NAPA Motion sensor and analysis

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Key Account Manager

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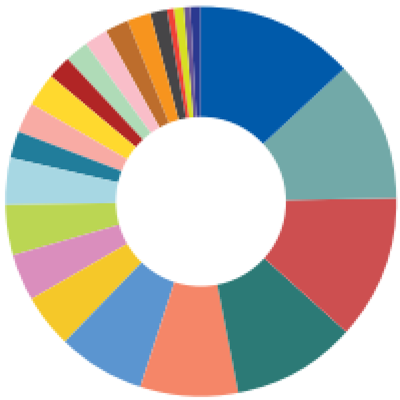
Background: statistics of claims for Container vessels (by Swedish club)

Graph 2.16: Frequency per loss code

Claims 5,000–3,000,000 (USD)

Period: 2011-2015
Types of vessel: Container
Type of claim: Cargo
As per 29/12/2015



Flooding of hold	12.99%
Improper cargo handling, shore-side	11.69%
Heavy weather	11.69%
Leaking container	10.39%
Reefer mechanical failure	7.79%
Insufficient lashing/securing by shipper	7.14%
Inherent vice	4.55%
Improper cargo handling, ship-side	3.90%
Collision	3.90%
Poor monitoring/maintenance of reefer unit	3.90%
Leaking hatch covers	3.25%
Damage post discharge	2.60%
Loading heavy containers on top of light	2.60%
Poor stowage	1.95%
Insufficient lashing/securing by stevedore	1.95%
Grounding	1.95%
Multiple causes	1.95%
Fire	1.95%
Leaking pipes	1.30%
Leaking vents	0.65%
Insufficient lashing/securing, ship-side	0.65%
Damage prior loading	0.65%
Contact	0.65%

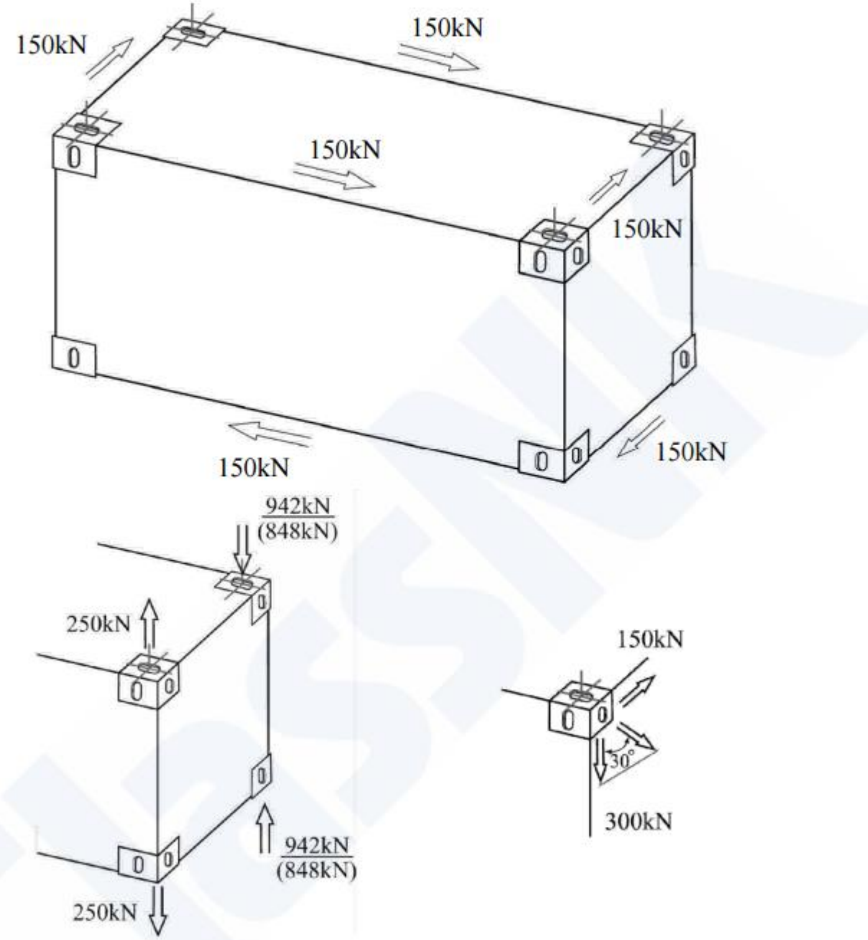
Background

- Container losses and cargo damages in bad weather causes financial losses and safety risks for container vessels
- ~28% of the container cargo damages are reported to be caused by bad weather or issues with the container cargo handling
- The damages are most often escalated in a bad weather when the ship motions start to cause significant accelerations to the container stacks.
- The preventive actions for avoiding these damages can be divided to following:
  - Cargo securing inside the container
  - Container lashing and securing the containers onboard the vessels
  - Route planning to avoid areas with expected heavy motions
  - In a case vessel not being able to avoid the heavy weather – selecting the course and speed of the vessel in order to minimize the motions
- For the latter two preventive actions – knowledge of the motions expected in the prevailing weather conditions is the key for effective decision making to avoid risky motions but still sailing effectively from port to port
- For this purpose NAPA has had a development project with ClassNK for measuring and analysing the motion responses in the measured weather conditions

Limiting forces for a container loaded to a vessel

- The forces are caused by several factors: the weight of the containers on top, lashing gear and most significantly, accelerations

- The known container loss cases show that the common mechanisms to lose a container stack are deformation of the lowest container in the stack by vertical force and ”popping” of a twistlock between containers due to horizontal accelerations

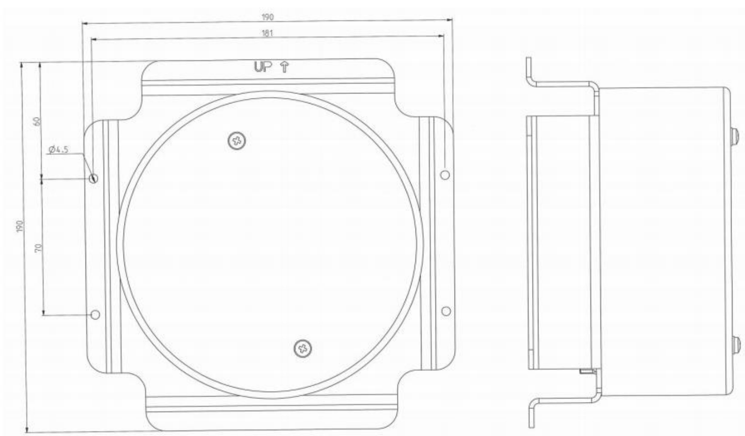


(Notes)
The underlined parts show changes that have been made by amendments up to 2014. Values shown in parentheses are allowable loads based on ISO1496-1:1990 before the amendments.

Fig.6.1 Allowable Loads on Each Part of Containers

Motion Sensor Development

- The goal was to find cost effective solution for measuring all relevant motion parameters with good accuracy and process the signals for required derivatives using FFT
- Motion Sensor is now packaged and works well on 4 ships, providing all relevant signals regarding all 6 degrees of freedom motions
- Statistical parameters for each derivative including averages, maximums, minimums etc. Can now be received to NAPA Office portal and be combined with nowcast data for the analysis.



Inclination sensor specification:

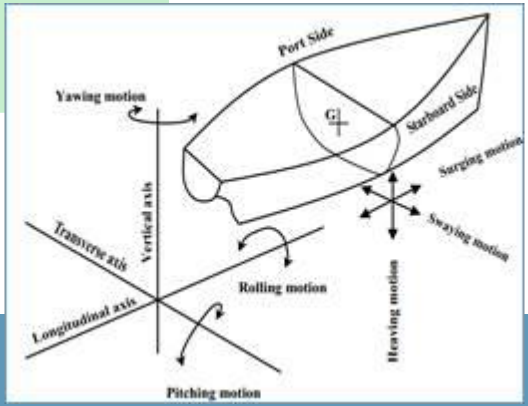
	Conditions	Min	Type	Max	Unit
Measurement range		-5		5	°
Resolution		0.001		0.005	°
Accuracy, digital output	Ta = +25°C		0.02		°
Accuracy, analogue output	Ta = +25°C		0.05		°
Accuracy, digital output	Ta = -25°C …+85°C		0.2		°
Accuracy, analogue output	Ta = -25°C …+85°C		0.25		°
Noise RMS			0.002		°
Operation temperature range		-25		+85	°C
Transmission rate			1		Hz

Motion sensor specification:

Measurement range	360° sensing in all axes			
	Accuracy			**Unit**
Roll / Pitch	0.2			°
Heading	0.8			°
	Accelometers	**Gyroscopes**	**Magentometers**	
Range	± 8 g	± 450 °/s	± 8 Gauss	
Gain Stability	< 0.1	< 0.05	< 0.5	%
Non-linearity	< 0.2	< 0.05	< 0.1	% FS
Alignment error	< 0.05	< 0.05	< 0.1	°

Signals Available from the motion sensor

Z Directional Acceleration	ZAcc	Heave Acceleration
Surge Average Period	SurgeAP	Surge average period
Sway Zero Crossing Period	SwayZCP	Sway zero crossing period
Sway Average Period	SwayAP	Sway average period
Heave Significant Value	HeaveSV	Heave significant value
Heave Zero Crossing Period	HeaveZCP	Heave zero crossing period
Minimum heave value in current period	HeaveMin	Heave minimum
Maximum heave value in current period	HeaveMax	Heave maximum
Roll Significant Value	RollSV	Roll significant value
Roll Zero Crossing Period	RollZCP	Roll zero crossing period
Roll Average Period	RollAP	Roll average period
Minimum roll value in current period	RollMin	Roll minimum
Maximum roll value in current period	RollMax	Roll maximum
Pitch Significant Value	PitchSV	Pitch significant value
Pitch Zero Crossing Period	PitchZCP	Pitch zero crossing period
Maximum pitch value in current period	PitchMax	Pitch maximum
Yaw Significant Value	YawSV	N/A
Yaw Zero Crossing Period	YawZCP	N/A
Yaw Average Period	YawAP	N/A



Analysis of motions

- Analysis of the motions were carried out by collecting data for some months, combining the results to nowcasted wave paramers and comparing the results to the calculated values based on strip methodology (today also panel method is available)
- Statistical model predicting the motions in prevailing weather conditions was also created in this process
- Ships used were one Ro-Ro vessel and 3 container vessels
- Conclusions were that the calculated values were to some extent close to reality
- Proper data set including sufficient distribution of the waves and encounter angles takes more time than expected

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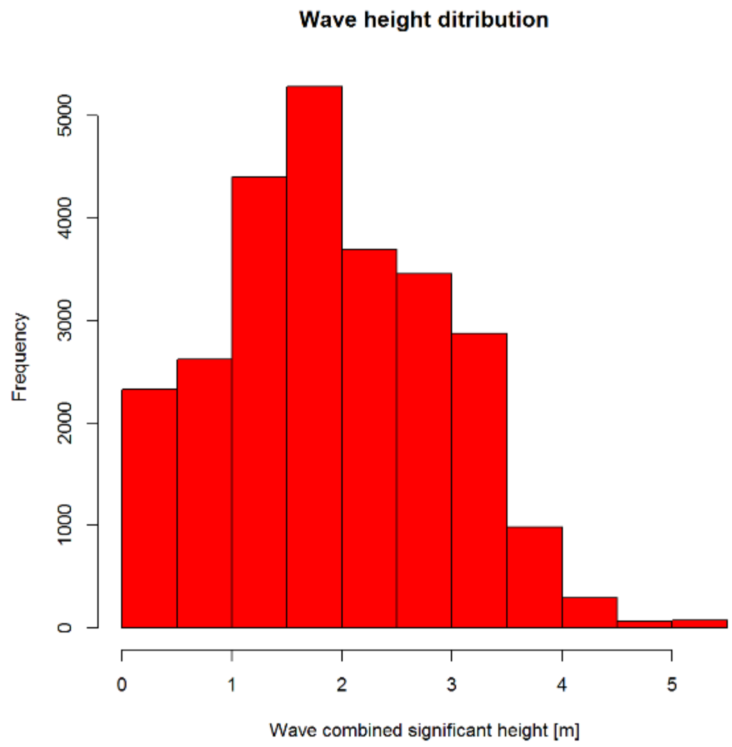

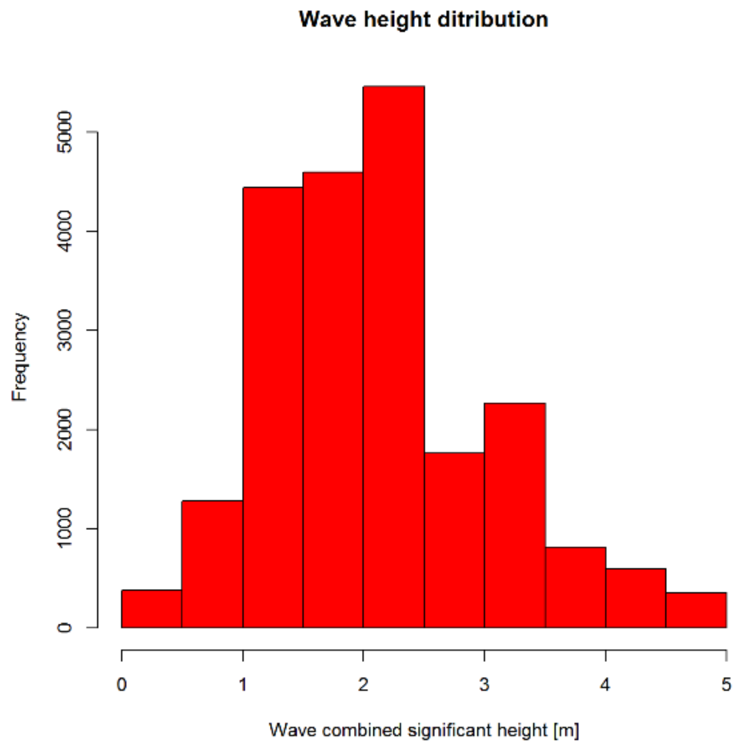

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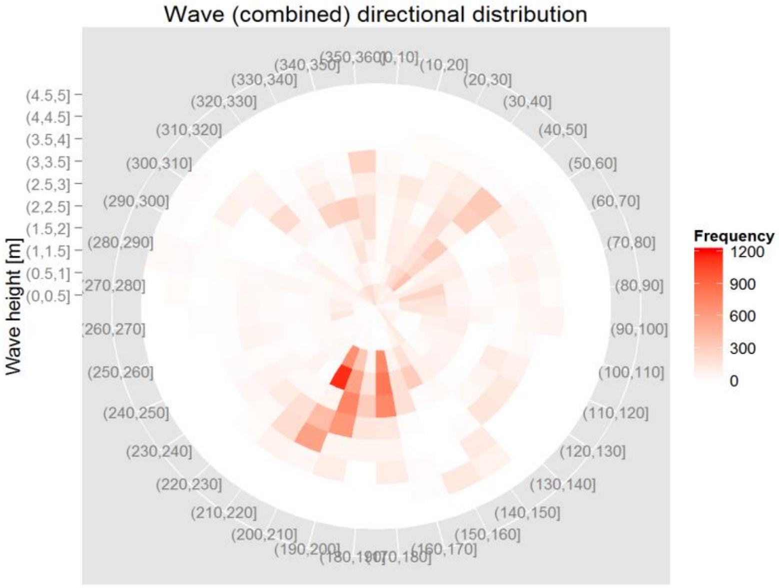

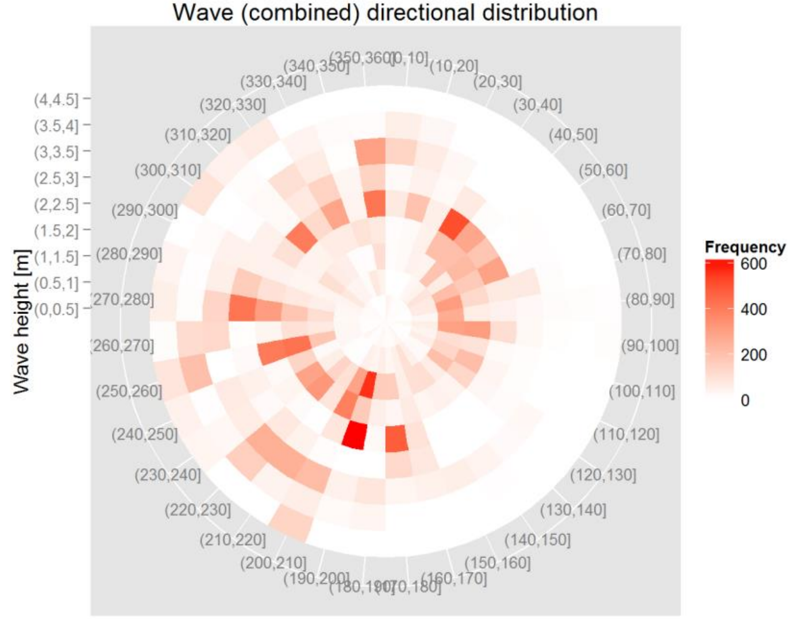

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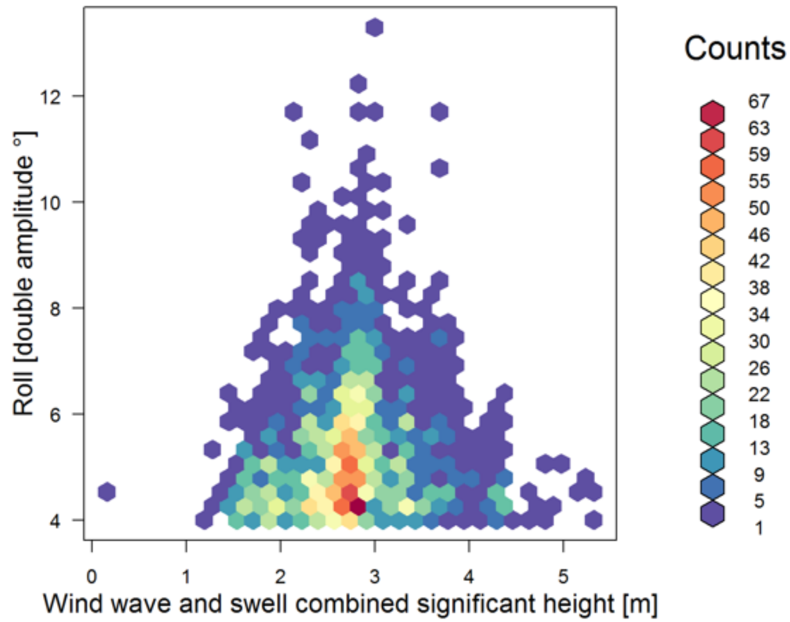


Figure 6. Bivariate histogram for roll amplitude vs. wave height

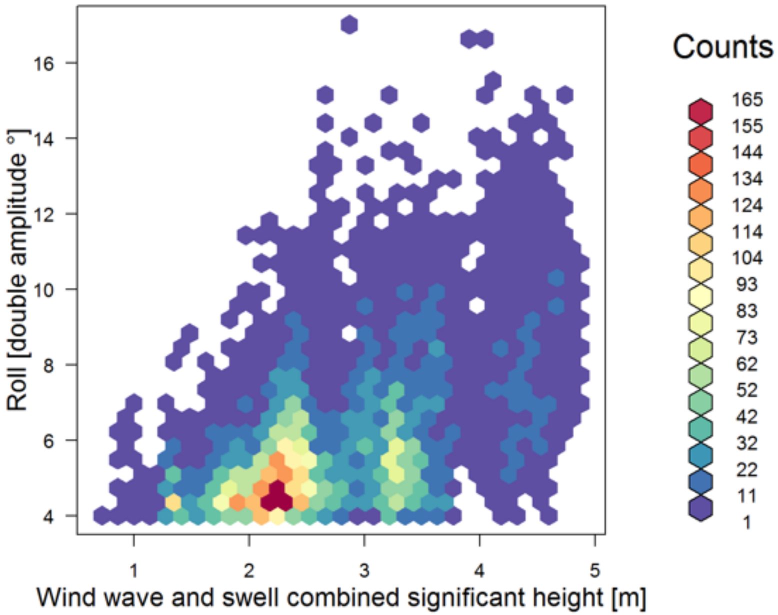


Figure 7. Bivariate histogram for roll amplitude vs. wave height.

Analysis of motions

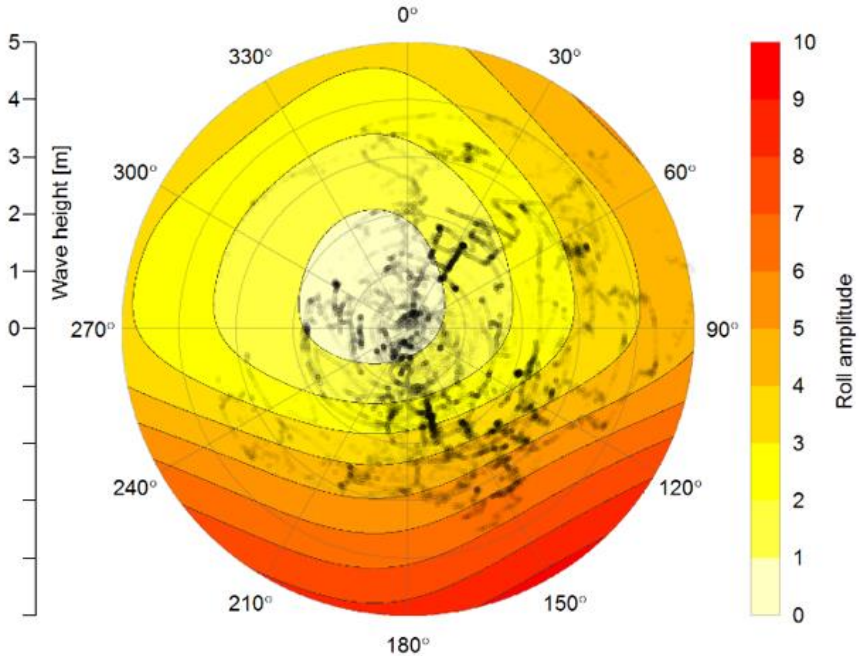


Figure 8. Polar diagram for roll amplitude

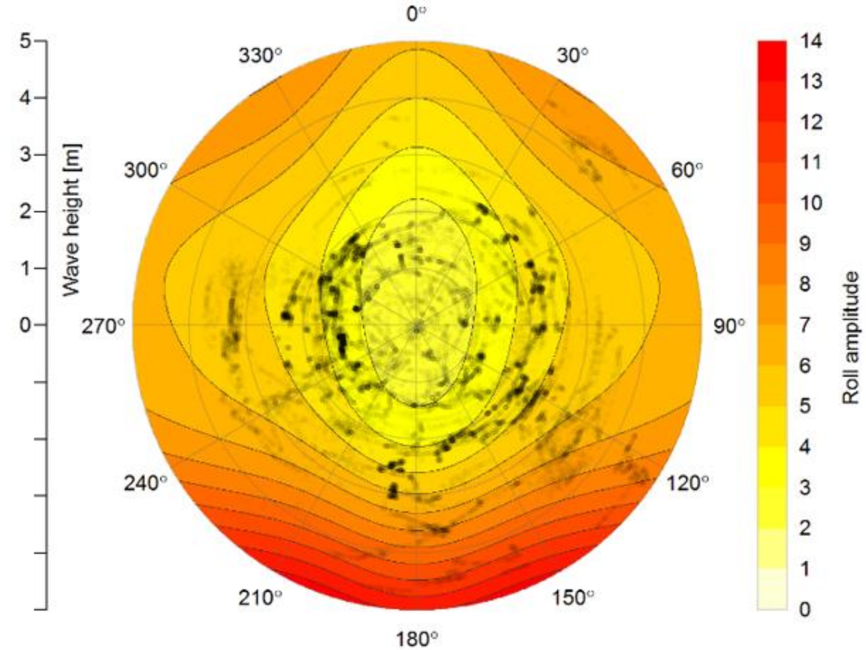
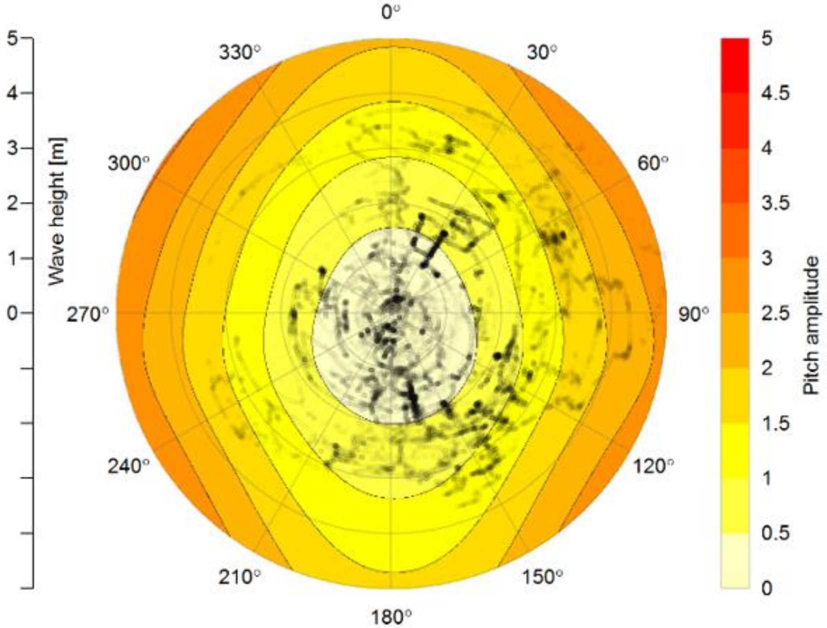
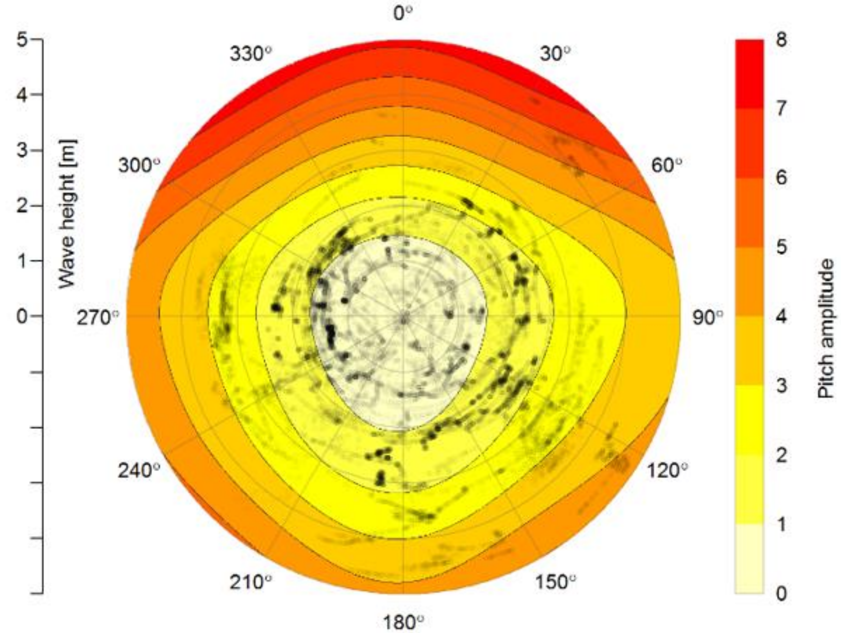


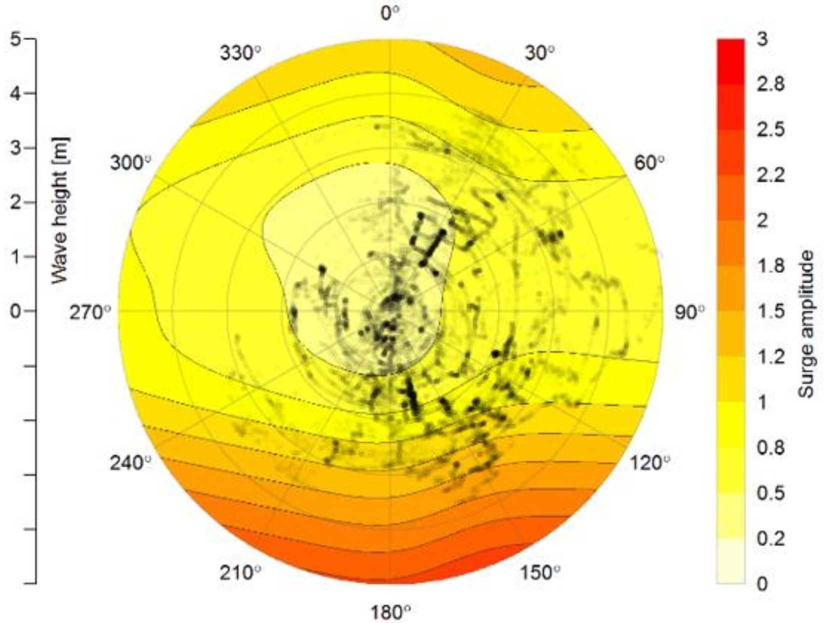
Figure 9. Polar diagram for roll amplitude

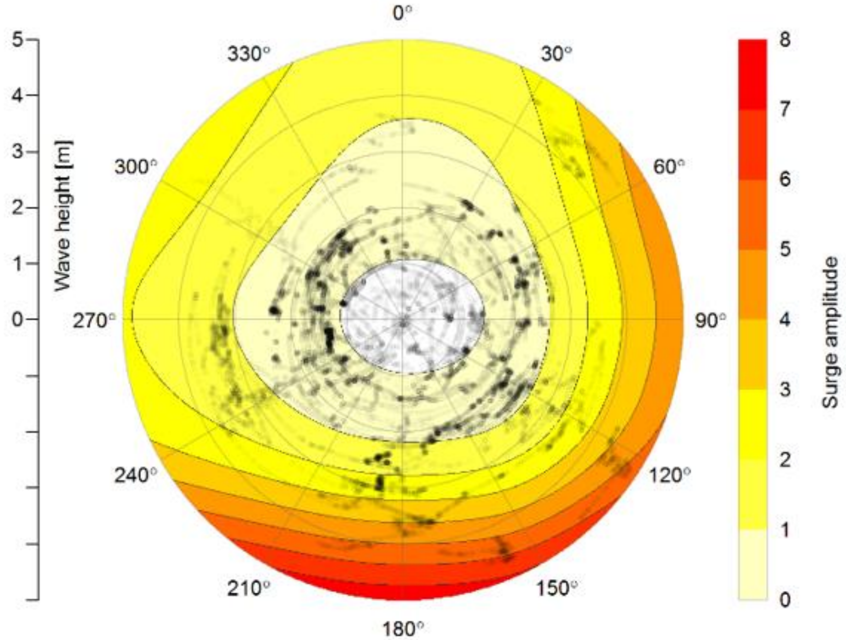
Analysis of motions





Analysis of motions





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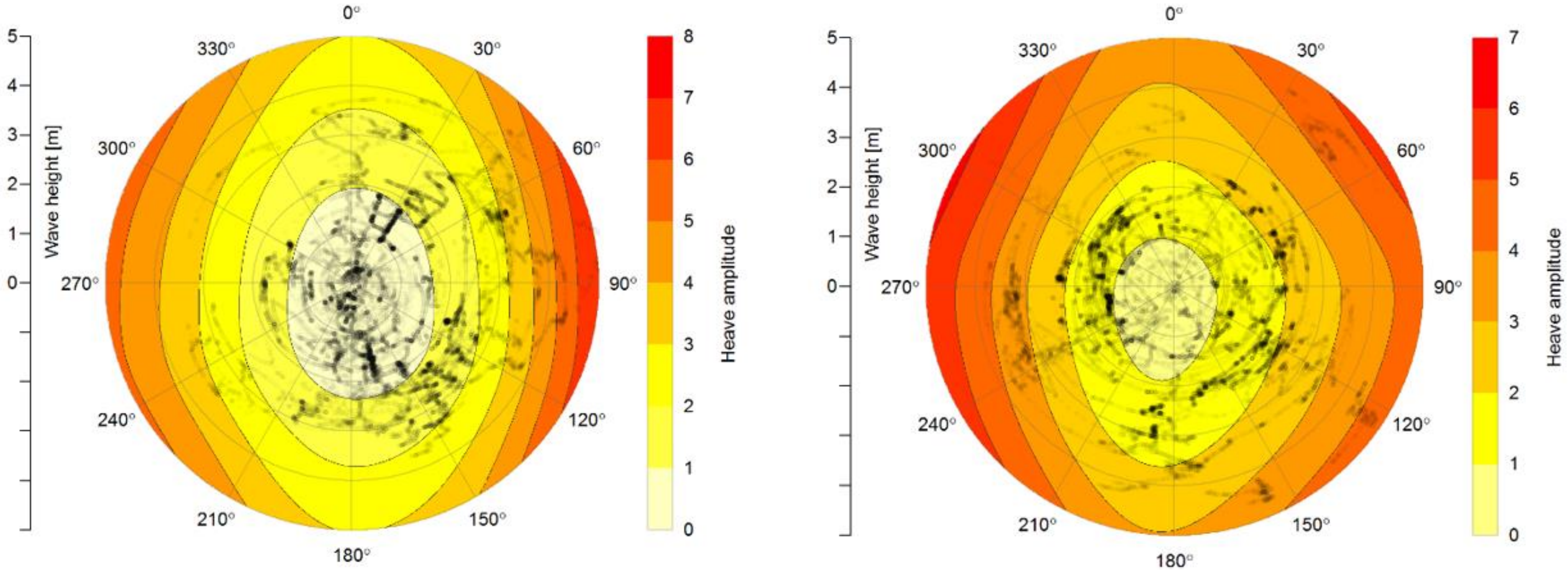


Calculated motions for Ship A, 3 cases

The actual GM from the loading condition is not available in measured data, therefore it is estimated from the roll period. The measured roll period was on average slightly below 21 seconds, from which the transverse GM-value was calculated to be approximately 3.5 m. Ship's speed was nearly constant during the measurements, and the value 16.3 and 14.8 knots was used in the calculations. Ship's draft was 13.83 m in the calculations.
The selected time intervals were 26-Dec-2014 at 00:00 - 06:00, 27-Dec-2014 at 18:00 - 24:00, and 1-Jan-2015 at 00:00 - 06:00. During these intervals the environmental conditions remain quite steady, and the measured motions are quite steady, too.

The mean values of wave conditions and ship's course during the time intervals are shown in the following table.

Time interval	26-Dec-2014 at 00 - 06	27-Dec-2014 at 18 - 24	1-Jan-2015 at 00 - 06
Swell height (m)	2.18	3.2	2.1
Swell direction (deg.)	231	219	176
Wind wave height (m)	0.62	1.7	0.18
Wind wave direction (deg.)	198	90	149
Swell period (s)	10.4	13.7	10.1
Wind wave period (s)	3.15	5.43	2.0
Ship's course (deg.)	64	64	64

Maximum values for the wave heights are shown below.

Time interval	26-Dec-2014 at 00 - 06	27-Dec-2014 at 18 - 24	1-Jan-2015 at 00 - 06
Swell height (m)	2.92	3.32	2.09
Wind wave height (m)	0.80	1.87	0.27

Results from NAPA calculations are shown for the maximum values of roll, heave, and pitch motions in the following table. Roll and Pitch motions are in degrees and Heave in meters.

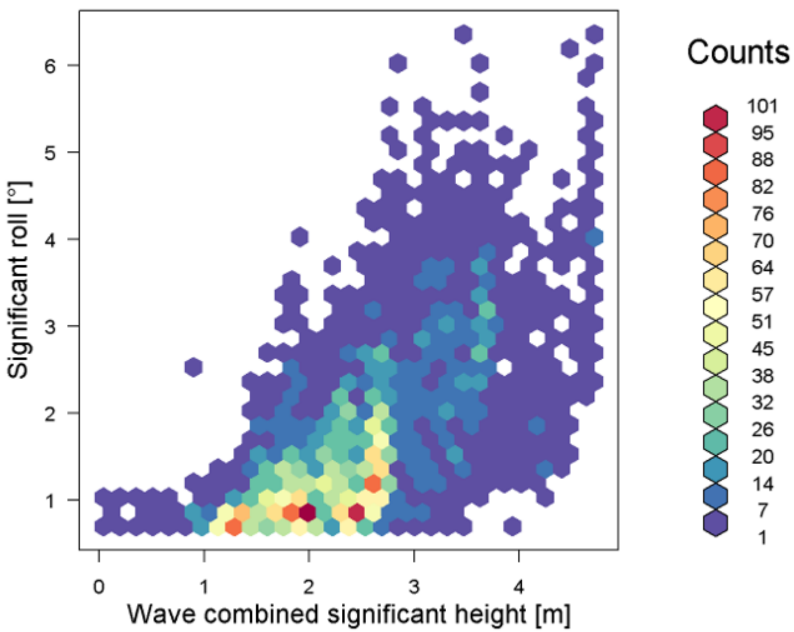
26-Dec-2014	Roll	Pitch	Heave
Calculated max.	12.87	1.94	2.29
Calculated mean	6.43	0.97	1.15
Measured max.	13.20	1.84	2.54
Measured mean	6.38	1.18	1.60
Error in max %	-2.5%	5.2%	-9.8%
Error in mean %	0.8%	-17.8%	-28.3%

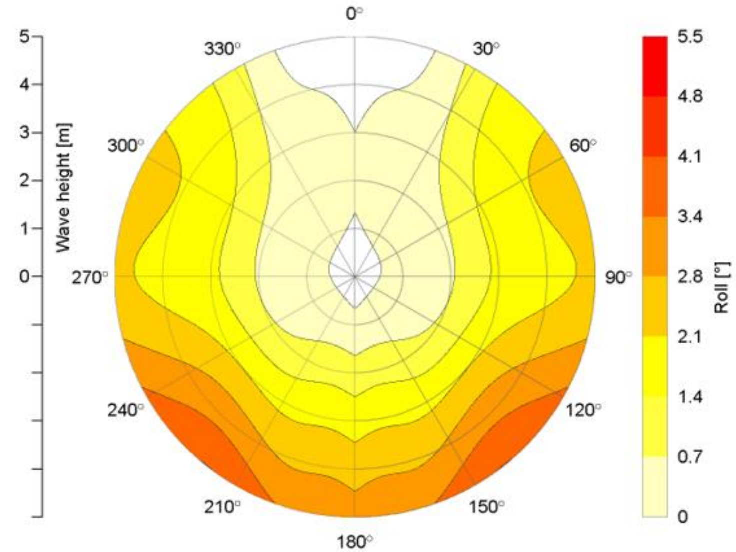
Calculated motions, comparison to measured

27-Dec-2014	Roll	Pitch	Heave
Calculated max.	12.73	2.45	3.95
Calculated mean	6.37	1.22	1.98
Measured max	11.74	3.54	5.21
Measured mean	6.05	2.13	3.42
Error in max %	8.43%	-30.8%	-24.2%
Error in mean %	4.9%	-42.5%	-42.2%
1-Jan-2015	Roll	Pitch	Heave
Calculated max.	8.26	1.34	2.47
Calculated mean	4.13	0.67	1.23
Measured max	4.99	1.13	1.76
Measured mean	2.48	0.81	1.11
Error in max %	65.6%	18.2%	40,2%
Error in mean %	66.8%	-17.6%	10.9%

The measured values are double amplitudes, and NAPA values have been converted to double amplitudes, and the actual wave height is taken into account. As the measured values are maxima of measurements during a 5 minutes' interval, the measured mean values are not exactly mean values of all motion double amplitudes. However, they can be considered as close to the mean values in the selected cases.

Alternate analysis, using symmetry assumption





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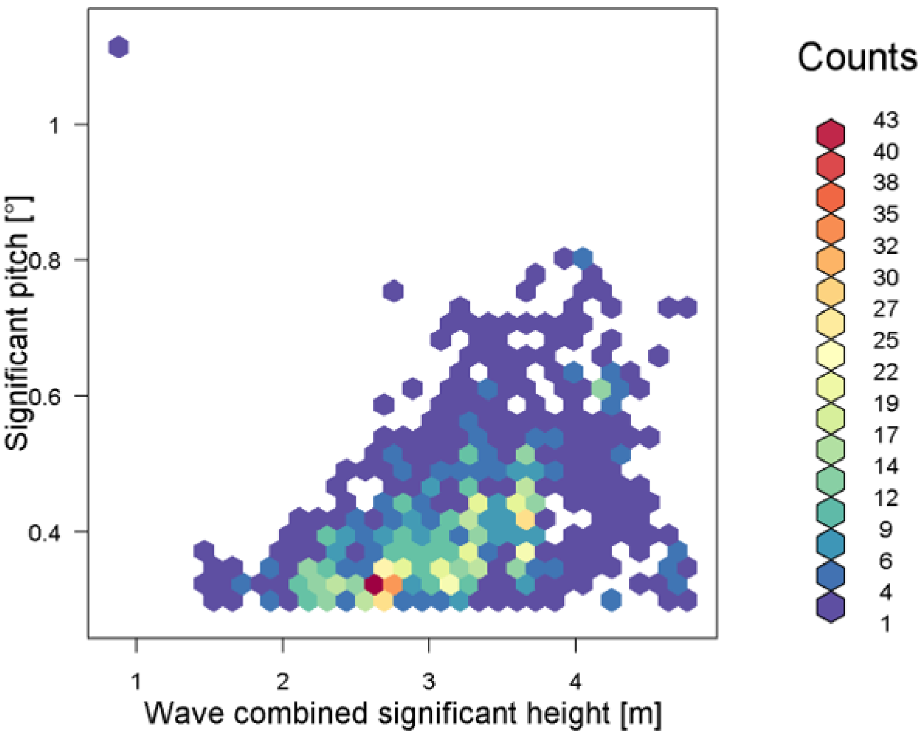
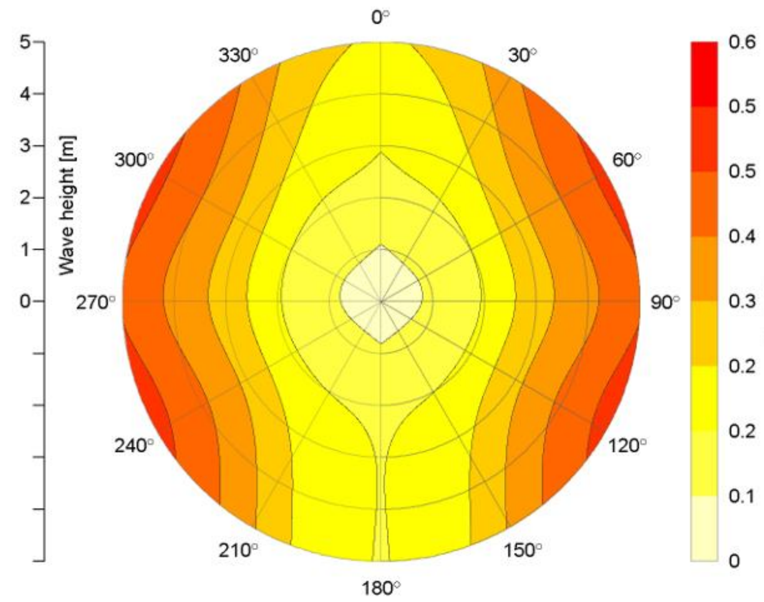
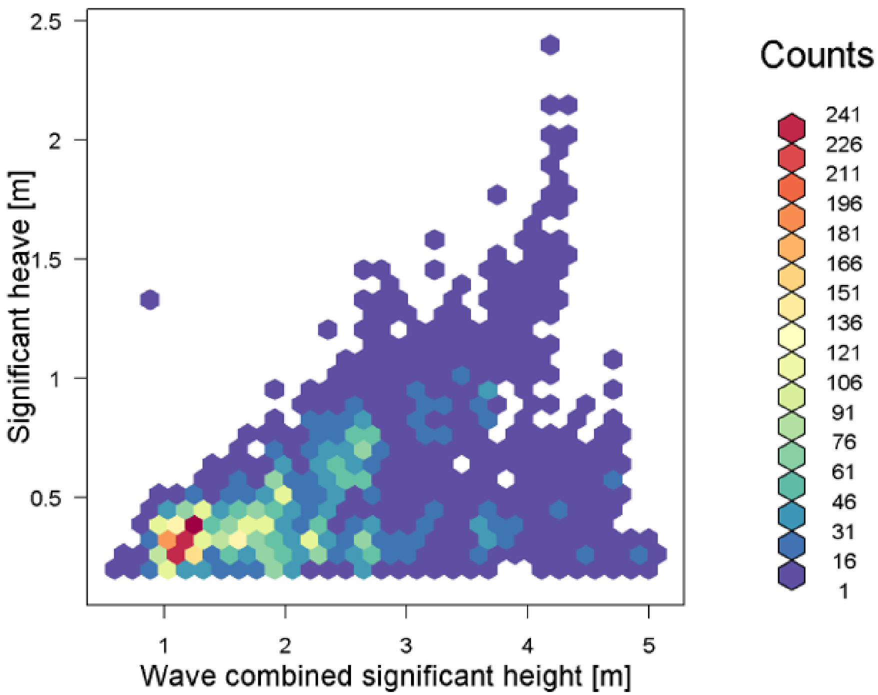
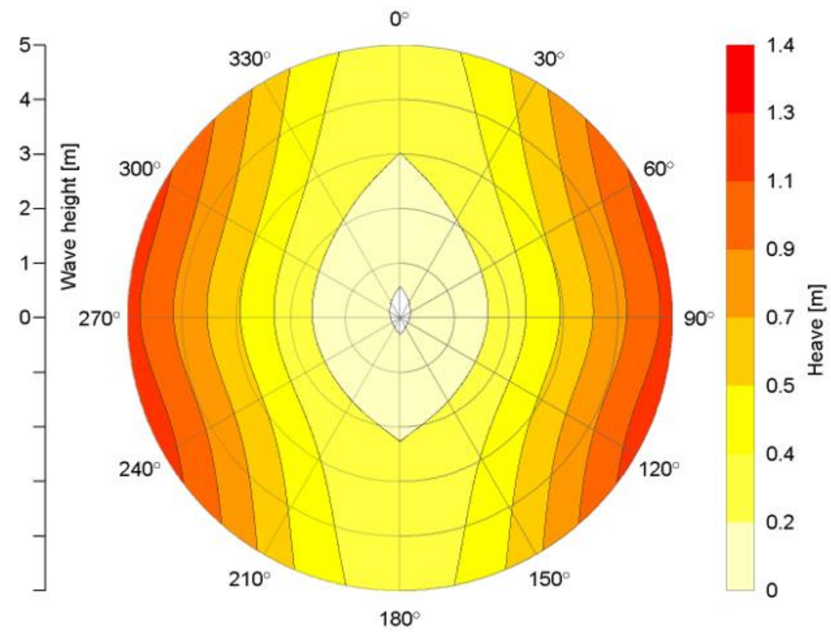




Alterante analysis, using symmetry assumption





Wrap up

Conclusions

The project goals were reached satisfactory. Each item in the scope is working and providing data and analysis as planned. The system is installed to 3 K Line vessels + test installation was done to MS Finlandia. Signal processing is working and analysis algorithms predict expectedly the motions in different environmental conditions. The overall package is ready to be productized if seen needed.

The test marketing has been carried out to some selected shipping companies. From these efforts the outcome is that commercial negotiation for pilot installations to Wan Hai is ongoing and expected to materialize in Q1-Q2 2017. Maersk Line has also shown interest to our project but for the time being they are carrying out their own research and did not see direct need for this solution.

Discussion

Even though the initial project goals have been met, the best understanding at the moment is that further development for the motion overall solution would be needed in order to make it a success. It seems that only measuring and analyzing the motions is not necessarily bringing enough direct value to the customers to make it enough lucrative for the end users to invest directly for this kind of solution. Following approaches has been considered (but not decided) as the future step:

1. Easier integration

Integrating the motion sensor to for example to the navigation system or a VDR could be considered. Currently NAPA has the possibility to provide motion sensor as a part of ClassNK – NAPA Green solution, but for the vessels not having that system installed, an alternative should be considered. The alternative should include possibility to integrate the sensor to an existing platform capable of handling the signal processing, data storing and sending the data to shore side for the analysis.

Such systems could be for example integrated navigational systems or modern VDR's.

Discussion

2. Proactive usage of motion analysis for avoiding risky conditions but at the same time optimizing the voyage for energy efficiency

Utilizing the motion prediction model created based on the measured motion data in the route planning stage appears to be the way of obtaining largest share of the value provided by the motion measurement and analysis. Using the prediction model in the voyage optimization tool in order to avoid risky predicted weather conditions but not overestimating those would provide clear benefits for the users and the industry.

3. Reactive decision support

In a case vessel entered the risky conditions the knowledge about the “safe escape” speed and course should be available onboard for supporting the masters decision to minimize the risk for escalating damages or casualties. Sharing the status and short term prediction of the vessel motions and the risks between ship and shore would support the masters doing the right decision without the pressure from the commercial departments of the operators.

Discussion

4. Support from the other stakeholders in the shipping industry to utilize motion solutions for the vessels

In discussions for example with the P&I Clubs regarding the motion topic it was clearly indicated that providing a clear message from stakeholders like P&I clubs (paying for the cargo damages) and stakeholders in charge of the rules like IMO, flag states and classification societies would help to increase the usage of the motion solutions within the riskiest ship types and furthermore reduce the economic losses caused by motions for all stakeholders. For providing such a clear message some more research for the correlation between reduced risks and damages when using motion solutions would be needed.

5. Further research on the mechanism of the cargo losses and parametric rolling cases

In several discussions and literature research it was identified that the most common mechanisms to lose a container stack are deformation of the lowest container in the stack by the vertical force and the ”propping” of a twist lock between containers due to horizontal accelerations. Further research could be useful for modelling these forces in different location of the container deck cargo and for calculating the motion related acceleration forces in these locations giving a clear indication for the operators of a risk level for losing a container due to these conditions. Similar study for car carrier cargo losses would also be of interest. During the project it was also noted that the parametric rolling case requires also slightly different approach for predicting the motion pattern as it is recorded with a motion sensor so seldom if ever that a calculation method supporting the statistical analysis would be needed.