Analysis of Total Ships Resistance with Variation of Hull Bow Types, Ulstein X-Bow, Spherical and Tapering Bulbous Bow using CFD Method

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Keywords: The Total Resistance, Model X-Bow, Spherical Bulbous Bow, Tapered Bulbous Bow.

Abstract: Ships must have good performance and economic value. To achieve it, optimum speed is needed with minimal engine power usage so it can increase the efficiency of fuel use. The use of engine power is closely related to the total resistance on a ship. One alternative way to reduce ship resistance is to install bulbous bow. This research aims to obtain the resistance of ships with variations in the type of bow shape of the ship. The analysis on this research uses numerical method using CFD. Variations in the modelling of bow design are; X-Bow, spherical and tapering bulbous bow. Based on the results of CFD calculations, each model is obtained, namely; the lowest value of the total resistances coefficient and total resistances model X-Bow 0,006565 and 242,76 KN, while for the spherical bulbous bow model is 0,007211 and 267,22 KN and for the lowest form of tapering bulbous bow the total drag coefficient and total resistance is 0,007368 and 273,40 KN. Referring to the results of the analysis, resistances of the ship model using the X-Bow design is the best model that can be used as an alternative if compared to spherical and tapering bulbous bow.

1 INTRODUCTION

Nowadays, various researches have been conducted in the field of ship which aims to improve optimum results both in terms of economy and performance. Ships are expected to have good performance when sailing, so the ship can sail in bad weather or extreme sea conditions. Besides, the target of the design optimizing efficiency is about the speed of the ship, which is how to get the ship design that has optimum speed but the minimum use of engine power so that it can increase the efficiency of fuel use. The use of engine power is closely related to the resistance experienced by a ship. One alternative way to reduce ship resistance is to install bulbous on the bow of the ship. Ships with a good bow will provide the efficiency of the resulting barriers so that ship operations and ship movements become better (Chrismianto, et.al, 2014) The hydrodynamic effect of bulb bow placement is based on changes in the distribution of flow around the bow, interfering with the waves that occur due to the hull so as to reduce the overall wave system (Francisco, et.al, 2007). Currently the concept in shipbuilding design especially in the bow of the ship to reduce fuel consumption is the Ulstein X-Bow Bulbous bow concept, which is a rounded structure in the bow of a ship that is below the surface of the water which functions to produce waves before the ship pushes water. The waves produced by the bulbous bow are opposite to the waves produced by the ship's body, so that both waves will offset each other and make the resulting waves smaller. The effect of using a bulbous bow can reduce the total resistance of the ship by 30%. (Watson, 1998) Therefore, through this research is expected to analyze the value of the total resistance experienced by ships with the Ulstein X-Bow design and the ship uses bulbous bow spherical and tapering. The purpose of this research was to obtain the total resistance of ships using Ulstein X-Bow and bulbous bow (tapering bulb and spherical bulb) with the calculation of CFD method.

2 LITERATURE REVIEW

2.1 Ulstein X-Bow Definition

Overall the shape of the Ulstein X-Bow is different from conventional bow. The Ulstein X-Bow is dominated by a high, rounded and expands slightly at the top of bow (Lewis, 1998). Ships with Ulstein

Kiryanto, ., Chrismianto, D. and Firdhaus, A.
Analysis of Total Ships Resistance with Variation of Hull Bow Types, Ulstein X-Bow, Spherical and Tapering Bulbous Bow using CFD Method.
DOI: 10.5220/0008374400600064
In *Proceedings of the 6th International Seminar on Ocean and Coastal Engineering, Environmental and Natural Disaster Management (ISOCEEN 2018)*, pages 60-64
ISBN: 978-989-758-455-8

X-Bow have great buoyancy because of increasing volume of the bow shape. Ulstein X-Bow was first introduced in 2005. Known as inverted bow because of the bow shape with the top flipped towards the rear. Ulstein X-Bow was originally designed for offshore vessel. A vessel with a bow like this has better seakeeping than a conventional bow. In addition to seakeeping, this bow is also able to increase fuel efficiency and makes waves more subtly.

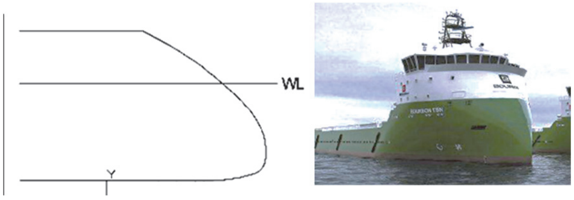

Figure 1: Ulstein X-Bow model.

2.2 Tapering and Spherical Bulbous Bow

Bulbous bow is a part of the ship located in the bow section. This part is a part that is integrated with the hull. The main function of this section is to reduce ship resistance when the ship is operating. The bulbous bow shape plays an important role in determining the magnitude of the benefits. The optimum shape depends on the size of the Froude number (Harvald, 1983). Most resistances on the ships are caused by the part of the ship that has direct contact with the fluid. The fluid, which the ships through, forms a wave pattern due to the movement of the ship's body that eventually causes friction with the hull, the working principle of the bulbous bow is to generate waves or interfere the waves of the ship coming from the bow, so that the incoming wave will lose power due to wave interference from bulbous bow and in the end the wave energy around the hull will decrease, thus the resistance of the ship will be decrease too.

Figure 2: Bulbous bow model.

2.3 Ship Resistance

Ship resistance is the most important factor that determines the power of the ship needed (Rawson and Tupper, 2001). Ship resistance is the study of fluid reactions due to the movement of the ship through the fluid. In order for a ship to move at a desired speed, the ship's resistance must be overcome by other forces that push the ship (Wartono, 1982) In terms of hydrodynamics the ship is the amount of fluid force acting on the ship in such a way that it opposes the movement of the ship. The main and most significant factor is the hull geometry and the wet surface of the vessel (Bhattacharrya, 1978). The resistance is the same as the force component that works parallel to the axis of the ship's velocity. the total resistance of the ship is calculated based on the mathematical approach of the Holtrop Method in the Principles of Naval Architecture Vol II, Second Revision (Lewis, 1988)

$$R_T = 0.5 C_t \rho V_s^2 S \tag{1}$$

Where:

C_t =total resistance coefficient,

S =wet surface area on hull (m2),

ρ = density of sea water (kg/m3)

V_s = service velocity (m/s)

2.4 Computational Fluid Dynamic (CFD)

Computational Fluid Dynamics (CFD) is an analysis system that includes fluid flow, heat transfer, and related phenomena. As a chemical reaction by using computer based simulation (numeric). This technique is very useful and can be applied in industrial and non-industrial fields. CFD codes are structured on numerical logarithms, so they can be used to solve problems in a fluid flow. Computational fluid dynamics code here consists of three main elements, namely:

a. Pre Processor.
b. Solver Manager.
c. Post Processor (Visualize).

One reason why CFDs are so successful and popular is their ability to simulate currents that are close to the original conditions, 3 dimensions, irregular current geometry, and phenomena that have complex physical. This is possible because it uses numerical solutions from equations that regulate fluid flow rather than using analytical solutions (Jayanti, 2004).

3 RESULTS AND DISCUSSION

On the table 1 is used ship principal dimension in the research.

Table 1: Principal Dimension.

Principal Dimension	
Length of Perpendicular (LPP)	99,20 m
Breadth (B)	18,94 m
Draft (T)	4,00 m
Height (H)	6,00 m
Displacement	4595,00 ton
Wetted Surface Area	1900,50 m²

Table 2: Dimension of model.

Model Dimension	
Length of Perpendicular (LPP)	2,02 m
Breadth (B)	0,39 m
Draft (T)	0,082 m
Height (H)	0,12 m
Displacement	0,0384 ton
Wetted Surface Area	0,794 m²

Furthermore, the ship's resistance analyses with the variation of the X-Bow form and bulbous bow model.

3.1 Modelling with CAD Software

From the main dimension data of the ship model, the ship body modelling was made with the help of CAD Modeller.

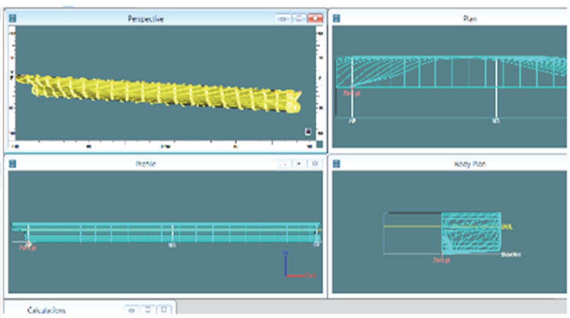

Figure 3: Modelling with CAD Modeller.

3.2 Modelling with CAD Software

Ship model making also uses CAD 3D software so that it can be opened in CFD software.

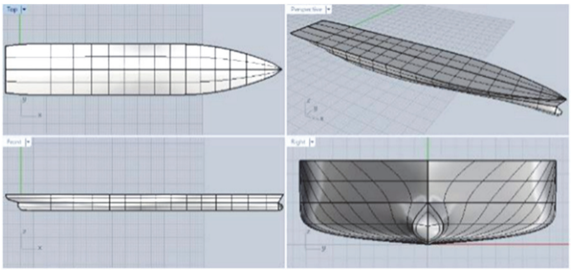

Figure 4: Modelling spherical bulbous bow with CAD 3D software.

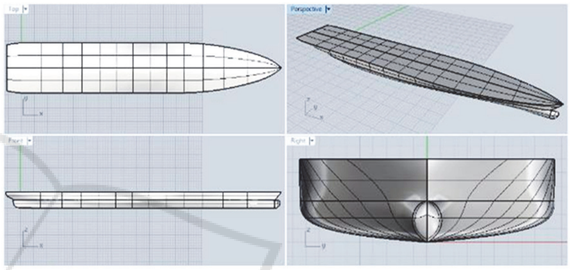

Figure 5: Modelling tapered bulbous bow with CAD 3D software.

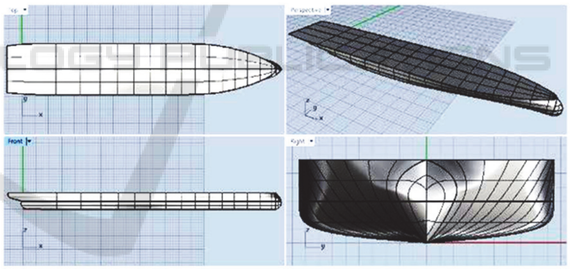

Figure 6: Modelling X bow with CAD 3D software.

3.3 Computational Fluid Dynamic (CFD) Simulation

The process of numerical simulation on Computational Fluid Dynamic starts from making a hull model. Modelling using the CAD software, then the file is exported in the form of a file igs. The model used must be solid. After the model is finished, the work continues using numerical simulations. The numerical simulation software used is software based on computational fluid dynamic. This simulation steps are divided into several stages including: geometry, mesh, setup, solution and result.

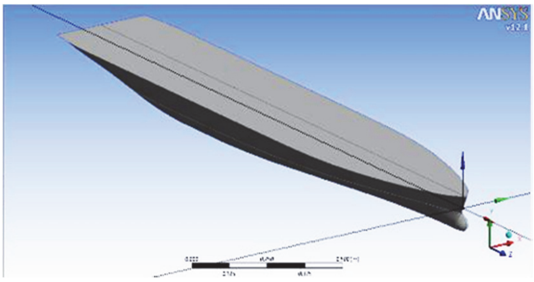

Figure 7: Geometry solid modelling.

After the running or simulation process is complete, the results can be seen in the result stage. The results obtained are the resistance value of the ship, the model and visualization of the flow on the free surface and station behind the hull.

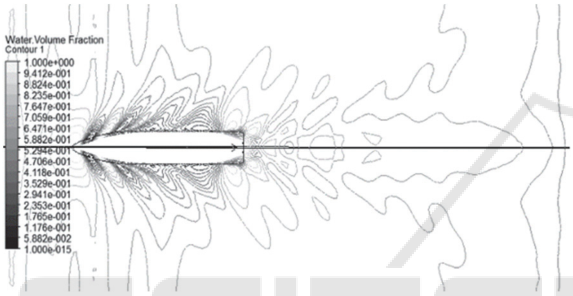

Figure 8: Visualization of fluid flow.

3.4 Validation

In this research to validate the results of the test model is using the results of towing tank test that has been done in previous research. Validation is used to determine the right boundary condition to be used in the boundary condition when analyzing 3 ship models using CFD software. The maximum error for validation between numerical method and towing tank test results is 10%.

Table 3: Validation Data.

Ship Model	Ct x 10^{-3} Experiment	Ct x 10^{-3} CFD	Difference
Model of spherical bulbous bow (1^{st} model)	6.362	5.999	0.363 (5.71%)
Model of tapered bulbous bow (2^{nd} model)	6.658	6.122	0.536 (8.05%)

The Ct results or the total drag coefficient obtained on the CFD Software for the spherical bulbous bow model is 0.005999, with the results still in the error criteria below 10% of the towing tank test results of 0.006362, so that there is a difference of 0.000363 or 5.71%. For the bow model of the bulbous bow tapering model is 0.006122, the results are still included in the error criteria below 10% from the towing tank test result of 0.006658, so that there is a difference of 0.000536 or 8.05%. And for the Ulstein X-Bow bow model is 0.005699, the results are included in the error criteria below 10% from the towing tank test results of 0.006214, and the difference of 0.000515 or 8.29%.

4 CALCULATION AND DISCUSSION

The result of Ship resistance analysis using CFD gathered, and then process it to get the final data. Ship resistance value from each models with various speed can be seen on the table below:

Table 4: Ct, Cf and Cr from each ship models.

Name of model	Fn Value	Ct x 10^3	Cf x 10^3	Cr x 10^3
1st model	0.129	6.604	5.092	1.511
	0.145	5.998	4.962	1.036
	0.161	6.413	4.848	1.563
	0.178	6.786	4.727	2.059
	0.194	7.211	4.632	2.578
2nd model	0.129	6.728	5.161	1.566
	0.145	6.122	4.986	1.135
	0.161	6.537	4.882	1.654
	0.178	6.905	4.758	2.147
	0.194	7.378	4.662	2.705
3rd model	0.129	6.195	5.054	1.141
	0.145	5.709	4.900	1.038
	0.161	6.135	4.807	1.317
	0.178	6.381	4.716	1.665
	0.194	6.575	4.613	1.951

Table 5: Calculation of Rt value (Total Resistances) for each 1: 1 scale model.

Name of model	Fn Value	Velocity (m/s)	Ct x 10^3	Rt (kN)
1st model	0.129	4.112	6.604	108.77
	0.145	4.626	5.998	125.04
	0.161	5.140	6.413	165.03
	0.178	6.564	6.786	211.31
	0.194	6.168	7.211	267.22
2nd model	0.129	4.112	6.728	110.96
	0.145	4.626	6.122	127.79
	0.161	5.140	6.537	168.45
	0.178	6.564	6.905	215.32
	0.194	6.168	7.378	273.40
3rd model	0.129	4.112	6.195	101.82
	0.145	4.626	5.709	118.54
	0.161	5.140	6.135	157.28
	0.178	6.564	6.381	198.26
	0.194	6.168	6.575	242.76

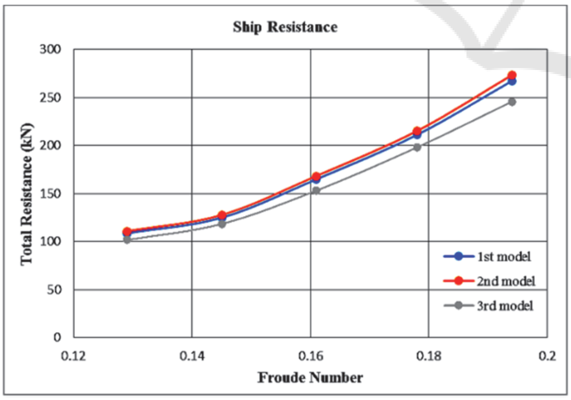

Figure 9: Graphic of total ship resistance.

From the table presentation, the calculation results and the graph image above show the difference in the total coefficient value and the total resistance value of each ship model according to the Froude number and the speed of each ship model.

1. The lowest total coefficient value produced by the three models when Froude number is 0.145 with a ship speed of 9 knots. The Ct value of model 1 was 0.005999 with Rt of 125.04 kN. Ct value of model 2 is 0.006122 with Rt of 127.79 kN. And model 3 has a Ct value of 0.005699 with an Rt value of 118.54 kN.
2. The highest total coefficient value is produced by the three models when Froude number is 0.194 with a ship speed of 12 knots. Ct model 1 was obtained at 0.007211 with Rt of 267.22 kN. Ct value of model 2 is 0.007368 with Rt of 273.40 kN. And model 3 has a Ct value of 0.006565 with an Rt value of 242.76 kN.

5 CONCLUSIONS

Based on the experiments and simulations that have been done, it can be concluded that of the three variations of the model, the lowest resistance value occurs in model 3 with the design of the X-Bow direction, namely the total coefficient of 0.006565 and the total resistance value of 242.76 kN. Whereas for model 1 and model 2 produce a total coefficient value of 0.007211 and 0.007368 respectively. With the total resistance value of model 1 is 267.22 kN and the total resistance value of model 2 is 273.40 kN.

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