RUDDER AREA EFFECT ON HEELING MANOEUVRE OF A FERRY

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SUMMARY

Ferry boat operation, particularly in Indonesia is increasing widely. Research on the boat by naval architects is intensifying as well. The aim of the study was to determine the effect of rudder on ship heeling manoeuvre.

Matrix Laboratory (MATLAB) simulation was used to predict the heeling angles. The simulation utilized model based on the concept of Mathematical Modelling Group (MMG). The model includes theory, separating components of hull equations, propeller and rudder as well as their interaction (hull, propeller, and rudder). The simulation results are compared with sea trial performance of ferry of KMP Sultan MURHUM.

It was obtained that the heel angle of 3.10°, 3.15°, 3.20° degrees for 1.632, 1.819, 2.078 square meter rudder area respectively. The results indicate that the greater the rudder area the greater the heel angle during the manoeuvre.

NOMENCLATURE

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \phi )</td>
<td>Roll angle</td>
</tr>
<tr>
<td>( \rho )</td>
<td>Density of water</td>
</tr>
<tr>
<td>( \beta )</td>
<td>Drift angle</td>
</tr>
<tr>
<td>( \delta )</td>
<td>Rudder angle</td>
</tr>
<tr>
<td>( \psi )</td>
<td>Course angle or heading</td>
</tr>
<tr>
<td>( \Lambda )</td>
<td>Rudder aspect ratio</td>
</tr>
<tr>
<td>( \varepsilon )</td>
<td>Phase angle</td>
</tr>
<tr>
<td>( a_H )</td>
<td>Rudder to hull interaction coefficient</td>
</tr>
<tr>
<td>( A_D )</td>
<td>Advances diameter</td>
</tr>
<tr>
<td>( A_R )</td>
<td>Rudder area</td>
</tr>
<tr>
<td>( B )</td>
<td>Ship breadth</td>
</tr>
<tr>
<td>( B_{44} )</td>
<td>Added inertia of roll motion</td>
</tr>
<tr>
<td>( C_1, C_2, C_f )</td>
<td>Constants for open water propeller</td>
</tr>
<tr>
<td>( CB (Cb) )</td>
<td>Block coefficient</td>
</tr>
<tr>
<td>( D_p )</td>
<td>Propeller diameter</td>
</tr>
<tr>
<td>( D_t )</td>
<td>Tactical diameter</td>
</tr>
<tr>
<td>( f_L )</td>
<td>Gradient of the lift coefficient of rudder</td>
</tr>
<tr>
<td>( F_N )</td>
<td>Normal force acting on rudder</td>
</tr>
<tr>
<td>( G )</td>
<td>Center of gravity of vessel</td>
</tr>
<tr>
<td>( I_{zz} )</td>
<td>Moment of inertia with respect to the z-axis</td>
</tr>
<tr>
<td>( J )</td>
<td>Advance coefficient</td>
</tr>
<tr>
<td>( J_{zz} )</td>
<td>Added moment of inertia around z-axis</td>
</tr>
<tr>
<td>( K )</td>
<td>Moment with respect to the x-axis</td>
</tr>
<tr>
<td>( K_Q )</td>
<td>Torque coefficient</td>
</tr>
<tr>
<td>( K_R )</td>
<td>Moment of rudder</td>
</tr>
<tr>
<td>( K_T )</td>
<td>Thrust coefficient</td>
</tr>
<tr>
<td>( LOA )</td>
<td>Ship length overall</td>
</tr>
<tr>
<td>( LBP )</td>
<td>Length of between perpendiculars</td>
</tr>
<tr>
<td>( m )</td>
<td>Mass of ship</td>
</tr>
<tr>
<td>( n (rpm) )</td>
<td>Propeller revolution</td>
</tr>
<tr>
<td>( V_A )</td>
<td>Advance velocity (m s(^{-1}))</td>
</tr>
<tr>
<td>( N )</td>
<td>Moment with respect to the z-axis</td>
</tr>
<tr>
<td>( P )</td>
<td>Propeller pitch</td>
</tr>
<tr>
<td>( P/D_p )</td>
<td>Propeller pitch ratio</td>
</tr>
<tr>
<td>( t_p )</td>
<td>Trust deduction factor</td>
</tr>
<tr>
<td>( T )</td>
<td>Draught of vessel</td>
</tr>
<tr>
<td>( r )</td>
<td>Turning rate or angular velocity</td>
</tr>
<tr>
<td>( r' )</td>
<td>Non-dimensional turning rate</td>
</tr>
<tr>
<td>( u )</td>
<td>Velocity in x-direction (surge)</td>
</tr>
</tbody>
</table>

\( \ddot{u} \) Acceleration in x-direction (surge)

\( U \) Vessel velocity

\( U_r \) Rudder inflow velocity

\( \nu \) Velocity in y-direction (sway)

\( \dot{\nu} \) Acceleration in y-direction (sway)

\( w_{p0} \) Effective wake fraction coefficient at propeller

\( w_{p0} \) Effective wake fraction coefficient of propeller in straight running

\( x, y, z \) Ship-fixed co-ordinate system

\( x_0, y_0, z_0 \) Space-fixed co-ordinate system

\( x_H \) The distance between the centre of gravity of hull ship

\( x_G \) Centre of gravity (positive if forward of amidships)

\( x_R \) The distance between the centre of gravity of ship and centre of rudder lateral force

\( X \) Force in x-direction acting on ship

\( X_0, Y_0 \) Forces in the \( x_0, y_0 \) direction

\( X_p \) Propeller thrust

\( X_R \) Rudder force in x-direction

\( Y \) Force in y-direction

\( Y_R \) Rudder force in y-direction

\( Z \) Number of propeller blades

1. INTRODUCTION

The number of ferry (boat) carrying trucks, bus, car, motor cycle, passengers, etc. is increasing in Indonesia. The operation could improve national economic growth. In ferry building, from design to delivery, a number of test must be conducted, particularly the ability of ship operations. The test includes testing the ship speed and maneuverability.

 Maneuvering characteristics are very important criteria to make sure ship can operate in certain situation and location. Maneuverability is very critical aspect especially in harbour and offshore operations such as tow and tug to avoid collision. Noor [1] suggested that...