Blade Modification and Performance Analysis of Micro Savonius Rotor

Yasir Ali, Khawaja Haider Ali, Aftab Ahmed, Ahmad Waqas and Qasir Ali

***Abstract* – The increasing need for energy and bad impacts of conventional sources of energy on the environment, especially in Pakistan, has shown to the quest for sustainable, environment-friendly and clean energy resource. Wind energy can be the best option in this regard. Savonius rotor is simple vertical axis wind turbine which is illustrated as economical, simplistic in design and construction and has satisfying starting torque at lower wind speeds. This makes it capable of generating mechanical energy at low wind speed.**

In the present work improvement in the construction of conventional Savonius blade was suggested to discover the best configuration of Savonius blade design. Flatness in the Savonius blade originating from the shaft of the rotor was proposed in four steps i.e. 25%, 50%, 75%, and 100% flatness. Above four blade configurations were designed, manufactured and tested. The performance of four configurations of the blade was investigated and then compared with the conventional form of Savonius blade (model-1). According to the observation, the blade configuration with 25%, 50%, and 75% flatness are comparable with the conventional Savonius configuration, whereas the blade configuration with 100% flatness contributes unoptimistic performance. The blade configuration with 50% flatness is more effective than the conventional Savonius configuration which gives 74% optimum increase with its performance.

***Index Terms* – Blade flatness, Configuration, Renewable energy, Wind energy, Savonius rotor.**

I. INTRODUCTION

The world is moving towards the clean energy and in clean energy resources; the wind is the most suitable energy. The fundamental part of a wind turbine is wind rotor. The wind turbine is classified into two main categories namely, horizontal axis wind turbine HAWT and vertical axis wind turbine VAWT [1]. Both of them have some advantages and disadvantages as well, they also differ in the type of application they are used. The HAWT are more efficient and generally have high performance at high wind speeds, but they are poor to work where there is turbulence in wind i-e (they don't perform well which is VAWT in design performs well in the direction of the wind. Savonius rotor is one form of the vertical axis turbines. It is straightforward in layout, has acceptable starting attributes, comparably low running speeds, and capability to capture the wind from all directions [1-2]. One of the major disadvantages of Savonius rotor is its low efficiency. Over the time, the designs of Savonius rotor have been changing to improve and enhance its efficiency [2].

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Alexander and Holownia [2] found the outcome of aspect ratio, overlap and gap of the blade and also the effect of adding end extensions, end plates, and shielding. The various Savonius rotor geometries were tested in the tunnel at wind velocity from 6 to 9 m/s. They find out that the rotor performance increases with increase in blade aspect ratio. They also find out that 3 and 4 bladed geometries give lower efficiency than two-bladed rotors. The efficiency also increases with increase in the extensions. Modi et al. [3] also estimated that the rotor with an end plate and shielding operate well than that of without end plates and without shielding.

Various researchers have made research on geometries of Savonius wind rotor to find out the best configuration. In this regard, Akwa et al. [4] concluded flow parameter also affects the performance of Savonius rotor and turbine geometry. Saha et al. [5-6] find out that the adding the number of blades to Savonius rotor decrease its performance, they also find the effects of adding rotor stages and concluded that the best configuration is two-stage rotor and increasing the number of stages decrease its efficiency due to the rotor's inertia. Another analyst, Kamoji et al [7] find out that Cp lean down is due to the increment of a number of rotor stages.

The kind of wind exploiting that Savonius turbine can generate efficiently is called small wind and is a fundamental factor of the solution to global warming. Small wind energy generation is now one of the rapidly expanding forms of domestic and residential electricity generation and is a great venture for landlords and small business owners.

The Savonius blade has been used as resistance type blade since long several modifications have been proposed by various researchers to improve its performance under various environmental and application conditions. In present study modification of conventional design Savonius blade have been proposed and analyzed to search possible alternate between Savonius and Sistan application conditions. In present study modification of conventional design Savonius blade have been proposed and analyzed to search possible alternate between Savonius and Sistan [8].

II. MATERIALS AND METHODS

There is a number of steps to enhance the output rotational speed or power coefficient of a turbine, such as constructing the optimal geometry of the rotor or by picking the finest rotor blade design. In this paper, for the advancement of the output rotational velocity of the turbine, different blade designs have been proposed and tested. By evaluating the performance of the rotors with different blade designs, various results obtained. Experimental analysis was conducted in the material testing laboratory of QUEST Nawabshah. For the useful execution of the experiments, it

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was vital to use an open subsonic tunnel, which can achieve velocities of air masses from 01 to 09 m/s [9].

Following mechanical processes were selected to manufacture and achieve final shape of models within given dimensions.

Cutting, Facing, Turning, Boring, Drilling, Grinding, Welding, Riveting, and nut bolting, Bending. The material used for making blades of the rotor was Aluminum sheets with 2 mm thickness. No vents were produced on blade profiles to reduce negative torque, hence model used in this study is non-vented. Several attempts have been made to optimize a number of blades and power of Savonius rotor. This study focuses on rotation of semicircular non-vented blades with varying flatness in blades profile [10].

III. DIMENSIONS AND DESIGN OF ROTOR MODELS

The conventional Savonius three-bladed rotor has been modified by introducing a flatness percent in the profile of the blade. Subsonic open type wind tunnel was used for testing of blades. Aspect ratio was 0.33 and height of wind tunnel was 30 cm along with 24 cm width.

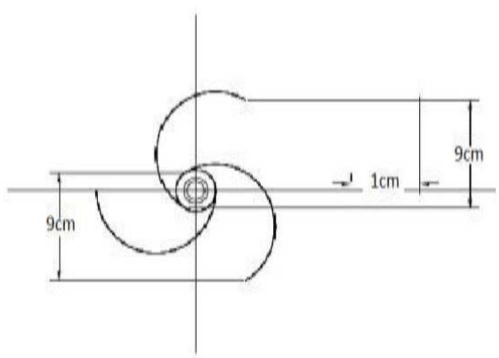

Fig. 1 Shows the conventional Savonius rotor.

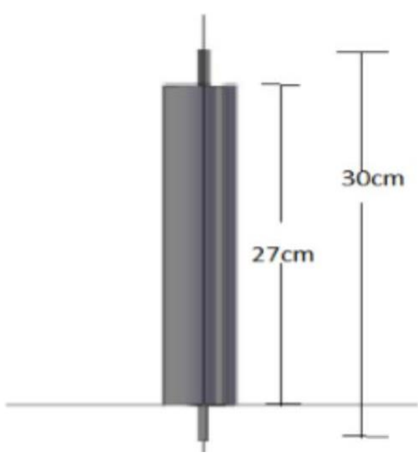

Fig 2 Represents the 3D Model of the conventional Savonius rotor.

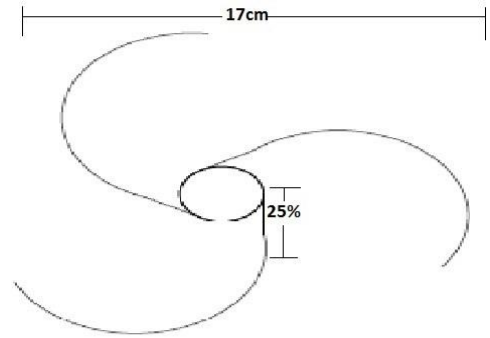

Fig 3 Model S1 with 25% flatness.

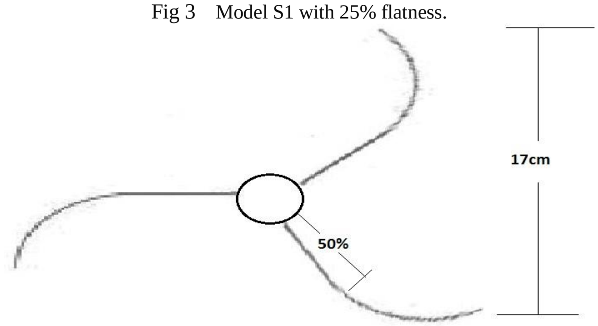

Fig. 4 Model S2 with 50% flatness.

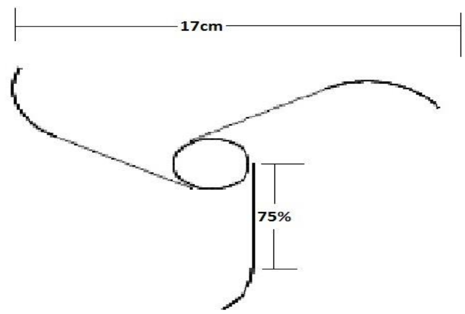

Fig. 5 Model S3 with 75% flatness

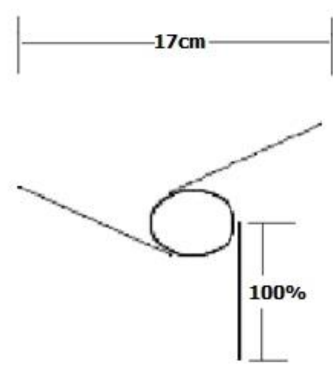

Fig. 6 Model Sistan with 100% flatness.

IV. TESTING METHODOLOGY

Many researchers have worked on the relationship between wind velocity and flatness of blades using controlled and free conditions. Some authors have compared

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the experimental and simulation results as well. Wind turbines should be designed in such a way that maximum output can be obtained [11].

The trial was conducted at various wind velocities between 1 to 9 m/s, the achievement of each model in terms of rotational speed at various wind velocities was investigated and compared to know the best rotor configuration and data were recorded at room temperature. The required data was measured by several digital instruments. The photo Photo-contact Tachometer was preferred to measure rotational velocity of the blade. The wind velocity (V) was measured using the digital Hot-wire Anemometer. The anemometer vane was fixed and stiffened in the subsonic wind tunnel - trial section between the straightened and the examining Savonius turbine [12].

Blockage correction is a technique to avoid any disturbance to wind tunnel air before passing over blades. Blockage effect must be taken into account before experimenting with any blade design. Blockage correction factor depends on the category of the wind tunnel, test section and blockage ratio. The relation between blockage correction and wind tunnel experiments of Savonius is given below [13, 14].

$$V^{\circ} = V\left(1 - \frac{1}{5}f\right) \quad (1)$$
$$F^{\circ} = F(1 - f) \quad (2)$$
$$N^{\circ} = N(1 - f) \quad (3)$$

Where f is blockage correction factor, V is wind speed, F is mechanical load, and N is rotational speed of the turbine. However, V°, F°, and $N^{\circ}$are blockage corrected values to reduce any blockage effect [14, 15].

V. RESULTS AND DISCUSSION

Five models of VAWT were tested using low-speed subsonic wind tunnel at various wind velocities ranging from 1m/s to 9m/s. Each model was a modified form of Savonius VAWT and was coded as S, S1, S2, S3, and Sistan.

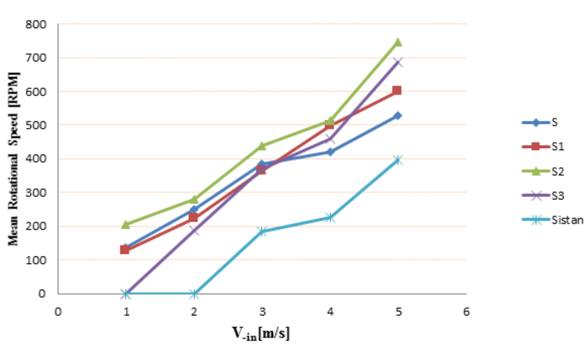

Fig. 7 Comparison between Rotational speed vs Wind speed.

Fig 7. Shows the comparison between all the models in terms of performance regarding rotational speed versus wind speed.

It also reflects the link between rotational velocity and wind speed for all the models of Savonius rotor proposed in this study.

According to the observation, It can be noted that at velocity 1m/s, the Savonius and S1 blade produces the same rpm while S3 and Sistan produces zero rpm whereas modified blade S2 produce higher rpm than all others, similarly at velocity 3m/s, 5m/s, and 7m/s, the blades Savonius, S1 and S3 produces nearly same rpm and Sistan produces low rpm while modified blade S2 again produce higher rpm and at 9m/s the modified blades S2 and S3 produces about 700rpm while Sistan, S1, and Savonius fall in the range of 400-600 rpm. So, it was concluded that the performance of modified blade S2 is greater than Savonius blade and all other modifications S1 and S3 in the Savonius blade.

VI. CONCLUSION

Following conclusions can be made from current investigation, analysis, and results of this research work:

i. Modification in the construction of conventional Savonius blade was suggested to devise the best configuration of Savonius blade design.
ii. Flatness in the Savonius blade originating from the shaft of the rotor as proposed in four steps i.e. 25%, 50%, 75%, and 100% flatness.
iii. Above four blade configurations were designed, manufactured and tested.
iv. The performance of four configurations of the blade was investigated and then compared with the conventional form of Savonius blade (model-01).
v. According to the observation, the blade configuration with 25%, 50%, and 75% flatness is comparable with the conventional Savonius configuration, whereas the blade configuration with 100% flatness contributes weaker performance.
vi. The blade configuration with 50% flatness is more effective than the conventional Savonius configuration which gives 74% optimum increase with its performance.

VII. FUTURE RECOMMENDATION

Following work has been recommended for future.

i. This configuration must be tested with other design and performance parameters to be recommended for future application. Semicircular and elliptical are two major blade profile designs to optimize rotor power by varying number of blades, cut angle and flatness of blades.
ii. Modification in the construction of conventional Savonius blade was suggested.
iii. Torque and power coefficient determination is also recommended for future work as it can help in full installation of the wind turbine.
iv. Determining different angles at which maximum torque and power can be achieved.

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REFERENCES

[1] Mahmoud, N. H., El-Haroun, A. A., Wahba, E., & Nasef, M. H. (2012). An experimental study on improvement of Savonius rotor performance. Alexandria Engineering Journal, 51(1), 19-25.
[2] Alexander, A. J., & Holownia, B. P. (1978). Wind tunnel tests on a Savonius rotor. Journal of Wind Engineering and Industrial Aerodynamics, 3(4), 343-351.
[3] Modi, V. J., Roth, N. J., & Fernando, M. S. U. K. (1984). Optimum-configuration studies and prototype design of a wind-energy-operated irrigation system. Journal of Wind Engineering and Industrial Aerodynamics, 16(1), 85-96.
[4] Adriane Prisco, P., Horcio Antonio, V., & Joo Vicente, A. (2012). A review on the performance of Savonius wind turbines. Renewable and Sustainable Energy Reviews.
[5] Saha, U. K., & Rajkumar, M. J. (2006). On the performance analysis of Savonius rotor with twisted blades. Renewable energy, 31(11), 1776-1788.
[6] Saha, U. K., Thotla, S., & Maity, D. (2008). Optimum design configuration of Savonius rotor through wind tunnel experiments. Journal of Wind Engineering and Industrial Aerodynamics, 96(8-9), 1359-1375.
[7] Kamoji, M. A., Kedare, S. B., & Prabhu, S. V. (2011). Experimental investigations on two and three stage modified Savonius rotor. Wind Engineering, 35(4), 483-509.
[8] Mohamed, M. H., Janiga, G., Pap, E., & Thévenin, D. (2011). Optimal blade shape of a modified Savonius turbine using an obstacle shielding the returning blade. Energy Conversion and Management, 52(1), 236-242.
[9] Sheldahl, R. E., Feltz, L. V., & Blackwell, B. F. (1978). Wind tunnel performance data for two-and three-bucket Savonius rotors. Journal of Energy, 2(3), 160-164.
[10] Kacprzak, K., Liskiewicz, G., & Sobczak, K. (2013). Numerical investigation of conventional and modified Savonius wind turbines. Renewable energy, 60, 578-585.
[11] Golecha, K., Eldho, T. I., & Prabhu, S. V. (2011). Influence of the deflector plate on the performance of modified Savonius water turbine. Applied Energy, 88(9), 3207-3217.
[12] Altan, B. D., & Atılgan, M. (2008). An experimental and numerical study on the improvement of the performance of Savonius wind rotor. Energy Conversion and Management, 49(12), 3425-3432.
[13] Chan, C. M., Bai, H. L., & He, D. Q. (2018). Blade shape optimization of the Savonius wind turbine using a genetic algorithm. Applied Energy, 213, 148-157.
[14] Alom, N., & Saha, U. K. (2018). Performance evaluation of vent-augmented elliptical-bladed savonius rotors by numerical simulation and wind tunnel experiments. Energy, 152, 277-290.
[15] Ramadan, A., Yousef, K., Said, M., & Mohamed, M. H. (2018). Shape optimization and experimental validation of a drag vertical axis wind turbine. Energy, 151, 839-853.