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A CASE STUDY ON THE OPTIMIZATION OF LONGITUDINAL CENTER OF BUOYANCY OF THE CARGO VESSEL

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ABSTRACT

The paper presents a case study on the optimization of longitudinal center of buoyancy (LCB) of the cargo vessel to minimize the ship resistance. Starting with the initial and non-optimized hull form of a cargo vessel, Lacken by method [1] is applied to make the new hull forms by adjusting LCB, however the displacement of the vessel is kept constant. The LCB optimization is performed in CAESES software, coupling with panel method code Ship Flow to calculate resistance and SIMPLEX optimization algorithm. To validate the optimization of the LCB, Reynold Average Navier Stokes Equation (RANSE) CFD method is used to determine the amount of total resistance reduction.

Keywords: LCB, Ship Resistance, Panel Method, Optimization, RANSE CFD.

I. INTRODUCTION

Nowadays, new-build ships are highly demanded in terms of energy efficiency and CO2 reduction which are depleting. In 2010, the International Maritime Organization (IMO) released the Energy Efficiency Design Index to measure the amount of CO2 a ship has removed during its operations. Therefore, it requires designers to come up with methods to reduce EEDI. One of the methods is to reduce ship resistance by optimizing the hull form. When the resistance of the ship is reduced, the amount of fuel consumed is also reduced and the amount of CO2 emitted is also reduced.

During hull form design, there are several important factors affecting the ship's resistance such as: position of center of buoyancy, length of parallel hull, shape of bow and stern, shape of water flow, shape of cross-sections [14]. This paper presents the effect of one of these important factors on the ship's resistance, which is the longitudinal center of buoyancy (LCB). The LCB of the original hull has been changed, but the main dimensions (vessel length, breadth, depth, and draft) are maintained by applying the Lackenby method [1].

There are now many methods for estimating ship resistance in the early stages of design. It is possible to mention the method of using the regression formula through testing the ship model such as Holtrop & Menden, Hollenbach [3]. The advantage of these methods is that they quickly give the results of the ship's resistance but have a relatively large error and are especially difficult to apply in this case when only one parameter, the center of buoyancy, is changed. The second most used method today is Computational Fluid Dynamics (CFD). This method has been widely applied in the world because it gives relatively accurate results compared to the results of model testing, as well as more economic benefits than the method of model testing due to unrestricted control. create model. However, the disadvantage of this method is that the computation time is relatively long, making it difficult to apply the optimal calculation. When calculating the optimization, it is necessary to calculate the resistance force on many hull forms to find the form with the smallest resistance. Another method is to use the table method, which calculates resistance by dividing the hull and the water-free surface into panels. This method ignores the viscosity of the liquid, also known as the potential flow method, so only wave resistance can be calculated. The remaining resistance components can be estimated by empirical formulas. By using this method, it is possible to realize the difference in ship resistance when changing one of the hull parameters such as longitudinal center of buoyancy (LCB). Another advantage is that the calculation time of this method is very fast compared to the CFD method. In fact, for fast fleets such as container ships, wave resistance accounts for a significant proportion of the total hull resistance component. In addition, changing the position of buoyancy along the hull greatly affects the distribution of the wave system along the hull, and mainly changes the wave resistance. Besides, the viscous resistance does not change significantly. Therefore, we can apply this method to calculate and then choose the hull with the smallest wave resistance. The RANSE CFD method will be used at the final stage, to determine the reduction in total resistance between the optimal hull and the original hull. The calculation diagram is shown in Figure 1.

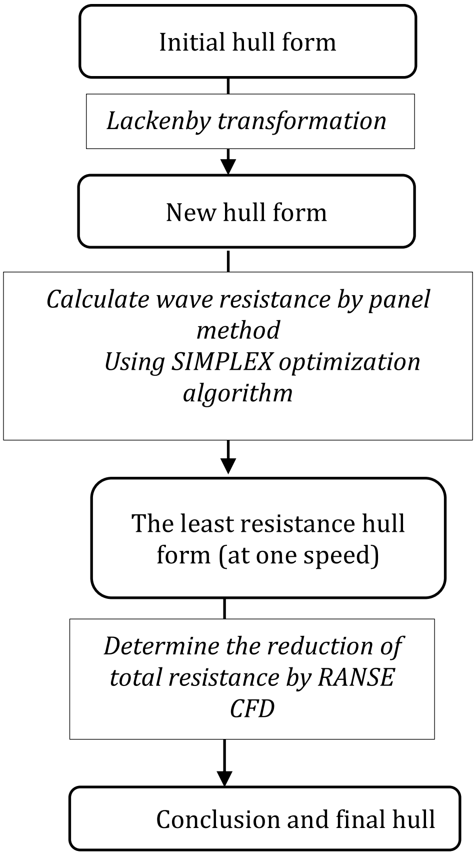


Figure 1: Optimization steps.

II. CASE STUDY

The case study here is a container vessel of which hull form is developed in a 3D software and not yet optimized. It is typical case for a naval architect. The method above will be applied to optimize the initial hull form in terms of resistance reduction by modifying the longitudinal center of buoyancy. The vessel will be optimized for a speed of 20 knots, corresponding to the Froude number of 0.23. In this speed, the wave resistance is accounted for 20-25% of the total resistance. The main dimensions of the container vessel in this study are presented in the Table 1 below.

III. CALCULATION RESULT

Optimal results are shown in Figure 3. Based on Nelder Mead Simplex algorithm, wave resistance has been calculated with multiple values of longitudinal center of buoyancy and minimum wave resistance is achieved when LCB is equal to 0.1968 % Lpp towards the bow (result is starred and framed in Figure 4). Minimum wave resistance CWTWC = 0.24 x 10^{-3}. Thus, compared with the wave resistance coefficient of the original hull of 0.368 x 10^{-3}, the wave resistance coefficient of the new ship has decreased by 34.7%. However, wave resistance only accounts for about 20% of the total resistance so it can be predicted that the new hull will have about 6% reduction in total resistance compared to the original hull.

The calculation results are also shown graphically in Figure 4, with the vertical axis being the wave resistance coefficient and the horizontal axis being the longitudinal center of the buoyancy xcb. On the graph, when moving the LCB towards the bow of the ship, the wave resistance decreases to the minimum value (at position xcb = 0.1968%), then begins to increase.

Figures 5 and 6 show the wave heights along the hull and the free surface heights of the original and new hulls. Wave shape and wave height at the bow of the new ship are significantly smaller than that of the original ship, so the wave resistance is reduced. Meanwhile, the wave height at the stern is almost unchanged.

Table 1. Main dimensions of the vessel

Hull form parameters		Unit	Value
Displacement Weight	Δ	ton	36,828
Draft	d	m	10.56
Length between Perpendiculars	L_{pp}	m	190.56
Breadth	B	m	32.2
Block coefficient	C_B	-	0.542
Mid ship section area coefficient	C_M	-	0.945
Longitudinal center of buoyancy	LCB/L_{pp}	%	48.52
Speed	v	Knots	20

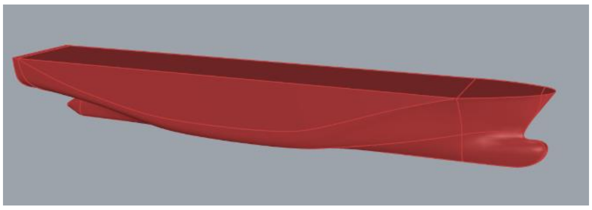
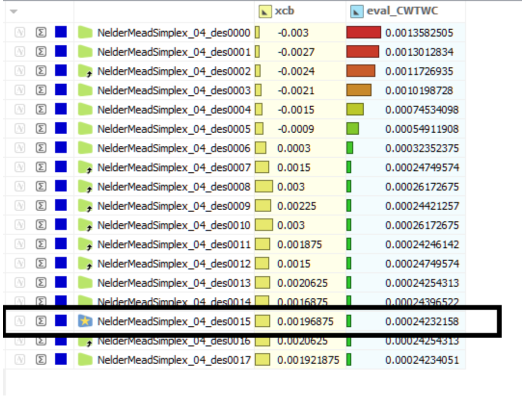


Figure 2: Initial hull form



	xcb	eval_CWTWC
NelderMeadSimplex_04_des0000	-0.003	0.0013582505
NelderMeadSimplex_04_des0001	-0.0027	0.0013012834
NelderMeadSimplex_04_des0002	-0.0024	0.0011726935
NelderMeadSimplex_04_des0003	-0.0021	0.0010198728
NelderMeadSimplex_04_des0004	-0.0015	0.00074534098
NelderMeadSimplex_04_des0005	-0.0009	0.00054911908
NelderMeadSimplex_04_des0006	0.0003	0.00032352375
NelderMeadSimplex_04_des0007	0.0015	0.00024749574
NelderMeadSimplex_04_des0008	0.003	0.00026172675
NelderMeadSimplex_04_des0009	0.00225	0.00024421257
NelderMeadSimplex_04_des0010	0.003	0.00026172675
NelderMeadSimplex_04_des0011	0.001875	0.00024246142
NelderMeadSimplex_04_des0012	0.0015	0.00024749574
NelderMeadSimplex_04_des0013	0.0020625	0.00024254313
NelderMeadSimplex_04_des0014	0.0016875	0.00024396522
NelderMeadSimplex_04_des0015	0.00196875	0.00024232158
NelderMeadSimplex_04_des0016	0.0020625	0.00024254313
NelderMeadSimplex_04_des0017	0.001921875	0.00024234051

Figure 3: Optimization result by Ship flow

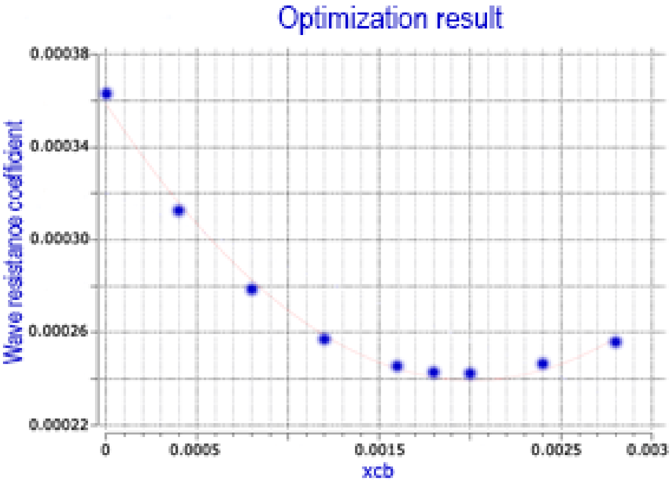


Figure 4: LCB vs Wave resistance coefficient

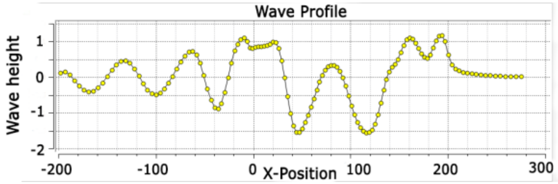


Figure 5a: Wave height along the hull of the initial hull

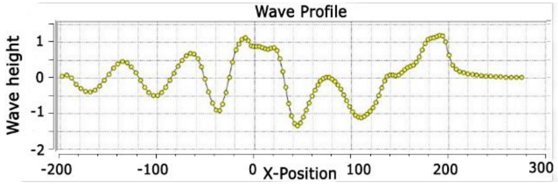


Figure 5b: Wave height along the hull of the optimized hull

As stated in the beginning of the paper, the panel method only gives us the wave resistance result. We need another method to get the total resistance of the vessel. Therefore, the RANSE CFD method is used in this case. This method is time consumption and only is used at the end of the optimization process. Total resistance of original hull form and the optimized one are given in the Table 2 below

Table 2. Total resistance calculation

	Total resistance	
Original hull	897,576	(N)
New hull	840,874	(N)
Reduction	**6.32%**	

IV. CONCLUSION

This paper presents the typical resistance optimization case in hull form design by coupling the panel method and CFD method. As a result, the total result of the optimized hull is reduced by 6% compared to the original hull. Here, only one variable is chosen for optimization, it is longitudinal center of buoyancy. The objective of the optimization is also just total resistance. Further study can be performed with multiple variables and multiple objectives to get much better hull form. The results also show the application of CFD in solving problems related to hydrodynamics of ships. With the rapid development of computational speed, the application of CFD in the calculation and design of ships is playing an indispensable role.

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