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Mekanika: Majalah Ilmiah Mekanika

Effect Of Turbine Blades Transformation on Savonius Turbine Performance

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Abstract
This study aimed to determine the effect of the transformation of Savonius turbine blades based on the Coefficient of Performance (C_p)-Tip Speed Ratio (TSR) curve. The transformation referred to here is the change in the blade angle so that the area of the cross-section of the returning blade is changed. Therefore, the opposing torque of the turbine obtained from the airflow is reduced. The specimen has three variations, without transformation or conventional turbine, the transformation of 5°, and transformation of 10°. With the reduction in the cross-sectional area of the returning turbine blade, it is expected that the turbine performance will increase. Experiments were carried out using wind tunnels with load variations at an air speed of 5, 6, and 7 m/s. The experimental result shows that the blade transformation movement causes a shift in the center of mass, increasing the turbine vibration that directly affects turbine performance. The negative effect from the vibration is greater than the positive effect caused by reducing negative torque. The experimental results show that conventional turbines have better performance than turbines with 5° and 10° blade transformations.

1 Introduction

With Indonesia's population being the 5th most populous country globally and still growing, Indonesia requires tremendous energy [1-4]. Until now, the input from power plants is still dominated by fossil energy (95.57%), and the remaining (4.43%) is renewable energy [5]. Considering the supply of fossil energy is limited and the effect of pollution on the environment [6], before all fossil energy runs out, further development is needed to be related to renewable energy.

Wind energy is a renewable energy that is freely available in nature, does not pollute the environment, can be used efficiently, and is predicted to overtake fossil energy [7-10]. One of the many ways to utilize wind energy is using the wind to rotate generators with the help of turbines. Small-scale power plants have grown more rapidly because they can function as independent power plants in hard-to-reach areas [11-14].

One type of turbine that is widely used is the Savonius turbine. Its relatively simple shape and relatively low performance have made this type of turbine researched by many people. Although very popular, the Savonius wind turbine has pretty low performance compared to the other wind turbine types. Savonius turbine rotates due to differences in drag forces in the turbine blades, namely positive drag force, which occurs on the advancing and opposing drag force, which appears on the returning blade. These drag forces create positive torque and negative torque, respectively. To increase the performance of the Savonius

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wind turbine, the net operating torque should be increased. In this study, the projected area of the returning blade is designed to be automatically reduced by adding hinges on the part of the blade.

The wind turbine performance is visualized with the C_p-TSR graph. The Coefficient of Performance (C_p) is the ratio of the energy captured by the turbine over the energy present in the fluid flow. The Tip Speed Ratio (TSR) is the ratio of the tangential velocity of the blade's tip over the velocity of the fluid flow. The equation of C_p and TSR can be written as follows (see Equation 1).

$$C_p = \frac{P_t}{P_a} = \frac{P_t}{\frac{1}{2}\rho\, A\, V^3} = \frac{T\,\omega}{\frac{1}{2}\rho\, A\, V^3} \tag{1}$$

$$\text{TSR} = \lambda = \frac{V_{rotor}}{V} = \frac{\omega . r}{V}$$

Where:

P_t = Energy captured by turbine (W)

P_a = Energi present in the fluid flow (W)

T = Torque (Nm)

ω = Rotational speed (rad/s)

r = Turbine radius (m)

2 Methodology

This study used an experimental approach using a low-speed wind tunnel. The turbine specimens are made from Polylactic Acid (PLA) 3D printed and aluminum plate material (Figure 1). The turbine blades have transformation variations of 0°, 5°, and 10°. This turbine was designed based on the previous research, which has a 120° blade angle (Figure 2) [5], three-bladed [15], and endplates [16]. The turbine torque and rotational speed are measured using the prony-brake system and tachometer.

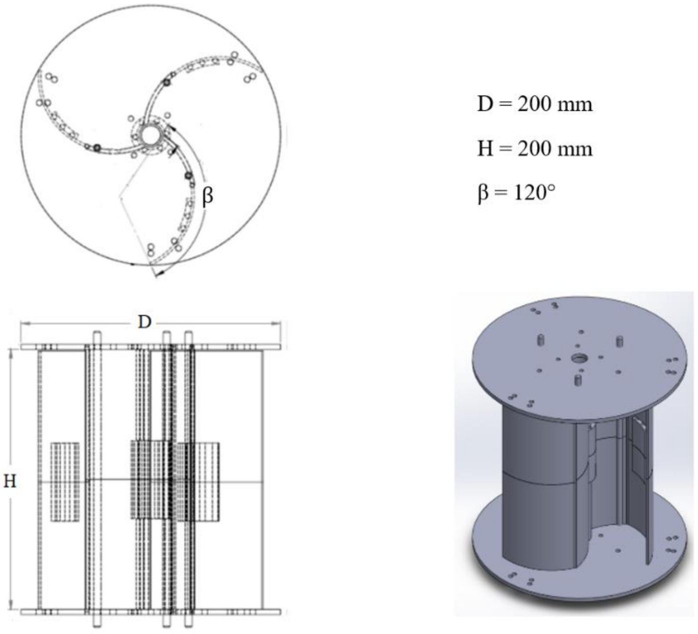

Figure 1. The specimen used in the experiment

This experiment uses wind speed variations of 5, 6, and 7 m/s with load variations of 25, 50, and 75 grams for wind speeds of 5 m/s; 25, 50, and 100 grams for wind speeds of 6 m/s; 50, 100, and 150 grams for a wind speed of 7 m/s. The turbine is measured after rotating for at least 30 seconds. The torque and rotational speed are measured five times at intervals of 10 seconds and then averaged. Hinges are put on the blades to transform the blades when in the returning position (Figure 2).

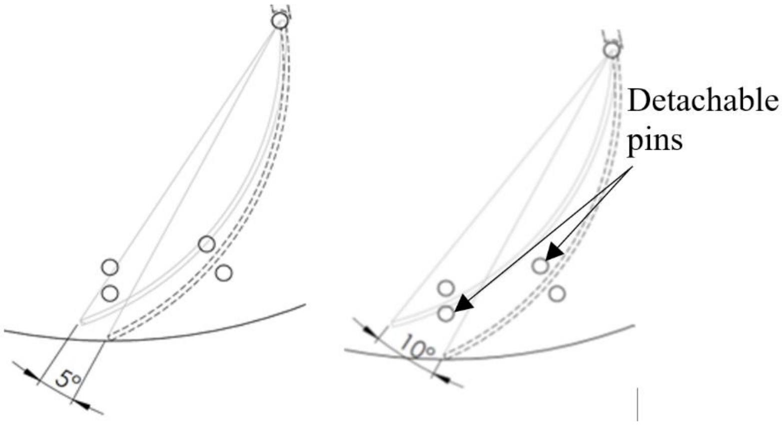

Figure 2. Visualization of blade transformation

3 Results and Discussion

The turbine's performance obtained in this study is presented in the graph as shown in Figure 3. From Figure 3, it can be seen that the C_p of 0° variation has a maximum C_p of around 0.039, higher than the 5° and 10° variations, which have a maximum C_p of around 0.036. The C_p of 5° variation is over the 10° variation at TSR <1, and vice versa at TSR> 1.

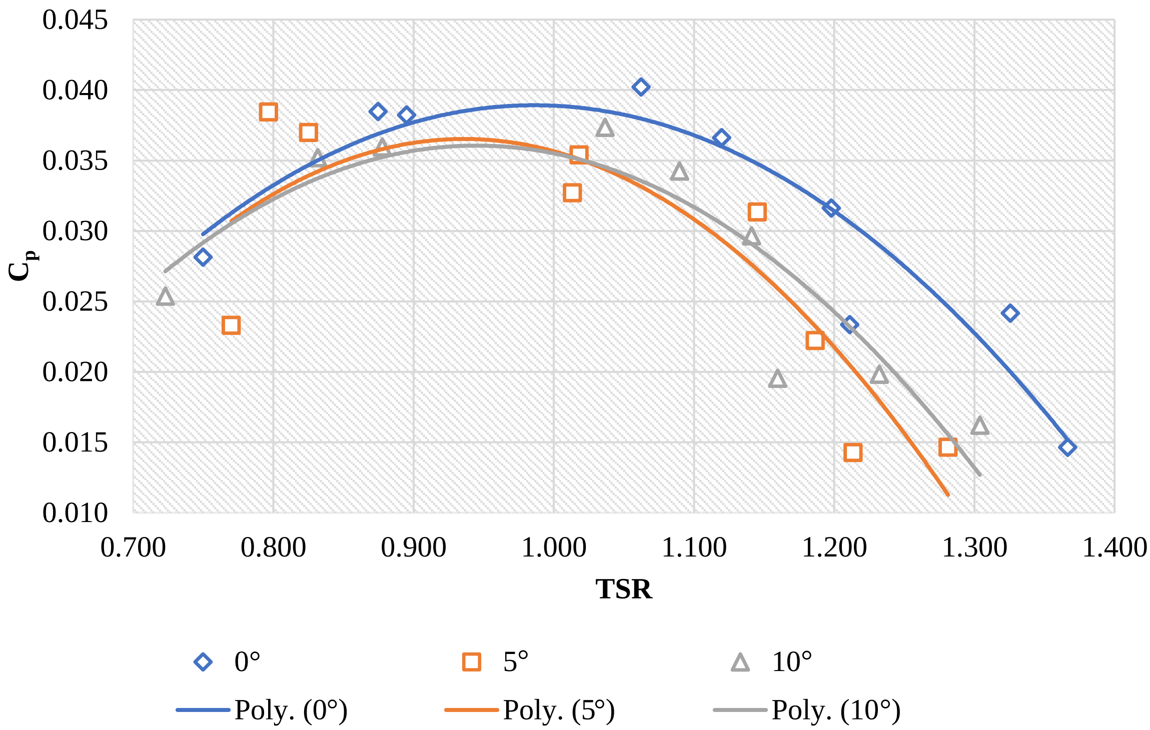

Figure 3. C_p – TSR graph

It is found that the blade transformation causes the center of mass of the turbine to shift periodically and makes vibrations which result in instability, causes friction, and reduces turbine performance. The placement of the pins (stoppers) also affects turbine performance. The momentum in the moving and stopping blades due to hitting the stoppers occurs on the turbine and creates negative torque, reducing turbine performance. This condition is visualized in Figures 4 and 5 which it can be seen that the force flow from the momentum has a distance from the center of rotation which creates negative torque and reduces turbine performance.

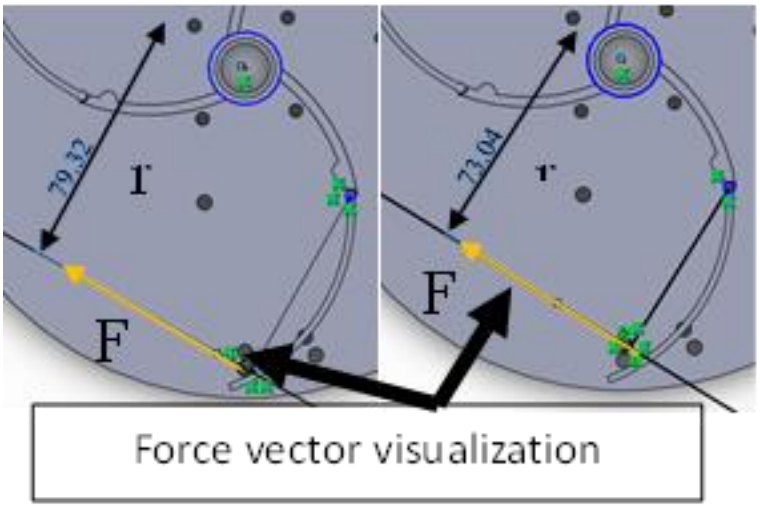

Figure 4. Force's vector visualization

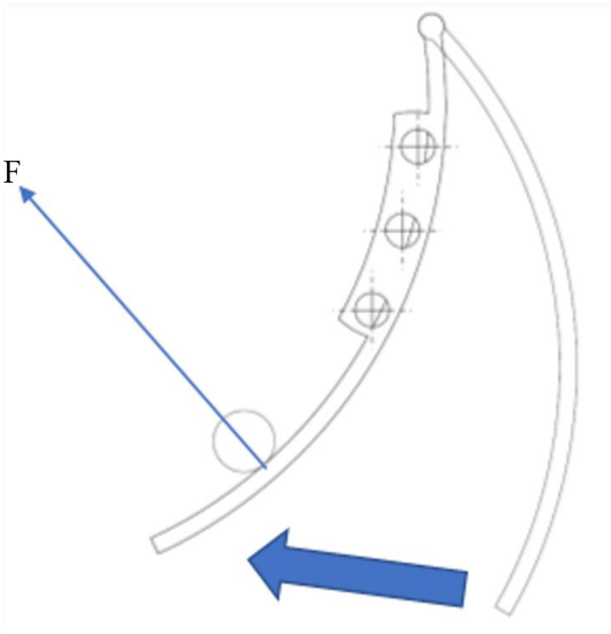

Figure 5. Impact Force generation

4 Conclusions

Based on data and results analysis regarding the effect of turbine blade transformation on the Savonius turbine, several conclusions are obtained as follows:

1. The transformation of the blade on the Savonius blade affects the turbine's performance.
2. The conventional Savonius turbine performs better than the 5° and 10° blade transformation turbines.
3. The blade transformation cannot improve the turbine’s performance due to vibrations from shifting the turbine’s center of mass due to blade transformation and temporary negative torque from the blade's momentum hitting the stopper.

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