COMFORT ON BOARD EVALUATIONS FOR HIGH SPEED VESSELS

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ABSTRACT: Dynamic nature of sea is a vital issue that certainly influences vessel operational performance and safety in a seaway resulting excessive dynamic loads, motions and accelerations. The literature reveals that absolute vertical accelerations in multiple axes and vibrations due to impacts on hull body are the most influencing parameters on motion sickness incidence (MSI). Actually the MSI seems to be the most adverse discomfort phenomena on humans among the others, those are motion induced interruptions (MII), motion induced fatigue (MIF), high impact injuries (HII) and the like. Obviously motion quality and its discomfort influences on humans are desired to be controlled and optimised in initial design stage by naval architects however reliable quantitative evaluations of discomfort levels are needed. In the case of high speed vessels, their usual light weight and high speed demand require a delicate evaluation on human comfort. This paper presents a state-of-art review of the current literature on comfort on board highlighting concrete design guidelines for high speed vessels.

1. INTRODUCTION

Dynamic nature of seaway influences ship hull body and thus crew and passengers who may encounter with adverse effects due to excessive dynamic loads, motions and accelerations. Ship motions increase the energy loss of human body on board and produce an increased level of fatigue and drowsiness in long voyages (Arribas and Pineiro, 2007). As several authors Rolnick and Lubow (1991) observed that people like car drivers and pilots usually do not get sick as they do control their motion themselves, whereas passive passengers and crew do. The most common adverse effect borne by accelerations of ship motions is defined as motion sickness (kinetosis) or seasickness incidence (MSI). The term ‘motion sickness’ is used to refer not only to vomiting and nausea but also drowsiness, headaches, sweating, stomach awareness, loss of appetite, and various cardiovascular and endocrinal changes (Money, 1991; Uijtdehaage et al., 1993). In fact the symptoms of MSI in general are pallor, cold sweating, nausea and vomiting due to motion (Bos and Dallinga, 2006). Another discomfort phenomenon is Motion Induced Interruption (MII) that may occur when ship motions become sufficiently large having low-frequency, large-amplitude and long-term exposure individuals experience slide or lose balance unless they temporarily abandon their allotted task to pay attention to keeping upright (McNamara and Baitisi 1980). The physical fatigue associated with ship motions is described by the term Motion Induced Fatigue (MIF) referring a bio-dynamic problem. Whole Body Vibrations (WBV) is a result of short or long-term exposures of human body with vessel responses to the environment (Table 1). Thus, operations on a moving platform often induce fatigue and degrade mental effort leading to decreased human performance. In the cases of the imposition of higher frequency vibrations induces corresponding motions and forces within the human body, creating discomfort and possibly resulting in degraded health (Griffin, 1990). Among all discomfort phenomena over individuals motion sickness is rated the worst (Turan et al., 2005).
Comfort on board is expressed as wellbeing quality of individuals (passenger and/or crew) in floating objects in operations. The current article focuses on evaluation techniques of motion sickness of high speed vessels providing with concrete information of the problem that would be useful for design applications.

Table 1. Phenomena describing comfort on board

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motion Sickness (MSI)</td>
<td>Low-frequency, short- and long-term exposure (habituation)</td>
</tr>
<tr>
<td>Motion-Induced Interruption (MII)</td>
<td>Low-frequency, large-amplitude, short-term event</td>
</tr>
<tr>
<td>Motion-Induced Fatigue (MIF)</td>
<td>Low-frequency, large-amplitude, long-term exposure</td>
</tr>
<tr>
<td>Whole-Body Vibration (WBV)</td>
<td>Medium/High-frequency, tolerable exposure determined by severity of motion</td>
</tr>
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</table>

2. EVALUATION OF MOTION SICKNESS INCIDENCE

The MSI is a vestibular related discomfort implying both real and illusory motion exposure perceived by our senses. Motion effects may drive an autonomic response that can lead emesis if not blocked (Dahlman, 2009). The MSI performance of a vessel is desired to be within the limits given by standards for human effectiveness (see Table 2). The MSI prediction algorithms used today is based on the work of O’Hanlon and McCauley (1974) and the ISO Standard 2631-1. Figure 1 shows predicted MSI rating obtained by the procedure of O’Hanlon and McCauley. Ship Motion Simulator developed by McCauley et al. (1976) suggested that it is mainly the vertical component of ship motion that causes sea sickness.

Table 2: Seakeeping performance criteria for human effectiveness in rms (NORDFORSK 1987).

<table>
<thead>
<tr>
<th>Vertical Acc.</th>
<th>Lateral Acc.</th>
<th>Roll Motion</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20 g</td>
<td>0.10 g</td>
<td>6.0°</td>
<td>Light Manual Work</td>
</tr>
<tr>
<td>0.15 g</td>
<td>0.07 g</td>
<td>4.0°</td>
<td>Heavy Manual Work</td>
</tr>
<tr>
<td>0.10 g</td>
<td>0.05 g</td>
<td>3.0°</td>
<td>Intellectual Work</td>
</tr>
<tr>
<td>0.05 g</td>
<td>0.04 g</td>
<td>2.5°</td>
<td>Transit Passengers</td>
</tr>
<tr>
<td>0.02 g</td>
<td>0.03 g</td>
<td>2.0°</td>
<td>Cruise Liner</td>
</tr>
</tbody>
</table>

Among the research efforts in the evaluation of the MSI the most recent and robust model seems to be the works of Bos et al. (see Bos and Bles, 1998; Bos and Dallinga, 2006; Bos et al., 2007; Turan et al., 2005). Referring the findings of the European project COMPASS, Bos and Dallinga (2006) reported that observation of Griffin (1990) at sea and the ISO (ISO, 1997) gave a more generic description of motion sickness in terms of a Motion Sickness Dose Value (MSDV). Thus MSDV is expressed as

\[ MSDV = a_w \sqrt{t} , \]

\[ a_w = \sqrt{\sum (w_i a_i)} , \]

where \( t \) is the time of exposure, \( a_w \) denotes frequency weighted \( (w_i) \) acceleration and \( a_i \) the specific acceleration component at the frequency (band) \( i \).

The proposal revealed also that next the local vertical motion, the local sway motion contributes was the second most important contributor to seasickness. The quantification should carefully take into account roll motion affect on lateral acceleration. Following the analogy of the ISO approach, better physical description was obtained by using \( a_v \) instead of \( a_w \) (or \( a_{wz} \)) only, with

\[ a_v = \sqrt{k_h (a_{wx}^2 + a_{wy}^2 + a_{wz}^2)} , \]

\( a_{wx} \) and \( a_{wy} \) as recorded in a ship fixed frame of reference. The coefficient \( k_h \) represents weight of the horizontal acceleration vector-sum with the vertical component. Finally they define an illness rating (IR) as
\[ IR = K \cdot MSDV, \]
\[ IR = K \cdot a\sqrt{t}, \]  

Where \( K \) is the proportionality constant highly depended on age, gender and sickness history of individuals (scaled from 0 to 3).

3. DISCUSSION OF MSI CONSIDERATIONS ON DESIGN

Motion sickness incidence is functionally characterized by ship motions and environmental influences exposed by individuals. MSI is desired to be an optimal between human and non human subsets. The social aspect of MSI is important that a fixed standard does not valid for all individuals since that the habituation, susceptibility based upon physiological characteristics and personality factors would vary. Thus a reliable the quantification of MSI requires taking into account all accelerations in the 6 degree of freedom as well as social references of age, gender and sickness history. Particularly for the latter multidisciplinary research efforts have been in progress considering the current literature. The major priority in optimizing the MSI for a ship design is human health and wellbeing. The optimal MSI defines and efficient person-machine system that would perform the continuity of safe riding, task force and mission effectiveness.

The MSI quantification for high speed vessels requires a careful analysis of ship motions using appropriate tools. The importance of survey studies has been sufficiently demonstrated in the literature as well as the experimental ones that certainly define acceptable convergence with the computed data (Khalid et al., 2010).

An approximate model of the MSI evaluation can be embedded in a concept design model that can define a feasible concept design space. Actually some robust numerical techniques such as artificial neural networks and expert systems are able to set the relations between ship motions/accelerations and design variables. As current author has implemented previously, the computed RAOs of motions and accelerations of statistically sufficient number of candidate vessels can be modelled (Alkan, Nabergoj and Trincas, 2005). The RAOs model is expressed in function of a set of design variables composed of main dimensions and other significant parameters for a constant speed of advance and wave parameter. The model can be extended to compute statistical response spectrums by inserting seaway statistical data of given seaway that would be input for MSI evaluations.

Human element in the design should be considered earlier. Locating critical stations near the effective center of rotation of a ship is advantageous. The design should consider head movements of individuals. Minimized head movements are desired to overcome motion induced sickness and fatigue. The operator should be aligned with a principal axis of the hull. The design should not accommodate combining provocative sources of motion sickness. The reflect of human element on ship design requires a multidisciplinary team effort.

High speed small crafts produce instantaneous and higher accelerations with respect to large ones. Researchers demonstrated that specially designed seats for the use of operators and individuals remarkably lowered motion induced effects (Dobbins et al. 2008).

4. CONCLUSIONS

Evaluation of comfort on board for high speed marine vehicles has a difficult nature surrounded by human element, ship motions, ocean environment and ship itself. The motion sickness constitutes the most dominant influence on the comfort on board quality of marine vehicles. The design impact of motion sickness must properly take role in the concept design level. The naval architects should endeavour incorporating ‘human factor engineering principles’ in ship design.

5. REFERENCES


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