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Effect of Rudder Bulb Installation on Ship Propulsion Performance of Anchor Handling Design VS 491 CD during Towing Barge Operation

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Abstract— **An anchor handling ship is a ship designed to support offshore operations in the form of handling offshore building anchors and carrying out activities of moving objects such as FPSO, Semi-Submersible Rigs, construction, production, and barges from one place to another where it requires bollard strength. pull which varies depending on the size of the object, besides that it is also to support other activities such as exploration and drilling. The VS 491 design type anchor handling tug supply (AHTS) vessel which has been built by a shipyard in Batam has a maximum bollard pull test of 255 tons. This paper will analyze the propeller thrust, power, and efficiency propeller before and after the installation of the Rudder Bulb (RB) respectively in free-running conditions and towing barge conditions in 50% barge conditions and full loaded capacity, as well as in draft, and Speed on certain Anchor Handling ships. The resistance of the object being towed (towing) will be calculated on the load and speed of each. By using Maxsurf, software Rhinoceros 3D, dan the Numeca CFD, the shape of the ship's hull is produced according to the original. Then validation is carried out by comparing the resistance in the calculation by Maxsurf/Holtrop and the resistance in the calculation by CFD where resulting in a difference of less than 5% so that it can be said that the form of the model is in accordance with the original shape of the ship. Based on the calculation results in the free running conditions of the Anchor Handling ship, the Propulsive Coefficient (Pc) without ESD Rudder-Bulb (RB) at speeds of 10, 12, and 16.36 knots is 0.5162, 0.5407, and 0.5769 respectively, while with ESD-RB each is 0.5008, 0.5417, and 0.5921. Comparison of the Propulsive Coefficient without ESD-RB and with ESD-RB, that at speeds of 12 and 16.36 knots, the Propulsive Coefficient (Pc) increased by 0.19% and 2.58%, respectively, but the Propulsive Coefficient (Pc) decreased by 3.08% at 10 knots. Based on the analysis that has been carried out, it indicates that the installation of the Rudder Bulb (RB) will give an increase in the Propulsive Coefficient (Pc) at speeds of 10 knots and above in free-running conditions, whereas when towing it hardly gives an increase in the Propulsive Coefficient (Pc).**

Keywords—AHTS, FPSO, Thrust, Resistance, Speed, Bollard pull, Rudder bulb, Barge, Maxsuft, and CFD.

I. INTRODUCTION

World's energy needs continue to increase. According to the projections of the World Energy Agency (International Energy Agency-IEA), by 2030 world energy demand will increase by 45% or an average increase of 1.6% per year. Most of about 80% of the world's energy needs are supplied by fossil fuels. The increase in world energy demand was mainly driven by the rate of population growth and GDP (Gross Domestic Product). He added that economic growth in the Asian region and the world, which makes an important contribution to world economic growth, greatly influences world energy demand.

The search for energy sources in the deep sea is increasing from year to year, including different types of marine structures that are not self-propelled such as submersible rigs, FPSO, FPU, and barges. Marine buildings often transfer operations for reasons that the contract period has ended, oil reserves have run out, and it is necessary to rejuvenate the marine buildings by carrying out conversion (conversion), and repair (refurbishment). As the offshore industry grows, so does the development of ships with special duties to support offshore activities, and these offshore support vessels have the fastest growth among other ships in the offshore sector [1].

This activity must be supported by a vessel capable of carrying out anchor handling and towing operations. Anchor Handling and Towing/Tug Supply-Vessel (AHTS) are most suitable for this activity where the ship generally has a multi-deck handler with a large lifting and pulling capacity which allows it to be able to tow large anchors, tow sea structures, and tow heavy chains, and long. The tensile strength of a ship called bollard pull must be supported by complex ship designs such as power engines, main winches/towing winches, Shark jaws and towing pins, Stern rollers, Anchor and mooring winches, Capstans, Tugger winches, Rope reels, hydraulic active heave compensated subsea cranes.

In this research, a simulation of tugging or tugging will be carried out with variations in load and the addition of an ESD (Energy saving device) in zone 3 in the form of a Rudder Bulb. The Rudder-Bulb was chosen because it is an ESD that has an optimal function for high thrust loads [2]. Therefore, the combination of using Kort nozzle and Rudder-Bulb will also be analyzed. Ship

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Anchor Handling Tug Supply (AHTS) type design VS 491 with Kort Nozzle which has been built by a shipyard in Batam has a maximum bollard pull of 255 tons and Barge as a towing object will be the source of data in this analysis.

A. Anchor Handling Tug Supply (AHTS) VESSEL

Anchor Handling Tug Supply Vessel (AHTS) – The AHTS combines several functions in a single hull. This includes handling the anchors and mooring chains for the drill rig, towing the rig and platform along with subsequent positioning on site, and supply of duty platforms. The required bollard pull has a strong influence on the design, as it determines the power requirements, propeller size, hull shape, and stern depth concerning propeller depth. that required immersion [3].

B. Barge

Barge Ships or Non-self-propelled units have the function of transporting cargo loaded with mining goods. Not only that, for areas that do not yet have good bridge infrastructure, barges are used as a means of transportation or car carriers wishing to cross the destination area. Barge is a ship without sufficient means of self-propulsion for transit. Assistance from other ships during transit or transportation services is assumed. Barges are primarily designed for self-loading and unloading in which the port and starboard portions are hinged at the end of the hopper bulkhead to facilitate rotation about the longitudinal axis when the bottom is exposed [4].

C. Energy Saving Device

A device known as an Energy Saving Device (ESD) is used to boost the effectiveness of ship propulsion, recover, and minimize energy losses, and reduce or minimize ship resistance. Axial, rotational, and frictional losses are the basis for the energy loss in the propeller and hull in some of the existing ESD. The primary goal of using ESD devices close to the propeller is to lessen axial and rotational disturbances, both of which play a significant role in energy losses.

D. Rudder-Bulb

A thin bulb known as the Rudder-Bulb is attached to the front edge of the steering wheel. The Rudder-Bulb fills the space behind the center of the propeller and enhances water flow in front of the rudder. Additionally, because the Rudder-Bulb lessens propeller-induced cavitation, the rudder will last longer, and the propeller hub will sustain less cavitation damage. Depending on the kind of vessel and the behavior of the rudder, computational fluid dynamics (CFD) models and tank tests have demonstrated instantaneous fuel savings of up to 1.5% when the bulb is fitted to the rudder. Bulk carriers, container ships, oil and chemical tankers, RORO ships, and cruise ships are a few examples of maritime vessels that would benefit most from this energy-saving technology due to their big propeller hub sizes and high thrust loads. The bulb can be fitted into vessels that are both new and old (retrofit) [2].

II. METHOD

A. Problem Identification and Research Stage

This activity must be supported by a vessel capable of carrying out anchor handling and towing operations. Anchor Handling and Towing/Tug Supply-Vessel (AHTS) are most suitable for this activity where the ship generally has a multi-deck handler with a large lifting and pulling capacity which allows it to be able to tow large anchors, tow sea structures, and tow heavy chains, and long. The tensile strength of a ship called bollard pull must be supported by complex ship designs such as power engines, main winches/towing winches, Shark jaws and towing pins, Stern rollers, Anchor and mooring winches, Capstans, Tugger winches, Rope reels, hydraulic active heave compensated subsea cranes. The VS 491 design-type anchor handling tug supply (AHTS) vessel built by a shipyard in Batam has a maximum bollard pull of 250 tons which will be the source of data in this analysis. In addition, the addition of ESD in Zone 3, namely the Rudder-Bulb which has the capability of high thrust loads will be added to the model simulation to increase the propulsion efficiency of tugboats when towing loads.

B. Ship Data

The ship data used in the present study is as follows.

Ship name	: Go Pegasus
LOA Length	: 91.00 m
Length LBP	: 79.35m
Width	: 22m
Height	: 9.6 m
Draft	: 8 m
Clear Deck	: 680 m^2
DWT	: 4500 tons
GT	: 7534
NT	: 2261
Bollard pulls	: 255 tons
Speed	: 16.8 Knots
Main engine	: Caterpillar Motoren GmbH & Co MAK VM32C, 2 X 8000 Kw @ 750 RPM
Main Generator	: 2 Cummins QSK60DM @ 1815 kW @ 1900 RPM
Shaft alternator	: 2 shaft alternators @ 4500 kW 440 V/3 phase/60 Hz
Class Notation	: 1A1 ICE-C Offshore Service Vessel AHTS Fire Fighter II OILREC SF COMF-V (3) E0 DYNPOS-AUTR NAUT-OSV(A) CLEAN DESIGN DK (+) HL (2.8) BIS TMON

C. Barge Data

The ship data used in the present study is as follows.

LOA	: 380 ft (115,824 m)
Width B	:100 ft (30,480 m)
Height D	: 28 ft (8,534 m)
Draft	: 22'-8.72 9" ft (6.927 m)
Deck Loading	: 10 tons per m^2

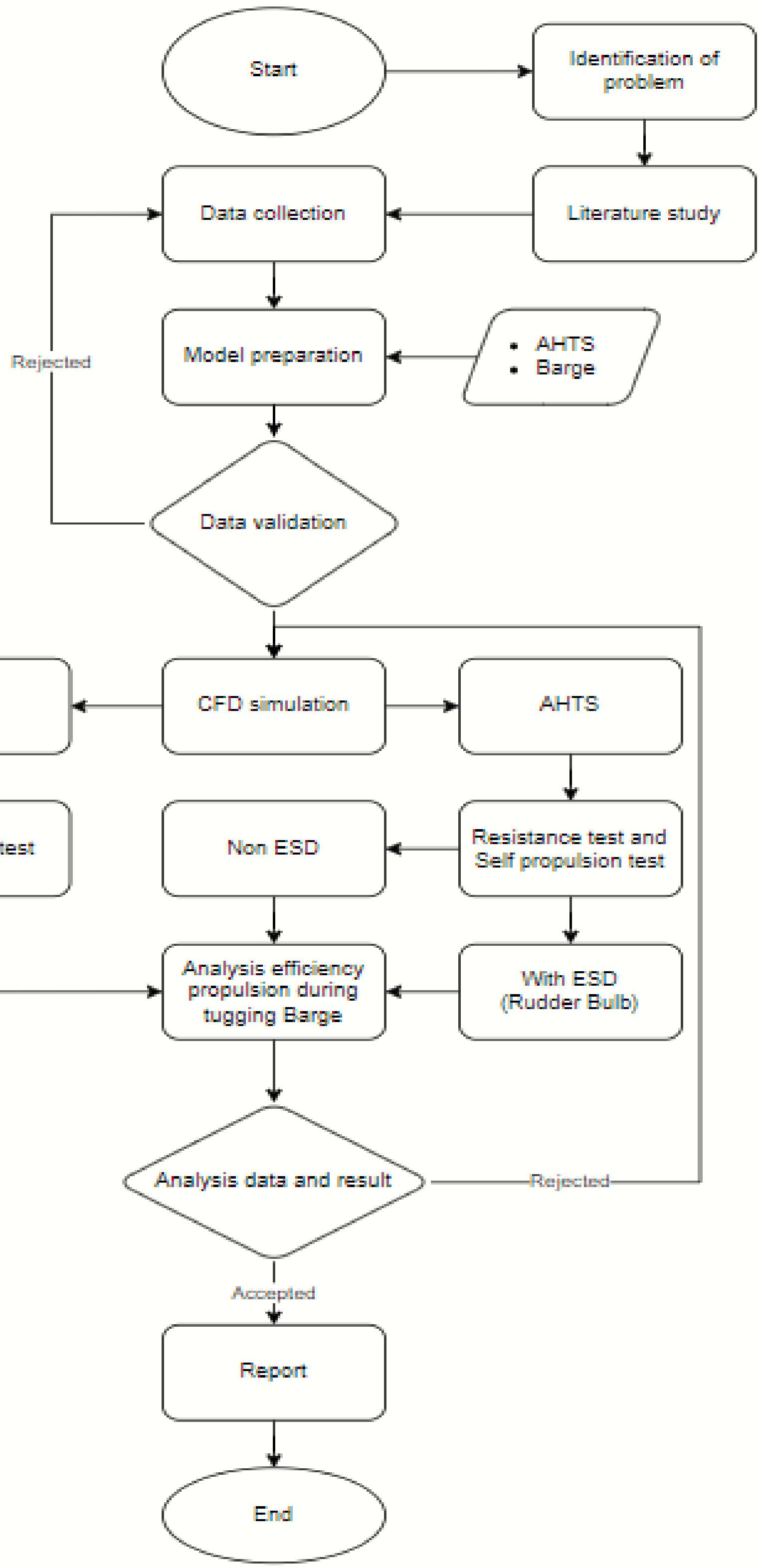

Figure 1. Research flowchart

TABLE 1.
DATA PROPERTIES OF INSTALLED PROPELLER

J IN AIR		6854 KGM ^{2}
J IN WATER	Des	9976 KGM ^{2}
J IN WATER	MCR	11700 KGM ^{2}
DIRECTION OF ROTATION		RIGHT HAND
NUMBER OF BLADES		4
Ae/Ao		0,655 (Af|Ab–50|50)
EXPANDED AREA – Ae		9,075 M ^{2}
P/D–des		1,05
DESIGNED PITCH – P		4410 MM
DIAMETER – D		4200 MM
CALCULATED WEIGHT		1214 KG
SECTION TABLES		VT405446
COORDINATE TABLES		VT405447
BLADE FLANGE		VD204148 rev. B

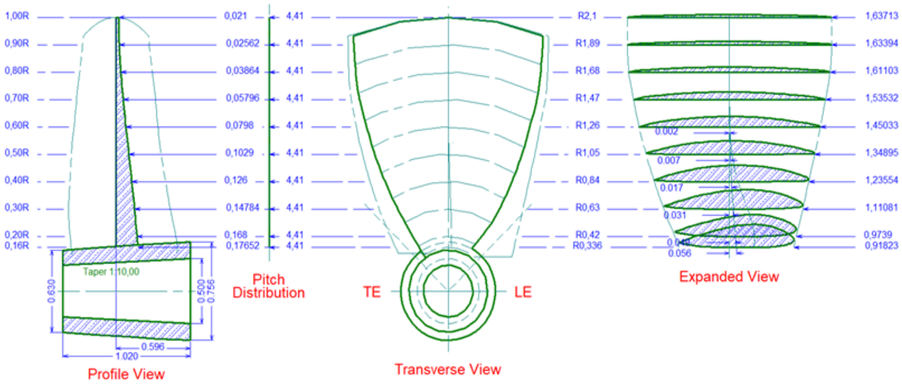

Figure 2. Geometry propeller type Ka 4-70

D. Installed Propeller

The propeller installed on the ship is a Controllable Pitch Propeller (CPP) with Ae/Ao 0.655 and additional ducting. Due to the incomplete geometry of the propeller, the propeller was made into the Kaplan Series. This type of propeller was chosen because it has KT KQ J data with ducting, but is of the Fixed Pitch Propeller (FPP) type. In addition, the 4-bladed Kaplan Series only has 3 types of Ae/Ao based on KT KQ J data [5, 6] namely 0.55, 0.70, and 0.75. From these limitations, the Ka4-70 propeller was chosen as a replacement propeller. Besides that, the type of ducting 19A was chosen, with the reason that the shape is more similar to the type of ducting 37. Based on the installed propeller data (Figure 2) the propeller pitch value is equated to 4410 mm.

E. Model Preparation

From the data obtained in the field, the Lines plan will be visualized in 3D using Maxsurf or Rhinoceros 3D software. The finished 3D shape of the hull is re-confirmed by means of displacement values, trims, and ship requirements.

F. Simulation and Validation

For the propeller at this stage, 3 types of testing were carried out, namely resistance test, open water test, and self-propulsion test using the CFD method to validate the actual towing tank test. The simulation refers to the towing test regulations from ITTC by defining the main parameters such as draft, ship speed, density, and type of test. Validation is done by comparing the software simulation results with experimental data. If the error is less than 5%, the CFD method used is valid to proceed to the model modification stage.

a. Changing the model to Parasolid format

The model is designed using maxsurf software (Figure 3), after which it is converted using rhinoceros 3D software (Figure 4) or exported to Parasolid format (.x_t) so that it can be read on CFD software.

b. Making the hull and propeller domains

Before the meshing process needs to be made a domain with a size of 2.5L forward, 4.5L backward, 1.3 up, 1.8 down, and 2L on the right and left sides of the ship. Figure 6.

c. Meshing hull and propeller models

- Meshing stages
- Initial meshing
- Adapt to Geometry
- Cube Formation
- The optimization process removes negative cells, concave cells, and twisted cells to a value of 0
- Making a viscous layer

d. Merging of hull and propeller domains

Domain merging or meshing is done using the Full Non-Matching Boundary (FNMB) feature. So that meshing in the propeller domain can continue the flow from the ship's domain, especially in the stern of the ship.

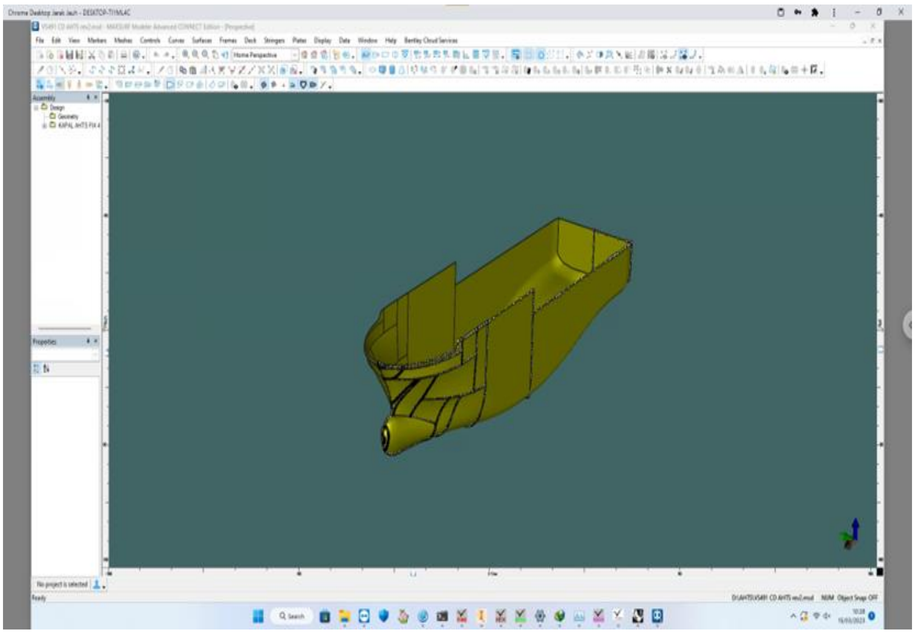

Figure 3. Hull Design on Maxsurf

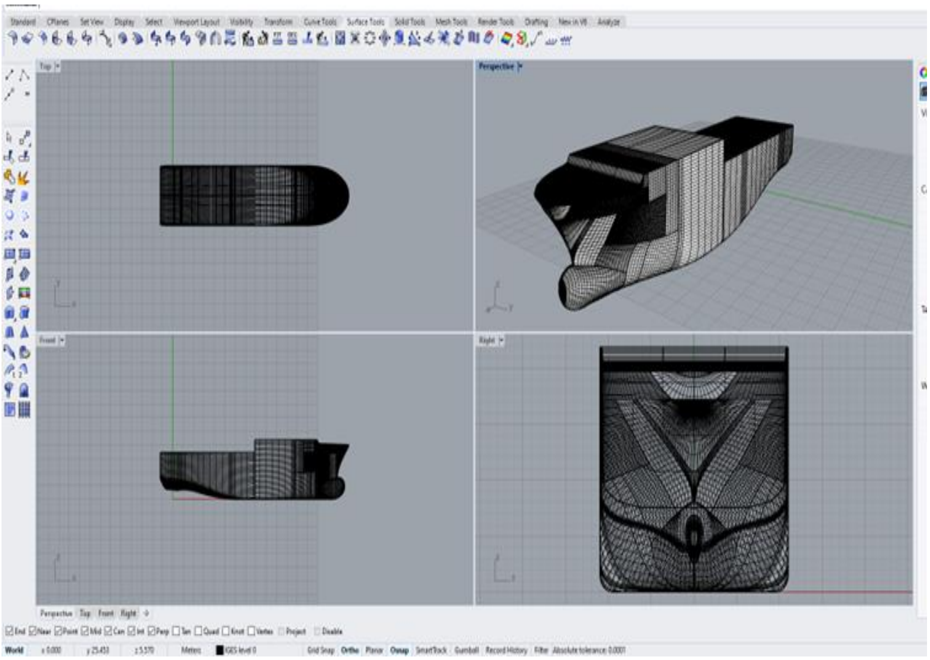

Figure 4. Rhinoceros 3D Surface Design

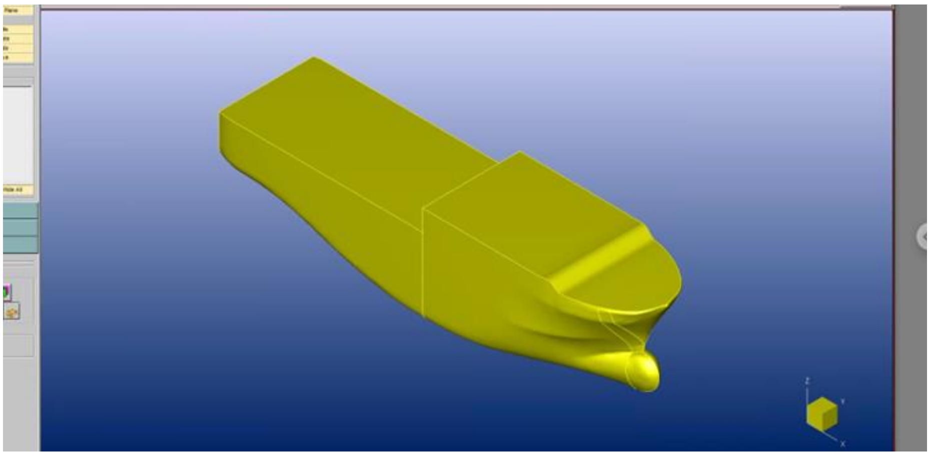

Figure 5. Parasolid Files

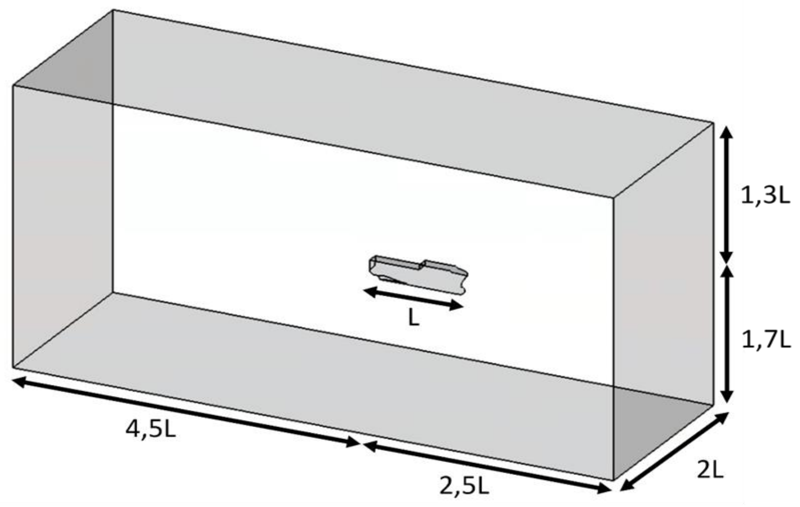

Figure 6. Domain Size

e. Retrieval of simulation results data

The data taken after the simulation is complete are graphic data and image data. Graphical data in the form of values of resistance, thrust, and torque from the ship and propeller are shown in Figure 12. Meanwhile, the image data is in the form of flow entering the propeller and flow around the stern of the ship shown in Figure 13. These two data will be analyzed to see the resulting performance.

1. Data Analysis

Based on the simulation results that have been validated and the main data is taken, namely the value of the ship's resistance, thrust, and propeller torque. The data is processed so that it becomes advanced velocity (Va) data, torque, and open water efficiency. When all the data has been fulfilled, the Propulsive Coefficient is calculated for all variations of the simulation. Before conducting a simulation on ESD, the first thing to do is to choose the optimal Rudder-Bulb from previous studies. Data analysis was carried out following the applicable propulsion system formula with the result being the Propulsive Coefficient when the ship uses ESD in its propulsion system. After that, empirical calculations were carried out to see the speed that the tugboat was able to pull with the resistance data on the moving ship.

2. Selection or Determination of Rudder-Bulb Shape

The rudder-bulb design has a very wide variety of shape references. However, in general, the rudder bulb design has 2 main variations, namely following the shape of the propeller boss and inflating or not following the shape of the propeller boss (Figure 14). Based on research from [7-9] the rudder-bulb shape following the boss propeller shape has a higher efficiency increase compared to a propulsion system without a rudder- bulbs. So with the ease of design, it was decided to choose the shape of the rudder bulb which follows the shape of the existing propeller shaft.

III. Results and Discussion

A. Calculation of Propulsion Efficiency without ESD Rubber-Bulb

For propeller or open water efficiency, it can be taken by plotting the KT KQ J graph of the propeller used. From J which has been obtained, a line is drawn up until it intersects with the efficiency graph as shown in graph 4.5 and an open water efficiency value of 0.5862 is obtained. In addition to plotting on the KT KQ J diagram, based on open water or propeller efficiency calculations, the propeller efficiency graph is obtained as follows.

The Propulsive Coefficient (PC) value can be obtained by multiplying all efficiencies, namely gastric efficiency, relative rotational efficiency, and open water efficiency. From calculations, the calculation of the Propulsive Coefficient value for speed variations is carried out, so that data is obtained as shown in table 2.

B. Comparison of Propulsion Efficiency without and with ESD Rubber-Bulb

After carrying out self-propulsion simulations on variations with and without ESD Rudder-Bulb, the comparison results are obtained as shown in Table 3.

Of all the efficiencies that have been obtained, they can be combined or multiplied to produce a Propulsive Coefficient value as shown in Table 2. The propulsive coefficient values at speeds 6 and 8 seem to fluctuate. This is possible because the hull efficiency value has increased significantly so in this condition the PC has also increased. However, keep in mind that under these conditions, the propeller can experience a stall or loss of thrust capability in which condition the KT KQ value and propeller efficiency cannot be predicted systematically. When viewed at other speeds such as at 10 knots, the difference or gap in PC values between without ESD and with ESD has decreased. but at speeds of 12 and 16.36 knots, the PC value increased by 0.19% and 2.58% when Rudder-Bulb was installed.

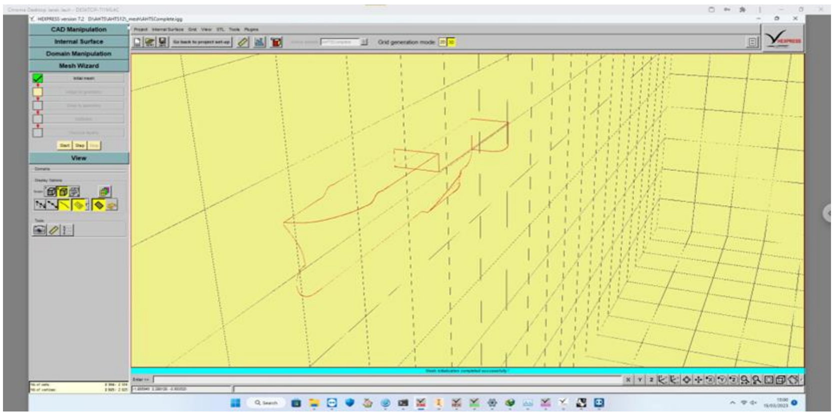

Figure 7. Initial Mesh

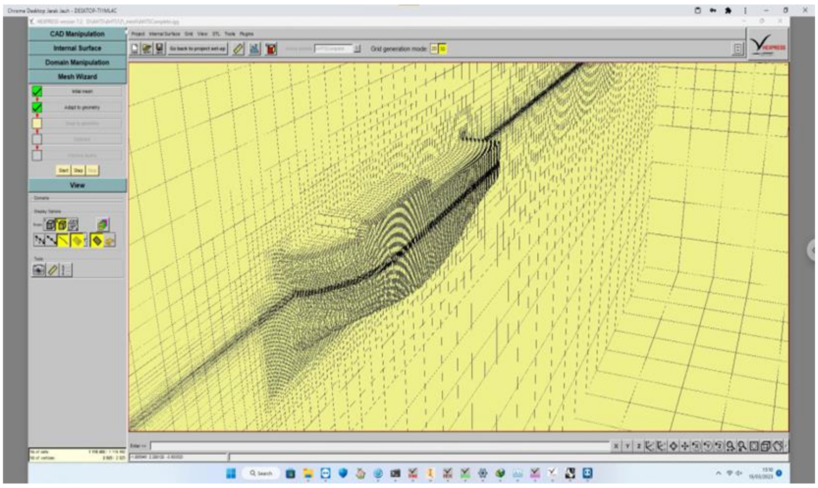

Figure 8. Adapt to Geometry

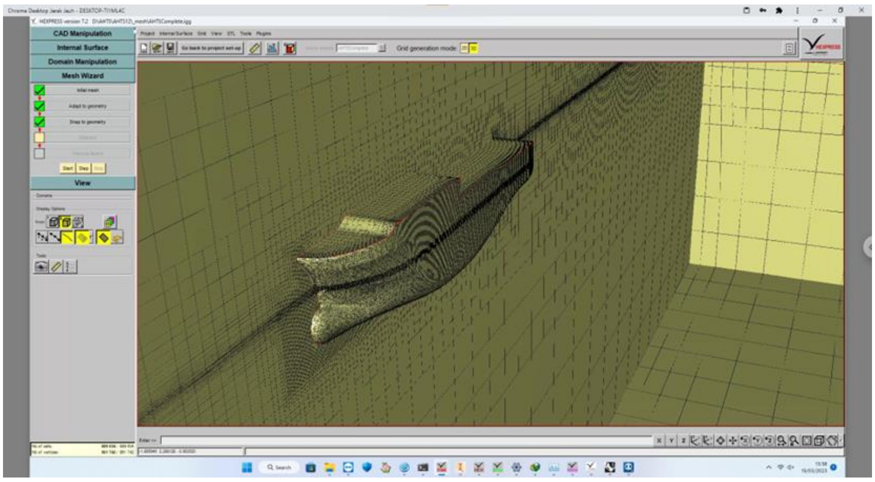

Figure 9. Snap to Geometry

C. Comparison of Propulsion Efficiency with 100% Barge Load

To look for conditions in the form of tugging, it is necessary to understand that tugging conditions are conditions when an AHTS ship pulls a barge at a certain speed. The AHTS resistance value will be added to the Barge resistance value to produce a new resistance value at a certain ship speed.

From the simulation that has been carried out, obtained comparative data for each efficiency in the propulsion system is shown in table 4. From these data, it can be concluded that with the addition of ESD in the form of Rudder-Bulb, the Propusive Coefficient value decreased by 1.04% and increased by 1.02%. It can be concluded that with the addition of propeller rotation and ship speed, the ESD Rudder-Bulb functions properly. Even when the PC is tugged, the PC value on Rudder-Bulb ESD is less than when it is not tugged.

D. Flow Visualization on Propellers

From the simulation that has been done, it can be seen the speed distribution at the rear of the propeller. From all the pictures at every speed, the boss propeller without ESD always experiences backflow. This makes the ship's resistance value higher when compared to ships installed with ESD. Higher resistance values are possible due to backflow which disturbs the surrounding flow patterns. However, at a speed of 16.36 knot, the reverse flow occurs to the front of the rudder and is greater than the other speeds, this makes the ship's resistance value without ESD smaller than with ESD. This is possible because the turbulence that occurs in the propeller boss occurs evenly in the distance between the boss and the rudder so that the flow from the shaft can be directly forwarded to the rudder without any obstacles.

On ships with ESD, the flow behind the propeller looks faintly have a higher value than without ESD, this is possible because there is no turbulence caused by the propeller boss. On the upstream or front side of the propeller, the flow has no difference at all, this means that the impact of installing the ESD does not significantly affect the flow entering the propeller.

IV. CONCLUSION

Broadly speaking, when the ESD Rudder Bulb is added, the Propulsive Coefficient value increases (less than 5%) at speeds above 10 knots. At a speed of 16.36 knots with the installation of the ESD Rudder Bulb, the propulsive coefficient has increased by 2.58%. The value of adding PC increases as speed increases when ESD Rudder-Bulb is added, this is in line with research conducted by Becker Marine Systems and Damen Marine Components, where ESD Rudder-Bulb is used for ships at speeds of more than 14 knots [2] . Visually, the flow on the propeller does not have a significant change in shape, this is due to the insignificant addition of the PC value. Only the turbulence area has changed and has an impact on increasing the ship's resistance gap between without and with ESD. As with the reference regarding the effectiveness of ESD to increase propeller efficiency, generally on large merchant ships with constant ship service speeds with better water flow into the propeller.

SUGGESTION

The suggestions given for continuing research in the field of Energy Saving Devices (ESD), especially Zone 3 or Rudder Bulb, are as follows.

1. Research can be developed with larger cargo ships to get more accurate results.
2. Research can be developed by adding an airfoil to the rudder or rudder-bulb to take advantage of the propeller downstream flow.

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