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Study of a Savonius Type Wind Turbines for its Aerodynamic Characteristics

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Abstract

The primary objective of this paper is to conduct a comparative study on the number of blade and different blade angles of a domestic savonius vertical axis wind turbine with semicircular shaped blades under a range of wind speeds. A domestic scale 6-bladed Savonius Vertical Axis Wind Turbine was manufactured to investigate the effect of blade number and blade angle on the maximum power generation by the turbine. Maximum power curves as a function of wind speeds were established for each configuration. The results show that the blade angle has positive effect to increase the power output of a Savonius turbine to a significant amount. The most efficient configuration is the 6-bladed turbine with an angle of attack of 10°. This configuration generated 27% more power compared to the 0° angle of attack at the wind speed from 10 to 15 km/h.

Introduction

Australia is one of the best wind resourceful countries in the world. Almost all of the major cities are situated along the coastal belt with average wind speeds of more than 8 m/s. With Australia's commitment to the Kyoto Protocol, which promised a target of 20% renewable power by 2020, it is wise to utilize the huge untapped potential of urban wind power generation [1-3]. However, one of the main disadvantages is that the atmospheric wind becomes highly turbulent and exhibits significant fluctuations of gust speed and high variability of wind direction caused by the urban structures and buildings. Under such conditions, existing Horizontal Axis Wind Turbines (HAWTs) are not very effective for power generation. The effect of solidity and blade angle has great impacts on aerodynamic performance of a Vertical Axis Wind Turbine (VAWT). It is crucial to understand the aerodynamic performance of a VAWT in urban and built up area where the atmospheric wind is at low speeds. The wind speed has a cubic effect on the power generated. Researchers like Zhang et al. [4] studied the effect of solidity and concluded that, by increasing the number of blades, the self-starting performance at low tip speed ratio was improved but the power coefficient reduced. Izadi et al. [5] have also studied the effect of number of blades on the aerodynamic performance of a venturi effect fluid turbine (VEFT) by numerical simulation. The results show that increasing the number of blades increases the magnitude of the torque generated by VAWT and, therefore, increases the efficiency of the wind turbine. However, a VAWT with a higher number of blades increases the manufacturing costs. Accordingly, there is an optimum design with respect to efficiency and capital investment. Li et al. [6] explored the effect of blade number on the starting performance of straight-blade vertical-axis wind turbine. They constructed a model which can change the number of blades from one to five. The starting torques at different azimuth angles were obtained by wind tunnel test and the results were compared with the simulation results by the starting torque of the model with one blade. They concluded that the starting performance was averagely improved with the increasing of blade number. These studies prove that we can increase the efficiency of Vertical Axis Wind Turbines by changing the number of blades. Alam et al. [7] reported a Savonius type VAWT for domestic scale wind generation. Their study was based on a preliminary design and testing of a card board model of a VAWT.

Methodology

In this study, a classic Savonius type VAWT rotor with semicircle shaped blades were modelled with variation of blade number and angle of the blade with respect to wind direction. The turbine was tested with 3 configurations with different angles over a range of wind speeds (10, 14, 18, 22 and 26 km/h). The first configuration was the 2-bladed rotor with angles orientation from 0°, 10°, 20°, 30° and 40°. The second prototype was a 3-bladed turbine with the same angle of orientation and the 3rd prototype was a 6-bladed turbine with the same angle of orientation. Fiber glass material with 2 mm thickness was used to manufacture the blade and rotor parts. Detailed dimensions of an individual blade are shown in Figure 1. Figure 2 shows the Angle of orientation for individual blade and the plan view of the 6 bladed rotor is shown in Figure 3.

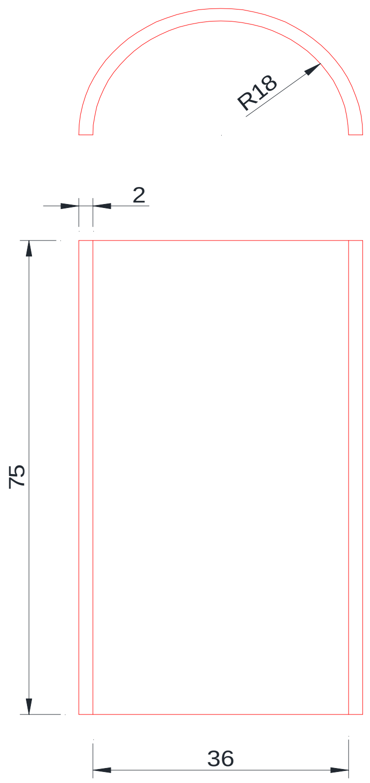

Figure 1. Dimensions (mm) of the semicircle shaped wind turbine blade.

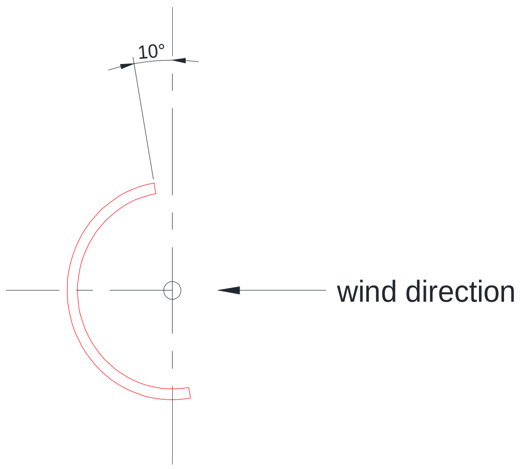

Figure 2. Angle of orientation for individual blade.

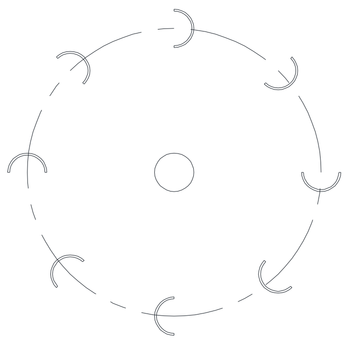

Figure 3. Plan view of the turbine configuration.

Wind Tunnel Testing

Tests were undertaken at RMIT Industrial Wind Tunnel. It is a closed return circuit wind tunnel with a rectangular test section (3 m width, 2 m height and 9 m length). The maximum wind speed of the tunnel is approximately 145 km/h. More details of the wind tunnel can be found in Alam et al. [11]. To measure various parameters (i.e., torque, rotor speed) at different wind speeds, the experimental setup was positioned and fixed at the middle of the wind tunnel test section.

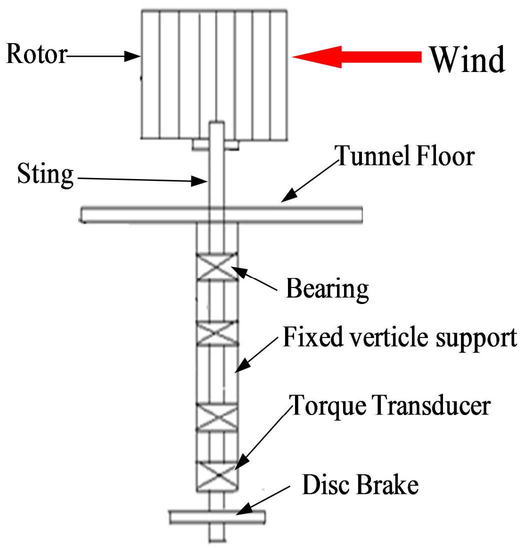

Figure 4. Schematics of experimental setup.

The rotor was connected to a torque transducer (model: T20WN, manufactured by HBM GmbH, Germany) and a mechanical breaking system through a circular rod and bearing supports. The setup was fixed properly to the wind tunnel floor to minimize vibration which may cause measurement errors. The setup was positioned 150 mm above the tunnel floor to minimize boundary layer effect. Figure 4 shows the schematic of the experimental setup and Figure 5 shows the experimental setup inside the RMIT Industrial Wind Tunnel. Opening of the cowling was positioned at 90 degree relative to wind direction for both rotor configurations. The torque transduce has the maximum capacity of 5 kN with 0.01% accuracy. Data logging software supplied by the torque transduce manufacturer was used to log the data (i.e., speed and torque). Each measurement was taken three times for each configuration and wind speed tested and the average values were presented in this study.

Figure 5. Prototype Savonius Wind Turbine.

Results and Discussion

Figure 6 shows the variation of power with wind speed for a 2 bladed Savonius type wind turbine at different Angle of orientation of the blade with wind speeds from 10, 14, 18, 22 and 26 km/h. It can be observed that the 0° angle of attack produced the best efficiency compared to the other orientation. The average power produced by the 2 bladed turbine at 10 to 14 km/h (average wind speeds in urban area) at 0° is 0.66 Watt compared to 0.4 Watt at 40° the least efficient configuration. This is an increase of 65%. The 20° blade angle was the second best efficient configuration producing an average of 0.56 Watt, followed by 10° at an average of 0.54 Watt and 30° with 0.46 Watt.

Figure 7 shows the variation of power with wind speed for 3 blade Savonius turbine at different blade angle. It can be observed that the 10° angle of attack produced the best efficiency compared to the other orientation. The average power produced by the 3 bladed turbine at 10 to 14 km/h (average wind speeds in urban area) at 10° is 2.25 Watts compared to 1.13 Watt at 40° the least efficient configuration. This is an increase of 99%. 0o was the second best efficient configuration producing an average of 2.22 Watt, followed by 20° at an average of 1.59 Watt and 30° at 1.28 Watt.

Figure 8 shows the variation of power with wind speed for 6 blade Savonius type turbine at different blade angle. It can be observed that the 10° blade angle produced the best efficiency compared to the other orientation. The average power produced by the 6 bladed turbine at 10 to 14 km/h (average wind speeds in urban area) at 10° is 7.45 Watts compared to 4.39 Watt at 40° the least efficient configuration. This is an increase of 70%. 20° was the second best efficient configuration producing an average of 6.23 Watt, followed by 30o at an average of 6.14 Watt and 0° at 5.86 Watt.

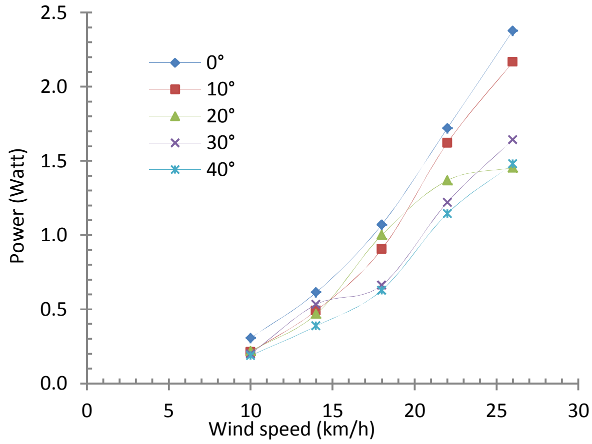

Figure 6. Power as a function of wind speed for 2 blades at different angle of attack.

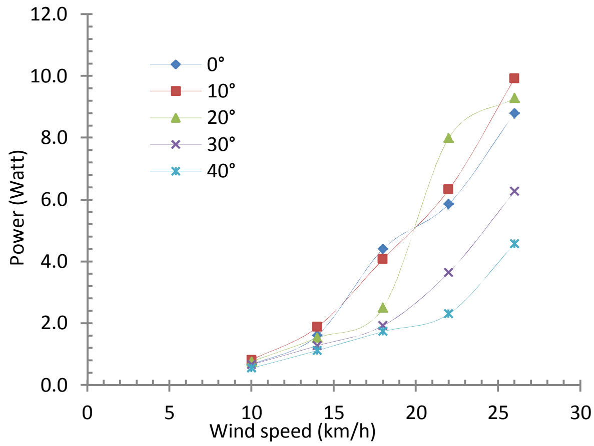

Figure 7. Variation of power with wind speed for 3 blades.

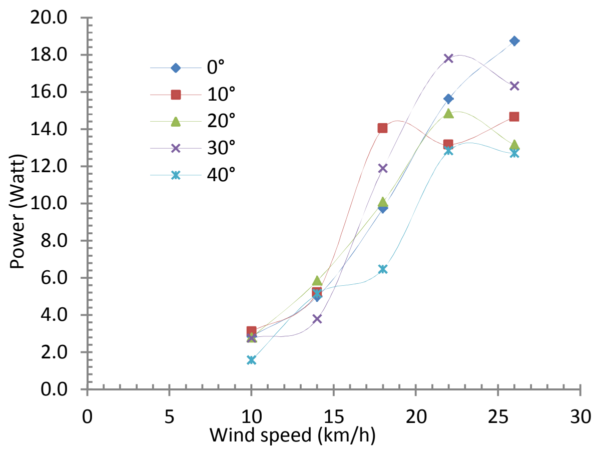

Figure 8. Variation of power with wind speed for 6 blades.

Conclusions

The results show that the blade angle has positive effect to increase the power output of a Savonius turbine to a significant amount. The most efficient configuration is the 6 bladed turbine with and angle of attack of 10°. This configuration generated 27% more power compared to the 0° blade angle at the wind speed from 10 to 15 km/h.

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