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Analysis of the Effect of Blade Thickness on Propeller Water Turbine Performance Using Computational Fluid Dynamic

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ABSTRACT

One of hydropower on lowest scale namely propeller pico-hydro, the turbine has a light workload so that allows it to be made from polymer with 3D printing manufacturing. The design of the propeller, the concerned the axial load which results in failure. A failure of designing the dimensions of the propeller turbine with polymer materials causes a fracture in the blades. This study aims to analyze the effect of blade thickness on the performance of a propeller water turbine. Data collection this study uses numerical simulation through computational fluid dynamics using SolidWorks Flow Simulation with the blade thickness variable used 1 to 3 mm with a fillet size 1.5 mm. Based on the results, the thickness of the blade affects the value of static torque. At a blade thickness of 2 mm, it shows the most optimal torque value compared to a thickness value below or above 2 mm.

Keywords: Blade thickness, Propeller, Water turbine, Pressure contour

INTRODUCTION

The current issue of global warming has underpinned the emergence of the concept of an environmentally building, or green building. To fulfill the green building concept, a building plan must meet the criteria for energy conservation, one of which is water conservation [1]. In its application, the form of water conservation can utilize the water systems such as pumping stations, piping systems, and drainage systems as a source of electrical energy on a small scale (Nurdin *et al.*, 2021). The water-energy conversion system into electrical energy in horizontal flow has been widely studied, one of which uses an axial water turbine namely propeller-type (Himawanto *et al.*, 2021) with the advantages of high performance, low production cost, easy maintenance compared to other turbine types [4].

In water energy or hydropower on the lowest scale namely pico-hydro (Nurdin *et al.*, 2020), the turbine has a light workload, so that allows it to be made with polymer materials, one of which is Acrylonitrile Butadiene Styrene or ABS with rapid manufacturing 3D printing technology (Darsono *et al.*, 2021). In the design of the propeller turbine, the most concerned loading is the axial load which has an impact on the blades [7].

Failure when designing the dimensions of the turbine propeller with polymer materials causes a fracture in the blades as shown in Figure 1. In the numerical simulation research conducted by (Darsono *et al.*, 2021), the failure of the blade fracture (with polymer material) can be minimized by increasing the thickness of the blade, this study shows that the thicker the blade, the higher the safety factor value. However, the thicker the propeller blade, the greater the tendency of the blocking effect to occur and potentially reduce the turbine performance. On the other side, the effect of this potential has never been studied before, so based on this, this study provides knowledge about the effect of blade thickness on propeller turbine performance.

This study aims to analyze how the effect of blade thickness on the performance of a propeller water turbine. In addition, this research directly contributes to optimizing the design of the blade thickness and the performance of the air turbine propeller on the pico scale.

RESEARCH METHOD

The basis for designing the propeller water turbine blade used in this study refers to the research (Ramos *et al.*, 2013), and final design based on research (Nurdin *et al.*, 2020) with several blades 5, and the blade angle 20^0 as shown in Figure 2. The blade thickness variable used in this study refers to the research (Darsono *et al.*, 2021) ie 1 mm to 3 mm with a fillet size 1.5 mm as shown in Figure 3. Meanwhile, the total rig assembly design with a flow system in the pipe refers to numerical simulation research (Darsono *et al.*, 2022) as shown in Figure 4. Data collection in this study uses numerical simulation through computational fluid dynamics using SolidWorks Flow Simulation.

Figure 1. Blade failure due to axial load (Darsono *et al.*, 2021)

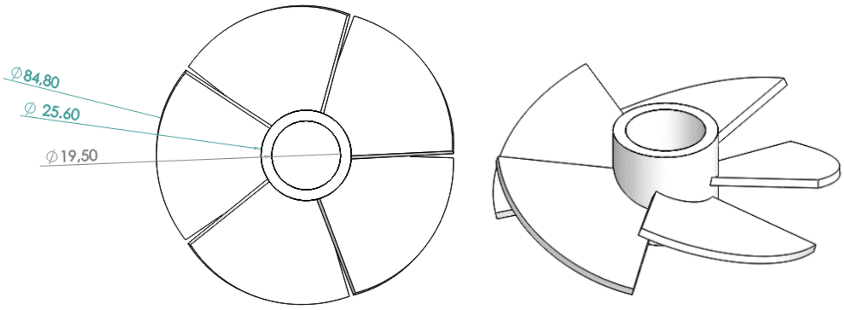

Figure 2. Propeller turbine design (Nurdin *et al.*, 2020)

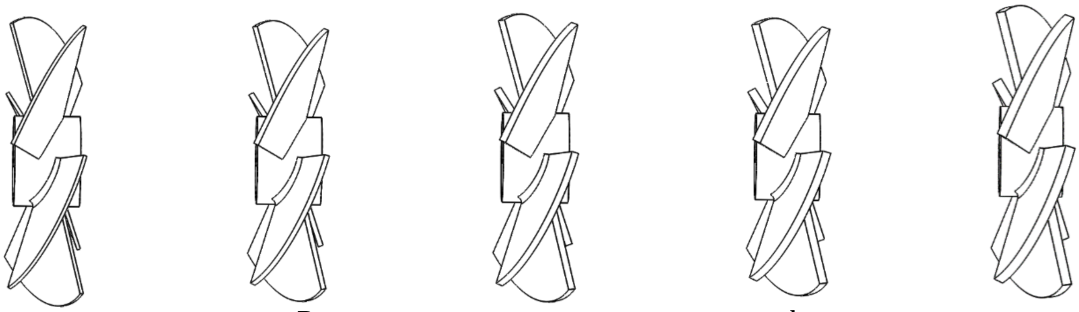

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Figure 3. Propeller turbine thickness (a) 1 mm, (b)1,5 mm, (c) 2 mm, (d) 2,5 mm, and (e) 3 mm

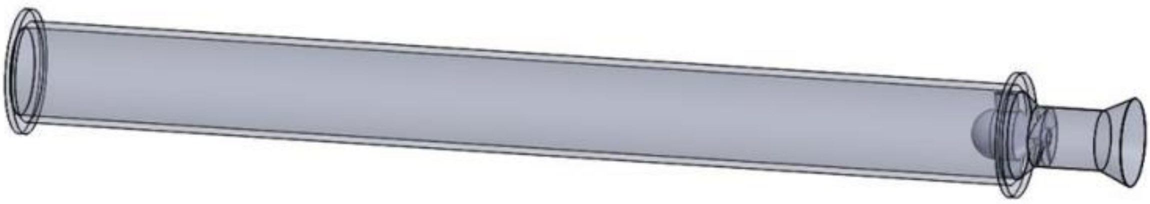


Figure 4. Total rig assembly design (Darsono *et al.*, 2022)

Boundary Condition

To meet accurate results according to the research objectives, the boundary conditions are set as shown in Figure 6. Figure 6 shows the flow parameter of 0.013 m^3 per second or 13 L/s in the inlet area with the pressure parameter at the outlet area of 101325 Pascal. The parameters of the results of this numerical simulation study are the torque value (Nm) that the turbine can produce under static conditions, by regulating the water flow in the direction (x), and the static torque SG (X) on the turbine propeller.

Mesh Setting

In addition to setting the Boundary Condition, in this study, the meshing setting was also carried out. The meshing arrangement in this study refers to the research (Nurdin *et al.*, 2020) (Darsono *et al.*, 2022) which has a similar design, and uses the meshing settings at level 5.

Flow Chart of Study

Based on the description about methods, the stages in this study using numerical flow simulation are shown in Figure 5.

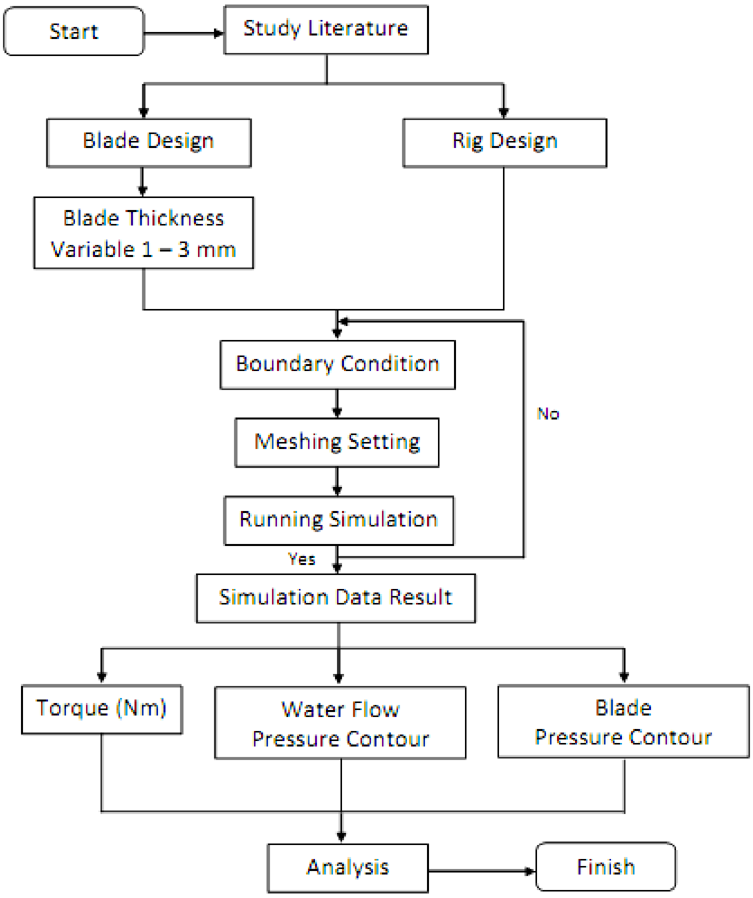


Figure 5. Flow chart of study

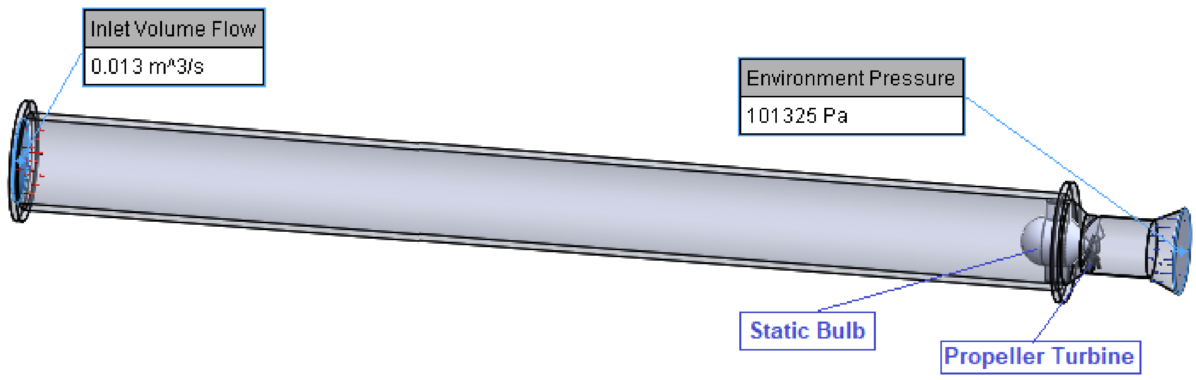


Figure 6. Boundary condition setting

RESULT AND DISCUSSION

This chapter discusses the results of the effect of blade thickness on the resulting torque value. The discussion includes an analysis of the flow pressure contour in the pipe before hitting the blade or suction area and analyzing the pressure contour on the turbine surface. The results of this study are shown in Table 1 with the lowest torque value of 1.21121 Nm at a blade thickness of 1 mm, then it increases at a thickness of 1.5 mm and 2.0 mm (2,93773), and then the torque value will be decreases at a blade thickness more than 2.0 mm.

In the study the thickness of the blade 1 mm resulted in the lowest torque value of 1.21121 Nm, then it increased to a thickness of 1.5 mm and reached its optimal value at a thickness of 2 mm with a value of 2.93773 Nm. Figure 7a shows the contour of the water flow pressure at a blade thickness of 1 mm lower than the pressure contour at a blade thickness of 2 mm (Figure 7b), this shows that a lot of water flow at a thickness of 1 mm passes through the gap between the blades (Nurdin *et al.*, 2020b) so that the energy converted by the turbine is relatively lower than the larger blade thickness as shown in Figure 7b.

Meanwhile, based on table 1 a thickness of more than 2 mm produces a decreasing torque value. Figure 7c shows the contour of the water flow pressure at the 3 mm thickness of the blade which is increasing compared to the contour of the water flow pressure at the 1 mm thickness of the blade (Figure 7a) and 2 mm (Figure 7b), this is due to the greater the value of the blade thickness, the narrower the gap between the blades so that the flow of water is obstructed when passing through the discharge area (Tito, 2013) (Farhan, 2016) and this obstructed a blocking effect occurs (Nurdin *et al.*, 2020a) (Nurdin *et al.*, 2020b).

Table 1. Numerical simulation result

THICKNESS	TORQUE
1,0 mm	1.21121 Nm
1.5 mm	2.33642 Nm
2,0 mm	2.93773 Nm
2.5 mm	2.35944 Nm
3,0 mm	1.43172 Nm

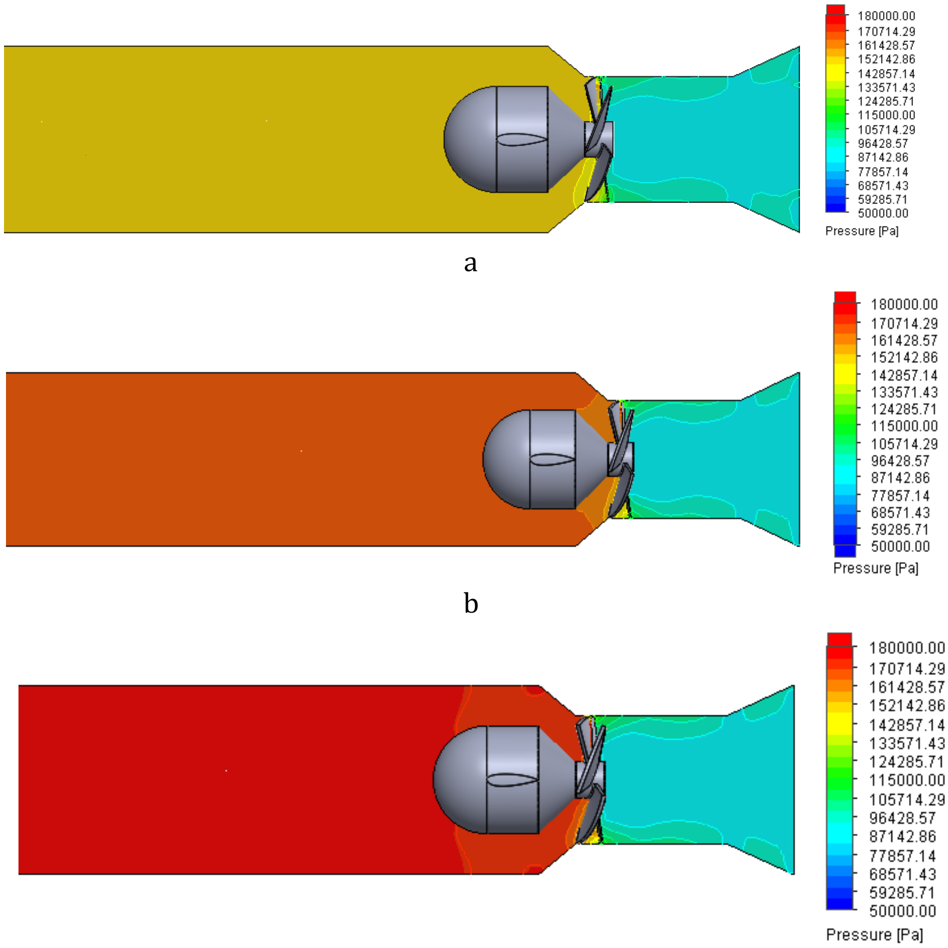
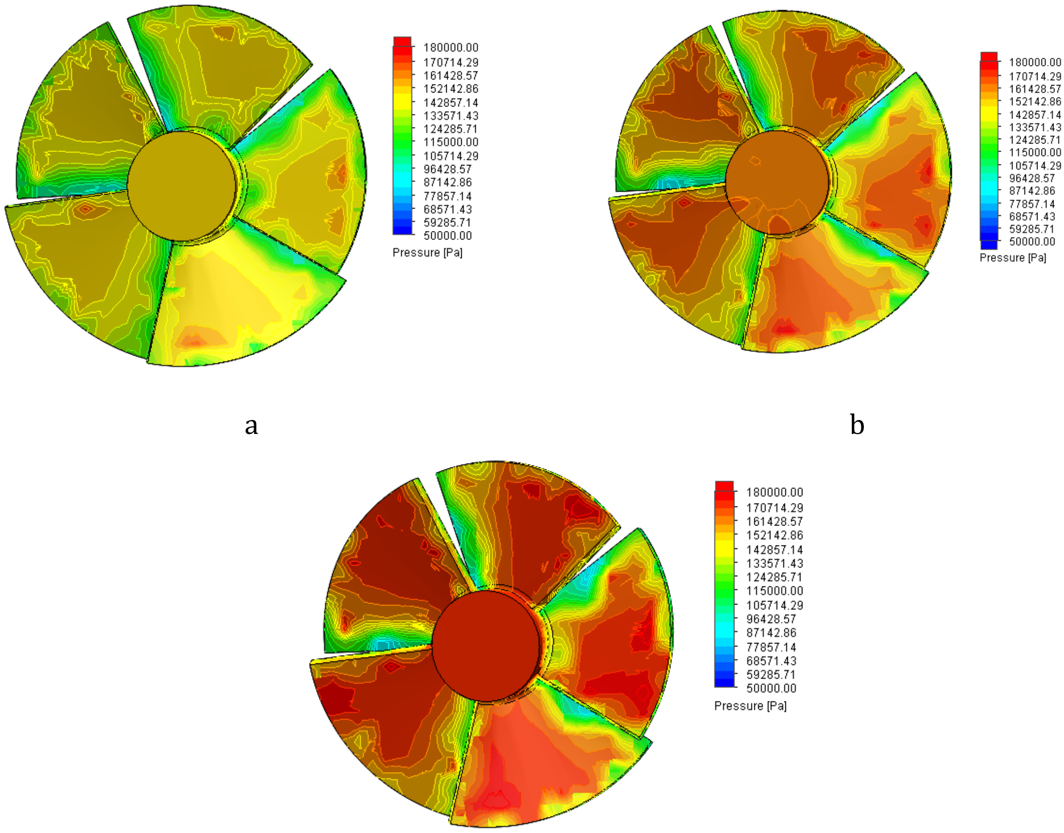


Figure 7. Water flow pressure contour at thickness blade (a) 1 mm, (b) 2 mm, and (c) 3 mm

In addition to the pressure contour analysis in the water flow, the pressure contour analysis can also be seen on the turbine surface as shown in Figure 8. Figure 8a shows the pressure contour at a blade thickness of 1 mm which is lower than at a thickness of 2 mm (Figure 8b) and 3 mm (Figure 8c). At a thickness of 2 mm the flow of water hitting the turbine is greater than the thickness of 1 mm and it forms a low pressure contour (Figure 8a), this causes the axial force received by the turbine to be greater (Himawanto *et al.*, 2021) compared to a thickness of 1 mm and generate greater torque. While the blade thickness of more than 3 mm shows a pressure contour that is greater than the thickness of 2 mm as shown in Figure 8c, this causes the axial force received to be greater, but the torque value generate is lower than the thickness of 2 mm. The decrease in torque value is due to the smaller gap between the blades, so that the velocity of the water passing through the gap increases further causing a whirlpool on the discharge side (Khare *et al.*, 2015) and obstructed water flow which causes the blocking effect phenomenon (Brijkishore *et al.*, 2020).



c

Figure 8. Blade pressure contour at thickness (a) 1 mm, (b) 2 mm, and (c) 3 mm

CONCLUSION

Based on the results of numerical simulation research and discussion, the thickness of the blade affects the value of static torque. At a blade thickness of 2 mm, it shows the most optimal torque value compared to a thickness value below or above 2 mm. This research directly contributes to one of the factors influencing the planning and design of the blades on the propeller turbine.

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