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SEAKEEPING ASSESSMENT FOR A 12000TDW OIL TANKER

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ABSTRACT

The paper presents a numerical investigation into the seakeeping performance of an oil tanker. The numerical analysis was performed by using the 3D potential flow linear method. The hydrodynamic calculation was carried out in order to predict ship motions in regular waves. Ship response in terms of RAO functions (response amplitude operator) was achieved and discussed.

Keywords: ship motions, 3D potential flow, regular waves.

1. INTRODUCTION

An important criterion in ship design refers to ship performance in waves. The estimation of ship motions and dynamic loads generated by the action of waves is a complex issue.

The level of acceleration induced on board depends on the ship motions and affects the comfort conditions on board, the size of induced wave loads or the size of the forces that secure the ship load. Knowledge of these physical quantities is vital for safety and structural integrity of the ship.

In most cases, the initial design phase is limited to predicting performance on calm water such as, for example, power-speed performance. Thoroughly, hydrodynamic analysis of wave action on ship structures are critically needed in both design and operational stages studies. It became essential for naval architects and classification societies to be able to develop hydrodynamic calculation, as a verification stage of engineering design [1]. This paper presents the assessment of seakeeping performance of an oil tanker ship. The hydrodynamic calculation was performed in order to predict ship motions in regular waves.

2. THEORETICAL MODEL

For the study of ship motions in regular waves, it was used an educational license of HydroStar software, HydroStar For Experts Bureau Veritas [2], [5]. The code is based on 3D diffraction / radiation potential theory 3-D panel for wave-body interactions taking into account the effects of forward speed. The evaluation of wave loads, motions, accelerations, relative motions, wave elevation is dedicated to all structure systems in deep and finite depth waters with or without speed. The hydrodynamic calculation is carried out in frequency domain [2].

It is assumed that the ship is a rigid body with six degrees of freedom, advancing at constant forward speed v, with arbitrary heading angle $\beta = 0...180$ degrees, in regular sinusoidal waves. The origin of the right handed coordinate system (x, y, z) is at the free surface level. The translatory displacements are the surge (η_1), sway (η_2) and heave (η_3) motions in Ox, Oy and Oz respectively.

The angular displacements are the roll (η_4), pitch (η_5) and yaw (η_6) motions around the axes parallel to Ox, Oy and Oz respectively, through the reference point.

For a given heading angle, speed and frequency of encounter ω_e , the translatory and angular displacements are written as follows

$$\eta_i = a_i \cos(\omega_e t - \varepsilon_i); \; i = \overline{1,6} \qquad (1)$$

where
a is the amplitude of the ship motion;
ε is the phase angle.

The encounter frequency is given by the relation:

$$\omega_e = \omega - \frac{\omega^2 v}{g} \cos\beta \qquad (2)$$

where v is the ship speed, $\omega = \sqrt{2\pi g / \lambda}$ is the wave frequency, g is the gravitational acceleration, λ is the wave length and β is the heading angle. The definition for the heading angle is given below, in Figure 1.

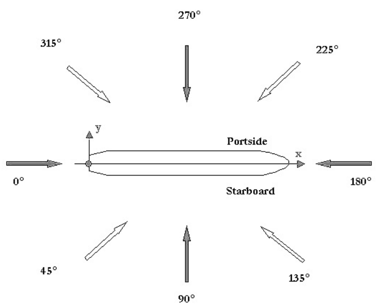

Fig.1. Sign convention for the ship motions

The ratio between the motion amplitude and wave amplitude is described by RAO functions (Response Amplitude Operator), defined as:

$$RAO = a / \zeta_w \qquad (3)$$

where ζ_w is the wave amplitude [3].

3. GEOMETRIC MODELING OF THE HULL DOMAIN

For the seakeeping analysis, a 12000tdw oil tanker ship was considered, having the main characteristics given in Table 1.

Table 1. Main characteristics

L_{WL}	122.79	[m]
L_{BP}	120	[m]
B	21.6	[m]
D	8.84	[m]
T_M	6.19	[m]
∇	12823	[m^3]
S	3436.2	[m^2]
C_B	0.779	-

The hull geometry was generated by using 3D Surface Modelling instruments, Rhinoceros software [6], Figure 2.

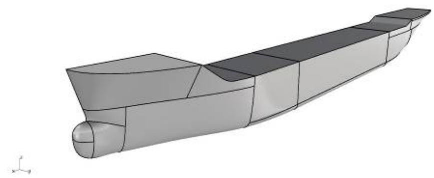

Fig.2a. 3D hull model of the oil tanker

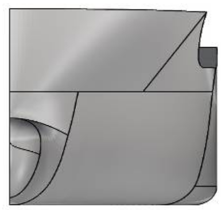

Fig.2b. 3D hull model. Forward part of the oil tanker

Fig.2c. 3D hull model. Side view of the oil tanker

The hydrodynamic analysis concerns only the submerged part of the ship hull.

Furthermore, the hull geometry was exported to FEMAP [7], in order to perform the mesh discretization of the surface of the hull, as depicted in Figure 3.

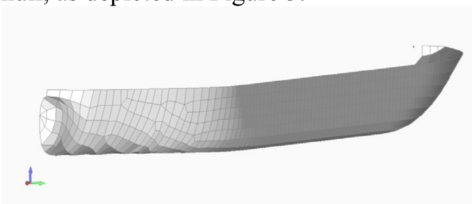

Fig.3. Mesh discretization using FEMAP

The input data containing the mesh discretization for the ship hull was considered in order to obtain the hydrostatic properties of the body (volume, centre of buoyancy, wetted surface, waterplane area and inertia, etc. [2]). In Figure 4 is given the ship hull visualization by using HydroStar tools [2].

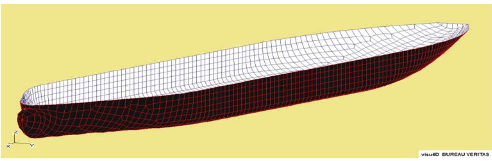

Fig.4. Mesh visualization

For the hydrodynamic calculation, the ship was considered in regular waves, at zero speed, having a heading angle, β between 180 and 360 degrees, with a step of 5 degrees. The wave frequency was in range of 0.01 and 2 [rad/s]. The radiation and diffraction computation was carried out having as input data the wave conditions (wave frequencies and headings, water depth) and provided as output, data on elementary solutions including added-mass, radiation damping and wave excitation loads [2].

Furthermore, the motions computation considering the mechanic properties (mass distribution, additional stiffness and additional damping matrices) outputted the motions of the floating body [2].

4. RESULTS ANALYSIS

In the following part are given the ship motion results, in terms of response amplitude operators, RAO [motion amplitude/ wave amplitude].

In Figure 5 is depicted the ship's heave amplitude operator.

It can be seen, in Figure 6, that the maximum value of the RAO function is obtained for a heading angle $\beta = 270^o$.

One may observe that the RAO function has maximum values for the wave length much bigger than the ship length (low frequency domain), after that, the RAO values decrease and become aproximatively constant while the wave length becomes much smaller with respect to ship length (high frequency domain).

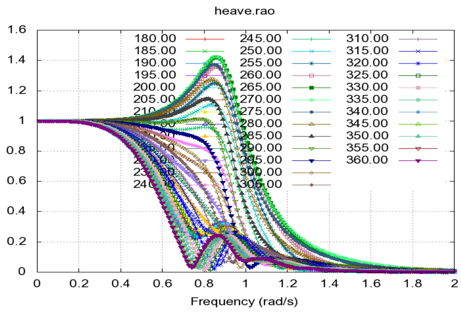

Fig.5. Ship's heave amplitude operator

Similarly to heave motion, the values for the pitch RAO functions are maximum for the wave length, aproximatively equal to ship length (ω ; 0.9 rad/s). For higher frequency domain, it can be observed that the roll amplitude decreases and becomes constant (Figure 7). In Figure 8 are given the maximum pitch RAO values, at a heading angle $\beta = 225^o$.

In Figure 9 the diagram shows that the maximum roll RAO function appears for wave length aproximatively equal to half of ship length, corresponding to wave frequency in range of 0.6 to 0.8 rad/s.

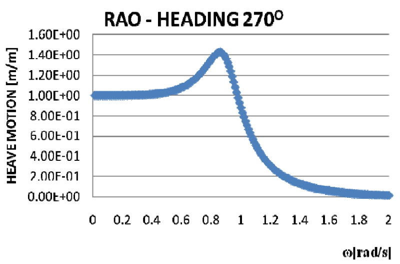

Fig. 6. Maximum heave amplitude operator

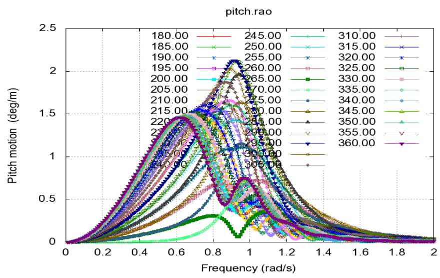

Fig.7. Ship's pitch amplitude operator

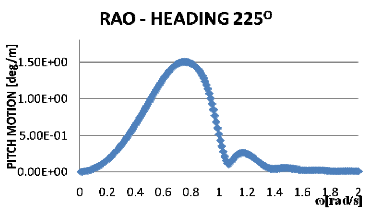

Fig.8. Maximum pitch amplitude operator

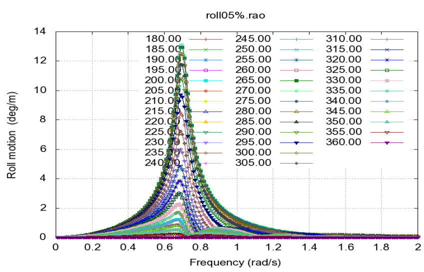

Fig.9. Ship's roll amplitude operator

5. CONCLUDING REMARKS

In order to estimate ship hydrodynamic response on waves, 3D potential flow linear method was used.

Further numerical analyses concerning pressure distribution and wave induced loads over the ship hull, for short and long term using wave spectra definition, are to be performed.

2D strip theory -3D BEM hydrodynamic methods comparison will also be taken into consideration, involving experimental results, too.

Acknowledgements

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REFERENCES

[1]. **Chen, X.B.** "*Hydrodynamics in Offshore and Naval Applications*", 6th International Conference on Hydrodynamics, Perth, Australia, 2004.

[2]. **Hydrostar for experts** 7.2, *user manual*, Reserch Department, Bureau Veritas.

[3]. **Pacuraru, S.,** „*Prediction of ship response in irregular waves*", The Annals of "Dunarea de Jos" University of Galati, Fascicle XI – Shipbuilding, ISSN 1221-4620.

[4]. **Domnişoru, L.,** "*Ship Dynamics. Oscillations and Vibrations*", Technical Publishing House, Bucharest, 2001.

[5]. ***HydroStar** 7.2 educational license.*

[6]. **Rhynocherus 5.0** *educational license*

[7]. **FEMAP 9.3** *educational licence*

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