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COMPARATIVE SEAKEEPING ANALYSIS OF A CLASS OF MAXY-YACHTS

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ABSTRACT

Comfort evaluation of mega-yachts has always been a measure of design refinement; in an increasing demand for luxurious accommodations and personalized profiles, the seakeeping performance is the unseen attribute that brings most of the comfort touch during a voyage aboard these engineering marvels. This paper is a continuation of a previous study, using the final forms of the new design inspired by the existing "Yacht A", and represents the complete comparative seakeeping analysis related to its performances compared to the results of a class of maxi-yachts designed in Italy to operate in the Caribbean area.

Keywords: seakeeping, mega yacht, yacht design.

1. INTRODUCTION

The evaluation of comfort on-board is a key issue during the design process for yachts and mega yachts [3]. In a previous paper the related aspects have been identified and some preliminary evaluations regarding the seakeeping qualities have been carried out. The main idea was to define a new design which could be of interest in the Black Sea area.

Table 1 Main characteristics of the maxi-yachts

Item	**Yacht A**	Yacht C	Yacht M	Yacht Z
L_{PP} (m)	**56.84**	63.00	63.00	63.00
Beam (m)	**9.51**	12.20	12.20	12.20
Z_{CG} (m)	**3.006**	3.720	3.600	3.720
Total mass (t)	**1027.0**	1027.0	1030.6	1026.0
X_{CG} (m)	**32.508**	32.727	32.784	31.504
Draught (m)	**2.307**	3.020	2.900	3.020

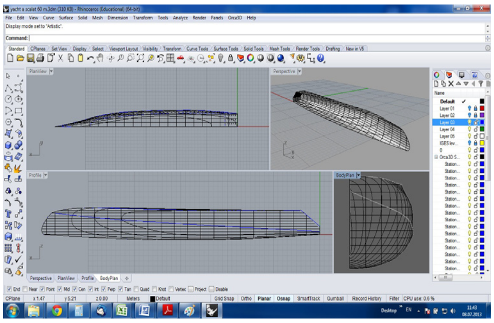

Fig.1 Lines plan of new "Yacht A"

To this purpose, an already existing mega yacht ("Yacht A") designed and built in Germany was considered as a basis to find out a solution of completely new fashion forms which allow for a generous area and better comfort on board. Mention should be made that the forms and the characteristics of the proposed new design (Yacht A) have been adapted to a much smaller scale and were not developed based on an already existing body plan.

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In order to be able to have a comparison basis regarding the seakeeping qualities of the proposed new design, three different mono-hull vessels of the same displacement, i.e. three maxi yachts designed to operate in the Caribbean Sea, have been considered. The main characteristics are summarized in Table 1 and the body lines in Fig. 1, 26, 27 and 28. More detailed information can be found in the previous paper [2].

2. CALCULATION OF SEAKEEPING PERFORMANCES

As compared to the previous study, after refining the body lines, the seakeeping calculations have been reconsidered. Moreover, in order to have a better evaluation of the yacht's behaviour, a greater number of heading angles have been considered, in the range of 60º - 180º with a step of 15º. At the same time, the cases referring to aft quartering and following seas have been neglected in order to be reconsidered from the point of view of stability evaluation in this special case. Consequently, the final headings angles have been 60º, 75º, 90º, 105º, 120º, 135º, 150º, 165º and 180º.

The evaluation has been performed using a computer code based on the well-known theory developed by Salvesen, Tuck and Faltinsen [4]. The program is able to calculate the amplitudes and phases for all six degrees of freedom, i.e. surge, sway, heave, roll, pitch and yaw motions as well as the hydrodynamic loads for any heading angle in regular waves. The main assumptions of the program refer to the nature of the fluid, considered to be inviscid. Considering that the ship's length is much larger than the beam and draft, the displacements of the ship and the waves are small. In other words, the slender body theory is assumed and the three dimensional hydrodynamic quantities are expressed in terms of the solution to the sectional two-dimensional problem of a cylinder with the same shape as the individual cross-sections oscillating on the free surface. The program is using the "close fit source distribution technique" developed by Frank. The nonlinear roll damping is introduced using Tanaka method.

The evaluation of the Response Amplitude Operators (RAO) of motions of the yachts are performed in the frequency domain allowing the determination of the behaviour of the floating body using appropriate sea spectra formulation for different sea states [1].

The spectral analysis will be used later for the stochastic approach which creates the possibility to evaluate the statistic values necessary as input data. A very important output is the determination of the accelerations at any defined point of interest which allows the evaluation of the dynamic forces to be used for strength analysis and scantling as well as for the determination of the comfort indexes to be compared to the recommended ones. The level of the accelerations along the hull represents the most important parameter in determining the percentage of passengers who will become seasick during a given length of a trip [3]. These evaluations, for the Black Sea area, will be performed in a next stage.

The results are presented synthetically, as mentioned above, in diagrams showing the amplitude of the oscillation and the wave amplitude ratio against the circular frequency of the incident wave, i.e. RAO's. All diagrams are represented graphically for all heading angles considered in this study for each yacht separately:

- Yacht A in Fig. 2 – Fig. 7;
- Yacht A in Fig. 8 – Fig. 13;
- Yacht A in Fig. 14 – Fig. 19;
- Yacht A in Fig. 20 – Fig. 25.

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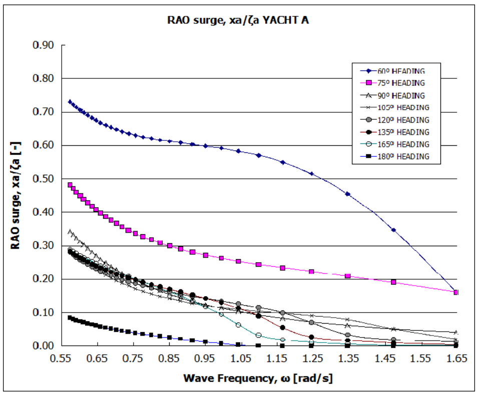

Fig. 2 RAO's surge motions for Yacht A

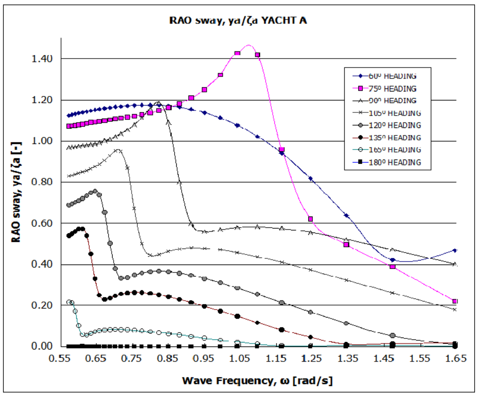

Fig. 3 RAO's sway motions for Yacht A

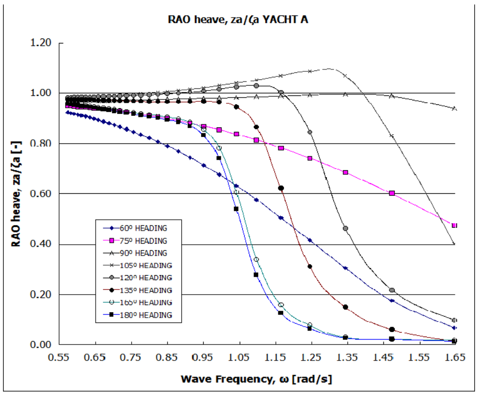

Fig. 4 RAO's heave motions for Yacht A

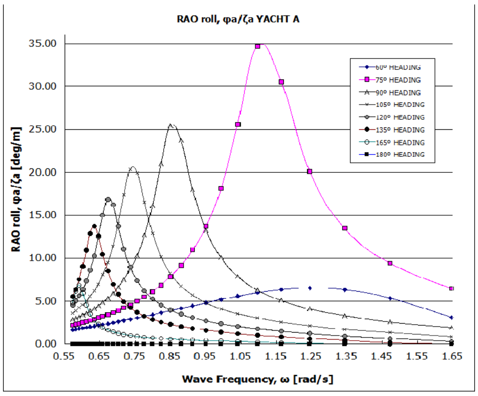

Fig. 5 RAO's roll motions - Yacht A

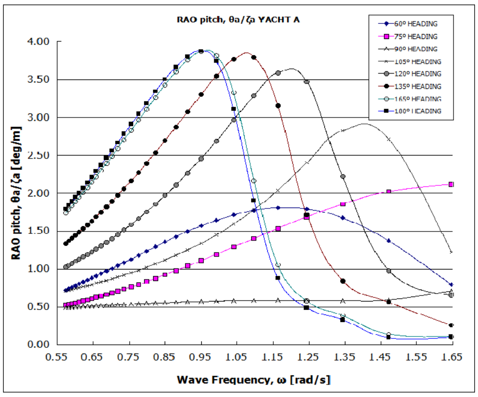

Fig. 6 RAO's pitch motions for Yacht A

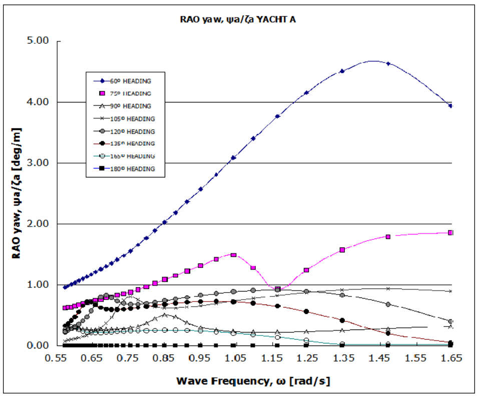

Fig. 7 RAO's yaw motions for Yacht A

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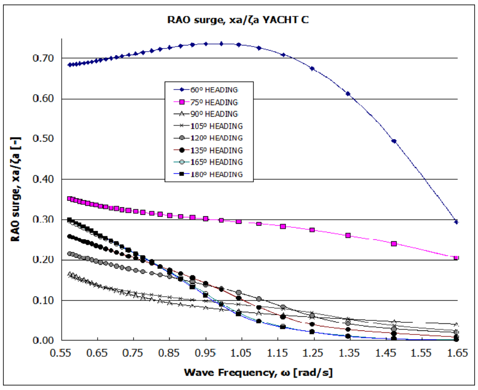

Fig. 8 RAO's surge motions for Yacht C

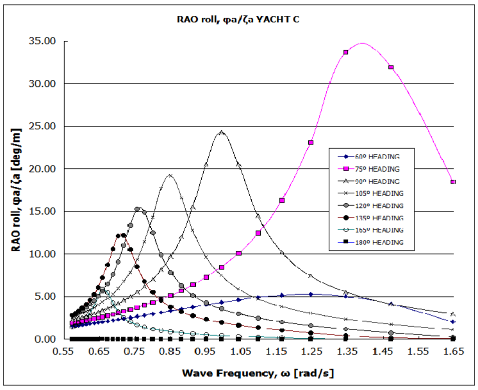

Fig. 11 RAO's roll motions for Yacht C

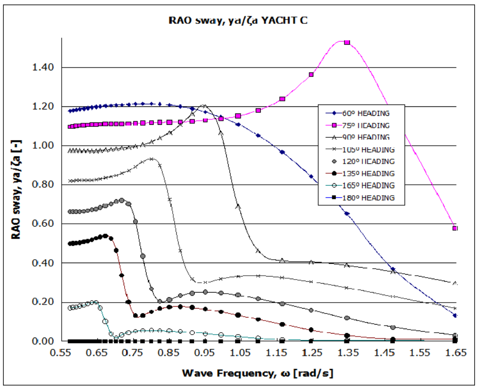

Fig. 9 RAO's sway motions for Yacht C

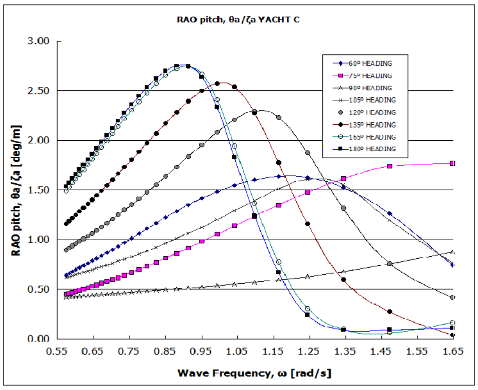

Fig. 12 RAO's pitch motions for Yacht C

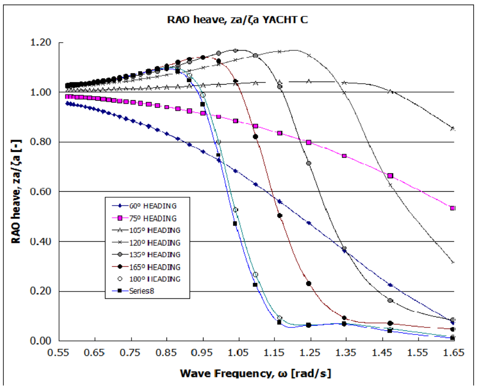

Fig. 10 RAO's heave motions for Yacht C

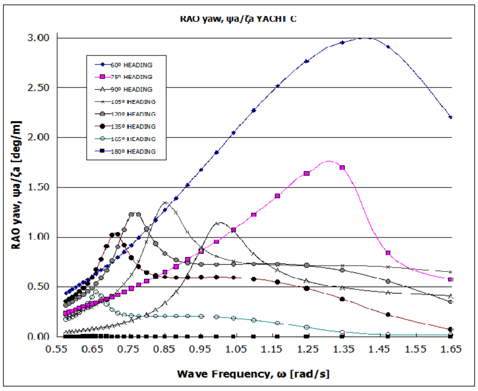

Fig. 13 RAO's yaw motions for Yacht C

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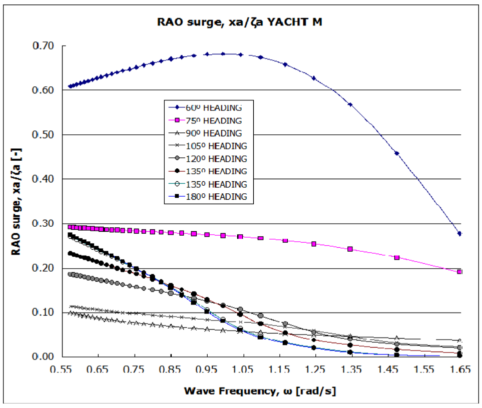

Fig. 14 RAO's surge motions for Yacht M

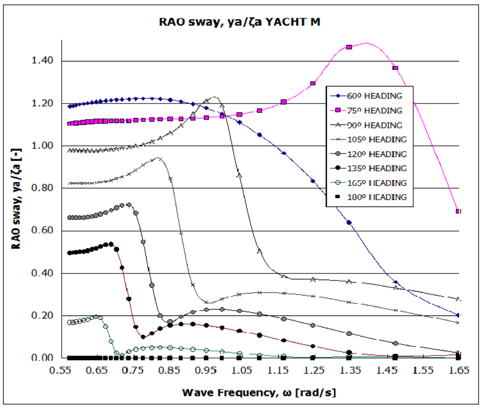

Fig. 15 RAO's sway motions for Yacht M

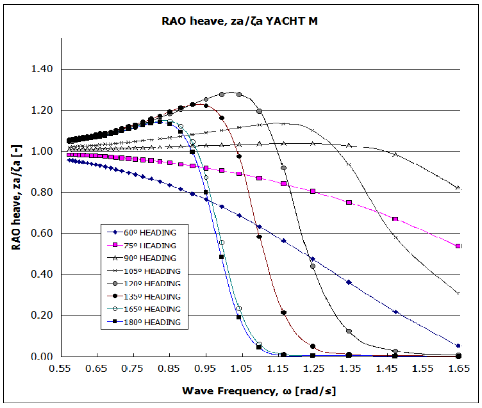

Fig. 16 RAO's heave motions for Yacht M

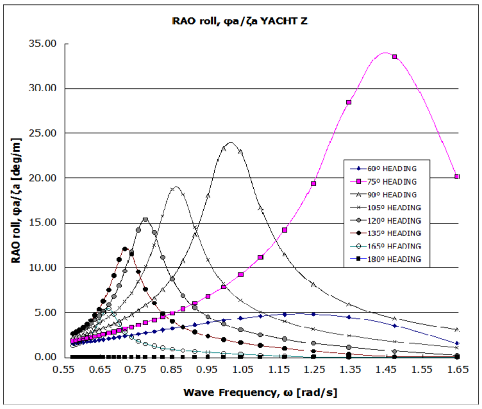

Fig. 17 RAO's roll motions for Yacht M

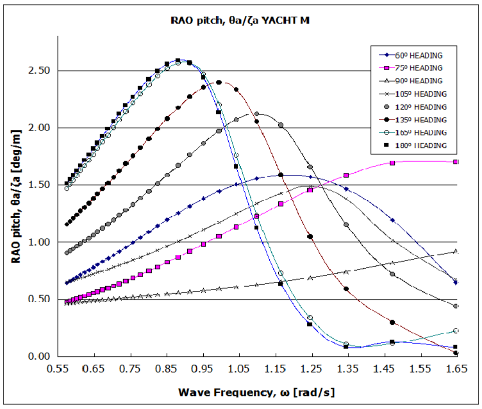

Fig. 18 RAO's pitch motions for Yacht M

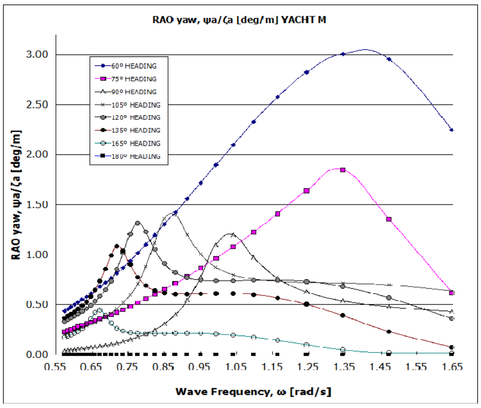

Fig. 19 RAO's yaw motions for Yacht M

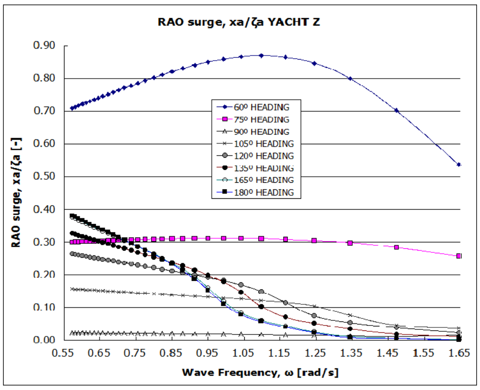

Fig. 20 RAO's surge motions for Yacht Z

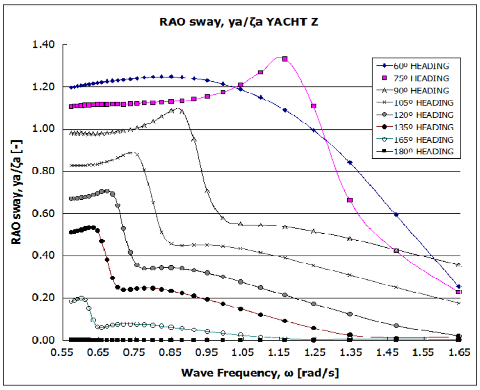

Fig. 21 RAO's sway motions for Yacht Z

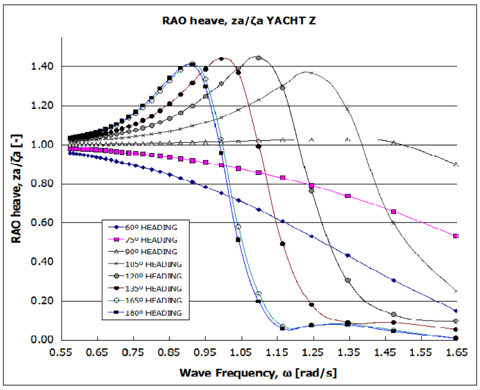

Fig. 22 RAO's heave motions for Yacht Z

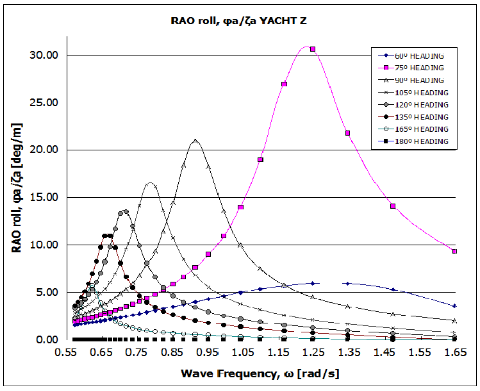

Fig. 23 RAO's roll motions for Yacht Z

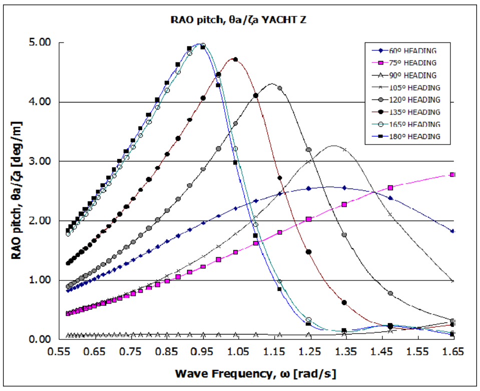

Fig. 24 RAO's pitch motions for Yacht Z

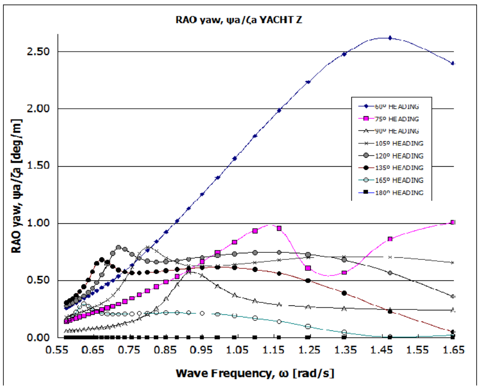

Fig. 25 RAO's yaw motions for Yacht Z

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3. CONCLUSIONS

In order to have a better image related to the type of forms used in the present work, the body plans of the yachts used for the comparative evaluation are presented in Figure 26 (Yacht C), Figure 27 (Yacht M) and Figure 28 (Yacht Z). As previously mentioned, the displacements and the lengths have been kept constant for all versions.

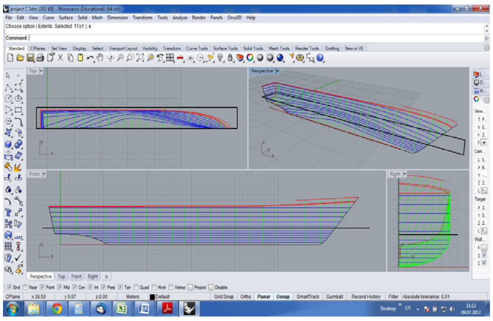

Fig.26 Lines plan of "Yacht C"

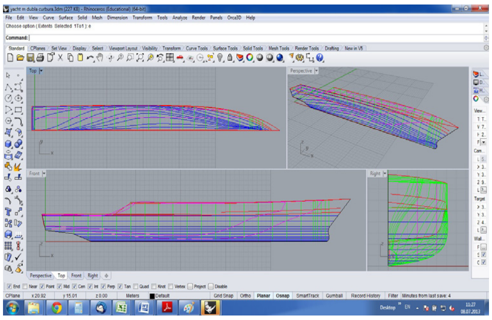

Fig.27 Lines plan of "Yacht M"

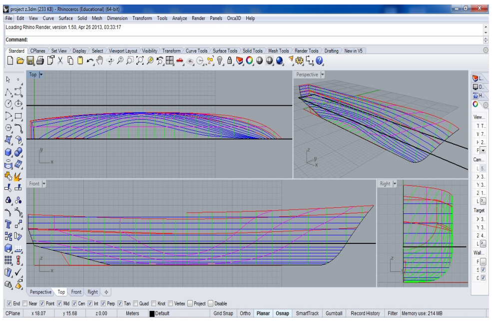

Fig.28. Lines plan of "Yacht Z"

After some improvements and refinements of the hull form of Yacht A, the comparative evaluation of seakeeping performances (RAO's), as compared to those of the "classic" Yacht C, Yacht M and Yacht Z, revealed quite similar behaviour which can be considered a good start in order to be able to continue the comfort analysis.

Surge, sway and heave motions are almost the same and no further modifications are expected as far as the forms of Yacht A which are already defined and the mass distribution has practically no influence. Yaw motions are very similar for all four yachts.

As regarding roll and pitch motions, they are higher for yacht A as compared to the other, but mention should be made that the inertial properties have been based on statistical formulae.

The following steps to be performed will be based on some more detailed information regarding the Yacht A and will consist in:

- Spectral analysis of the motions responses using the spectral formulation for the Black Sea;
- Calculation of the accelerations in different areas of interest on-board for a range of sea states;
- Evaluations of the Motion Sickness Incidence (MSI) which represents the average percentage of people suffering from seasickness after 2 hours of exposure to a given level of vertical acceleration.

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