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The Simulation Study of Horizontal Axis Water Turbine Using Flow Simulation Solidworks Application

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Abstract. The design of Horizontal Axis Water Turbine in pico hydro power plants involves many parameters. To simplify that, usually using computer simulation is applied. This research performs simulation process variation on turbine blade number, turbine blade curvature angle, turbine bucket angle and blocking system tilt angle. Those four variations were combined in order to obtain the best design of turbine. The study used Flow Simulation Solidworks application, and obtain data on turbine speed, pressure, force, and torque. However, this research focused on turbine torque value. The best design of turbine was obtained in the turbine with 6 blades, blade curvature angle of 65° and bucket angle of 10°, and blocking system tilt angle of 40°. In the best turbine, the produced torque value was 8.464 Nm.

1. Introduction

A water turbine as an alternative and a small-scale power plants was classified as pico hydro of power plants because it usually produces a maximum power output of 5 kW. Many researcher interests to do a study on this topic because of its advantages for the remote area which need small electric power even though producing a small power output. Many studies have been conducted to develop pico hydro power plants and involved so many parameters [1-3]. For example, Chen et al. developed a Vertical Axis Water Turbine (VAWT) using a drag type turbine which only involved the number of turbine blades and the form of blocking system. In order to obtain generated power equal to 88,2 W with a flow rate of water equal to 1,5 m/s the research need until three generation of the research [3]. Due to many parameter affect to the turbine performance, researches by simulation method in order to minimize experimental time and cost were also interesting topics [4-9]. Chen et al. also conducted a simulation study using ANSYS CFD for turbine blades and blocking system form. Another research designed and studied flow simulations on blade turbine propellers using the Flow Simulation Solidworks application. The study used a mass flow rate parameter of 1.499 m^3/s as input and resulted in a turbine speed distribution of 0 to 10,949 m/s [9].

A Horizontal Axis Water Turbine (HAWT) is proposed in order to generate electric power in the high rise building wich has the capability to be directly installed in the pipeline of collected waste and rainfall water. It is difficult to collect data directly using the experimental method with many used parameter. To facilitate the data collection, this study first conducted a computational simulation of fluid dynamics in turbine system with various variations such as blade number, blade curvature, turbine bucket angle and blocking system angle using simulation. All of those parameters will be varied to get the most efficient turbine system. In the implementation of simulation, an appropriate method was required to get the best result.

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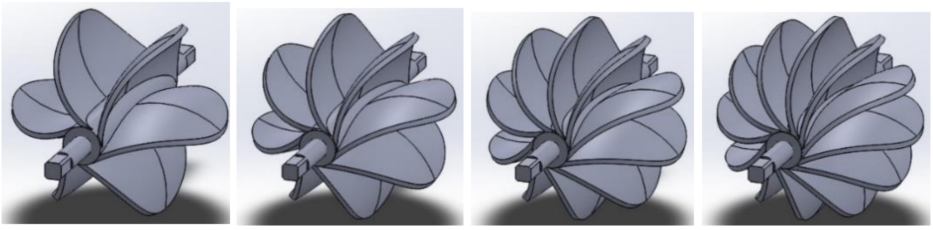
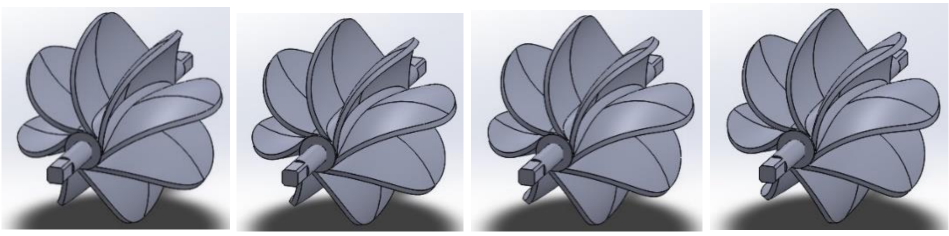
2. Method

Fluid dynamic simulation in this current study is carried out using flow simulation SolidWorks 2014 application which has the capability in analyzing the design of product particularly related to fluid flow. Through this application, data on water flow would be obtained including speed, pressure, flow rate, turbine torque, etc. Thus, those data used to analyze the best variation of turbine system based on morphological matrix method. Turbine blade number, blade curvature angle, bucket angle, and angle of blocking system are shown as figures 1, 2, 3, and 4.



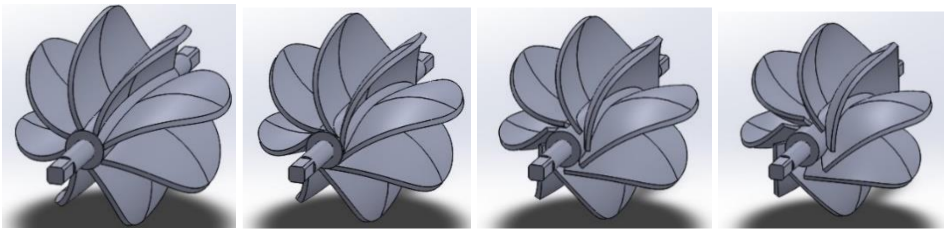
(a) (b) (c) (d)

Figures 1. Turbine blade number of (a) 6, (b) 8, (c) 10, and (d) 12 blades



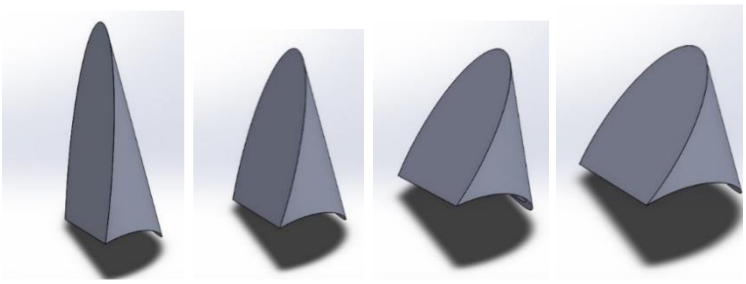
(a) (b) (c) (d)

Figures 2. Turbine blade curvature angle of (a) 65°, (b) 70°, (c) 75°, and (d) 80°



(a) (b) (c) (d)

Figures 3. Turbine blade bucket angle of (a) 5°, (b) 10°, (c) 15°, and (d) 20°



(a) (b) (c) (d)

Figures 4. Turbine angle of blocking system of (a) 20°, (b) 30°, (c) 40°, and (d) 50°

Morphological matrix is one of the creative technical tools to yield ideas, based on the potential characteristic variation of a problem. Morphological matrix is a random design that can be used individually or in the group. The result of this morphological matrix concept development is then poured into the simulation. The variation to be simulated in this research included turbine and blocking system

variations. There are three components of designed turbine variation: turbine blade number, blade curvature angle and bucket angle. Meanwhile, for blocking system, there was one type, and it was only varied for its tilt angle. Here is the designed model of turbine variation and blocking system.
Before simulation of all obtained turbine variations from the morphological matrix, meshing validation was conducted first as a pre-study step in this research. Meshing validation was required to obtain the best mesh level out of eight mesh levels existing in Flow Simulation Solidworks of 2014. Meshing validation was carried out from 3rd level mesh to the best mesh. The best mesh level is the condition when there is no more cell number increase, or in other words, the number of the cell has been constant as shown in figure 5.

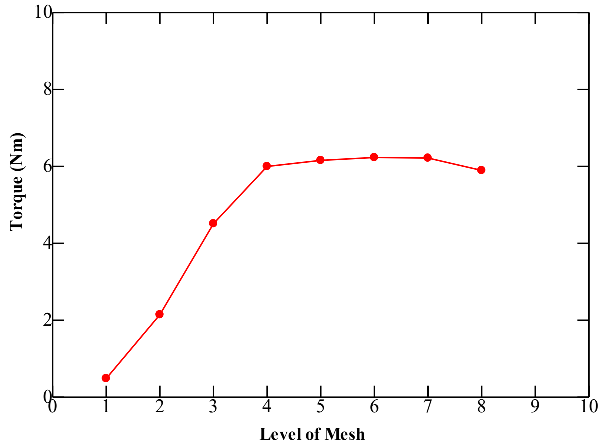


Figure 5. The graph of meshing validation.

3. Results and Discussions

In this subchapter, the effect of the four parameters on the turbine torque will be analyzed. The best turbine design dealing with highest torque value, because of the higher the torque value, the higher is the power produced.

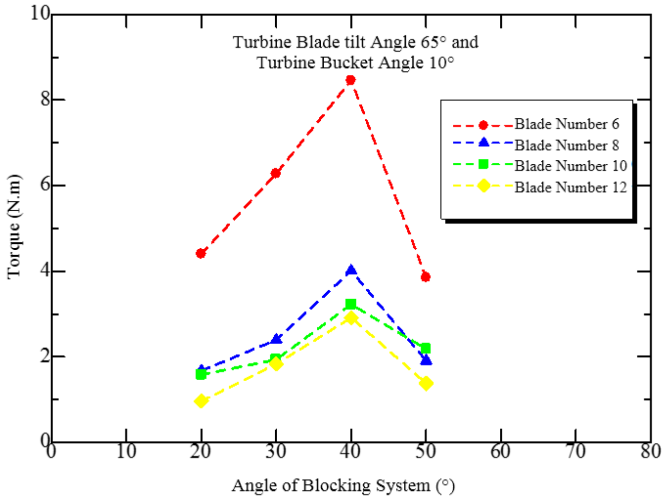
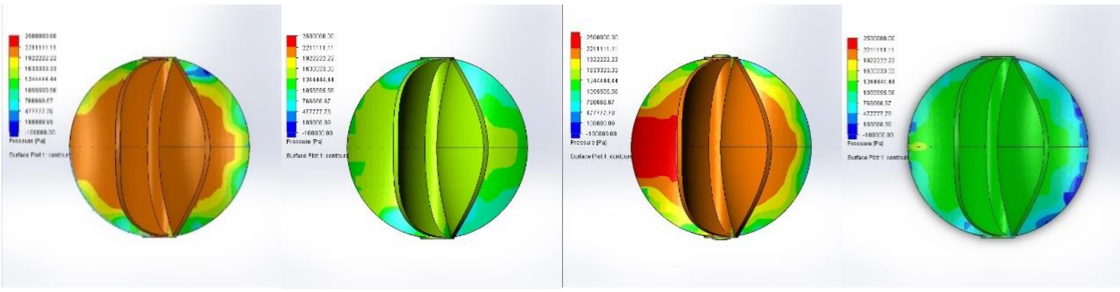


Figure 6. The Value of Highest Torque

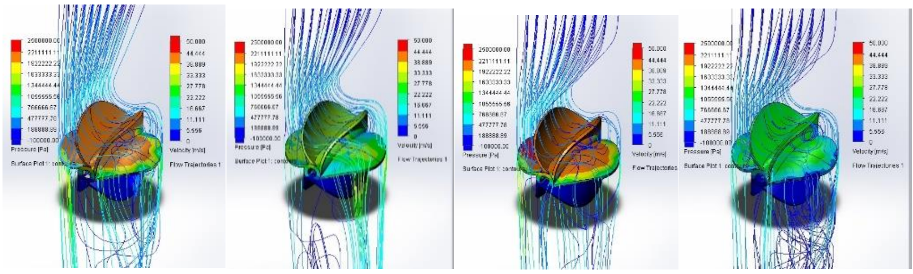


(a) (b) (c) (d)

Figures 7. Pressure plot on the turbine with the blades number of 6, the blade curvature angle of 65° and bucket angle of 10° at various blocking system angle of (a) 20°, (b) 30°, (c) 40°, and (d) 50°

Figure 6 is a chart of the best turbine design by varying the number of the turbine blade, turbine blade tilt angle and turbine bucket angle. The result of the analysis showed that turbine with 6 blades, the turbine blade tilt angle of 65º and turbine bucket angle of 10º producing the largest torque of 8.464 N·m. The turbine produced high torque value because it was affected by blocking system with the best tilt angle of 40º. Thus, combining those four variables will result in the best design of turbine using the produced torque.

Figures 7 shows the pressure obtained on the same turbine blade with a different angle of blocking. Turbine with 40° angle of blocking had direct flow towards the main blade of the turbine, so that in this turbine get big pressure and centered on the main blade. It can be concluded that in the turbine with the blades number of 6, the blade curvature angle of 65° and the bucket angle of 10 ° and with the blocking system angle of 40° can create great momentum and energy in the turbine.



(a) (b) (c) (d)

Figures 8. Velocity plot on the turbine with the blades number of 6, the blade curvature angle of 65° and bucket angle of 10° at various blocking system angle of (a) 20°, (b) 30°, (c) 40°, and (d) 50°

Figure 8 shows the distribution of fluid flow in the turbine. As shown on a turbine with a blocking angle of 40°, the fluid flow velocity increases as it passes through the top of the blocking system and continues to increase until it reaches the turbine blade. After passing turbine blades the velocity of fluid flow tends to decrease. It shows that most of the fluid flow is right on the turbine blades so that it can produce high force and torque. The turbine surface area and the angle of the blocking system have a great effect on the results. So turbines with 65° curvature angles, 10° bucket angles and 40° blocking system slope angle are the best designs of all variations.

4. Conclusion

Research on horizontal axis water turbine (HAWT) simulation by flow simulation of SolidWorks application give the result that the best turbines which produce the highest torque of 8.464 Nm are generated with 6 number of blades, 65° blade curvature angle, 10° bucket angle, and 40° blocking system angle.

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