Experimental Studies of Performance Savonius Wind Turbine with Variation Layered Multiple Blade

Y Kurniawan¹, D D D P Tjahjana¹*, B Santoso¹

1 Mechanical Engineering Department, Faculty of Engineering, Sebelas Maret University, Surakarta 57126, Indonesia
E-mail: danar1405@gmail.com

Abstract. The solution to various environmental problems now is the development of renewable energy. One of the renewable energy that was sociable to the environment and easily obtained is wind energy. Savonius wind turbines are proper to be applied in Indonesia which have low wind speeds, besides that Savonius also has many advantages over other wind turbines. In this paper experimental study is done a study on conventional Savonius wind turbine and modified Savonius wind turbine by added multiple layer 90°, 115°, 135° at positions 0° and 30°. The schematic supportive testing is done by blower fan. The wind speed used in testing with a range of 4.99 m/s to 7.27 m/s. The test results showed that the addition of multiple layers could be increased Savonius's power coefficient to 17.6%. The maximum power coefficient obtained by Savonius turbine was 0.120 with variations multiple layer 90° at 0° position. So, the addition of multiple layer can be improved the performance of the Savonius wind turbine.

Keywords: renewable energy, savonius wind turbine, multiple layer

1. Introduction
The main serious problems with the environment such as global warming, pollution, energy scarcity, depletion of fossil fuels and increasing economic growth have resulted in many demands for renewable energy needs [1]. One of the fastest growing renewable in the world today is wind energy. Wind energy was capable of producing energy with non-fossil fuels [2]. Moving wind or air energy were source of renewable and easily to find. In addition, wind energy was environmentally sociable and did not cause air pollution [3]. For the use of wind energy, certain wind turbine mechanisms were compulsory. Wind turbines were devices that can be used in wind energy in conversion systems, where wind kinetic energy was extracted and converted into electrical energy with additional devices by generators [4]. In general, wind turbines were divided into two types as Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT) [5]. HAWT is a wind turbine that is widely used today. HAWT can be produced large power at high wind speeds but cannot be produced output power when receiving wind at the low speeds [7,8].

Indonesia has a plan to use renewable energy as one of the main sources of national energy. 23% of the total national energy production will be produced in 2025 [8]. For equatorial regions such as Indonesia which had a fairly low average wind speed and wind direction had varies flow. With this condition, VAWT was appropriate to be applied because it can be operated in areas that had low wind speeds or below 2 m/s [9]. Popular types of VAWT are Darrieus and Savonius. Darrieus wind turbine is high efficiency, but have low self starting torque [10]. Savonius wind turbines had many advantages such as producing high torque to make it easily in rotating, simple design, easy maintenance, relatively low investment costs, quiet operation, and capable to operate in all wind directions [11]. Therefore, Savonius turbines were attractive to be developed as micro and small scale power plants and to be allocated in urban areas. Besides many advantages, the Savonius turbine had low efficiency. Various
studies had been carried out to improve the performance of Savonius turbines. Savonius turbine performance was predisposed by design based on several design parameters such as blade shape, number of blades, geometry design and wind inlet speed [12]. The testing in experiment of the effect of number Savonius turbine blades resulted that power coefficient ($C_p$) on the use of two blades was greater than the three blades [13]. When the number of blades increased, the value of $C_p$ obtained would be decreased. In addition $C_p$ is influenced by the appearance of negative torque due to the wind direction which hitting the returning blade side which becomes a rotating turbine disturber [14]. Overlap ratio was a way to overcome the occurrence of negative torque. Overlap ratio was the main parameter that can be affected the structure of wind flow in Savonius. This parameter proved that able to produce optimum power in variation of the overlap ratio of 10% - 15% [15]. Another factor that can be improved Savonius turbine performance was the parameter of adding end plates to the upper and lower sides of the blade. The aim of the end plate was to prevent air flow from spilling to both ends of the blade so that it can be increased momentum transfer from the air flow and reduced negative torque [16]. This parameter can be increased efficiency significantly [15,16]. The development of optimum blade profile and shapes is very influential on the aerodynamics of wind turbines that intention to efficiently harvest wind energy [19]. Sharma et al. [20] was conducted a simulation by modifying the Savonius turbine by adding multiple quarter blades which were installed parallel to Savonius advancing blade. Consequently, the power coefficient increased to 8.89% compared to conventional turbines with the same geometry, this was caused by incoming wind flow on the side advancing blade is directed to the other side of the blade so that it can be reduced the negative torque on the returning blade side. Sharma et al. [21] was conducted a simulation study with multiple layer parameters on the Savonius turbine. The results showed that the addition of multiple layers to get the maximum $C_p$ of 0.226 at the speed of 8.23 m/s. In this study was used Savonius turbines with the addition of multiple layer blade and tested experimentally. The purpose of this experimental test was to determine the effect of adding multiple layers that flowing fluid from each blade advancing through a variation of the overlap ratio to turbine performance. The variation made were in size and position of multiple layers in the overlap ratio of 10%. Multiple layer additions are expected to increase Savonius turbine efficiency because multiple layers can accelerate fluid flow flowing on each advancing blade, with the purpose of the negative torque that occurs when the turbine rotates becomes reduced.

2. Experimental equipment and measurement method
The experimental set-up of the test bench structure supports Savonius wind turbines, fan blowers and measuring devices. Figure 1. shows a schematic diagram of an experimental testing apparatus without wind tunnel. The schematic test wind source consisted of a series of 4 fan blowers arranged in a 2x2 configuration. The distance between blower fan and shaft turbine is 1000 mm to get stable and uniform wind velocities [22]. Wind speed was regulated by a variable dimmer switch device with a range of 4.99 m/s to 7.27 m/s. Experimental was equipped with a prony brake system (for loading systems) placed on the bottom of the turbine. The wind from the fan blower was directed towards the turbine so that the Savonius turbine rotates and then the rotation per minute (rpm) was measured by a tachometer.

1. Fan Blowers
2. Savonius Turbine
3. Prony Brake
4. Frame Fan Blower
5. Turbine Frame

**Figure 1.** Testing Schematic
Savonius wind turbine with design geometry High (H) = 400 mm, Diameter (D) = 400 mm, aspect ratio (H / D) = 1, and overlap ratio of 10%, number of blades are 2 blades and turbine material was made of aluminum with a thickness of 1.3 mm. The combinations of the parameters dimensions is made with the large multiple blade layers at 90°, 115°, 135° (fig. 2) and the position of multiple layers 0° and 30° (fig. 3). The wind used in this study also varied with 5 different speeds, namely 4.99 to 7.27 m/s. Turbine performance was visualized in the graph between $C_p$, $C_T$ and TSR.

![Figure 2](image1.png)

**Figure 2.** (a) Savonius wind turbine with variation multiple layer; (b) geometry savonius with multiple layer 90°; (c) 115°; (d) 135°

![Figure 3](image2.png)

**Figure 3.** Savonius wind turbine with variation of multiple layers and position 30°

3. Results and discussion

3.1 The influence of multiple layers with sizes 90°, 115° and 135°

The curve of the power coefficient ($C_p$) and the torque coefficient ($C_T$) from the Savonius wind turbine obtained from the experimental results at 10% overlap are shown in Figure 4. Results obtained from experimental studies showed that the values of $C_p$ and $C_T$ toward TSR. The $C_p$ curve of the Savonius wind turbine is described as a parabola. $C_p$ from Savonius was low at low wind speeds and increase with high wind speed. Studies experiment with conventional Savonius turbines obtain value of $C_p$ 0.102, the results are relatively lower because occurs the flow is not focused or divided when the wind flow hits the middle of the advancing blade. Therefore it can reduce the positive torque produced (figure 5.a) [23]. The best performance showed by turbines with variation multiple layer 90°. The use of Savonius turbines with the addition of multiple layers increases the area of the rotor surface, thus it can improve Savonius turbine performance [21]. Static testing of Savonius turbines by adding layers shows that $C_{TS}$ tends to decrease in the rotor positions 0° - 90°. Then, it rises in the position of the rotor 90° - 180° [24].

In figure 4, variations in the addition of multiple layers 90° and 115° can be increased the value of $C_p$ and $C_T$ compared to conventional Savonius. This was because increasing the open area on the blade advancing side. And this will be increased kinetic energy effectively when the fluid flow entered [20], the turbine can absorb well-received kinetic energy accordingly. With an overlap ratio of 10%, the fluid flow received by the advancing blade quickly flowed into other advancing blades, thus it can be increased the positive torque to the advancing blade (figure 5.b). Increased open area on the side of the
blade advancing increases addition of multiple layers can also increase moment of inertia because the mass will increase at the end of the advancing blade. The results of the Savonius turbine experiment with variations in the addition of multiple layers 90° obtained $C_p$ 0.120 at TSR 0.428 and increased 17.6% against conventional Savonius turbines. While the maximum $C_p$ value for variations of multiple layer 115° is 0.105 at TSR 0.445. Figure 5.c shows multiple layers increasing the velocity of fluid flow in a advancing blade. The results attained were not maximal because the mass of multiple layers material overloaded the Savonius turbine rotation.

Figure 4. (a) Graph of the relationship of $C_p$ with TSR in multiple layer size variations; (b) graph of the relationship of $C_T$ with TSR in multiple layers size variations

Turbines added with multiple layers 135° had $C_p$ 0.092. Multiple layers 135° will be reduced the surface area on advancing blades and making non-focused fluid flow into other advancing blades thereby reducing turbine performance (figure 5.d). The use of multiple layers that were too long made the performance of the turbine were decreased, this is caused by excessive mass of multiple layer material overloading the speed of the rotating turbine. To improve Savonius turbine performance that was commensurate with the effort did not add excessive weight and complex design [21].

Figure 5. Fluid flow direction to the savonius turbine; (a) conventional savonius turbines; (b) multiple layer 90°; (c) multiple layer 115°; (d) multiple layer 135°

3.2 The Influence of multiple layers with a size of 90° at positions 0° and 30°

Figure 6.a and 6.b showed that the values of $C_p$ and $C_T$ from the results of the Savonius experiment with 90° multiple layers at positions 0° and 30°. The results showed that $C_p$ was shaped like a parabola, $C_p$ increased by increasing TSR to reach maximum $C_p$ and then decreases with increasing TSR. In contrast to $C_T$ which tends to decreased with increasing the TSR. Turbines with the best results were variations of multiple layer 90° combined with position parameters that changed to 0° and 30°. The best $C_p$ was obtained by the turbine with multiple layers 90° at position 0° which is 0.120. In a turbine with multiple layers 90° at position 30° it obtain $C_p$ 0.104 at TSR 0.446. At position 30° increases the power coefficient of 1.9% against conventional Savonius. This variation can increase $C_p$ is relatively small because the multiple layers did not perfectly flowing fluid and the moment of inertia was smaller than the position 0° (figure 7), because multiple layer masses were in between of the
advancing blade tip and the turbine root, so the turbine could not swing maximally when spinning.

Figure 6. (a) Graph of the relationship $C_p$ with TSR at multiple layers variations 90° at position 0°  
(b) Graph of relationship $C_T$ with TSR at multiple layers variations 90° at position 30°

Figure 7. Fluid flow direction to the Savonius turbine with multiple layer 90° and position 30°

4. Conclusion
In order to improve the performance of the Savonius wind turbine, an experimental study had been carried out on the Savonius turbine with addition variation of multiple layer 90°, 115°, 135° and at positions 0° and 30°. The results showed that the Savonius turbine with 90° multiple layer variations at position 0° obtaining the best results. In these variations $C_p$ the Savonius turbine increased by 17.6% compared to conventional Savonius turbines. The addition of variations in the size and the appropriate position of the multiple layers can be produced a maximum fluid flow and a high moment of inertia, so able to increase the positive torque on the Savonius turbine.

5. Acknowledgment
The research is supported by Universitas Sebelas Maret Surakarta through PNBP research grant (PU UNS), T.A. 2018, No: 516/UN27.21/PP/2019.

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