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Hull Form Design for Baltic Ice Class Aframax Tanker

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Abstract

A hull form of Baltic ice class IA Aframax tanker has been developed taking into consideration of powering performance in brash ice channels based on IA class rules. Speed performance of the ship hull form in normal seagoing has been validated through model tests in a towing tank. The hull form design developed in this work has demonstrated good speed performance in normal seagoing although the ship design is entitled to ice class IA.

Keywords: Baltic ice class IA Aframax tanker, brash ice channels, Finnnish-Swedish ice class rules

1 Introduction

Baltic seas has become a more important voyage route since large crude oil tankers started to transport crude oil from places such as the Primorsk oil harbor in Russia. Finnish-Swedish ice class (FMA 2002) has recently amended a regulation on the structural design and engine output required for the ships which will be, in the winter season, navigable in the brash ice channels broken by icebreakers in Baltic seas. Baltic ice class ships should meet two aspects of performances; minimum required speed of 5.0 knots for navigation in ice channels and a minimum speed loss in normal seagoing when compared with the existing ships. Finnish-Swedish ice class rules classify the ice class ships for Baltic seas into four classes: IA Super, IA, IB, and IC. The rules also describe how to determine minimal required engine output for each ice class.

Recently many of ship owners requested to construct Baltic ice class ships according to the revised ice class rules; thus ship yards including Hyundai Heavy Industries initiated to develop Aframax size Baltic ice class tankers up to the ice class IA grade. For Baltic ice class vessels, engine should retain power performance enough to make the vessels go through the brash ice channels in a minimum speed of 5.0 knots in a given ice condition although the frequency of navigation is relatively low. Baltic ice class ships need to have minimum speed loss in normal sea going when compared with the existing normal ships because they navigate more frequently in the normal sea route without ice. A competitive ship should be optimized in view of price and speed performance through a series of the preliminary design processes including main parameters, engine selection, and hull form design.

If the hull form of the existing ship is, for example, applied to Baltic ice class IA Aframax size tanker, the required engine output becomes bigger as much as the power of

VLCC when the power is estimated by the formula in new rules. In the view of preliminary design, bigger engine power means the bigger engine size and it gives rise to reduction of dead weight tonnage. On the other hand, for the lower engine powered ship, the length of ship has to be more increased to reduce ice resistance in ice-going and this gives rise to the additional cost of the ship. Thus, it is required to develop new hull form for better competitive Baltic ice class ships.

In this work, a new hull form of Baltic ice class IA Aframax tanker has been at first developed because a great demand is expected for the construction of this size. Hull form design has been carried out to achieve better speed performance in brash ice channels based on IA class rules. In addition, the hull form was designed to minimize the speed loss when compared with an existing normal ship of 105,000 DWT size and 42m beam. Moreover, the speed performance in normal seagoing was validated through the model tests in HMRI towing tank, and it showed that the designed hull form has good speed performance in spite of being entitled to ice class IA.

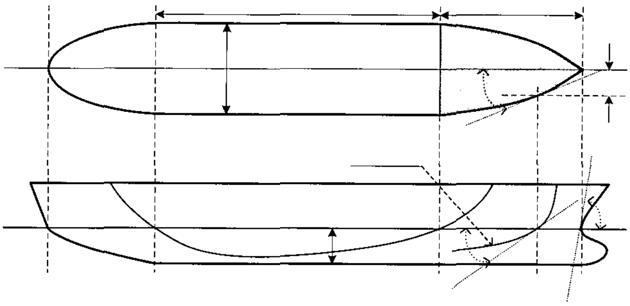


Figure 1: Definition of ship dimensions and main parameters

Table 1: Description of main parameters

LBOW	Length of the bow [m]
LPAR	Length of the parallel midship body [m]
α	The angle of the waterline at B/4 [deg]
AWF	Area of the waterline of the bow [m2]
ϕ1	The rake of the stem profile [deg]
ϕ2	The rake of the bow at B/4 [deg]

2 Hull form development of Baltic ice class IA Aframax tanker

In this work, we selected an existing ship, 105,000 DWT standard tanker as a reference ship from the beginning of the development of Baltic ice class IA Aframax tanker because most vessels operating through Baltic route are Aframax sized.

2.1 Main engine power and performance in ice-going

Finnish-Swedish ice class rules state that required engine power should be sufficient enough to make a ship navigate in a minimum speed of 5.0 knots in the brash ice channels. The rules also propose a formula for the calculation of the required engine power. The previous rules other than the current new ones argued that the required engine power varies directly proportional to ship displacement. The new rules, however, recommend that the delivered power of the engine should not be less than the value calculated by a formula (Kaj 1997):

$$P_D = K_e \frac{(R_{CH}/1000)^{3/2}}{D_P} \; [kW] \quad , \quad R_{CH} = f\begin{pmatrix} L, B, T, L_{BOW}, L_{PAR}, \\ \alpha, \phi_1, \phi_2, A_{WF} \end{pmatrix}$$

where P_D is the net delivered power from the propeller, K_e is a proportional constant applicable for conventional propulsion systems, and R_{CH} denotes a function of many parameters closely related to the bow shape of the hull form. The parameters included in the function are defined in Figure 1 and Table 1.

Ice towing model tests (ITTC 1996) should be carried out to acquire higher level of accuracy in the estimation of the required engine power. It was, however, impossible to reflect the results of ice towing model tests at the phase of initial hull form design in this work. For that reason, the new formula was used in the prediction of the powering performance of the hull form design. Nevertheless it is generally accepted that the formula can represent qualitative performance of hull designs although no results of model scale experiments are available for this size of ice class ships.

Table 2: Comparison of main particulars and required powers

	105,000 DWT Aframax tanker		Baltic ice class IA Aframax tanker	
Ship Model No.	T189A		T358	
LOA	244.0 m		244.0 m	
LBP	234.0 m		236.9 m	
B	42.0 m		42.0 m	
Design draft	13.6 m		13.6 m	
Volume	108,085 m3		108,240 m3	
LCB	124.9 m from AP		125.1 m from AP	
Required power (ice class IA)	31,967 PS (CPP)	35,589 PS (FPP)	22,733 PS (CPP)	25,309 PS (FPP)
NCR power	16,580 PS		18,240 PS	

2.2 Main particulars and hull form design

As shown in Table 2, if a hull form design of an existing 105,000 DWT tanker is applied to the Baltic ice class IA tanker, the engine power required for the ice class is estimated to be about twice 18,420 PS at NCR condition. Assuming that the engine power calculated from the new formula is to be realistic for the navigation in ice, it may be concluded that engine length should be increased by 5 m, resulting in the subsequent loss of cargo volume of the ship. Schematic arrangement of main engine based on this investigation is illustrated in Figure 2. Thus, it is required to develop new hull form for better competitive Baltic ice class ships.

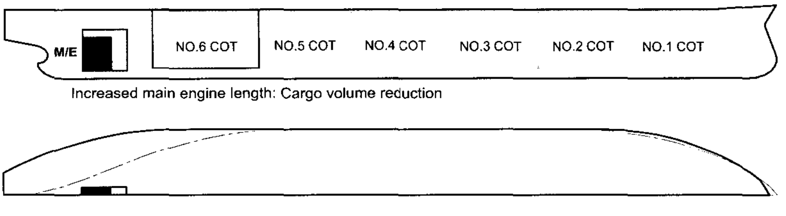


Figure 2: Schematic arrangement of main engine

To develop a new hull form for Baltic ice class ship, the effects of hull form parameters on the required power calculated by the new formula have been investigated based on ice class IA and the results are illustrated in Figure 3. The results show that propeller diameter (Dp) and ship breadth (B) are closely related with the required engine power. However, propeller diameter should be less than ballast draft and the ship breadth is in general kept fixed at the preliminary design stage. Accordingly the most important parameter we may choose for a variable in the determination of speed performance in ice-going on the stage of hull form design, is the angle of waterline (α) at B/4.

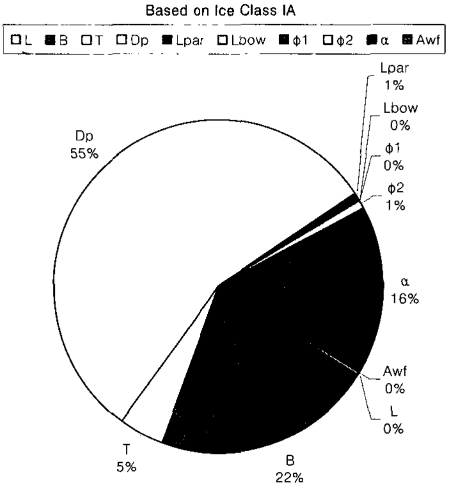


Figure 3: Correlation between required power and hull form parameters

Through the parametric study of hull from parameters, it is concluded that the following design methods can reduce the required power in ice-going operation for smaller angle of waterline at B/4.

① With an increase in the length-beam ratio, L/B, it is possible to make the bow waterline shape streamlined and sharp for better speed performances both in ice and normal seagoing. This, however, may lead to a rise in the ship cost when compared with the non-ice classed ships.

② The reduction in the length of the parallel part of ship can make the bow waterline shape sharp, but this may subsequently reduce a large amount of the dead weight of ship.

③ To avoid the resulting side effects when using the two design methods mentioned above, it is desirable to make an angle of waterline at B/4 smaller than that of the existing ship for better performance in ice when the fixed ship length is fixed. However, this kind of hull form may cause the entrance angle of bow waterlines to be large, thus making the bow end shape blunt. This blunt bow will result in excessive wave breaking which in turn causes any speed loss in normal seagoing.

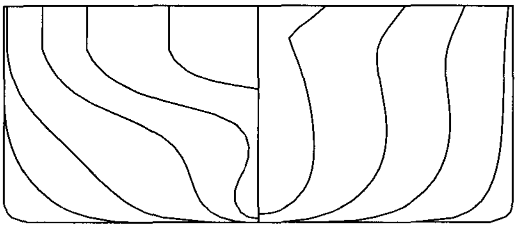


Figure 4: Body plan of Baltic ice class IA Aframax tanker

In this study, we have concluded that the third design method is most profitable in terms of ship cost and dead weight. Ship owners will prefer this design to maximize their profits in ship cost and operations. We should make up for the speed loss in normal seagoing when using design concept: it is recommended that LBP (the length between perpendiculars) should be increased while LOA (the overall length) is fixed. This will result in decreases of waterline angle at B/4 and the bow entrance angle. Through numerical computations to investigate optimum bow waterline shape, a new hull form of Baltic ice class IA Aframax tanker has been developed which demonstrated no additional speed loss in normal seagoing. The body plan of the new hull form is shown in Figure 4.

In view of hull form design, the waterline of LWL is very smooth and accordingly shoulder-induced wave height is expected to be lower than that of the existing ship although the wave height produced in the bow tip is a little high. The bow shape retains an icebreaking bulbous bow, which is useful in pushing aside ice pieces in the brash ice channel with good performance.

When we started to study the hull form design for Baltic ice class IA, the effort for power reduction was aimed at avoiding unexpected increase in main engine size. It is presently known that the contracts for Baltic ice class ships are increased in numbers, and accordingly the model tests in ice towing tank are frequently carried out to evaluate the ice resistance for Aframax or Suezmax size tankers. A recent report of ice towing model tests indicates that the power required for Aframax or Suezmax tankers does not exceed 30 to 40 percent of the power calculated by the rule formula. This means that the real power required for ice-going class could be much less than the NCR power required for conventional seagoing class. In this case, it might be concluded that hull form design for power reduction in ice class is not necessary for an ice class ship. However, we don't have to underestimate the importance of design efforts for power reduction since operational margin (e.g. RPM margin against torque limit) can be sufficiently established as a result of power reduction efforts.

3 Numerical calculation and model tests

For a competitive ice class ship, a new hull form design (ship model No.: T358) has been achieved. We aimed at designing a hull form which has better speed performance in ice-going and no speed loss in normal seagoing when compared with the existing 105,000 DWT standard tanker ship (ship model No.: T189A).

In this work, we could not estimate the performance in ice-going condition because ice towing model test was not conducted at the stage of hull form design. However, the speed performance in normal seagoing was predicted through the numerical calculations and the model tests in HMRI towing tank: resultantly speaking, the new hull form design exhibited good powering performance without speed loss when compared with the comparative hull form of T189A (as shown in Table 4).

For the comparison of hull forms, T358 and T189A, numerical calculations were performed using a potential-based numerical code. The pressure distributions on the hull surfaces are shown in Figures 5 and 6. Wave profiles produced along the hulls are compared as shown in Figure 7. To begin with, the computed wave profile of T358 is in accord with the observed wave profile through the model tests from a qualitative point of view especially around the bow part of a ship. The pressure fluctuation the bow part in T358 is smaller than that of T189A. The outstanding feature is the difference of bow wave system. The wave profile of T189A shows a typical wave shape produced in the tankers characterized by a big hollow on the shoulder part of low speed full ships. In the wave profile of T358, the large hollow produced in T189A is split into two small hollows around the shoulder part of the ship; wave-making resistance in T358 is expected to be small to a certain extent. The difference of wave systems between T189A and T358 has been clearly observed in the model test as shown in Figures 8 and 9. Wave elevations measured in the model tests are very similar to those calculated by the potential code. Figures 8 and 9, in particular, demonstrate that maximum wave elevation around the bow part of T358 is smaller than that of T189A although they were measured at 15.0 knots for T358 and 14.5 knots for T189A.

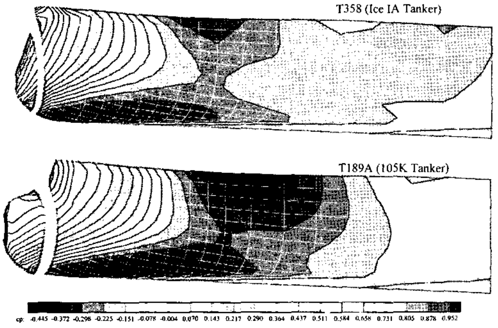


Figure 5: Pressure distributions in bow parts

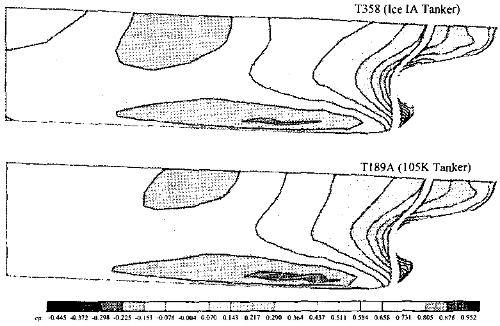


Figure 6: Pressure distributions in stern parts

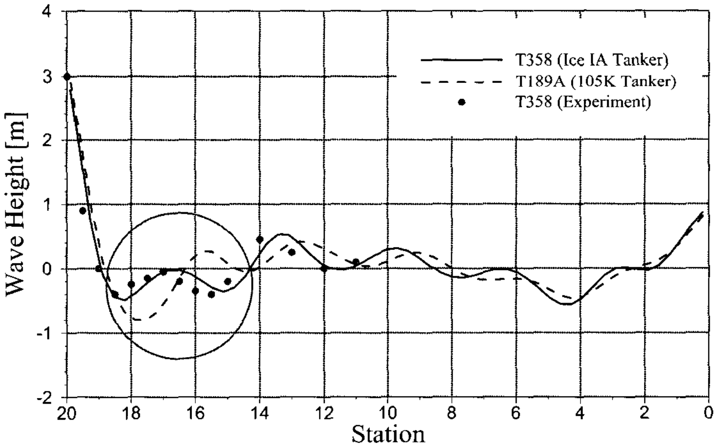
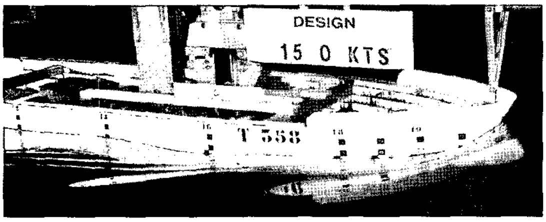


Figure 7: Comparison of the calculated wave profiles between T358 and T189A



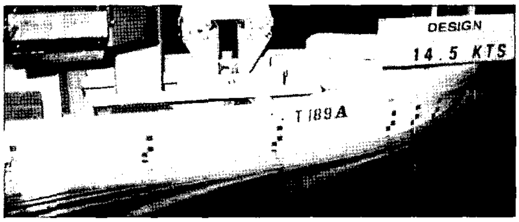


Figure 8: Bow wave profile of T358

Figure 9: Bow wave profile of T189A

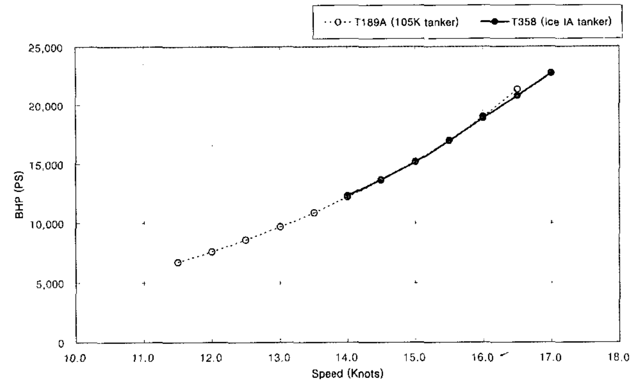


Figure 10: Comparison of brake horse powers

Table 3 shows the model test results of T358 with HP582. Compared with the target speed aimed at this work, the result for the new design shows good speed performance. Table 4 and Figure 10 contain the comparison of the model test results of T358 and T189A Additional motel tests for T358 with a design propeller HP352 for the 105,000 DWT existing tanker have been conducted to compare the speed performance of the two ships in normal seagoing. The comparison of the brake horsepower (BHP) between T189A and T358 is shown in Figure 10. Although a slight increase in BHP of T358 is observed at 14.0 knots, the result at 15.0 knots shows almost no difference between the two models in power level. Over 15.0 knots a slight reduction of power has been achieved in the new design. In terms of NCR power level (16,580 PS for T189A), it has been confirmed that T358 shows no speed loss in normal seagoing when compared with T189A.

Table 3: Model test results of T358

	Target speed	M/T result
Propeller	HP582 (8.1 m), CPP	
Speed (%)	100.0	99.9
NCR Power	18,240 PS	

Table 4: Comparison of model test results

	T358	T189A
Propeller	HP352 (7.2 m), FPP	
Speed (%)	100.1	100.0
Power	16,580 PS	

4 Conclusions

A new hull form for the Aframax tanker graded Baltic ice class IA has been developed. Design process is introduced through the study of the speed performances in ice-going and normal seagoing. For a competitive ice class tanker design in view of the ship cost and the speed performances in comparison with an existing 105,000 DWT standard tanker, it is suggested that the increase of LBP keeping LOA fixed. The design will make an ice class tanker retain good speed performance in normal seagoing condition as well as in ice-going condition.

In the present work, speed performance in ice-going condition has been evaluated based on the required engine output calculated by the formula in the new Finnish-Swedish ice class rules. When estimating required power using the new formula, although the calculation may differ from the model tests, the new ice class design exhibited a powering reduction by 10,000 PS when compared with the existing 105,000 DWT Aframax tanker. This amount of power reduction may contribute to the optimum capacity of main engine and the operational margin in view of RPM margin against torque limit.

In view of the speed performance in normal seagoing, the new hull form design developed in this work demonstrated good result: almost no speed loss in comparison with the existing 105,000 DWT standard tanker through the numerical calculations and the model tests in towing tank.

For future work, we intend to further improve the hull form design and the outlines of main engine, reflecting the results of the ice towing model tests.

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