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Darrieus Helical Turbine for Open Channel with Different Blade Angle and Flow Velocity to Improve Turbine Efficiency

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***Abstract*—Darrieus helical turbine is a type of CFWT (Cross Flow Water Turbine) turbine which is the development of the Darrieus Turbine for wind with the advantage of having a stable torque at various current speeds and can rotate at low current speeds. The objectives of this final project are (1) To make 5 models with 3 blades of Darrieus helical turbine based on NACA 0012 with various blade angles; (2) To test the performance of Darrieus helix turbine model with variations in blade angle; (3) to analyze the performance of Darrieus helix turbines and comparing the variations of the blade angle made in order to obtain the best performance. The final project method includes the design of the Darrieus helical turbine design, manufacture and assembly of the turbine, the testing phase, and the processing and data analysis stages. The test was carried out at the flow velocity of 0,55-0,58 m/sec with a variation of the blade angle of 0°, 10°, 20°, 30°, 40°. The wind turbine performance test analysis is based on the calculation of turbine efficiency. The test results show that the Darrieus helical turbine has the best efficiency of 29,84% at a speed of 0,55 m/s with a blade angle of 30° and then efficiency is 20,41% at a speed of 0,58 m/s with a blade angle of 20°.**

Keywords*—Darrieus helical turbine, open channel, flow velocity, blade angle, efficiency

I. Introduction

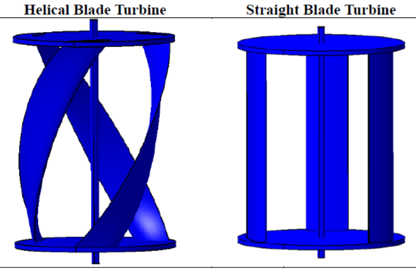
The consumption for energy sources in Indonesia to meet the needs of power plants is still dominated by fossil energy, such as petroleum and coal. Fossil fuels are energy that is not renewable, so if exploited continuously then fossil fuel reserves will be depleted [1]. So as an alternative to fossil energy we utilize renewable energy sources. There is a wide range of renewable energy such as water, microhydro, PV, and biomass [2-4]. One example that we can apply in Indonesia is microhydro power plant, because if seen from its geographical location, Indonesia has great potential to utilize PLTMH technology. Darrieus turbines are better at generating power but generate vibration at a high tip speed ratio. Meanwhile, Darrieus helical turbines are better than starting rotation [5-7]. Darrieus turbines have straight blades while Darrieus helical turbines have helical blades. Two turbine types, helical turbines have a higher value and more stable power. Helical turbines have all the superior characteristics of Darrieus turbines without the weak characteristics of Darrieus turbines [8]. If the turbine blade is fixed and cannot be adjusted then the angle of attack of the blade will change at any time depending on the position of the blade which consequently changes the dynamic force of the water to the blade and therefore the turbine tends to shaking. Therefore, one to overcome it is to make the turbine blades can be adjusted pitch or angle of blades [9-10]. In addition, the greater the slope angle value, it can increase the self-starting torque and turbine efficiency. In addition, the number of blades also affects the performance of a turbine. The number of blades not only affects power coefficient, but also affects the stability of the structure. The main purpose of this final task is to find the efficiency of the Darrieus helical turbine with different of blade angles. To achieve these main objectives are formulated specific objectives as follows: (1) to make 5 models Darrieus helical turbines based NACA 0012 with different of blade angle; (2) to test performance of Darrieus helical turbine model with different of blade angle; (3) to analyze of Darrieus helical turbine and compare the variation of blade angle and flow velocity to obtain the best performance.

Water flow technology is divided into two categories namely Axial Flow Turbine, the direction of water flow parallel to the turbine shaft and Cross Flow Water Turbine, which is the direction of water flow perpendicular to the turbine shaft. Cross Flow Water Turbines are developed from Darrieus turbines used for wind [11]. The difference of Darrieus helical turbines lies in the direction of the blade position. If Darrieus blade has an upright position direction, on the turbine Darrieus helix has a helical position direction. The three model CFWT can be seen in Figure 1.

Fig. 1. Three model CFWT with different (a) Darrieus 1931; (b) Darrieus helical turbine 1997; (c) Archard and Maitre [4].

The use of turbines to convert kinetic energy into mechanical energy in river currents and ocean currents is water current turbines or hydrokinetic turbines. In the low head flow is utilized three-bladed helical turbines that can also be utilized at tidal currents. Darrieus helical turbine application was selected for research based on several considerations; not all water flows have a high head, rivers in the downstream area although with a low head but have a large discharge that is very likely to be utilized, the physical structure of these turbines does not require complex design and civil work, the absorption of technology in the community is more applicative [12]. Darrieus turbine has experimentally studied the effects of solidity, water speed and on the performance of Darrieus turbines that have three blades with straight and helical blade types. Solidity has very little effect on performance but the greater the solidity, the turbine will go down its spin or vice versa. For different water speeds, it will change its performance which if the water speed is higher then the greater the efficiency. In addition, the tilt (helical shape) of the blade at the angle of helical 43.7° has the highest efficiency compared to other helical angles where the highest efficiency is about 15%. The performance turbine influenced the amount of blade and the type of asymmetrical blade used to study its performance. From the results of symmetrical studies used to study its performance. From the experimental results showed that the number of 3 pieces of blade has a higher efficiency blade compared to the number of 2 pieces of blade. In addition, the shape of the circular chamber enlarges its efficiency [13].

Darrieus helical turbine is a type of CFWT (*Cross Flow Water Turbine*) which is a development of Darrieus turbine for wind. In 1925, the first vertical axis wind turbine concept by George Jean Marie Darrieus was an airfoil blade. The foil on Darrieus turbine rotates and relative flow changes. In a small attack blade, the force of the small lift produced by the foil will have a volatile tangential force due to the varied attack blade [14]. Moment and power comparison of helical blade turbine and straight blade Darrieus can be seen in Figure 2.



	Helical Blade Turbine		Straight Blade Turbine	
	Average	Fluctuant Ratio (%)	Average	Fluctuant Ratio (%)
Force (N)	646.67	20%	659.71	101%
Moment (N-m)	40.05	77%	15.78	198%
Power (W)	146.76	50%	116.34	327%

Fig. 2. Moment and power comparison of helical blade turbine (left side) and straight blade Darrieus (right side) [15].

In 1931 it was developed into a Darrieus turbine water turbine with a hydrofoil blade. Alexander M. Darrieus explained that helical blade known as Darrieus helical turbine type developed a type of cross-flow fluid flow turbine in 1993-1995, both of which are suitable for use in watersheds. The difference is that Darrieus Turbines are better at generating power but provide vibration at a high tip speed ratio. The Darrieus helical turbine is an improvement over the Darrieus turbines [16]. In addition to other types of water current turbines, helical turbines have the highest efficiency [2]. Another advantage of helical turbines is that it has a self-starting capability (the turbine ability to accelerate from a still state to a state where it can produce power to rotate). While Darrieus does not have that ability [17].

II. Research Methods

In the manufacture of Darrieus helical turbines, a selection of designs that have been adjusted to the data that has been obtained at the time of field survey measurement so that obtained the characteristics of the Darrieus helical turbines to be made. The design begins with the design of turbine blades, test channels, and turbine frames as well as other auxiliary equipments to support the process of testing the characteristics of Darrieus helical turbines as desired. Darrieus helical turbine has dimensions of height of 46 cm and diameter of 32 cm. The design of the blade dimensions of the Darrieus helical turbine uses the NACA 0012 with a chord length of 14.5 cm. A test channel is a flow channel model used or functioned as a test of the potential flow of water to test the performance or performance of water turbines. The test channel in the labolatorium of energy conversion techniques is elliptical with specifications including channel width (l) = 40 cm and channel depth z = 60 cm. The process of activities in the manufacture of Darrieus helical turbines based on drawing design and size planning and predetermined calculations. In the manufacture of turbine determined types of materials to be used fiberglass, resins, and iron cylinders using AISI 37 material diameter 10 mm and ring diameter 30 mm as blade holder. The Darrieus helical turbine model uses the NACA 0012 base with a height of 46 cm and a chord length of 14.5 cm and the distance between blades forming a blade of 1200. For manufacturing, tools and materials are needed to support the process such as saws to cut turbine blades, drill bits to make holes where bolts, bevel protactors and mistars for the purposes of measuring turbine blades, sandpaper and putty to perform finishing which is further done tightening. Parameters measured in the test include head on flow channel, turbine stroke area, rotation of turbine shaft legible using tachometer, loading test using disc brake. To know the characteristics of the turbine, torque is calculated from the weight of the load multiplied by the length of the torque arm. While the data is used to calculate discharge, mechanical power, hydraulic power and turbine efficiency. All the data is made in the form of a table with characteristic charts so that it can be used as a discussion and analysis material. Prepare all the test equipment to be used both as supporting and measuring components such as pitot tubes, rulers, spring balance, tachometers and axal pumps, fill the water on the test line up to a height of 50 cm, install an axial pump with the propeller arm and turbine frame on the testing pool, turn on the axal pump at normal speed, read the flow potential head with the pitot tube when there is no turbine, and turn off an axial pump. Implementation testing with dipping the turbine into a pond with the turbine depth being in the middle position of the flow, turning on the axial pump at low speed, starting with zero load at the time of initial testing, measuring the resulting rotation by tachometer, reading the resulting mass by pulling the spring balance mounted at arm length on the disc brake to gain torque, reading the turbine head in and out by looking up and down the water on the pitot tube in each loading, read high in and out of the turbine by looking at the measurable water surface on the ruler in each loading, recording the measuring value obtained from the rotation, mass, head, water height and load that reads, in the same way repeat the experiment until the load where the turbine cannot rotate, perform the same steps on each turbine with variations in the speed of the axial pump, tidying up the tool after the testing process, process data, record results in tables, and create in the form of characteristic graphs of each - each variation in water flow speed. At this stage obtained after testing and retrieval of data, the parameters measured are torque from the turbine, turbine rotation, discharge size. After all the tests are completed, the turbine performance data can be obtained and then a graph of the turbine performance characteristics can be graphed. Analysis was conducted by comparing the maximum efficiency of the Darrieus helical turbine variations that have been tested. Open channel for turbine testing can be seen in Figure 3.

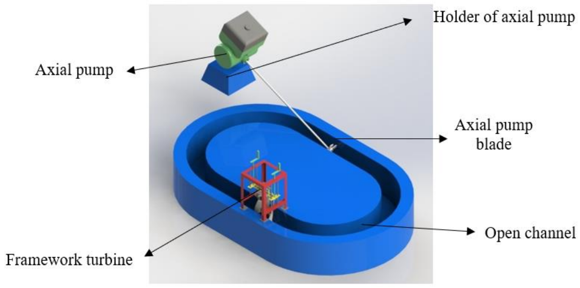


Fig. 3. Open channel for turbine testing.

III. RESULTS AND DISCUSSION

Figure 4 shows the relationship between efficiency and rotation. Darrieus helical turbines tested at the flow velocity of 0.55 m/s. There are 5 turbine show curves with blade angle variations of $0^{0,}$ 10^0, 20^0, 30^0, and 40^0. The result of test turbine at blade angle of 0^0 produce an efficiency of 20.13 % at 45.7 rpm, blade angle 10^0 the resulting efficiency is 17.18% at 52 rpm. At blade angles of 20^0 produces turbine efficiency of 11.86% at 53.3 rpm. The test turbine at blade angle 30^0 have an efficiency of 29.84% at 50.8 rpm. While at blade angle 40^0 obtained turbine efficiency of 12.71% and rotation of 44.4 rpm. Furthermore, the best efficiency from turbine characteristics of 29.84% on the blade 30^0 with a rotation of 50.8 rpm.

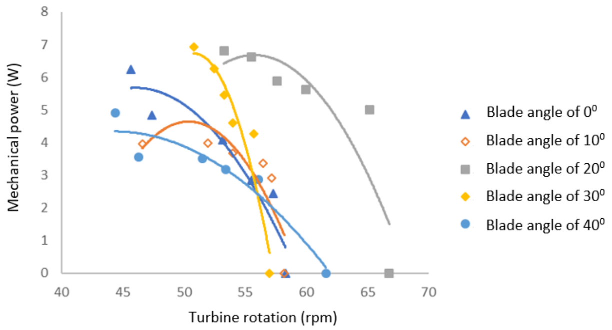


Fig. 4. The performance of mechanical power vs turbine rotation at flow velocity of 0.55 m/s.

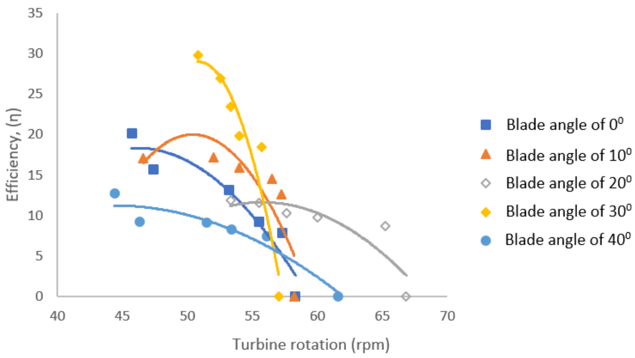


Fig. 5. The performance of efficiency vs turbine rotation at flow velocity of 0.55 m/s.

Figure 4 and Figure 5 peak points on blade of 0^0 produce an efficiency of 14.77% at 49.8 rpm for a peak point on blade 10^0 the resulting efficiency is 11.47% at 51 rpm. At blade 20^0, the peak efficiency is 20.41% at 54.6 rpm. On a 30^0 blade, the resulting peak point is 12.2% efficiency at 51.4 rpm, while at 40^0 blade the peak efficiency is 9.66% and at 40.7 rpm. The best efficiency value of these characteristics is 20.41% at blade 20^0 with a rotation of 54.6 rpm.

Testing and data processing aim to determine the characteristics of the Darrieus helical turbine with blade variations for 0^0, 10^0, 20^0, 30^0 and 40^0. The value of turbine efficiency is influenced by the input power obtained from hydraulic power and the output power, namely mechanical power. Hydraulic power is affected by flow and head. Discharge is inversely proportional to head. The greater the discharge, the smaller the head. Mechanical power is affected by rotation and torque. Torque is inversely proportional to rotation. The smaller the rotation, the greater the torque generated. From the test data, it is obtained the shape of the parabolic curve from the mechanical power graph, which reaches the optimum point where the turbine's mechanical power has decreased after reaching the peak point. In the graph of the efficiency characteristics of rotation, a parabolic curve is also formed which shows the optimum efficiency of the blade variation.

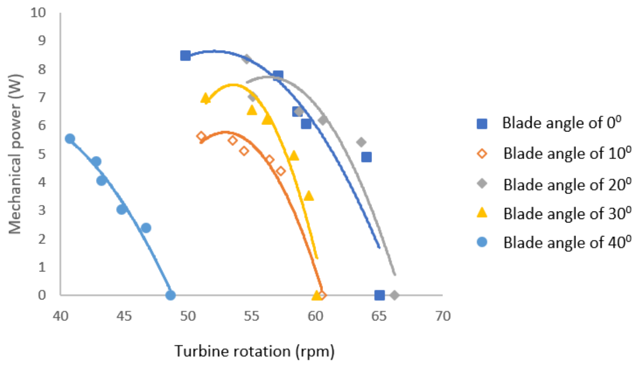


Fig. 6. The performance of mechanical power vs turbine rotation at the flow velocity of 0,58 m/s.

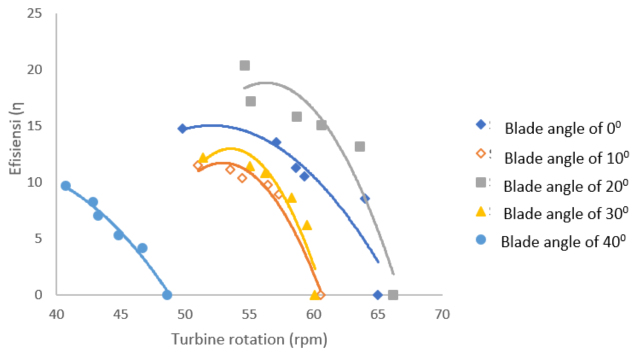


Fig. 7. The performance of efficiency vs turbine rotation at the flow velocity of 0,58 m/s.

Based on the analysis and calculation from Figures 4 - 7, it can be seen that each water velocity test of 0.55 m/s to 0.58 m/s has the highest mechanical power value and the highest efficiency in each of the variations of the blade. At a speed of 0.55 m/s, the highest mechanical power at blade angle 30^0 is 6.92 W. At a speed of 0.58 m/s, the highest mechanical power at blade angle 0^0 is 8.48 W. At a speed of 0, 55 m/s, the highest efficiency at the angle blade 30^0 is 29.98%. At a speed of 0.58 m/s, the highest efficiency at the angle blade 20^0 is 20.41%. So, the highest efficiency at the blade angle 30^0 is 0.55 m/s and a rotation of 50.8 rpm with an efficiency value of 29.84% and the highest mechanical power of 8.48 W at the blade angle 0^0 the flow velocity of 0.58 m/s at the turbine rotation of 59.8 rpm.

IV. Conclusion

- Darrieus helical turbine has 3 blades using fiberglass which can be changed the blade angle, each blade is based on NACA 0012 series with a chord line length of 14.5 cm, maximum thickness of 1.74 cm and blade height of 46 cm.
- Darrieus helical turbine has the best performance of blade 0º at the flow velocity of 0.5 m/s with an efficiency of 20.13%, mechanical power of 6.22 W, and hydraulic power of 30.93 W. Then the blade angle 10º at a flow velocity of 0.55 m/s with an efficiency of 17.18%, mechanical power of 3.98 W, and hydraulic power of 23.20 W. The blade angle 20º at the flow velocity of 0.58 m/s with an efficiency of 20.41%, mechanical power of 8.37 W, and hydraulic power of 41.01 W. The blade angle 30º at the flow velocity of 0.55 m/s with an efficiency of 29.84%, mechanical power of 6.92 W, and hydraulic power of 23.20 W. Furthermore, the blade angle 40º at the flow velocity of 0.55 m/s with an efficiency of 12.71%, mechanical power of 4.91 W, and hydraulic power of 38.67 W.
- Darrieus helical turbine has the best performance on a 30º blade at the flow velocity of 0.55 m/s with an efficiency of 29.84%, a mechanical power of 6.92 W, and a hydraulic power of 23.20 W and a torque of 1.30 Nm. So it can be seen that the variation of blade angle can affect the amount of efficiency generated.

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