Safer Fishing Vessel Seakeeping

(Safecatch)

D. Bass[1], J. Vera[1], D. Cumming[2], and A. Akinturk[2]

[1]*Faculty of Engineering and Applied Science, Memorial University of Newfoundland*
St. John's, NL, A1B 3X5, Canada

[2]*Institute for Ocean Technology, National Research Council Canada*
St. John's, NL, A1B 3T5, Canada

Email: dbass@engr.mun.ca

ABSTRACT

In the last three-four years, the Institute for Ocean Technology (IOT) and Memorial University of Newfoundland (MUN) have joined together to establish motion profiles of the Newfoundland fishing fleet. The objective has been to develop and validate a numerical tool, called MOTSIM [13] that will be used to evaluate motion stress profiles using the notion of Motion Induced Interrupts (MIIs) (or any other similar parameter) and their impact on crew safety. This has involved conducting sea trials of representative vessels of the fleet and corresponding model tests in the wave basin of IOT (only the smallest of the vessels has been tested at IOT at this time). In parallel, MOTSIM has been further developed and validated using the full scale and experimental results. This report discusses numerical challenges encountered in simulating these trials and the model test, and reviews the methods developed to overcome these challenges. Comparisons between the numerical simulations and the full scale trials are presented. The simulations are also compared with the model test results. Based on the results, the numerical simulations seem to correlate reasonably well with the trials and the experiments. There is now sufficient evidence to have some confidence in the motion and MII predictions of MOTSIM to allow an analysis of the motion stress levels on vessels of the Newfoundland fleet to be made. An example of the methodology involving MII values to demonstrate the effect of fishing vessel length on crew comfort and safety is presented.

1. INTRODUCTION

SafeCatch is part of an umbrella initiative called SafetyNet [1] , whose aim is to understand and mitigate the health and safety risks associated with employment in a marine environment. The aim of this study is to develop and validate a numerical ship motions prediction tool with the intention of using it to assess the physical stress levels on fishers associated with vessel motions on board fishing vessels. Stress levels are evaluated on the basis of the number of ‘motion induced interrupts’ (MII) per minute that occur at a particular location on a boat. A motion induced interrupt is effectively a ‘loss of balance’ incident, where the fisher has to make a special effort to avoid ‘tipping or slipping’ either by adjusting his stance of by holding on (of course in some instances the fisher may well fall). Such incidents are associated with accelerations due to the boat motions and depend on where the fisher is working. The boat motions depend on the sea conditions and the shape and size of the boat. If the boat motions can be correctly predicted then so can the number of MII per minute that occur at any location on the vessel. The prediction of a ‘loss of balance’ incident is based on a ‘rigid body’ modeling of the fisher and may therefore under or over predict the ‘destabilizing’ effects of particular accelerations acting on the human body (which of course is flexible).

Fishing is the most dangerous occupation in Newfoundland and Labrador. Over the past decade, the rates of reported injuries and fatalities have nearly doubled. These trends have the effect of reducing the sustainability of the fishery, increasing health care and compensation costs, and straining the available search and rescue resources. The tools developed in this study should help to improve working conditions on board fishing vessels. For example parametric studies of fishing vessel designs and their optimization based on MII criteria can be carried out.

In order to achieve this objective, a number of sea trials have been conducted to establish the motion profiles for the fishing fleet of Newfoundland and Labrador. As a next step, possible correlations between motion levels and the physical/motion stress levels will be investigated based on the Motion Induced Interrupts criteria ([2] ,[3] ,[4] , and [5]). The final objective is to develop means to reduce critical motions of fishing vessels from a vessel design and operational point of view.
In this report, selected results of the correlation study between MOTSIM predictions and the sea trial observations are presented.

2. SEA TRIALS

The vessels used in the trials and their lengths are: M/V Louis M. Lauzier (39.6m), CCGS Shamook (22.9m),CCGA Roberts Sisters II (19.8m), CCGA Miss Jacqueline (19.8m), CCGA Nautical Twilight (13.7m) and CCGA Atlantic Swell (10.7m). The last four were the vessels selected from the Canadian Coast Guard Auxiliary Fleet of fishing vessels. M/V Louis M. Lauzier, on the other hand, is the training vessel used by Memorial University and is included to illustrate that some of the difficulties encountered in predicting the motions of the fishing vessels may be related to the size of the vessels.

The target sea conditions would typically range from sea state 2 to 4. Sea trials were carried out nominally 10 nm east of St. John’s.

A more detailed description of the vessels and the instrumentation used in their trials are given in [6] through [12].

3. SIMULATIONS OF MOTIONS OBSERVED IN SEA TRIALS

In this section we describe some of the results of the simulations of motions of the six vessels. In all six sea trials involving these vessels, the seas were complex and multi-directional, making the task of representing the sea states in the numerical simulations particularly difficult and therefore open to doubt. For example identifying what was head seas proved to be no easy task. For smaller vessels the complexity of the sea state probably has more effect on the motions. The larger vessels effectively filter out some higher frequency or lower amplitude waves and possibly only respond to certain waves in certain directions.

Motions simulations were run in MOTSIM, a non-linear time domain code [13]. The code has been modified to output MII values for chosen positions on the vessel along with the six degrees of freedom motion data.

Generally the better predicted motions are pitch and surge acceleration. These are shown below for the 6 vessels. The speed of the vessels was the lower one used in the trials. For the 39.6m vessel it was at 6 kt and the rest at 4 kt.

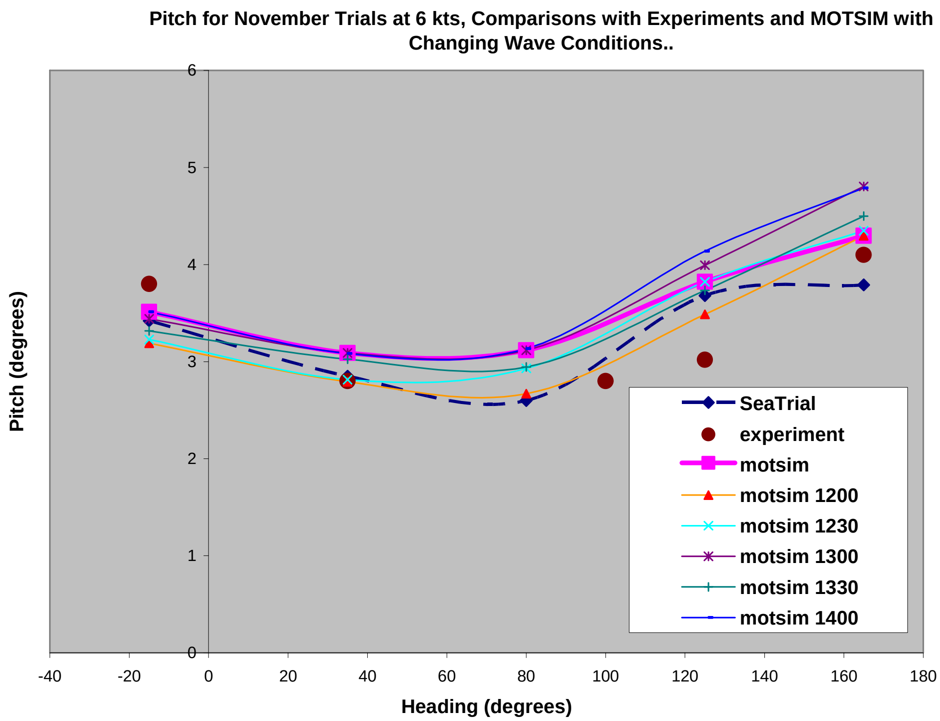

Figure 1. Pitch Motions for the Lauzier (39.6 m); Comparisons of Simulations (Neptune data), Sea Trials and Model Tests.

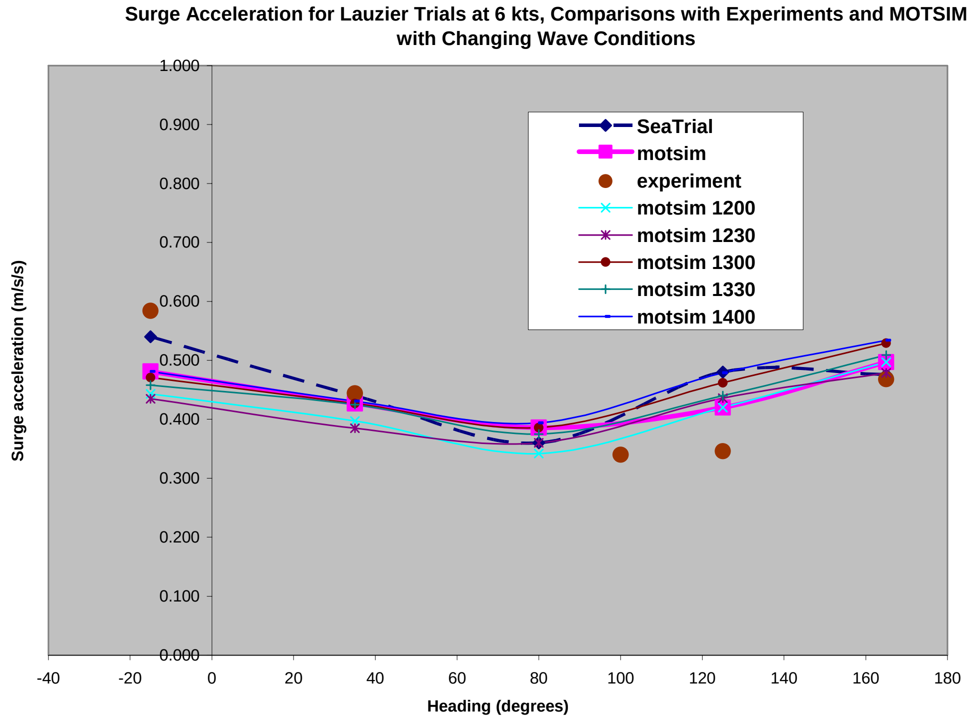

Figure 2. Surge Accelerations for the Lauzier (39.6 m); Comparison of Simulations (Neptune data), Sea Trials and Model Tests.

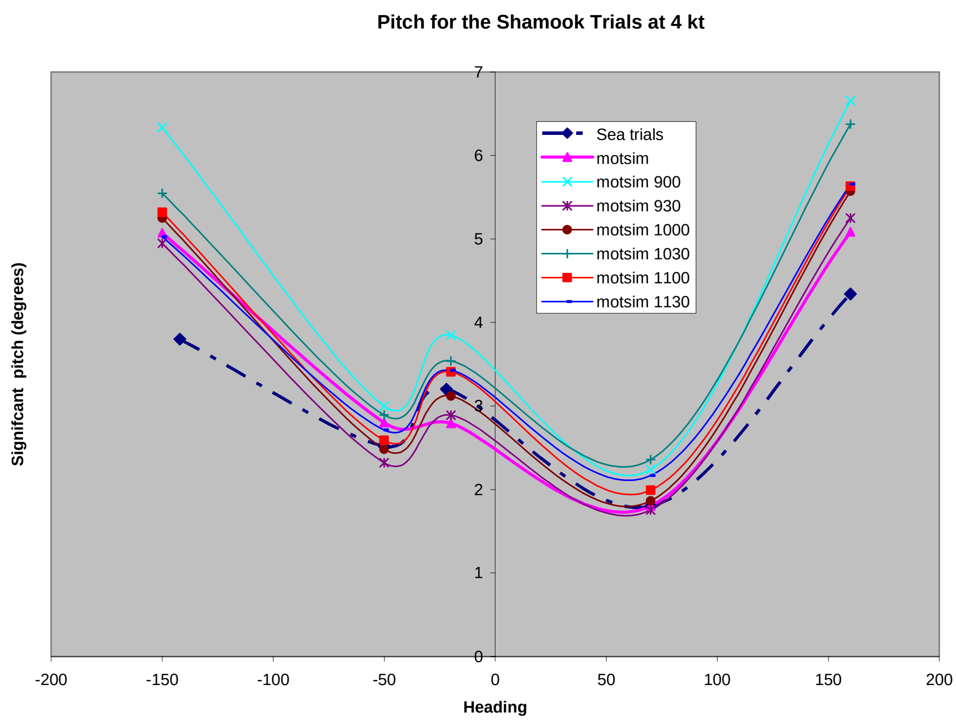

Figure 3. Pitch Motions for the Shamook (22.9 m); Comparisons of Simulations (Neptune data), Sea Trials .

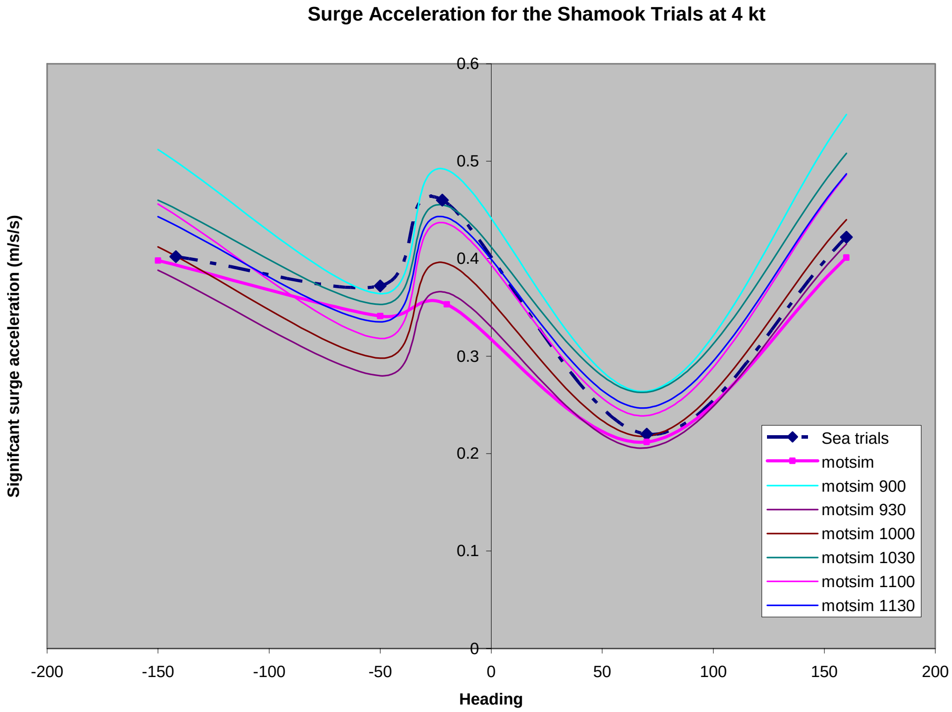

Figure 4. Surge Accelerations for the Shamook (22.9 m); Comparisons of Simulations (Neptune data) and Sea Trials.

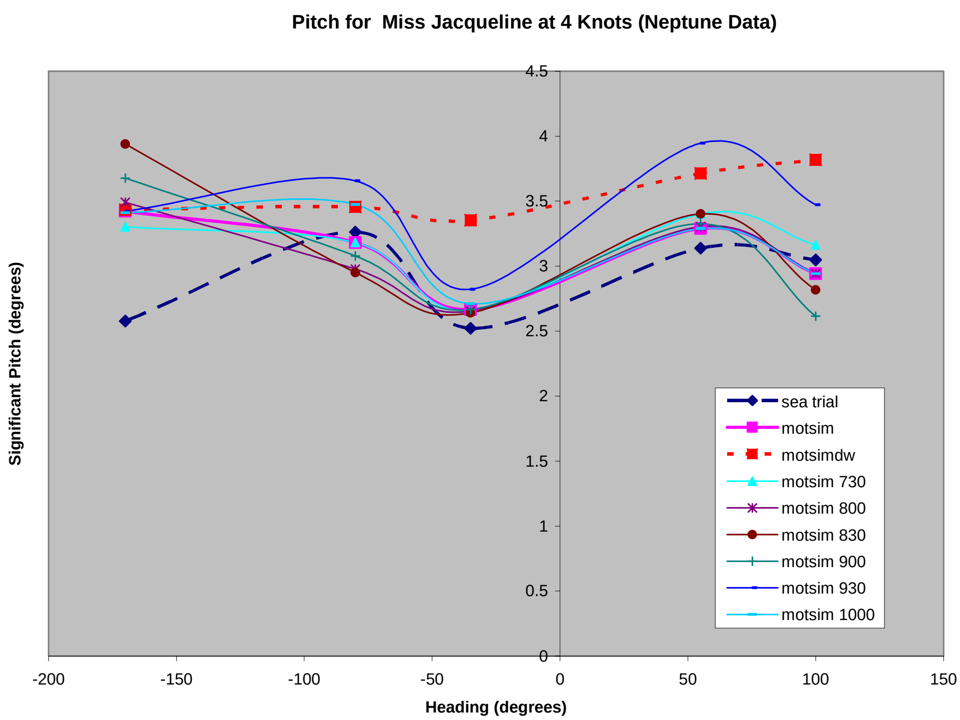

Figure 5. Pitch motions for Miss Jacqueline (19.8 m); Comparisons of Simulations (Neptune data) and Sea Trials .

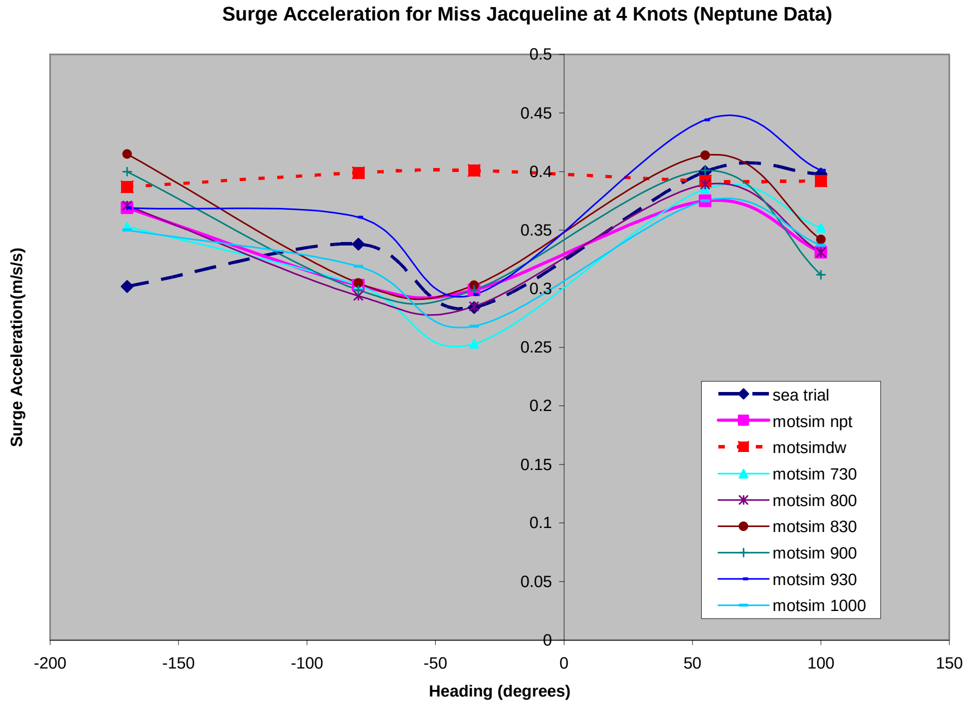

Figure 6. Surge Accelerations for Miss Jacqueline (19.8 m); Comparisons of Simulations (Neptune data) and Sea Trials.

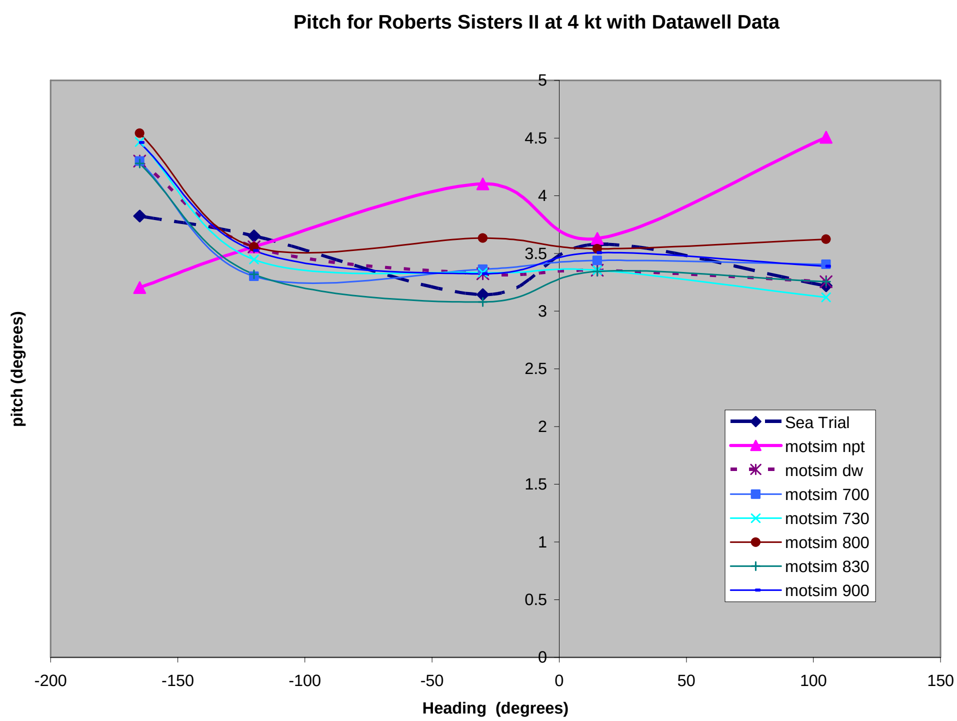

Figure 7. Pitch motions for Roberts Sisters (19.8 m); Comparisons of Simulations (Datawell data) and Sea Trials.

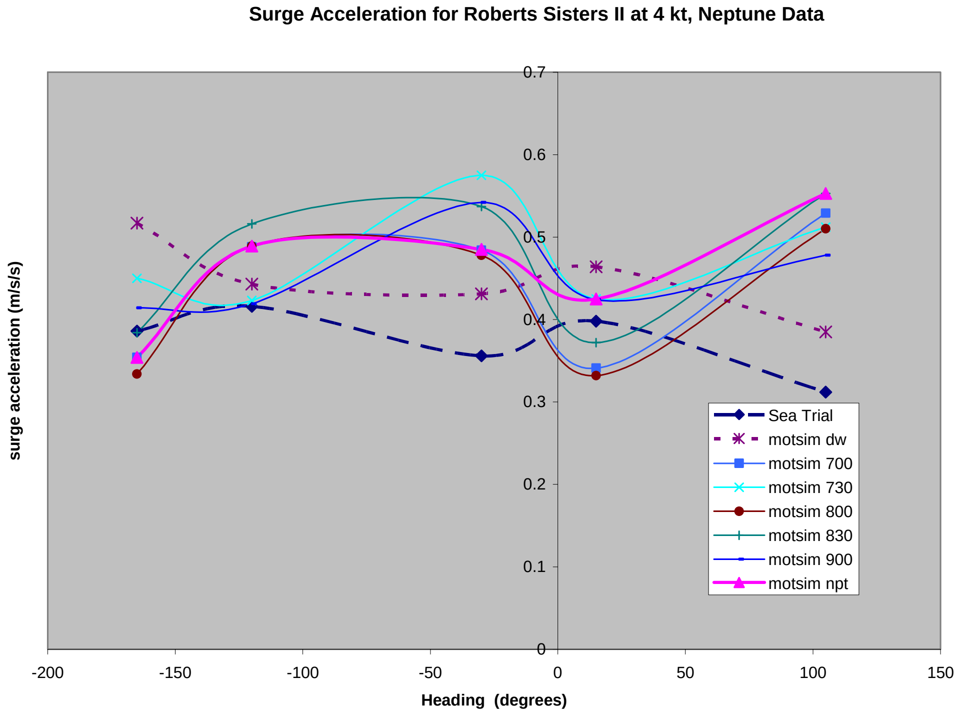

Figure 8. Surge Accelerations for Roberts Sisters (19.8 m); Comparisons of Simulations (Datawell data) and Sea Trials.

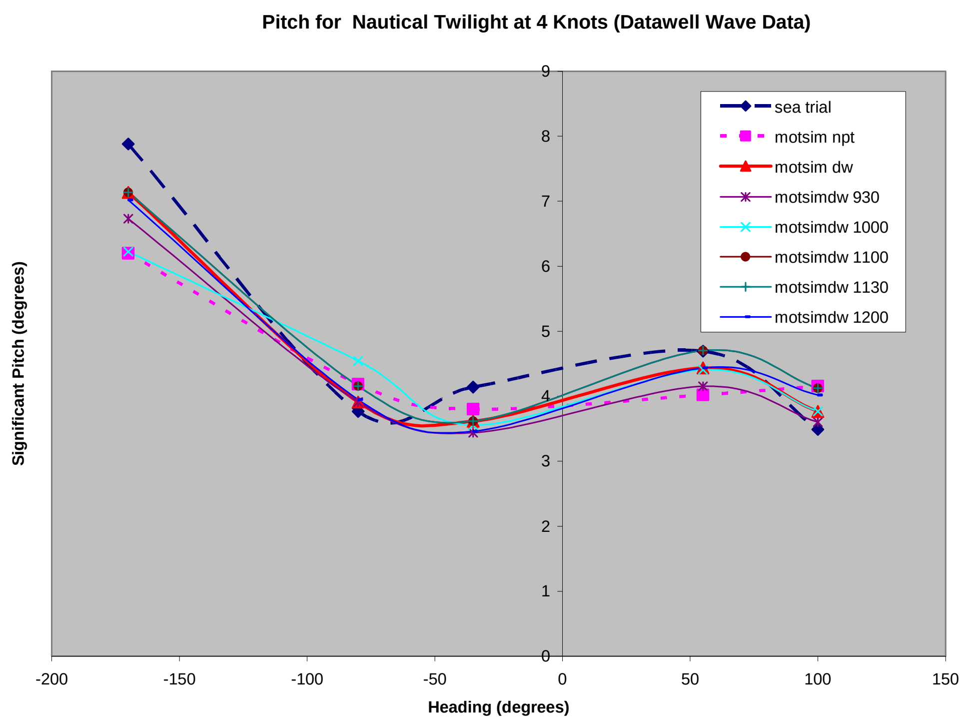

Figure 9. Pitch motions for Nautical Twilight (13.7 m); Comparisons of Simulations (Datawell data) and Sea Trials.

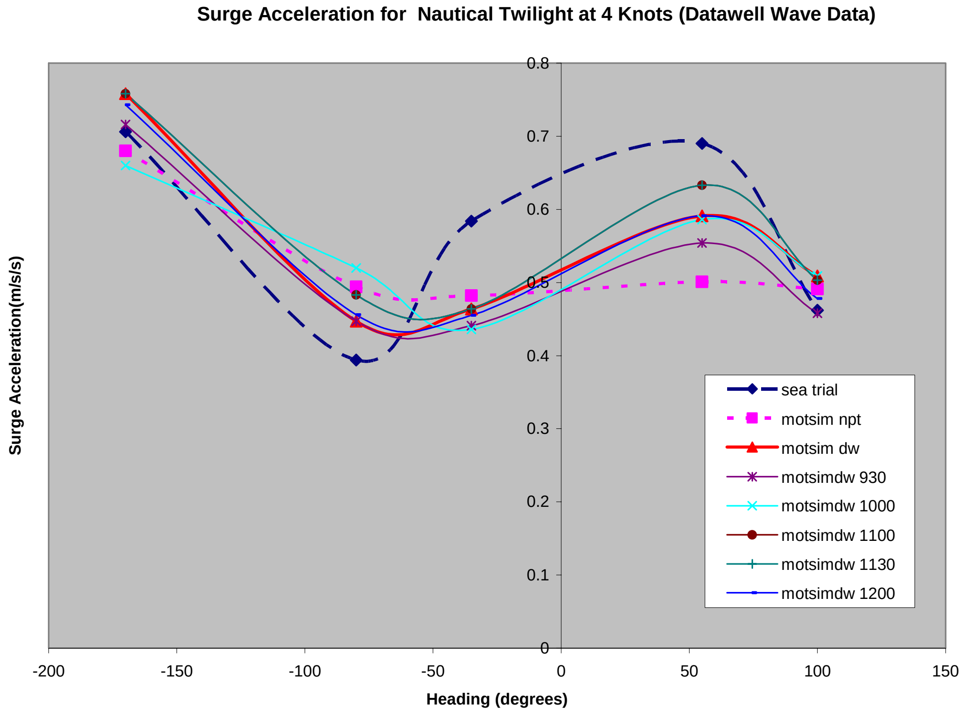

Figure 10. Surge Accelerations for Nautical Twilight (13.7m); Comparisons of Simulations (Datawell data) and Sea Trials.

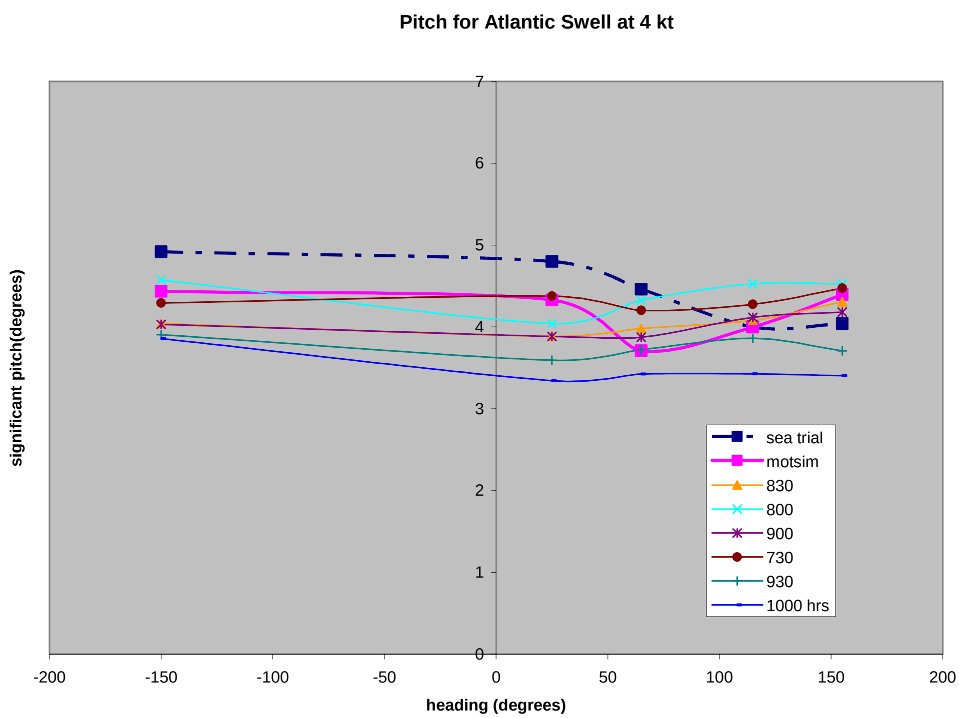

Figure 11. Pitch motions for Atlantic Swell (10.7 m); Comparisons of Simulations (Neptune data) and Sea Trials.

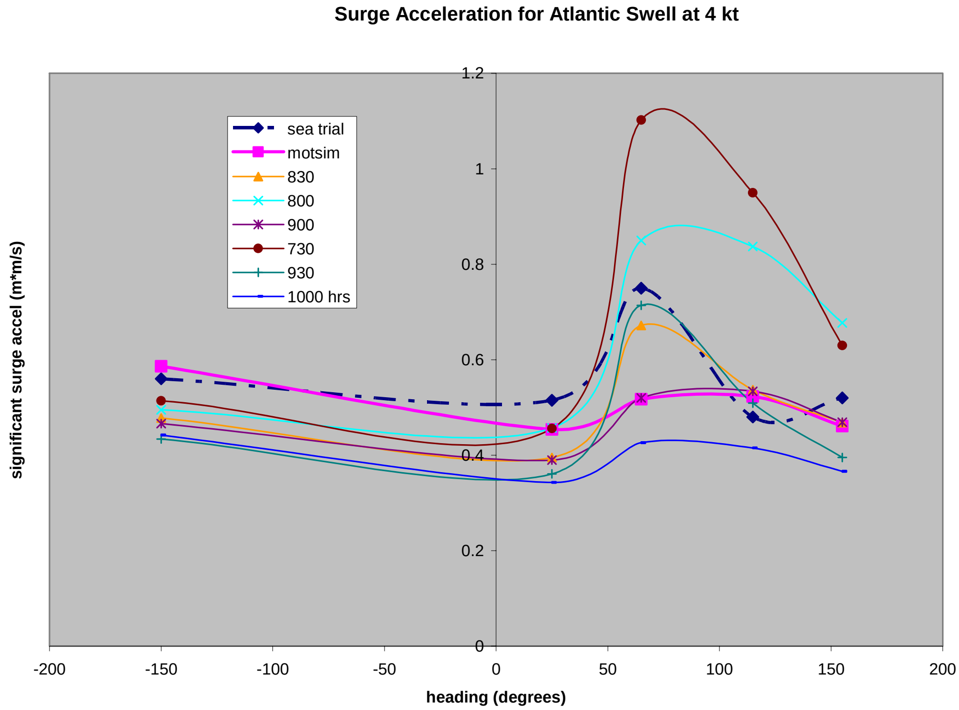

Figure 12. Surge Accelerations for Atlantic Swell (10.7 m); Comparisons of Simulations (Neptune data) and Sea Trials.

The above figures show the results of the simulations using the appropriate wave data recorded at the time of the particular sea trial (approximately). For example if the trial for the heading referred to as bow seas took place at 1200 hours then that is the wave data used to generate the simulated motions at the bow seas heading. These are labeled simply 'motsim' in the legends. Other simulations were carried using one set of wave data for all the headings. For example the 'motsim1200' legend in figure 1 indicates that the wave data recorded at 1200 hours was used to generate motions for all headings. The idea here is to show the possible variation in results due to variations in the wave field representation. In fact in some cases it is clear that the wave field was also changing over the course of the sea trials (e.g. for the CCGA Atlantic Swell trials). It should be made clear that what is referred to as 'head seas' (taken to be 180 degrees) in the trial logs sometimes came out to be quite different based on a more careful analysis of the wave and motion data. Similar remarks apply to other 'named' headings

There is in general a noticeable decrease in prediction accuracy as the vessels decrease in length. The significant wave heights ranged from around 3 m for the Lauzier trial to around 1.5 m for the Atlantic Swell, with the others somewhere in between.

In three of the sea trials shown here (CCGA Miss Jacqueline , CCGA Roberts Sisters and CCGA Nautical Twilight.), wave data were collected from two different wave buoys – a small Neptune wave buoy [14] (20 kg) and a larger Datawell buoy (75 kg). In some of the simulations the Neptune data is mainly used and shown and in others the Datawell data. In each graph, there is one set of data showing results from the other wave buoy. For example in figure 7, most of the simulations are based on the Datawell data, however there is one set of simulations (labeled ‘motsim npt’) for which the Neptune data has been used and is included for comparison. In some cases the results are very similar for both wave buoys and in others there are some clear differences. In some trials, the Neptune based simulations appeared to give better agreement with the sea trial data, but not in others. The reason for that is not clear. What is apparent from these discrepancies is that an accurate modeling of the form of the wave field is vital for good predictions of motions. Generally there were more differences in the predictions of lateral motions (sway, roll and yaw) using the different wave buoy data. These motions are more dependent on wave slope than wave amplitude and that may be less well modeled by the wave buoy wave data representation..

The worst correlation of simulations with sea trial data came from yaw motions. Fortunately yaw motions generally have little effect on the MII rate since they are relatively slow. The yaw motions in the sea trials are dependent on the form of the control parameters for the rudder autopilot and these were not known. In fact in the case of the smallest of the vessels (Atlantic Swell) the vessel was steered by the helmsman –something that is extremely difficult to simulate

4. DISCUSSION

It is apparent from the above results that motions are not always well predicted especially for the smaller vessels. Space does not permit showing all the results. It is apparent however from the above results and from those not shown that generally the correct range of values for each rotational motion or linear acceleration is predicted over the range of headings in the sea trials. For example in the case of surge acceleration for the Nautical Twilight (Figure 10), the range of surge acceleration in the sea trials is 0.4 to 0.7 m/s/s which is also the overall range of values predicted by MOTSIM in the simulations even though heading for heading the results appear less than ideal. A similar remark could be applied to sway acceleration for this vessel (see figure 13) It should be emphasized that there are some doubts over whether the data from the wave buoy(s) and its derived representation as a second order 2 parameter Fourier series represents the sea surface sufficiently well. It is possible that the representation does not sufficiently resolve the changing sea state in the time domain even though it may be adequately resolved in the frequency domain (from a statistical perspective).

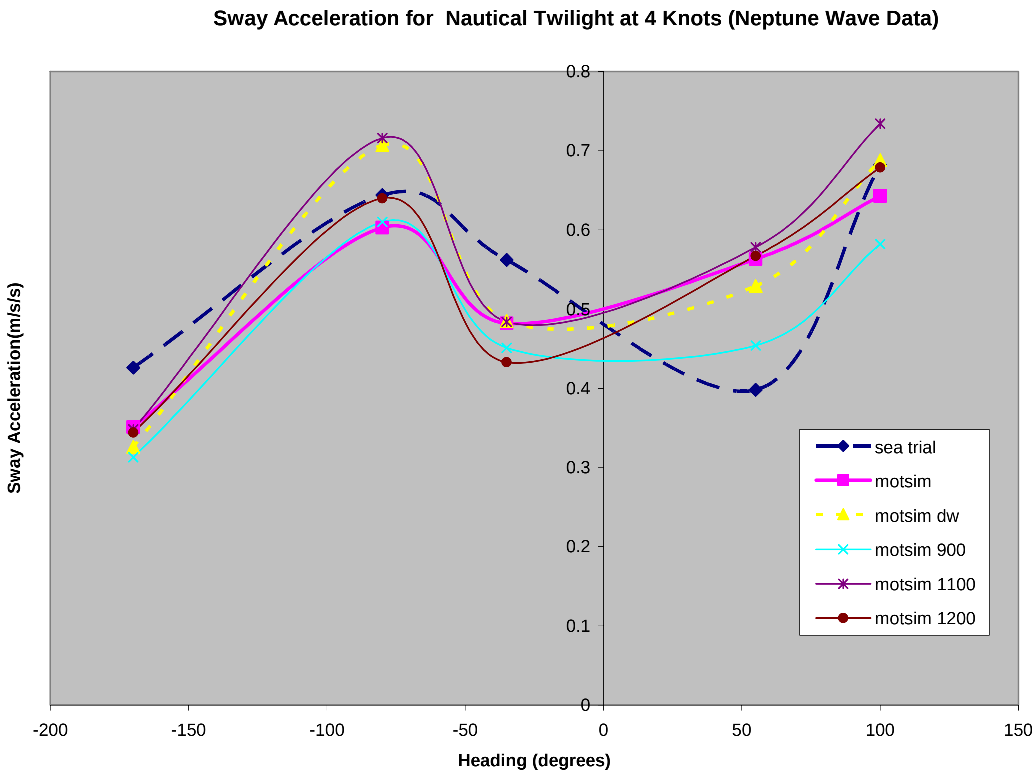

Figure 13. Sway Acceleration *Nautical Twilight*

The motivation for the study was related to the possible assessment of the hazards associated with motions (calibrated from MII's) of fishing vessels using MOTSIM simulations. The question then arises as to whether the above results would give credibility to MII predictions. Firstly it is unlikely that such complex sea states as encountered at the sea trial site (10 nm from St. John's) would persist as the vessels move further offshore. For more unidirectional seas the results (heading for heading) are likely to be better. The Atlantic Swell will probably remain in complex seas and will likely be the most difficult to predict MII's for. Nevertheless it may be fairly claimed that the motion predictions for all these vessels are in the 'right ball park' and that MII's are likely to be at times over-predicted and at others under-predicted, resulting in a generally fair assessment of their magnitudes on average. Note that generally yaw does not play a significant role in MII determination.

An example from a recent study illustrates the usefulness of the predictions in assessing motion stress profiles on vessels of varying lengths and displacements.

Figure 14 shows MII/minute averaged over 5 locations within 5 m of amidships for 4 vessels of varying lengths but similar designs. The parent hull form is a 65 footer (19.8 m) (Chidley). The 80 foot and 100 foot Chidley boats are stretched versions of the parent hull. There is also an 80 foot vessel (designed by TriNav) that is of a similar design but of a deeper draft. The high MII/minute for the Chidley 65 footer are for the vessel at a light displacement (shrimp condition). When the vessel is at a deeper displacement, the comfort level of the vessel increases considerably.

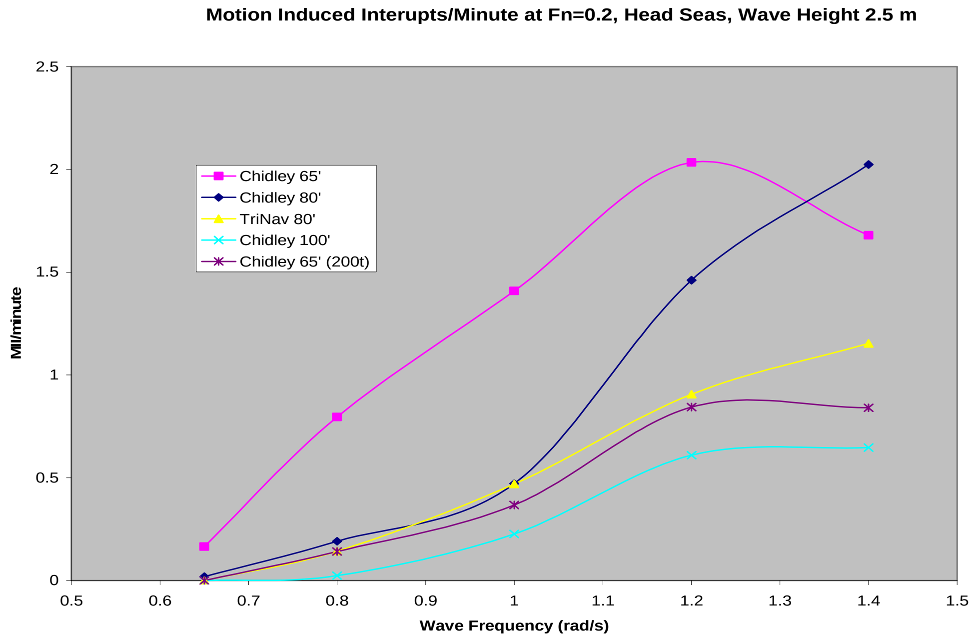

Figure 14. MII/minute for Fishing Vessels of Varying Length in Head Seas.

MII/minute values of greater than 1.6 are considered to be indicative of a significant level of risk of accidents occurring. The 65 foot vessel will quite often be sailing in conditions where this MII level is likely to occur (2.5 m waves are common in spring and fall). The MII/minute values given here are based on averaging values taken from 5 different positions on board the vessel. There are then clearly positions where this level is exceeded. One such position would be in the wheelhouse or on the shelter deck. Positions not considered here, where the levels would be higher, include those further aft and further forward.

The effect of vessel length on MII levels is apparent from figure 14. From other work that has been carried out, it is apparent that these levels increase further for vessels in the 35 foot to 45 foot range. On such vessels fishing in early spring and late fall, when wave conditions are more severe, accidents are more likely to happen. In fact the smaller vessels generally are unable to fish very often at these times of the year, not so much explicitly due to the risk of accidents but rather because the fishers are simply unable to perform requisite fishing tasks due to the excessive motions of their boats.

5. CONCLUSIONS

In this report, some of the results of the correlation study between a time domain numerical code –MOTSIM, and sea trials are presented.

Overall, it seems that the ranges on the motions obtained by MOTSIM match well with the observed ones from the sea trials. Heading for heading the results, on the other hand, appear not so well predicted. Among the reasons suspected for this are

- Doubts on the accuracy of the representations of the measured sea conditions by the wave buoys. Though these representations of the sea states may be adequately resolved in the frequency domain, their time domain representations may not be sufficiently well resolved.
- It appears that the larger the vessel size is, the better the predictions are.
- Issues related to whether an autopilot was in use during the trials or not. Simulating the response of a human skipper has been proven to be very difficult.

In conclusion, the predictions of the present version of MOTSIM are generally better for larger size vessels, while motion predictions for smaller vessels remain a further challenge. It is not clear whether this is more a function of the difficulty in adequately representing (or reproducing) the sea conditions or some general inability of Motsim to predict motions of these small vessels due to an inadequate modeling of the hydrodynamic interactions of waves with small craft. Nevertheless MII predictions for all these vessels should give reasonable estimates of the levels of motion stress to be expected in typical working conditions.

6. FUTURE WORK

At present there is only one set of experimental tests with which to compare the simulations and fishing boat sea trial data (Atlantic Swell). The Lauzier experimental tests were part of another project. The tests on the smallest boat were probably the most difficult to carry out because of the greater sensitivity of the vessel to the wave field representation. It is hoped that model tests on the two 65 foot vessels will be carried out sometime in the next year or so. From these, one might better be able to judge how well tests in a wave tank can reproduce sea trial observations.

As far as validation of Motsim is concerned it would be worthwhile carrying out more sea trials further out to sea where the wave systems encountered are likely to be somewhat less complex. This would help in pinpointing some of the reasons for the discrepancy between the Motsim predictions and the field observations.

ACKNOWLEDGEMENTS

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