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Analysis of Bow and Aft Modification Effect on DTMB 5115 Ship Resistance

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Abstract Resistance reduction is the most important goal in ship design that causes higher speed and lower fuel consumption. Hydrodynamic optimization is an effective and robust design method that plays an indispensable role in ship hull form optimization. Designers and shipyards are required to produce vessels according to draft and speed specifications which have superior hydrodynamic performance under calm water conditions (the contract condition), and the optimization of ship hull designs is a vital part of achieving this goal. Resistance value of DTMB 5415 model has been measured by Maxsurf software and compared with CD Adabco Stare-CCM+ CFD based software results. These methods are used to compare the calm-water drags of several bow and aft forms and to define optimized hull for which the total (friction + wave) calm-water drag is minimized. The total drag is estimated using Holtrop method in Maxsurf. Comparisons of CFD calculations and experimental measurements for DTMB 5415 hull form show that CFD calculations are reliable. Bow type has been replaced with bulb and few changes have been done on aft that has better behavior than other types of aft on resistance and total resistance on hull has been decreased with replaced bulb and modified aft.

Keywords: *resistance, bulbous-bow, hull form, DTMB 5415*

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1. Introduction

Although CFD-based hull form optimization is not routinely used for ship design, a significant number of applications of CFD tools for hydrodynamic optimization attest to growing interest in hydrodynamic optimization. This growing interest in hydrodynamic optimization is a useful development because ship design implies optimization, e.g. minimization of a functional that appropriately weighs payload, ship speed, motions, and calm water drag. Achieving to a hull form with the least resistance, good stability and good maneuverability due to specific sea area, is very important on military ships. Basic resistance components is shown on Figure 1.

The main component of total resistance divided to two components of the frictional resistance and pressure resistance and second one divided to viscous pressure resistance and wave resistance. An important factor in the resistance change due to modification of the bow and aft form is viscous pressure and wave resistance that could be decreased by optimized bow and aft modification. These modifications almost has no effect on friction resistance.

2. Model Introduction

The DTMB model 5415 has been designed in David Taylor Model Basin in 1980 and was first studied extensively using CFD techniques when it was chosen to be one of three test cases in the Gothenburg 2000 workshop for computational fluid dynamics applied to ship flows. Participants were asked to focus particularly on the total resistance, the wave profile along the hull and the selected locations close to the ship, the overall wave pattern in the near field, and the mean flow velocities near the stern, particularly at the propeller plane. Experimental data for this model has been obtained by three laboratories; DTMB, IIHR, and INSEAN (Instituto Nazionale per Studi ed Esperienze di Architettura Navale). Geometry and dimensions are illustrated in Table 1.

A series of four hull forms are considered in this study. These hull forms are original DTMB, bow modified vessel, aft modified vessel and DTMB with bow and aft modification. These four hull forms are compared with each other to show which one has lower drag in the particular speed range. These comparisons has been done by Star CCM+ and Maxsurf software to find how accurate the Maxsurf is. In Star-CCM+ software, drag value has been computed at 10, 24 and 30 knots and no more speeds was necessary.

Table 1. Dimensions and coefficients of DTMB 5415

LOA (m)	152.23	Displacement (m^3)	8424.4
LPP (m)	142.00	Wetted area (m^3)	2972.6
LWL (m)	142.18	CB	0.507
BWL (m)	19.06	CM	0.81
T (m)	6.15	LCB	-0.68

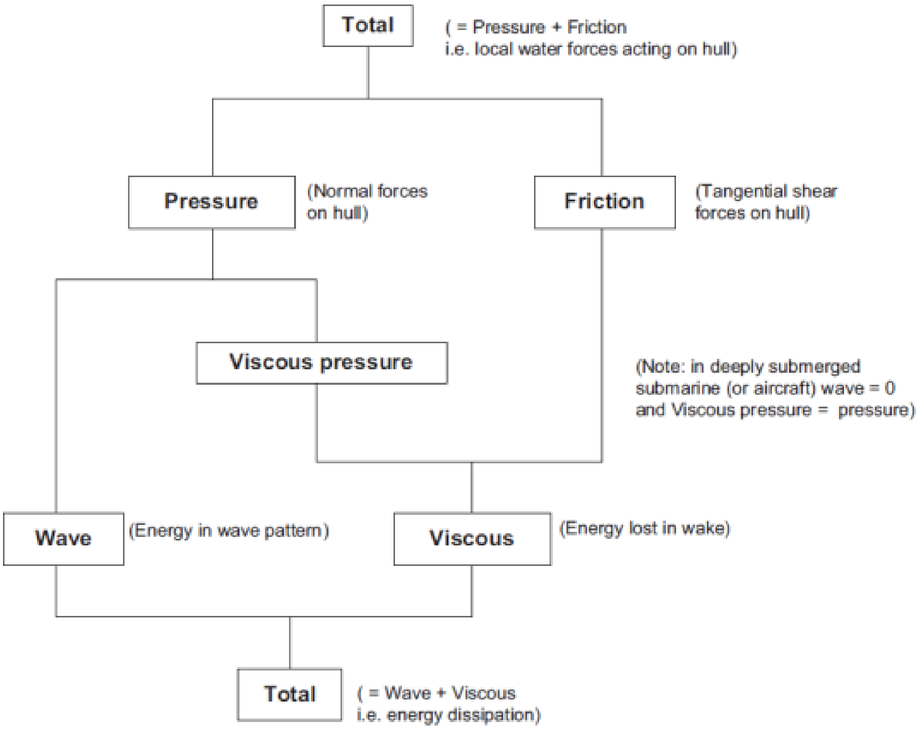

Figure 1. Basic resistance components

Figure 2. DTMB 5415 geometry

3. Numerical Setup and Mesh Generation

The commercial software CD Adapco Star-CCM+ V.10.04.011 has been used for the resistance calculations. It is well known that the accuracy of CFD results and the calculation time strongly depends on the type of the mesh and number of cells used. So calculations has been done several times to find optimum mesh number. Two million meshes is suitable for three meter geometry to get correct results as shows in Figure 3. The free surface is modeled with the two phase VOF technique. A segregated flow solver approach is used for all simulations. The Reynolds stress problem is solved by means of k-ε turbulence model. Mesh scene on bow and free surface view has been shown on Figure 4 and Figure 5.

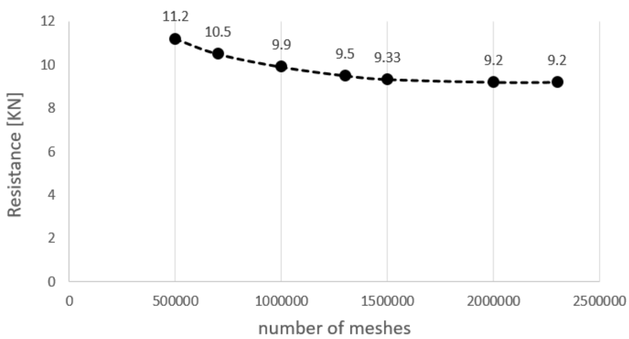

Figure 3. Mesh Independence

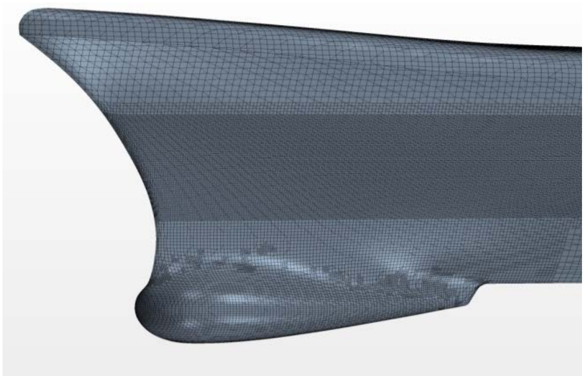

Figure 4. Mesh scene on bow

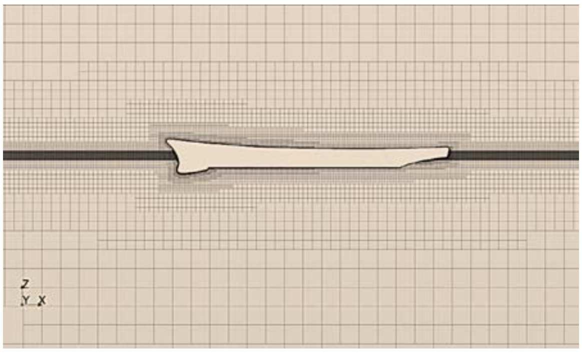

Figure 5. Mesh scene on free surface

4. Bow Modification

According to Bernoulli's equation, bulb shaped bow can decrease drag by decreasing wave height. Bow shape of vessel has been changed to bulbous bow as shown in Figure 3 and bow sonar has been omitted. Although this type of bow is not the best, this modification has decreased total drag as shown in Figure 7.

A bulbous bow may yield five types of transformation: the longitudinal translation of the bulb length, the vertical translation of the bulb tip, the transverse translation of the bulb fullness, the sectional area translation of the bulb at the Forward Perpendicular (FP) position, and the corresponding fair transition translation of the ship main forepart and dimensions can optimize by genetic algorithm or other optimization methods. Just one type of bulbous-bow has been tested in this study to show behavior of flow around the hull.

5. Aft Modification

Aft shape of vessel has important effect on drag due to viscous pressure resistance. The aft was optimized for better pressure recovery and reduction of stern pressure losses. Figure 8 shows the modification of aft geometry, which was carried out using b-spline. The pressure contours indicate a better pressure recovery at the transom for the best transom design. In this case, total drag has been compared with original DTMB to find out the effect of aft modification on drag. The results are shown in Figure 9.

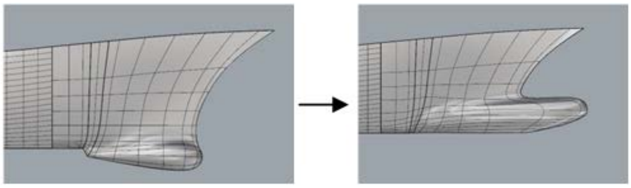

Figure 6. Bow modification

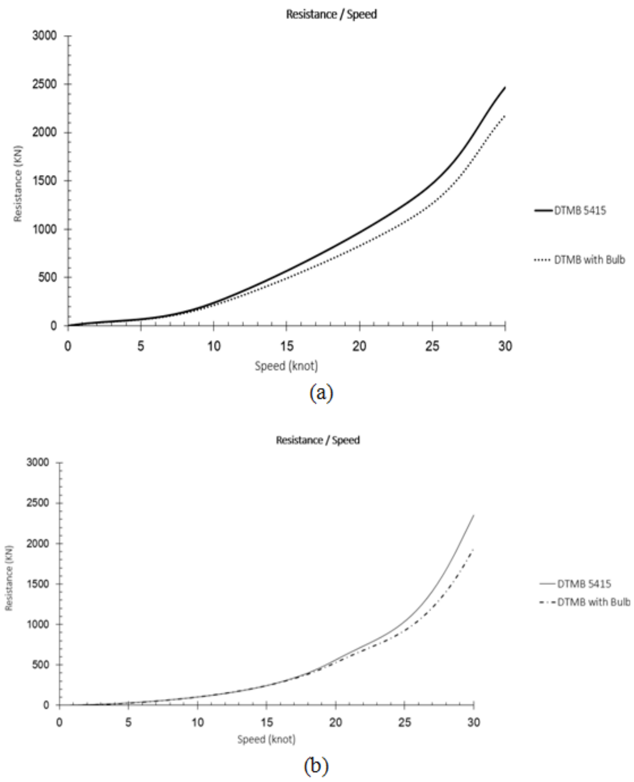

Figure 7. Bow modification drag comparison (a) CFD (b) Maxsurf

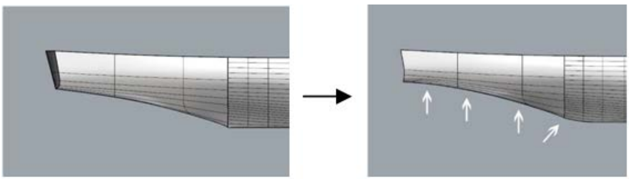

Figure 8. Aft modification

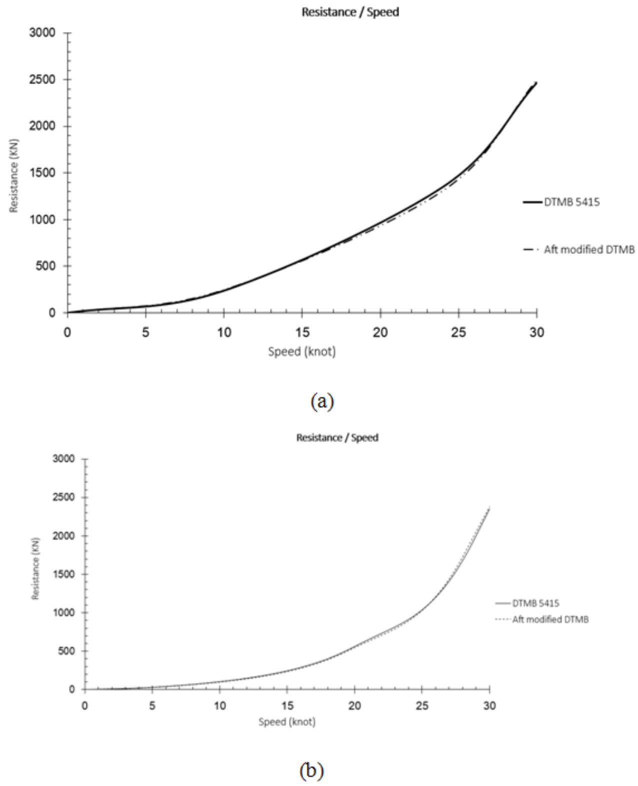

Figure 9. Aft modification drag comparison (a) CFD (b) Maxsurf

As the results are shown in Figure 9, Aft modification has a few positive effect on drag so transom is optimized.

6. Bow and Aft Modification

On the next step, modified bow and aft are used together to create a new optimized hull as shown in Figure 10. Total drag has been computed by CFD and Maxsurf and compared with original DTMB. All previous results also are shown in Figure 11 to observe and compare the charts better.

As shown in Figure 11, total drag of vessel with modified Bow and Aft is less than other hull forms which is because of desire coordination between bow and aft form that causes less wave making and viscous pressure resistance. Wave patterns around the hull are compared in DTMB with bulb and DTMB with aft and bow modification at the same speed in Figure 12.

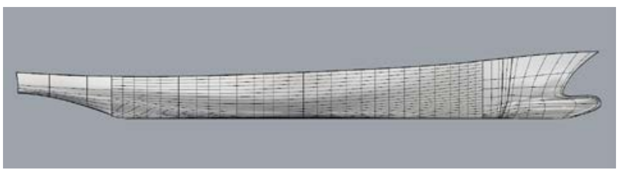

Figure 10. Bow and aft modification

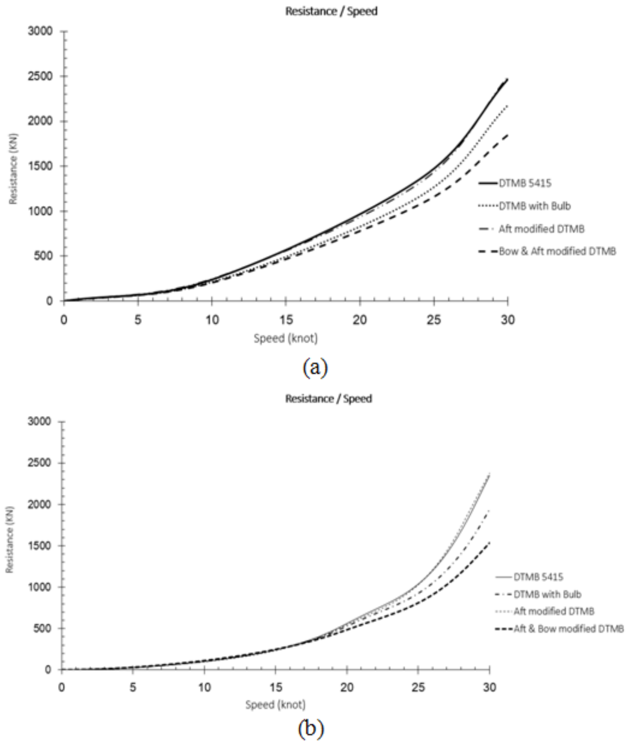

Figure 11. Aft and bow modification total drag (a) CFD (b) Maxsurf

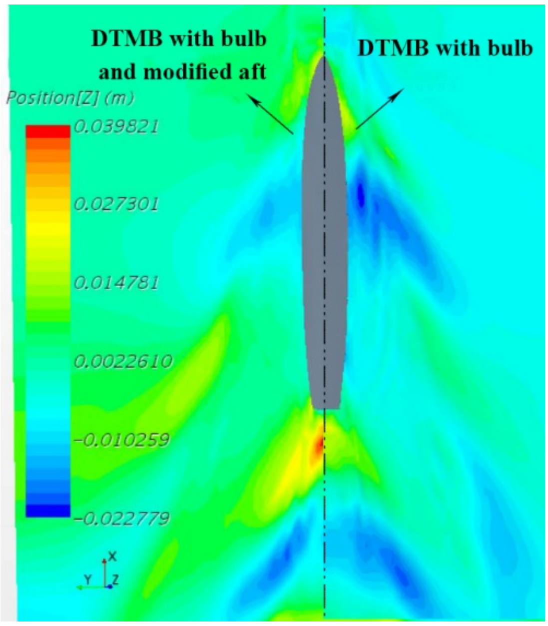

Figure 12. Wave pattern around the hull

7. Conclusions

The comparison of charts resulted from CFD and Maxsurf indicated that both software show same difference in drag value of modifications, but usually values that resulted from Maxsurf are less than Star-CCM+ software values. Figure 7 shows that bulbous-bow decreases total drag of vessel due to the reduction of wave height. Then the aft type has been modified that results drag decreasing in comparison with original DTMB, but not so much. On the final step, as shows in Figure 11 and Figure 12, a vessel with bulbous-bow and modified aft have been tested by CFD and Maxsurf. This vessel has lower drag in comparison to the previous modified hull forms and original DTMB, in other words it is optimized. This optimization is due to good coordination between modified bow and aft that causes lower wave making resistance and lower viscous pressure resistance, as shows in Figure 12.

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