



Archimedes Screw Turbines (ASTs) Performance Analysis using CFD Software Based on Variation of Blades Distance and Thread Number on The Pico Hydro Powerplant

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Abstract. Pico hydro is a powerplant that uses water as turbine propulsion that can generate electricity by a generator. This research will discuss the numerical analysis of the effect of the number of threads on the turbine blades. The analysis process uses the Computational Fluid Dynamic method and the software used in ANSYS FLUENT. Variation 1 uses 9 threaded blades, variation 2 uses 6 threads, variation 3 uses 4 threads. Based on the simulation results in variation 1 with the number of blades 9 threads, the highest torque at TSR 12 is 0.00984111 Nm, power is 0.007671419 Watt. The water pressure entering the turbine blades in variation 1 is 0.097098 Pascal and the water pressure coming out of the blades is 0.047954 Pascal, there is a total pressure drop of 0.4914 Pascal. Based on the torque and power values of the Archimedes turbine in the three variations, it is known that variation 1 has the best performance followed by the other two turbine variations.

Keywords: pico hydro; powerplant; turbine; blade; torque

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1. Introduction

Archimedes Screws Turbines (ASTs) is small hydroelectric powerplant that can be applied even in low head sites, offer a clean and renewable source of energy and are safe for wildlife and especially fish than other hydro generation options [1].

The need for energy from year to year has also increased which is very relevant, especially in developing countries such as Indonesia, according to the Perusahaan Listrik Negara (PLN) data the level of electricity consumption in Indonesia from year to the year 2008 - 2018 has increased [2].

One of the renewable energy sources currently being researched is water flow. The use of various types of turbines is increasingly advanced. Indonesia is an agricultural country which produces water continuously, so water turbines are preferred over wind turbines because of the flow of water in Indonesia is relatively stable [3].

The density of water which is almost 1000 times the density of air causes the force and torque that affects the turbine to be even greater. Hydroelectric power is currently one of the options in utilizing renewable energy sources [4].

This research is using the advantages of numerical CFD simulation are the speed of calculation and the ease of constructing the grid model (connect), CFD software is a reliable and accurate tool to predict turbine performance so that from the CFD simulation can get the output of the turbine torque based on the variation of blades distance and thread numbers [5].

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2. Methodology

This research uses the software of ANSYS FLUENT 17.0 simulation method. The result of the Ansys simulation data was used to analyze the prototype of the Archimedes turbine on the powerplant pico hydro simulation [6].

2.1 Pre-Simulation

Pre-Simulation is the first step in building and analyzing a CFD model. The technique is to model the workpiece, create a mesh, and then apply boundary conditions and fluid properties [7]. The entire geometry of the Archimedes Turbine was drawn in the SolidWorks software. Drawing using software Solidwork is easier than drawing directly on Geometry on the Ansys-Fluent menu.

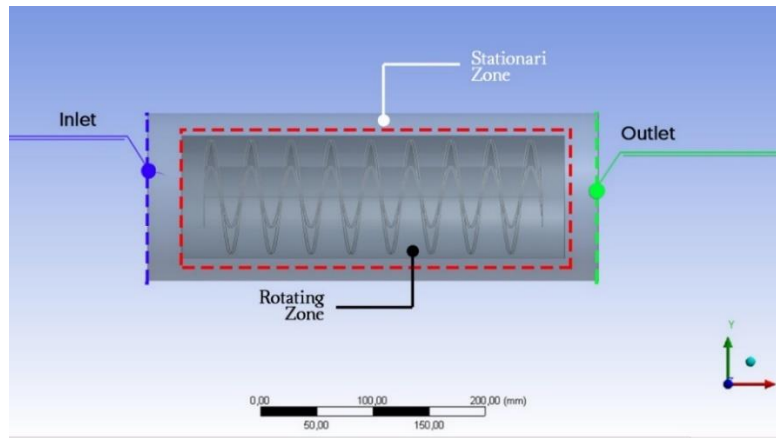


Figure 1. Addressing geometry

a. Geometry

Figure 1 shows addressing on the geometry of the Archimedes turbine to be simulated. The addressing, among others, for the inlet and outlet shows where the start and end of the simulation. Stationary Zone and Rotating Zone show the area of the fluid that is in direct contact with the turbine which is not in direct contact.

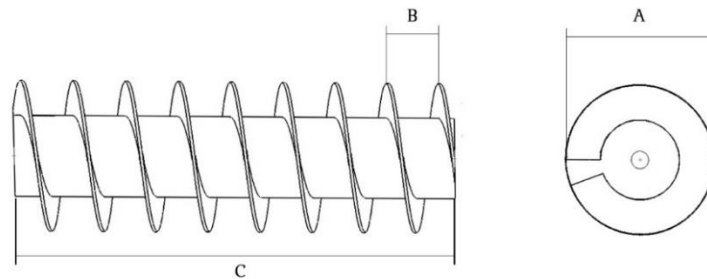


Figure 2. Archimedes Screw Turbin

Table 1. Geometry Variation

Turbine	Variation 1	Variation 2	Variation 3
A/B	0.3	0.5	0.75
Number of threads	9	6	4
Turbine diameter (A)	101.6 mm	101.6 mm	101.6 mm
Turbine length (C)	300 mm	300 mm	300 mm
Distance between blades (B)	35 mm	50.8 mm	76.2 mm

b. Mesh

The research used tetrahedral mesh to divide the objects into smaller parts [8]. At the mesh stage, do enumeration of objects into small elements connected by dots (nodes) getting smaller, If the meshing is made, the calculation results will be more accurate but requires more computational. At this stage,

the selection and arrangement of a meshing strategy or object enumeration are carried out. Mesh results obtained from this stage will be used as a reference for calculations in the next stage.

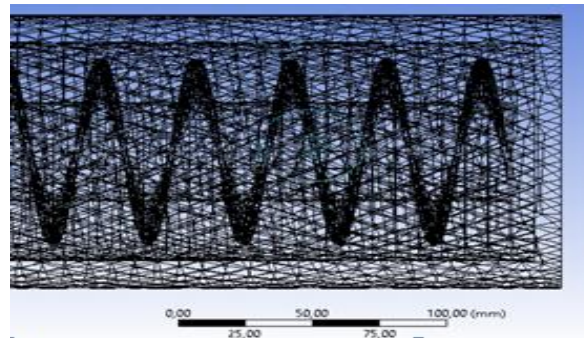


Figure 3. Meshing

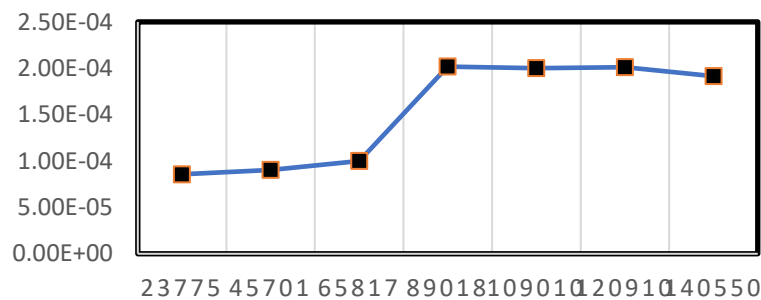


Figure 4. Independence Of Mesh

To determine the best mesh, Independence of Mesh needs to be done which can be seen from how sensitive the mesh is. In Figure 4 it can be seen that the number of meshes is 89018. After the simulation, the highest torque value among the others is 0.0002017 Nm. Because the change in the torque value in the variance of the number of meshes afterward is not significant, the number of mesh used is 89108.

2.2 Simulation

Simulation is a step to calculate the conditions applied during pre-simulation. At this stage, a simulation process is carried out based on the results of the meshing of the geometry that has been created using the Ansys-Fluent software [9]. The processes carried out include:

a. Materials

In the Materials menu, there is a choice of the type of material to be used in the simulation. Material type is divided into two types, namely solid and fluid. Solid materials consist of copper, aluminum, glass, silicone, wood, and others. While the fluid material consists of water-liquid, water vapor, water and etc. In this research, the author uses water-liquid as a fluid, as shown in Figure 5.

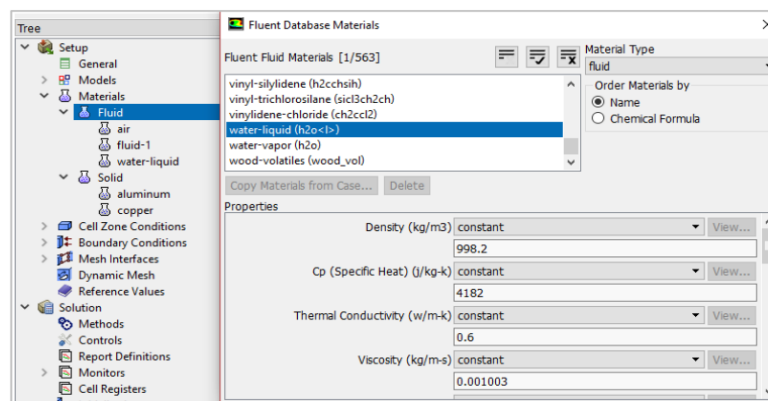


Figure 5. Materials toolbar menu

b. Cell Zone Conditions

Cell zone conditions list the required cell zones. At this stage, each zone is adjusted to the name, type of material, and activities [10]. Cell zone settings on research this is as shown in Figure 6.

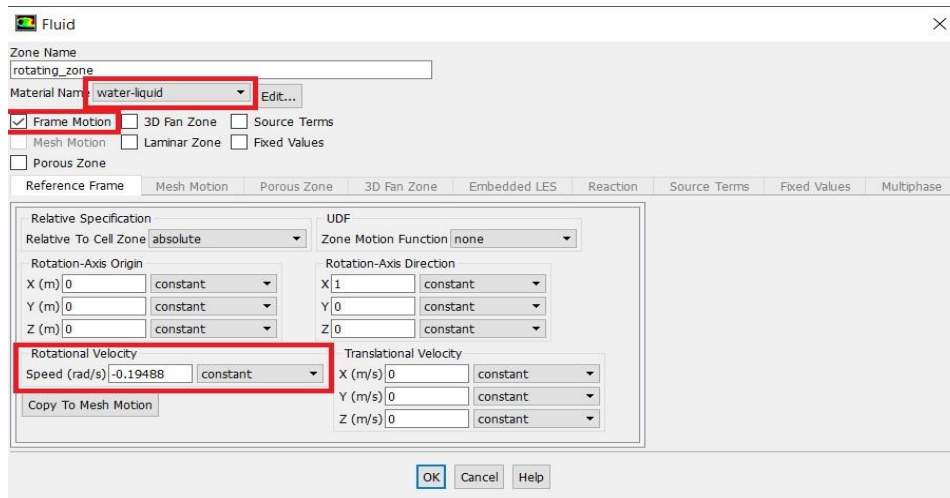


Figure 6. Cell Zone Conditions Toolbar Menu

c. Boundary Conditions

At this stage, it is a process to provide boundary conditions in the form of the data needed for the data simulation. There are five types of boundary conditions applied in the simulation, namely inlet boundary conditions, contact areas, interfaces, interiors, and walls [11]. At this stage, we determine the inlet of the incoming water discharge into the system at $0.0033 \text{ m}^3/\text{s}$.

d. Mesh Interface

At this stage, the author uses it to unite the stationary zone and the rotating zone so that it is not read as a restricted zone, so in this condition, the author uses menu matching on the mesh interface. For settings as shown in Figure 7.

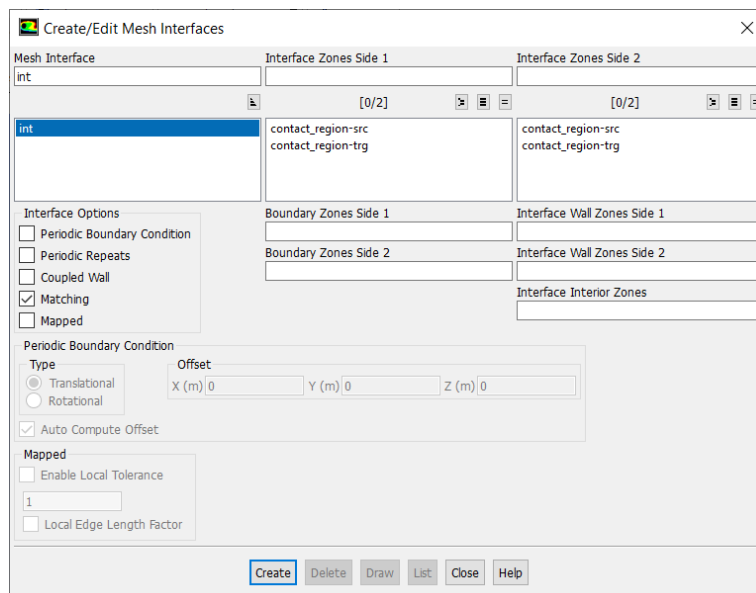


Figure 7. Mesh Interface Toolbar Menu

e. Monitor

At this stage, the process is to determine what parameters will be read and recorded by the system. In this research simulation, the author needs moment data to determine the torque, beside that, at this stage it is determined which areas are the simulation points as shown in figure 8 and figure 9 [12].

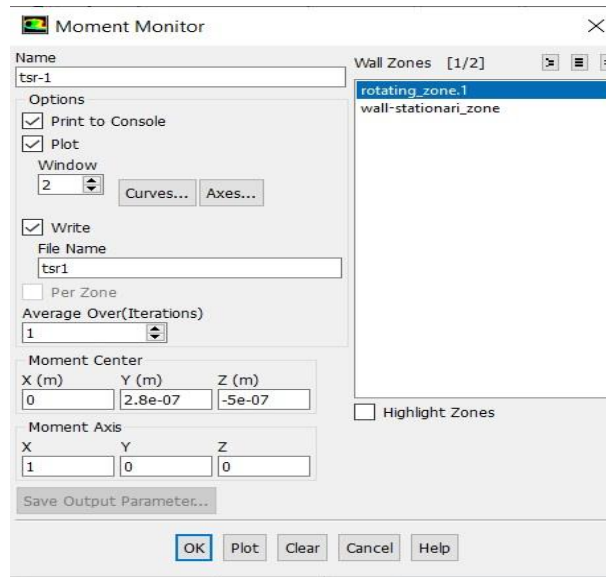


Figure 8. Monitor Toolbar Menu

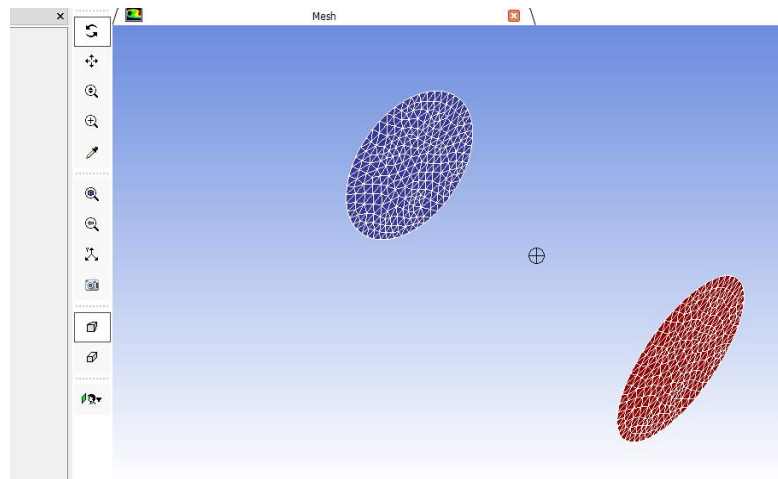


Figure 9. Center point simulation

3. Results and Discussions

In this section, the author will discuss the outputs of the simulation such as turbine torque, power, and simulation contours:

3.1 Turbine Torque

Variation 1 with a ratio of the distance between turbines of 0.35 gets the highest torque at TSR 12, which is 0.00984111 Nm. And variation 3 with a ratio of 0.76 gets the lowest torque value, namely: 0.00683142 Nm. The narrower the distance between the blades, the higher the torque applied, as shown in Table 2.

Table 2. Torque of turbine Archimedes

Turbine Torque				
Total Water Flow (m ³ /s)	TSR	Variation 1	Variation 2	Variation 3
0.0033 m ³ /s	TSR 1	3.02E-04	4.07E-05	6.93E-04
	TSR 3	1.65E-03	2.71E-03	6.92E-04
	TSR 6	3.56E-03	3.81E-03	2.13E-03
	TSR 9	7.39E-03	5.33E-03	4.23E-03
	TSR 12	9.84E-03	8.24E-03	6.83E-03

3.2 Power

At the setup stage, there is a monitor menu, by utilizing this menu, the torque value is obtained for various variations in the distance between the turbine blades of the Archimedes Turbine. Then the torque value is entered into the equation so that the power of the Archimedes turbine is obtained.

a. Variation 1

$$T = 0.009841$$

$$W = 0.77952$$

$$P_{\text{out}} = (0.009841) \cdot (0.77652) = 0.00767 \text{ Watt}$$

Power generated by Variation 1 with a total thread 9 is 0.00767 Watt.

b. Variation 2

$$T = 0.00824$$

$$W = 0.77952$$

$$P_{\text{out}} = (0.00824) \cdot (0.77652) = 0.00642 \text{ Watt}$$

Power generated by Variation 2 with a total thread 6 is 0.00642 Watt.

c. Variation 3

$$T = 0.00683$$

$$W = 0.77952$$

$$P_{\text{out}} = (0.00683) \cdot (0.77652) = 0.00532 \text{ Watt}$$

Power generated by Variation 3 with a total thread 4 is 0.00532 Watt.

Table 3. Power of Turbine Archimedes

Turbine Power			
Total Water Flow (m ³ /s)	Turbine	Total Thread	Power (Watt)
0.0033 m ³ /s	Variation 1	9	0.007671419
	Variation 2	6	0.006426589
	Variation 2	4	0.005325280

Table 3 shows the power value of the Archimedes turbine in various variations. The highest power produced by the Archimedes Turbine occurs in variation 1 of 0.007671419 watts followed by variation 2, and the power lowest when positioned at variation 3 for each variation of flow rate. Turbine power is strongly influenced by torque.

3.3 Pressure Contour

In Figure 10, Figure 11, and Figure 12 it can be seen that the fluid pressure has different parts experienced an increase in pressure during passing through the turbine and there was a decrease again after through the turbine.

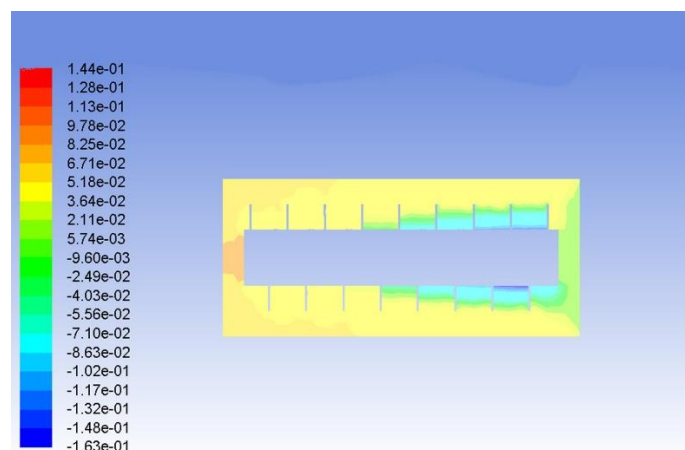


Figure 10. Pressure contour for variation 1

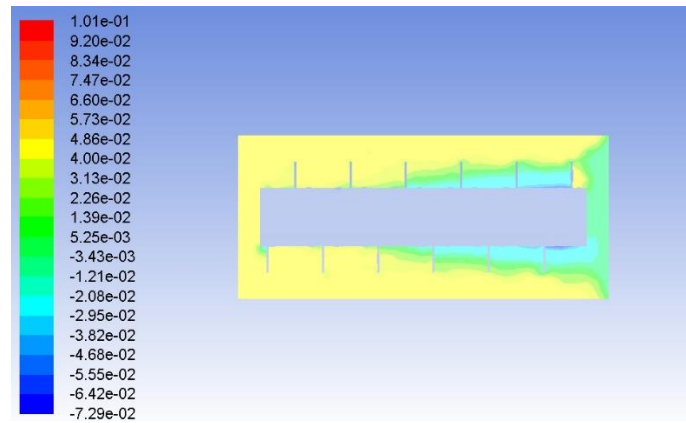


Figure 11. Pressure contour for variation 2

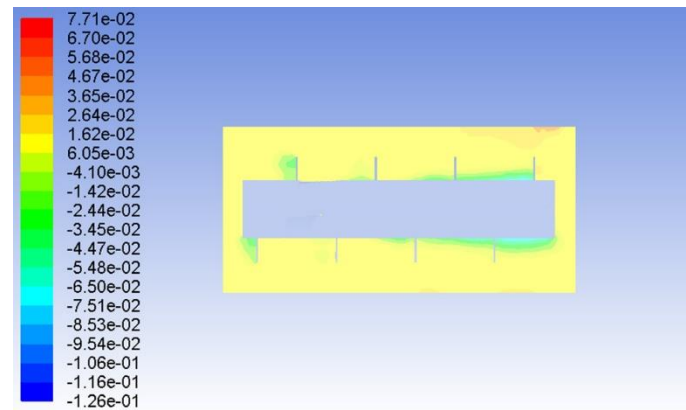


Figure 12. Pressure contour for variation 3

It can be seen from the design of variation 1 with a red contour at the inlet indicating that the highest number of turbine blade threads will produce greater pressure because a greater number of threads makes the turbine move very high so that it can increase the turbine torque, but is directly proportional to the increase in pressure drop, as shown in table 4.

Table 4. Pressure Drop

Pressure Condition				
Turbine	Total Thread	Pressure In (Pascal)	Pressure Out (Pascal)	Pressure Drop (Pascal)
Variation 1	9	0.097098	0.047954	0.049144
Variation 2	6	0.046187	0.040828	0.005359
Variation 3	4	0.020056	0.020055	0.000010

In Figure 12 it can be seen that with less number of threads, the minimum frictional force in the design is reduced which causes almost no change in pressure as shown in the table 4, the effect is getting smaller on the torque value produced by the turbine.

4. Conclusions

From the results of the research and analysis above, this research concludes as follows: Based on the torque comparison graph that has been obtained from the simulation results, the torque value of variation 1 with the number of blades 9 threads gets the highest torque at TSR 12, which is 0.00984111 Nm, but on the other hand, experiences the highest pressure a decrease of 0.4914 Pascal. Based on the torque and power values of the Archimedes turbine in the three variations, it is known that variation 1 has the best performance followed by the other two turbine variations.

Acknowledgments

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