Fishing Vessel Safety Project : Seakeeping tests for the Robert's Sisters II

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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/18253444
Student Report; no. SR-2009-29, 2009-01-01

National Research Council Canada
Institute for Ocean Technology

Conseil national de recherches Canada
Institut des technologies océaniques

SR-2009-29

Student Report

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Oates, C., 2009. Fishing Vessel Safety Project: Seakeeping tests for the Robert's Sisters II. St. John's, NL : NRC Institute for Ocean Technology. Student Report, SR-2009-29.

Canada

DOCUMENTATION PAGE

REPORT NUMBER	NRC REPORT NUMBER	DATE	
SR-2009-29		December 2009	
REPORT SECURITY CLASSIFICATION		**DISTRIBUTION**	
Unclassified		Unlimited	
TITLE			
Fishing Vessel Safety Project: Seakeeping Tests for the Roberts Sisters II			
AUTHOR(S)			
Carolyn Oates			
CORPORATE AUTHOR(S)/PERFORMING AGENCY(S)			
National Research Council, Institute for Ocean Technology, St. John's, NL			
PUBLICATION			
SPONSORING AGENCY(S)			
IOT PROJECT NUMBER	**NRC FILE NUMBER**		
KEY WORDS	**PAGES**	**FIGS.**	**TABLES**
MII's (Motion Induced Interruption's), OEB (Offshore Engineering Basin), Robert Sisters II, SafetyNet Initiative	ii, 17	35	

SUMMARY

This report describes the model tests that were conducted in the OEB (Offshore Engineering Basin) at IOT (Institute for Ocean Technology), for the Robert Sisters II fishing vessel. This project is a small component of the overall SafetyNet Initiative project and is aimed at understanding the MII's (Motion Induced Interruption's) of fishing vessels. In November of 2004, the Robert Sisters II sea trials were conducted 10 nm off of St. John's, NL. A numerical model simulation of the vessel was also used based on a code developed between researchers at ITO and Memorial University. This report takes the results obtained from the model tests and uses the data to validate both the sea trials and numerical results. The model test results were shown to correlate with that of the sea trials and numerical results, thus helping to better mitigate MII's.

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Summary

This report describes the model tests that were conducted in the OEB (Offshore Engineering Basin) at IOT (Institute for Ocean Technology), for the Robert Sisters II fishing vessel. This project is a small component of the overall SafetyNet Initiative project and is aimed at understanding the MII's (Motion Induced Interruption's) of fishing vessels. In November of 2004, the Robert Sisters II sea trials were conducted 10 nm off of St. John's, NL. A numerical model simulation of the vessel was also used based on a code developed between researchers at ITO and Memorial University. This report takes the results obtained from the model tests and uses the data to validate both the sea trials and numerical results. The model test results were shown to correlate with that of the sea trials and numerical results, thus helping to better mitigate MII's.

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1.0 Introduction

This report describes the seakeeping experiments conducted on Model IOT761 for the Robert Sisters II fishing vessel, during the summer and fall of 2009 in the OEB (Offshore Engineering Basin). The data obtained from the model tests was used to correlate with the sea trials data carried out in November of 2004, as well as to validate MOTSIM, numerical prediction software. This report will describe the model tests that were carried out in the OEB during the summer and fall of 2009, the data analysis procedure, provides the results of the sea trial /physical model/numerical model correlation exercise and recommendations to improve the overall correlation in future.

2.0 Background

This fishing vessel safety project is just a small component integrated into the overall Safety Net initiative project at IOT. This project will aid in helping researchers understand the health and safety risks involved with employment in a marine environment. Research will be conducted on the occupational health and safety of seafood harvesters. Fishing is the most dangerous occupation in Newfoundland and Labrador, and is increasingly so. Over the past ten years accidents related to fishing injuries and fatalities has nearly doubled thereby making it extremely important to understand the risks so they can be mitigated. These trends have the effect of increasing health care and compensation costs, straining the available search and rescue efforts and thus reducing the sustainability of the fishery. Research on this issue has been limited and has thus hindered the development of effective solutions to issues surrounding seafood harvesters.

2.1 Description of model

The model for the Robert Sisters II was built at IOT on a 1:10.67 scale**.** Figure 1 shows a picture of the completed model. The model was fabricated of wood and glass conforming to a surface, which was generated from offsets constructed according to IOT standard construction procedures. The hull was made using a Styrofoam™ HI 60 polystyrene foam core. Renshape™ was used in areas requiring local reinforcement. The general geometry of the hull was machined by IOT's line milling machine, which covered the hull with 10 ounce cloth and resin, primed, sanded and painted with three coats of Imron™ Polyurethane 1300U Enamel high gloss yellow paint. The wheelhouse was assembled forward of the model.

Figure 1: Roberts Sisters II Model

Very little additional weight was needed to ballast the model to the desired draft and trim since the model is so small. The placement of electronics/instrumentation was crucial for matching the hydrostatics. A swing test and inclining experiment was conducted on the model to ensure it's integrity and performance in waves. A rectangular passive anti-roll tank (ART) with internal baffles was placed aft of the wheelhouse. The tank has an inlet port at the top for convenient filling using 2.88 kg of fresh water dyed blue for enhanced visibility during video recording. The anti-roll tank's period was matched to the natural roll period of the model. A sketch of the ART can be seen in Figure 2.

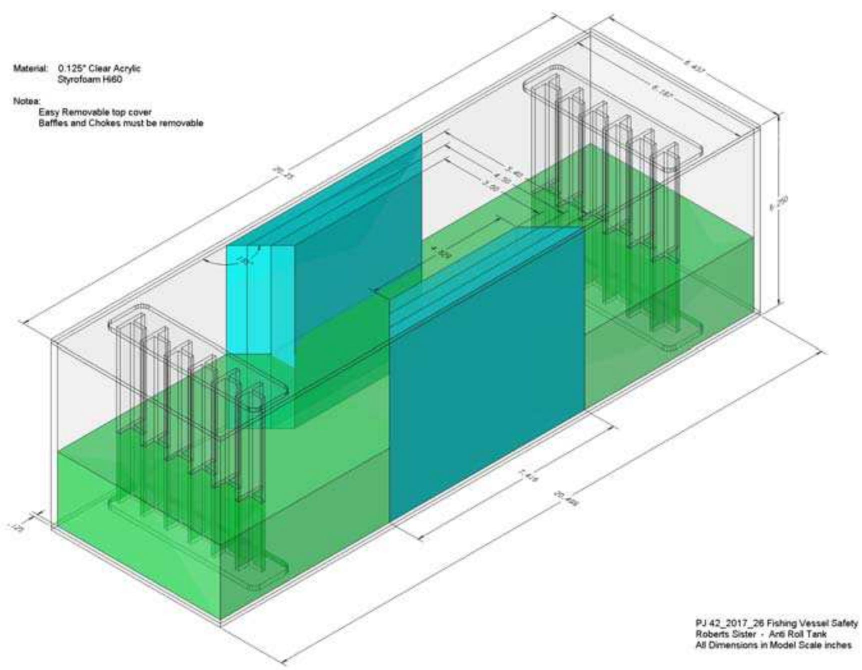

Figure 2: Anti-Roll Tank Configuration

The model was equipped with:

1) BEI Systron Donner Inertial Division MotionPak II system. : The MotionPak II is a solid state, six degree of freedom, inertial sensing system used to measure angular rates and linear accelerations.
2) Analog Devices, Inc. Model ADIS16405: Motion measurement package that incorporates a tri-axial digital gyroscope angular rate sensor, tri-axial digital linear acceleration sensor as well as built-in signal conditioning, calibration and power management electronics.
3) QUALISYS: The QUALISYS system was used to determine six motions: orthogonal linear displacements (X, Y, Z) in the tank co-ordinate system translated to an origin at the model's center of gravity, the heading angle, and the pitch and roll angle in a body co-ordinate system.
4) Bow Accelerometers: Three orthogonally mounted linear accelerometers were installed well forward of the MotionPak II to measure accelerations solely to provide verification of the MotionPak II analysis algorithm.

2.2 Description of Numerical Prediction Program 'MOTSIM'

MOTSIM is a non-linear time domain code developed by researchers at Memorial University and IOT that simulates six degrees of freedom motion. The geometry is defined in terms of a series of sections each described by a set of panels. The code determines the intersections of these panels with the waterline at each time step and redefines the paneling describing the ship's waterline. The principle characteristics of this computational intensive software are:

- Non-linear Froude-Krylov forces based on the calculated wetted surface of the hull at each time step; and
- Radiation and diffraction forces are determined as a single set of scattering forces (based on relative motions) and obtained from memory functions, which are evaluated, based on linear theory using a three-dimensional panel code.

3.0 Discussion

3.1 Description of Seakeeping Test Program

Two types of programs were used for the model test, irregular and regular wave programs. The irregular wave program consisted of performing experiments while transiting at two different forward speeds: Trawling speed (2-5 knots full scale) and cruising speed (7-8 knots full scale). Five different headings were used for this process with respect to the dominant incident waves (head, bow, beam, quartering and following). The model was launched from various positions throughout the OEB, which corresponded to that of the sea trials. Tests were run with the ART filled for bow, beam and quartering seas at trawl speed only. Repeat runs were then conducted to investigate uncertainty issues.

The regular wave program was also carried out under certain launch positions. The runs were carried out in beam and quartering seas at both trawling and cruising speed with and without ART filled. The runs were carried out over a range of frequencies.

3.2 Online Data Analysis

After each run commenced in the OEB, an online analysis was performed in the OEB control room workstation to verify the integrity of the acquired data.

The following is a list of parameters examined throughout the course of the online analysis to provide an indication of the quality of the data acquired.

- Verifying the value of the shaft rps, model forward speed, and heading angle as being relatively constant and the correct magnitude.
- Comparing the standard deviation of the motion channels output by QUALISYS, ADIS and MotionPak II.
- Reviewing the QUALISYS signal integrity channel for evidence of signal loss. If significant signal loss was detected during critical segments of the run, the run was normally repeated.
- Plotting and comparing the pitch and roll angle data output from QUALISYS on the same time base as the integrated roll and pitch rate data from the MotionPak II.

3.3 Offline Data Analysis

Once model testing was completed the next step in the process is to perform the offline analysis. The offline analysis was conducted to merge all irregular and regular runs for a given heading angle/forward speed with and without the ART filled. The steps in the analysis is described below:

1) Initial offline data analysis:

- All measured channels from instrumentation plus dropout monitoring channel ‘RMS error’ (QUALISYS) and wave board monitoring channels were converted from GDAC to GEDAP format (described in Reference 25). The model scale data was converted to full scale using Froude scaling laws. (scaling factor = 10.67).
- The following 13 channels were isolated for further analysis:

    1) South Center Wave Height
    2) MotionPak II Roll Rate

3) MotionPak II Pitch Rate
4) MotionPak II Yaw Rate
5) MotionPak II Surge Acceleration
6) MotionPak II Sway Acceleration
7) MotionPak II Heave Acceleration
8) Shaft Speed
9) Rudder Angle
10) QUALISYS X Displacement
11) QUALISYS Y Displacement
12) QUALISYS Pitch Angle
13) QUALISYS Roll Angle

- The rudder angle and shaft speed channels were low pass filtered using a high frequency cut-off value of 3 Hz to remove signal noise.
- Routines were executed to compute a model speed channel (m/s) from the smoothed QUALISYS planar position (X, Y) data.
- A second full-scale speed channel was computed from the smoothed QUALISYS planar position (X, Y) data (knots) and output as Channel 14.

2) Select Time Segments

Select time segments for all 14 channels – each run starting from 0 s and having a minimum of at least 60 s after the final segment. The segments for each channel start and end at the same time with a 3 s overlap between segments.

3) Merge Data

The data for each channel of each segment is smoothly merged using a 3 s overlap.

4) Analysis of MotionPak II Data

- The sign of MotionPak II Heave Acceleration was changed by multiplying by –1.
- Dedicated FFT based MotionPak II motions data analysis software was run to compute motions at the CG in an earth fixed co-ordinate system using a value for

low frequency cut-off (F1) of 0.06 Hz for the irregular waves and 0.83 * ($1/T_E$) Hz full scale for regular waves where T_E is the wave encounter period. Since the MotionPak II unit was not fitted exactly at the location of the nominal model CG, it was necessary to move the computed motions to a new location as follows:

X = 0.8269 m aft full scale

Y = 0.2316 m to starboard full scale

Z = 1.4557 m down full scale

The following 18 channels were output: three orthogonal angular accelerations/rates/angles (roll, pitch and yaw) and three orthogonal linear accelerations/velocities/displacements (surge, sway and heave).

- The channels are re-ordered and some channels are discarded. The following 18 channels are retained:

CHANNEL DESCRIPTION	UNITS
1) MotionPak II Surge Displacement	m
2) MotionPak II Surge Acceleration	m/s^2
3) MotionPak II Sway Displacement	m
4) MotionPak II Sway Acceleration	m/s^2
5) MotionPak II Heave Displacement	m
6) MotionPak II Heave Acceleration	m/s^2
7) MotionPak II Yaw Angle	deg.
8) MotionPak II Yaw Rate	deg./s
9) MotionPak II Pitch Angle	deg.
10) MotionPak II Pitch Rate	deg./s
11) MotionPak II Roll Angle	deg.
12) MotionPak II Roll Rate	deg./s
13) Shaft Speed	rps
14) Rudder Angle	deg.
15) QUALISYS Pitch Angle	deg.
16) QUALISYS Roll Angle	deg.
17) Forward Speed	knots
18) South Center Wave Probe	m

It is noted that during analysis of the MotionPak II data that 5% of the data is lost off the start and end of each MotionPak II channel.

5) Review Data, Select Final Time Segments

   All 18 channels are reviewed in the time domain to ensure there are no anomalies and manually de-spiked as required. For irregular wave runs, the optimum 1200 s (20 minutes full scale) is identified and selected.

6) Basic Statistics Computed

   It was noted that there was significant noise on several of the acquired channels probably emanating from RF sources or from local mechanical vibration on the model. To eliminate this noise, a rectangular band pass (normally 0 to 0.4 Hz or 0 to 0.5 Hz) filter was applied. This did not affect the mean value of the data however significantly reduced the standard deviation.

   A procedure was run to compute the basic statistics (minimum, maximum, mean ands standard deviation) for all 18 channels and the data output in an ASCII format file.

   Comparison between QUALISYS and MotionPak II roll and pitch angle data in the time domain is carried out as a final verification. In addition, a few channels of the filtered data were compared to the unfiltered data to ensure the filtering process did not introduce any anomalies.

   A zero crossing analysis was performed on MotionPak II heave displacement to count the number of upcrossings and downcrossing using a threshold value of

0.05 m. This value is assumed to be equal to the number of wave encounters. This information was appended to the end of the ASCII statistics file.

A zero crossing analysis was performed on the wave data from the south center wave probe for regular wave runs to determine the average wave height and period using a threshold value of 0.05 m. This information was appended to the end of the ASCII statistics file.

A spectral density analysis using 22 degrees of freedom was executed on the wave data from the south center wave probe for irregular wave runs to estimate the significant wave height (H_{m0} = 4 * SQRT (M0) where M0 is the first spectral moment) as well as the period of the spectral peak (T_{pd}) using the 'Delft Method'. This information was also appended to the end of the ASCII statistics file.

4.0 Results

4.1 Comparison of Full Scale, Physical Model and Numerical Model Data

Based on model tests, sea trials and numerical results, comparisons of all data were made in two separate analyses, regular and irregular waves. There are some factors to consider when reading the comparison and viewing the plots. The model data is intended to reflect that of the sea trials, however there are sources of error in both the model tests as well as sea trials that prevents the results from correlating. Some of these sources of error are discussed in the conclusions/recommendations.

4.2 Irregular Wave Data Comparison

A comparison was made based on the results gathered from the Robert Sisters II sea trials in 2004, model tests carried out in the OEB and numerical data results obtained from MOTSIM. This comparison is based on irregular wave data.

All tests were carried out at 4 knots (trawling speed), 8 knots (cruising speed) and 4 knots with the anti-roll tank full. All three scenarios were used in the comparison plots. The plots compare each acceleration/angular rate to the heading angle at each speed for all sets of data. The figures are shown in Appendix A.

4.2.1 Trawling Speed with ART empty

Figures 3-8 from Appendix A shows the comparison plots for irregular waves at trawling speed with ART empty. The model results as well as the numerical result for amot_4ktnp_m165 for surge shows to be over predicted in comparison to the MOTSIM results and sea trials. Although at bow seas all results are consistent. Results for sway and heave were fairly consistent with the model tests being slightly under predicted for at following and quartering seas and over predicted at beam, bow and head seas. Both model test and MOTSIM are under predicted at following and quartering seas for roll angle, consistent at beam seas, and over predicted at bow and head seas.

4.2.2 Cruising Speed with ART empty

Figures 9-14 shows the comparison plots for irregular waves at cruising with ART empty. For surge acceleration, all results are in consistent at bow seas and slightly over predicted at following, quartering, beam and head seas. Model test results for both sway and heave show to be under predicted at following and quartering seas and over predicted at beam, bow and head seas. The roll angle shows to have consistent results for MOTSIM at beam bow and head seas, while the model test results are over predicted. Both model test and MOTSIM results are under predicted for following and quartering seas.

4.2.3 Trawling speed with ART filled

Figures 15-20 shows the comparison plots for irregular waves at trawling speed with the anti-roll tank filled. Sea trials were not conducted with the ant-roll tank is use at head seas or following seas, so comparison will only be made for quartering, beam and bow seas. The MOTSIM result for amot_ktnpt_m165 is greatly over predicted for sway, pitch and roll. Roll angle is of main interest in this comparison

Appendix B shows the comparison of roll angle versus encounter wave frequency with and without the anti-roll tank filled. Figure 31 shows this comparison at trawling speed in beam seas. At an encounter frequency of roughly 0.93 and greater, the ant-roll tank is seen as effective, thus reducing the roll angle. These results are consistent at cruising speed as well which is shown in Figure 32. Another comparison is made during quartering seas. Figure 33 shows the plot for quartering seas at cruising speed, which shows that at an encounter wave frequency of about 0.85, the anti-roll tank is effective. Figure 34 shows the comparison for quartering seas at trawling speed. This plot shows the anti-roll tank to have higher roll angles compared to the angles with the anti-roll tank empty. This is due to the fact that the encounter wave frequency never reached the value of the roll period for the model.

4.3 Regular Wave Data Comparison

Another comparison was made based on the data for the physical model in regular waves created in the OEB. There were 8 cases considered in this testing, which ran at both trawling and cruising speed. The first 4 cases were conducted at beam seas, with the last 4 cases being conducted in quartering seas. Case 2 and 4 were conducted with and without baffle tanks present in the anti-roll tank. The runs were also conducted with the anti-roll tank both full and empty. The plots display the relationship between the acceleration/angles and the wave period. These plots can be seen in Figures 21-30 in Appendix C.

5.0 Conclusions/Recommendations

The purpose of this report was to correlate the model test data with full scale and MOTSIM. The results showed to be promising in that the data was sufficiently correlated when also considering discrepancies in the data. Below is a list of sources of error in the results that could have caused some uncertainties in the comparisons.

Model Geometry

The model geometry may have been a factor in the discrepancies between both the sea trial and MOTSIM results. The scale factor is approximate, but the Robert Sisters II geometry itself has some uncertainty. The keel was estimated on the model as well, which could have impacted the differences in results. Also note that the Robert Sisters II was fitted with a nozzle propeller, however, the nozzle was not present on the model. There also uncertainties into the results obtained when the anti roll tank was full. The position of the modelled tank was approximated and its performance could have been altered with regard to materials used and the system in general.

Wave buoy

During the sea trials, several wave buoys were used to record the sea state at a given time. This data was used to describe the sea state the vessel was experiencing during a run. The sea trial runs were approximately 20 minutes long. While the wave buoy was retrieving data concerning the sea state, the readings applied to the vessel, which at some point was 15-20 minutes away where the sea state could have been different. This circumstance could be a reason for the discrepancies in results as well. A future consideration would be to use several wave buoys at different locations to track the sea states at different points along the sea trial path, and use an average of these conditions.

Waves and Sea State

During the sea trials it also would have been optimal if the sea state remained constant, however, local sea conditions are constantly changing due wind speed, current etc. The integrity of the wave data is therefore compromised.

The waves used in the OEB for the model runs were 11 o'clock waves. One nominal wave was used. Discrepancies in the model data and MOTSIM data could be due to the fact that the entire wave spectrum was used for MOTSIM. So any changes in significant wave height could be the cause of an excess or lack of energy for the waves in the model runs. Figure 35 shows that the 11 O'clock significant wave height lies roughly around the mean at about 2.3 m. Appendix D shows the nominal significant wave heights for each heading and corresponding speed. From this table it can be seen that the significant wave heights vary for every different heading, speed etc. This means that the waves being used in the OEB for the model runs do not exactly match those at which occurred during sea trials, which will produce differences in the results.

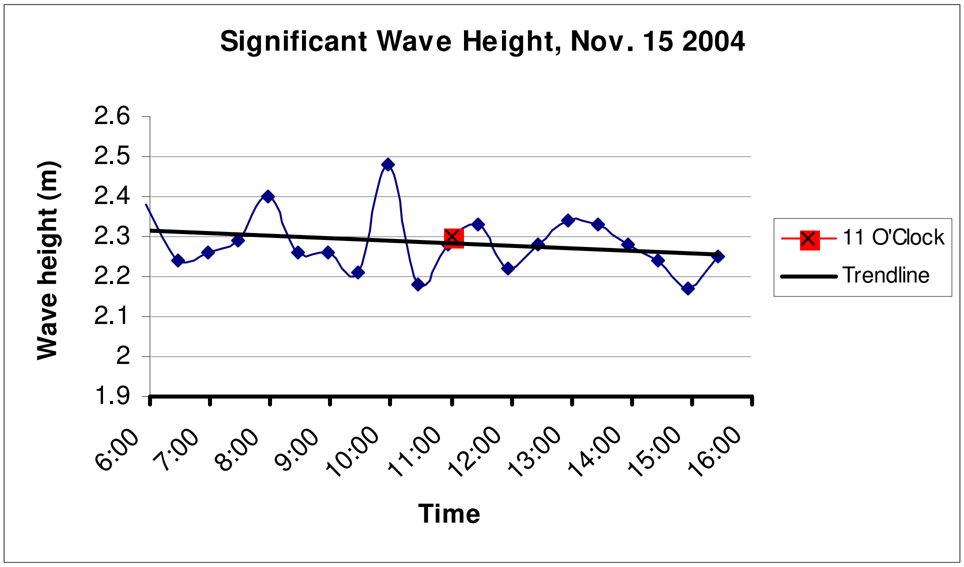

Figure 35: Significant Wave height vs. Time (Sea trial data)

Other Factors

Any other factor in discrepancies in results could have been due to the fact that the actual sea trials took place at a distance where it was still possible to have reflections of the waves from land. The size of the OEB was also not desired for proper model testing and mimicking the desired conditions was difficult due to its size. It should also be noted that the target speed at which the model progressed was not always exact, and was averaged out over the total number on runs.

Appendix ‘A’

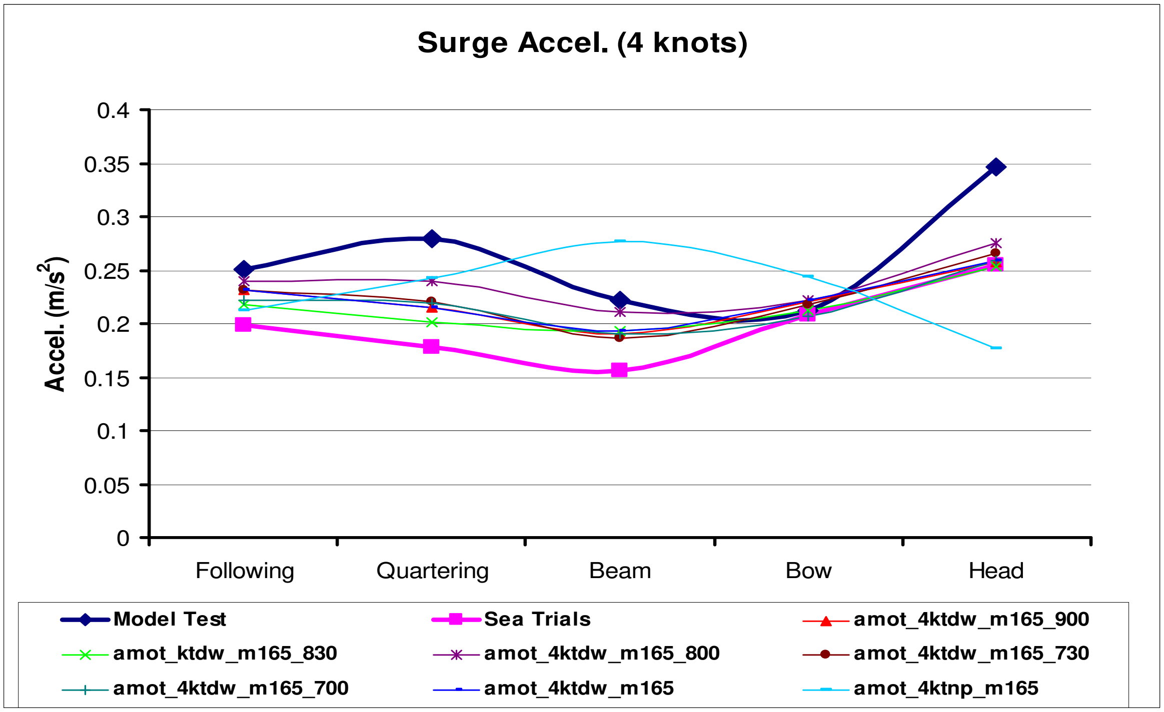

FIGURE 3: Surge Accel. vs. Heading – Trawl Speed, ART Empty

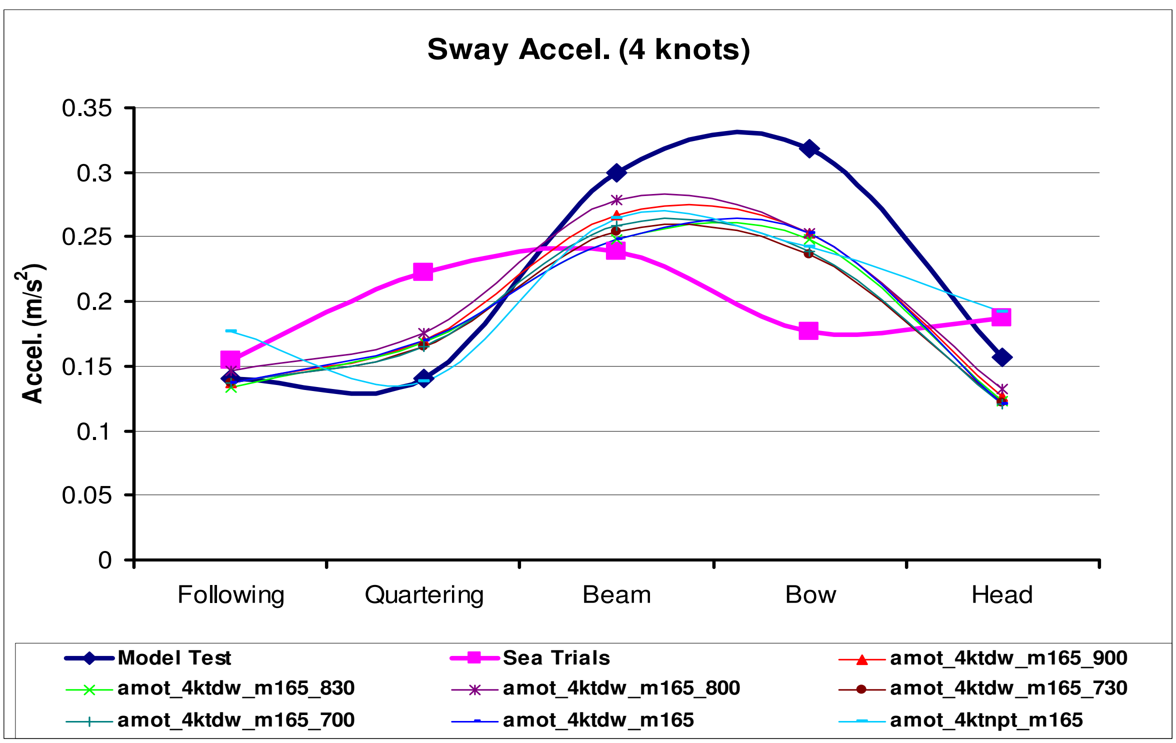

FIGURE 4: Sway Accel. vs. Heading – Trawl Speed, ART Empty

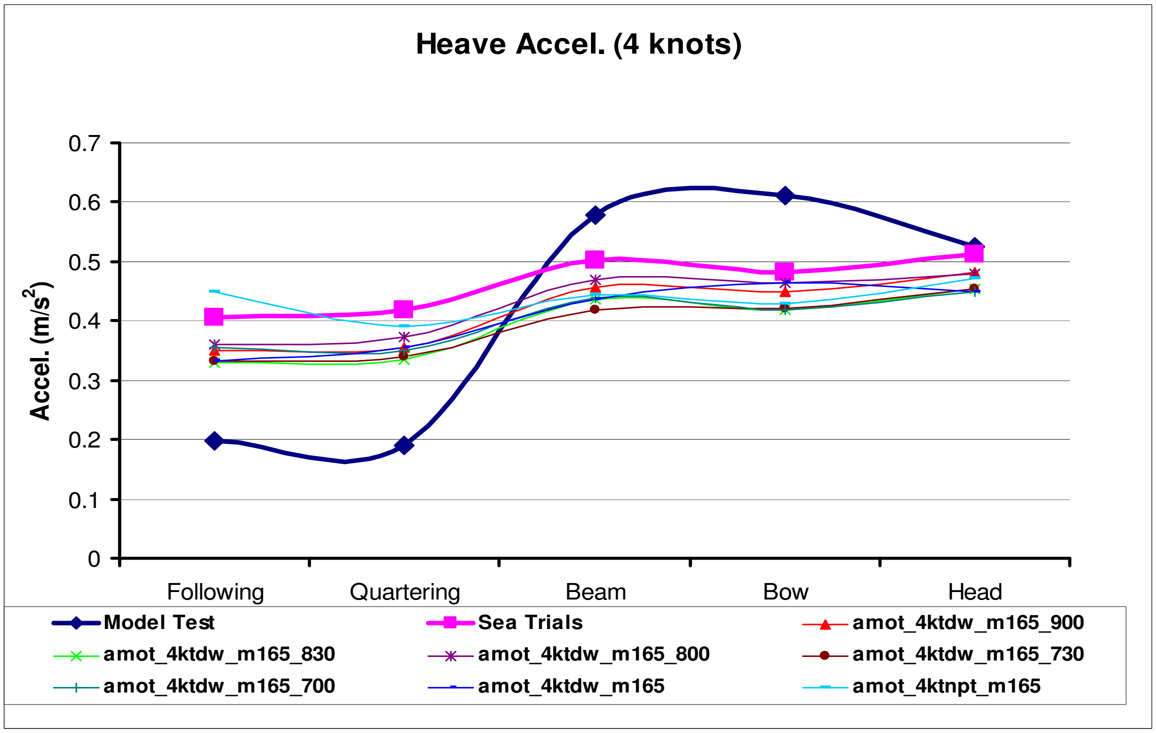

FIGURE 5: Heave Accel. vs. Heading – Trawl Speed, ART Empty

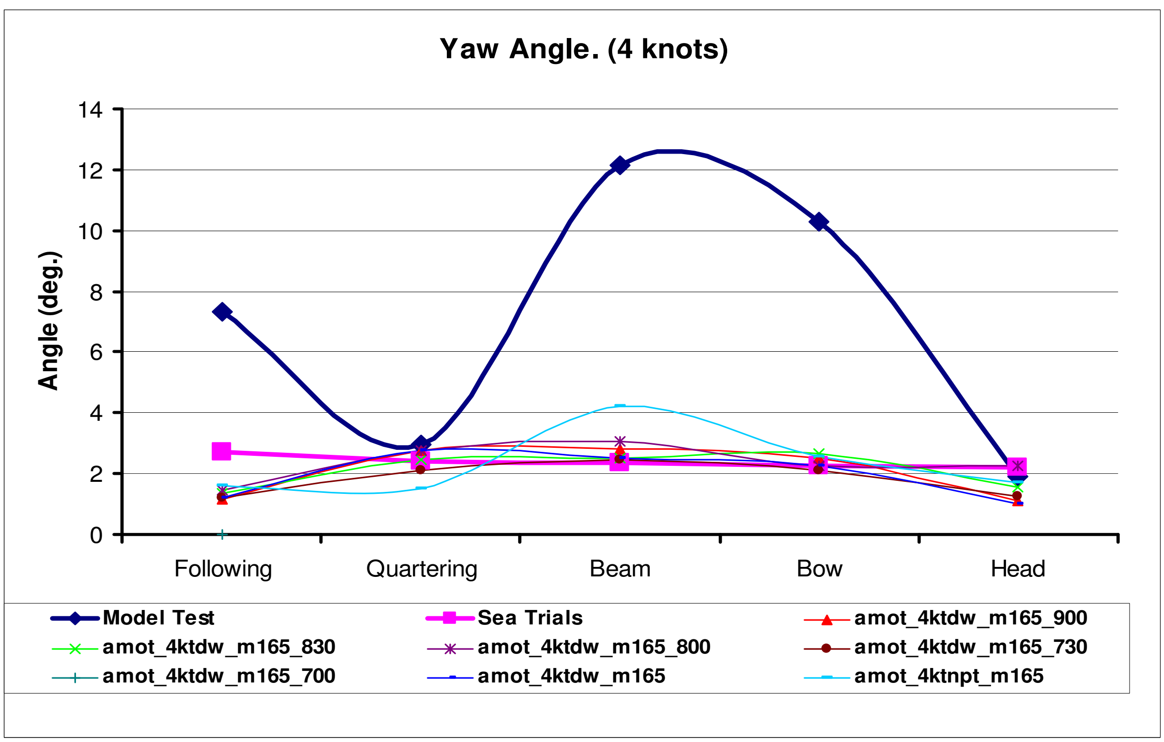

FIGURE 6: Yaw Angle. vs. Heading – Trawl Speed, ART Empty

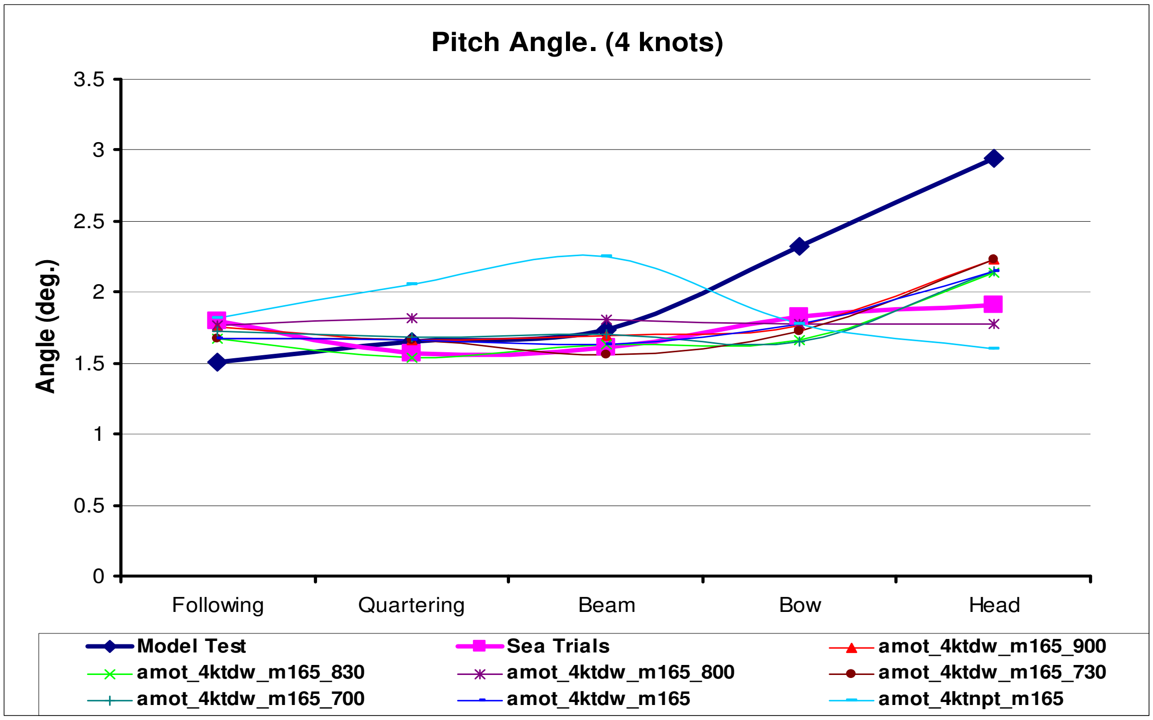

FIGURE 7: Pitch Angle. vs. Heading – Trawl Speed, ART Empty

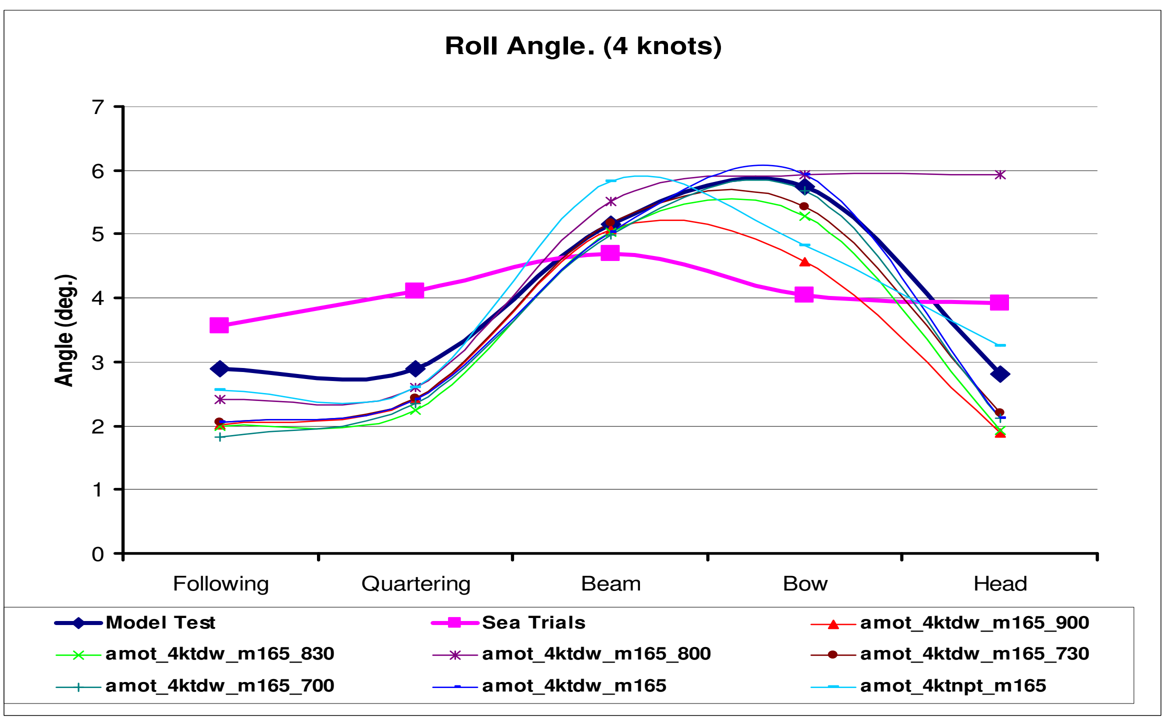

FIGURE 8: Roll Angle. vs. Heading – Trawl Speed, ART Empty

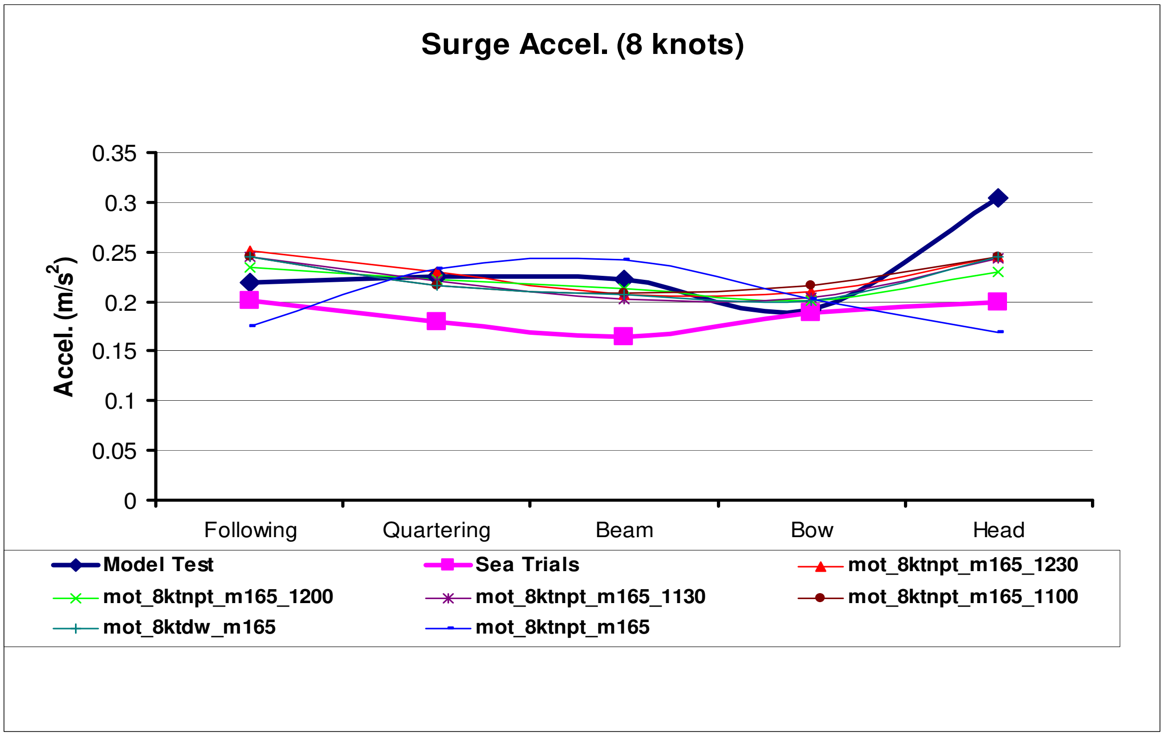

FIGURE 9: Surge Accel. vs. Heading – Cruising Speed, ART Empty

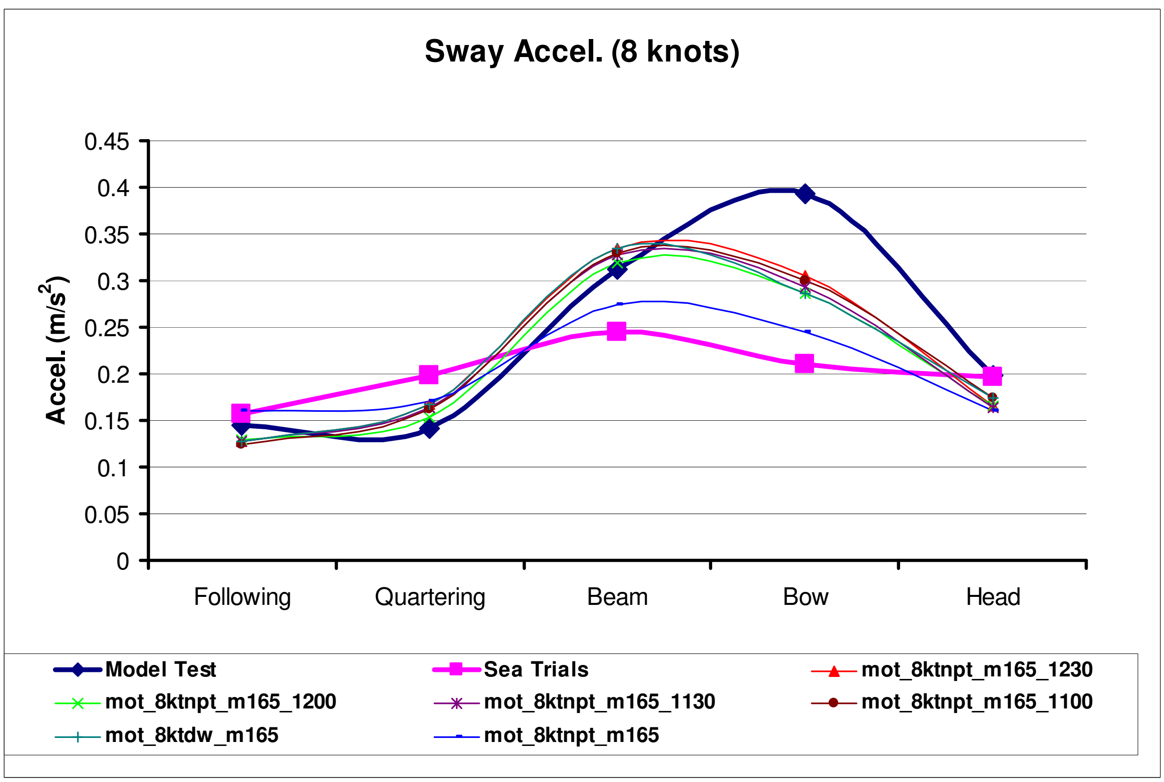

FIGURE 10: Sway Accel. vs. Heading – Cruising Speed, ART Empty

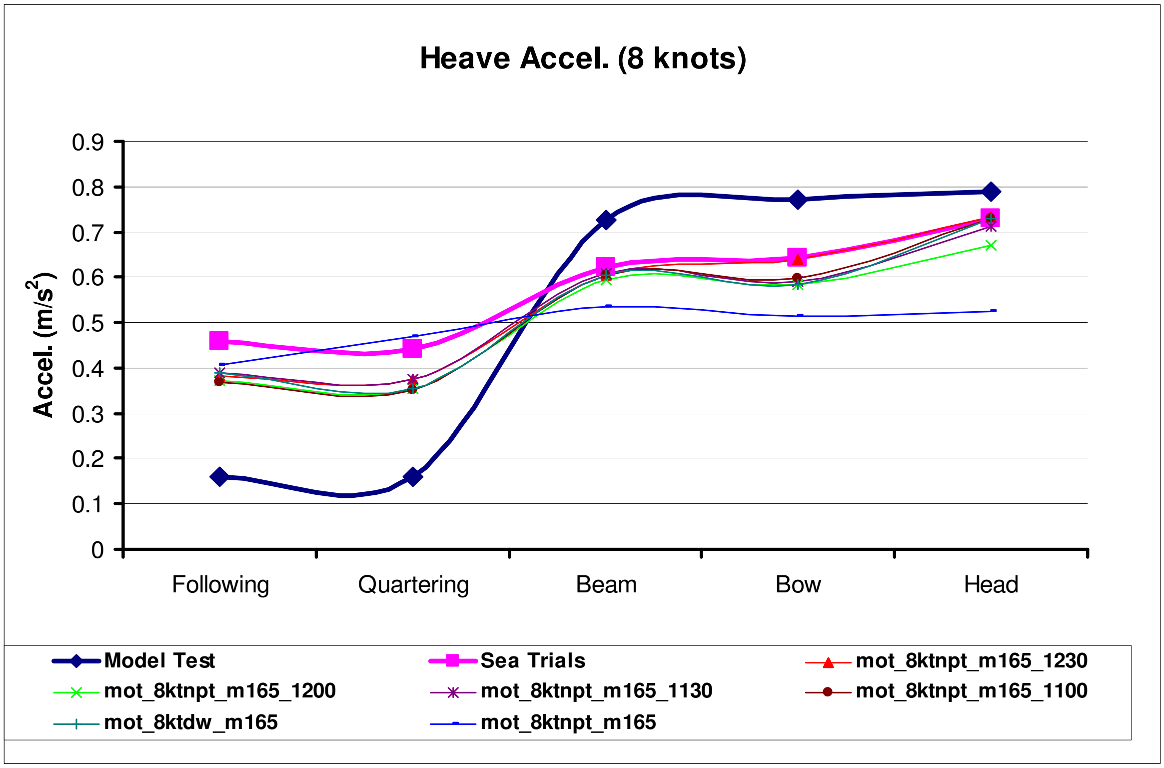

FIGURE 11: Heave Accel. vs. Heading – Cruising Speed, ART Empty

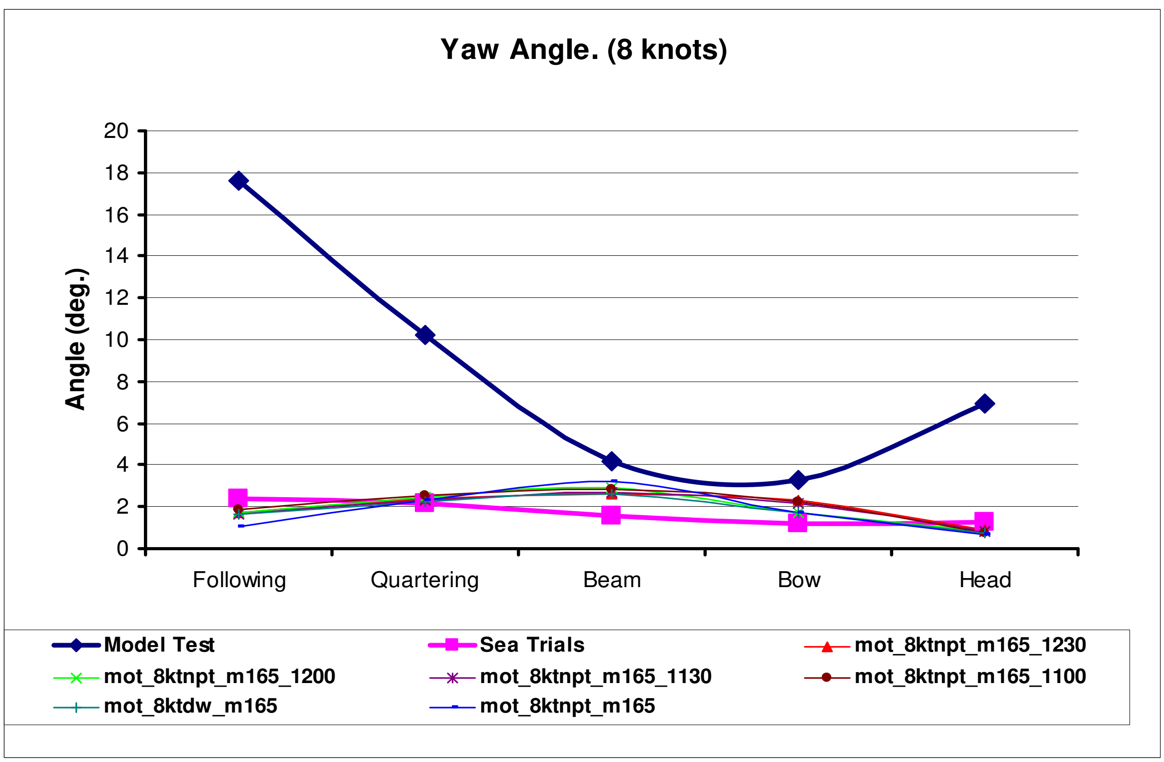

FIGURE 12: Yaw Angle. vs. Heading – Cruising Speed, ART Empty

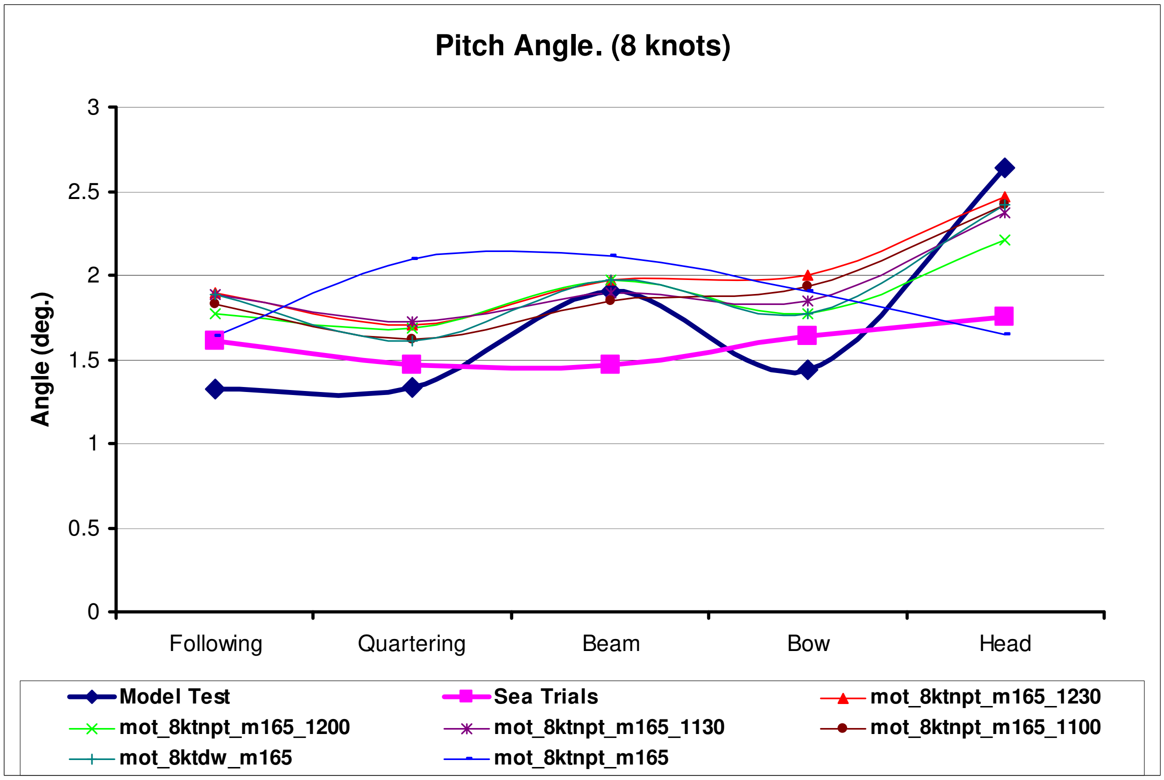

FIGURE 13: Pitch Angle. vs. Heading – Cruising Speed, ART Empty

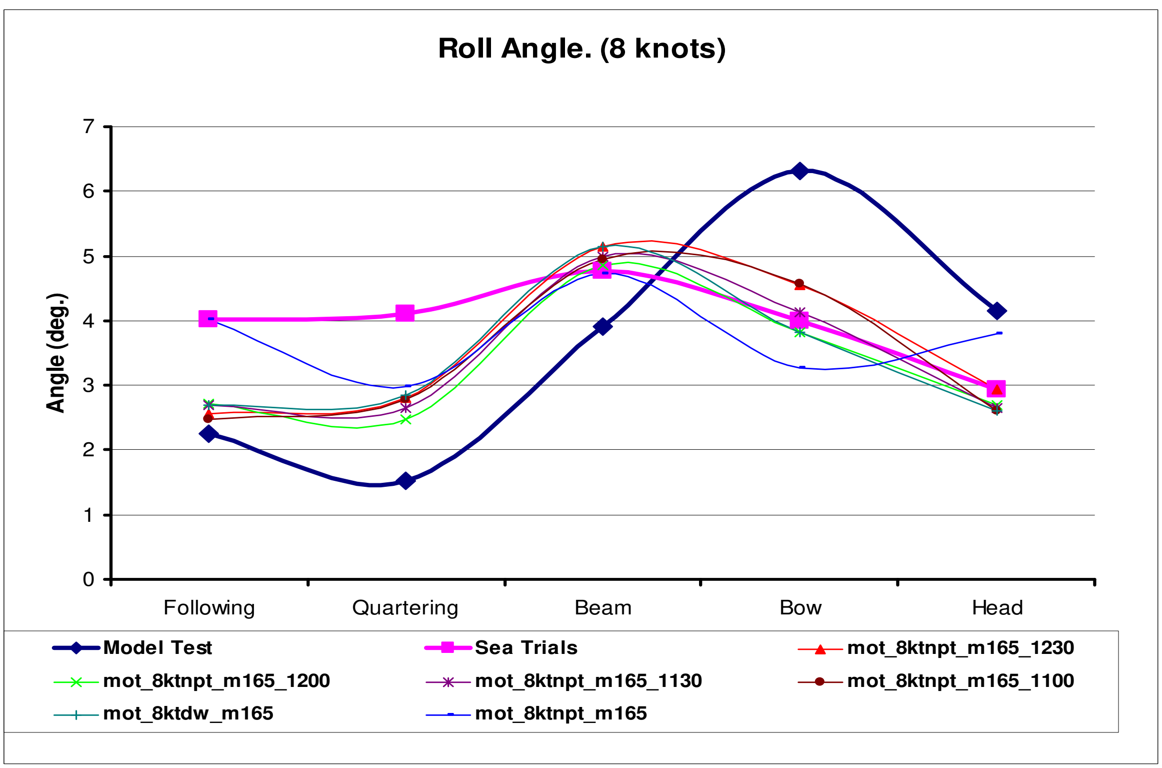

FIGURE 14: Roll Angle. vs. Heading – Cruising Speed, ART Empty

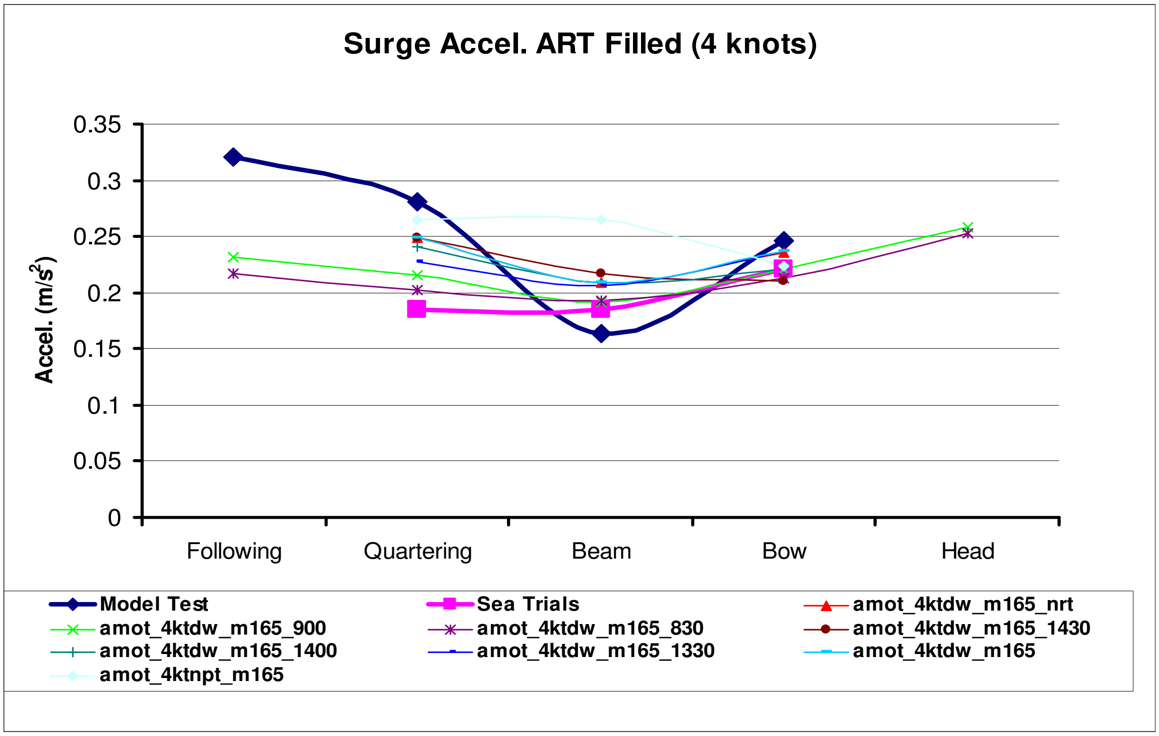

FIGURE 15: Surge Accel. vs. Heading – Trawl Speed, ART Filled

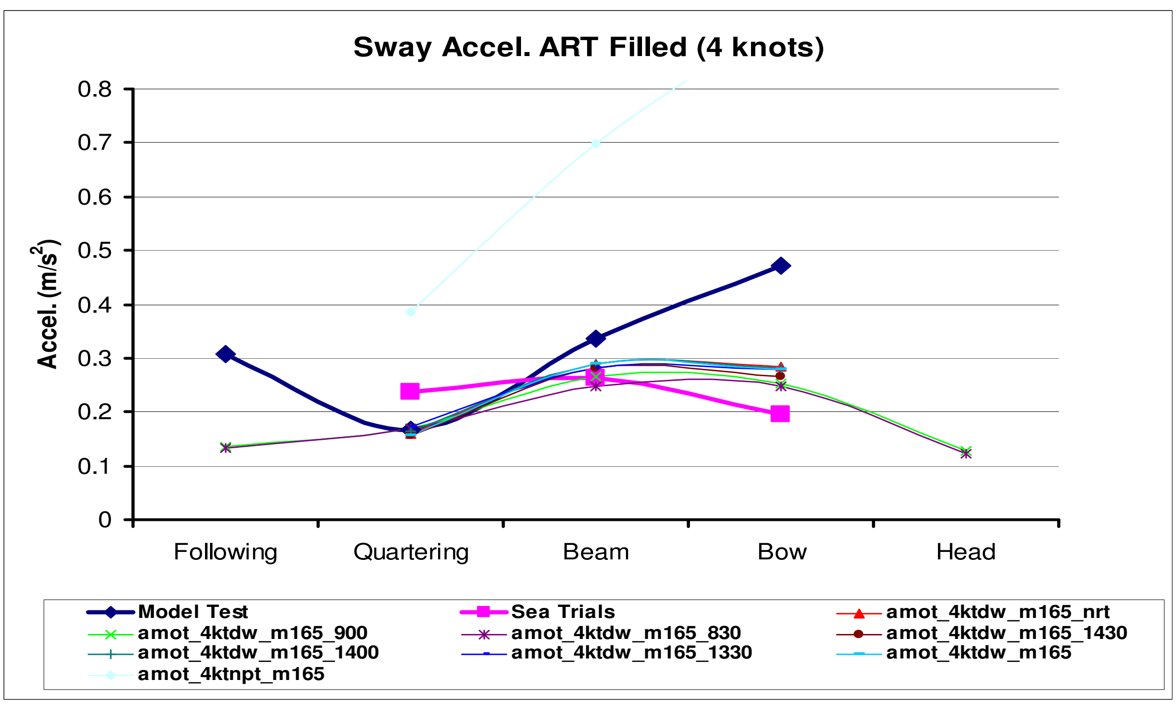

FIGURE 16: Sway Accel. vs. Heading – Trawl Speed, ART Filled

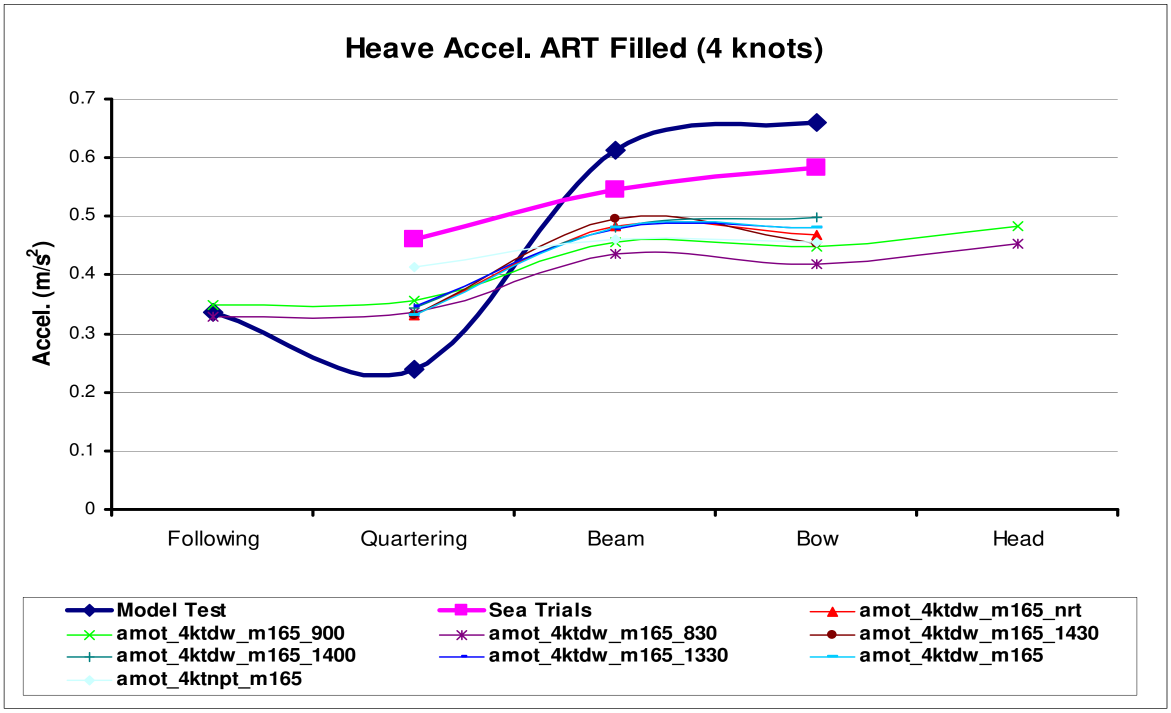

FIGURE 17: Heave Accel. vs. Heading – Trawl Speed, ART Filled

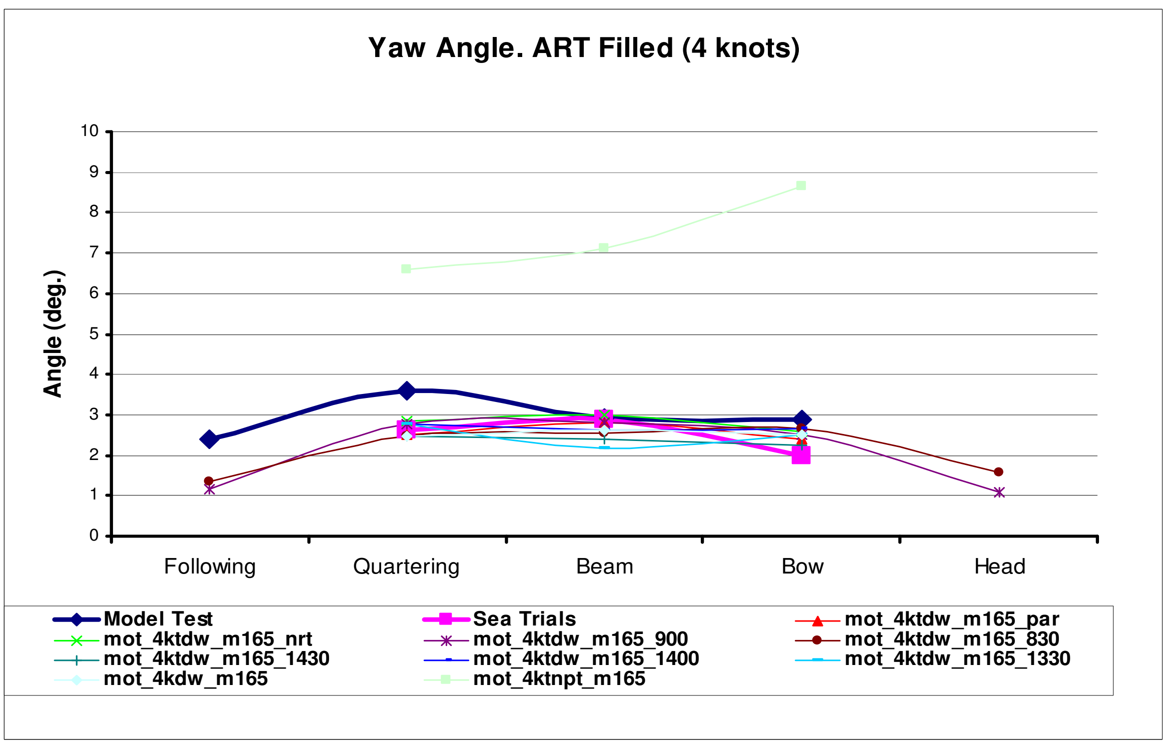

FIGURE 18: Yaw Angle. vs. Heading – Trawl Speed, ART Filled

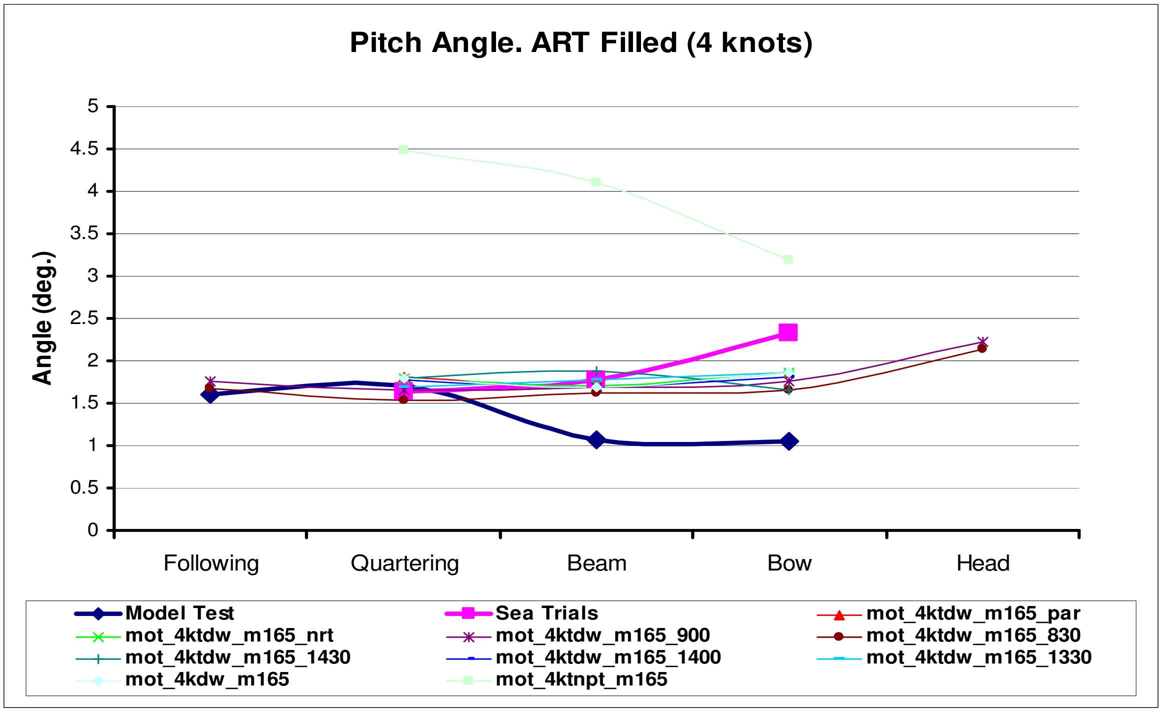

FIGURE 19: Pitch Angle. vs. Heading – Trawl Speed, ART Filled

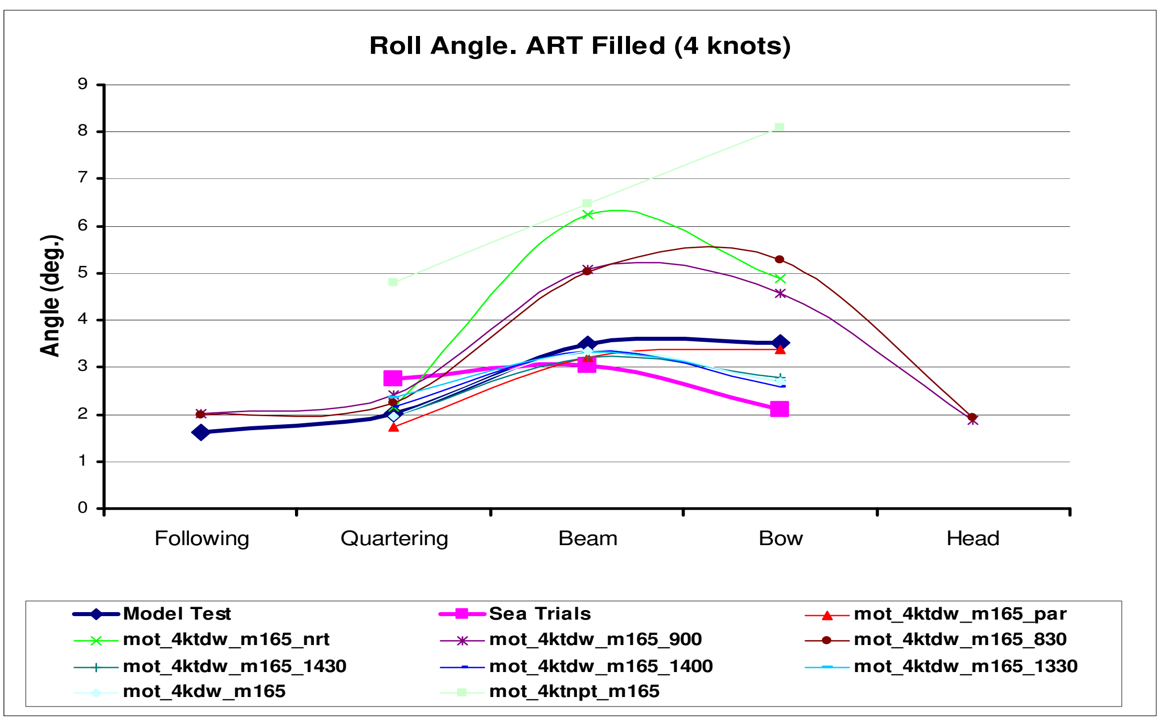

FIGURE 20: Roll Angle. vs. Heading – Trawl Speed, ART Filled

Appendix ‘B’

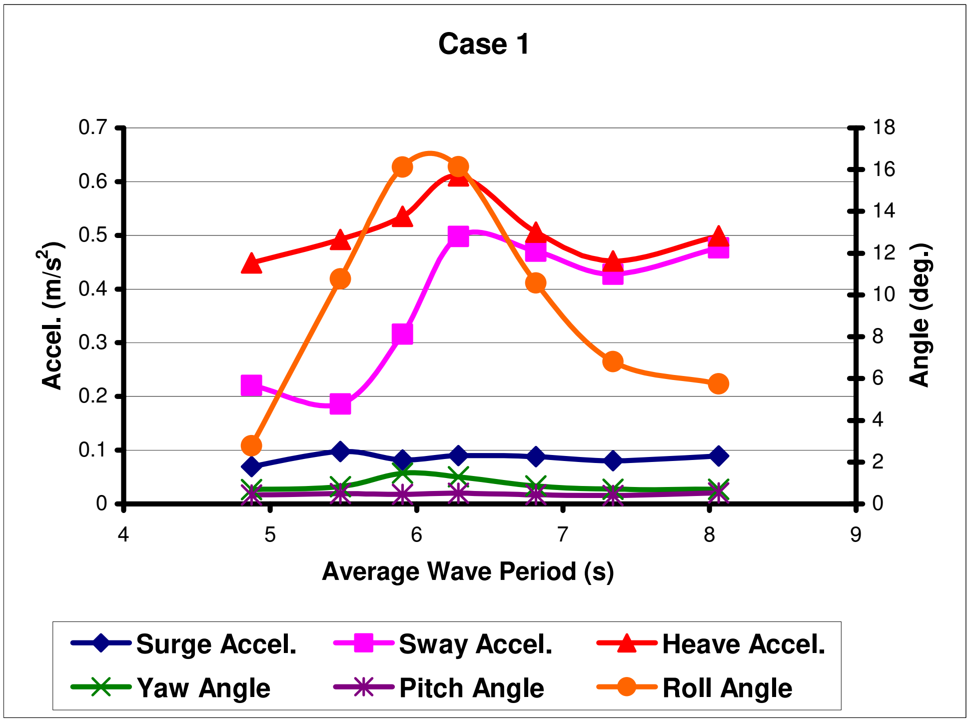

FIGURE 21: Accel./Angle vs. Average Wave Period – Case 1 (Beam Seas, 4 knots, ART Empty)

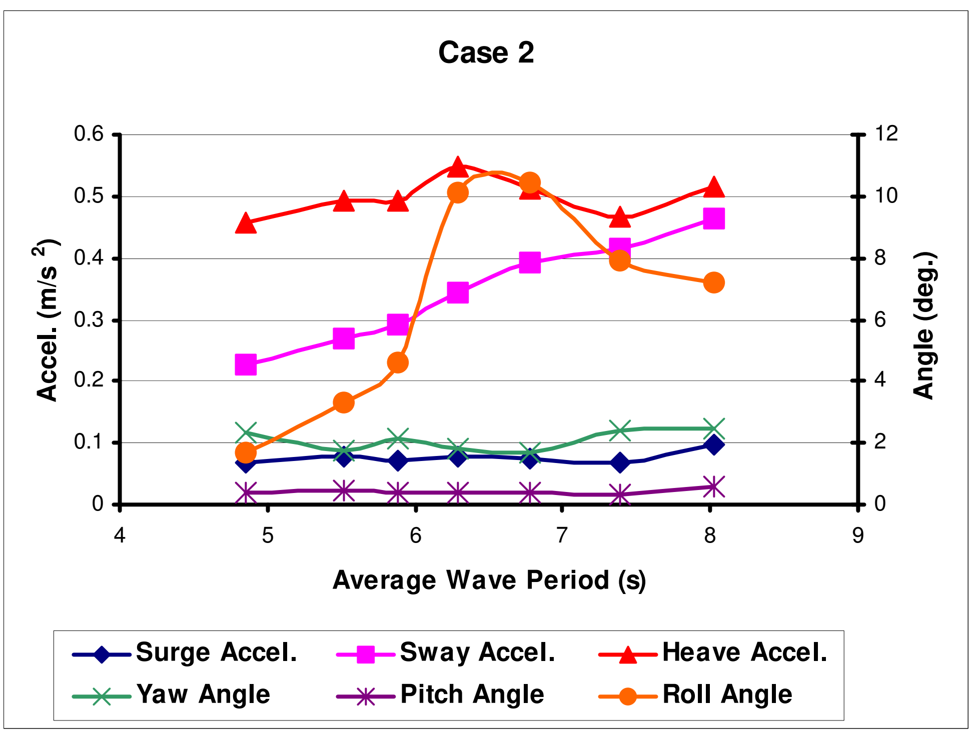

FIGURE 22: Accel./Angle vs. Average Wave Period – Case 2 (Beam Seas, 4 knots, ART Filled)

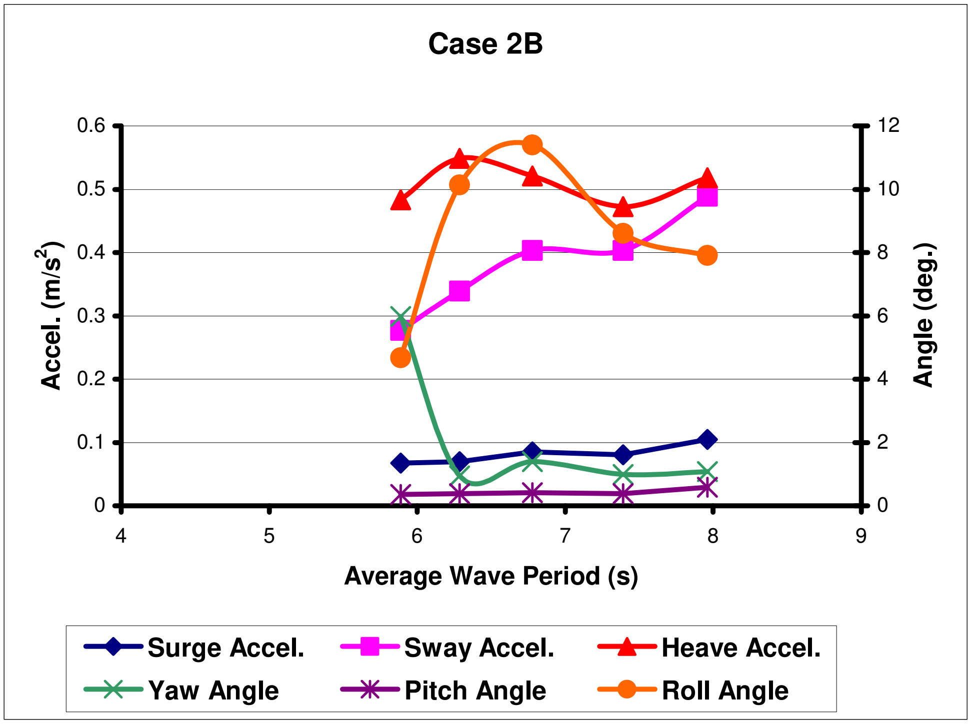

FIGURE 23: Accel./Angle vs. Average Wave Ht. – Case 2B (Beam Seas, 4 knots, ART Filled - fitted with baffles)

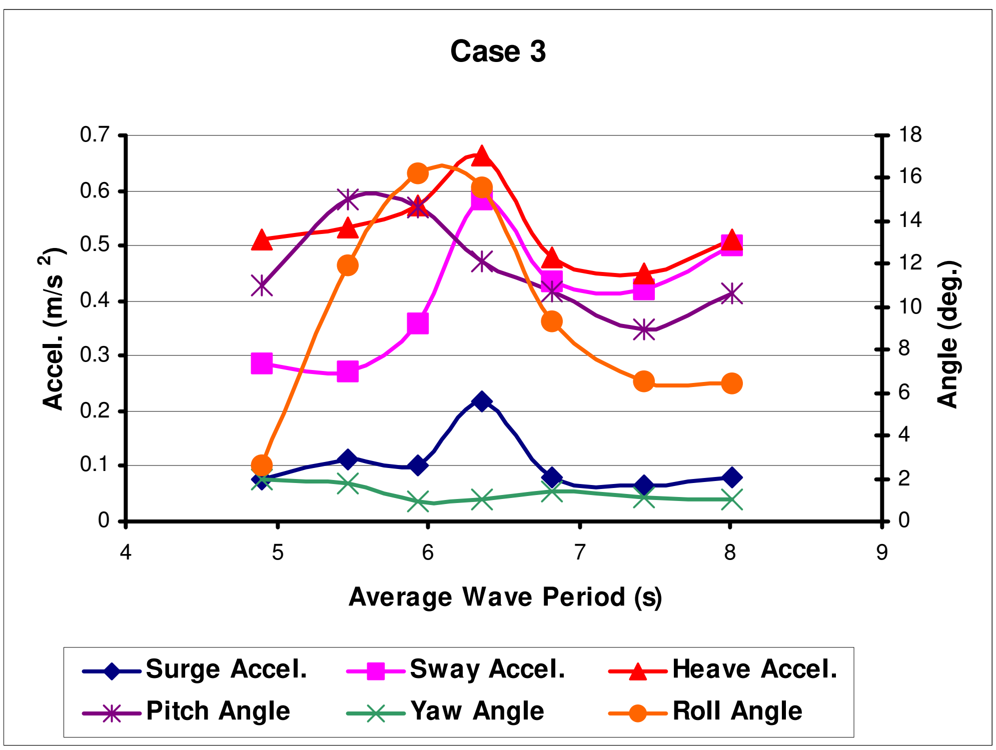

FIGURE 24: Accel./Angle vs. Average Wave Period – Case 3 (Beam Seas, 8 knots, ART Empty)

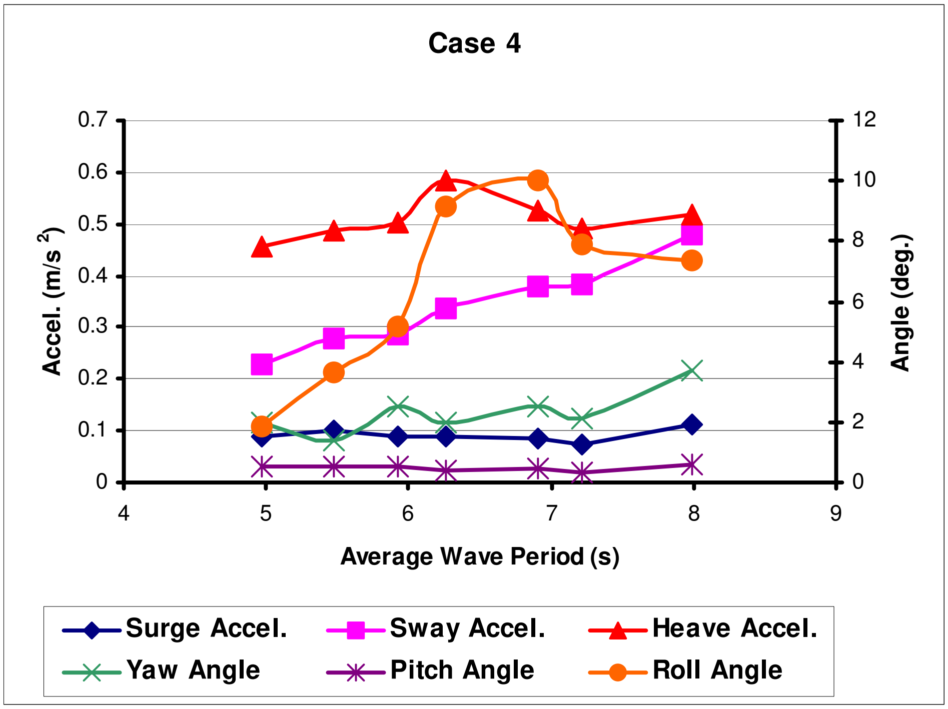

FIGURE 25: Accel./Angle vs. Average Wave Period – Case 4 (Beam Seas, 8 knots, ART Filled)

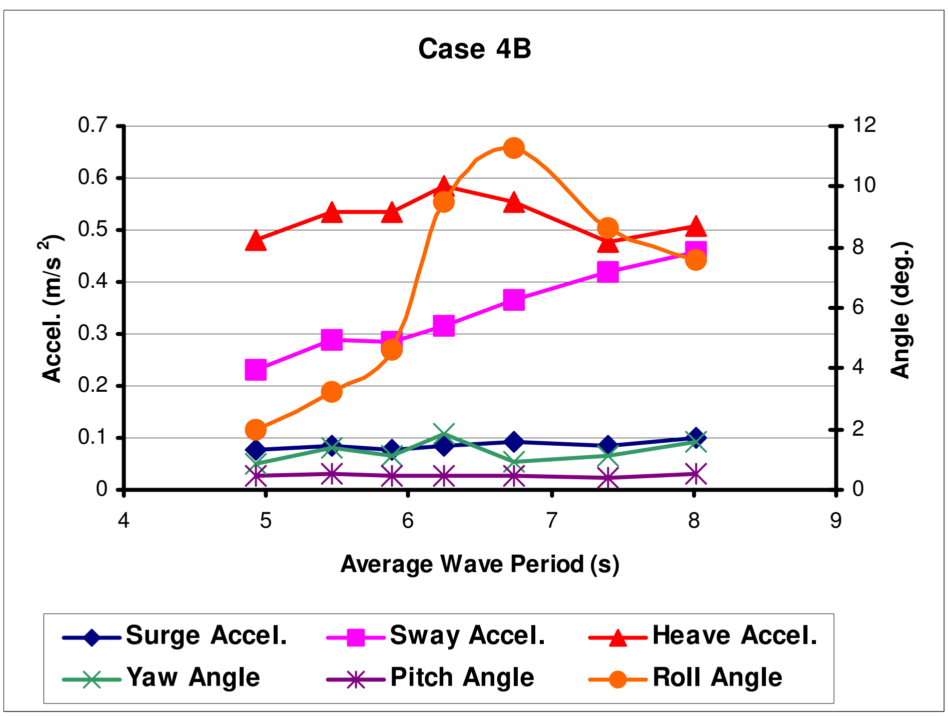

FIGURE 26: Accel./Angle vs. Average Wave Period – Case 4B (Beam Seas, 8 knots, ART Filled - fitted with baffles)

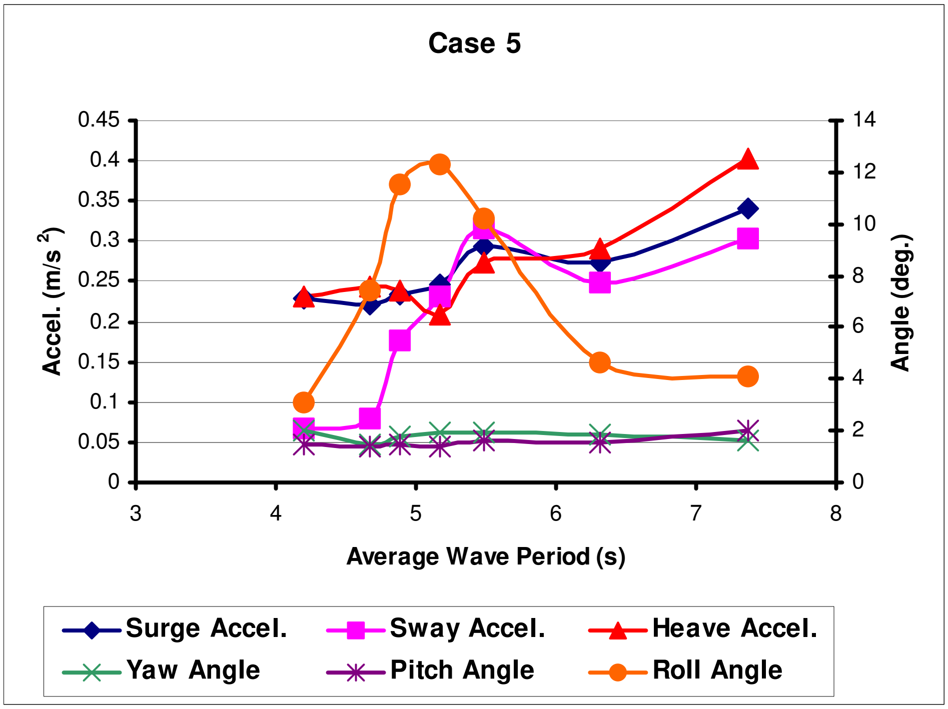

FIGURE 27: Accel./Angle vs. Average Wave Period – Case 5 (Quartering Seas, 4 knots, ART Empty)

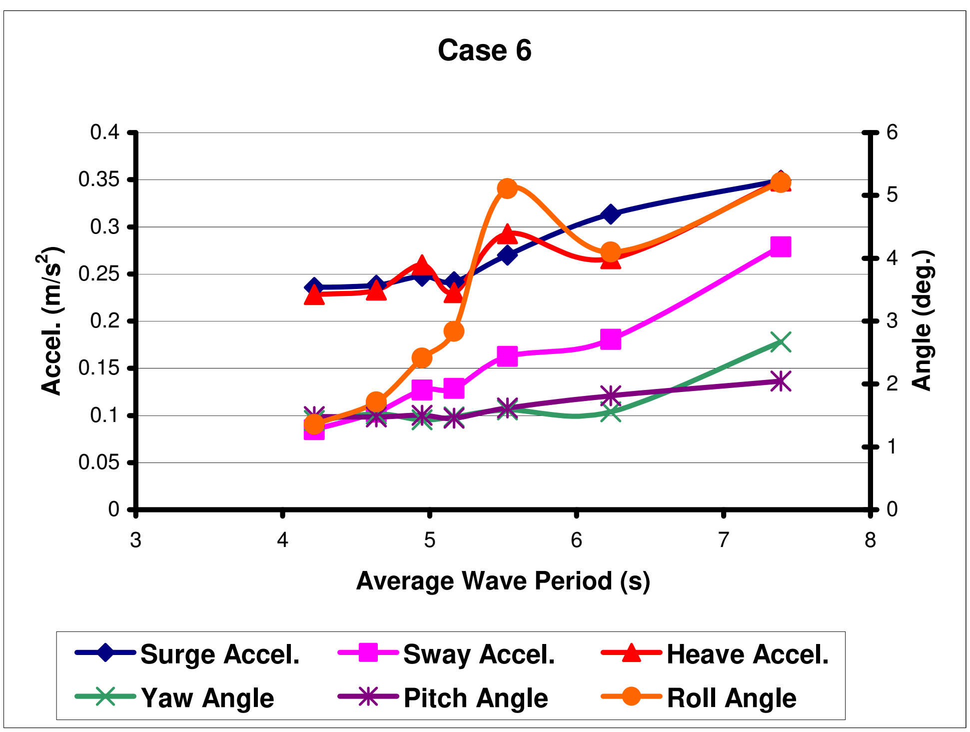

FIGURE 28: Accel./Angle vs. Average Wave Period – Case 6 (Quartering Seas, 4 knots, ART Filled)

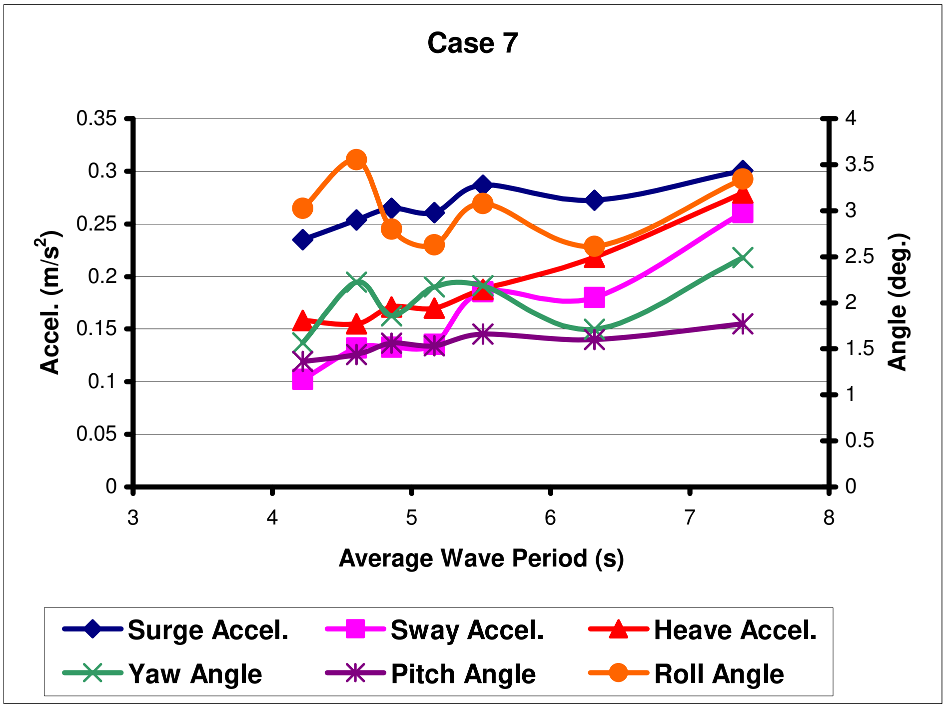

FIGURE 29: Accel./Angle vs. Average Wave Period – Case 7 (Quartering Seas, 8 knots, ART Empty)

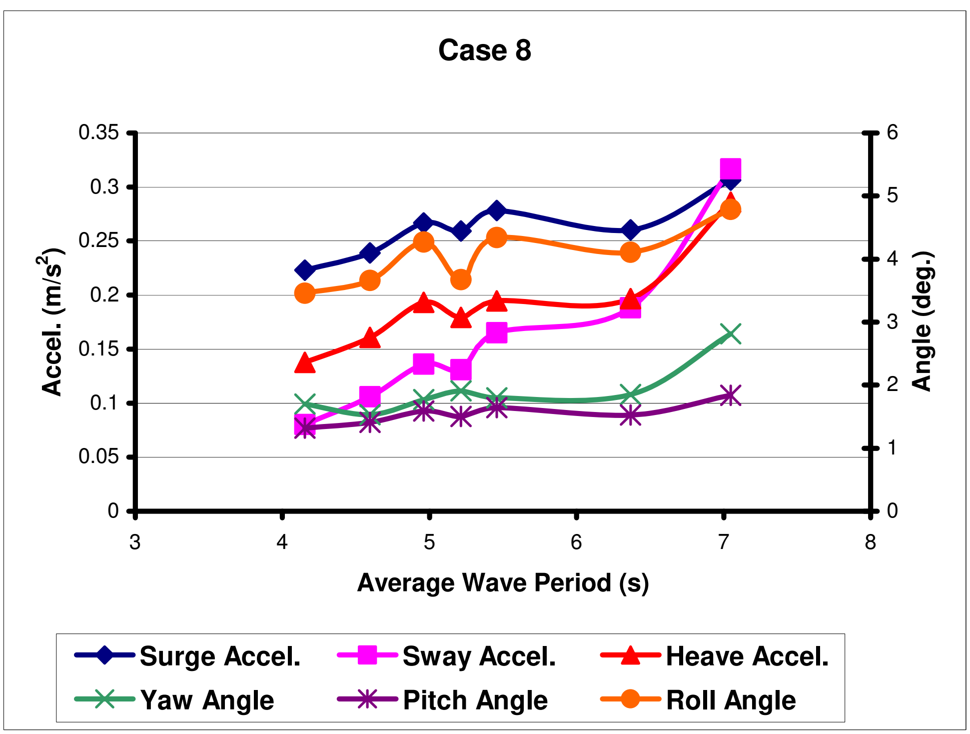

FIGURE 30: Accel./Angle vs. Average Wave Period – Case 8 (Quartering Seas, 8 knots, ART Filled)

Appendix 'C'

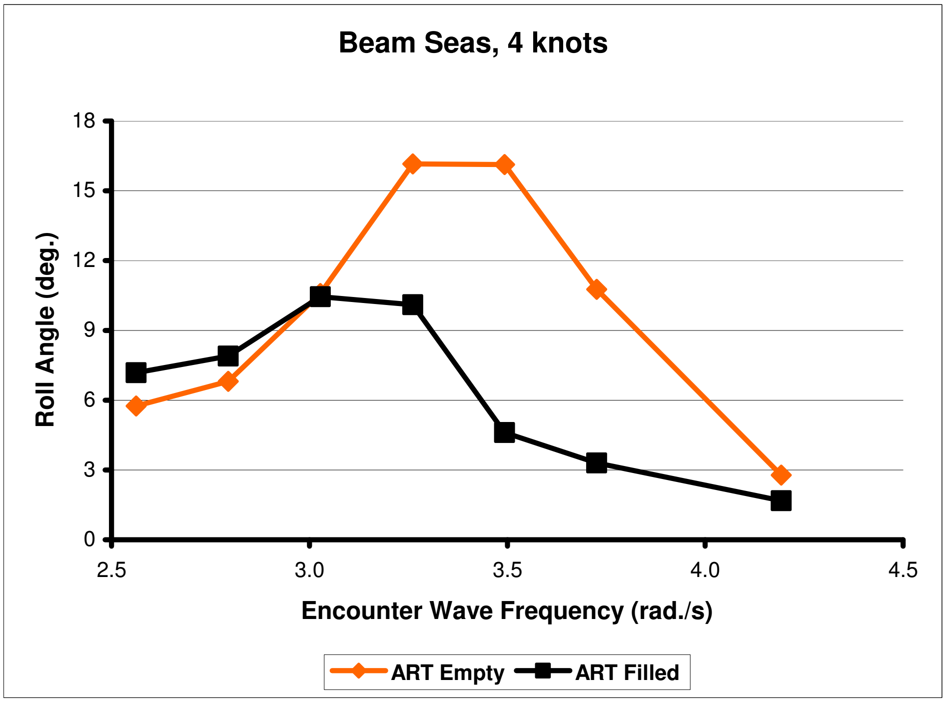

FIGURE 31: Roll Angle vs. Encounter Wave Frequency – Beam Seas, 4 knots, With/Without ART Filled

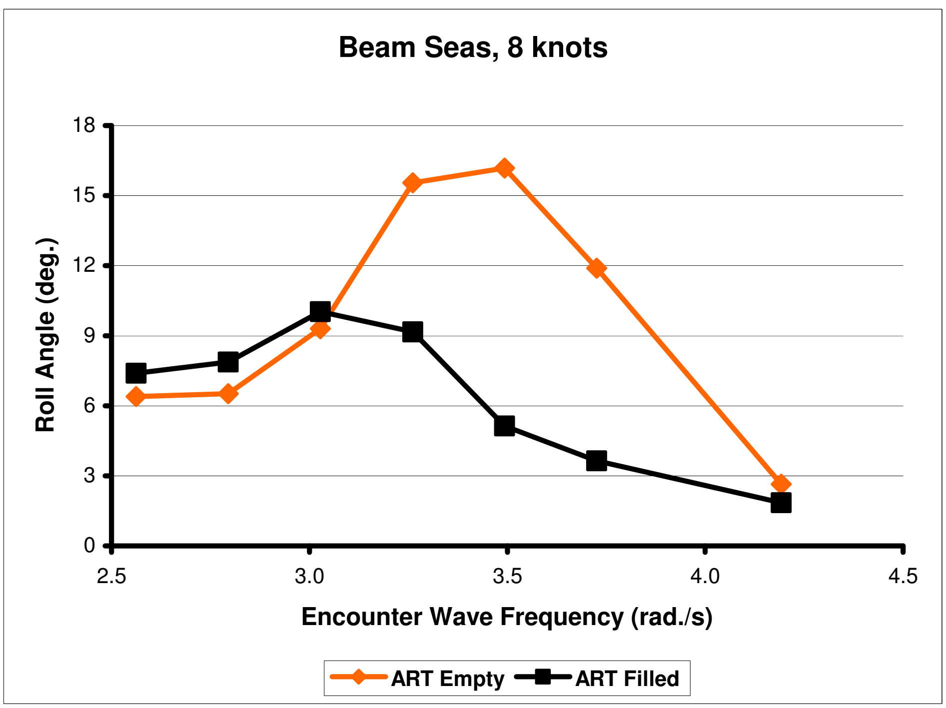

FIGURE 32: Roll Angle vs. Encounter Wave Frequency – Beam Seas, 8 knots, With/Without ART Filled

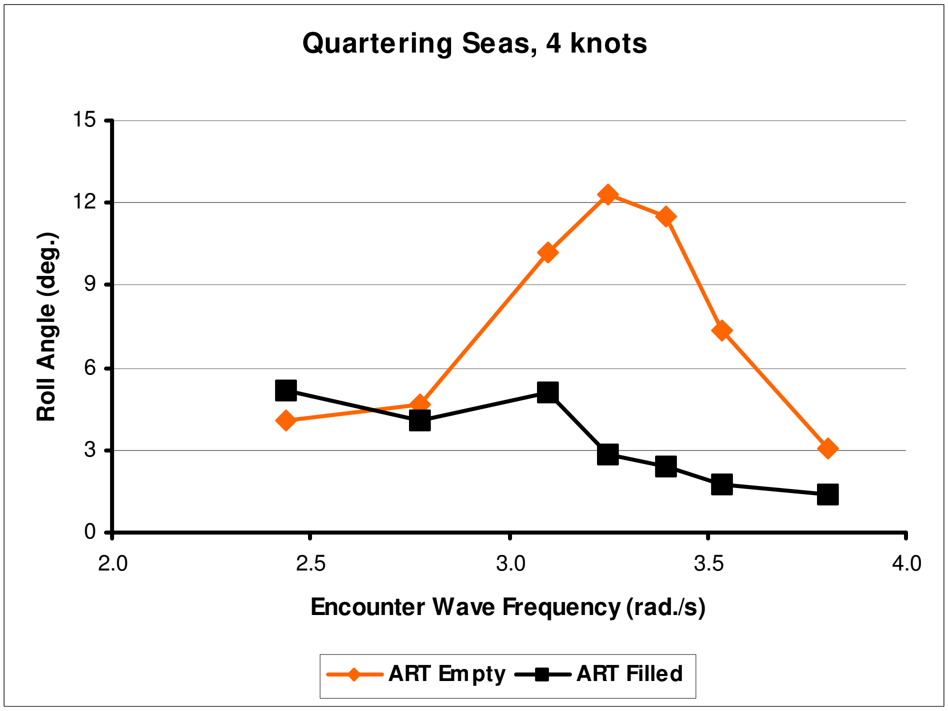

FIGURE 33: Roll Angle vs. Encounter Wave Frequency – Quartering Seas, 4 knots, With/Without ART Filled

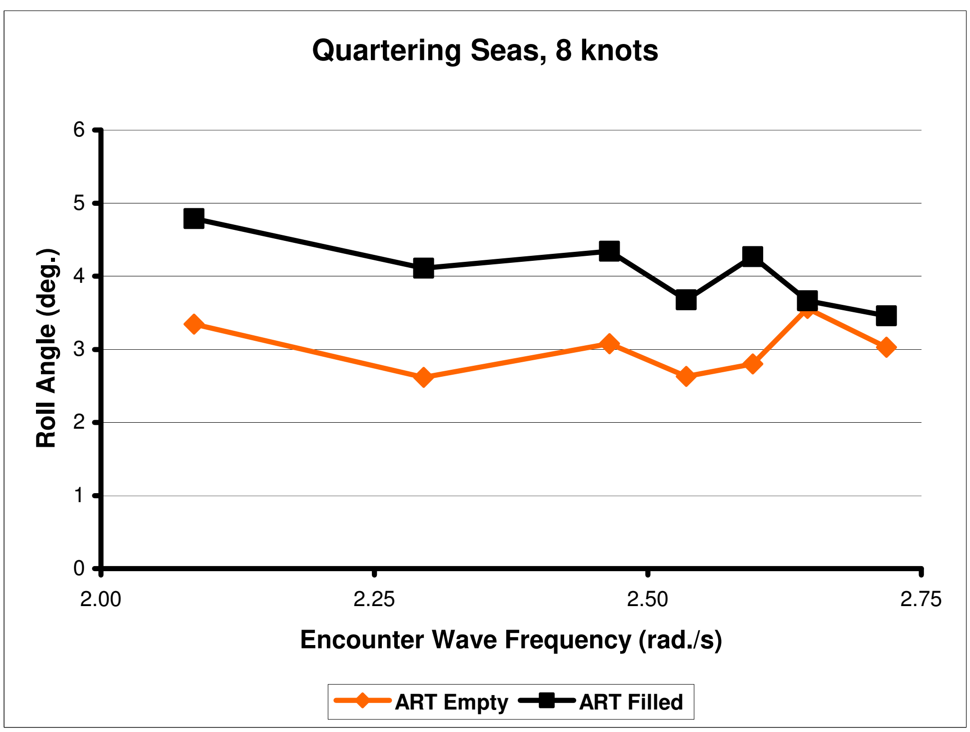

FIGURE 34: Roll Angle vs. Encounter Wave Frequency – Quartering Seas, 8 knots,

Appendix 'D'

Run Log for Seakeeping Trial on CCGA Roberts Sisters II - Vessel 'C1'

Fishing Vessel Research Project (Proj. 2017) Date: Nov. 15 2004

Nov 9, 04: 10 minute drift run in Harbour 10MIN_DRIFT_20041109151656.CSV
Wind 5 knots, 350 degrees magnetic
Salinity 24.0 ppt, sea water temp 6.3 C
Drafts: aft 13' 7" (4.140 m), fwd. 9' 2" (2.794 m)

Nov. 15	Drafts: fwd. 9'2" (2.794 m), aft 13' 7" (4.140 m)	Salinity 20.1 ppt, sea water temp 5.9 C	Density 1015.8 kg/m^3
04:15	Departed St. John's		
05:50	Launch wave Neptune buoy 47 33 42 N, 52 26 11 W, 165 m depth ,1.9 to 2 knot drift		
06:30	Visibility excellent, overcast, apparent wave direction 75 degrees true, sea state 2		
06:40	At buoy,	salinity 31.1 ppt, sea water temp 5.7 C	Density 1024.5 kg/m^3
07:00	Low frequency waves not being recorded by Neptune buoy		
07:20	Waves appear to be dropping		
08:50	No water on deck, or bow spray noted		
09:30	Approximately 3 miles from buoy at end of test pattern due to tidal drift		
14:00	Filled ART to working level	14.75" (37.465 cm measured at wharf (tank sight glass) at end of trial)	
16:20	Recover wave buoy. Significant tension on entire mooring due to tidal current. Steel cable section could not be retrieved with pot hauler and was recovered by hand (very difficult).		
16:30	At buoy,	salinity 23.7 ppt, sea water temp 6.0 C	Density 1018.6 kg/m^3
18:00	At dock	salinity 20.8 ppt, sea water temp 6.0 C	Density 1016.4 kg/m^3

Run #	File Name	Start Finish Time	Course Relative to Incident Waves	Location Start/Finish Latitude deg N	Long. deg W	Nominal SWH (m)	Nominal Period (s)	SOG (kts.)	COG (Deg. TRUE)	Wind Speed (kts.)	Wind Direction (Deg. Mag.)	Eng. RPM	Shaft RPM	Comments:
1	0DRIFT_2004_1115055619.csv	05:56 06:21	beam drift	47.5544 47.5466	52.4375 52.4496	2.58	12.34	1.8	N/A	12	240	N/A	0	Drift 1.8 knots to SW
2	THEAD_2004_1115064947	06:49 07:14	Head	47.5553 47.5591	52.4332 52.4075	2.44	12.34	2.6	073	20	340	836	141	very strong current, buoy submerging at wave peaks

Run #	File Name	Start Finish Time	Course Relative to Incident Waves	Location Start/Finish Latitude deg N	 Long. deg W	Nominal SWH (m)	Nominal Period (s)	SOG (kts.)	COG (Deg. TRUE)	Wind Speed (kts.)	 Direction (Deg. Mag.)	Eng. RPM	Shaft RPM	Comments:
3	TFOL_2004_1115072149.csv	07:21 08:01	following	47.555 47.5412	52.417 52.4898	2.63	10.89	4.8	253	7	110	761	128.6	Engine at idle due to current
4	TBOW_2004_1115080800.csv	08:08 08:33	bow	47.5391 47.5279	52.488 52.4648	2.61	10.89	3.0	120	19	290	760	128.4	Engine at idle
5	TBEAM_2004_1115083828.csv	08:38 09:03	beam	47.529 47.545	52.464 52.471	2.55	12.34	2.6	344	17	020	720	121.8	Engine at idle
6	TQUART_2004_1115090757.csv	09:07 09:32	quartering	47.542 47.5156	52.472 52.4949	2.82	12.34	4.8	210	13	200	720	121.8	Engine at idle
7	0DRIFT_2004_1115101000.csv	10:10 10:35	beam drift	47.555 47.5482	52.439 52.4511	2.04	12.34	1.4	N/A	17	050	N/A	0	Drift rate 1.4 knots
8	CHEAD_2004_1115104952	10:49 11:14	head	47.5556 47.5552	52.423 52.3491	1.98	9.75	7.2	092	12	310	1640	274.3	Wind freshening
9	CFOL_2004_1115111949.csv	11:19 12:01	following	47.553 47.555	52.359 52.4769	1.99	10.89	7.1	270	5	080	1320	221.3	Apparent quartering sea, winds shifting
10	CBOW_2004_1115120544.csv	12:05 12:30	bow	47.555 47.5149	52.571 52.421	2.08	10.89	7.0	135	21	280	1420	237.9	waves 25 degrees off of the bow
11	CBEAM_2004_1115123606.csv	12:36 13:01	beam	47.518 47.5678	52.419 52.4144	2.1	9.75	7.0	000	16	010	1660	277.7	

Run #	File Name	Start Finish Time	Course Relative to Incident Waves	Location Start/Finish Latitude deg N	Location Start/Finish Long. deg W	Nominal SWH (m)	Nominal Period (s)	SOG (kts.)	COG (Deg. TRUE)	Wind Speed (kts.)	Wind Direction (Deg. Mag.)	Eng. RPM	Shaft RPM	Comments:
12	CQUART_2004_1115130535.csv	13:05 13:30	quartering	47.5622 47.5273	52.4191 52.4706	1.9	9.75	7.0	225	9	180	1200	201.4	
	ART filled to working level	14:00												
13	ART_TBEAM_2004_1115141318.csv	14:13 14:39	beam	47.553 47.5752	52.445 52.4578	2.25	9.75	3.2	340	20	030	840	141.7	beam sea determined visually
14	ART_TQUART_2004_1115144226.csv	14:42 15:07	quartering	47.572 47.5441	52.4596 52.4819	2.24	10.89	4.7	206	16	210	740	125.1	
15	ART_TBOW_2004_11151923.csv	15:19 15:44	bow	47.539 47.5305	52.482 52.4587	2.25	10.89	2.0	115	19	290	750	126.8	visibility reduced to 1 mile wind increasing

Summary of Wave Statistics Collected Using Datawell Directional Wave Buoy

CCGA Roberts Sisters II **Fishing Vessel Research Proj. 2017**
November 15, 2004

NF Time	Sig. Wave Height (m)	Mean Wave Period (s)	Mean Wave Frequency (Hz)	Maximum Spectral Density (m^2/ Hz)	Maximum Wave Direction (deg. TRUE)
05:27	2.44	7.14	0.1400	12.27	121.03
05:57	2.38	7.02	0.1425	9.80	118.22
06:27	2.24	6.78	0.1475	10.40	114.00
06:57	2.26	6.67	0.1500	7.63	102.75
07:27	2.29	6.67	0.1500	9.60	122.44
07:57	2.40	6.78	0.1475	9.85	116.81
08:27	2.26	6.78	0.1475	11.21	119.63
08:57	2.26	6.67	0.1500	7.01	108.38
09:27	2.21	6.56	0.1525	6.37	99.94
09:57	2.48	6.56	0.1525	9.56	125.25
10:27	2.18	6.35	0.1575	8.39	126.66
10:57	2.28	6.45	0.1550	8.31	126.66
11:27	2.33	6.67	0.1500	12.15	118.22
11:57	2.22	6.45	0.1550	8.78	132.28
12:27	2.28	6.35	0.1575	7.30	108.38
12:57	2.34	6.56	0.1525	9.00	118.22
13:27	2.33	6.56	0.1525	12.52	121.03
13:57	2.28	6.45	0.1550	8.14	119.63
14:27	2.24	6.25	0.1600	8.39	112.59
14:57	2.17	6.06	0.1650	6.34	121.03
15:27	2.25	5.97	0.1675	8.69	122.44
15:57	2.15	6.15	0.1625	6.97	106.97