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Hydrodynamic analysis of an offshore supply vessel operating around the Escravos water

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ABSTRACT: The seakeeping worthiness of every floating structure is of paramount importance since it's a measure that determines safety operations of both facility and crew members, hence the need for its hydrodynamic analysis. This research research aimed at carrying out a hydrodynamic analysis of an offshore supply vessel plying the theescravos water in the Niger delta region of the country. The key important components of the hydrodynamic parameters are the added resistance and the hydrodynamic potentials of added mass and damping which were all computed. The added resistance computed from the developed MATLAB program was compared with a standard industrial software, SEAKEEPER, which shows good agreement. Also, the hydrodynamic potentials for four headings were also estimated and found to agree well

KEYWORDS:(11Bold)addedmass, hydrodynamicdamping, addedresistance, heading, wave frequency, response

I. INTRODUCTION

Offshore transportation across waterways are a major means of moving goods and humans from one part of the globe to another. The means of transportation which were typically vessels of various kinds have evolved over the years owing to the human needs, hence the different types of vessels. offshore operations are heavily involved with the transportation of equipment and crew workers to and from the platforms as well.

The seaworthiness of such crafts is an important aspect of the preliminary and detailed design phase of the vessel and as such important notes need be taken. In this research, the hydrodynamic analysis of an offshore supply vessel operating along the escravos water would be examined. This will consider the strip theory formulation since the vessel fufils the slender body conditions(L/B>>3).Also the salveson approach for the added resistance will be considered

Theory of the problem

The oscillating body, in the fluid carries along some 'added mass' along its body mass during this oscillation and the viscous nature of the fluid provide a natural damping for this oscillation with some restoring force to bring the body back to its initial condition[1],[2],[3],[4] Including all of these into equation one becomes

$$(\mathrm{M} + \mathrm{mass}_{\mathrm{added}})\ddot{\eta} + \mathrm{B}\dot{\eta} + \mathrm{C}\eta = \sum \mathrm{F}_{\mathrm{ext}} \quad (1)$$

Where:

$\mathrm{mass}_{\mathrm{added}}$ = fluid added mass of the body experiencing the oscillation

B = Viscous Damping

C =Restoring forces

$\mathrm{F}_{\mathrm{ext}}$ =Excitation forces responsible for this oscillation

Equation 3.2 was for a single degree of freedom. Generally, the response equation can be written for the complete six degree of motion. For the complete mode of motions of the vessel which are the surge, sway, heave, roll, pitch and yaw, the generalized response equations can be written as

$$\sum_{j=1}^{6}\left[\left(\mathrm{M}_{i,j} + \mathrm{A}_{ij}\right)\ddot{\eta}_j + \mathrm{B}_{ij}\dot{\eta}_j + \mathrm{C}_{ij}\eta_j\right] = \sum \mathrm{F}_i (2)$$

Where:

$\mathrm{M}_{i,j}$ the general 6 by 6 mass matrix of the vessel

A_{ij} the global added mass matrix and

B_{ij} the global hydrodynamic damping matrix and

C_{ij} is the global restoring coefficient

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$F_i$the resultant of all other forces in the $_{ith}$ mode of vessel response

Also, various coupled(combined) cases can be considered and examined as well. For seakeeping analysis, coupled heave and pitch and uncoupled roll are considered. For maneuverability, surge, sway and yaw are considered. Accordingly, since we are more interested in the seakeeping capabilities of the vessel, which is primarily important for averting sea sickness occurrence, the motion responses, the coupled response in heave and pitch can be written respectively as [5],[6],[7]

$$(M + A_{33})\ddot{\eta} + B_{33}\dot{\eta} + C_{33}\eta + A_{35}\ddot{\eta}_5 + B_{35}\dot{\eta}_3 + C_{35}\eta_5 = F_3 e^{iwt} \quad (3)$$

$$(A_{55} + I_{55})\ddot{\eta}_5 + B_{55}\dot{\eta}_5 + C_{55}\eta_5 + A_{53}\ddot{\eta}_3 + B_{53}\dot{\eta}_3 + C_{53}\eta_3 = F_5 e^{iwt} (4)$$

Where,

$I_{55} = Mr_{55}$; r_{55} = radius of gyration of the ship for pitch

Hydrodynamic potentials

The strip method requires computation of the two-dimensional potential coefficients for each cross section. Then, the total hydrodynamic coefficients can be found easily by integrating the cross-section values over the ship length. The theory on the calculation of the two- dimensional potential coefficients is given by Ursell and Tasai. First, using Ursell's method, a ship cross-section in a complex plane is mapped to the more convenient circular cross section in another complex plane so that the velocity potential of the fluid around the ship cross-section can be computed. To achieve a more accurate transformation of a cross- sectional hull, close-fit conformal mapping is used. Then, the y and z coordinates of a ship's cross section in a complex plane may be described as

$$y = M_s \sum \quad (-1)^n a_{2n-1} \sin\sin((2n-1)) \quad (5)$$

$$x = M_s \sum \quad (-1)^n a_{2n-1} \cos\cos((2n-1)) (6)$$

Where

a_{2n-1} Are the conformal mapping coefficients

θ Mapped angle

M_c Scale factor

The parameters are 0 to N number of parameters, where N equals to 10 is used in close-fit conformal mapping. These values are used in Tasai's theory for deep water to solve hydrodynamic coefficients. Therefore, two-dimensional added mass and damping coefficients heave, can be computed using Ursell and Tasai methods. The detailed computation of be found in Tasai's work[8],[9],[10]

Conformal mapping, Ursell and Tasai methods of finding 2-D potential coefficients and determining mass and damping matrices

$$a_{33} = \frac{\rho b_0^2}{2} \frac{M_0 B_0 + N_0 A_0}{A_0^2 + B_0^2} (7)$$

$$b_{33} = \frac{\rho b_0^2}{2} \frac{M_0 B_0 + N_0 A_0}{A_0^2 - B_0^2} \omega_e (8)$$

Expressions for pitch and their coupling effects can be found in Journee (Journee, 1992)

Added Resistance Estimation

The added resistance due to wave experienced by marine crafts in realistic seaways. Added resistance, also known as sea-margin, is the resistance on a ship induced by winds or waves in a seaway[11],[12].Going through the evan's design spiral, the propulsive estimations of ships which are a consequences of the resistance computations is a vital aspect of the preliminary and detailed design stages of ships from an efficient design perspective as well as economic point, the later which translates to the amount of crude used in running your main engines.

A lot of methods have been used in predicting the added resistance of ships in waves and the one adopted for this paper would be the Salvesen method [13],[14] and [15],[16]

The added resistance is famously written as

$$R_{AW} = \frac{ik}{2}(\eta_3 F_3 + \eta_5 F_5) + R_7 (9)$$

Where

$$F_3 = \zeta \int e^{-ik\zeta} \left[c(\zeta) - \omega_0 \left(\omega_e a_{33}(\zeta) - ib_{33}(\zeta)\right)\right] d\zeta \quad (10)$$

$$F_5 = -\zeta \int e^{-ik\zeta} e^{-kz} \left[c(\zeta) - \omega_o \left(\zeta + \frac{iU}{\omega_e}\right) \left(\omega_e a_{33}(\xi) - ib33\xi d\xi \right.\right. \quad (11)$$

$$R_7 = \frac{\zeta^2 k w_0^2}{2\omega_e} \int_L e^{-2kz} b_{33}(\xi) d\xi \quad (12)$$

And

ω_e = encounter frequency

Results and discussions

The hydrodynamic analysis results of a supply vessel operating along the escravos-warri water way with the following particulars will be presented below. The offsets were gotten by manually obtaining sectioning the lines drawings using the rhinoceros' software,[7],[17] exporting the coordinated into a text file and reading it into the program.

Table 4.1: Principal particulars of supply vessel

Particular(s)	Value	Unit
Length of vessel	65.5	M
Breath of vessel	7.62	M
Draft	2.4	M

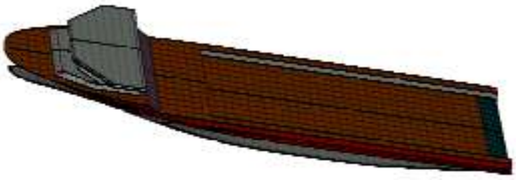

Figure 1: Offshore supply vessel

The environmental conditions for these simulations would be a wave height of 4.5m which typically depicts the maximum for a rough sea around in the region especially during the 8^{th} month of the year and a frequency of 2hertz. The analyses would depict a random sea which would have headings of 0,60,90 and 180 covering following, beam, quartering, and head seas respectively with an interval of 30^0 heading for the first three headings.

The added mass resistance due to the wave was also compared with the standard SEAKEEPER. which is a seakeeping module of Maxsurf, an industrial standard software. It is represented in figure 2 below

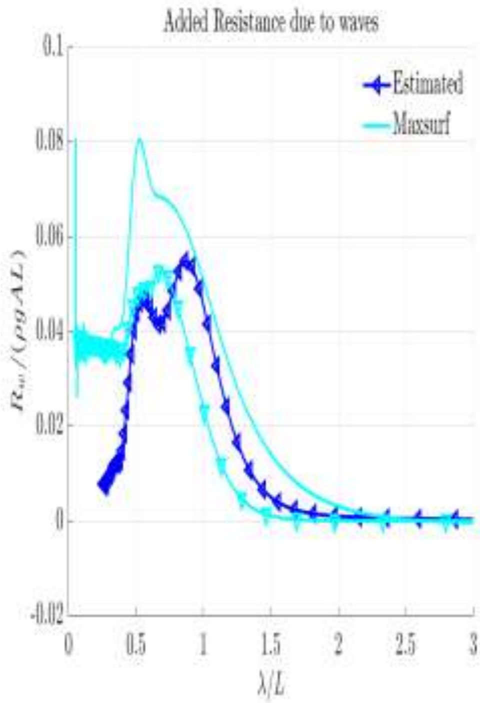

Figure 2: Added resistance of vessel due to wave

The estimated added resistance tends to follow that of the computed one from Seakeeper from a normalized wavelength pf 0.26m up to a 3. This shows a good agreement between both algorithms and hence reasonable predictions. Although the estimated algorithm could not account for very low normalized wavelength.

The hydrodynamic potentials of added mass and damping for the various headings are show in figures 4 and 5 below

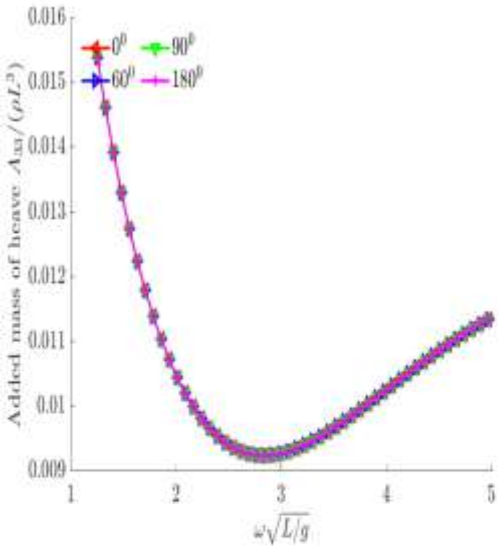

Figure 3: Added mass for the given headings

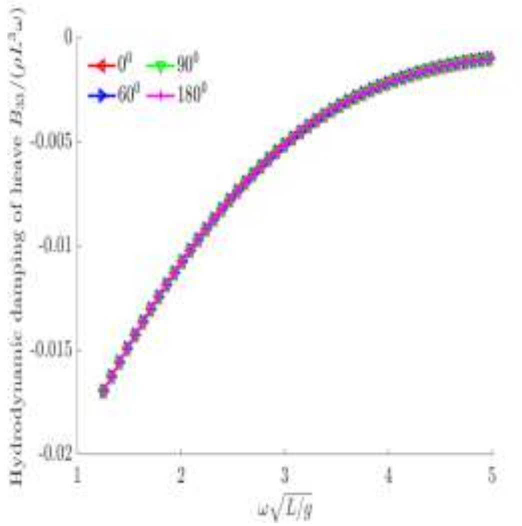

Figure 4: Normalized damping

It can be observed that the hydrodynamic potentials both added mass and damping would be same for the considered headings. It would also be important to note that at very high frequency, the hydrodynamic potentials of the added mass component will be infinity. Also, for certain frequencies, which are the so called 'irregular frequencies' there are no numerically computed hydrodynamic potentials of added mass and damping, hence they are generally omitted when carrying out seakeeping analysis

II. CONCLUSION

This research considers the hydrodynamic analysis of an offshore supply vessel sailing along the escravoswater. The important seakeeping parameters of the added mass and damping for four headings were computed of the heaving and pitching mood. These modeswere given more importance since they are paramount to motion sickness, which is a determining factor for crew discomfort as it unsettles the inner human organs. Another important parameter is the added resistance which determines the ability of the vessel in overcoming extra hydrodynamic effects. The added resistance also aids the estimation of the propulsive power of the vessel. The comparison of the estimated added resistance with that of the computed value from the seakeeper software shows good agreement as well.

REFERENCES

[1]. Amin-Afshar, M. (2021, October). Salvesen's method for added resistance revisted. America society of mechanical engineers.

[2]. Chakrabarti, S. (1998, October). Physical Model Testing of Floating Offshore Structures. Dynamic Positioning Conference, 13 – 14.

[3]. Chandrasekaran, S. a. (2014). Numerical study on geometrical configurations of perforated cylindrical structures. Journal of Performance of Constructional Facilities, 37-45. doi:0.1061/(ASCE)CF.1943-5509.0000687

[4]. Cornelius, P , W., & Vermeulen, R. (1965). Quantity equations. Applied Scientific Research, 12, 1-17.

[5]. Coullings, A. (2013). Validation of a FAST semi-submersible floating Wind turbine numerical model with Deep C wind test data. In A. Coullings, Validation of a FAST semi-submersible floating Wind turbine numerical model with Deep C wind test data (pp. 321-334). U.S.A: Journal of Renewable & Substainable Energy.

[6]. Salvaseon, T. (1970). Ship motion and sea loads. Society of Naval Architects and Marine Engineers, 5-13.

[7]. Elakpa Ada Augustine, D. I. (2018). Development of Preliminary Ship Motion Prediction tool for coupled Heave and Pitch. American Journal of Engineering Research, 195-204.

[8]. Ellis, B. D. (1992). Conventialism in Measurement Theory. (L. Erlbaum, Ed.) hilosophical and Foundational Issues in Measurement Theory, 167-180.

[9]. Greco, M. C. (2013). 3D domain decomposition for violent wave-ship interactions. Int. J. Numer. Methods .

[10]. Hughes, t. A. (1993). Physical Models and Laboratory Techniques.

[11]. ISSC. (2015a). a. Report of Technical Committee I.2 Loads. In: Proceedings of the 19th International Ship and Offshore Structures Congress.

[12]. Journee, J. M. (1992). Strip Theory Algorithms(Revised Report). Nertherlands.

[13]. Kashiwagi, M. (2021). Wave-Body Interaction Theory((Theory of Ship Waves). In M. Kashiwagi, Wave-Body Interaction Theory((Theory of Ship Waves) (pp. 31-88). Japan.

[14]. Kim, D. E. (2012). Estimates of long-term combined wave bending and whipping for two alternative hull forms. Transactions Society of Naval Architects and Marine Engineers SNAME, 1-30.

[15]. Kyong-Hwan, K., & Yonghwan, K. (2011). Numerical study on added resistance by

using a time domain rankine panel method. Journal of ocean engineering, 1357-1367.
[16]. O.M, F. (1993). Sea Loads on Ships and Offshore Structures. In F. O.M, Sea Loads on Ships and Offshore Structures (pp. 220-243). UK: Cambridge.
[17]. Ordu Azunna, D. O. (2021). Analysis of the Heaving Motion of a Semi-Submersible Adapted for Offshore Accomdation. International Resrarch Journal of Mordernization in Engineering Technology and Science .
[18]. Salvesen, & N. (1978). Added resistance of ships in waves. Journal of Hydronautics, 24-34.