

Performance Investigation of Cylinder Rotation Against the Performance of Savonius Turbine for X/D of 0.25

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Abstract—Cylinder rotation accelerates the flow on the side near the advancing region by strengthening the reattached flow zone. This is expected to increase positive torque, thereby improving the power output of the Savonius turbine. This work was carried out experimentally by adding cylinders in the advancing area. The experimental study was performed in the exit wind tunnel, with the wind speed kept constant at 7 m/s. The model has a height of and a diameter of 40 cm, and the cylinder rotated at 10, 20, and 30 rpm. The distance between the cylinder and the turbine shaft along the Y-axis was 40 cm, and along the X-axis was 10 cm. This work aims to determine the torque coefficient and power coefficient by varying the cylinder rotation. The best performance results were obtained at 30 rpm, with an increase of 26.18% compared to without a cylinder.

Keywords—Savonius, Cylinder, Advancing, Rotation, Performance.

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I. INTRODUCTION

Numerous turbine design contributions have been extensively researched for performance improvement through numerical and experimental studies, such as the use of barriers, changing the shape blade and number of blades. The installation of barriers in the advancing and returning areas has proven to increase turbine performance. Variations in the overlap ratio and the original blade have been studied using a set of two deflector plates placed in the side of advancing and returning areas with a Re of 1.32×10^5 . This study produced the largest C_p of 0.35 for TSR or $\lambda=1.08$ [1]. The impact of the deflector location was investigated showing an optimal configuration have the best power coefficient improvement by 34% [2]. Deflector could

improve up to 133% in C_p with a square formation [3]. The study was compared a standard Savonius increasing the power coefficient by almost 40% is finally obtained at $\lambda = 0.7$ [4]. The performance enhances exceeds 30% [5]. Plate deflector can enhance the efficiency significantly [6].

The combination of two-blade turbines can improve the performance of Savonius using circular and elliptical contours with the highest C_p value increase of 11% [7]. Savonius performance investigations have been conducted experimentally by looking at the bucket and overlap model parameters. The results show the best Savonius performance in the overlap range of 0.1 - 0.15 [8]. This overlap is continued with a numerical study by producing the biggest torque at an overlap of 0.2. The contribution of the Myring equation in efforts to improve performance has been proven experimentally and numerically by producing the highest C_p at $n = 1$ [9-13]. Savonius blocked by a deflector indicates an increase in its performance [14-16]. The placement of the cylinder has been investigated by varying the stagger at the returning area, which indicates that a 60° stagger is able to increase turbine performance, but when positioned directly upstream of the turbine center, it has a negative impact by reducing performance [17].

The flow pattern along the Savonius with the cylinder positioned on the upstream side again has indicated maximum performance at a stagger angle of 60°. Indications of increased pressure in the front area and decreased pressure in the forward area of the rear side were observed with CFD. Stagger 0° in front of the Savonius (right in the center of the turbine) has an impact on flow blockage, so that performance decreases [18]. Performance improvement is also proven by a cylinder placement on the rear blade of around 12.2%, TSR = 0.65, at $S/D = 1.4$ [19].

The cylinder rotation contribution has been

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investigated experimentally and numerically [20]. Turbine rotation can positively influence flow acceleration near the advancing blade, thereby strengthening the reattached flow region and increasing positive torque. This results in higher turbine power output. Turbine rotation is also applied in this paper, where the effect of rotation on Savonius performance will be investigated at the cylinder position ($X/D=0.25$). This work aims to obtain C_t and C_p values. The study investigated C_t and C_p values experimentally using $d_s/D = 0.5$ by varying cylinder rotation at 0, 10 rpm, 20 rpm, and 30 rpm.

II. METHOD

A. Experimental Study

An experimental study was conducted to investigate the Savonius performance subjected to flow disturbance in the advancing region by a rotating cylinder. A detailed illustration of the experiment will demonstrate the process of converting wind energy to rotate the Savonius turbine.

The experimental scheme uses a blower to direct wind into a Savonius wind turbine model. The wind is directed into the model using a wind tunnel with an exit size of 30 cm x 30 cm. The wind flow is uniformed using a honeycomb. An anemometer is used for this experimental as represented in Figure 1.

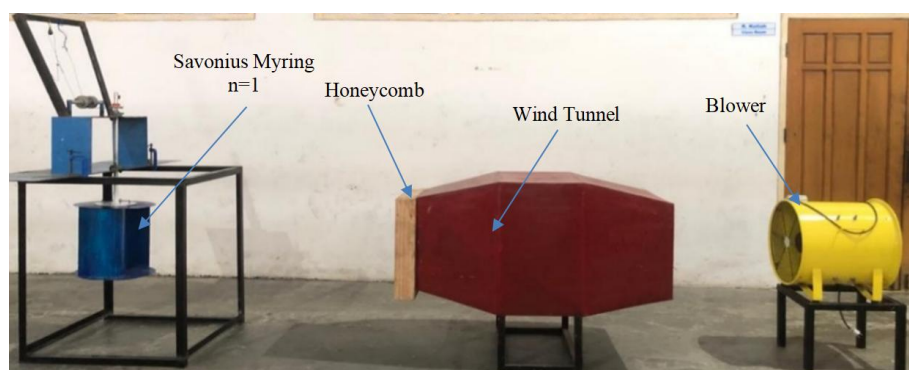


Figure 1. Experimental Scheme

B. Savonius Turbine and Cylinder Position

The performance study of the Savonius turbine in Figure 2 used a turbine model measuring 40 m high and

40 m in diameter. The turbine was mounted using a vertical shaft. A pulley was attached to the turbine shaft to generate torque, as shown in Figure 3.

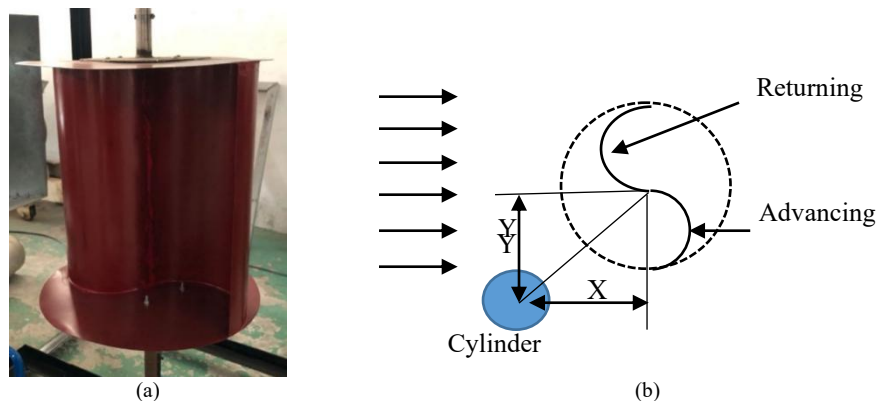


Figure 2. (a) Savonius and (b) cylinder position from turbine

TABLE 1.
SIZE OF SAVONIUS WIND TURBINE

Symbol	Parameters	Value	Unit
D	Diameter of Savonius	400	mm
d	Diameter of Blade	200	mm
H	Height of Turbine	400	mm
t	thickness	1	mm

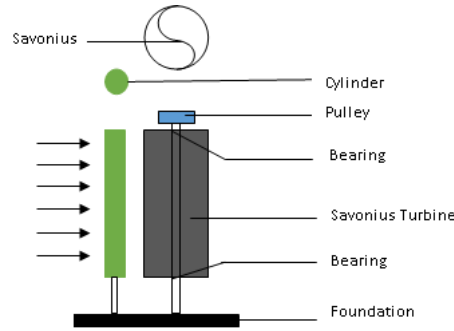


Figure 3. Torque Measurement Scheme

C. Taking Data for Experimental Study

Experimental data were collected using measuring equipment such as a tachometer and anemometer. The tachometer is used to record Savonius rotation data, while the anemometer measures the wind speed passing

through the Savonius turbine. This equipment will be explained in detail below.

The turbine rotation resulting from the wind speed conversion is measured using a digital tachometer. The tachometer used is a laser type, as shown in Figure 4.



Figure 4. Tachometer

D. Parameters

The performance of Savonius are called power coefficients. The TSR equation is called the Tip Speed Ratio (λ), which is obtained from the Savonius rotation as in equation (1). Turbine rotation is useful for finding the torque, which is then used to calculate coefficient of torque (C_T) as shown in equations (2) and (3). The power coefficient (C_p) is obtained from the multiplication of λ and the torque coefficient, which can be seen in equation (4);

$$\lambda = \frac{\omega \cdot D}{2 \cdot U} \quad (1)$$

$$T = (M - S) \cdot \left(\frac{d_p + d_n}{2} \right) \quad (2)$$

$$C_T = \frac{T}{T_f} \quad (3)$$

$$C_p = \lambda \cdot C_T \quad (4)$$

Angular speed is mentioned ω , the free stream velocity is denoted by U , the Savonius diameter is denoted by D , coefficient of power is denoted by C_p , and the torque coefficient is denoted by C_T .

III. RESULTS AND DISCUSSION

The graph of torque coefficient against λ is shown as in Figure 5. The graph discusses the influence of cylinder rotation on the performance of the Savonius at variations in cylinder rotation of 10 rpm, 20 rpm, and 30 rpm compared to without a cylinder. The curve trends indicate that the behavior of the rotated cylinder impacts performance improvement. Increasing cylinder rotation results in an increase in the Savonius torque coefficient. All curves show a decreasing torque coefficient with increasing λ . Furthermore, it can be seen that a lower λ value results in a higher torque coefficient. This occurs because increasing the load on the turbine causes the turbine rotational speed to decrease, followed by a corresponding decrease in the λ value.

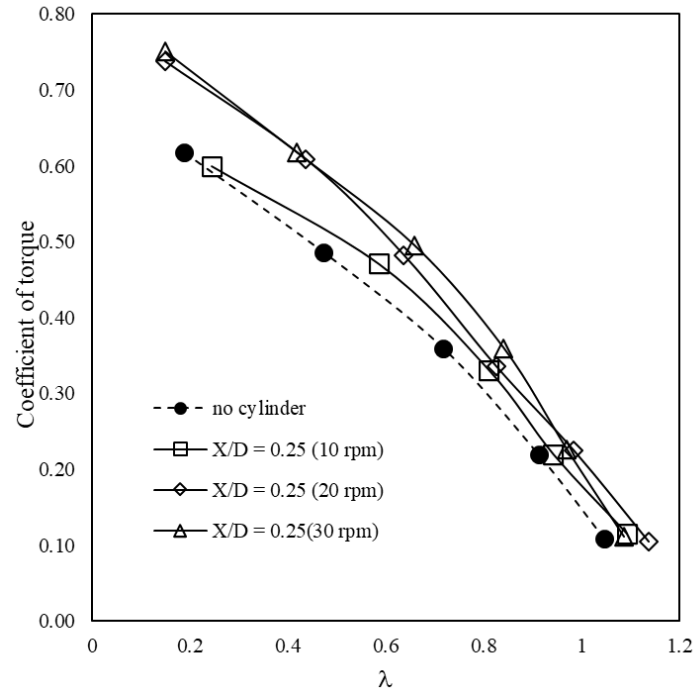


Figure 5. C_t versus λ by varying the cylinder rotation

The C_p graph against λ by varying the cylinder rotation of 10 rpm, 20 rpm, and 30 rpm is presented as in Figure 6. The contribution of the cylinder rotation at a position next to the advancing area at the $X/D=0.25$ position to the C_p value has been proven by the increasing C_p value, which is called Savonius

performance. Savonius performance increases with the addition of cylinder rotation at 10 rpm, 20 rpm, and 30 rpm. The percentage increase in the C_p value by varying the cylinder rotation at $X/D = 0.25$ can be seen in Table 1.

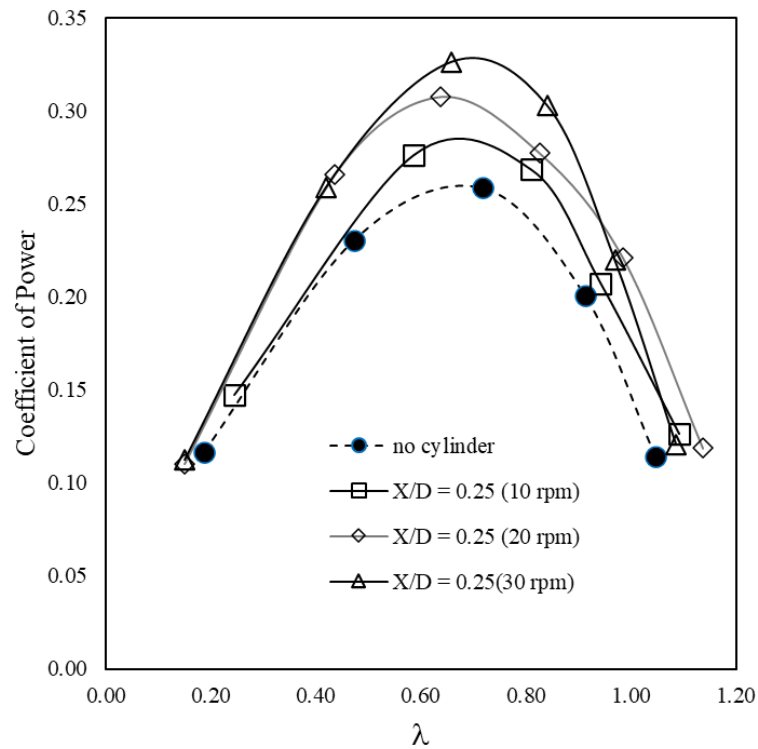


Figure 6. C_p versus λ by varying the cylinder rotation

TABLE 2.
IMPROVEMENT OF THE PERFORMANCE

Variables	λ	C_p	Improvement (%)	Result
No cylinder	0.7184	0.259	-	-
X/D = 0.25 (10 rpm)	0.5867	0.276	6.87	Increase
X/D = 0.25 (20 rpm)	0.6376	0.307	18.88	Increase
X/D = 0.25 (30 rpm)	0.6585	0.326	26.18	Increase

The Savonius performance improvement in Table 1 increases with increasing cylinder speed. A cylinder speed of 10 rpm produces a C_p value of 0.276 with a performance increase of 6.87%. A cylinder speed of 20 rpm produces a C_p value of 0.307 with a performance increase of 18.88%. Meanwhile, increasing the cylinder speed again to 30 rpm proves that the Savonius turbine performance increases by 26.18%.

IV. CONCLUSION

The cylinder is placed in the advancing area with a ds/D of 0.5 and a placement position at $X/D = 0.25$. Varying the cylinder rotation at 10, 20, and 30 RPM with a wind speed of 7 m/s kept constant shows that the higher the cylinder rotation of the circular cylinder installed on the advancing blade. It will improve the C_p , and the largest C_p value occurs at a cylinder rotation of 30 rpm, a C_p value of 0.326 when $\lambda = 0.6585$, and the increase was around 26.18%.

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