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Habitability Considerations Onboard Fishing Vessels of the Newfoundland Fleet

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ABSTRACT

Fishing vessel habitability is a growing issue of concern given the current realities that the Newfoundland fleet has to venture further offshore for more extended periods of time in order to compete for fish stocks. These issues are further complicated by the fact these vessels were not designed to accommodate the harsh ocean and environmental conditions typical of the seasonal dates regulated for harvesting. This paper looks at how such parameters as MII (Motion Induced Interruptions), postural stability vary in different vessels of the fleet. The results are based on the recently conducted sea trials of the five example vessels of the fleet and their corresponding numerical simulations using MOTSIM. MII, or other relevant parameters can be computed for different locations onboard, which might correspond to the locations of different harvesting or operational activities, for given sea conditions. The paper presents results for motion levels as well as human factors related parameters for the vessels used in these sea trials. The lengths of the vessels are 10.7, 13.7, 19.8 and 24.9m, which approximately cover all sizes included in the fleet.

Keywords: crew comfort, MII, fishing vessels

NOMENCLATURE

D_i	Displacements (i = 1 .. 3, in x, y and z directions respectively)
$\ddot{}$	As superscript indicated double derivative
Fr	Froude number
L_{OA}	Length over all
$S_{S,P}$	Sliding estimator for starboard and port
$T_{a,f}$	Tipping estimators for aft and forward
$T_{S,P}$	Tipping estimators for starboard and port
d	See Figure 3
f	Frequency
g	Gravitational acceleration
h	See Figure 3
l	See Figure 3
η_i	Motions (i = 1 ... 6): surge, sway, heave, roll, pitch, and yaw
μ_S	Static friction coefficient

1. INTRODUCTION

This study is a part of a greater initiative called SafetyNet [1]. It aims at the understanding and mitigating the health and safety risks associated with employment in a marine environment. Serving to this objective, this study focuses on assessing the physical stress levels associated with the vessel motions on board fishing vessels of the Newfoundland Fishing Fleet.

With nearly doubled rates of reported injuries and fatalities over the past decades, fishing continues to be a very dangerous occupation in Newfoundland and Labrador. These trends affect the sustainability of the fishery, increase the cost of health care, and strain the available search and rescue resources. In order to achieve the objective, a numerical tool MOTSIM [2] has been developed and has been validated through sea trials and model tests under this study. This tool will enable accurate predictions of motions of fishing vessels, thus the motion related parameters to assess physical/motion stress levels such as MII's and other postural stability indices [3] to [6]. The final objective is to develop means to reduce critical motions of fishing vessels, hence, improve the working conditions on board.

This paper focuses on the different postural stability related parameters. Sample results are shown to map the postural stability indices to the motion profiles for representative vessels of the fleet.

2. SEA TRIALS

Five vessels from the auxiliary fleet of the Canadian Coast Guard were used in these sea trials. The vessels selected varied in size to cover the range of sizes in the Newfoundland fishing fleet. Two of them had anti roll devices installed on board. Table 1 gives brief descriptions of these vessels. Vessels A, B, C1 and C2 in the table are fishing vessels operating on the coastal areas of Newfoundland. Vessel D, on the other hand, is an inshore fisheries research vessel operated by the Canadian Coast Guard [7].

During the trials, each vessel was loaded up to what might be considered "normal working" load conditions. The trials were conducted in nominally 165 m depth of water approximately 10 nm due east of St. John's. The tests followed the ITTC standard run pattern. The target sea conditions would typically range from sea state 2 to 3, with significant wave heights varying from 1 to 2.5m. During the course of each trial, sea conditions would tend to change. Two such changes are given in Figures 1 and 2 for Vessels A and C1 respectively. During the trials of Vessel A, the wave buoy broke down after approximately 10am. Therefore, sea conditions needed to be predicted for the remainder of the day (marked Linear in the legend in Figure 1).

A more detailed description of the vessels and the instrumentation used in their trials is given in [7] through [14].

3. HABITABILITY CONSIDERATIONS

In this study, to assess the habitability on board of fishing vessels two ship motions related parameters will be used: MII [3] and postural stability criteria [15].

3.1 MII's

A motion induced interruption is defined as an incident, caused by ship motions, forcing a person on board either to lose his/her balance or abandon the task s/he is performing to respond to the motions effects. It can manifest itself in three different ways: loss of postural stability, sliding and lift-off. The loss of one's balance is the most frequent type reported. A more comprehensive discussion on the subject can be found in the references from [4] to [6]. In MOTSIM [2], a numerical simulation tool for ship motions, which is under development in this study, MII has been implemented based on the models in the above references. In this model, the human body is treated as a rigid body. It will loose its balance when the tipping moment T exceeds the righting moment provided by the body (see Figure 3). In the figure, the ratio of h/l is called the tipping coefficient. The following equations are given for a person facing aft with roll starboard down and pitch bow down (after Baitis, in [3]).

Slides

$$S_S = (\ddot{D}_2 + g\,\eta_4) - \mu_S\, g, \quad S_S > \mu_S\, g$$

$$S_P = (-\ddot{D}_2 - g\,\eta_4) - \mu_S\, g, \quad S_P > \mu_S\, g$$

Tips

Lateral Tipping

$$T_S = (-\frac{1}{3} h\ddot{\eta}_4 + \ddot{D}_2 + g\,\eta_4) - \frac{l}{h}\ddot{D}_3, \quad T_S > \frac{l}{h} g$$

$$T_P = (\frac{1}{3} h\ddot{\eta}_4 - \ddot{D}_2 - g\,\eta_4) - \frac{l}{h}\ddot{D}_3, \quad T_P > \frac{l}{h} g$$

Longitudinal Tipping

$$T_a = (\ddot{D}_1 + \frac{1}{3} h\ddot{\eta}_5) - \frac{d}{h}\ddot{D}_3, \quad T_a > \frac{d}{h} g$$

$$T_f = (\ddot{D}_1 - \frac{1}{3} h\ddot{\eta}_5) - \frac{d}{h}\ddot{D}_3, \quad T_{fa} > \frac{d}{h} g$$

Table 1 Vessel Descriptions

Vessel	Name	L_{OA}, m	Beam, m	Draft, m	Displacement, t	Notes
A	CCGA Atlantic Swell	10.64	4.27	1.52	16.87	Fiberglass, no anti-roll device
B	CCGA Nautical Twilight	13.69	7.01	3.05	78	Fiberglass, no anti-roll device
C1	CCGA Robert Sisters II	19.79	7.01	3.81	246	Fiberglass, anti roll tanks
C2	CCGA Miss Jacqueline IV	19.80	7.32	3.05	205	Steel hull, paravanes
D	CCGS Shamook	24.89	6.55	3.21	198.6	Steel, no anti roll device

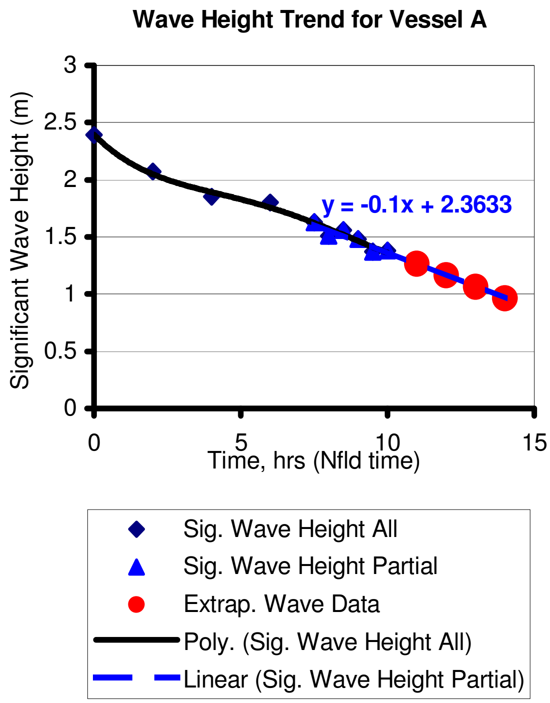

Figure 1 Variation of the significant wave height during the sea trials of Vessel A [8].

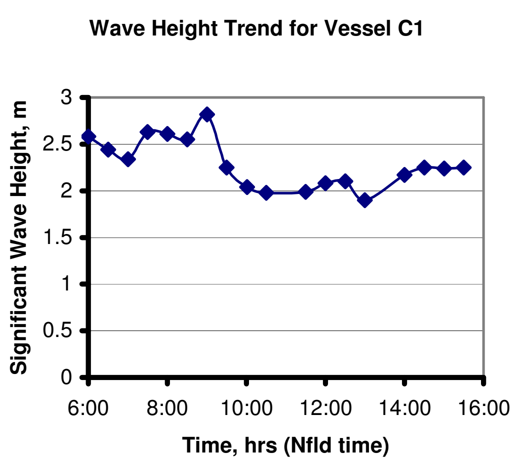

Figure 2 Variation of the significant wave height during the sea trials of Vessel C1 [12].

3.2 Postural Stability Criteria

In a parallel study, Japanese researchers developed a postural stability criterion applicable to fishing vessels [15]. Based on the experiments on their research ship, they established a relationship between ship motions and the ability that a crewmember can maintain his/her balance. They suggested a threshold value as follows:

$$t = M_{1X} + 0.1659\, M_{1Y} + 0.1133\, M_{1Z} < 0.22 \qquad \text{Eqn. 1}$$

Where M_1 is the first moment of a ship acceleration spectrum, the second subscript is the direction, e.g. x, y and z.

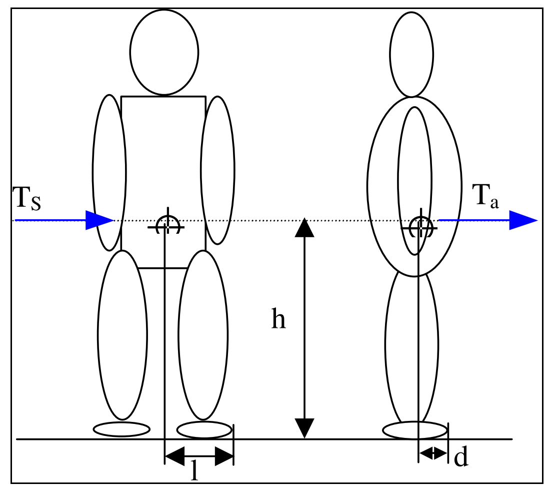

Figure 3 Model for slides and tips for a person on deck (after Baitis, in [3])

4. RESULTS AND DISCUSSION

Using MOTSIM, MII values were computed for different locations on board of Vessel A, CCGA Atlantic Swell. The locations are shown in Figure 4. The computed MII values for this vessel, based on the JONSWAP Wave Spectra with 2m significant wave height and 6.3s modal period, at Fr = 0.2 are given in Figure 5. It is suggested that MII values greater than 1.5 indicate a serious risk location in terms of motion induced interruptions. Location 3 in this case, appears to be a serious risk area based on the above criteria. The least risk location to work on board is in the neighborhood of amid ship followed by the stern area. It is interesting to note that for the lower ship speed, following seas are the most favorable in terms of MII values. However, for overall safety, vessel's stability should also be taken into consideration simultaneously, i.e. dynamic loss of stability in following seas. Head or bow seas proved to be the worst heading for crewmembers to work on all of the locations considered.

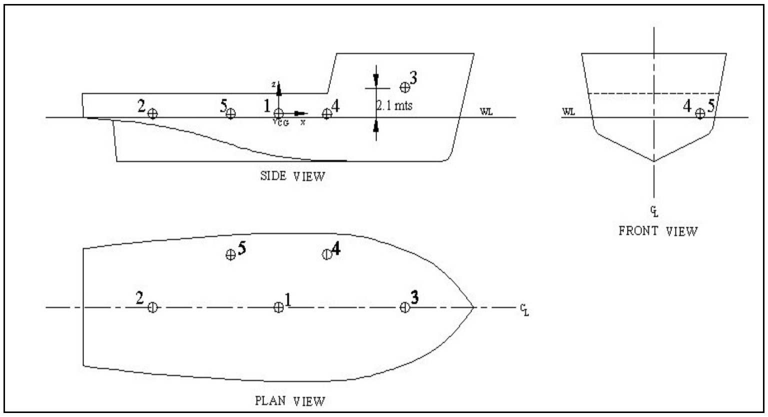

Figure 4 Locations on board Vessel A for MII computations

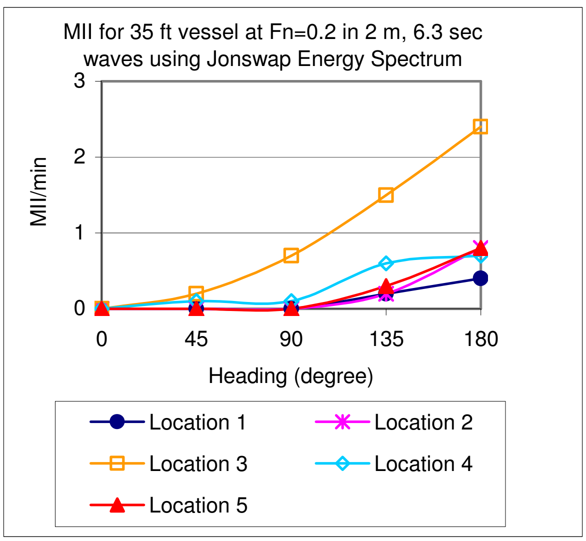

Figure 5 MII per minute computed for Vessel A at Fr = 0.2, based on the JONSWAP Wave Spectrum with 2m significant wave height and 6.3s modal period.

The following figures are given for the *t* values, Eqn 1 above. The orientation of the crewmember was the same as the one assumed in MII calculations, i.e. crewmember facing aft.

Figures 6 and 7 show the t values for Vessels A and C1 respectively. Recall that $t > 0.22$ (Eqn. 1 above) is serious risk region for one's loosing his/her balance. Also note that the motion data used in computing t values for these figures are what were measured during the sea trials. Significant wave height values for these trials are given in Figures 1 and 2. Therefore, there are some differences in the sea conditions for different headings indicated in the figures even for the same vessel. Nevertheless, the sea conditions are assumed to be "close to normal" working conditions for these vessels. Hence, the figures depict a picture in terms of postural stability index t. In both figures, it is clear that working on Location 1, which is in the vicinity of the nominal center of gravity of the vessel, is preferable, i.e. much less risk. In Figure 1, it seems data point for following seas is contradictory to MII comparisons discussed above. There may be few reasons for this: firstly, as reported in [6] and [8], determining the accurate heading during the trials has proven to be a rather difficult task. The terminology 'following sea' probably does not make a great deal of sense in a complex multidirectional sea where a small vessel may respond more to a less dominant directional component of the seaway. Secondly the calculations of MII were based on a unidirectional sea. Thirdly, the motion data show very large yaw angles, i.e. poor course keeping during the runs, which may have been resulted in higher t values.

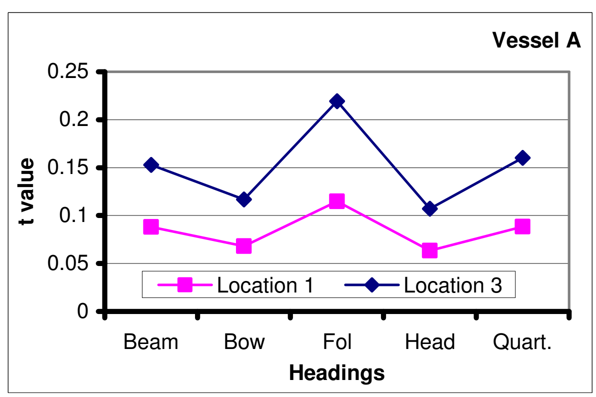

Figure 6 *t* values for Vessel A at Fr = 0.2 (trawling speed) for Locations 1 and 3 given in Figure 4 (crew member facing aft).

5. CONCLUSIONS

In this paper, some of the results of study to assess habitability conditions on board fishing vessels of the Newfoundland and Labrador fleet are presented.

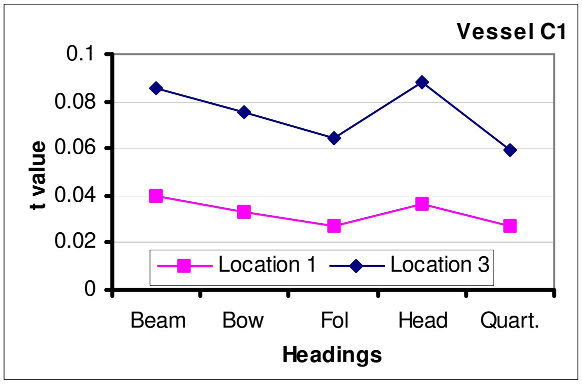

Figure 7 *t* values for Vessel C1 at Fr = 0.18 (trawling speed) for Locations 1 and 3 given in Figure 4 (crew member facing aft).

Two parameters used for this purpose: motion induced interruptions and *t* value (postural stability index). Although further analysis is underway, present results indicated that:

- The two parameters selected to assess habitability show agreement with each other in general terms, i.e. implied (qualitative) risks of losing postural stability are the same.
- The same location on board appears to be the highest risk area, i.e. Location 3, among the locations considered.
- There is some discrepancy between the two parameters in assessing the worst heading. However, this may very well be due to the failure to accurately assessing the heading during the trials and the differences in the sea conditions for which they were calculated.

For further study, the analysis needs to be extended other vessels of the sea trials. Perhaps, in order to better compare the results of the two parameters, MOTSIM can be used to compute the both MII's and *t* values. This would shed a light on effectiveness of these parameters in assessing the habitability.

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