Experimental Analysis of Pitching Motion in Various Angle of Attack for Mini Submarine On Surface Condition

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Abstract—For the operational mini submarine necessary to analyze pitching motion when it probably to adaptation from snorkeling to dive condition. Further more, function of angle of attack is urgently needed. However, slope adaptation reach optimal as information urgently needed for navigator guidance. Furthermore, need to be realized for feasibility study more detail with various angle of attack to find maximum angel of attack on the mini submarine. This feasibility study was conducted in MOB Hydrodynamic Laboratory

Index Terms—mini submarine, slope, physical model test, MOB

I. INTRODUCTION

Submarine is designed with the main ballast tanks fulls, the weight of water displaced will be as close as possible to the weight of the boat, see Fig. 1. That is, there should be a balance between displacement and buoyancy, referred to as neutral buoyancy [1], [2]. If true neutral buoyancy is achieved the boat will float at whatever depth it presently is, unless something acts on it to make it rise or sink, see Fig. 2. In practice, submariners prefer to maintain very slight positive buoyancy, so that if power if lost the boat may be expected to slowly rise to the surface.

The problem of water sloshing in closed forepeak ballast. This phenomenon can be described as a free surface movement of the contained fluid due to sudden loads [3]. Sloshing is a liquid vibration phenomenon caused by the movement of the ballast. When the ballast is in transit, the sloshing would affect stability of the system severely caused by pitch of angle when submarine in quick dive cause couple motion [4]. So it is necessary to minimize the impact of sloshing and avoid large amplitude resonance. Sloshing has been studied for many years by analytical and numerical methods[5,6].

In a quick dive, the negative tank is important. By flooding this tank the boat is made negatively buoyant, which gets the boat under water quicker. Once submerged, though, the negative tank is blown “to the mark.” the submarine to be heavier than the water it displaced while diving, because you want to get under as quickly as possible.

The equations of motion for a submarine are similar to those for a surface ship, however they include all six degrees of freedom[7]. For a submarine it is normal to take the origin as the longitudinal center of gravity (LCG), rather than mid-ships, as this simplifies the equations, and for a submarine this position is fixed (unlike for a surface ship)[8]. The axis system used is shown in the notation. Note that the origin is on the centerline, which is where the transverse center of gravity is assumed to be. Positive directions are along the positive axes, and positive rotations are clockwise as seen from the origin looking along the positive direction of the axes.

The first approach in the modeling of sloshing liquids involves using numerical schemes based on linear and/or non-linear potential flow theory. These type of models represent extensions of the classical theories by Airy and Boussinesq for shallow water tanks. Faltinsen [9] introduced a fictitious term to artificially include the effect of viscous dissipation. Considering the importance of nonlinear effects in the sloshing response, Faltinsen [9] analyzed nonlinear sloshing by perturbation theory.
Numerical simulation of sloshing waves in a 3-D tank has been conducted by [10,11].

Two experimentally derived empirical constants were included to account for the increase in liquid damping due to breaking waves and the changes in sloshing frequency, respectively. The attenuation of the waves in the mathematical model due to the presence of dissipation devices is also possible through a combination of experimentally derived drag coefficients of screens to be used in a numerical model [12].

II. METHODOLOGY

The design model is based on a plan lines obtained from the owner. From the lines of this plan will be made for the scale model of the ship. The next stage is to use the offset table for plotting the results of the previous scale. After the scale has been determined then in print and create models. The dimension of submarine as shown Table I and was designed by computer in Fig. 3.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>SHIP (m)</th>
<th>MODEL (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOA</td>
<td>22.00</td>
<td>700.00</td>
</tr>
<tr>
<td>B Total</td>
<td>4.29</td>
<td>136.30</td>
</tr>
<tr>
<td>D Total</td>
<td>5.13</td>
<td>163.30</td>
</tr>
<tr>
<td>L</td>
<td>2.60</td>
<td>82.70</td>
</tr>
<tr>
<td>dim. Press Hull</td>
<td>3.00</td>
<td>95.50</td>
</tr>
<tr>
<td>JR. FS</td>
<td>1.10</td>
<td>35.00</td>
</tr>
<tr>
<td>JR. WL</td>
<td>1.00</td>
<td>31.80</td>
</tr>
<tr>
<td>JR. BL</td>
<td>0.30</td>
<td>9.50</td>
</tr>
<tr>
<td>Scala</td>
<td>31.43</td>
<td></td>
</tr>
</tbody>
</table>

If the origin of the axes is taken at the position of the longitudinal, and transverse centre of gravity, then both \( x_G \) and \( y_G \) will be equal to zero, simplifying these equations.

\[
M = I_{yy} \ddot{\phi} + (I_{xx} - I_{zz}) \rho p - (\dot{p} + gr) I_{xy} + \left( p^2 - r^2 \right) I_{cx} + (qp - r) I_{cx} - m \left[ x_G (\dot{u} - uq + v\dot{v}) - z_G (\dot{u} - vr + w\dot{w}) \right] \quad (1)
\]

When surfacing, water is retained in the casing, and other free flood spaces, for a period before it can escape [13,14]. This will raise the centre of gravity above that assumed for the steady state calculations used to generate Fig. 5. The length of time that this Eater talies to escape will depend on the size of the free flooding holes. The large holes may affect the hydro-acoustic noise generated when submerged [15].
A submarine in surfaced condition has to satisfy the same stability principles as that of a surfaced ship, see Fig. 6. The primary requirement in surfaced condition is that, it should remain afloat even after any kind of damage. Which means, there should be a significant volume of the hull above the waterline. This is called the Reserve of Buoyancy (ROB). The figure below represents the volume of the hull that contributes to reserve of buoyancy.

The ROB of a submarine is basically the ratio of the effective volume of all the MBTs to the volumetric displacement of the submarine in surfaced condition. The effective volume is the total “blowable” volume of the tanks (i.e. volume of the tank required to be filled to submerge the submarine). And just like surfaced ships, the surface displacement of the submarine is the weight of the submarine minus the free flood water. Now note in Fig. 7, that in submerged condition, the only structure providing buoyancy is the pressure hull. Hence, the weight of the submerged submarine minus the free flood water is equal to the buoyancy on the fully pressure hull that contributes to reserve of buoyancy.

Submarines are very weight sensitive, as in, during the entire operation of a submarine, all operations are to be carried out in such a way so that there is minimum shift in the longitudinal position of the centre of gravity. As shown in the figure below, the slightest change in longitudinal centre of gravity will cause a trimming moment that results in a drastic decrease in the water plane area. Since the longitudinal metacentric height will be proportional to the on the waterplane area, any trimming moment rapidly reduces the metacentric height.

### III. RESULT AND DISCUSSION

In order to exercise the method developed above, submarine considered. A sketch of the submarine is shown in Fig. 8 to 10. The Submarine has the following geometric and mass properties: length = 700 mm, reference diameter = 163 mm, mass = 4.8 kg

Pitch curves as in Fig. 11. The test results indicate that the pitch behaviour of the submarine-like body is highly nonlinear and derivation of a single correlation factor for all experimental configurations would not be practical.

The closed casing configuration which provides additional buoyancy and hence a greater restoring moment. This creates a stiffer system and therefore a smaller pitch period. The submarine had a pitch period of about 4.3 seconds for 5 degrees, 1.4 seconds for 10 degrees and 4.8 seconds for 15 degrees.

The primary effect from the smaller period appears to be a pitch coupling interaction during the first two or three cycles causing the hump in the decrement curve and reducing much of the initial roll motion.

As part of a validation of the coupled motion and six-degree-of-freedom method were performed to predict the flow field, hydrodynamic coefficients, and the motion paths of submarine at an initial speed = 0 knots. It clearly shows the orientation of the body at that instant in time and the resulting flow field due to the body at angle of attack.
IV. CONCLUSION

A series physical model experiments were carried out to determine the effects of a free flooding casing on pitch motions of a submarine operating at the surface. The goals were to determine whether a free flooding casing was necessary for a seakeeping model of the submarine, which would add complexity and expense to the experiments and if so, how to construct it to best duplicate the full scale dynamics.

The physical experiments showing little to no change in pitch damping for the different blockage configurations, but an increase in pitch damping when going from a large to a small casing opening size.

The change in position of the centre of gravity that used in the physical experiments led to an analysis of the vessel’s pitch period as a function of KG. At the experimental condition, the pitch period became very sensitive to any changes in the GM caused either by a change in the vertical centre of gravity, or the centre of buoyancy resulting from an open or closed casing[12]. The natural pitchperiod of a vessel is a critical parameter for seakeeping experiments, as it affects where resonance occurs in various sea states.

The study concluded that a free flooding casing physical experiments showed any flow over the top of the pressure vessel. Extra consideration will also be given to the model GM and pitch radius of gyration to ensure roll period is reflective of the full scale vessel.

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REFERENCES


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