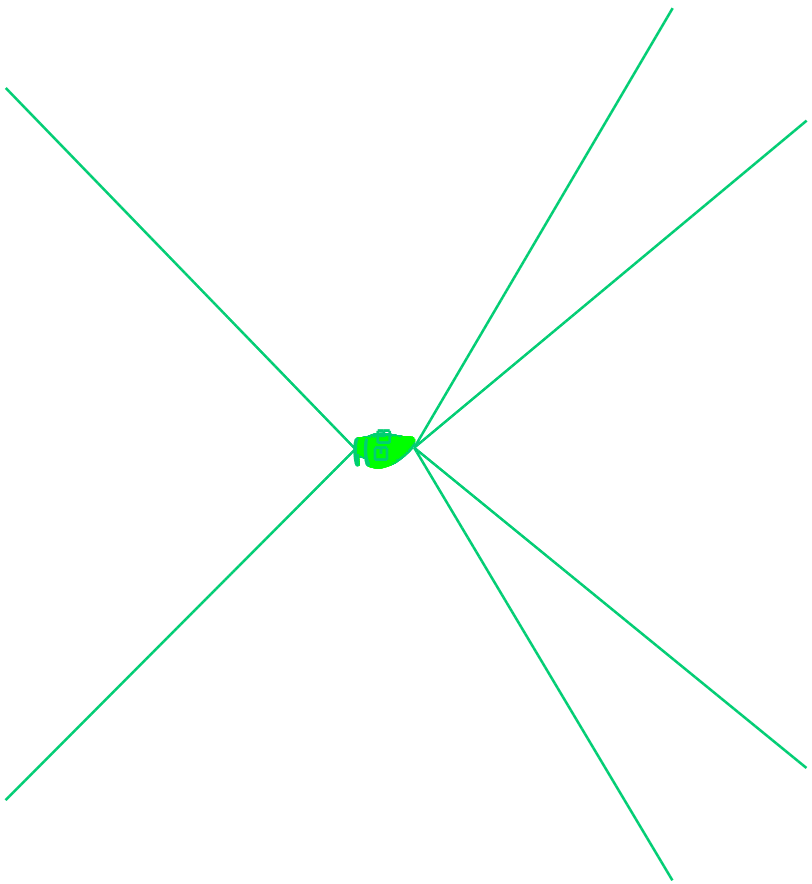
Wello Penguin Mooring Analysis
Environment ENam1 - Intact System
Event 1.0



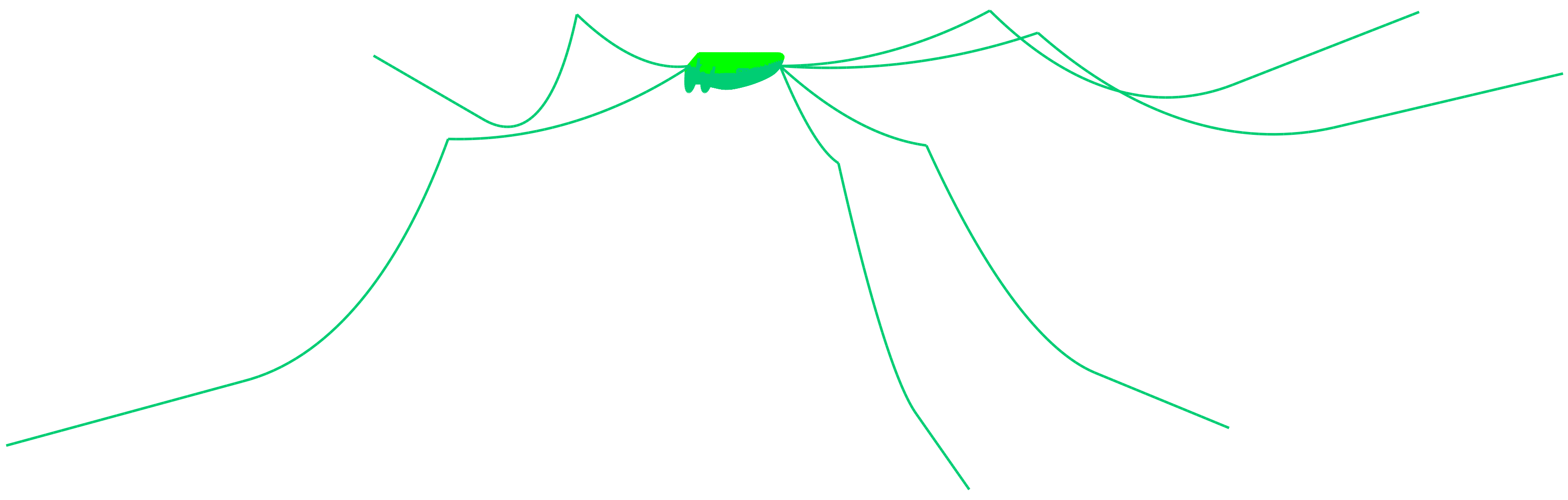
Wello Penguin Mooring Analysis
Environment ENam2 - Intact System
Event 1.0



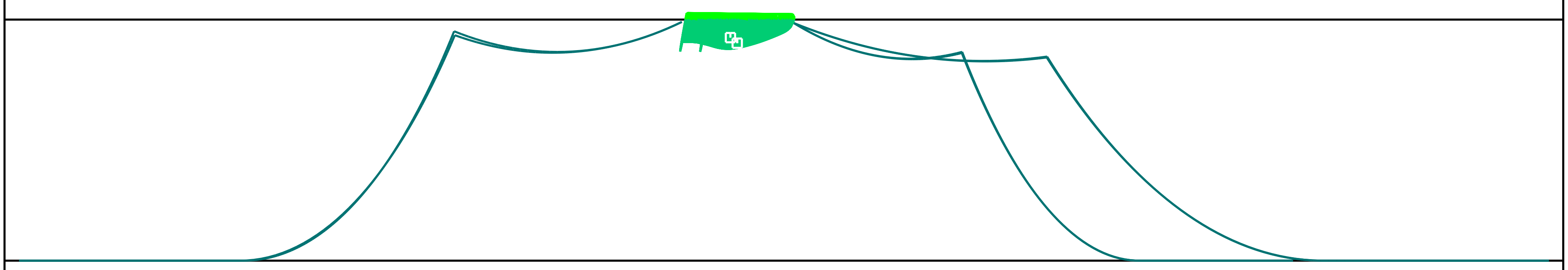
Wello Penguin Mooring Analysis
Environment ENam2 - Intact System
Event 1.0



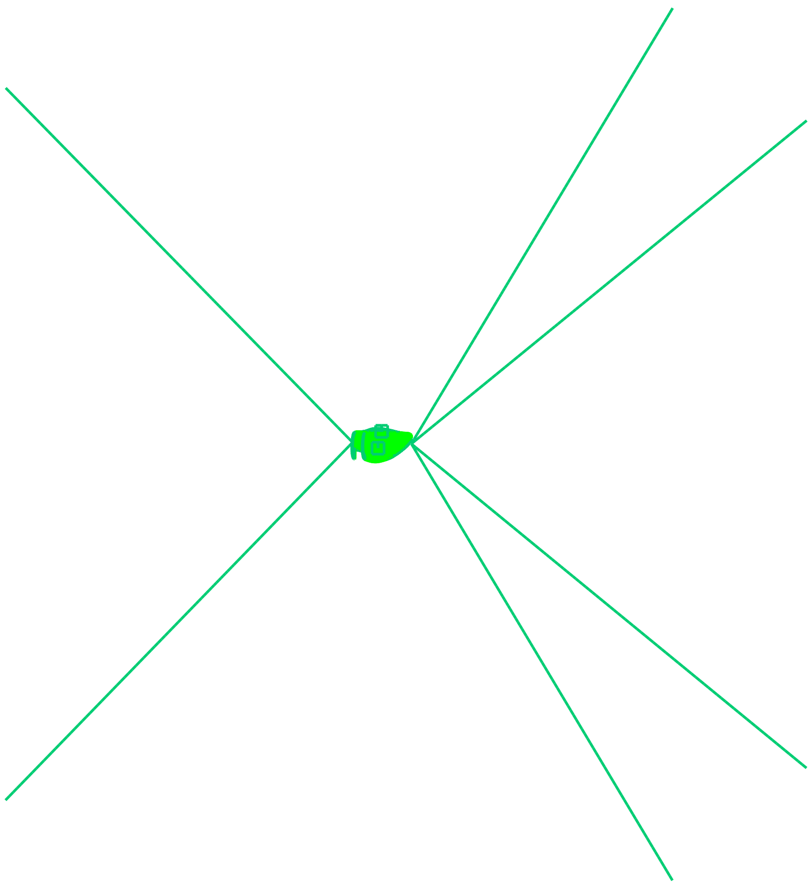
Wello Penguin Mooring Analysis
Environment ENam2 - Intact System
Event 1.0



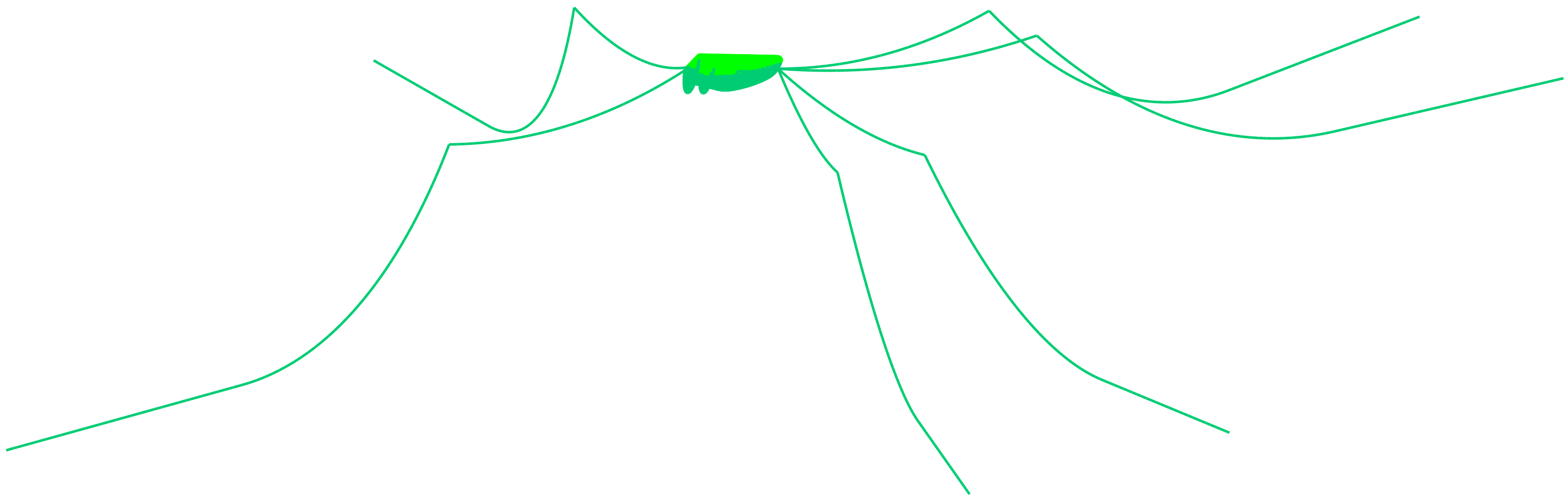
Wello Penguin Mooring Analysis
Environment ENam3 - Intact System
Event 1.0



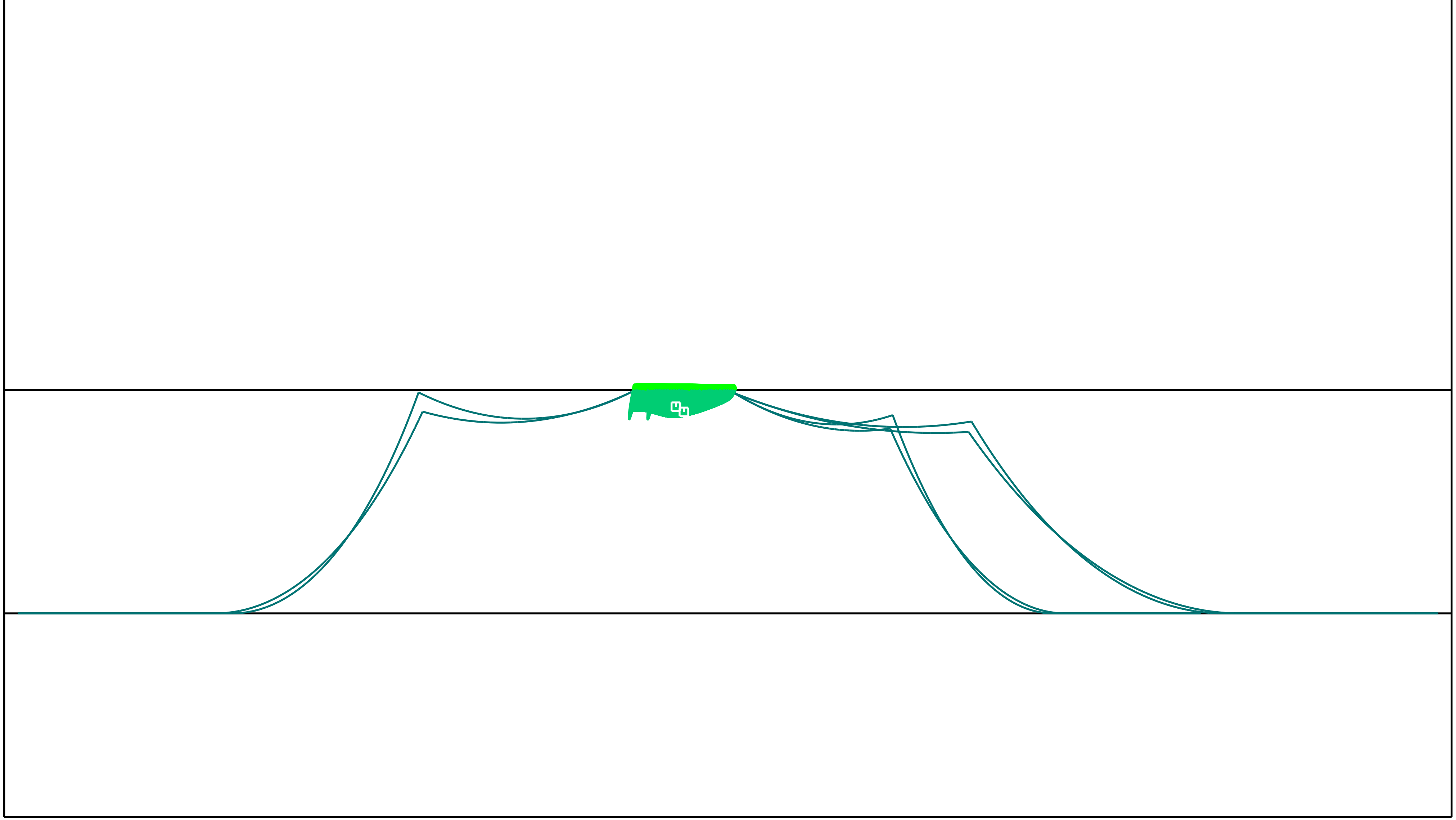
Wello Penguin Mooring Analysis
Environment ENam3 - Intact System
Event 1.0



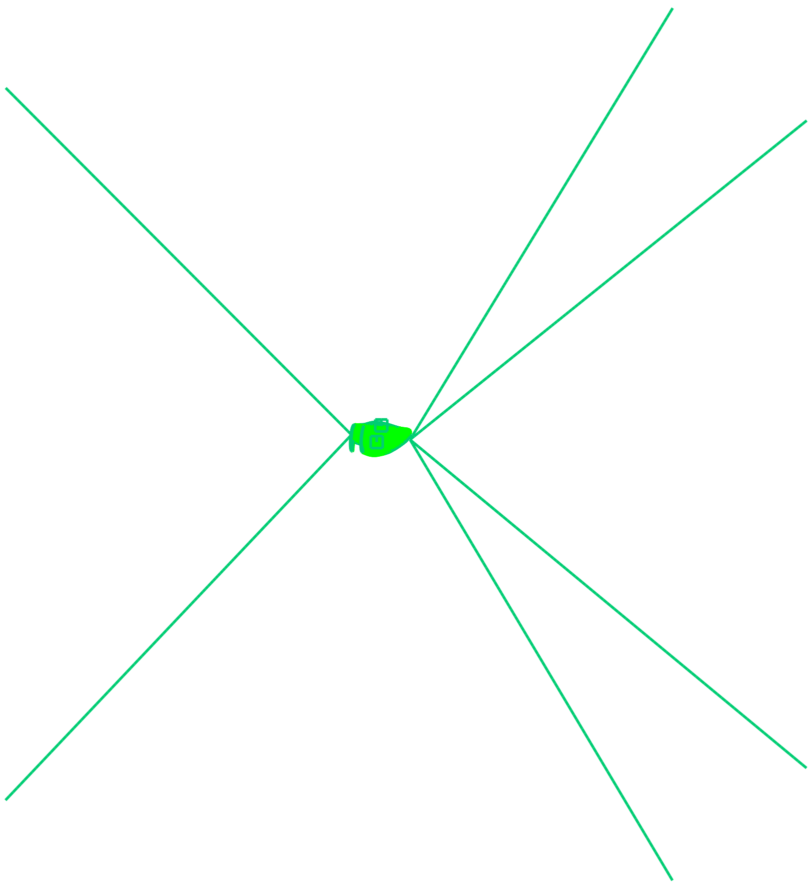
Wello Penguin Mooring Analysis
Environment ENam3 - Intact System
Event 1.0



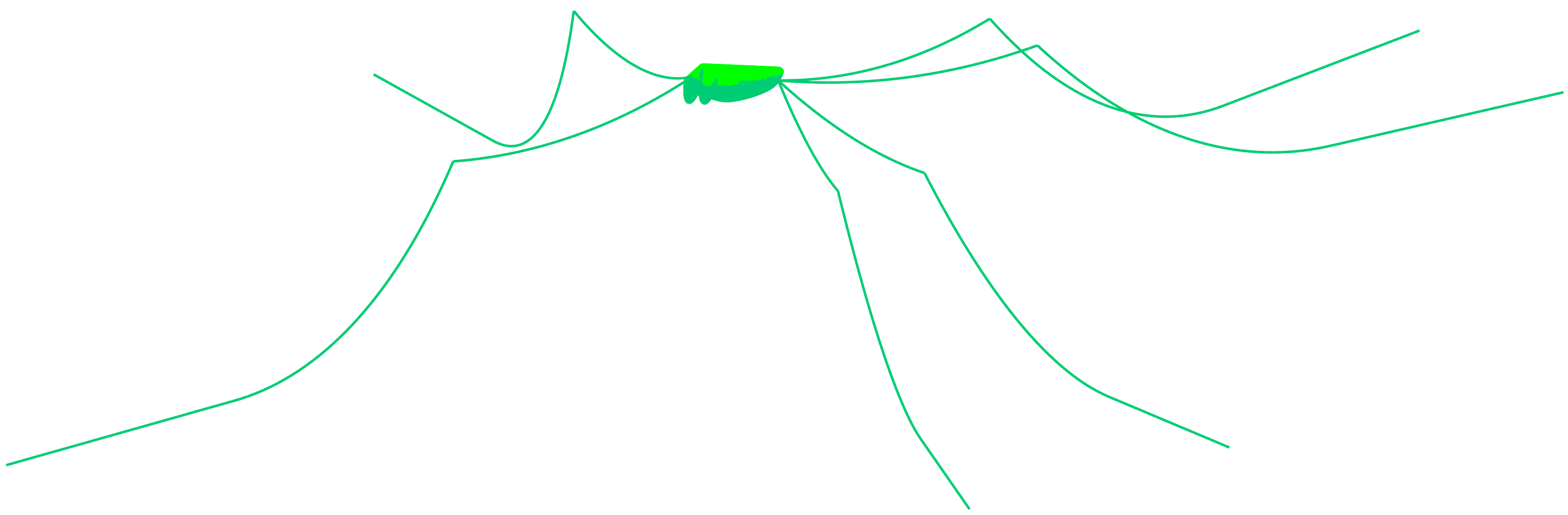
Wello Penguin Mooring Analysis
Environment ENam4 - Intact System
Event 1.0



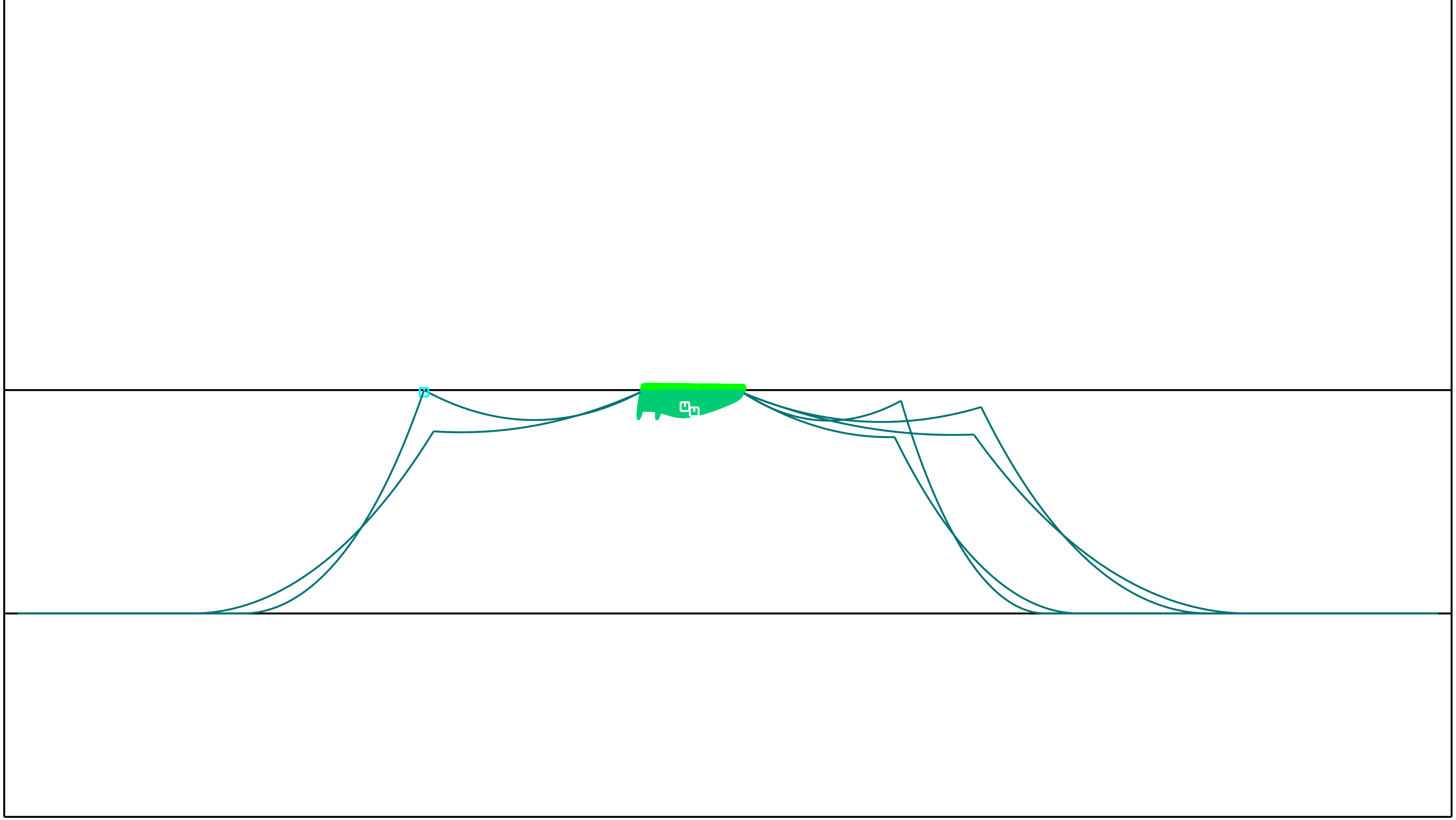
Wello Penguin Mooring Analysis
Environment ENam4 - Intact System
Event 1.0



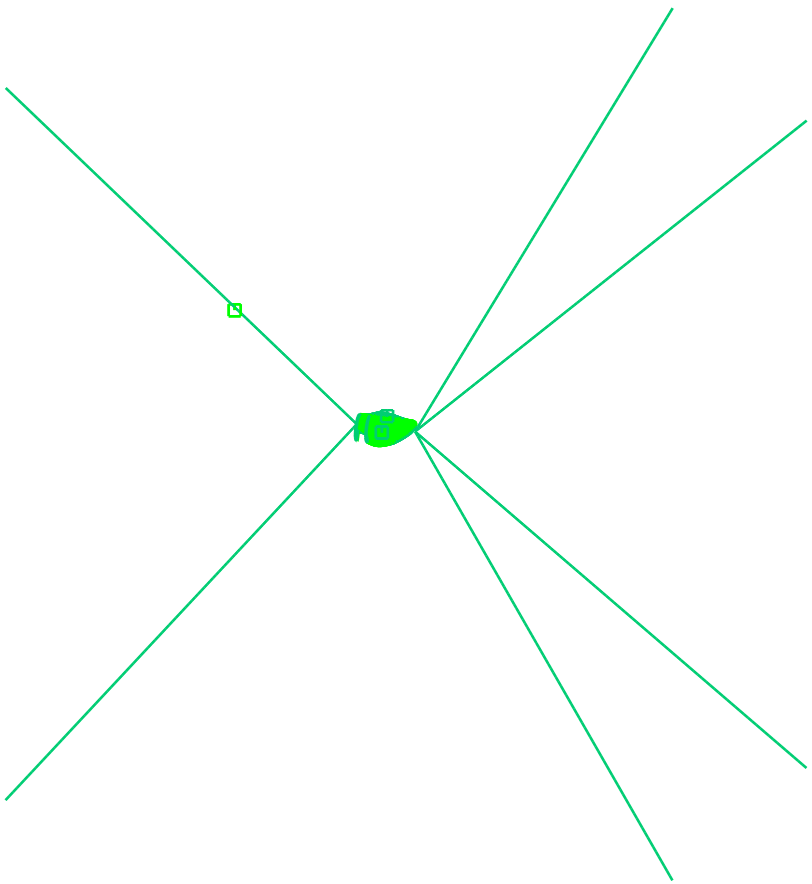
Wello Penguin Mooring Analysis
Environment ENam4 - Intact System
Event 1.0



Wello Penguin Mooring Analysis
Environment ENam5 - Intact System
Event 1.0



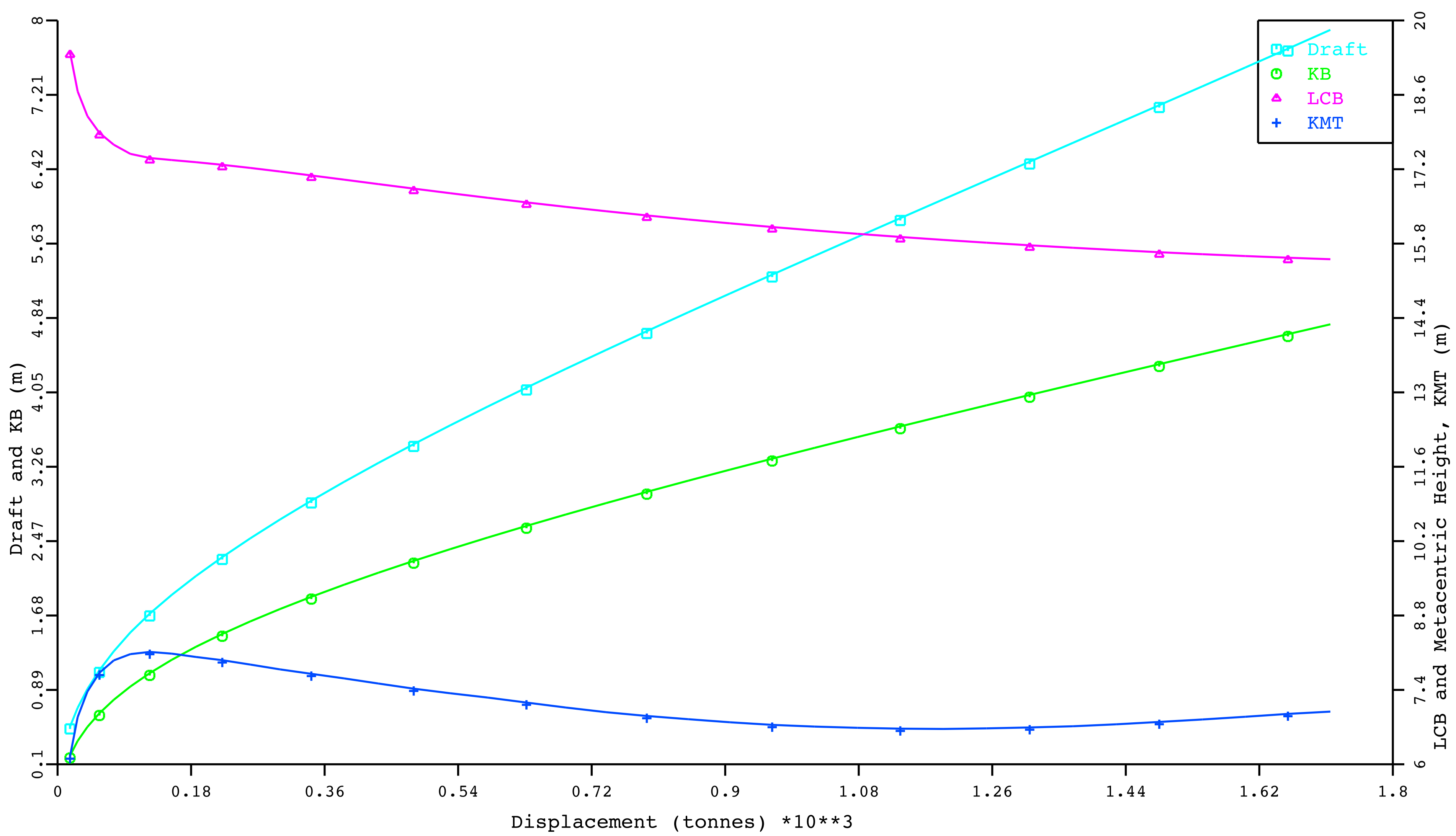
Wello Penguin Mooring Analysis
Environment ENam5 - Intact System
Event 1.0



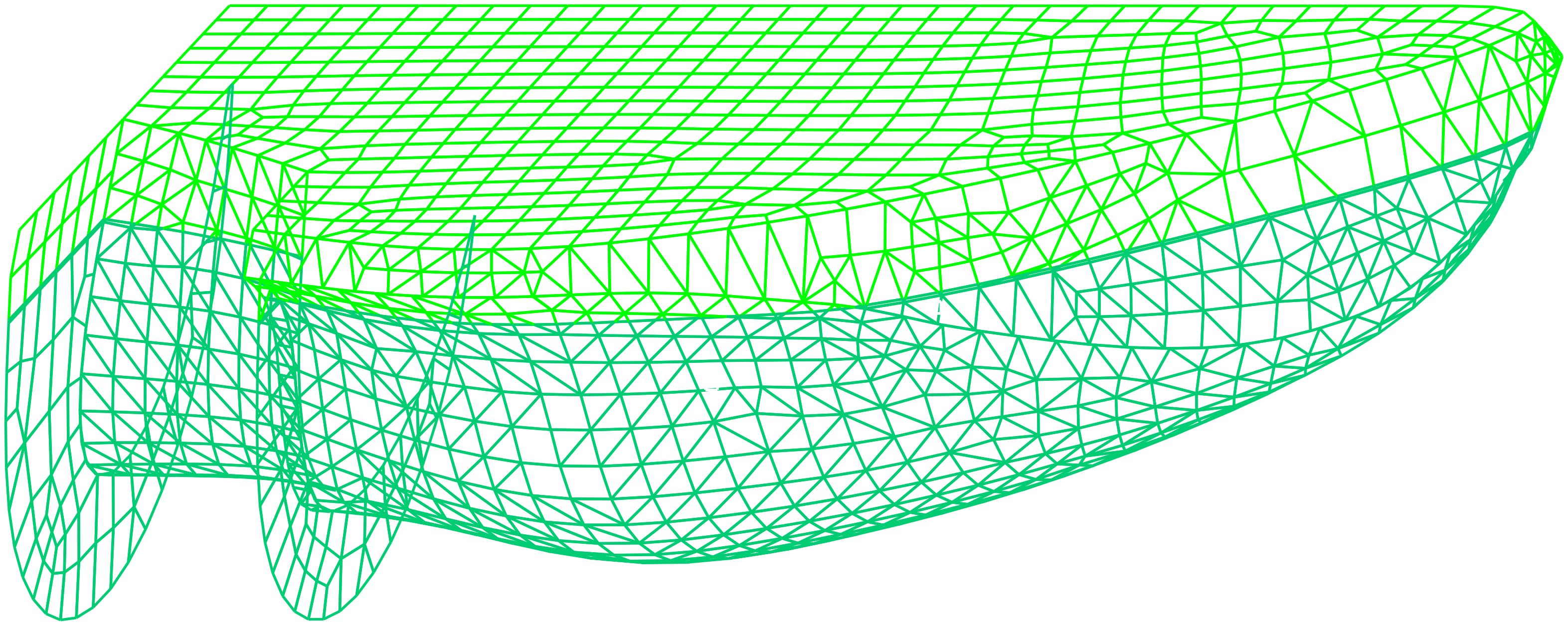
<u>APPENDIX D</u>

HYDRODYNAMIC RESULTS

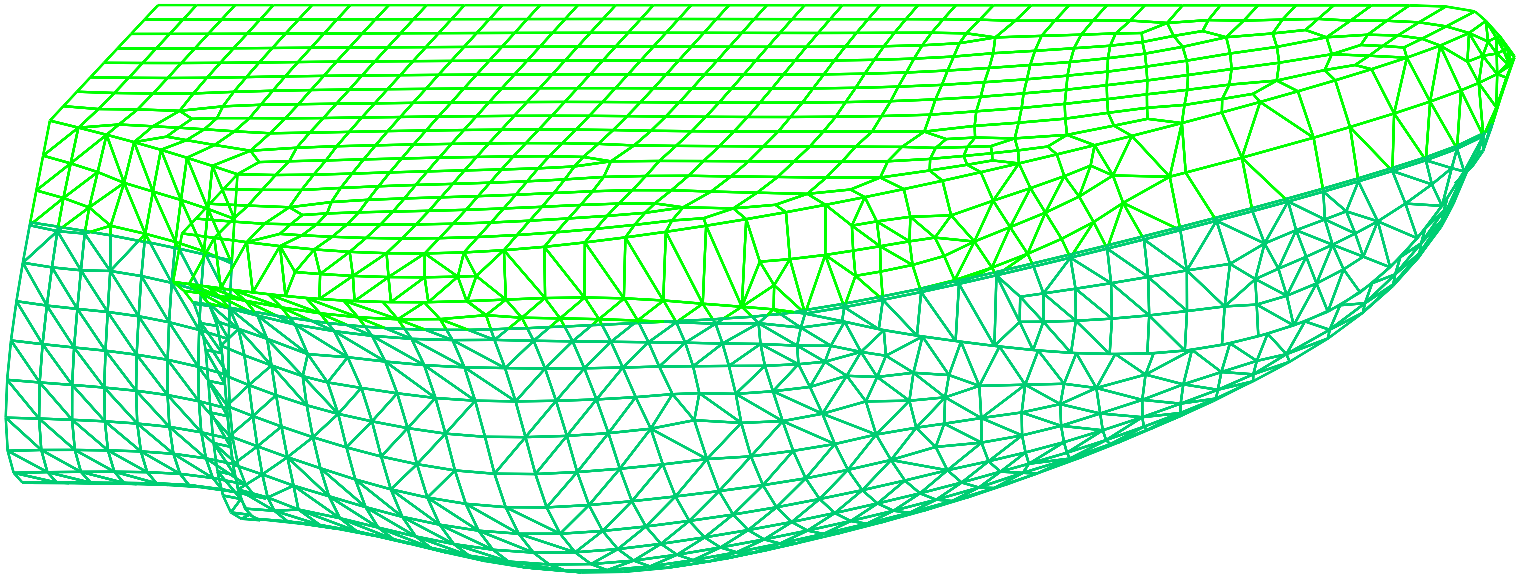
Hydrostatic Particulars



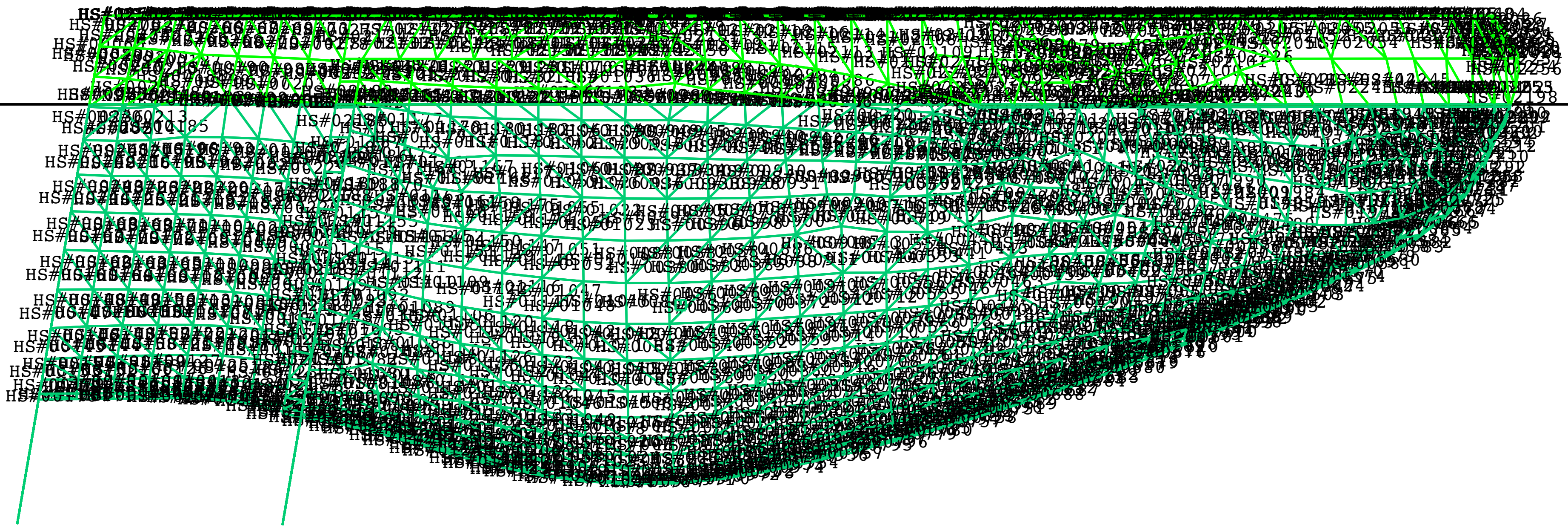
WELLO PENGUIN - HYDRODYNAMIC ANALYSIS
Event 1.0



WELLO PENGUIN - HYDRODYNAMIC ANALYSIS
Event 1.0

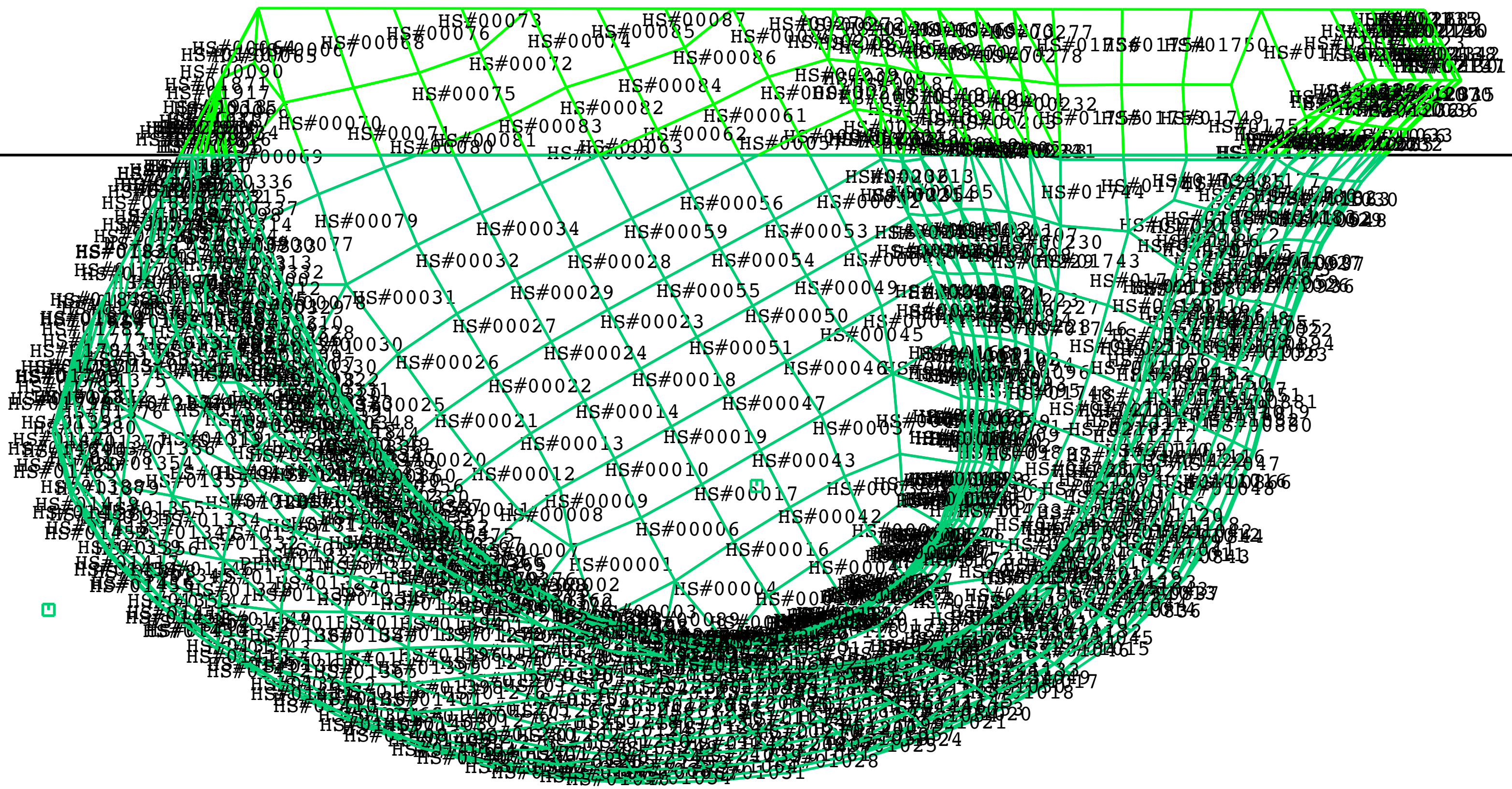


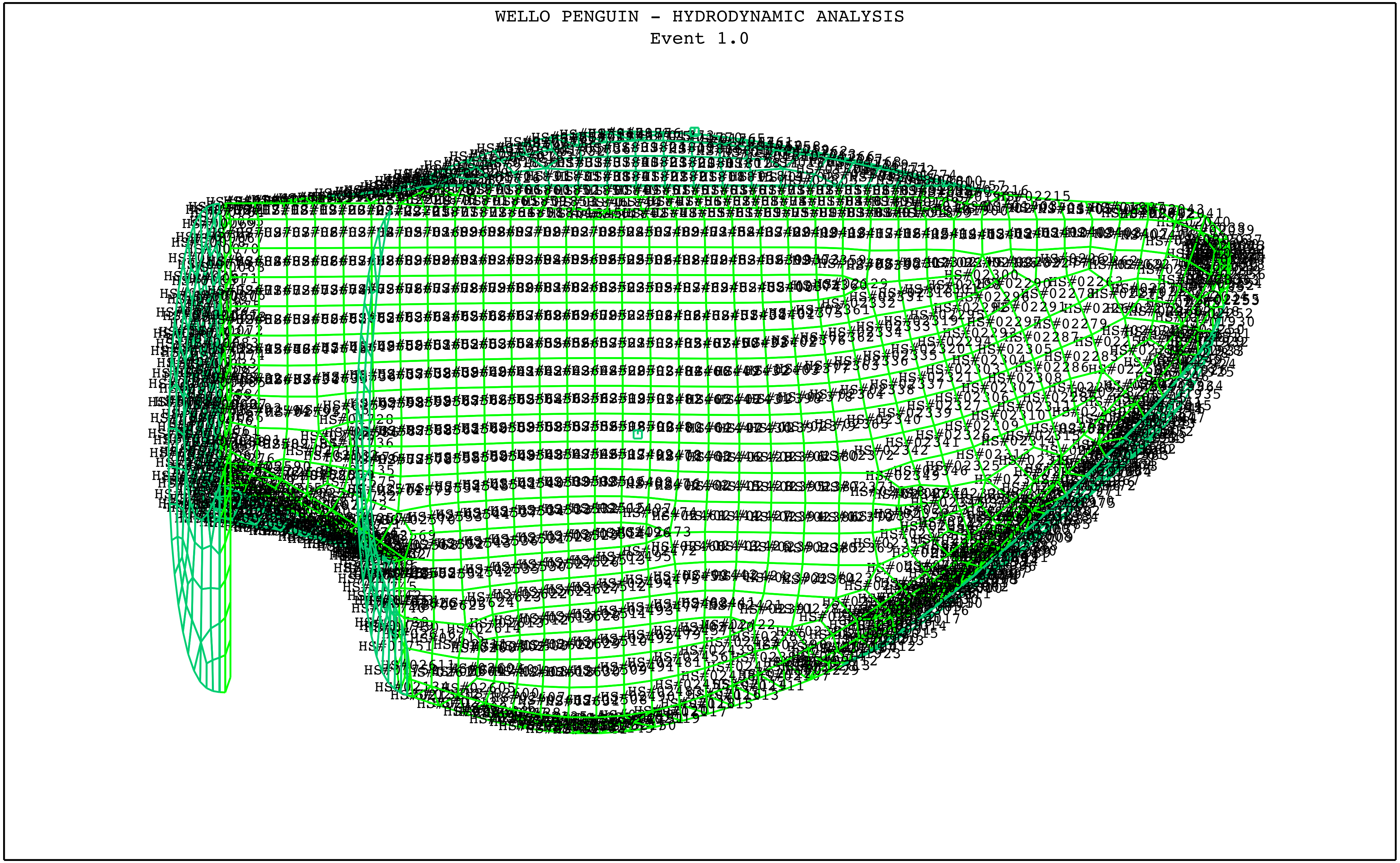
WELLO PENGUIN - HYDRODYNAMIC ANALYSIS
Event 1.0



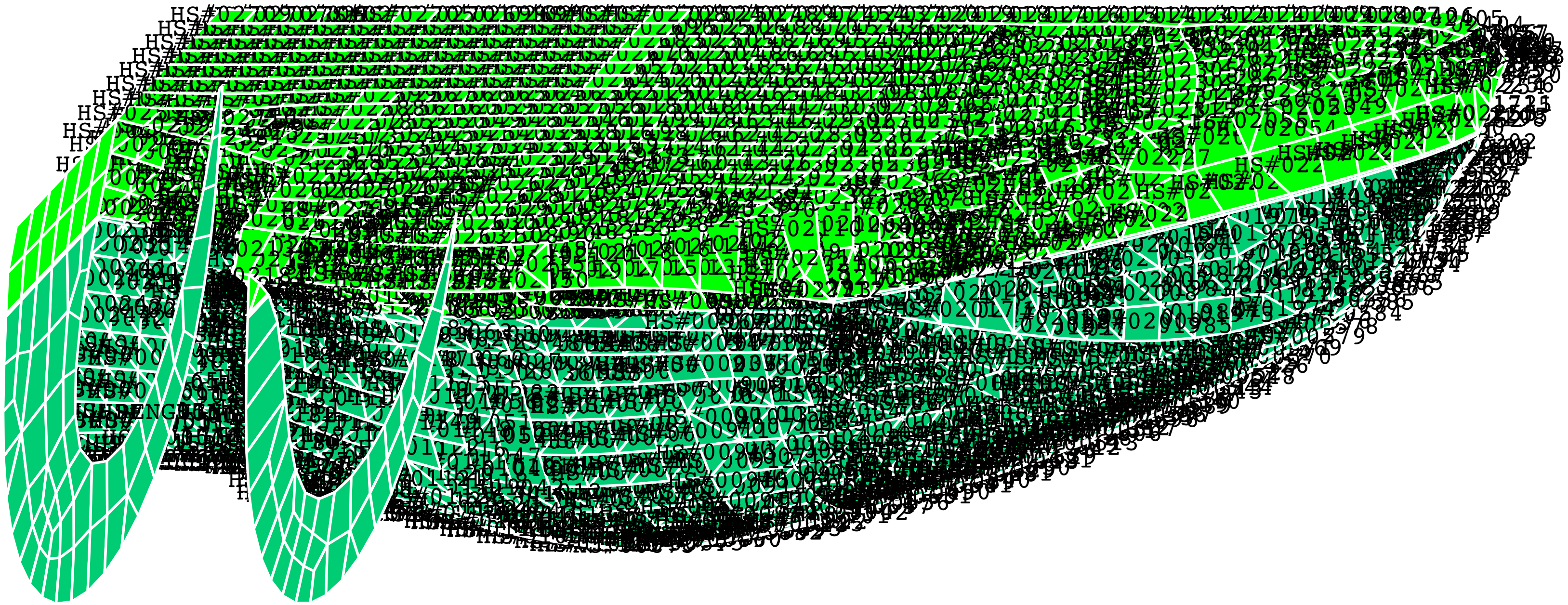
WELLO PENGUIN - HYDRODYNAMIC ANALYSIS

Event 1.0

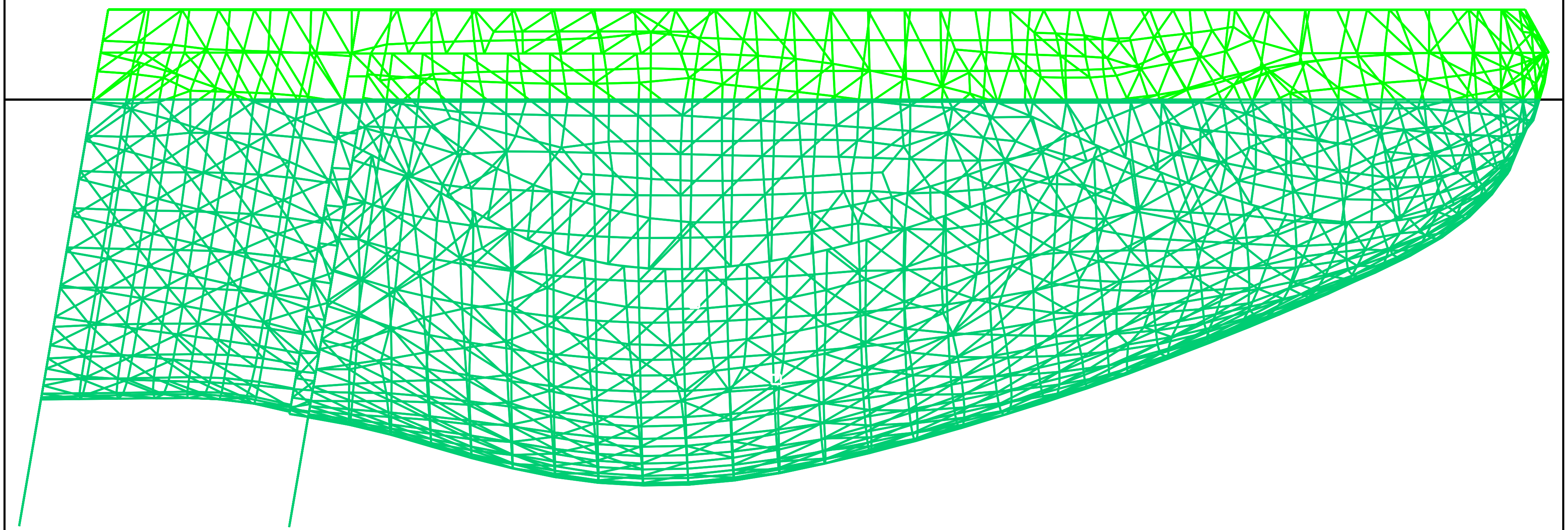


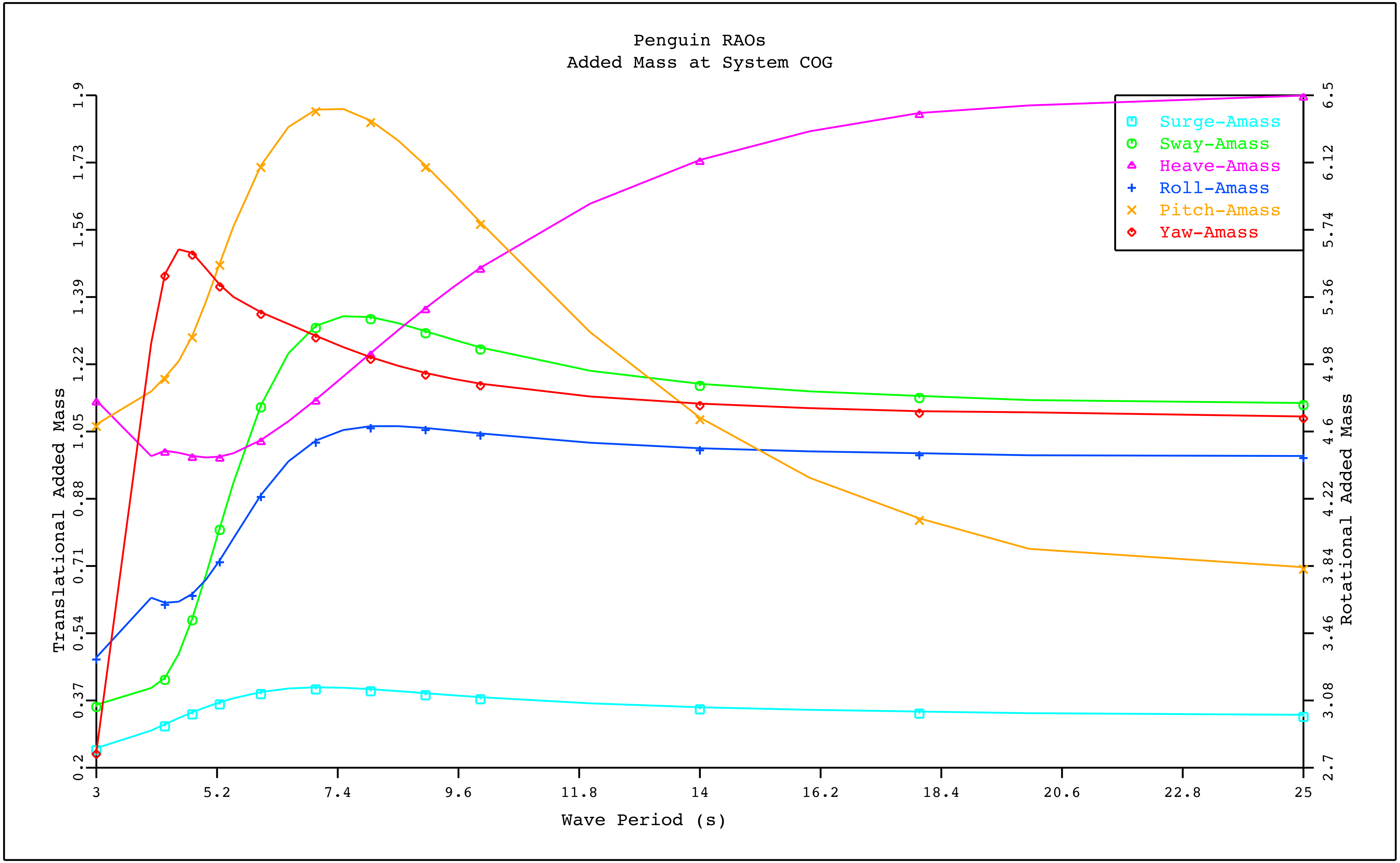

WELLO PENGUIN - HYDRODYNAMIC ANALYSIS
Event 1.0

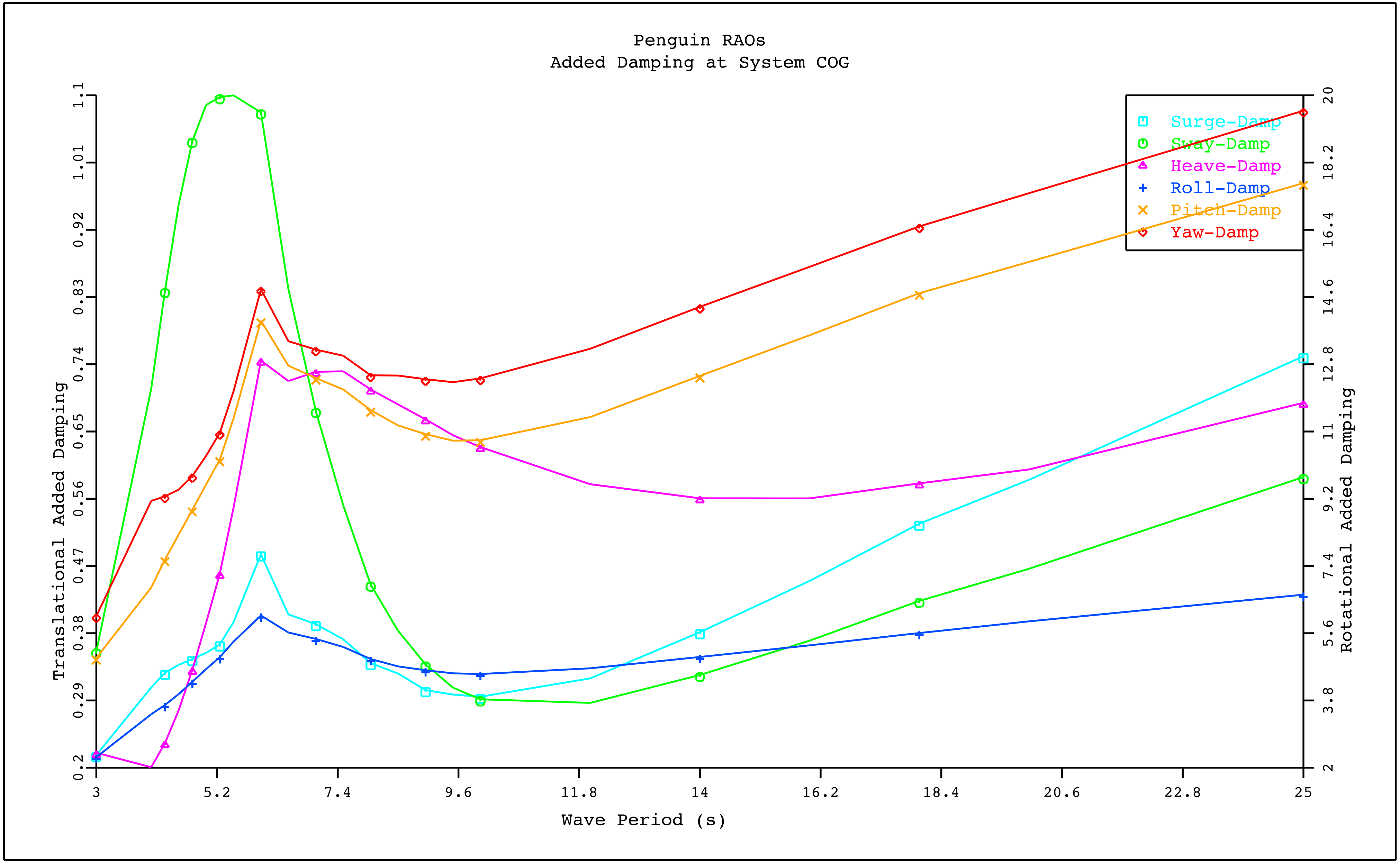
WELLO PENGUIN - HYDRODYNAMIC ANALYSIS
Event 1.0

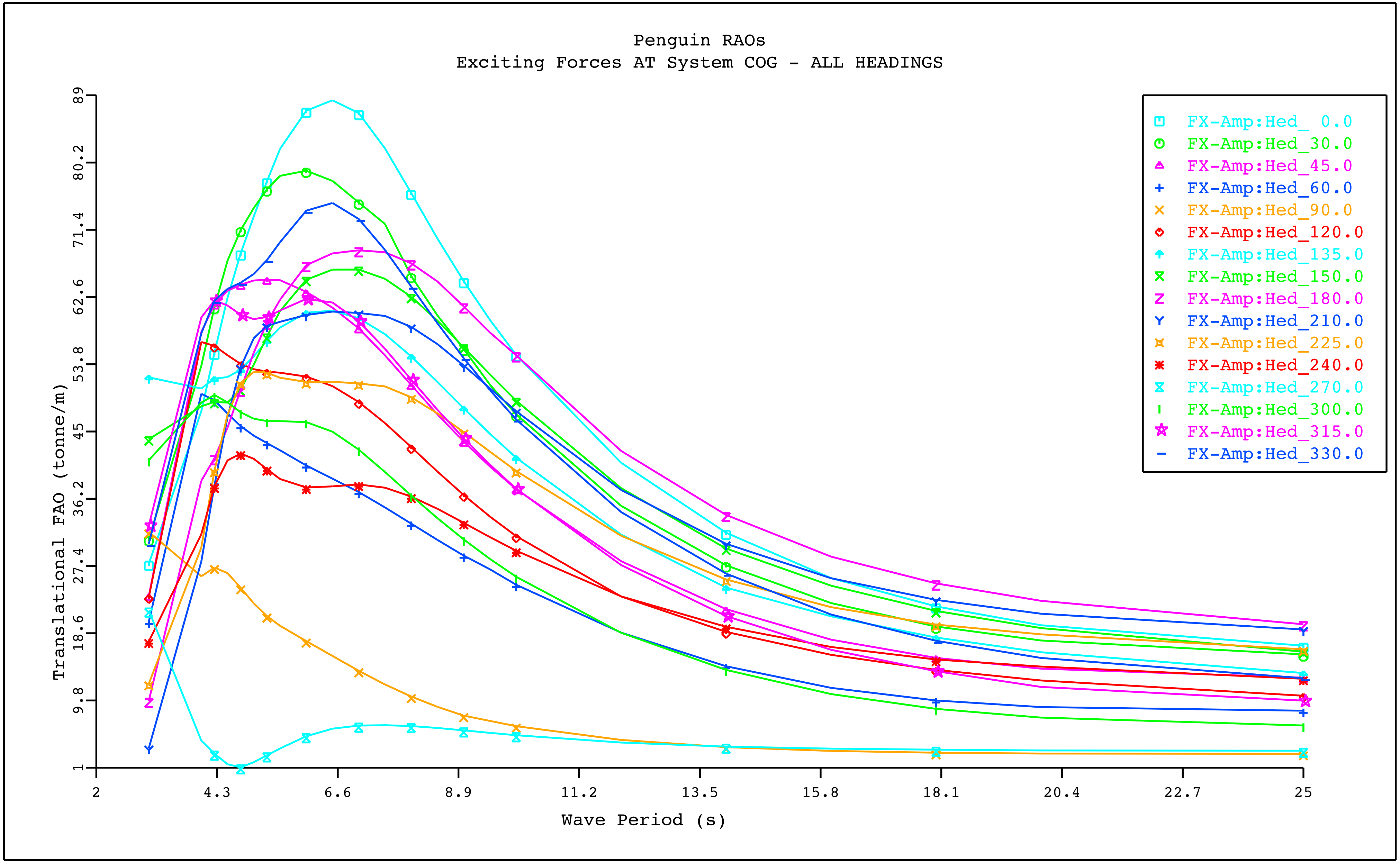


WELLO PENGUIN - HYDRODYNAMIC ANALYSIS
Event 1.0

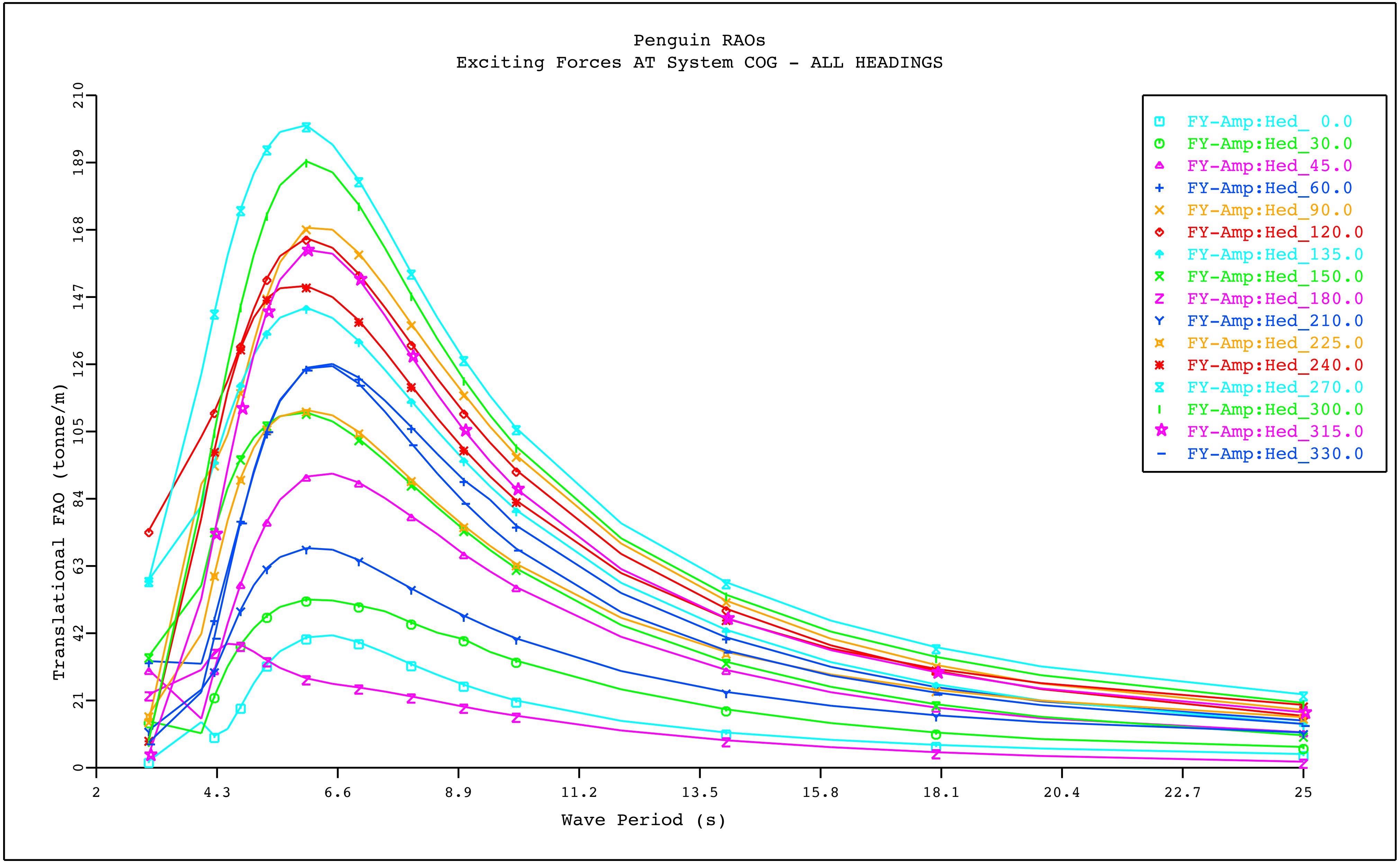



Penguin RAOs
Added Mass at System COG
Surge-Amass
Sway-Amass
Heave-Amass
Roll-Amass
Pitch-Amass
Yaw-Amass
Translational Added Mass
Rotational Added Mass
Wave Period (s)
0.2
0.37
0.54
0.71
0.88
1.05
1.22
1.39
1.56
1.73
1.9
2.7
3.08
3.46
3.84
4.22
4.6
4.98
5.36
5.74
6.12
6.5
3
5.2
7.4
9.6
11.8
14
16.2
18.4
20.6
22.8
25

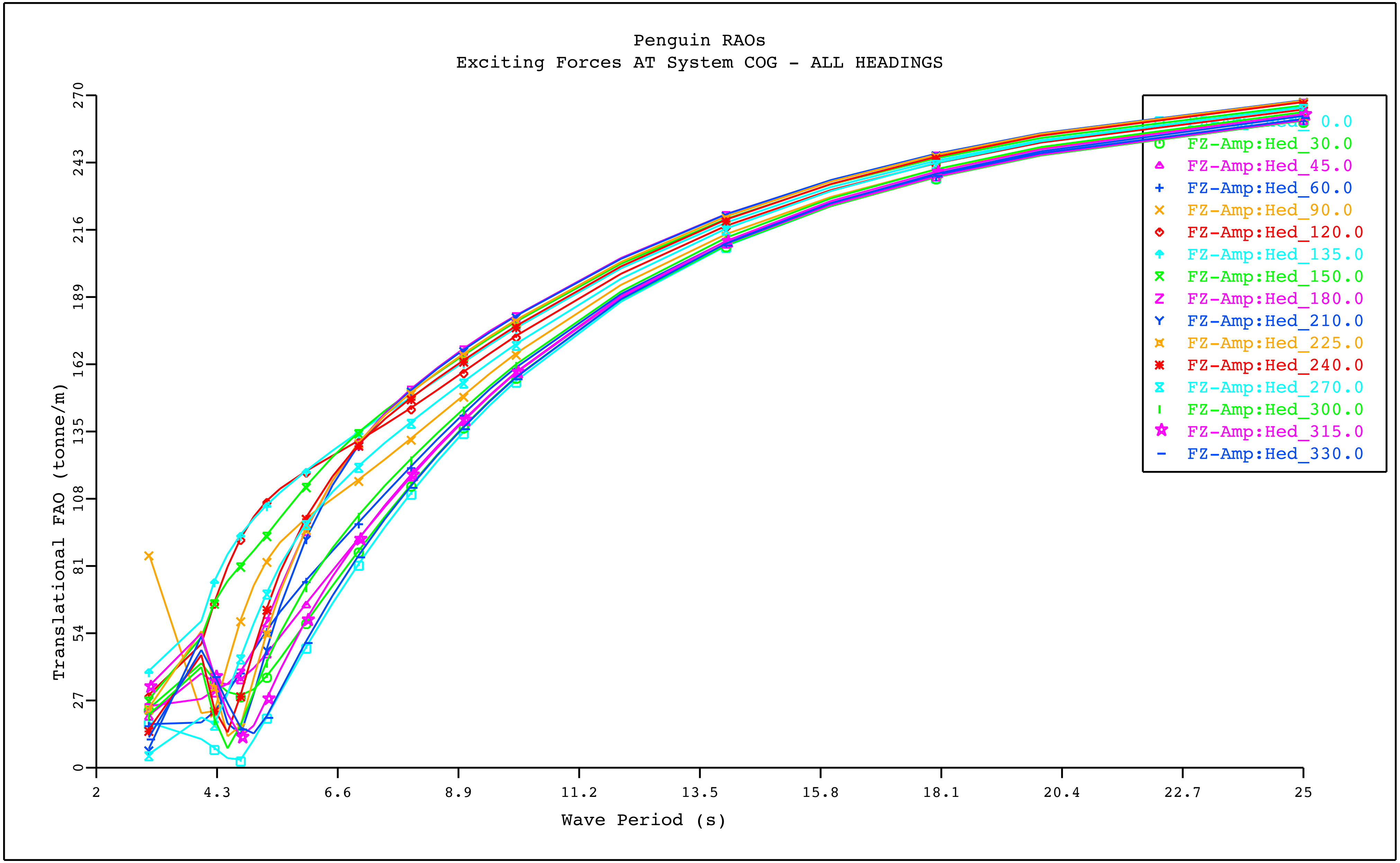

Penguin RAOs
Added Damping at System COG
Surge-Damp
Sway-Damp
Heave-Damp
Roll-Damp
Pitch-Damp
Yaw-Damp
Translational Added Damping
Rotational Added Damping
Wave Period (s)
0.2
0.29
0.38
0.47
0.56
0.65
0.74
0.83
0.92
1.01
1.1
2
3.8
5.6
7.4
9.2
11
12.8
14.6
16.4
18.2
20
3
5.2
7.4
9.6
11.8
14
16.2
18.4
20.6
22.8
25



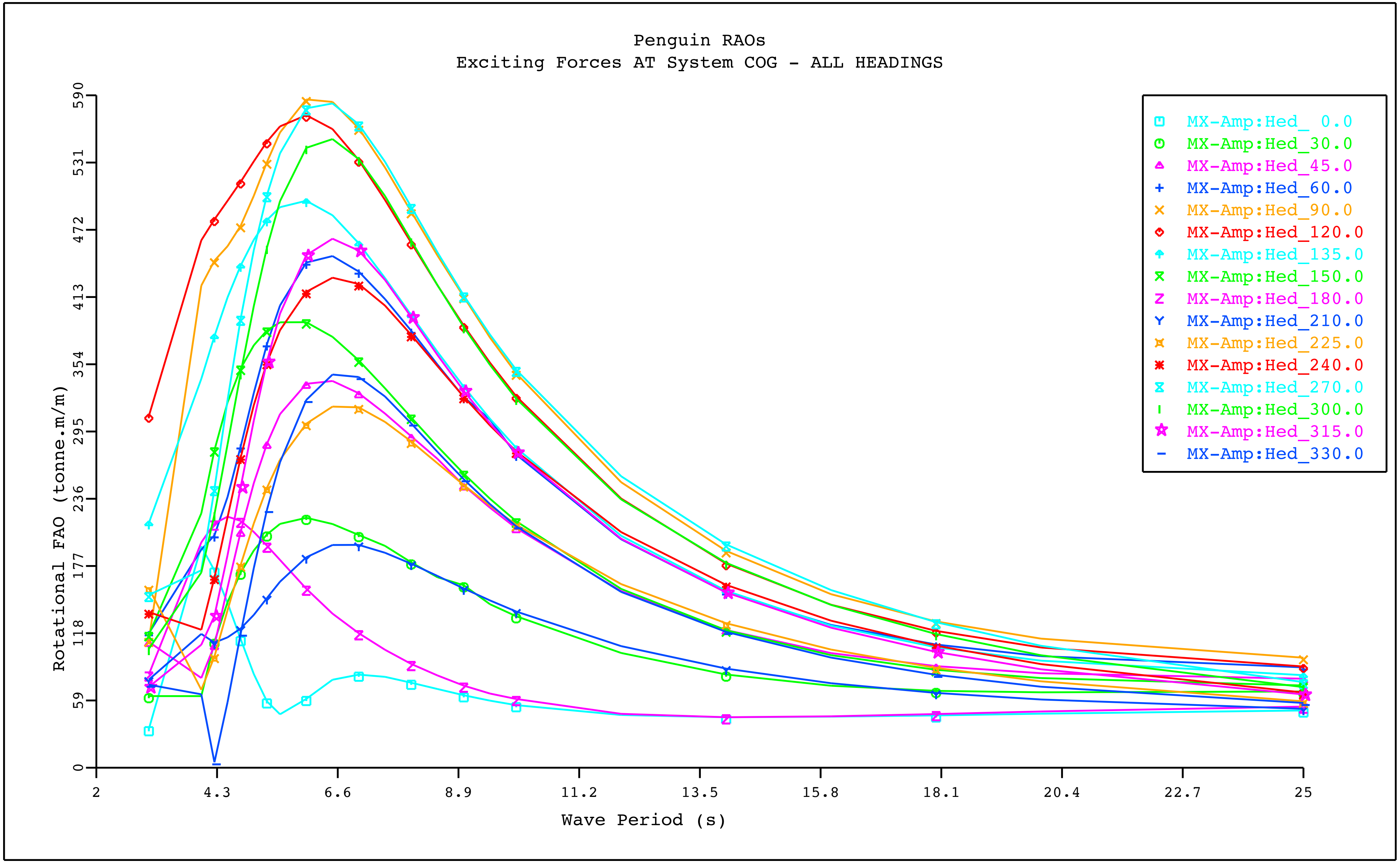
Penguin RAOs
Exciting Forces AT System COG - ALL HEADINGS
Translational FAO (tonne/m)
89
80.2
71.4
62.6
53.8
45
36.2
27.4
18.6
9.8
1
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
Wave Period (s)
FX-Amp:Hed_ 0.0
FX-Amp:Hed_30.0
FX-Amp:Hed_45.0
FX-Amp:Hed_60.0
FX-Amp:Hed_90.0
FX-Amp:Hed_120.0
FX-Amp:Hed_135.0
FX-Amp:Hed_150.0
FX-Amp:Hed_180.0
FX-Amp:Hed_210.0
FX-Amp:Hed_225.0
FX-Amp:Hed_240.0
FX-Amp:Hed_270.0
FX-Amp:Hed_300.0
FX-Amp:Hed_315.0
FX-Amp:Hed_330.0



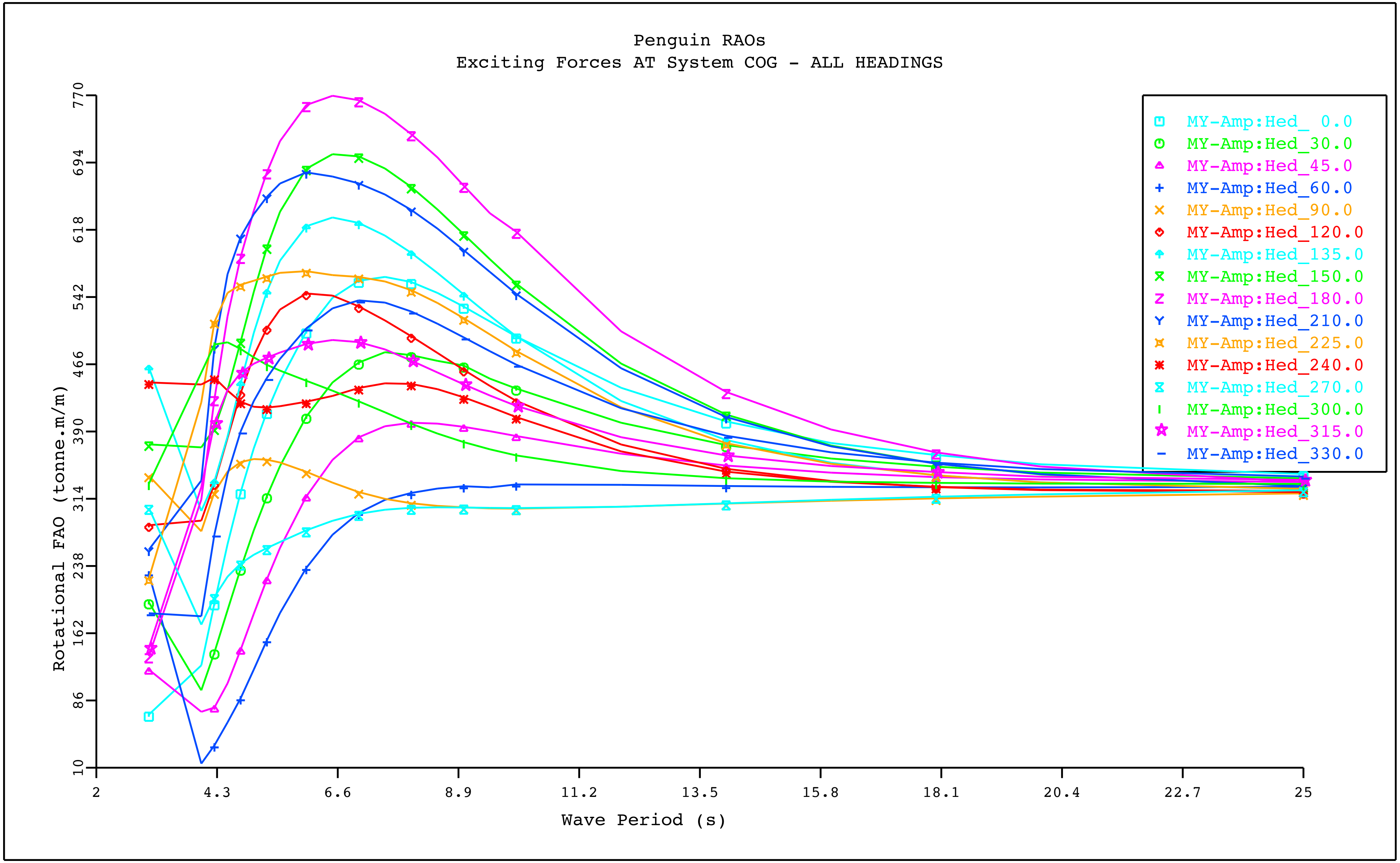
Penguin RAOs
Exciting Forces AT System COG - ALL HEADINGS
Translational FAO (tonne/m)
Wave Period (s)
0
21
42
63
84
105
126
147
168
189
210
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
FY-Amp:Hed_ 0.0
FY-Amp:Hed_30.0
FY-Amp:Hed_45.0
FY-Amp:Hed_60.0
FY-Amp:Hed_90.0
FY-Amp:Hed_120.0
FY-Amp:Hed_135.0
FY-Amp:Hed_150.0
FY-Amp:Hed_180.0
FY-Amp:Hed_210.0
FY-Amp:Hed_225.0
FY-Amp:Hed_240.0
FY-Amp:Hed_270.0
FY-Amp:Hed_300.0
FY-Amp:Hed_315.0
FY-Amp:Hed_330.0



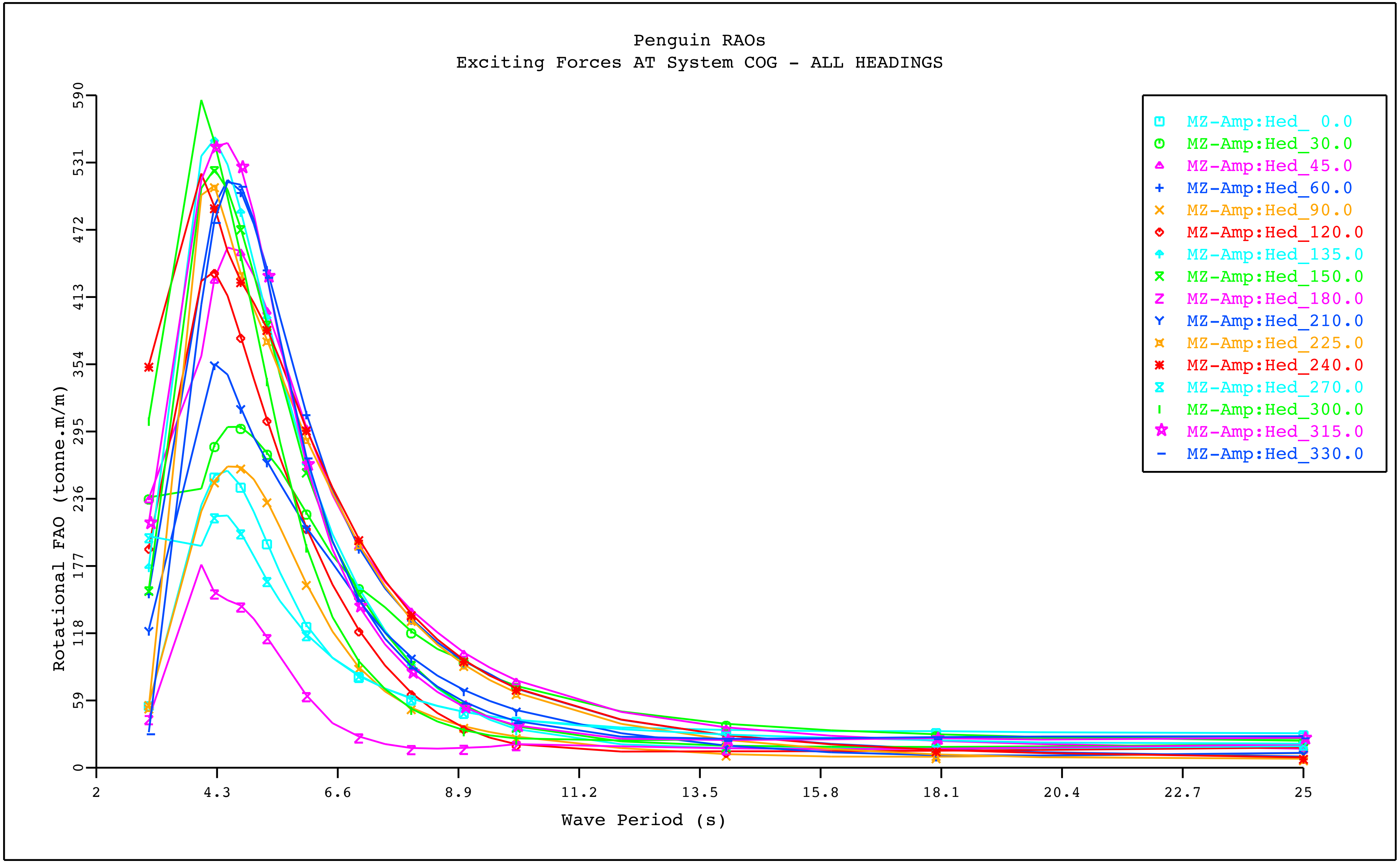
Penguin RAOs
Exciting Forces AT System COG - ALL HEADINGS
Translational FAO (tonne/m)
Wave Period (s)
0
27
54
81
108
135
162
189
216
243
270
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
FZ-Amp:Hed_30.0
FZ-Amp:Hed_45.0
FZ-Amp:Hed_60.0
FZ-Amp:Hed_90.0
FZ-Amp:Hed_120.0
FZ-Amp:Hed_135.0
FZ-Amp:Hed_150.0
FZ-Amp:Hed_180.0
FZ-Amp:Hed_210.0
FZ-Amp:Hed_225.0
FZ-Amp:Hed_240.0
FZ-Amp:Hed_270.0
FZ-Amp:Hed_300.0
FZ-Amp:Hed_315.0
FZ-Amp:Hed_330.0

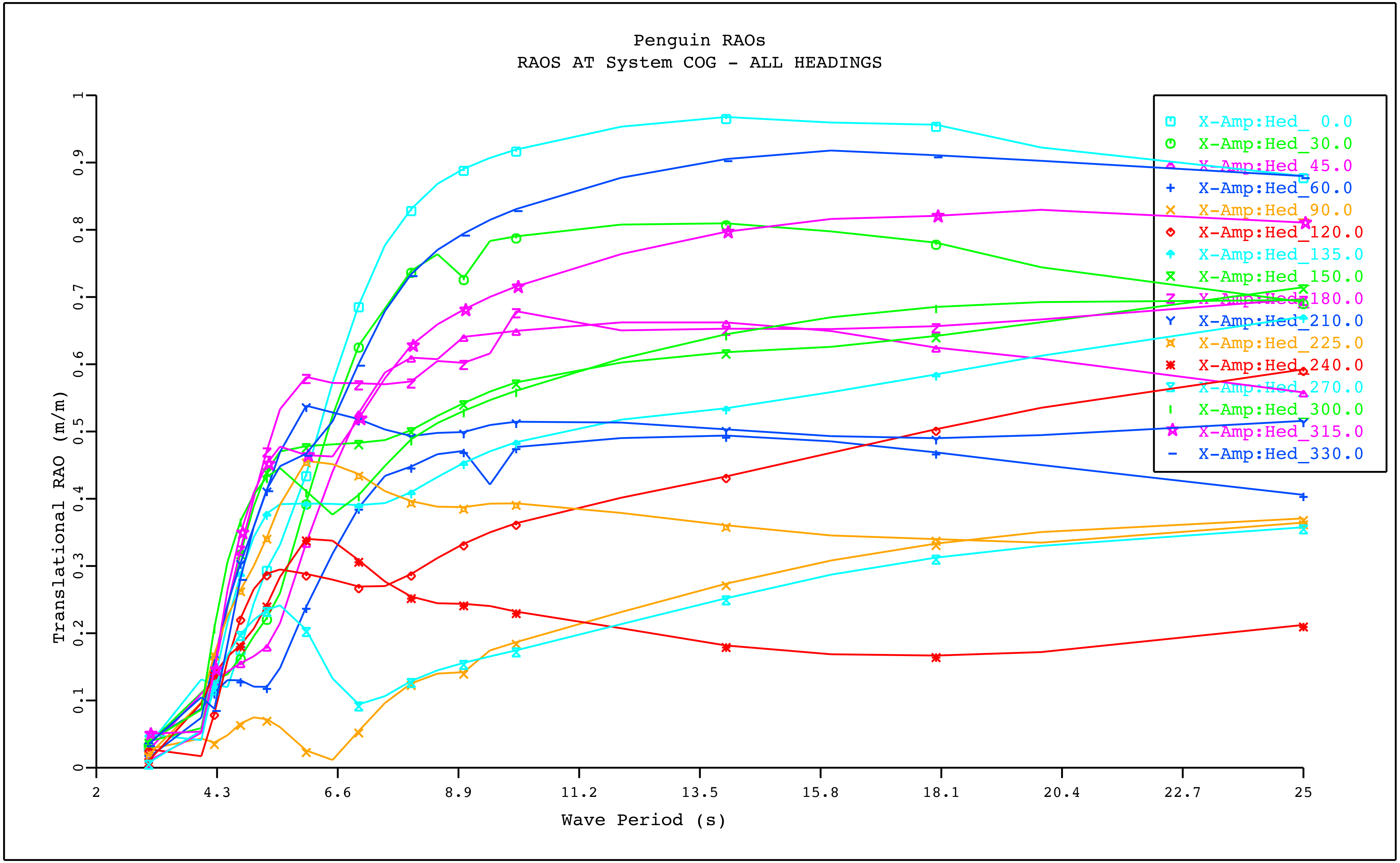


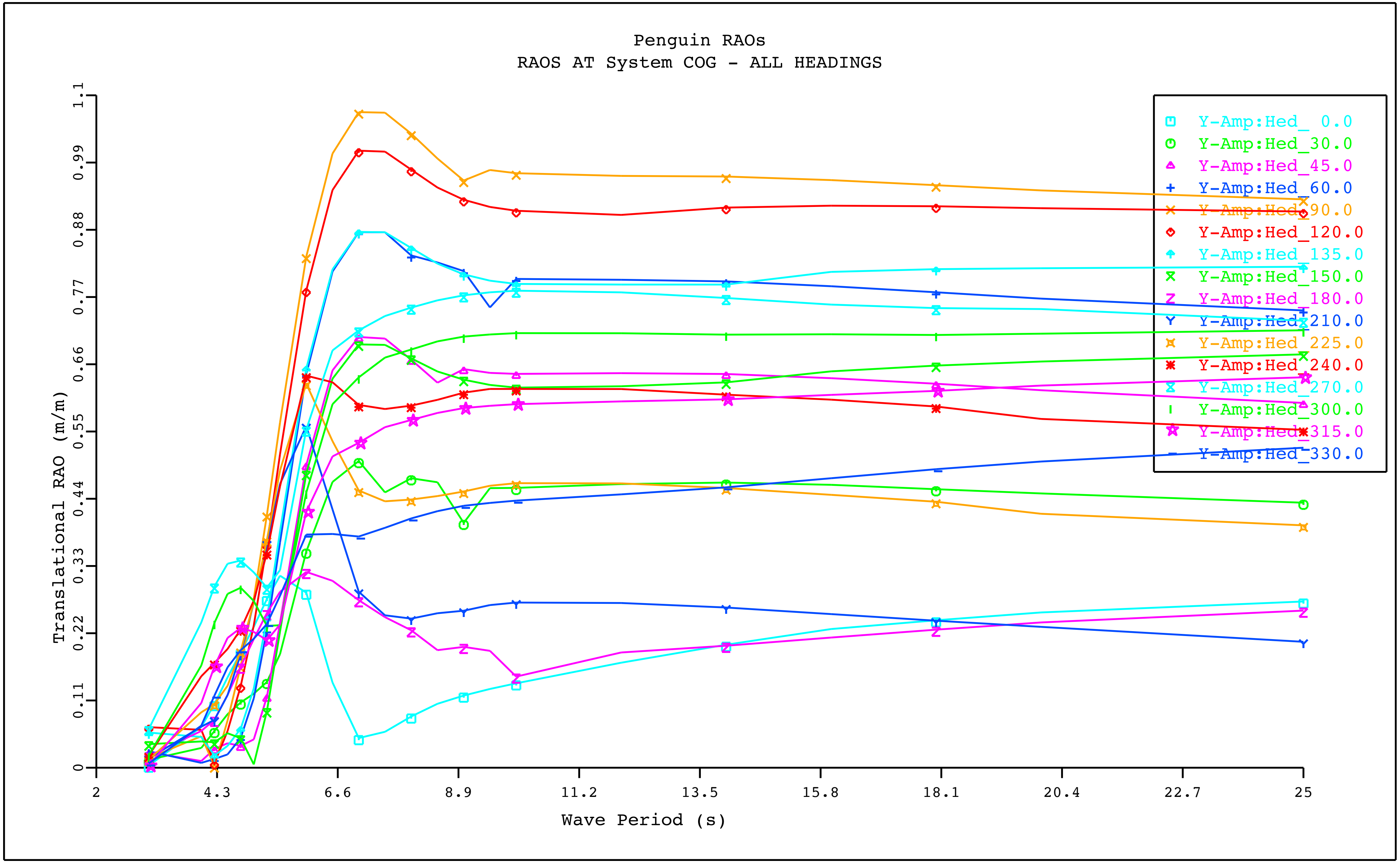
Penguin RAOs
Exciting Forces AT System COG - ALL HEADINGS
Rotational FAO (tonne.m/m)
0
59
118
177
236
295
354
413
472
531
590
Wave Period (s)
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
MX-Amp:Hed_ 0.0
MX-Amp:Hed_30.0
MX-Amp:Hed_45.0
MX-Amp:Hed_60.0
MX-Amp:Hed_90.0
MX-Amp:Hed_120.0
MX-Amp:Hed_135.0
MX-Amp:Hed_150.0
MX-Amp:Hed_180.0
MX-Amp:Hed_210.0
MX-Amp:Hed_225.0
MX-Amp:Hed_240.0
MX-Amp:Hed_270.0
MX-Amp:Hed_300.0
MX-Amp:Hed_315.0
MX-Amp:Hed_330.0



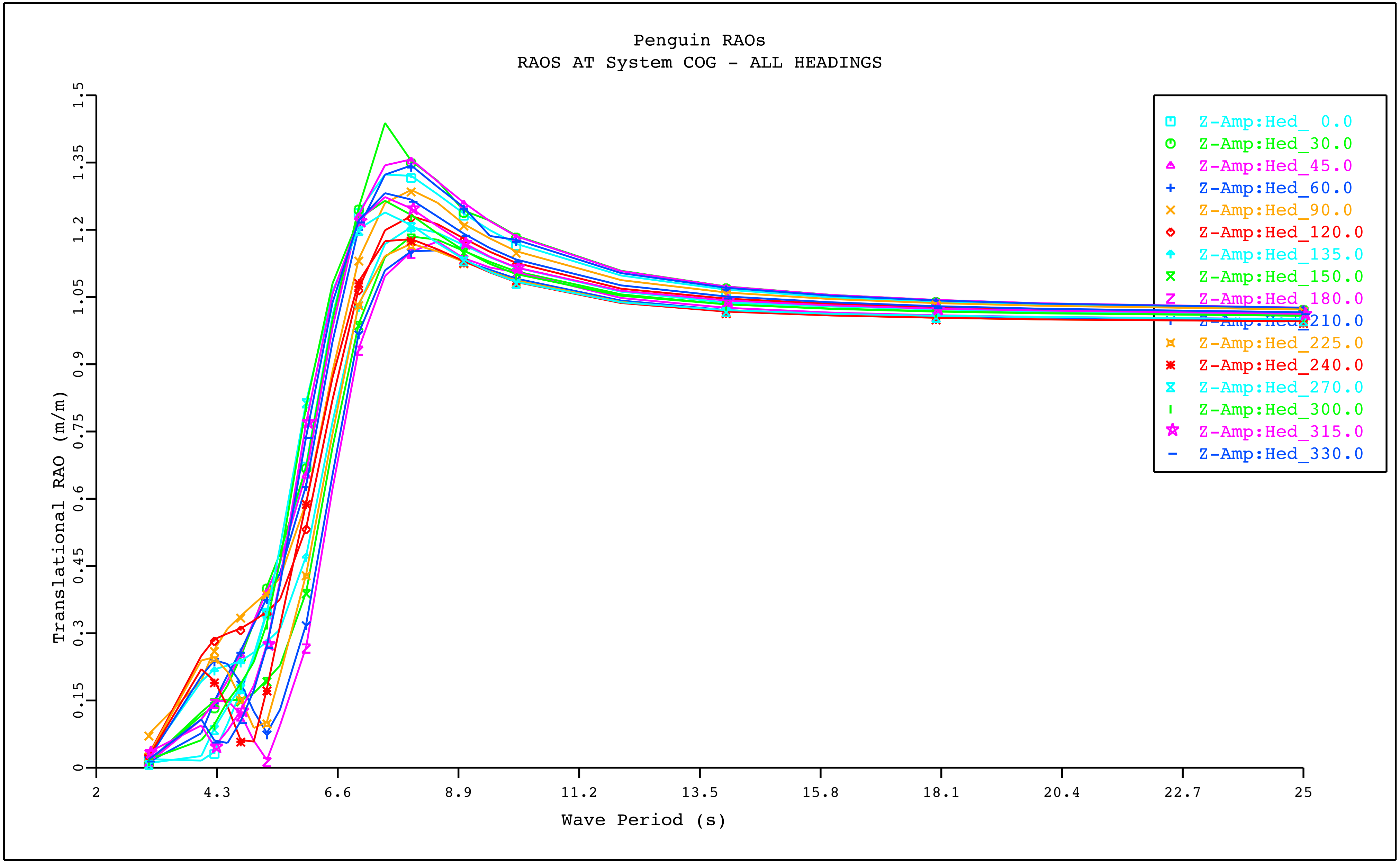
Penguin RAOs
Exciting Forces AT System COG - ALL HEADINGS
Rotational FAO (tonne.m/m)
Wave Period (s)
770
694
618
542
466
390
314
238
162
86
10
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
MY-Amp:Hed_ 0.0
MY-Amp:Hed_30.0
MY-Amp:Hed_45.0
MY-Amp:Hed_60.0
MY-Amp:Hed_90.0
MY-Amp:Hed_120.0
MY-Amp:Hed_135.0
MY-Amp:Hed_150.0
MY-Amp:Hed_180.0
MY-Amp:Hed_210.0
MY-Amp:Hed_225.0
MY-Amp:Hed_240.0
MY-Amp:Hed_270.0
MY-Amp:Hed_300.0
MY-Amp:Hed_315.0
MY-Amp:Hed_330.0


Penguin RAOs
Exciting Forces AT System COG - ALL HEADINGS
Rotational FAO (tonne.m/m)
Wave Period (s)
0
59
118
177
236
295
354
413
472
531
590
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
MZ-Amp:Hed_ 0.0
MZ-Amp:Hed_30.0
MZ-Amp:Hed_45.0
MZ-Amp:Hed_60.0
MZ-Amp:Hed_90.0
MZ-Amp:Hed_120.0
MZ-Amp:Hed_135.0
MZ-Amp:Hed_150.0
MZ-Amp:Hed_180.0
MZ-Amp:Hed_210.0
MZ-Amp:Hed_225.0
MZ-Amp:Hed_240.0
MZ-Amp:Hed_270.0
MZ-Amp:Hed_300.0
MZ-Amp:Hed_315.0
MZ-Amp:Hed_330.0

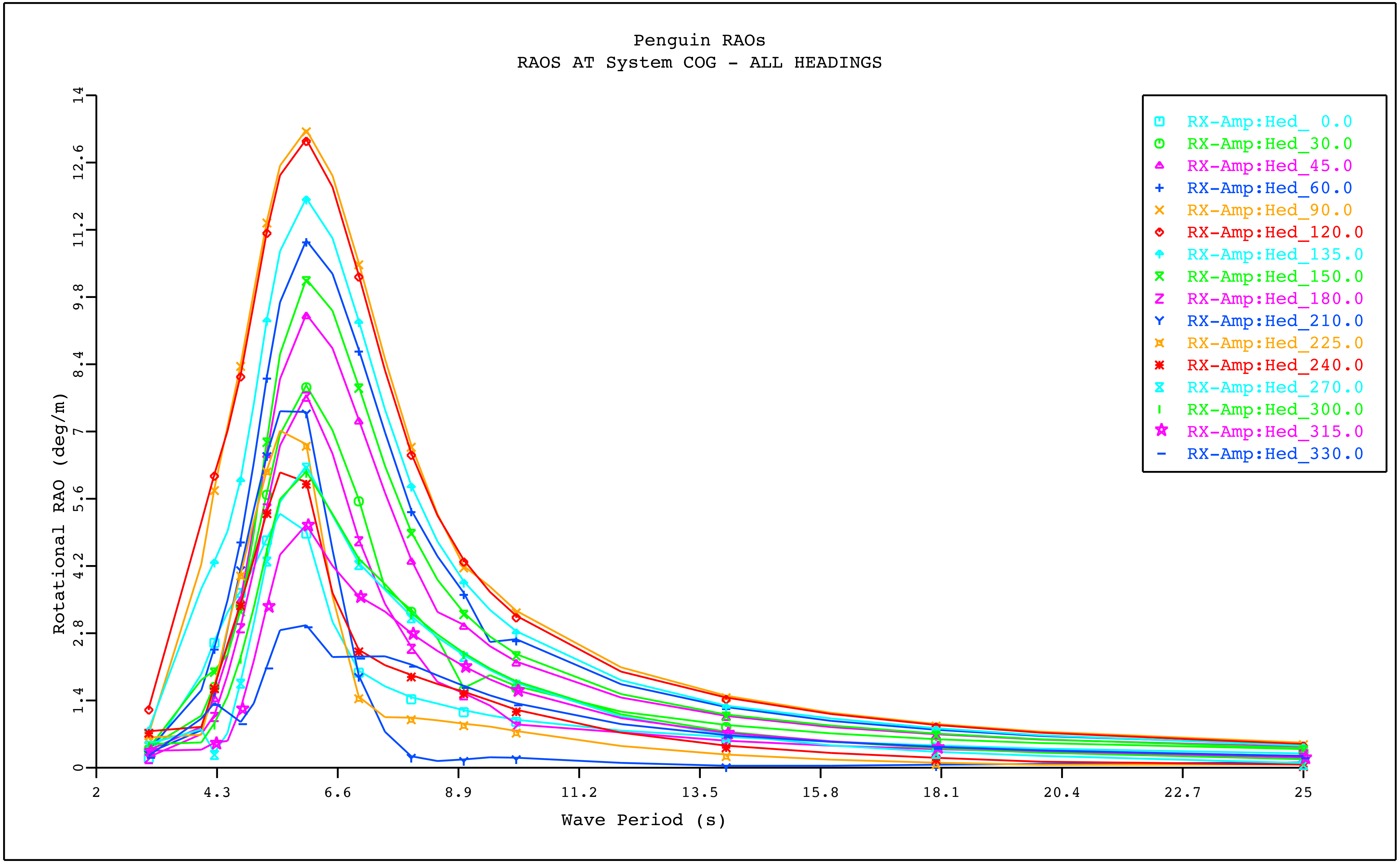

Penguin RAOs
RAOS AT System COG - ALL HEADINGS
Translational RAO (m/m)
Wave Period (s)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
X-Amp:Hed_ 0.0
X-Amp:Hed_30.0
X-Amp:Hed_45.0
X-Amp:Hed_60.0
X-Amp:Hed_90.0
X-Amp:Hed_120.0
X-Amp:Hed_135.0
X-Amp:Hed_150.0
X-Amp:Hed_180.0
X-Amp:Hed_210.0
X-Amp:Hed_225.0
X-Amp:Hed_240.0
X-Amp:Hed_270.0
X-Amp:Hed_300.0
X-Amp:Hed_315.0
X-Amp:Hed_330.0



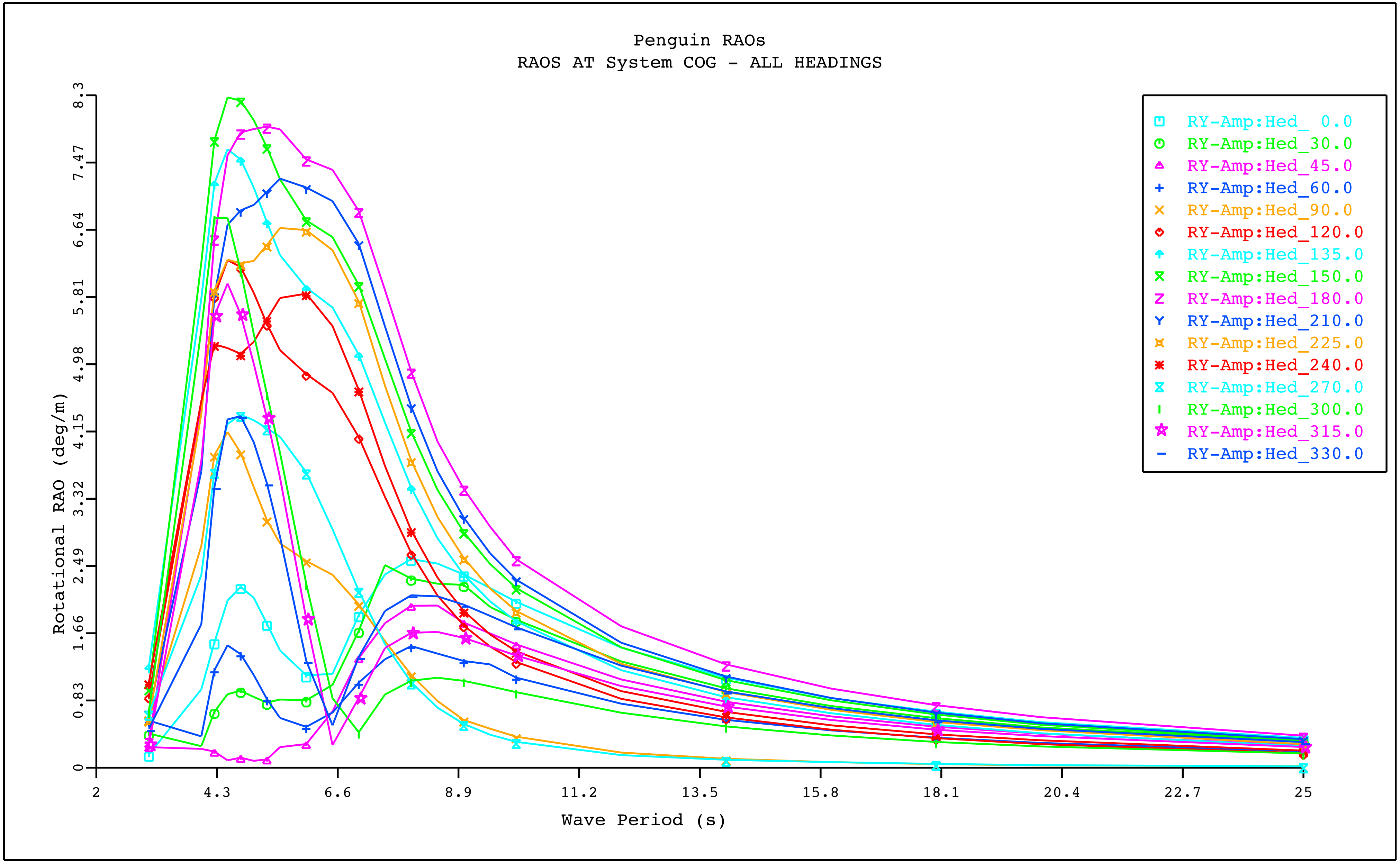
Penguin RAOs
RAOS AT System COG - ALL HEADINGS
Translational RAO (m/m)
Wave Period (s)
0
0.11
0.22
0.33
0.44
0.55
0.66
0.77
0.88
0.99
1.1
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
Y-Amp:Hed_ 0.0
Y-Amp:Hed_30.0
Y-Amp:Hed_45.0
Y-Amp:Hed_60.0
Y-Amp:Hed_90.0
Y-Amp:Hed_120.0
Y-Amp:Hed_135.0
Y-Amp:Hed_150.0
Y-Amp:Hed_180.0
Y-Amp:Hed_210.0
Y-Amp:Hed_225.0
Y-Amp:Hed_240.0
Y-Amp:Hed_270.0
Y-Amp:Hed_300.0
Y-Amp:Hed_315.0
Y-Amp:Hed_330.0



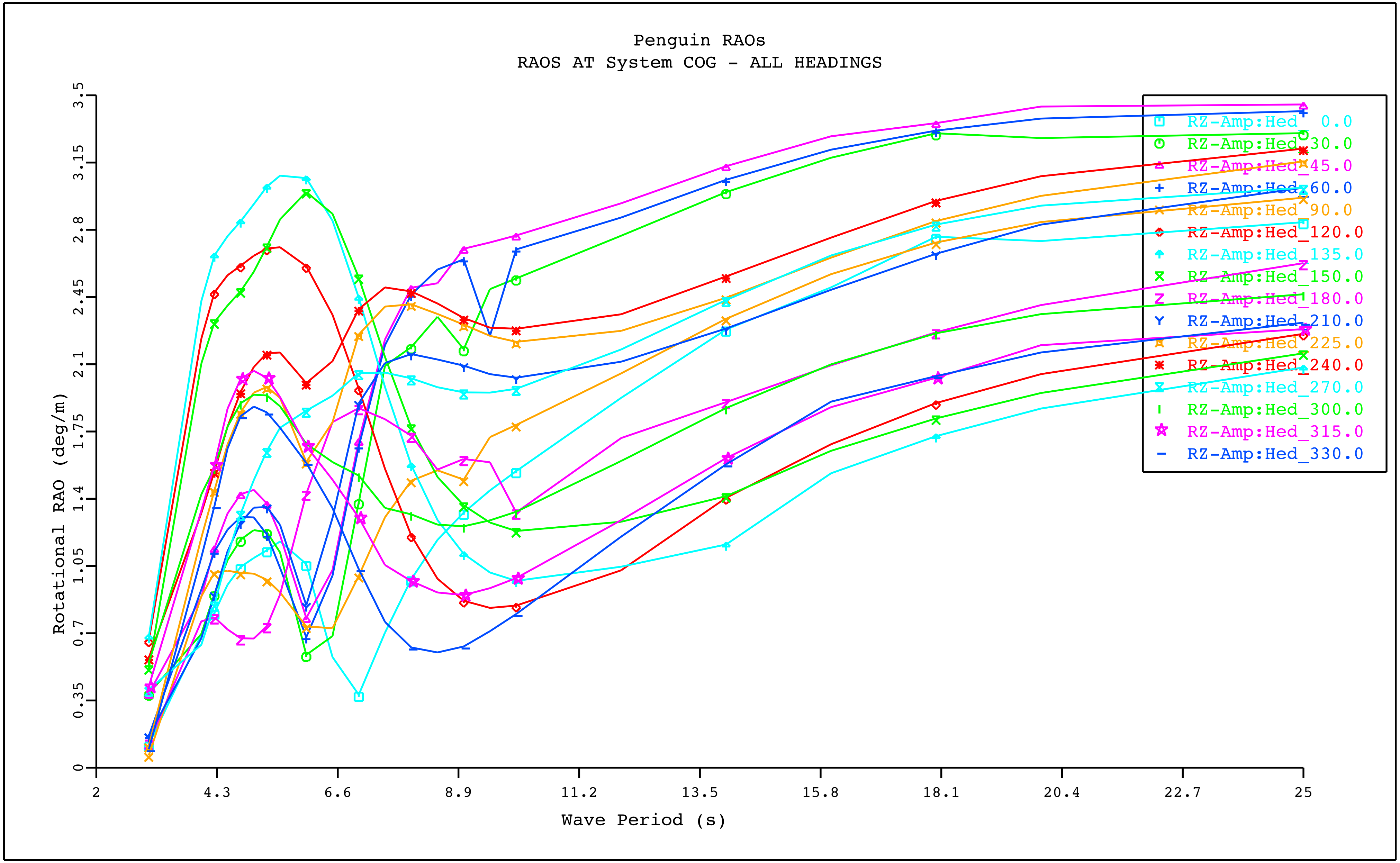
Penguin RAOs
RAOS AT System COG - ALL HEADINGS
Translational RAO (m/m)
Wave Period (s)
0
0.15
0.3
0.45
0.6
0.75
0.9
1.05
1.2
1.35
1.5
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
Z-Amp:Hed_ 0.0
Z-Amp:Hed_30.0
Z-Amp:Hed_45.0
Z-Amp:Hed_60.0
Z-Amp:Hed_90.0
Z-Amp:Hed_120.0
Z-Amp:Hed_135.0
Z-Amp:Hed_150.0
Z-Amp:Hed_180.0
Z-Amp:Hed_210.0
Z-Amp:Hed_225.0
Z-Amp:Hed_240.0
Z-Amp:Hed_270.0
Z-Amp:Hed_300.0
Z-Amp:Hed_315.0
Z-Amp:Hed_330.0

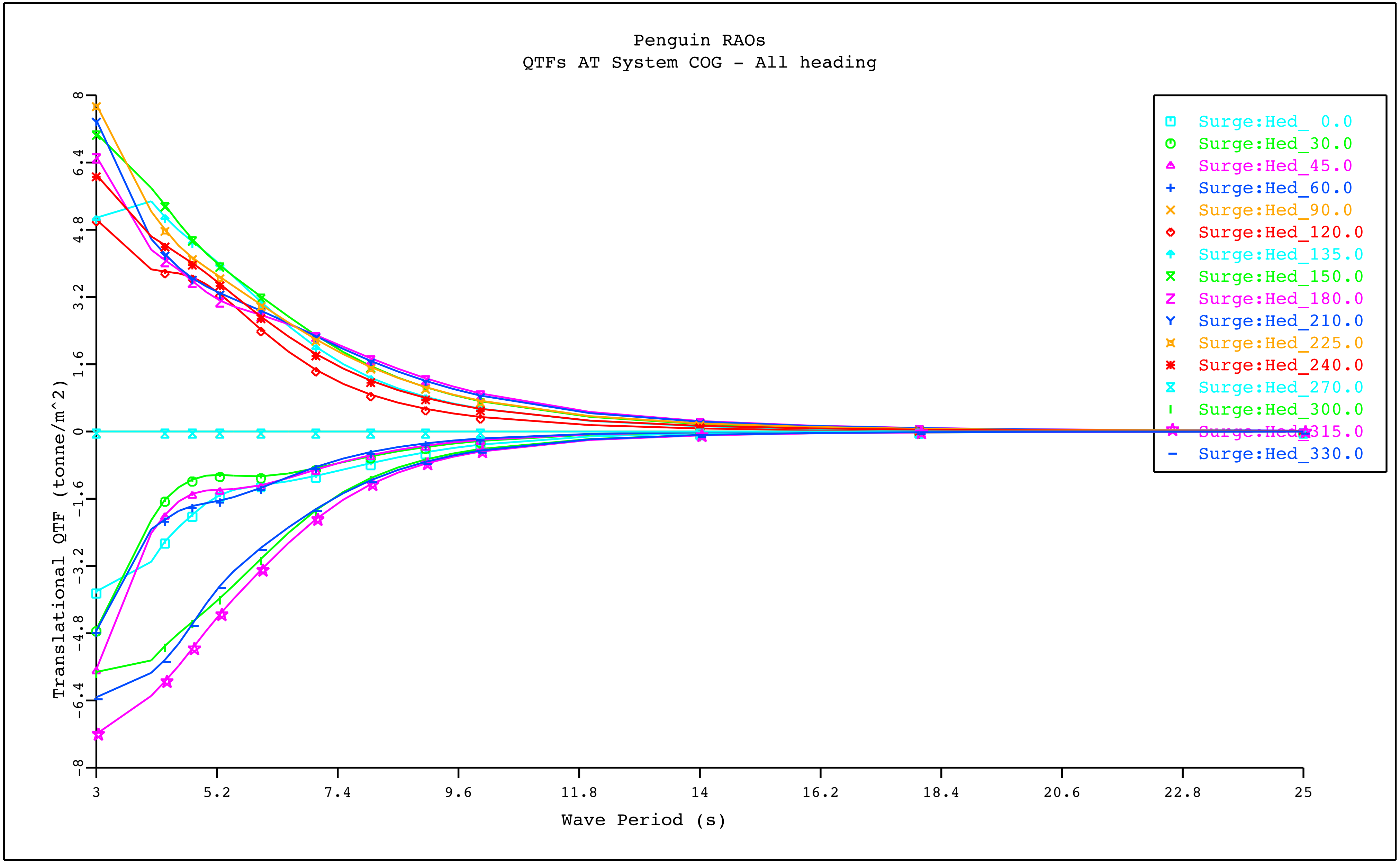


Penguin RAOs
RAOS AT System COG - ALL HEADINGS
Rotational RAO (deg/m)
0
1.4
2.8
4.2
5.6
7
8.4
9.8
11.2
12.6
14
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
Wave Period (s)
RX-Amp:Hed_ 0.0
RX-Amp:Hed_30.0
RX-Amp:Hed_45.0
RX-Amp:Hed_60.0
RX-Amp:Hed_90.0
RX-Amp:Hed_120.0
RX-Amp:Hed_135.0
RX-Amp:Hed_150.0
RX-Amp:Hed_180.0
RX-Amp:Hed_210.0
RX-Amp:Hed_225.0
RX-Amp:Hed_240.0
RX-Amp:Hed_270.0
RX-Amp:Hed_300.0
RX-Amp:Hed_315.0
RX-Amp:Hed_330.0

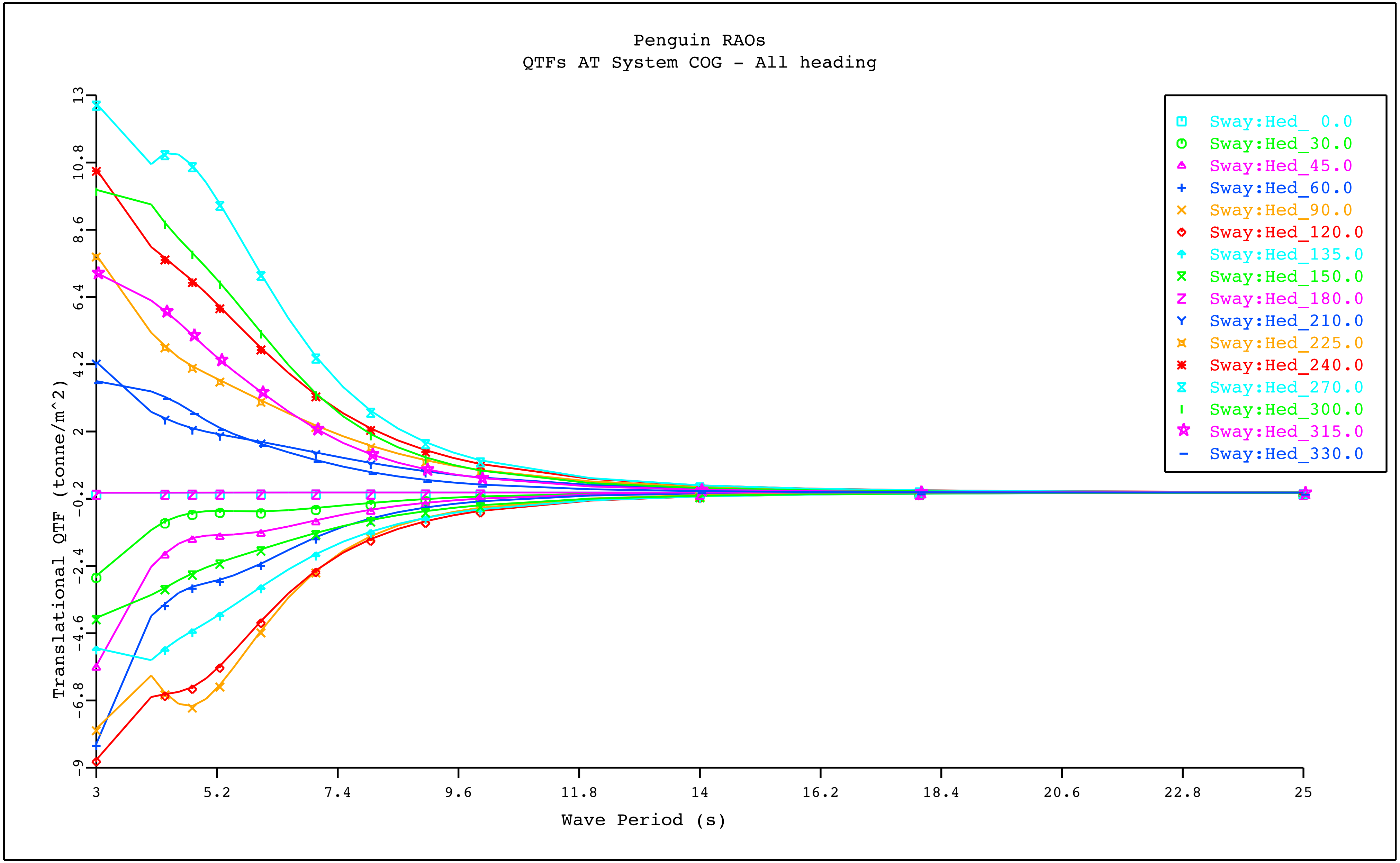


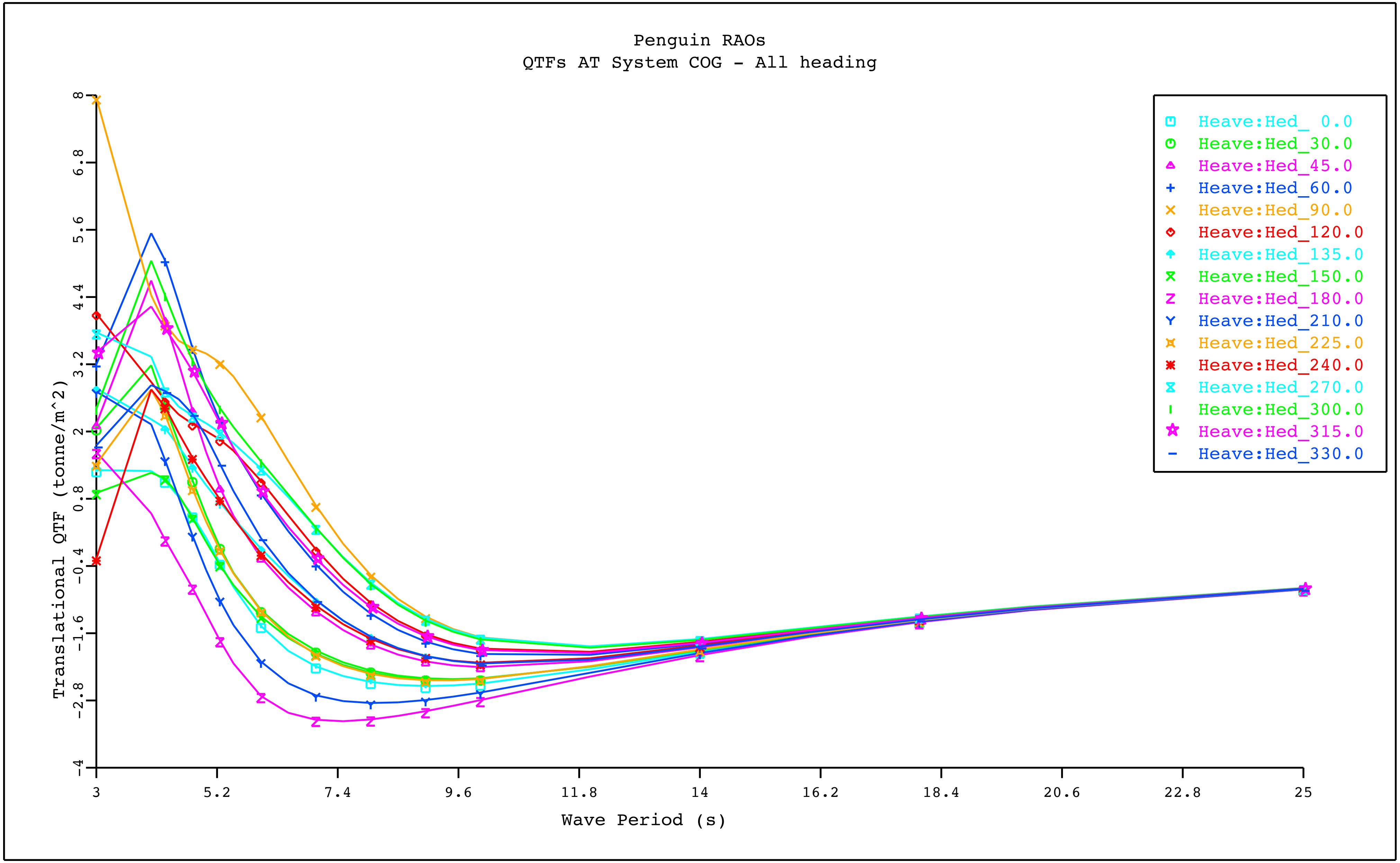
Penguin RAOs
RAOS AT System COG - ALL HEADINGS
Rotational RAO (deg/m)
Wave Period (s)
0
0.83
1.66
2.49
3.32
4.15
4.98
5.81
6.64
7.47
8.3
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
RY-Amp:Hed_ 0.0
RY-Amp:Hed_30.0
RY-Amp:Hed_45.0
RY-Amp:Hed_60.0
RY-Amp:Hed_90.0
RY-Amp:Hed_120.0
RY-Amp:Hed_135.0
RY-Amp:Hed_150.0
RY-Amp:Hed_180.0
RY-Amp:Hed_210.0
RY-Amp:Hed_225.0
RY-Amp:Hed_240.0
RY-Amp:Hed_270.0
RY-Amp:Hed_300.0
RY-Amp:Hed_315.0
RY-Amp:Hed_330.0


Penguin RAOs
RAOS AT System COG - ALL HEADINGS
Rotational RAO (deg/m)
Wave Period (s)
0
0.35
0.7
1.05
1.4
1.75
2.1
2.45
2.8
3.15
3.5
2
4.3
6.6
8.9
11.2
13.5
15.8
18.1
20.4
22.7
25
RZ-Amp:Hed_ 0.0
RZ-Amp:Hed_30.0
RZ-Amp:Hed_45.0
RZ-Amp:Hed_60.0
RZ-Amp:Hed_90.0
RZ-Amp:Hed_120.0
RZ-Amp:Hed_135.0
RZ-Amp:Hed_150.0
RZ-Amp:Hed_180.0
RZ-Amp:Hed_210.0
RZ-Amp:Hed_225.0
RZ-Amp:Hed_240.0
RZ-Amp:Hed_270.0
RZ-Amp:Hed_300.0
RZ-Amp:Hed_315.0
RZ-Amp:Hed_330.0

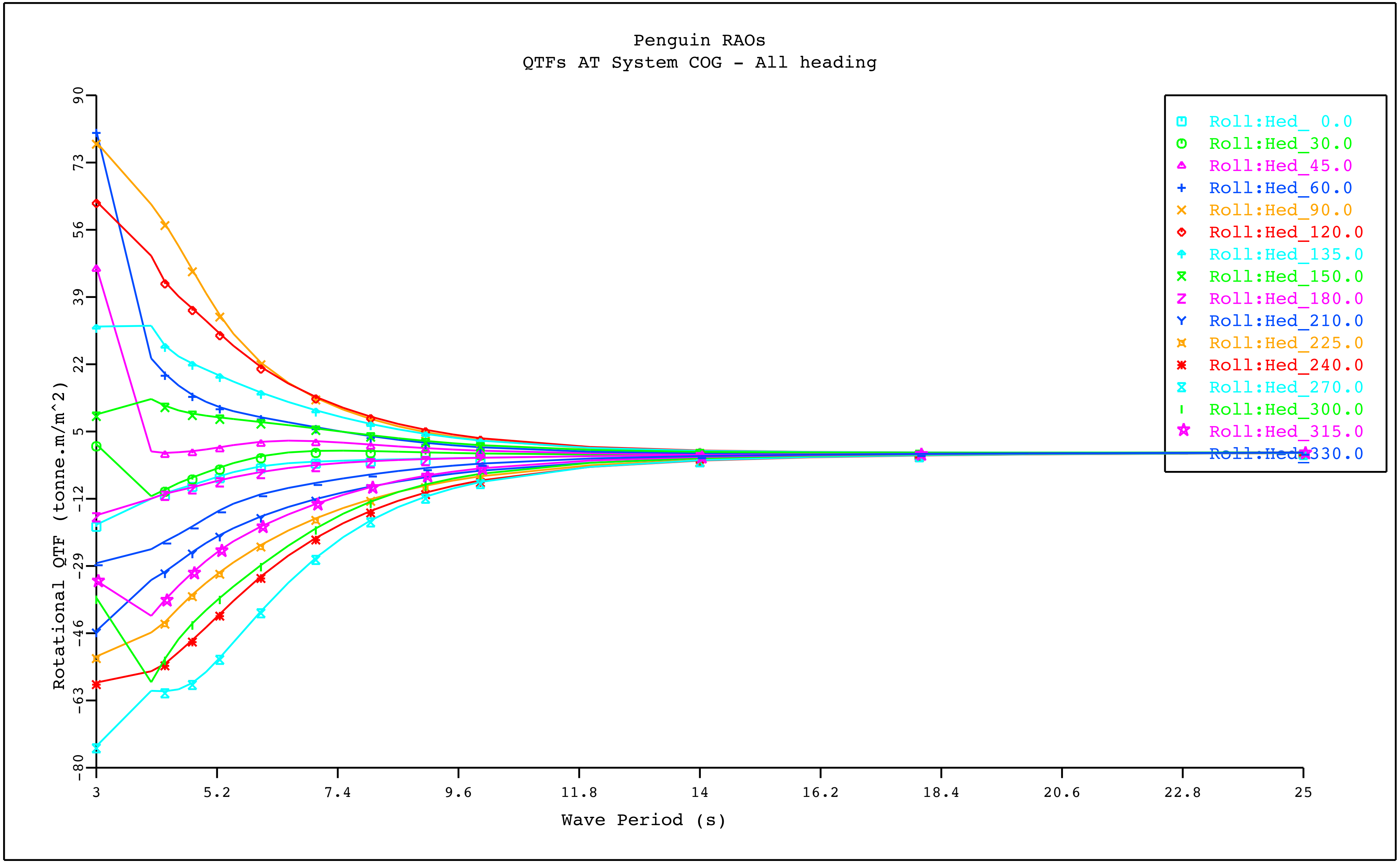


Penguin RAOs
QTFs AT System COG - All heading
Translational QTF (tonne/m^2)
Wave Period (s)
8
6.4
4.8
3.2
1.6
0
-1.6
-3.2
-4.8
-6.4
-8
3
5.2
7.4
9.6
11.8
14
16.2
18.4
20.6
22.8
25
Surge:Hed_ 0.0
Surge:Hed_30.0
Surge:Hed_45.0
Surge:Hed_60.0
Surge:Hed_90.0
Surge:Hed_120.0
Surge:Hed_135.0
Surge:Hed_150.0
Surge:Hed_180.0
Surge:Hed_210.0
Surge:Hed_225.0
Surge:Hed_240.0
Surge:Hed_270.0
Surge:Hed_300.0
Surge:Hed_315.0
Surge:Hed_330.0

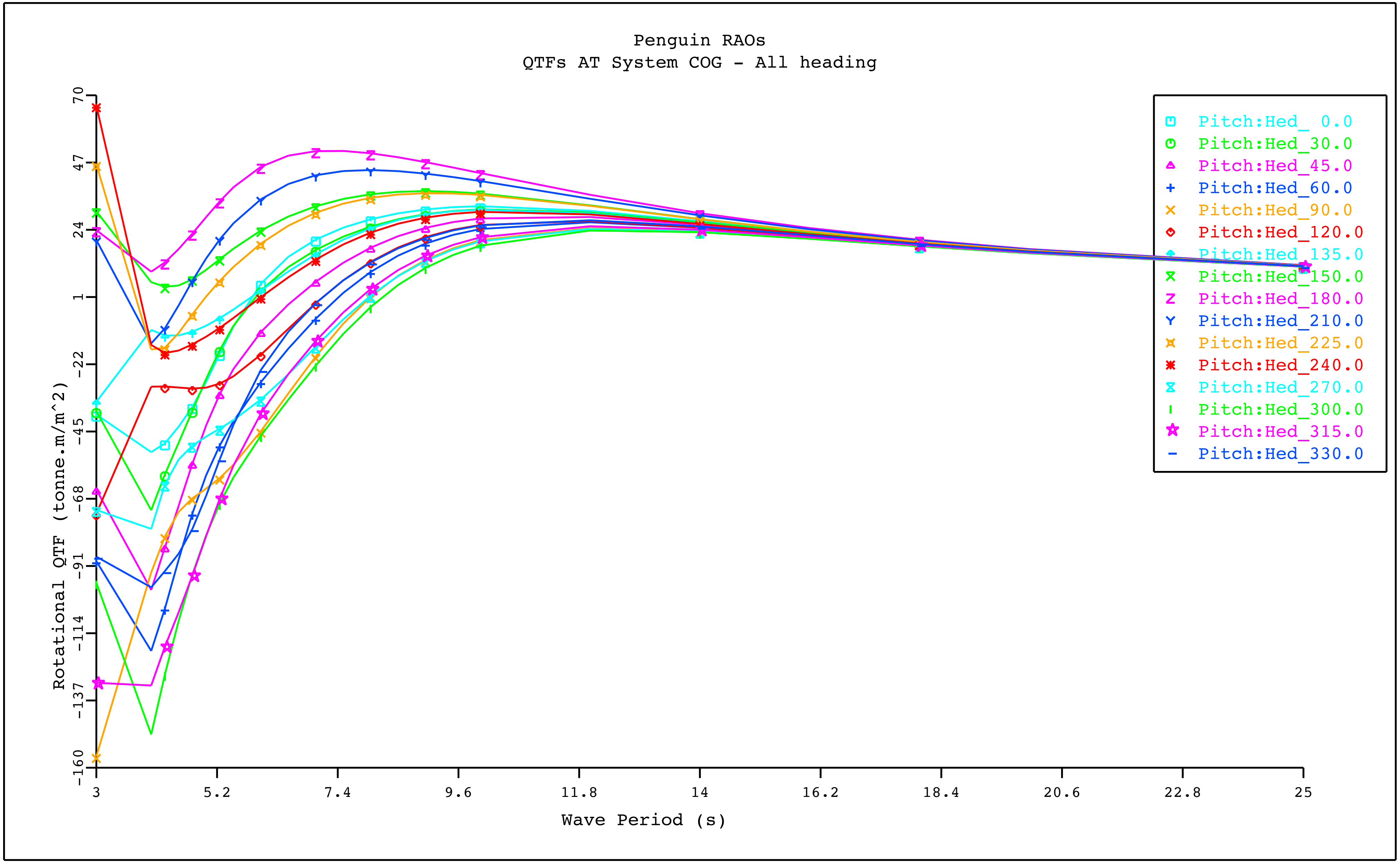

Penguin RAOs
QTFs AT System COG - All heading
Translational QTF (tonne/m^2)
Wave Period (s)
13
10.8
8.6
6.4
4.2
2
-0.2
-2.4
-4.6
-6.8
-9
3
5.2
7.4
9.6
11.8
14
16.2
18.4
20.6
22.8
25
Sway:Hed_ 0.0
Sway:Hed_30.0
Sway:Hed_45.0
Sway:Hed_60.0
Sway:Hed_90.0
Sway:Hed_120.0
Sway:Hed_135.0
Sway:Hed_150.0
Sway:Hed_180.0
Sway:Hed_210.0
Sway:Hed_225.0
Sway:Hed_240.0
Sway:Hed_270.0
Sway:Hed_300.0
Sway:Hed_315.0
Sway:Hed_330.0



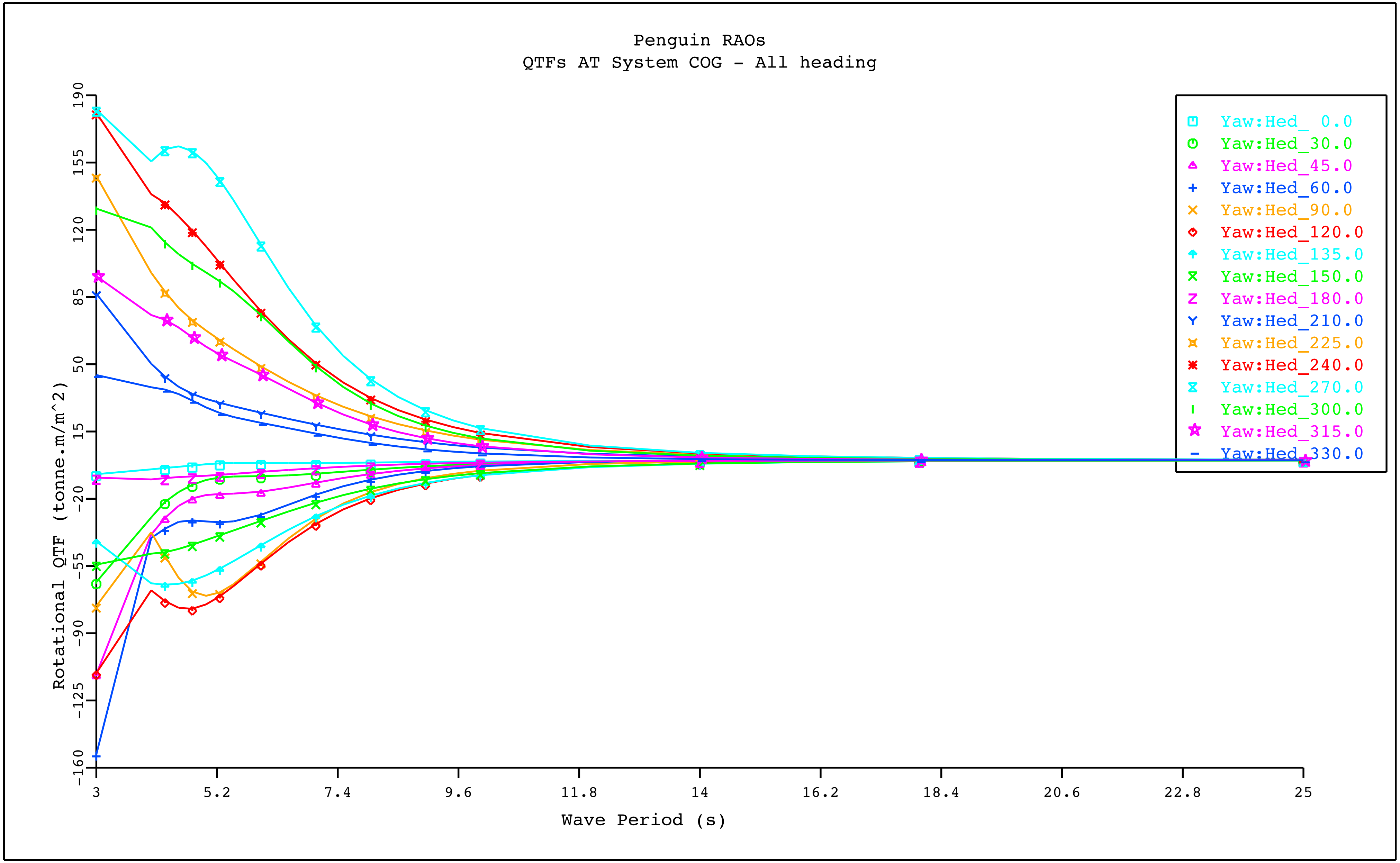
Penguin RAOs
QTFs AT System COG - All heading
Translational QTF (tonne/m^2)
Wave Period (s)
8
6.8
5.6
4.4
3.2
2
0.8
-0.4
-1.6
-2.8
-4
3
5.2
7.4
9.6
11.8
14
16.2
18.4
20.6
22.8
25
Heave:Hed_ 0.0
Heave:Hed_30.0
Heave:Hed_45.0
Heave:Hed_60.0
Heave:Hed_90.0
Heave:Hed_120.0
Heave:Hed_135.0
Heave:Hed_150.0
Heave:Hed_180.0
Heave:Hed_210.0
Heave:Hed_225.0
Heave:Hed_240.0
Heave:Hed_270.0
Heave:Hed_300.0
Heave:Hed_315.0
Heave:Hed_330.0



Penguin RAOs
QTFs AT System COG - All heading
Rotational QTF (tonne.m/m^2)
90
73
56
39
22
5
-12
-29
-46
-63
-80
3
5.2
7.4
9.6
11.8
14
16.2
18.4
20.6
22.8
25
Wave Period (s)
Roll:Hed_ 0.0
Roll:Hed_30.0
Roll:Hed_45.0
Roll:Hed_60.0
Roll:Hed_90.0
Roll:Hed_120.0
Roll:Hed_135.0
Roll:Hed_150.0
Roll:Hed_180.0
Roll:Hed_210.0
Roll:Hed_225.0
Roll:Hed_240.0
Roll:Hed_270.0
Roll:Hed_300.0
Roll:Hed_315.0
Roll:Hed_330.0



Penguin RAOs
QTFs AT System COG - All heading
Rotational QTF (tonne.m/m^2)
Wave Period (s)
70
47
24
1
-22
-45
-68
-91
-114
-137
-160
3
5.2
7.4
9.6
11.8
14
16.2
18.4
20.6
22.8
25
Pitch:Hed_ 0.0
Pitch:Hed_30.0
Pitch:Hed_45.0
Pitch:Hed_60.0
Pitch:Hed_90.0
Pitch:Hed_120.0
Pitch:Hed_135.0
Pitch:Hed_150.0
Pitch:Hed_180.0
Pitch:Hed_210.0
Pitch:Hed_225.0
Pitch:Hed_240.0
Pitch:Hed_270.0
Pitch:Hed_300.0
Pitch:Hed_315.0
Pitch:Hed_330.0



Penguin RAOs
QTFs AT System COG - All heading
Rotational QTF (tonne.m/m^2)
Wave Period (s)
190
155
120
85
50
15
-20
-55
-90
-125
-160
3
5.2
7.4
9.6
11.8
14
16.2
18.4
20.6
22.8
25
Yaw:Hed_ 0.0
Yaw:Hed_30.0
Yaw:Hed_45.0
Yaw:Hed_60.0
Yaw:Hed_90.0
Yaw:Hed_120.0
Yaw:Hed_135.0
Yaw:Hed_150.0
Yaw:Hed_180.0
Yaw:Hed_210.0
Yaw:Hed_225.0
Yaw:Hed_240.0
Yaw:Hed_270.0
Yaw:Hed_300.0
Yaw:Hed_315.0
Yaw:Hed_330.0