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Variation of Pitch Ratio Propeller Bos Cap Fins (PBCF) on Fishing Ship’s B-Series Propeller

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Abstract. In general, ships are designed with different functions and purposes, such as fishing boats that have a special mission (finding, catching and conserving fish) so that the ship has special design parameters as well. Apart from having good speed and maneuvering, fishing boats must also move quietly with low vibrations. In order to achieve this goal, the most important aspect in designing fishing boats is planning the propulsion system, optimizing the efficiency of the ship's propulsion system by minimizing losses caused by vortices, which focus on modifying the fin boss propeller geometry. The purpose of this study was to determine the effect of the boss propeller fins geometry on propeller efficiency, by using the CFD (Computational Fluid Dynamic) approach with variations in the diameter and tilt model of the fins. It was found that the larger diameter of the fins had a greater thrust value where the diameter 35 cm of fins have a better thrust value than 25 cm fins, while the slope 39º of fins has a more optimal thrust value.

INTRODUCTION

Propeller efficiency affects engine performance [1]. If the propeller performance cannot produce the desired efficiency, the fuel consumption of the engine will not match the planned design which causes the engine to be wasteful. Hub vortex or the presence of turbulent flow at the hub is one of the problems which can reduce propeller performance [2]. By having a vortex appearing on the propeller hub, it can reduce speed and propeller efficiency. Vortex hubs also erode the rudder. The interaction between rudder and propeller creates several problems such as cavitation which is caused when the boat speed is low.

Considering the vortex hub problem in 1988, the idea emerged to develop Propeller Boss Cap Fins (PBCF). PBCF can increase the thrust and decrease the propeller torque by reducing the vortex hub due to the rotation produced by the fins. PBCF can increase efficiency directly, whereas full-scale trials can reduce power by 3.7% PBFC has been installed on 16 vessels and increased efficiency by 3.5% [3].

Parts of the geometry in PBCF that affects performance is the diameter and angle of inclination of the fins on the hub. Research has been conducted with various types of hubs. Using divergent hubs resulted in reduced efficiency [4], while another found that different types of hubs influenced the eddies produced [5]. From these two studies, it can be concluded that there is a need for further study of the PBCF diameter size and inclination angle to obtain a suitable PBCF design.

This study aims to determine the effect of pitch ratio PBCF on fishing boat propellers on the value of thrust and torque. This study was conducted using CFD simulation.

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PROPELLER BOS CAP FINS (PBCF)

PBCF planning is usually done by combining empirical design with test model validation. The designer chooses the geometric PBCF empirically and determines the optimal value through the test model [3] without due consideration to the interaction between PBCF and propeller. The integrative propeller dan PBCF design method that including theoretical design and numerical optimization design, based on potential flow theory, CFD tools, improved particle swarm optimization algorithm, and test models provide higher efficiency for the propellers in the same design conditions. The test results of the cavitation tunnel model show that the designed propeller and PBCF have higher efficiency, and the design method is effective, reliable, and practical [6].

Using the quasi-random batch method with an optimization algorithm approach, the PBCF design is able to increase efficiency by 1.3% compared to propellers without PBCF [4]. Determination of the fin angle at PBCF greatly affects propeller performance, choosing the wrong angle will actually reduce propeller efficiency [7]. According to the analysis conduct by Kawamura [8], both increasing Reynolds number and the presence of hull wake are affected of PBCF performance at the computations test. At full-scale condition, propeller efficiency is significantly larger than that at the model test condition.

PROPELLER DESIGN

Fishing Ship Propeller

This data was obtained from previous research which was obtained from Semeru Teknik shop located on Nusantara road, Makassar. This data is selected propeller data based on the geometry of fishing boat propeller data

TABLE 1. Propeller data

Propeller Type	FPP – B-Series	
D (m)	0.76	
Z	4	
P/D	0.93	
Ae/Ao	0.55	
N (Rps)	13.29	

Modeling of Propeller

After the data collection process is complete, which is carried out by direct observation in the field, the next step is to create a Propeller model according to existing data. The 3D propeller model is shown in Fig. 1.

FIGURE 1. 3D model of propeller

Boundary

The enclosure size used in this research is 2xD upstream length, 5xD downstream length and 3xD zone diameter, where D is the propeller diameter as can be seen in Fig. 2.

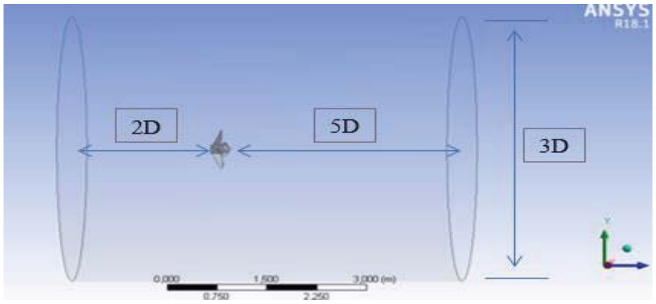


FIGURE 2. Propeller and fluid domain

Mesh

The mesh used in this study is a structured mesh, based on the results of previous studies that the use of unstructured meshing types in analyzing B-series performance has better results when compared to the use of meshing structure types. Model meshing is shown in Fig. 3.

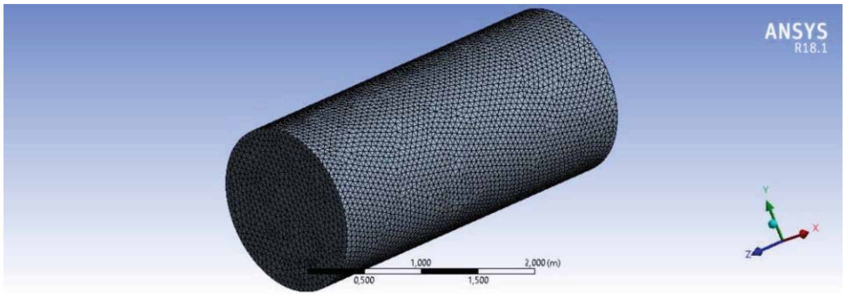


FIGURE 3. Meshing CFD model

Computation

Physical Properties and Fluid Properties

TABLE 2. Physical conditions and flow in the stationary fluid domain

No	Parameter	Information
1	Domain type	Fluid domain
2	Material	Water
3	Reference pressure	1 atm
4	Bouyancy model	Non bouyant
5	Domain motion	Stationary
6	Mesh Deformation	None
7	Heat transfer	None
8	Turbulence	Shear Stress Transport
9	Vilocity Tipe	Cartesian
10	Cartesian Velocity Component	Automatic With Value $U=0m/s^1,V=0m/s^1,W=0m/s^1$
11	Relative Pressure	1 Pa

TABLE 3. The physical condition of the propeller in the domain

No	Parameter	Information
1	Domain type	Immersed Solid
2	Material	Steel
3	Angular Velocity	13.29 RPS
4	Domain motion	Rotating
5	Axis Definition	Two Points
6	Rotation axis From	X=0, y=0, Z=0
7	Rotation axis To	X=0, y=0, Z=1

Boundary Condition

The boundary condition setting in this simulation is divided into two conditions, namely inlet and outlet. Inlet boundary conditions are used to accommodate the inflow behavior of the system. The outlet boundary conditions are used for the behavior of the flow leaving the system. Meanwhile, the opening limit condition is used as an open boundary condition. The parameter of the boundary conditions can be seen in Table 4 and Table 5.

TABLE 4. Outlet boundary condition

No	Parameter	Information
1	Boundary Type	Inlet
2	Flow Regine	Subsonic
3	Mass and Momentum	Total Pressure (Stable)
4	Relative Pressure	0 (psi)
5	Turbulence	Medium (intensity = 5 %)

TABLE 5. Inlet boundary condition

No	Parameter	Information
1	Boundary Type	Opening
2	Flow Regine	Subsonic
3	Mass and Momentum	Opening Pres.and Dirn
4	Relative Pressure	1 psi
5	Flow Direction	Normal to Boundary Condition
6	Turbulence	Medium (intensity = 5 %)

The setup process can be seen in Fig. 4.

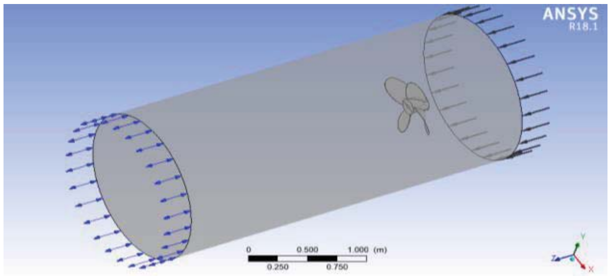


FIGURE 4. Set up of physical and fluid properties and boundary condition

Computation Results

By using the k-epsilon turbulence model in the fluid model's default domain, the result of the CFD simulation can be seen in Fig. 5.

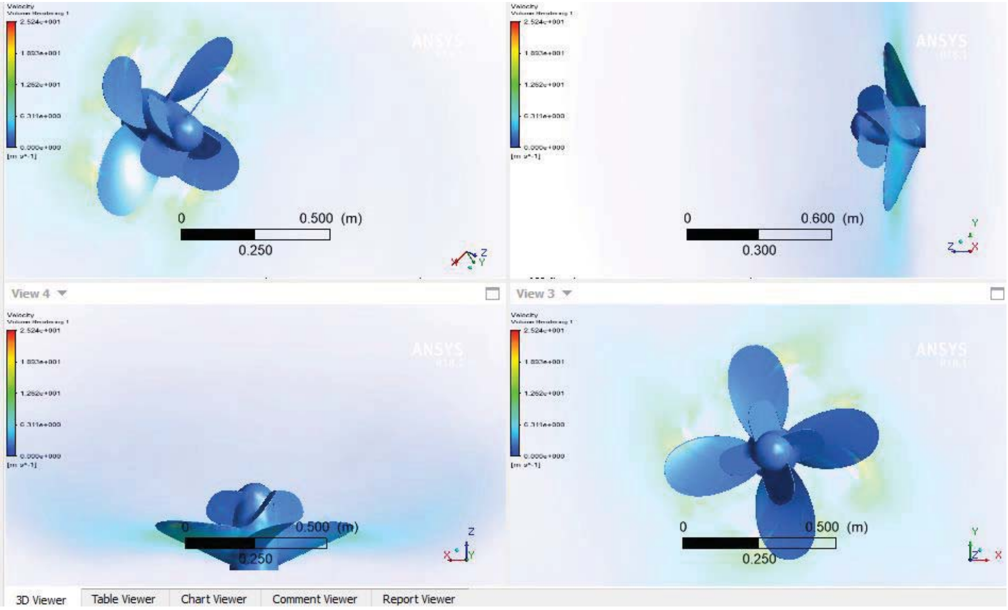


FIGURE 5. CFD simulation result (aerial velocity view)

After the solution process or running the simulation is complete, the results can be seen at the results stage. In this study, the desired results are the values of the thrust (force) and the torque of the model. The CFD result can also view a visualization of the model flow (propeller), pressure contours, temperature, and so on.

DISCUSSION

Figure 6 shows the difference between the Wageningen open water test and the CFD simulation results. The biggest difference, namely 8.83%, lies in the torque coefficient (Kq) at J = 0.2 and the small difference is 0.21% which lies in the thrust coefficient (Kt) of the propeller at J = 0.2.

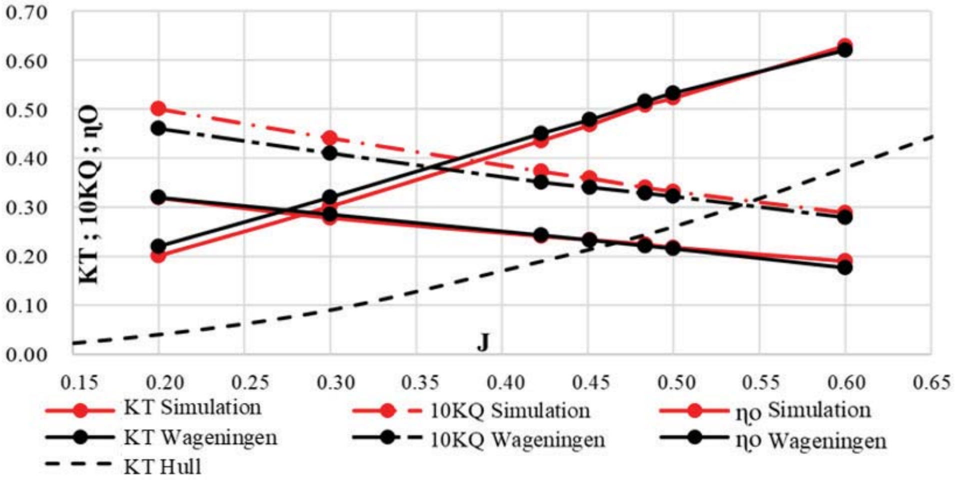


FIGURE 6. Difference between Wageningen and CFD simulation (propeller without PBCF)

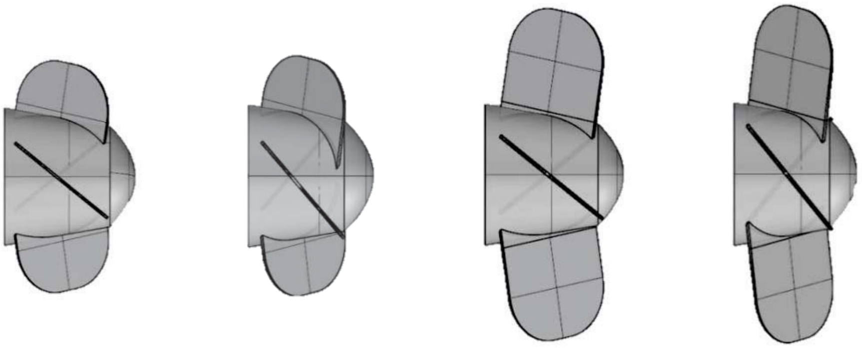
Based on the figure above, it can be seen that there is a difference in the results of calculating thrust and torque using Wageningen open water test and CFD simulation for around 0.21 - 8.7%.

Fin Variation

Propeller simulated before was added with 4 variations fins. Variations focused on the size of the diameter and slope of the fins, the variations of the fins are as follows:

TABLE 6. Variations on the PBCF

No.	Name	D (cm)	Z	Radius(°)
1	Prop Fins 39x25	25	4	39
2	Prop Fins 39x51	25	4	51
3	Prop Fins 35x39	35	4	39
4	Prop Fins 35x51	35	4	51



Fins 39x25 Fins 39x51 Fins 35x39 35x51

FIGURE 7. Model of 4 variation of fin PBCF

The CFD simulation results of the variation can be seen in Fig. 8.

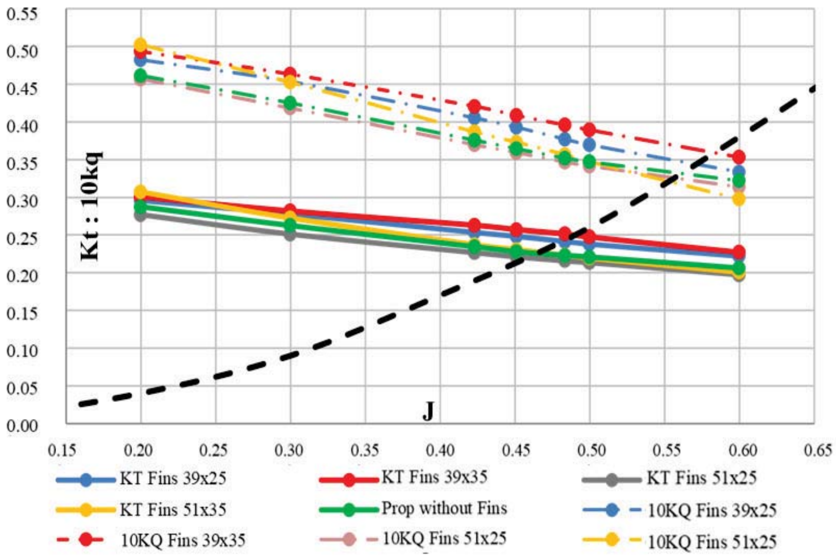


FIGURE 8. CFD simulation result on 4 fins variation

Figure 8 shows the relationship between the thrust coefficient (Kt), the torque coefficient (Kq) and the advance coefficient (J) on each tested propeller. The value of the thrust coefficient (Kt) and the torque coefficient (Kq) is inversely proportional to the advance coefficient (J), where each increase in the value of the advance coefficient (J), the thrust coefficient (Kt) and torque coefficient (Kq) will be smaller.

From Figure 8, it can be seen that the propeller fins 39x35 with fins diameter D = 35 cm, fins slope = 39º has better thrust coefficient (Kt) and torque coefficient (Kq) and meets the ship's operating conditions at a value of J = 0.46. Propeller fins 51x25 D = 25 cm, the slope of fins = 51º has a lower thrust coefficient (Kt) and torque coefficient (Kq) than others.

From the results described above, the diameter of the fins is very influential with the increase in thrust of the propeller itself, where the diameter of 35 cm has a greater thrust than the diameter of the fins of 25 cm. equal to the diameter, the slope of the fins also has a big effect, where the slope of the fins is 39º more optimal than fins with a slope of 51º.

Effect of PBCF on Fishing Ship Propeller

By using the propeller fins 39x35 on a fishing ship propeller, the difference of thrust and torque to the propeller without PBCF can be seen in Fig. 9.

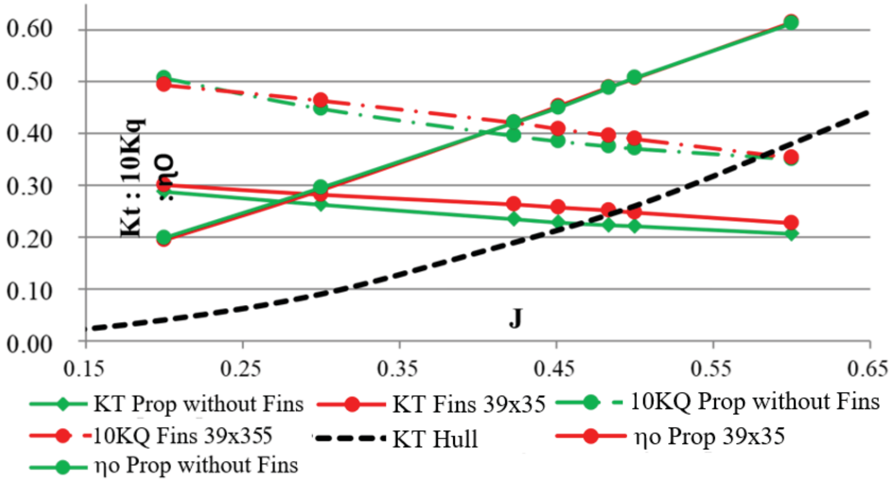


FIGURE 9. Difference between propeller without PBCF and propeller with PBCF

From the figure above can be found that the addition of fins on the fishing ship propeller is very influential in increasing the value of the thrust coefficient and torque coefficient on the propeller. It means the PBCF can increase the efficiency of the propeller.

CONCLUSION

Based on the analysis of the simulation results that have been carried out, it can be concluded that in the open water test, the propeller which is added with boss cap fins (PBCF) has an increase in the value of the thrust coefficient and torque coefficient on the propeller. The value of the thrust coefficient and torque coefficient of the propeller increases as the diameter of the fins increases. To increase the thrust and torque of the propeller, it is necessary to adjust the angle and diameter of the fins. Propeller fins 39x35 with D = 35 cm, fins slope = 39º, can be used in a 30 GT fishing boat propulsion system.

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