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The overall motion sickness incidence applied to catamarans

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ABSTRACT: *The Overall Motion Sickness Incidence is applied to the hull form optimization of a wave piercing high-speed catamaran vessel. Parametric hull modelling is applied to generate two families of derived hull forms, the former varying the prismatic coefficient and the position of longitudinal centre of buoyancy, the latter instead the demi-hull separation. Several heading angles are analysed in a seaway, considering all combinations of significant wave height and zero-crossing period under two operating scenarios. The optimum hull is generated and vertical accelerations at some critical points on main deck are compared with the parent ones. Finally a comparative analysis with the results obtained for a similarly sized monohull passenger ship is carried out, in order to quantify, by the OMSI, the relative goodness in terms of wellness onboard of monohulls and catamarans, as a function of sea states and operating scenarios.*

KEY WORDS: Overall motion sickness incidence; Catamarans; Hull form optimization.

INTRODUCTION

During the last decade the high-speed waterborne transportation became more and more important, together with the growing interest in developing safer and more comfortable fast ships, capable of being competitive for both domestic, cross-strait and international passenger ferry markets (Fang and Chan, 2007). In this respect, to increase passenger ships' seakeeping performances, designers proposed a wide variety of arrangements, ranging from classical mono-hulls to multi-hulls, mainly with catamaran or SWATH configuration. From this point of view, it is well known that mono-hulls show slower wave induced vertical accelerations (Marón and Kapsenberg, 2014), compared to similarly sized catamarans, especially in moderate and rough sea conditions (Bouscasse et al., 2013), while multi-hulls, catamarans among others, seem to be the most attractive solution in calm and slight seas, thanks to larger deck areas and good transverse stability.

Following the first hydrodynamic experiences on multi-hulls carried out by Everest (1968), many researchers, Insel and Molland (1992), Molland et al. (1995) and Muller-Graf et al. (2002) among others, performed both theoretical and experimental studies, devoted to the assessment of resistance performances of catamarans, paying attention to both demi-hull forms, dimensions and transverse separation. Around the same time the initial pioneering works, devoted to seakeeping analysis of catamarans, were carried out by Kogan (1971), Wahab et al. (1971), Belenky et al. (1979) and subsequently were followed by a variety of theoretical and experimental studies, carried out by many researchers, Faltinsen et al. (1991) among others. In this respect, the improvement of comfort level onboard passenger ships, and the consequent reduction of motion sickness incidence, have been always considered the most important design factors, especially for high-speed vessels (Campana et al., 2009; Diez

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and Peri, 2010). The initial studies regarding the motion effects on humans, sponsored by the US Navy in the early 1970's, were carried out by O'Hanlon and McCauley (1974), who conducted a series of experiments on over 500 subjects, exposed to the effects of various combinations of motion frequencies and magnitudes up to two hours, finding that the main sickness cause is the vertical component of the motion. After the development of the first mathematical model by O'Hanlon and McCauley (1974), namely the Motion Sickness Incidence, Lawther and Griffin (1987; 1988) carried out similar studies on car ferries operating in the English Channel and analysed the consequent sickness among passengers. They obtained similar results, in the correlation between MSI and vertical acceleration, but they also found that both roll and pitch motions, even if not provoking sickness in themselves, when combined with heave, may produce more seasickness than predicted by classical models (Wertheim et al., 1998).

As is well known, all motion sickness indices are highly site dependent, as ship vertical acceleration on main deck varies along the ship length and breadth, depending on the heading angle between the vessel route and the prevailing sea direction (Sariöz and Sariöz, 2005; 2006). In this respect, to estimate more reliably the sickness incidence onboard passenger ships, the Overall Motion Sickness Incidence OMSI proposed by Scamardella and Piscopo (2014a), may fulfil this lack and furnish more reliable values of the comfort level onboard passenger ships. In this paper the OMSI is chosen as a parameter to estimate the seakeeping qualities of a high-speed catamaran, varying both demi-hull separation and hull forms. Starting from a wave piercing high-speed catamaran, assumed as a parent hull, a parametric study (Cakici and Aydin, 2014) is carried out, systematically varying both the demi-hull separation and the hull prismatic coefficient. Various heading angles are analysed, under all statistically relevant combinations of significant wave height and zero-crossing period for Mediterranean Sea region, in order to obtain the most reliable value of the above mentioned index. Finally, the obtained results are compared with those ones presented by Scamardella and Piscopo (2014a), for a similarly sized mono-hull at the same speed, to highlight the different behaviour between mono and multi-hulls in terms of comfort levels onboard, as a function of both significant wave height and zero-crossing period.

MOTION SICKNESS EVALUATION

The overall motion sickness incidence

The main parameter to estimate the passenger comfort onboard is the ship vertical acceleration, combined with both roll and pitch motions. The Motion Sickness Incidence (MSI) is defined as the percentage of passengers who vomit after 2 hours of exposure to a certain motion and is given by:

$$MSI = 100\left[0.5 + erf\left(\frac{\log_{10}\left(0.798\sqrt{m_4}/g\right) - \mu_{MSI}}{0.4}\right)\right] \tag{1}$$

where the factor μ_{MSI} is defined as follows, according to O'Hanlon and McCauley (1974):

$$\mu_{MSI} = 0.654 + 3.697\log_{10}\left(\frac{1}{2\pi}\sqrt{\frac{m_4}{m_2}}\right) + 2.320\left[\log_{10}\left(\frac{1}{2\pi}\sqrt{\frac{m_4}{m_2}}\right)\right]^2 \tag{2}$$

or, alternatively, by the following equation proposed by Lloyd (1998):

$$\mu_{MSI} = -0.819 + 2.32\left[\log_{10}\left(\sqrt{\frac{m_4}{m_2}}\right)\right]^2 \tag{3}$$