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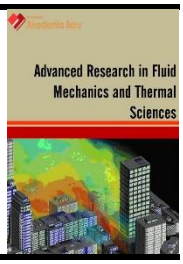

Performance of Savonius Horizontal Axis Water Turbine in Free Flow Vertical Pipe as Effect of Blade Overlap

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ABSTRACT

Water in vertical wastewater pipes has the potential to produce electrical energy due to its big momentum force. This paper proposed a Savonius turbine as an electric generator which works efficiently at low speed and limited head. This study specifically aims to investigate the effect of the overlap ratio of the blade mounted on a 3-inch diameter pipe at a maximum head of 2m at Savonius Horizontal Axis Water Turbine (HAWT) to the coefficient of power and tip speed ratio. The optimal result of this study was obtained in the blade overlap ratio of 0.3 at every discharge. The most optimal performance occurred at the discharge of 11.9 l/s with variation of overlap, while 0.3 had the most optimal performance of 30.58 Watt power output, TSR of 0.79 and power coefficient 0.19.

Keywords:
Overlap ratio; picohydro; Savonius; coefficient of power; power output

1. Introduction

Rapid changes in human culture is always followed by an increase in energy consumption. However, when this consumption increase is not accompanied by a relative increase in natural resources, the worst result is energy crisis. Various efforts have been put into the invention of renewable energy sources, with one of them being the utilization of water energy in multi-storey building waste channels. A lot of researches have been conducted to find the design of a water turbine in a water channel pipe. Water type drag turbines mounted on horizontal channels of clean water pipes have been studied to be capabe of producing 88.2 Watt electricity, but has a pressure drop of 5m at 1.5m/s fluid velocity [1]. Savonius turbine is a type of wind turbine that has a simple design and is relatively inexpensive to manufacture [2]. Another advantage of this turbine is its initial torque which has the ability to rotate at a low fluid speed [3]. Also, an advantage of making it is its attractive application as hydroelectric power plants [4]. However, this turbine has a low efficiency below 25% [5]. Savonius single stage installed on a water flow pipe only produces 0.3 Watt of electric

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power [6]. Subsequently, a research on Savonius water turbines equipped with blade shapes has been carried out [7]. As it developed, its performance was assessed using various methods [8]. One of the methods used in improving the performance was the regulation of fluid direction regarding turbine blades [9]. The main idea of this method is that the fluid is controlled by the guide to crush the concave turbine blade and block the fluid which crushes the convex turbine blade, and as a result, increases the Savonius turbine torque. The results of the analysed data indicates that the directional installation of the turbine can increase efficiency by 50% [10]. Other literatures that have been studied also state that the regulation of the direction and speed of the working fluid improves the performance [11,12]. This result has also been strengthened by a simulation proving that these regulations are capable of improving turbine efficiency [13]. The above description evidently shows that setting the direction of water flow greatly affects the performance of this turbine. Hence, the shape of the blade must be designed to direct the flow of water to the maximum. Furthermore, Patel *et al.,* [14] have carried out a simulation in which they modified the Savonius turbine blade overlap for directing fluid . The principle of working overlap is that after water pounds the concave blade of the turbine, it then flows through the overlap gap, adding thrust to the other blade. This study aims to obtain the best overlap design of Savonius installed in water flow of pipes.

2. Methodology

This study refers to previous studies, in which turbines have an overlap ratio of β = e/d [14]. The blade curve is semi cylinder (180°), endplate Do/D = 1.1, aspect ratio as = H/D = 1 [15], and blade number of 2 [16]. Also, the thickness of the plate in turbine design is 2mm. Dimensions of turbine can be seen in Figure 1. The variations in the overlap ratio are 0, 0.1, 0.2, 0.3, and 0.4. Parameters used on study such as aspect ratio, end plate, and the curve of semi-cylinder turbine (180°) were the same during the test, while the differences were in the overlap ratio and discharge. Turbine specimens with overlap ratio variations can be seen in Figure 2. Its design is made in 3D printing, which can produce precise prototypes using software. However, the one with a 2 mm thickness is made of PLA (Polylactic Acid) material. The data collected is rpm obtained using a tachometer, while the current and voltage are obtained using a multitester. The working principle of this research is that water is pumped from the bottom tank to the upper tank. Water from the upper tank is then poured down to hit the turbine blades which then spin, driving the generator to produce electricity. The amount of discharge was regulated using valve during this study.

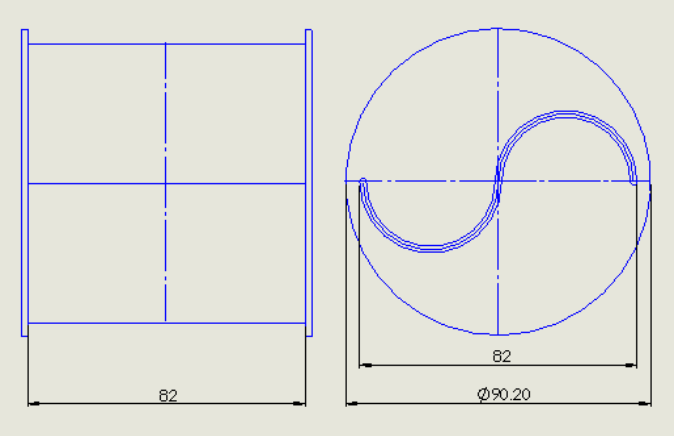

Fig. 1. Turbine dimension

Overlap 0.1 Overlap 0.2 Overlap 0.3 Overlap 0.4 Overlap 0.5

Fig. 2. Variation of blade overlap ratio

3. Results

In this chapter, effect of the variation of blade overlap ratio on performance of turbine Savonius with varied discharge will be discussed. Data without overlap ratio will be compared with overlap ratio variation. Then all variations of blade overlap ratio will be tested with variation of discharge. Effect of fluid flow rate variation on fluid power can be seen in Figure 3.

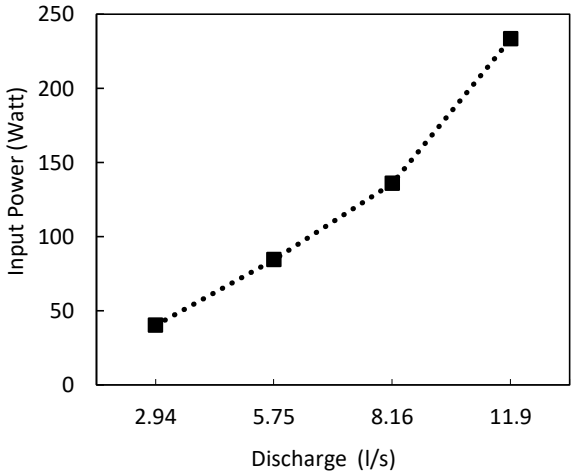

Fig. 3. Graph showing the ratio of input power to the flow rate of water

Figure 3 shows the amount of input power at each fluid discharge. Discharges of 2.94 l/s, 5.75 l/s, 8.16 l/s, and 11.9 l/s yielded input power of 40.24 Watt, 84.31 Watt, 135.72 Watt, and 233.43 Watt. The smallest input power was obtained at a discharge of 2.94 l/s, while the largest was obtained at a discharge of 11.9 l/s. The obtained results indicate that the greater flow of fluid that enters, the greater the input power it generates. Based on the experimental results obtained using multitester, the variation of bladeoverlap ratio affects the resulting Pout. The amount of Power output (P_{out}) generated by each variation of the blade overlap ratio can be seen in Figure 4.

In Figure 4 it can be seen that blend overlap ratio affects the output power generated by Savonius turbine. The results of blend overlap ratio and output power at each variation of the discharge are the same. However, the output power at each blade overlap ratio increases with an additional discharge. Tip speed ratio is the tangential speed at the tip of the blade against the actual speed of the fluid, while the power coefficient is the ratio of the actual power generated by rotor blade to the power acting on fluid. The graphical illustration showing the effect of speed ratio tip (TSR) on power coefficient (Cp) can be seen in Figure 5.

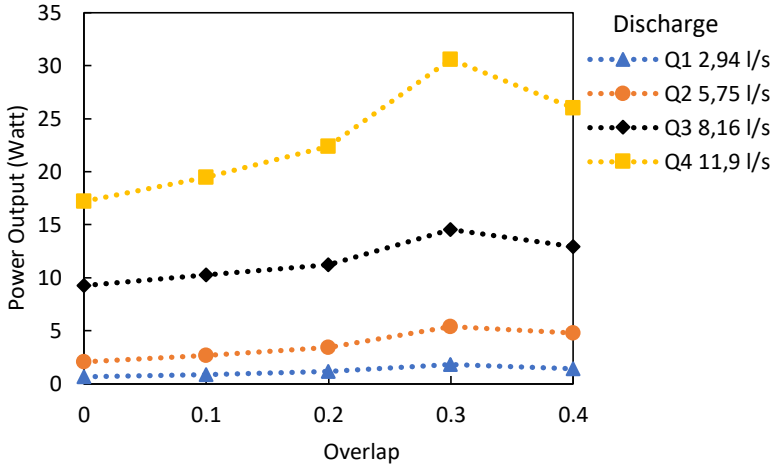

Fig. 4. Graph showing the relationship between overlap ratio and Power output

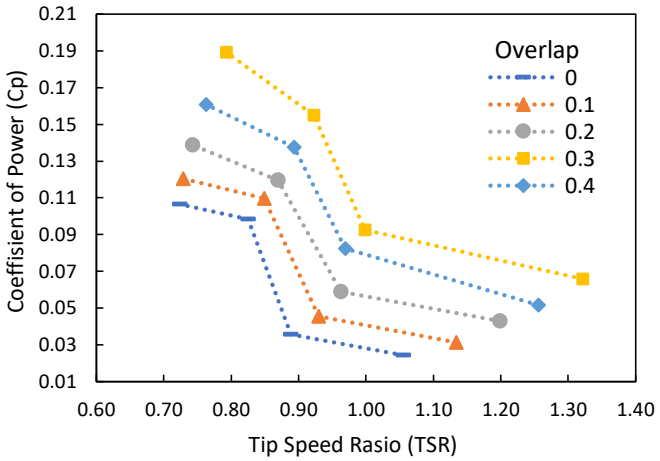

Fig. 5. Graph showing the relationship between TSR and Cp at variation of overlap ratio.

Figure 5 shows that all variation blade overlap ratio decreases Cp value followed by an increase in TSR value. A decreased Cp value is due to a smaller discharge variation. Therefore, the variation of discharge greatly affects the value of Cp, given the fact that when discharge is low, the value of Cp will also be low and vice versa. From the data shown in Figure 5, the maximum Cp value at discharge of 11.9 l/s was obtained at 0.3% overlap ratio of 0.19 with TSR value of 0.79, while the minimum Cp value was obtained at overlap 0 ratio of 0.11 with TSR value of 0.72. Then at the discharge of 2.94 l/s, the maximum Cp obtained on blade ratio overlap 0.3 was 0.07 with value of TSR 1.32 while minimum Cp value obtained on overlap ratio 0 was 0.02 with value of TSR 1.06. Therefore, the obtained graph showing the relationship between TSR and Cp indicates that an increase in Cp is not followed by an increase in TSR.

4. Conclusions

Based on data of influence ratio overlap variation turbine Savonius blade on performance which have been analysed, it can be concluded as follow.

I. With head 2 m, the obtained maximum power output value at overlap ratio of blade 0.3 was equal to 30.58 Watt.

II. The maximum and minimum coefficient of power at the 11.9 l/s discharge was obtained at the 0.3 overlap ratio of 0.19, and the minimum in the overlap ratio of 0 is 0.11.

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