INVESTIGATION INTO SEAKEEPING PERFORMANCE OF AN OIL TANKER ON REGULAR WAVES

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ABSTRACT

In this paper, an investigation into the seakeeping performance of an oil tanker on regular waves is presented. The numerical simulation was performed using a 3D diffraction/radiation potential theory 3-D panel software. The analysis concerns the full loading case of the ship at zero and design speed. Two discretizations were considered and for the numeric modelling two different values of linear viscous dumping coefficient were applied.

Keywords: seakeeping, regular waves, potential flow

1. INTRODUCTION

An important criterion in ship design is represented by the ship's performance in waves. Estimation of ship motions and dynamic loads induced by wave action is still a complex problem [1]. The level of acceleration induced on board depends on the ship's motions and affects the comfort conditions on board. In most cases, the initial design phase is limited to estimating calm water performance.

The methods used in the calculation of wave induced loads on floating bodies have been developed over several decades [2]. At first, the ship geometry was represented using 2D strip theory, which conducts the estimation of ship motions, dynamic pressure and wave induced loads with reasonable accuracy. Also, this method is suitable for slender bodies. However, for lower encountering frequency values, for ships with full hulls, such as oil tankers, or high Froude number, the results obtained using this method are not satisfactory. It then became possible to develop three-dimensional methods to predict the seakeeping performance for various hull forms. Among these, the boundary element method - BEM is widely used.

The technique consists in representing the surface of a body in a fluid domain through a number of panels. Each panel is considered to generate a simple flow stream. The problem is solved by satisfying the boundary conditions on each panel. The panel method has some limitations. It considers the potential flow field without modelling the actual viscous effects, boundary layers or flow separations. In this study, non-linear effects will be ignored during the evaluation of added masses, damping coefficients and ship motions single amplitudes. The current study was carried out using HydroStar software with an academic license [3], which is a hydrodynamic software that provides solutions to first-order problems of wave diffraction and radiation and also the QTF of second-order low-frequency wave loads for floating bodies with or without forward speed in deep water and in finite water depth. The numerical method is based on the potential flow theory. It solves the 3D linear radia-

tion and diffraction problem using the panel method. It is assumed that the ship is a rigid body with six degrees of freedom, advancing at constant forward speed v, on regular waves, with heading angle β=0…180 degrees, in regular sinusoidal waves. The origin of the coordinate system (x, y, z) is at the free surface level. The estimation of ship motions on regular waves was carried out for

the circular wave frequency, ω_e, in the range

between 0.2 and 2 rad/s for zero and design speed. The heading angle is between 0 to 180 degrees, with a step of 45 degrees.

The analysis was carried out for all 6 DOF but in this paper are only discussed:
• translation along the Ox axis (heave motion);
• rotation around the Oy axis (pitch motion);
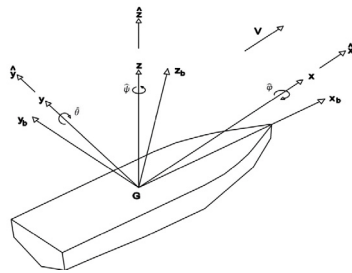• rotation around the longitudinal axis, Ox (roll motion).

Fig. 1. Motions and coordinate system

The results are represented in the frequency domain, in the form of amplitude response operators (RAO), which represent the ratio between the amplitude of the motion and the amplitude of the considered wave.

2. GEOMETRY AND ANALYSIS CONDITIONS

In the present study, the sea peering performance of an oil tanker was estimated. The main characteristics of the ship are summarized in Table 1. The studies were performed for zero speed and design speed, i.e.12 Knots.

Table 1. Main characteristics for the Oil Tanker

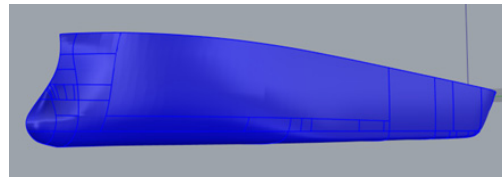| Parameter	Unit	Value
Length (waterline), L_{WL}	[m]	311.2
Length, L_{PP}	[m]	300
Beam, B	[m]	55
Draft, T	[m]	22
Depth (maximum), D_{max}	[m]	29.6
Displacement, Δ	[m^3]	297660
Block coefficient, C_B	-	0.8

Fig.2. Ship geometry

The hull geometry was generated by using 3D Surface Modelling Instruments, Rhinoceros software (academic licence), Fig. 2.

The mesh discretization of the surface was performed using the FEMAP program (academic licence) and is depicted in Fig. 3. Two discretizations were considered, one with elements of size 2.5 m and another one with the size 1.8 m. The generated panels and the number of nodes for both simulation cases are tabulated in Table 2.

Table 2. Number of nodes and panels for simulation cases

Simulation Cases	Number of Nodes	Number of Panels
C1 – 2.5 m	2433	2311
C2 – 1.8 m	4512	4349

Fig. 3a. Mesh discretization using FEMAP (2.5 m)
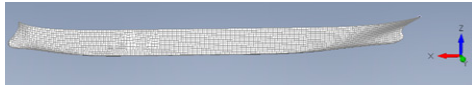
Fig. 3b. Mesh discretization using FEMAP (1.8 m)

Fig. 4a. and 4b. present the ship hull visualization by using HydroStar tools.
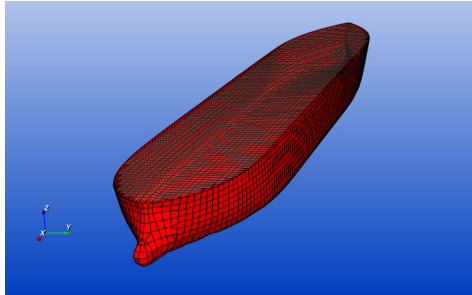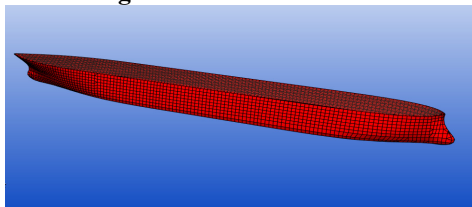

Fig. 4a. Mesh visualization

Fig. 4b. Mesh visualization

The ship is considered at the full loading case at 0 Knots and also 12 Knots, and the heading angles between 0° and 180° with a step of 45° degrees and the circular wave frequency ranging from 0.02 to 2 rad/s with a step 0.02.

The fluid model used in HydroStar is the perfect flow model without viscosity. Yet, viscosity and appendages increase the damping for roll motion to such an extent that it cannot be neglected. In order to have a more realistic roll damping a linear viscous damping coefficient is introduced.

The linear viscous damping coefficient is set to 5% in the first case, then the numerical analysis was also carried out for the case where it was considered 8%.
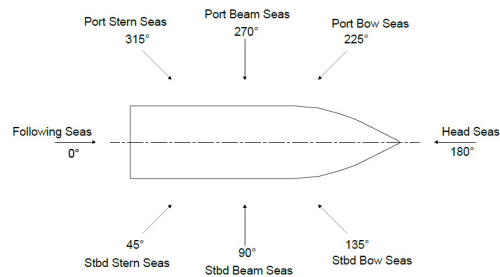
Fig.4. Schematic representation for heading regular waves

3. RESULTS AND DISCUSSIONS

The hydrodynamic response is obtained considering the ship in regular waves with an amplitude of a_w=1m and a wave height of H=2m. The Response Amplitude Operators (RAO) units are m/m for the translation degrees and degrees/m for the rotational motion.

Figure 5 depicts the response amplitude operators for heave, pitch and roll motions of the considered vessel in regular waves, at zero speed, 4349 panels, and 5% viscous damping.

It is observed that the higher values are found in the low frequency domain, decreasing after the wave frequency of 0.8 rad/s. The maximum value for RAO heave is obtained for the case of the heading angle of 90 degrees (beam wave) and is 1.82 m/m, at the frequency of 0.5 rad/s. For the other angles, local maxima are recorded at a similar frequency, but of smaller amplitude. Starting with the frequency value of 0.8 rad/s, the response of the ship becomes insignificant.

The RAO pitch has the maximum value for the case of the heading angle of 45 degrees and is 0.84 degrees/m, at natural frequency, then gradually decreases and starting from the frequency of 1 rad/s, it becomes negligible. For heading angles of 0 and 180 degrees, the amplitude of roll motion is insignificant.

Analysing the graphs, it can be seen that the highest value of the roll RAO function is in the case of the ship on beam regular waves and has the value of 4.6 degrees/m, at the frequency of 0.36 rad/s. At the other heading, local maxima are recorded at the same frequency but with lower values.
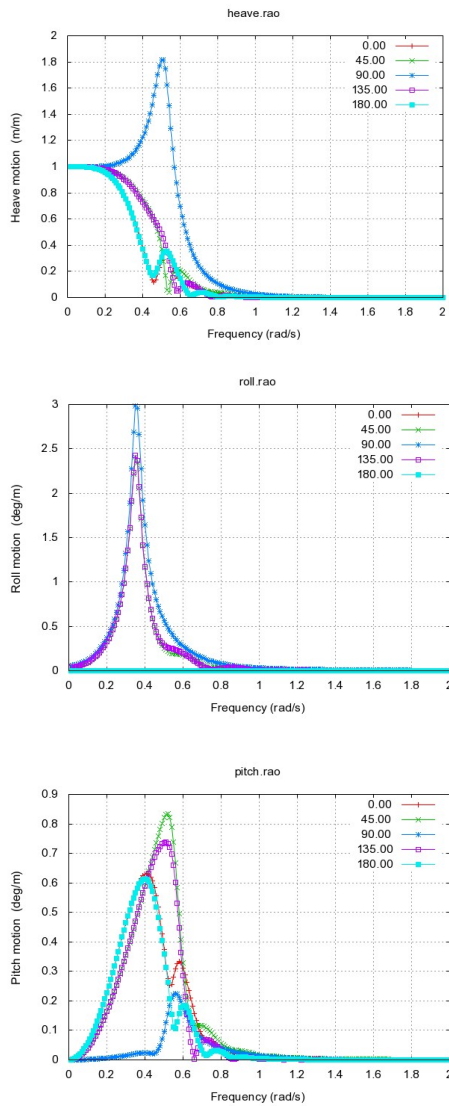
Figure 6 depicts the response amplitude operators for the same motions, at zero speed, 4349 panels, 8% viscous damping.

Fig. 5. RAO heave, roll and pitch at v=0, 4349 panels, 5% viscous damping
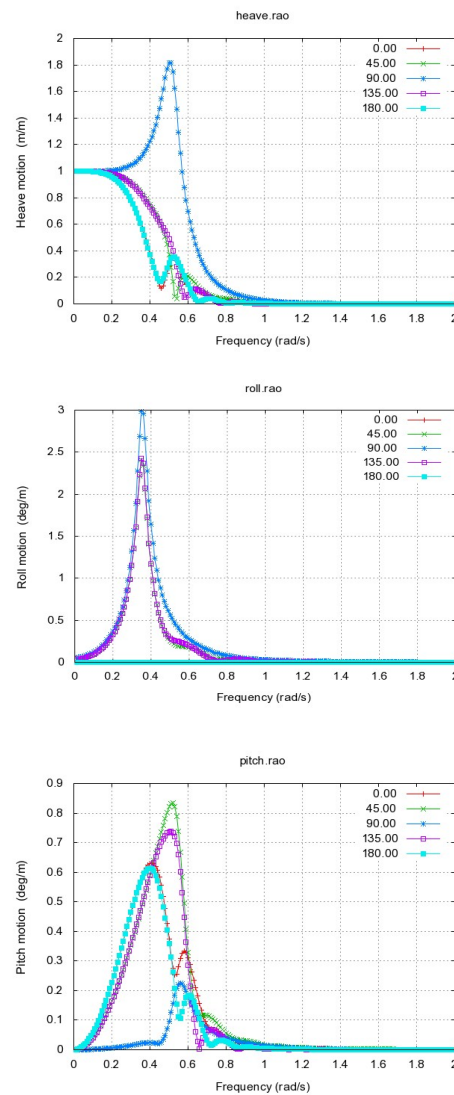

Fig. 6. RAO heave, roll and pitch for v=0, 4349 panels, 8% viscous damping

The maximum value of heave is recorded for the case of the transverse wave, being 1.82 m/m at the frequency of 0.5 rad/s. Starting with the wave frequency of 0.8

rad/s, the vertical oscillations become very small.

For the pitch motion, the maximum is recorded for oblique wave, β=135° and is 0.74 degree/m, at the frequency of 0.5 rad/s. At the other angles, local maxima are recorded at the frequency of 0.4 rad/s, respectively 0.55 for the transverse wave, but their amplitude is smaller.

The highest value in the case of roll motion occurs at the transverse wave, 90 degrees and is 2.97 degrees/m, at the frequency of 0.35 rad/s. For the angles of 0 and 180 degrees, the responses are insignificant and for the angles of 45 and 135 degrees, the local maxima are recorded at the same frequency of 0.35 rad/s.

Compared with the situation where the damping coefficient was considered 5%, it was seen that the ship's response decreases from 4.6 deg/m to 2.97 deg/m around the same frequencies.

The following results are estimated for the design speed case, v=12 Knots.

Figure 7 shows the response amplitude operators for all six Degrees of Freedom (DOF) of the considered vessel in regular waves, at 12 Knots, 4349 panels, 5% viscous damping.
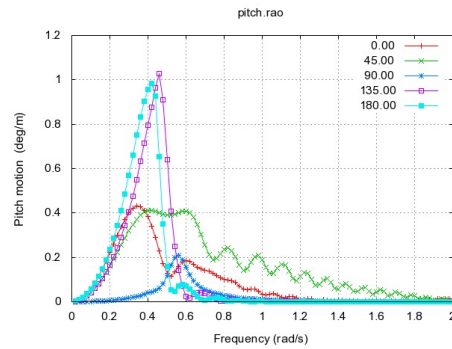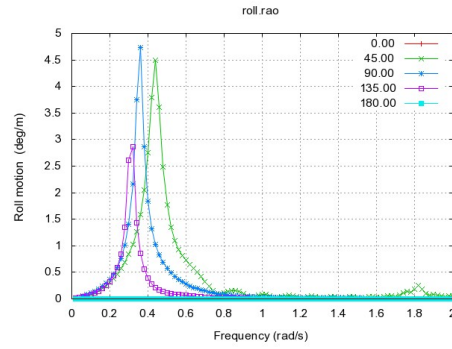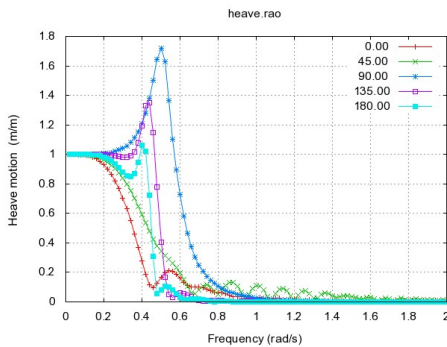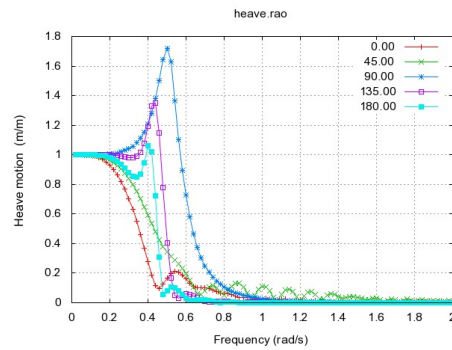

Fig. 7. RAO heave, roll and pitch at v=12 Knots, 4349 panels, 5% viscous damping

It is observed that for heave motion, the largest response is obtained in the case of the transverse wave, 1.72 m/m at the frequency of 0.5 rad/s.
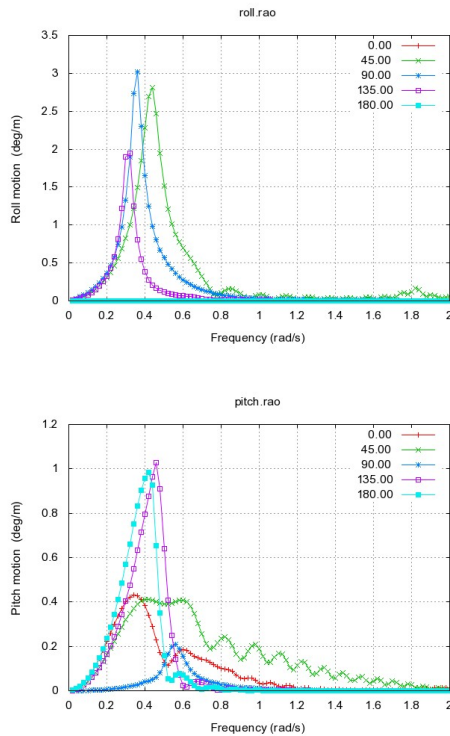
Fig.8. RAO heave, roll and pitch at v=12 Knots, 4349 panels, 8% viscous damping

Considering the linear viscous damping coefficient from 5% to 8%, it can be observed for roll motion, the maximum decreases from the value of 4.73 degrees/m to 3.02 degrees/m, around the same frequencies.

Also, it can be observed that for β=0˚ and 180˚ the roll motion has no significant values.

4. CONCLUDING REMARKS

The analysis was carried out for both the considering two values for linear viscous damping coefficient. Also, the calculations were performed for two discretization grids with 4311 and 2311 panels respectively.

Results discussion and comparison were carried out. While the number of panels did not influence the amplitudes of ship motion, using an increased linear viscous, it reduces the amplitude of roll motion both for zero and design speed. Furthermore, a time-domain analysis is to be done for different loading cases of the oil tanker.

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