Optimization of Blade Curve of Pump as Turbine for Piko Hydro Power Plants

M Mustafa*, H Hantarum, S Suryono
Universitas Merdeka Madiun, Serayu Street 79 Madiun, East Java, Indonesia, 63133
*mustafa@unmer-madiun.ac.id

Abstract. The use of the NS 50 water pump that functions as a turbine for the Piko Hidro Power Plant was an idea in finding simple and easy alternative energy in its assembly. In this application, a water pump was used as a turbine so the working principle was reversed, where water from a certain height will move the pump, so that the pump impeller rotates and continues to rotate the generator and will generate electrical energy. This study emphasizes the experimental pump functioned as a turbine (PAT) by modifying the same in and out angles on the PAT blade. An NS-50 pump water pump with a capacity of 563.22 liters/minute and a total head of 20 m was tested. The variables used were water level (H) was 3 meters and variations in the different entry and exit angles of the impeller in the 7 specimens used. The pump was then connected to a generator and the result was electricity. The results showed that the best variation was in variations in the exit and entry angles of 30/30, rotation was 810 rpm and the power produced was 90 watts. The experimental results show good results theoretically.

1. Introduction
Today the development of energy is directly proportional to the development of the age. Population growth, industrial development, and technological progress are the main reasons and evidence that energy is very important for life. The need for energy is unfortunately not in line with the resources that are used or used as the main source of energy production. In 2010, many countries have realized the importance of utilizing renewable energy sources as a substitute for non-renewable energy such as petroleum, coal and gas which has had very damaging effects on the earth. With the depletion of reserves of non-renewable energy sources will release carbon emissions into the atmosphere which is a major contributor to global warming.

Energy needs will always increase as a function of population growth. For conventional energy such as oil and gas, high demand if not matched by production capacity causes scarcity resulting in price increases and energy crisis. One of the efforts related to the energy policy is to develop and increase energy diversity including potential energy now and in the future. This shows the importance of developing the renewable energy sector.

Indonesia is targeting an electricity rate of 90% for the population with a current (predicted) number of more than 273 million. The average standard for electricity is 450 watts per house. Thus, it takes around 9000 MW until 2025. Hydroelectric Power Plants (HPP) in Indonesia has the potential to reach 70,000 MW. Thus the 9000 MW shortfall is predicted to be fulfilled through hydropower. Of the 70,000
MW potential, only around 6% has been utilized. In remote areas, meeting electricity needs through hydropower can be assisted with Micro Hydro Power Plants (MHPP).

Indonesia's natural conditions are very rich in the potential of water that can be used as electricity generation. Therefore, it is necessary to optimize the utilization of water resources for energy fulfillment. The Pikohidro system as one of the new renewable energy sources that can provide great benefits to the community in meeting electrical energy without having to incur high costs for power transmission systems or environmental care in general because the implementation of the system is integrated with its utilization.

The basic principle of hydropower, if water can be channeled from a certain height to a lower level, then the resulting head of water can be used to do work. These uses can move mechanical components into rotational energy that is channeled to the shaft to drive a generator to generate electricity. The choice of a good turbine for each particular place depends on the characteristics of the place, head and discharge available. Turbine innovations that are modern, expensive are all obstacles for rural communities. However, if we use a pump that is mass produced and is reasonably priced, clean, green and sustainable is a solution for the electricity needs of rural communities. The generation scale targeted for household use ranges from 400W - 5000 W.

One economical alternative to building small-scale hydroelectric power plants is to use pumps as turbines. The field of science that specializes in operating pumps as turbines is often referred to as PAT, short for Pumps As Turbine. Several types of water pumps can be applied as water turbines, usually pumps are driven by electric motors to raise a certain amount of water to a certain height. In pump applications as turbines, the working principle of the pump is reversed, which is given a drop of water from a certain height to rotate the pump impeller. This impeller rotation will be continued to turn the generator so that electricity is produced.

The important thing in efforts to optimize this turbine is that the turbine's performance will change if there is a change in the curve and shape of the turbine blade. In this study will test experimentally to determine the performance of the output power generated by the turbine blade by modifying the entry and exit angles of the blade and blade shape using variation of BW1, BW2, BW3, RD4, FW5, FW6 and FW7 on the use of pumps as turbines. This study was held in Mechanical Engineering Department Laboratory at Merdeka University of Madiun.

1.1. Formulation of the problem
The formulation of the problem in this research is how the influence of impeller blade curvature on the pump as a turbine on turbine mechanical power and turbine efficiency.

1.2. Scope of problem
Limitation problems in this study are:
1. The height of the turbine with the upper reservoir is 2, 3 and 4 meters.
2. Opening valve regulating discharge 20%, 40%, 60%, 80% and 100%.
3. Turbine impeller curvature:
   - BW1 : radius curvature 15 cm with backward orientation
   - BW2 : radius curvature 13 cm with backward orientation
   - BW3 : radius curvature 11 cm with backward orientation
   - RD4 : straight blade with no radius curvature
   - FW5 : radius curvature 15 cm with forward orientation
   - FW6 : radius curvature 13 cm with forward orientation
   - FW7 : radius curvature 11 cm with forward orientation

2. Basic theory
Water turbine is a device to convert potential energy of water into round energy and then converted into electrical energy by generators. Before carrying out the design and selection of water turbines, a
feasibility test and analysis of the water resources that will be utilized for its potential energy is needed, especially the availability of head and water discharge from the water source for the designed load.

After knowing the potential head that exists at the source of the water flow, then determine the type of turbine and the planned load. Where the burden of the plan must not exceed the availability of potential energy from water sources, because it will result in not achieving maximum operational efficiency and economically detrimental.

2.1. Pico Hydro
Pico-scale hydroelectric power plants are power plants that produce an electric power output of no more than 5 kW. Piko-scale hydroelectric power plants in principle utilize different heights and the amount of water discharges per second that exists in the flow of water from irrigation channels, rivers or waterfalls. This water flow will rotate the turbine shaft so that it produces mechanical energy. This energy then drives the generator and the generator generates electricity.

Some text.

2.2. Pump as Turbine
Hydropower systems convert energy from water that falls into mechanical energy with turbines. In some cases, it may be more appropriate to replace the turbine with a centrifugal water pump, and run it in reverse. One economical alternative to building small-scale hydroelectric power plants is to use pumps as turbines.

Usually the pump is driven by an electric motor to raise a certain amount of water to a certain height. In pump applications as turbines, the working principle of the pump is reversed, which is given a drop of water from a certain height to rotate the pump impeller. This impeller rotation will be continued to turn the generator so that electricity is produced.

3. Research Methods
The test was carried out at laboratory of Mechanical Engineering Department, Merdeka University of Madiun. The equipment used includes: NS 50 pumps, centrifugal pumps and electric generators.

3.1. Installation testing on pumps as turbines
3.2. Test Specimens
In this test using 7 specimens consisting of: BW1, BW2, BW3, RD4, FW5, FW6, FW7. Specimen specimens are made from composite materials. This is intended to look for light objects that are light and resistant to pressure.

![Specimen 1 (BW1)](image1)
Curvature of the impeller radius of 15 cm (Backward)

![Specimen 2 (BW2)](image2)
Curvature of the impeller radius of 13 cm (Backward)

![Specimen 3 (BW3)](image3)
Curvature of the impeller radius of 11 cm (Backward)

Figure 1. Installation testing on pumps as turbines
4. Result and Discussion
Tests carried out on the pump as a turbine with a head surface height of 2, 3 and 4 meters while the variation of discharge at the valve openings 20%, 40%, 60%, 80% and 100%

4.1. Power of Fluid flow
The power of the fluid flow (Ph) can be seen in Figure 2. below.

![Figure 3. Relationship of discharge (l/s) to water power (watts)](image-url)
4.2. **Turbine Efficiency**

Turbine Efficiency can be seen in Figure 3. below, that describe the relationship between mechanical power and turbine efficiency.

![Figure 4](image)

**Figure 4.** The relationship between mechanical power and turbine efficiency

5. **Conclusion**

From the test results it can be concluded as follows.

1. The highest mechanical power value is 34.29 watt at 4 meter head and BW2 specimens indicate that the ability of the turbine to rotate is obtained from the incoming water power and torque magnitude. The amount of shaft rotation and output power is influenced by the height of the falling water and the volume entering the turbine.
2. The highest output power value of 90 watts at a height of 4 meters in the BW2 specimen is due to the influence of the shaft rotation on the rotation of the generator as well as the ability of the blade angle to change the flow speed.
3. The highest efficiency at the 4 meter head is the highest magnitude at 29.92%. The two highest values were obtained in BW2 specimen variations.

**References**

[1] Abidin, M.A., 2015, *The influence of the large angle of the blade curvature on the performance of an overshot curved blade;* Undergraduate thesis; Mechanical Engineering Department Brawijaya University of Malang.

[2] Arriaga, M., 2010, *Pump as Turbine-A pico-hydro alternative in Lao People’s Democratic Republic*, Renewable Energy, 35.

[3] Derakhshan, S., Mohammadi, B., dan Nouhakhsh, A., 2009. *Efficiency improvement of centrifugal reverse pumps*, ASME Journal of Fluids Engineering p. 131.

[4] Dietzel, F., 2005, *Turbines, Pumps and Compressors*, Publisher : Erlangga, Jakarta.

[5] Himawanto, D. A., dan Danardono, D., 2015, *Effect of the Bucket and Nozzle Dimension on the Performance of a Pelton Water Turbine*. Modern Applied Science, 9(1), 25.

[6] Jain, S. V., Swarnkar, A., Motwani, K. H., dan Patel, R. N., 2015, *Effects of impeller diameter and rotational speed on performance of pump running in turbine mode*. Energy Conversion and Management, 89, 808-824.

[7] Morris, A. L., dan Harris, C. L., 2011, *A technique for probing sublexical representations*. Psychonomic Bulletin & Review, 8(1), 118-126.
[8] Nautiyal, H., dan Kumar, A., (2010). Reverse running pumps analytical, experimental and computational study: A review, Renewable and Sustainable Energy Reviews 14.

[9] Singh, P., dan Nestmann, F., (2010). An optimization routine on apredictionandselectionmodelfor the turbine operation of centrifugal pumps, Experimental Thermal and Fluid Science 34.

[10] Singh, P., dan Nestmann, F., (2011). Internal hydraulic analysis of impeller rounding in centrifugal pumps as turbines. Experimental Thermal and Fluid Science, 35(1), 121-134.

[11] Situmorang, dkk., 2014, Performance of Shimizu Type Ps-128 Bit Water Pump Works as a Water turbine; Undergraduate thesis; Mechanical Engineering Department, Sam Ratulangi University.

[12] Yang, S. S., dan Qu, X. Y. (2012). Effects of impeller Trimming Influencing Pump As Turbine. Computers & Fluids, 67, 72-78.

[13] Zuo, Z., dan Wu, Y., (2015). Pressure fluctuations in the vaneless space of high-head pump-turbines: a review. Renewable and Sustainable Energy Reviews, 41, 965-974.