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Angled and Curved Bladesof Deep-Water Wheel Efficiency

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ABSTRACT

Electricity is used to operate many electrical appliances and devices. The most basic power can be transmitted to remote distance just with a power cable. This makes a lot of countries including Indonesia looking for many ways to harvest energy to increase the electricity supply to meet human needs. Besides, relying on fossil fuel which is very limited and would probably finished in a short time, one of the applications that are geared towards the use of renewable energy, such as water energy, wind energy, solar energy, and geothermal. One potential source of renewable energy in Indonesia is by utilizing water as an electrical power generation. This water energy is widespread throughout the territory of Indonesia. The experiment done on this research is comparing two kind of under current water wheel, which is the angled bladed water wheel and the horizontal Curved bladed water wheel. Both of these waterwheels were observed under a blade number of 6, 8 and 10. These two kinds of waterwheel were set up to have the same basic dimensions. The experimental activity was also set up on the same conditions, such as the water flow rate, the water velocity and the head energy. The experiment was conducted in the Fluid Machinery Laboratory, Mechanical Engineering Department, Engineering Faculty, Hasanuddin University in Makassar. The efficiency result for the angled blade water wheel on a water flow rate Q = 0.0137 m ^{3} / s, is 57, 197% for the water wheel with a blade number of 6. While for the 8 bladed, angled blade water wheel, the efficiency found is η = 49, 391% and finally for the 10 bladed water wheel (angled bladed under a flow rate of Q = 0.0137 m ^{3} / s) the efficiency is as big as η = 26.595%. The efficiency result for the curved blade water wheel on a water flow rate Q = 0.0137 m ^{3} / s, is 53.983% for the water wheel with a blade number of 6. While for the 8 bladed, curved blade water wheel, the efficiency found is η = 35.703% and lastly for the 10 bladed water wheel (curved bladed under a flow rate of Q = 0.0137 m ^{3}/s) the efficiency is as big as η = 26.595%.

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INTRODUCTION

Energy consumption in Indonesia in 2013 was almost unchanged up 0.2% from 2012, grew significantly below the average growth rate in a decade. This is due to the economic slowdown in the rate of primary energy consumption to achieve 48% higher than a decade ago. While 32% of coal has further strengthened its position as the second largest fuel natural gas exceeded in 2006. Over the past few decades, the demand for coal increased by 180%, energy recycling by 56%, hydro 28%, in the range of 27% oil and gas increased by 9%. However, we have to remember that Indonesia's oil reserves are currently only 3.7 billion barrels left, or only 0.2% of total oil reserves in the world today(BP Statistical Review of World Energy, 2013).

According to the National Energy Outlook of Indonesia's, energy consumption increased by about 2.2% in recent years. The energy consumption is still largely dominated by the industrial sector, followed by the household sector, and the transportation sector. While the electricity sector, power plant in Indonesia is still dominated by the use of fossil fuels, especially coal which is available in limited quantities and will someday run out, while the demand for energy continues to grow. While the area is still experiencing power shortages such as Sulawesi, Kalimantan, and Nusa Tenggara, and Papua power plants are still using fuel oil, where the generation cost component is the largest component (http://indonesia.wordpress.com).

One potential alternative energy sources to be developed in Indonesia is water or hydro energy sources. Water is a source of energy that is cheap and relatively easy to obtain, because the potential energy stored in the water (water falls) and kinetic energy (the water stream flow). Water power (hydropower) is the energy obtained from flowing water. Energy that can be harnessed from water power could be used in the form of mechanical energy

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and electrical energy. Utilization of water energy is mostly done by using a water wheel or water turbine which utilizes the existence of a waterfall or river water stream flow. Many rivers and lakes as well as the primary channel and discharge water in Indonesia indicated the initial capital for the development of water energy. However, the exploitation of this energy source must also consider for the existing ecosystems.(http://tubagus-indra.blogspot.com).

Water wheel is a traditional mechanical equipment used for centuries to convert the energy possessed by the water into mechanical energy used to drive various types of equipment that helps in daily life, for example as a small scale to large scale generator prime mover to generate electricity. Water wheels fitted with blades which these blades are driven by water and then transfer the force to the wheel's axis producing a rotational force. (Paryatmo, W., 2007).

Siahaan, DH, (2009) has conducted a research on a flat bladed water wheel. In his report, a water wheel was tested using varying rates of water flow and load but the blade number were constant, 12 flat blades with a diameter of 0.75 m. Efficiency produced by his experiment reached 55%.

It is considered that the different blades number changes the efficiency of the water wheel due to the change of flow behavior between blades. However, scientific evidences explaining this phenomenon are very few. Therefore, the aim of this study is to clarify the effect of blade number on the efficiency of the water wheel. Two types of water wheel blades, angled-blades and curved-blades are discussed.

Ii. Method and equipment:

The test installation is shown in Figure 1. The water channel had a length of 400cm, width of 25.5 cm, and height of 30 cm. A water wheel was installed on the test channel so that head input and the shape of water flow to the water wheel could be observed. The shaft of the turbine was placed 20cm from the end of the channel. A water tank was placed at the end of the test channel. This tank served to store water that flowed from the channel to damp water fluctuation. The water was pumped through a distribution pipe using a 5kW centrifugal pump into a reservoir connected to the test channel. The water flowing in the test channel turned the water wheel. The reservoir and test channel were propped up by a mounting.

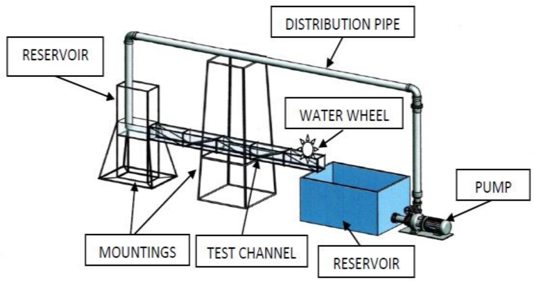

Fig. 1: Isometric view of the test installation.

Specifications of the water wheel used in this experiment can be seen in Figures 2 – 5. All blades were of identical measurements the only variation was in blade model.

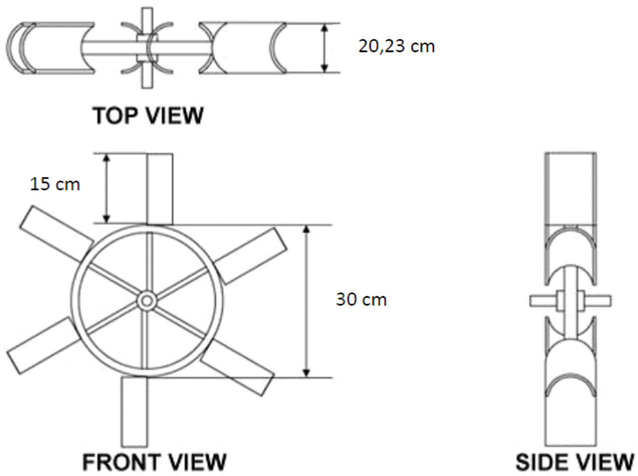

Fig. 2: Vertical curved blade model.

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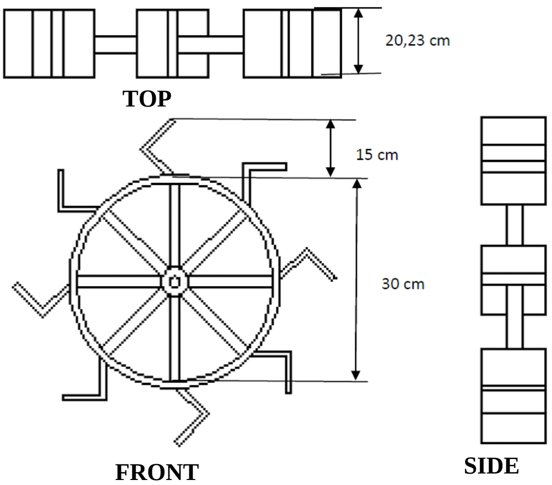

Fig. 3: Angled bladed model.

Fig. 4:A Picture of a vertical curved bladed model

Fig. 5:A Picture of an angled bladed model.

The electrical powermeasurement system by using ammeter and volt meter is show in Figure 6.

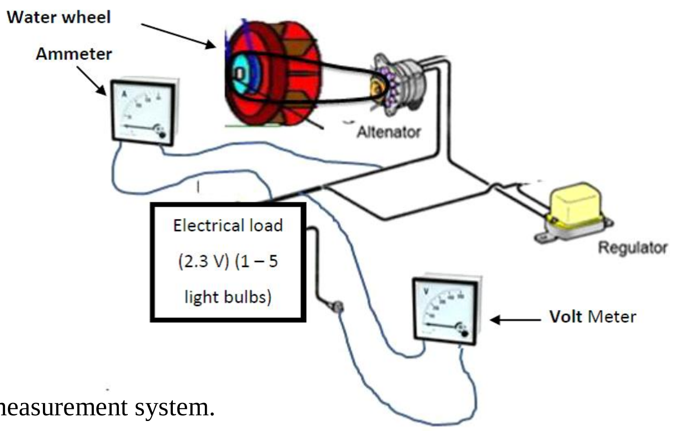

Fig. 6: Electrical power measurement system.

Figure 7 is a circuit diagram illustrating the placement of electrical measurement devices; both the positive and negative leads of the voltmeter were hooked up to the generator, whereas only the positive lead of the ammeter is connected to the generator.

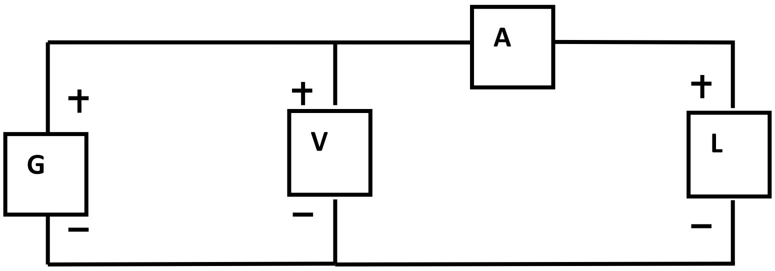

Fig. 7: Electrical Measurement System Circuit diagram.

The following equation is used to measure the rate of fluid flow (Q) in the water channel:

$$Q = V/t \quad (1)$$

Where:
V= volume of the test reservoir (20L)
t = time needed to fill the 20L reservoir
The water velocity (U) was estimated as

$$t = \frac{t1+t2+t3.....tn}{n} \quad (2)$$

Where; $t_1, t_2 .... t_n$= amount of measurements

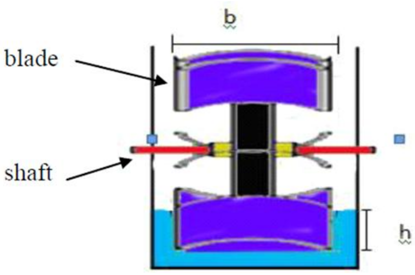

Fig. 8: Vertical curve blade.

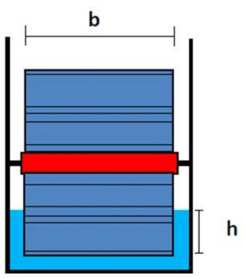

Fig.9: Angled blade.

The area of blade submerged in water (A) was derived from Fig. 8 and Fig. 9 as

$$A = b \times h \quad (3)$$

where: b = widthof blade submerged in water
h = height of water in reservoir
Equation 4 is used to calculate force applied to water wheel:

$$P_{water} = 1/2\rho .A . U^3 \quad (4)$$

Where: ρ = density of water
Thetotal electrical energy produced by the turbine was estimated using equation 5.

$P_{gen} = E \cdot I$ (5)

Where:E = voltage, volt. I = 1.4 ampere

Thetotal efficiency was obtained by using equation 6 as:

$\eta_{ins} = P_{gen}/P_{water} \times 100\ \%$ (6)

Where:

P_{gen} = power produced by generator, watt

P_{water} =power absorbed at blades, watt.

RESULTS AND DISCUSSION

Angled Bladed:

The relationship between generator power (P_{gen}) and load (*n* light bulbs) for 6, 8, and 10bladed can be seen in Figure 10. In Figure 10 it could be seen that the power generated (P_{gen}) is inversely proportional to the total electrical load (*n* light bulbs): the greater the load the lower the power generated. Another trend that could be derived from the data is that the amount of blades on the wheel is also inversely proportional to the power produced at the generator; it is clear the most power is generated by the 6-bladed variant.

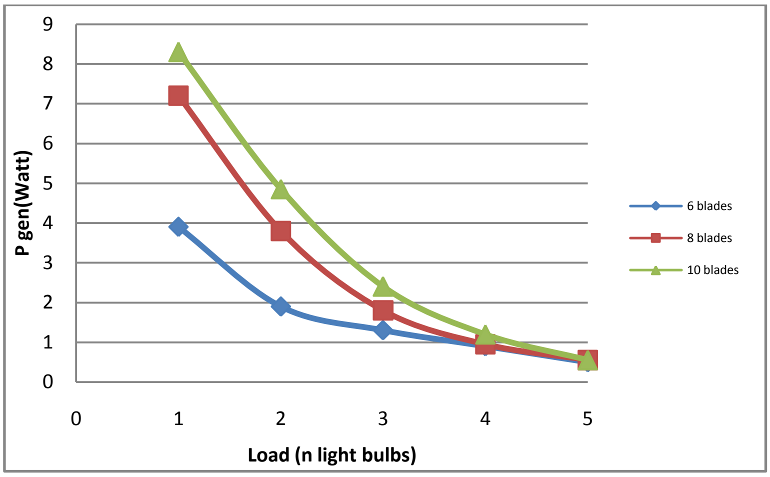

Fig.10: Relationship between P_{gen} (watt) and load (*n* light bulbs) for Q = 0.0137 m^3/s.

The relationship between efficiency and electrical load (*n*light bulbs) for 6, 8, and 10bladed variants can be seen in Figure 11. The same trend with that in Figure 10 was observed since the water power was constant.

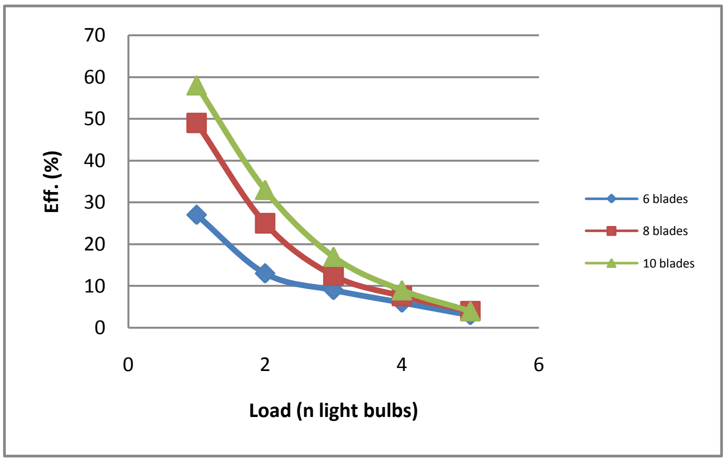

Fig.11: Relationship between efficiencyand electrical loadfor Q = 0.0137 m^3/s.

Vertical Curved Blade:

The relationship between power generated (P_{gen}) and electrical load (*n* light bulbs) for 6, 8, and 10bladed variants can be seen in Figure 12. It is clear that power generated (P_{gen}) has a negative correlation to the total electrical load (*n* light bulbs). A similar behavior is displayed by the vertical curved blade, thus the greatest power

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is generated by the 6-bladed variant.

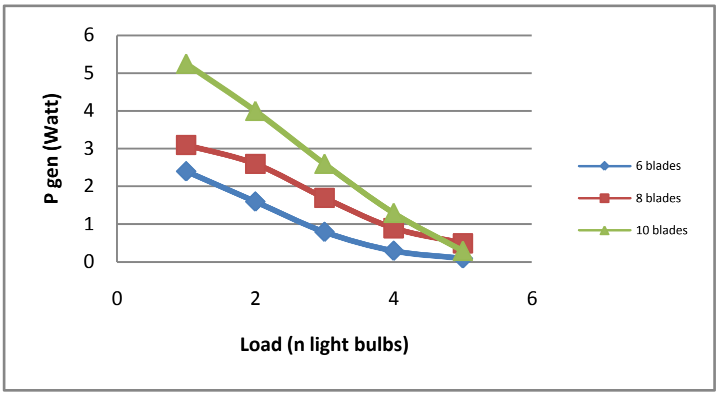

Fig. 12: Relationship between P_{gen} (watt) and electrical load (*n* light bulbs).

The relationship between efficiency and electrical load (*n* light bulbs) for 6, 8, and 10bladed variants can be seen in Fig. 13. The same trend with that in Figure 12 was also observed for the water power.

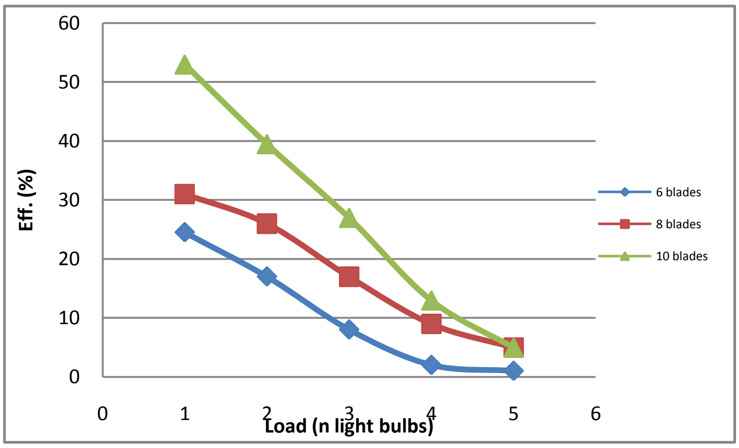

Fig. 13: Relationship between efficiencyand electrical load (*n* light bulbs).

A graph comparing the performance of a 6 vertical curved bladed water wheel with the 6 angle bladed water wheel can be seen in Figure 14 below:

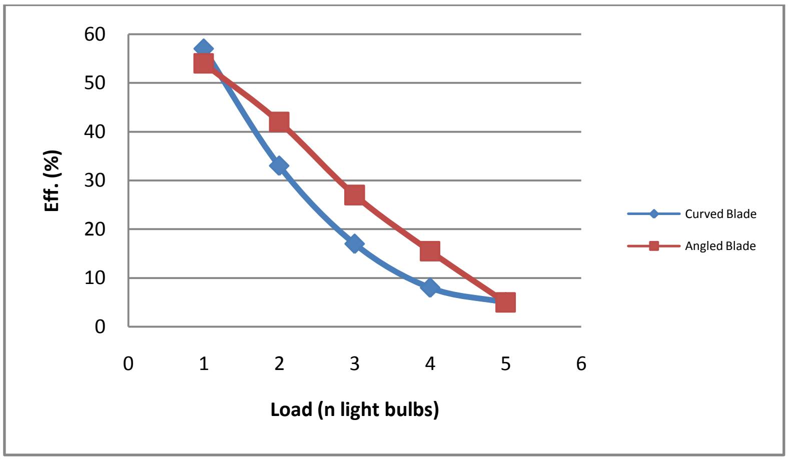

Fig. 14: Comparison of efficiency between the 6 curved bladed variant with the 6 angle bladed variant.

It is clear that the efficiency of the vertical curved blade is inversely proportional to the electrical load the machine is driving (*n* light bulbs); the larger the electrical load the lower the performance (efficiency). The relationship is linear with a linear regression equation.

The 6-bladed angled model also displays similar behavior the greater the load, the lower the efficiency but the relationship is polynomial with a polynomial regression equation.

Conclusion:

The results of the experiment show that for a water flow rate of, the 6-bladed vertical curved blade variant achieved an efficiency of 53.983%, whereas the 6-bladed angled blade variant had an efficiency of 57.197%. The 8-bladed vertical curved blade performed with an efficiency of 35.703%, whereas 8-bladed angled blade variant had an efficiency of 49.391%. The 10-bladed vertical curved blade variant achieved an efficiency of 26.595%, and the 10-bladed angled blade variant had an efficiency of 26.595%. It is seen from the data that the 6-bladed variants of both vertical curved blade and angled blade models achieved the greatest efficiency; the angled blade model performed better by about 3.214%. For the 8-bladed variants, the angled blade model also performed with 13.698% greater efficiency. The 10-bladed variants of both models indicated a similar performance. From the data comparison, it can thus be concluded that under the conditions tested, the 6-bladed angled blade variant performs the most efficient.

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