THE EFFECT OF BLADE CURVATURE ANGLE OF SAVONIUS WIND TURBINE L-TYPE ON THE PERFORMANCE

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ABSTRACT: The wind is a renewable energy source (alternative energy) as a substitute for the dwindling fossil fuel. L-type Savonius wind turbine is a technology that is widely used to convert wind energy into mechanical because its construction is simple and cheap. The disadvantage of this turbine is having a lower efficiency than other types of wind turbines. Modification of the curvature of the L-type Savonius wind turbine blade is assumed can improve its performance because it affects the direction and magnitude of wind and wheel velocity, consequence impact to power. Thus, the blade angle is interesting to review. There are three angles of blade studied: 30º, 45º, and 60º. Based on results, the blade angle influences the performance of the L-type Savonius wind turbine, where the 45º blade angle produced better performance than 30º and 60º.

1. INTRODUCTION

The wind is a renewable source that can be used as a substitute for fossil fuels [1]. Wind turbines are a technology used to convert wind energy into mechanical energy [2][3]. The wind turbine that is widely used is the L-type Savonius turbine because it has good self-starting capabilities and can operating at low wind speed (<3 m / s). The operating conditions of the L-type Savonius turbine match the characteristics of wind energy in Indonesia, which is an average of 5 m/s [4]. Furthermore, The Savonius wind turbine has a simple shape so the investment costs are cheap, easy to manufacture, and do not depend on the wind direction [5][6][7][8].

Due to the abundant potential of wind energy in Indonesia, the downstream wind turbine as an independent power plant continues to be studied. Soelaiman, et.al. (2006) [9] concluded that the L-type blade of the Savonius wind turbine has a better performance than the U-type blade. Mahendra, et.al. (2012) [10] concluded that the performance of the 3 blades type-L Savonius turbine produced higher performance than 2 blades. Ully, et.al. (2017) [11] studied the effect of guide vane on the performance of L-type Savonius turbines and concluded that the guide vane has a positive effect on its performance. This is alleged because the wind velocity vector directed to the blade is converted maximally [11].

The disadvantage of the L-type Savonius wind turbine is its performance lower than other types (Darrius, propeller, multiblade, etc.) because of the low torque and rotation generated [7]. This stimulated Bachtiar (2019) [7] to conducted the configuration of the L-type Savonius turbine overlap size. He allegedly the wind that hit the inactive blade through the overlap significantly improved his performance [7], which is believed to be an optimum size for overlap. Feasibility of aluminum as a blade material carried out by Wijiyanti and Saparin (2019) [12]. They studied the effect of using aluminum on the tip speed ratio and concluded that the aluminum runner produced an average TSR of 2 [12], where this value is higher than the graphical dependency TSR with a power coefficient (CP) of 1.5. To increase the torque, the blade angle is a possible alternative. Since the blade configuration affects the direction of the runner velocity so that it affects the torque, the consequence is to power. Thus, the blade angle of the L-type Savonius wind turbine is proposed to be studied.

2. METHOD

2.1. Performance Analysis

Wind energy potential is a function of the density (ρ), areas (A), and wind speed (V), represented in Eq. 1:

$$P_W = \frac{1}{2} \cdot \rho \cdot A \cdot V^3 \tag{1}$$

The measured power is mechanical power (P_T), where its function of torque (τ) and angular velocity (ω), represented in Eq. 2:

$$P_T = \tau \cdot \omega \tag{2}$$

The torque is measured using a Prony-brake system (see Fig. 1).
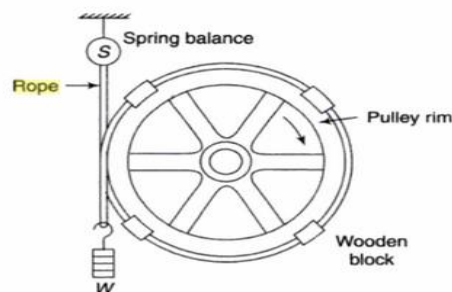

Fig. 1. Schematic of Prony-brake system [13][14]

The principle of the Prony-brake is loading (F_1), the F_1 from 10 gr to 80 gr. Furthermore, friction from the belt with the pulley and (F_1 is accumulated in the spring balance (F_2). From Fig. 2, analysis for torque becomes:

$$\tau = (F_2 - F_1) \cdot r_{pulley} \tag{3}$$

where r_{pulley} is pulley radius. Whereas, the ω is measured using a tachometer. The tachometer is measured wheel rotation (n). The n converts to the ω using Eq. 4:

$$\omega = \frac{2 \cdot \pi \cdot n}{60} \tag{4}$$

Turbine performance or power coefficient (C_P) is a function of P_T and P_W:

$$C_p = \frac{P_T}{P_W} \cdot 100\% \tag{5}$$

TSR is the ratio between the runner velocity (U) with V, represented in Eq. 6:

$$\text{TSR} = \frac{U}{V} \qquad (6)$$

2.2. L-type Savonius Wind Turbine Configuration

The L-type Savonius rotor wind turbine (Fig. 1) is a development of the rotor model were it dominantly. absorbs the drag force from the wind [15].

Fig. 2. Schematic of L-type Savonius wind turbine blade

The L-type Savonius turbine model tested has a height of 0.3 m, a width of 0.4 m, blade number is three, runner material is aluminum, and blade angle variation: 30º, 45º, and 60º.
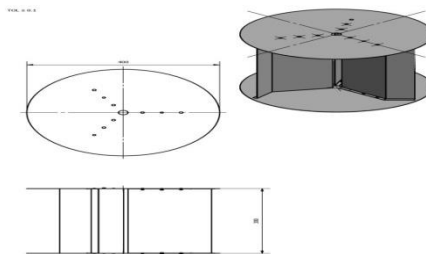

Fig. 3. Dimensions of the L-type Savonius Wind Turbine

3.　RESULTS AND DISCUSSION

Tables 1, 2, and 3 are the results of the runner tests with blade angles of 30, 45, and 60, respectively. From Tables 1, 2, and 3, the Savonius-L wind turbine that produces the most torque is a curvature angle of 45°. Each loading until the turbine stops, the torque produced by the 45° Savonius-L wind turbine is the highest compared to 30° and 60°. The Savonius-L 45° wind turbine produces the highest power of 0.295 W (3.27 % η), while the Savonius-L 30° produces a power of 0.270 W (3.02 % η) and the Savonius-L 60° is 0.260 W (2.87% η).

Tabel 1. The test results of 30° blade angle

n (rpm)	ω (rad/s)	F_1 (N)	F_2 (N)	ΔF (N)	τ (N·m)	P_T (W)	C_P (%)
112	11.72	0	0	0	0	0	0
75	7.85	0.098	1.079	0.981	0.0343	0.270	2.99
63	6.59	0.196	1.373	1.177	0.0412	0.272	3.019
50	5.23	0.294	1.570	1.275	0.0446	0.234	2.595
46	4.81	0.392	1.766	1.373	0.0481	0.231	2.572
32	3.35	0.491	1.913	1.422	0.0498	0.167	1.853
26.9	2.82	0.589	2.085	1.496	0.0524	0.147	1.638
13	1.36	0.687	2.183	1.496	0.0524	0.071	0.792
0	0.00	0.736	2.354	1.619	0.0567	0	0

Barlin et al.

Tabel 2. The test results of 45° blade angle

n (rpm)	ω (rad/s)	F_1 (N)	F_2 (N)	ΔF (N)	τ (N·m)	P_T (W)	C_P (%)
130	13.607	0	0	0	0	0	0
82	8.583	0.098	1.079	0.981	0.034	0.295	3.274
63	6.594	0.196	1.472	1.275	0.045	0.294	3.270
49	5.129	0.294	1.888	1.594	0.056	0.286	3.179
41	4.291	0.392	2.036	1.643	0.058	0.247	2.742
27	2.826	0.491	2.183	1.692	0.059	0.167	1.860
23	2.407	0.589	2.256	1.668	0.058	0.141	1.561
16	1.675	0.687	2.354	1.668	0.058	0.098	1.086
0	0.000	0.785	2.403	1.619	0.057	0	0

Tabel 3. The test results of 60° blade angle

n (rpm)	ω (rad/s)	F_1 (N)	F_2 (N)	ΔF (N)	τ (N·m)	P_T (W)	C_P (%)
101	10.571	0	0	0	0	0	0
58	6.071	0.098	1.128	1.030	0.036	0.219	2.432
49	5.129	0.196	1.643	1.447	0.051	0.260	2.886
41	4.291	0.294	1.717	1.422	0.050	0.214	2.374
29	3.035	0.392	1.766	1.373	0.048	0.146	1.621
29	3.035	0.441	1.790	1.349	0.047	0.143	1.592
21	2.198	0.491	1.815	1.324	0.046	0.102	1.132
15	1.570	0.540	1.839	1.300	0.045	0.071	0.794
0	0.000	0.589	1.937	1.349	0.047	0	0

The curvature angle causes the blade length to be different so that the performance is different. The difference in blade length affects the blade profile (areas), consequence, runner rotation is different. In the Savonius-L turbine 45 °, the area that receives wind and holds the wind is not too wide or too small so that the wind flow is more optimal on the turbine blades. Whereas on a curvature angle of 30 °, the blade profile that is perpendicular becomes a barrier when it is against the direction of the wind flow (increased drag). For a curvature angle of 60 °, the large blade curvature causes the wind flow to be obstructed (a drag) thereby reducing the rotation speed of the runner.

4. CONCLUSION

Based on the results, the curvature angle 45º is the right recommendation for the Savonius-L wind turbine where it produces higher turbine power than the curvature angle of 30º and 60º, namely 0.295 W (3.27% ŋ) with a torque of 0.059 Nm, and ω of 8.58 rad/s.

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Barlin et al.

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