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A Study on The Ship Motion in Waves by Panel Method

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Abstract
Computational Fluid Dynamics (CFD) offers a modern, highly accurate approach for analyzing a ship's hydrodynamic parameters. However, using RANSE (Reynold Averaged Navier Stokes Equation) CFD approach is time consuming. This study explores an alternative approach by employing potential flow theory through the panel method to analyze ship motions in regular waves. This method offers a significant reduction in computational time while maintaining reasonable accuracy. The analysis is performed on a Wigley hull, and the numerical results are validated against available experimental data to assess the method's reliability.

Keywords: *CFD, panel method, practical approach, ship motion, regular waves, Wigley.*

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I. INTRODUCTION

Ship motions refer to the oscillations a vessel undergoes as a rigid body when operating in waves or still water. In contrast to positive characteristics such as buoyancy, stability, floatability, maneuverability, and steerability, seakeeping behavior often carries negative implications, leading to various undesirable and even hazardous outcomes. These may include capsizing due to external loads; water ingress through deck openings caused by wave impacts and splashing; reduced speed due to increased resistance and adverse effects on the performance of the propeller and main engine; redistribution of inertial forces acting on the hull, superstructure, and onboard equipment; and negative impacts on the living conditions of crew and passengers, such as seasickness.

Given these concerns, it is essential for ship designers to study the seakeeping characteristics of vessels to predict their behavior in waves. This enables the development of both design and operational solutions to minimize motion responses. Within the scope of this paper, the authors present a method for calculating ship motions in regular waves using the panel method. Using this method, there are several approaches. Tasai method [1]: Tasai (1959) (1961) used Ursell's method combined with Lewis's two-parameter conformal transformation theory in calculating the ship's roll parameters. This method has the advantage of being suitable for manual calculation due to the small amount of calculation work (because it only uses two parameters), so it is often used in the initial design stage which requires time. However, because it uses some approximate calculation formulas, the accuracy of this method is quite low. Journee's method (1992) [2] used Tasai's method combined with the multi-parameter conformal transformation method. Usually, 10 parameters are used to define the ship's cross-section in calculating the ship's roll parameters. This method has the advantage of being highly accurate (due to the use of many parameters). However, its disadvantage is that it cannot be calculated manually due to the complexity of the calculation and cannot be used for pear-shaped ribs or tail ribs with too small fat coefficients. Frank's oscillation source method [3]: This method has overcome the disadvantage of the Journee method (1992) that it can be applied to calculate pear-shaped ribs or tail ribs with too small fat coefficients. In this method, the velocity potential of the immersed volume is described by the distribution of source points. In which the density of the sources is an unknown function but is determined from the integral equation expressing the boundary conditions on the immersed part. The hydrodynamic pressure is determined from the velocity potential using the linear Bernoulli equation. The integral of this hydrodynamic pressure over the immersed volume gives us the hydrodynamic force and moment. Frank's method has the disadvantage of a large calculation time, compared to the other two methods. However, nowadays, with the continuous development of computer systems and microprocessors, the disadvantage of the Frank method in terms of large calculation time has been overcome. Therefore, with the ability to calculate for most types of ship hull shapes (including pear-shaped bows or stern frames with very small fat coefficients) and giving highly accurate results, this method is being widely applied in the world in calculating ship roll. For this reason, the author used this approach for the calculation step.

With the development of electronic computers, the application of CFD to solve problems related to ship hydrodynamics is becoming more and more popular. Many authors have used the method of "Navier Stokes equation with average Reynold number" - Reynold Averaged Navier Stokes Equation (RANSE). The advantage of this method is that the fluid is simulated with viscous properties and close to real fluids. Yoo-Chul Kim, 2016 [7], applied the URANSE method (Unsteady Reynold Averaged Navier Stokes Equation) to calculate the force acting on the ship and the ship's rolling on the waves. Yavuz Hakan Ozdemi, 2016 [8] also applied RANSE to calculate the rolling and additional drag for the KVLCC2 ship's hull. The results obtained are very positive and close to the model test results. However, the disadvantage of RANSE compared to the method using potential flow in Ansys Aqwa software is the calculation time. Normally, it takes many hours to many days to get the calculation results when using RANSE. While the method using potential function, considering the fluid as an ideal fluid only takes a few minutes. Although the accuracy of RANSE is higher than the potential function method, to quickly get the calculation results, the method using potential flow is still widely used. To evaluate the accuracy of this method, the authors used Ansys Aqwa to calculate with Wigley's hull and compared it with the model test results. Details are shown in the following part of the article.

II. CALCULATION SETUP

2.1. Ship model

First, the authors choose the Wigley envelope as the computational model. This is a linear form that is widely used to check the calculation results using the CFD method [2]. The geometrical characteristics of this envelope are expressed in the form of mathematical equations, so analytical methods can be applied to calculate the hydrodynamic characteristics of the ship's envelope. The Wigley envelope is represented by the equation:

$$\frac{Y'}{B} = \left(1 - \frac{Z'^2}{T^2}\right)\left(1 - \frac{4X'^2}{L^2}\right)\left(1 + \alpha\frac{X'^2}{L^2}\right)$$

in which: T- draft; X', Y', Z' here are the coordinates of the point on the hull in the direction X, Y, Z respectively

However, to compare with experiment result, the author choose the particular parameters of the hull form as follows:

Table 1: Basic dimensions of the Wigley hull

Dimension		**Unit**	
Length overall	*LOA*	[m]	3
Breadth	*B*	[m]	0.3
Draft	*T*	[m]	0.1875
Midship coefficient	C_M		0.667
Vertical center of gravity		[m]	0.17
Speed	*V*	[m/s]	1.63
Wave direction	β	[deg]	180

The hull form of Wigley hull is described in the Figure 1 below, for simplification, only model scale is calculated to compare with experimental result.

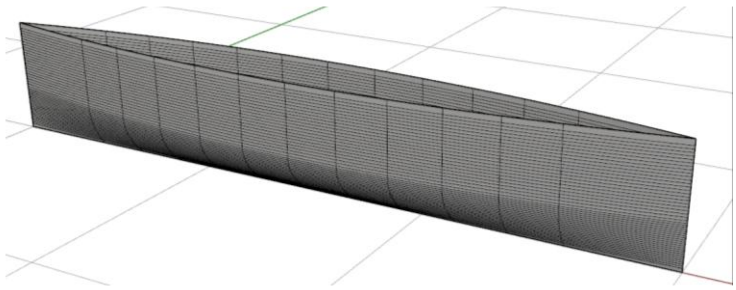

Figure 1: Wigley hull

2.2. Calculation setup

The calculation is performed in the in-house panel code, with the steps are described as follows:

Step 1: Import the model into the software , select the unit used in the calculation (SI system) and set the waterline position d = 0.1875 m.

Step 2: Set the calculation parameters of the radius of inertia kxx = 0.102 m, kyy = 0.75 m and kzz = 0.78 m; the center of gravity of the ship KG = 0.17 m. The parameters of mass and mass moment of inertia Ixx, Iyy and Izz will be automatically calculated by the software.

Step 3: Divide the hull by the panel, in this setup we use 1144 panel

Step 4: Set boundary conditions and calculation parameters. Setting boundary conditions and calculation parameters is extremely important because it directly affects the accuracy of the obtained results. In this problem model, the authors set up the following calculation parameters and boundary conditions:

- Parameters of the water volume surrounding the ship's hull (Sea Geometry): depth: 500m; width and length (X, Y) = 1000m;
- Boundary conditions: incompressible, non-viscous fluid, the free surface is the flow path, no fluid element can pass the free surface. The ship is considered large compared to the surrounding fluid (KC coefficient - Keulegan Carpenter number is less than 2). With this boundary condition, the fluid element is bonded to the ship's hull;
- Wave direction: 180 degrees, ship speed: 1.63 m/s corresponding to Froude number = 0.3;
- Incident wave frequency: from 2 Rad/s to 8 Rad/s, divided into 80 steps to create a smooth curve graph.

III. RESULT AND DISCUSSION

After setting up all the parameters, we proceed to calculate using Aqwa. Here, due to the limitation of the number of pages of the article, the authors only present the calculation results for vertical rolling (heave motion) and main keel rolling (pitch motion). Figures 2 and 3 show the results obtained in calculating vertical rolling and main keel rolling with the support of CFD, compared with the results of model testing performed in the laboratory of ship hydrodynamics, Delft University, Netherlands [6]. Here, the parameters and are called amplitude-frequency characteristics or RAO (Response Amplitude Operator) are determined by the formula:

$$Z_a'' = Z_a / \zeta_a \ \text{and} \ \theta_a'' = \theta_a / \zeta_a$$

where: Za, θa – heave and pitch motion amplitude; ζa – wave amplitude.

The calculation result is plotted in the graphs below, to compare the result of heave motion and pitch motion with experimental data.

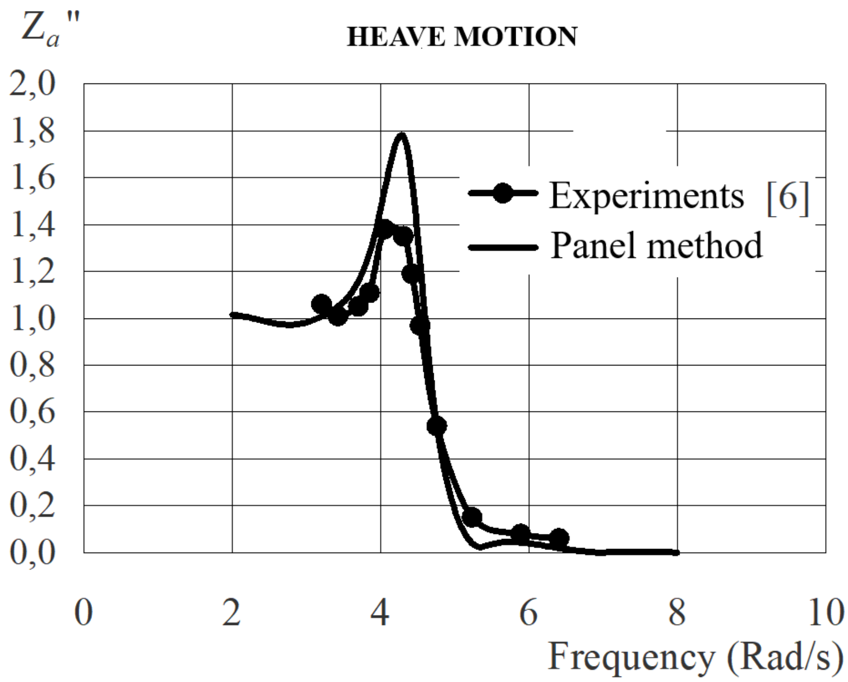

Figure 2: Heave motion – experiments and panel method

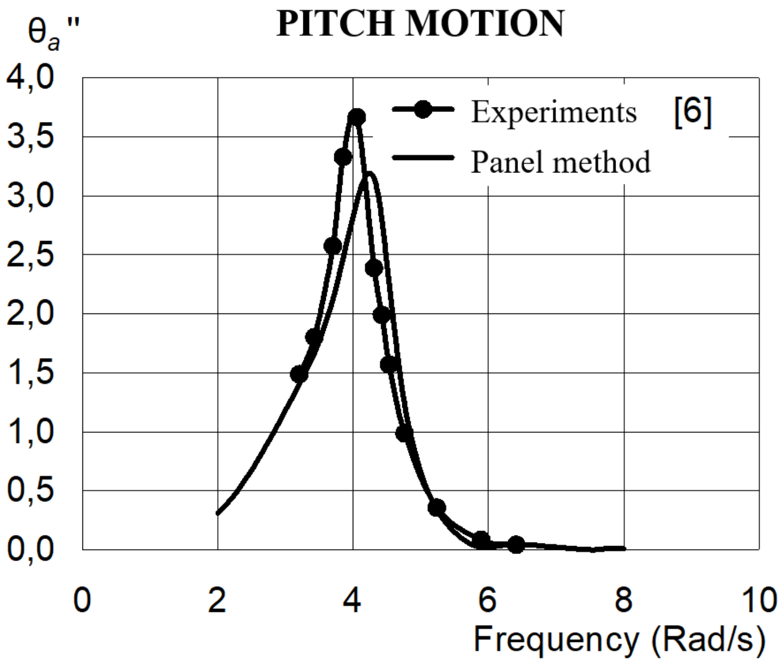

Figure 3: Pitch motion – experiments and panel method

From Figure 2 and Figure 3, we can see that, if we look at the whole picture, the results obtained when calculating the ship's motion by panel method have the same shape of the oscillation amplitude compared to the model test results. If we look at the calculation error aspect, we only see the difference between the model test results and panel method at the point with the largest amplitude. This may be because when testing the model, the distance between the oscillation frequencies is larger than when calculating by software, so the point with the largest oscillation amplitude is not selected correctly.

Besides, it is possible that the number of panels is not sufficient to capture the peak amplitude, increasing the number of panels could resolve these issues.

IV. CONCLUSION

Based on the study of ship motion, the article has obtained the following results:

- Presented the theoretical basis of the method of calculating ship roll on harmonic waves according to different theories, the advantages and disadvantages of each method.
- Presented the sequence of steps to calculate ship roll on harmonic waves when applying the panel method.
- The calculation results applying the panel method for the Wigley hull have confirmed that the boundary conditions and calculation parameters set by the authors are correct.
- The research results show that the ability of developed panel code in calculating ship roll is quite good because it gives highly reliable results (compared to the model test results). This confirms the great applicability of panel code in the field of ship motion and floating structure design

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