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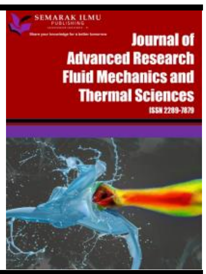

Variations Rake Angle Propeller B – Series Towards Performance and Cavitation with CFD Method

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ABSTRACT

Fuel consumption is most widely used in ship propulsion system, therefore, in ship propulsion system must be considered and designed as efficiently as possible. Propeller is one of the mechanical components on a ship, which can run ships from one place to another. The most important thing in a propeller is the mechanical properties or strength of the propeller in accepting the load to be able to run the ship. Another factor that affects mechanical propeller properties is the propeller design itself. In propeller design, one thing that can be considered is the rake angle of propeller. The rake angle is the slope angle between the propeller blade and the propeller center. The rake angle on the propeller is used to increase the amount of mass water used to produce thrust that needed by ship. Reducing the rake angle can increase the efficiency of the B-Series propeller slightly. Previous research has analyzed the effect of variations in rake angle to determine the relationship between thrust and fluid flow in the B-series propeller, but for the cavitation that occurs in the propeller has not been analyzed. In this research, variations ware made from the B-Series propeller rake angle to obtain propeller thrust and cavitation values. The analysis carried out in this study is to use the CFD (Computational Fluid Dynamic) method and the results obtained from the simulation with greatest thrust and efficiency, that is in the 5º rake angle variations of 2310,273 KN and 70% efficiency, while the smallest thrust value is variation of rake angle 25º for 1110,933 KN. Then for the largest cavitation level in the variation of the 25º rake angle and the smallest at the 15º original rake angle.

1. Introduction

In a ship, there are important components in the ship propulsion system. In ship propulsion system there are several main components, such as main engine, Stern tube system and propeller. In Indonesia, there are still many ships that use diesel engine. In its operation, the consumption of fuel is most widely used in ship propulsion system, therefore, in ship propulsion systems must be considered and designed as efficiently as possible.

One of the ship propulsion system components is propeller. Propeller is one of mechanical component on a ship, which can run ships from one place to another. The most important thing in a

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propeller is the mechanical properties or strength of the propeller in accepting the load to able to run the ship. Another factor that affects mechanical properties of propeller is the propeller design itself and surface of the disc [1]. In propeller design, one thing that can be considered is the rake angle of propeller. The rake angle is the slope angle between the propeller blade and the propeller center [2]. The rake angle on the propeller is used to increase the amount of mass of water used to produce thrust that needed by ship. In G. Kuiper's book states that reducing the rake angle can increase the efficiency is the B-series propeller slightly [3]. Increasing rake propeller also improve the performance and especially the generated thrust of conventional propellers [4]. But, there is some evidence that slight backwards rake can reduce cavitation with small reduction of propeller efficiency [5].

The principal working of propeller is to move the initial from rotational power into thrust on a particular fluid can be like water or air, motion to produce pressure differences between the face and back surfaces and also hydrodynamic characteristic and produce fluid, surface, and flow characteristic [6-8]. Due to the difference in speed of the foil causes a difference in pressure on the leaves which eventually occurs cavitation, whereas cavitation is the emergence or formation of gas bubbles in the leaf part of the propeller because the pressure decreases with a temperature which will cause evaporation even though the water will boil or evaporate at a temperature of 100 degrees celcius.

There are many types of cavitation, for example bubble, sheet, and vortex cavitation [9]. If a propeller leaf has cavitation, it will be very disadvantage, such as damage to the material on the leaves can be hollow or broken which will cause a decrease in the efficiency of the propeller so that the force is reduced, noise and vibration can occur [10,11]. From the vibration and noise, there is standard of comfort that sacrifices the efficiency of the propeller. The conflicting requirement between efficiency and comfort compel designers to balance cavitation and efficiency performance, and require owners to pay more for the repair of the propellers, so a balance between comfort and efficiency of the propeller with this need to be analyzed cavitation. The cavitation analysis is expected to be able to get the best propeller. In the previous study analyzed the effect of variations in rake angle to determine the relationship between thrust and fluid flow on the B-series propeller, but for the cavitation that occurred in the propeller has not been analyzed maximum and low level of cavitation.

The analysis that will be carried out in this study is to use a viscous method where this method is a simulation technique that considers or incorporates fluid viscosity in one method. CFD has several advantages because it minimizes costs and time [12]. CFD (Computational Fluid Dynamic) is one of the techniques included in the viscous method. Using CFD can produce an effect from a simulation of a good propeller model. In this research, NUMECA software will be used, which is one of the CFD software. This software can analyze the performance and cavitation of propellers that occur with variations from a predetermined rake angle, so that from the results of the analysis it can be seen that maximum performance and low cavitation of the B-Series type propeller.

Effect of propeller geometry has multi objective constraint to obtain optimum result propeller design [13]. Researchers have to choose the constraints that must be taken in order to find out the boundaries of the problem depending on capability.

2. Methodology

The methodology used in the study is a polynomial design to obtain best propeller. After that, make propeller model with rhinoceros software and the simulation use software CFD that is NUMECA [14]. More details be described as follows

2.1 Preliminary Design

In the preliminary design phase, it is the initial stage that is carried out to determine or choose the propeller that will be used in this study. In this study using the polynomial design method in determining the propeller to be used. The principle dimension and calculation steps that must be done in the preliminary design are as follows

i. Lpp= 230 m
ii. Lwl = 232.5 m
iii. B = 32.2 m
iv. D = 19 m
v. T = 10.8 m
vi. S = 9530 m^2
vii. Cb = 0.651
viii. Cm = 0,985
ix. Vs = 24 Knot

The total resistance calculation was taken from the KCS vessel data which was then analyzed by Max surf software. So that the results of the total resistance value of RT = 1333.5 KN.

2.2 KT Design Curves, KT, KQ, and Efficiency

On a KT-KQ-J curve on a particular AE/AO it consists of several KT curves and propeller efficiency whose amount depends on the number of P/D variations, and one design KT curve. Where efficiency and KT are the ordinate axes and J is the abscissa axis. This design curve is obtained from the calculations $\Delta K_T ; \Delta K_Q$ that have been made in the polynomial design. Calculated based on exponential numbers obtained from the literature [14].

This calculation is classified based on the price of AE/AO and P/D. KT curve and efficiency are forms of variations in price of AE/AO and P/D. So, in one price variation AE/AO there are 12 variations in the price of P/D. The following is the B-Series Polynomial Wageningen which is used to determine the price of ΔK_T; ΔK_Q. After finishing the numbers finally form a graph and are cut by the resistance value of the ship so that it can be seen the value of the thrust coefficient, torque, and efficiency.

2.3 Calculation Efficiency Propeller

Value of efficiency is calculated at each price of advance (J) price for each variation of AE/AO and P/D From the above data, we get the Kt-Kq-J graph with the following value variations

i. Variation in pitch ratio (P/D) are: 0.500 - 1,400
ii. AE / A0 variations on each blade
iii. Variation J between 0.00 - 0.17
iv. Propeller diameter (D) is taken at 0.70T = 7.56 m
v. Blade propeller (Z) is taken by propellers in number 3, 4, 5 and 6 blade

So that the graph is obtained in each variation of the propeller with the number of leaves, on each Ae/A0 graph

Figure 1 explains, how do we determine the highest efficiency of the propeller we are looking for performance, namely B-3, B-4, B-5, B-6. With all the possibilities (optimization) Ae/A0, P/D, J, Z, With the KT Design that we have determined. From this, we get some of the highest efficiencies that we have not selected. Its selection mechanism is the highest efficiency, which does not cause cavitation.

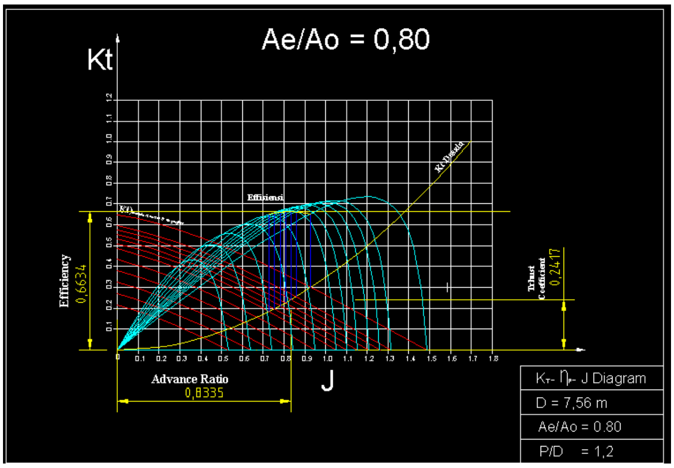

Fig. 1. Graph KT, KQ, J at Ae/A0 = 0,80

2.4 Propeller Cavitation

This cavitation calculation is done to check whether the propeller has cavitation or not. Calculations are done using the Burrill diagram [9]. Furthermore, this cavitation calculation compares the price of the thrust loading coefficient (σ C) calculation with a coefficient of thrust loading 5%. The price of the calculated thrust loading coefficient cannot be greater than the price of the thrust coefficient is loading on the Burrill diagram. Calculation of the thrust coefficient on the Burrill diagram by entering the price of the cavitation number in the area of 0.7R. To get the price of the cavitation number can be found with the following formula

$$\sigma 0.7\mathrm{R} = \frac{(188{,}2+19{,}62h)}{V_{A}{}^{2}+4{,}836\, n^{2}D^{2}} \quad (1)$$

2.5 Design and Model of Propeller

The condition of choosing a propeller is having a high thrust and no cavitation, so the type of propeller chosen is 86-80. Dimension Of Propeller

i. Type = B6 - 80
ii. Number of Blades (Z) = 6 Blades
iii. Rotation (N) = 85.16 rpm
iv. Diameter (D) = 7560 mm
v. Pitch ratio (P/D) = 1.2
vi. Efficiency = 0,663

Propeller blade foil based on the table dimensions of Four, Five, Six and Seven-bladed Wageningen B-screw Series [15]. Based on these parameters the propeller can be drawn according to a predetermined standard.

Y face and Y back obtained from previous calculations are the result of mirroring the foil propeller against the local axis of each foil. Whereas in actual conditions, the foil-foil is tilted and forms an angle to the flat plane. That angle is called pitch angle (α). Each foil has a price of α which varies depending on the price of the pitch and position of the foil on the rotating axis of the propeller [16].

The results of the previous calculation generator line are in a vertical line, whereas in reality the line generator line forms a backward angle to the vertical line of the designed rake angle. Therefore, position foil - foil must be transformed or shifted back as far as Y rake with the formula [1]

$$Yrake=r.Tan\ (\varepsilon) \qquad (2)$$

Making a propeller model is done using CAD software. The propeller model that will be created is adjusted to the limits of the problem that has been determined at the start, namely the propeller used is the B6-80 series. Rake variation are 5º, 15º, and 25º. The image file is formed para solid so that it can be read in cfd software.

2.6. Simulation Propeller Model

After making the essay and succeeding solidly, then the next model is tested or running. In testing using C-Wizard by providing RPM values in accordance with previous calculations, namely 85.16 and velocity advance (Va) values. This test is conducted to determine the thrust and cavitation values on the propeller model that has been made.

Figure 2, 3 and 4 are solid model images of variations in the angle of attack of the propeller before we run. The figure explains from the front and side view, with variations in the angles of attack are 5º, 15º, 25º.

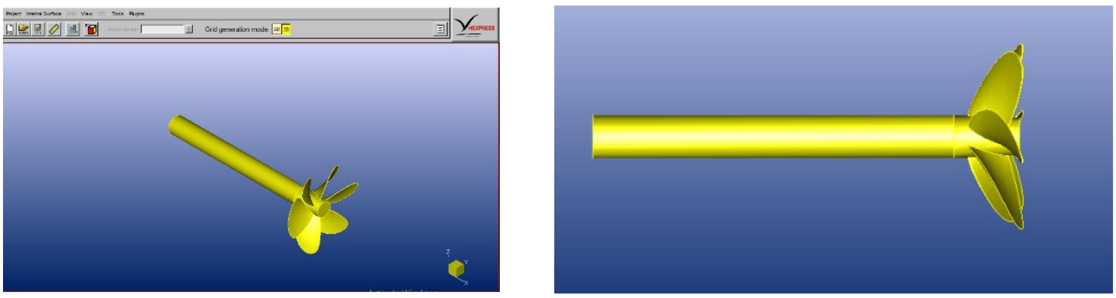

Fig. 2. Model solid with rake angle 15º

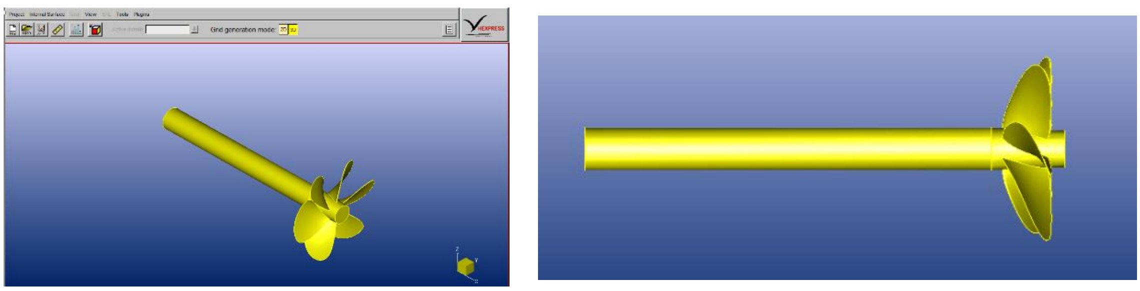

Fig. 3. Model solid with rake angle 5º

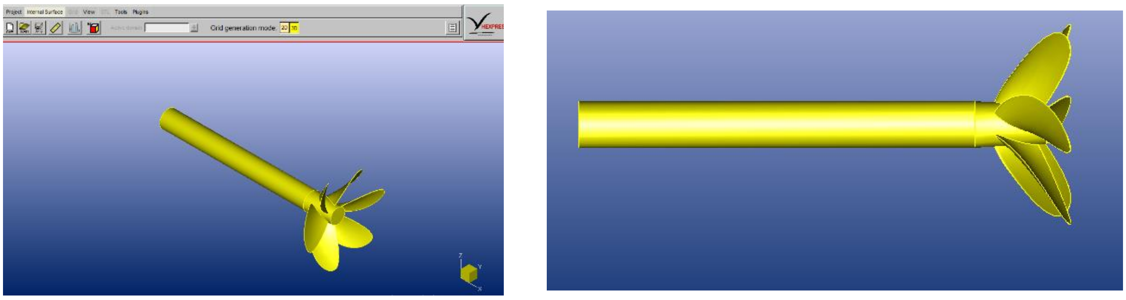

Fig. 4. Model solid with rake angle 25º

3. Results and Discussion

3.1 Validation

Validation is executed by making the Thrust value in the numerical calculation that has been done before as a reference, which is equal to T = 1630.258 KN. And the results of the simulation thrust were obtained at T = 1829, 464 KN. So that variations in rake angle can be done after the thrust value in the simulation and calculation is close to the same. So that variations in rake angle can be done after the thrust value in the simulation and calculation is close to the same.

3.2 Analysis Result of Simulation

From the results of the force or thrust graph in software, at the original rake angle or 15º has a thrust value = 1829,464 kN and torque = 2686,709 kNM, then at the 5º rake angle the thrust value increases to T = 2310,273 kN and torque = 3293,502 kNM, while at the rake angle 25º the thrust value experiences a considerable decrease significant to T = 1110,933 kN and torque = 2813,888 kNM.

From the literature review, to calculate the efficiency formula [2]

$$\mathrm{Eff} = \mathrm{Kt.J}/(2\pi.\mathrm{Kq}) \qquad (3)$$

So that the value of efficiency is obtained in the variation of the rake angle as shown in Table 1 below.

Table 1
Result of efficiency

Variation (º)	J	Va	*T*	*Q*	Kt	10Kq	Eff
Rake 5	0.833	8.94	2310	3293.5	0.34	0.646	0.70384
Rake 15	0.833	8.94	1829	2686.7	0.27	0.527	0.68324
Rake 25	0.833	8.94	1111	2813.8	0.16	0.552	0.39614

From the results of the calculation of efficiency, the 5º rake angle has the highest efficiency value and the lowest in the rake angle variation of 25º.

From the literature review to calculate cavitation number, the following formula is used [9]

$$\sigma = \frac{p0 - pv}{\frac{1}{2}\rho\, v^{\wedge}2} \qquad (4)$$

At this stage, a simulation is carried out by activating cavitation on additional models and outputs on computation control. So that the results can be obtained as follows.

Figure 5 is the result of running the propeller with a rake angle of 15º on the face, while Figure 6 shows the result of running the propeller with a rake angle of 15º on the back. Figure 7 is the result of running the propeller with a rake angle of 5º on the face, while Figure 8 shows the result of running the propeller with a rake angle of 5º on the back. Figure 9 is the result of running the propeller with a rake angle of 25º on the back, while Figure 10 shows the result of running the propeller with a rake angle of 25º on the face.

From the results of the picture below, based on the color cavitation contour that occurs on the face and back of the propeller leaf the highest cavitation level occurs at a 25º rake angle, and the best or smallest occurs at the original rake angle or 15º.

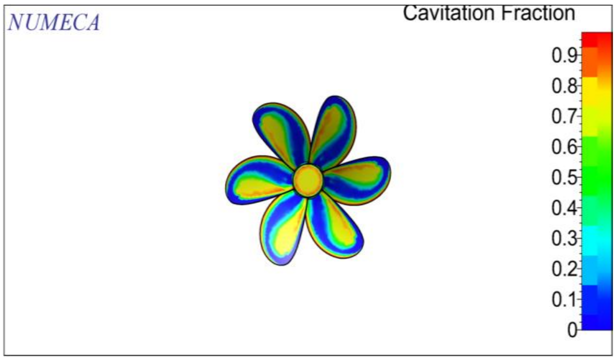

Fig. 5. Result cavitation at rake angle 15º face

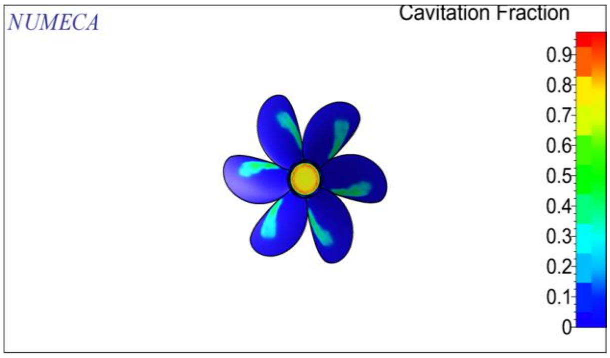

Fig. 6. Result cavitation at rake angle 15º back

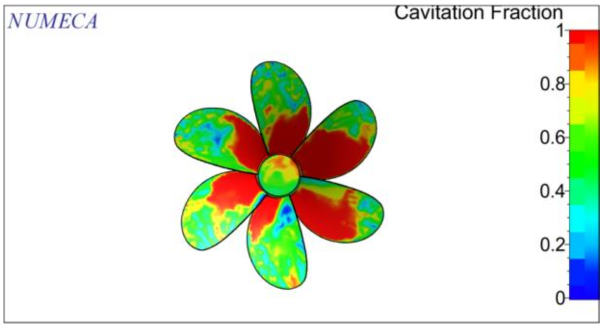

Fig. 7. Result cavitation at rake angle 5º back

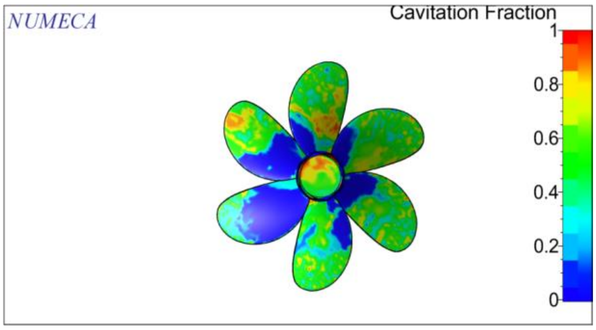

Fig. 8. Result cavitation at rake angle 5º face

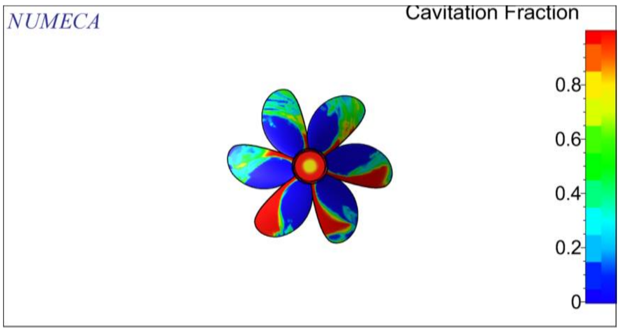

Fig. 9. Result cavitation at rake angle 25º face

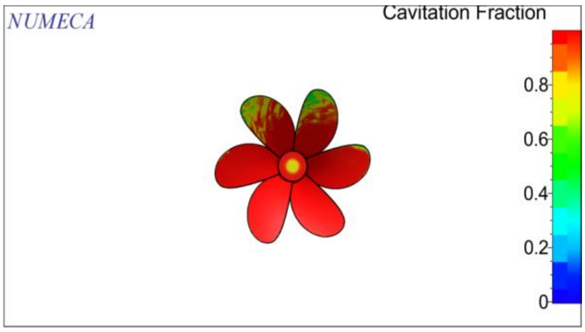

Fig. 10. Result cavitation at rake angle 25º back

4. Conclusions

Based on data analysis and discussion that has been done, conclusions can be drawn as follows: In the propeller B6-80 model with a variation of the rake angle of 5º, the greatest thrust value is T value = 2310,273 KN and has a considerable cavitation level compared to the propeller model with the original rake angle and has the most efficiency value high. In the propeller B6-80 model with a variation of the rake angle of 25º, it has the smallest thrust value that is T value = 1968.312 KN and has the highest cavitation level compared to the other two propeller models. In the propeller B6-80 model with the original rake angle / 15º, it has a thrust value with T value = 1829,464 KN and has a small cavitation level or can be classified as not cavitation.

From each model that has been made, it can be concluded that changing the rake angle can affect thrust values, propeller efficiency and cavitation levels. If reducing the rake angle from the original angle can increase the thrust value and increase the efficiency value but also increase the level of propeller cavitation, while increasing the rake angle causes the thrust value to decrease, reducing the value of efficiency and adding a significant level of cavitation.

for future research, it is necessary to do research on modification of the B-Series propeller blade at an angle of attack of 5º, because at this angle of attack it produces the highest efficiency, but not the smallest cavitation-free, so it is expected that at an angle of attack of 5º it will produce the greatest efficiency and the smallest cavitation-free, by increasing the number of propeller blades to reduce the propeller load because the foil turns thinner to reduce cavitation.

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