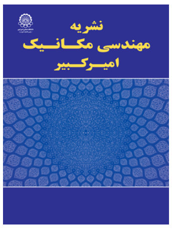

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Experimental Study on Effective Parameters on Vertical Axis Wind Turbine Performance

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ABSTRACT: Concerns about the usage of fossil fuels have led to more attention to renewable energies such as wind energy. Utilization of wind turbines in the urban industry is one of the challenging topics in wind energy area. Particularly, due to the limitations of the wind conditions in the urban areas (i.e. low speed wind, high level of variation of wind direction and high turbulence level) and the space limitations within the cities, utilization of vertical axis wind turbines in micro scales have become of interest. The focus of the present study is on these types of turbines and assessing the parameters affecting their aerodynamic performances. Two types of vertical axis wind turbines (Savonius and a straight blade Darrieus) were designed and constructed in micro-scale. The effect of wind speed on the Savonius turbine is experimentally studied. Results show that this turbine performs better at lower wind speeds. The effect of the aspect ratio and the vertical position of the blade struts on the performance of the Darrieus turbine is also experimentally assessed. The results show that the best vertical position for struts is the tip of the blades. It was also experimentally observed that the turbine with aspect ratio one has the best aerodynamic performance.

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1. Introduction

Nowadays, given the increasing human need to energy especially in urban area, renewable energy such as wind energy have received attention particularly. Using Vertical Axis Wind Turbines (VAWTs) have become more conventional in urban industry due to their advantages in comparison with Horizontal Axis Wind Turbines (HAWTs) [1]. The most important ones are their independence of wind direction and their acceptable performance in urban wind conditions with low wind speed and high levels of turbulence. In additio=n, due to the limitation of available space in urban areas, turbines with appropriate sizes are needed. In particular, Recently, micro-scale wind turbines have received more attention because of their good ability to adapt to any space, in large numbers and different layouts. Micro turbines are defined as turbines with power less than 0.25 kW (rotor diameter less than 1.25 m) [2].

Two types of VAWTs have been used in urban industry: Savonius and Darrieus. Different parameters are effective on the performance of Savonius wind turbines, such as the use of endplate, aspect ratio, blade overlap and number of blades and stages [3]. It has been found that the optimum value for the endplates is usually 1.1 times the diameter of the turbine. This turbine has the best performance in the upper aspect ratio and it suggested 1 to 8.4 in some articles [4]. For blades overlap, it has been shown that the optimum value is 10% to 20% of the blade diameter. Many articles suggested 2 bladed turbines with 2 stages [4]. Similarly, the performance of Darrieus VAWTs is affected by different parameters including type of blade's airfoil, aspect ratio, blades angle of attack, solidity (the ratio of the area that the turbine blades occupy and swept area of the turbine), location and shape of struts of the blades and turbulence intensity and speed of wind inflow. Several studies have been conducted to assess the effects of the above-mentioned parameters. It has been found that Darrieus wind turbine has the best performance when the aspect ratio is near 1 or exactly 1, the blade has symmetrical airfoil shape. Also, previous investigators showed that as the solidity increases, the maximum power coefficient occurs in lower tip speed ratios. Moreover, with increasing solidity, the power coefficient increases and then decreases [3].

All the previous investigations have focused on the turbines larger in size than micro turbines, that is much less attention has been paid to the impact of influential parameters on the performance of micro scale wind turbines. Therefore, the focus of the present research is on the design of the micro scale VAWT (Savonius and Darrieus). For this purpose, an experimental study is carried out to investigate these issues. Two types of turbines are designed and constructed in micro scale and their aerodynamic performances have been investigated. As an important objective, a suitable setup is prepared to measure the power output of the turbines in micro scale. In addition, it is tried to study the effect of some parameters on the performance of Savonius and Darrieus turbines. The performance of Savonius wind turbine at different wind speed (different Reynolds numbers) has been investigated. For the Darrieus turbine, The effect of the aspect ratio and the position of blade struts on the turbine performance has been experimentally studied.

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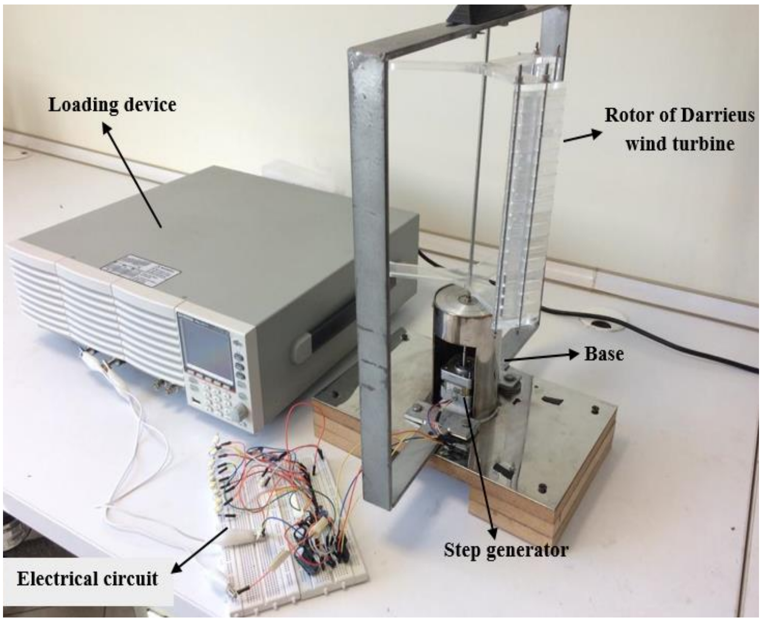

Fig. 1. Darrieus VAWT with its testing equipment.

2. Methodology

A wind simulator is used to assess the turbines's aerodynamic performance and to measure their power output. The shafts of the turbine rotors are connected to a generator (a stepper motor) to convert the mechanical energy of the rotor to the electrical one. Using different loads, i.e. electrical resistances and a loading device, different powers are obtained at different rotational speeds of the turbine. To compare the performance of different turbine rotors, their power coefficients are plotted versus tip speed ratios. The power coefficient is calculated using Eq. (1).

$$C_P = \frac{P_{Turbine}}{0.5\rho A V^3} \tag{1}$$

where ρ is density of air, A is rotor effective surface area and V is wind speed. The tip speed ratio is computed using Eq. (2).

$$TSR = \frac{R.\omega}{V} \tag{2}$$

where r is the turbine rotor radius, ω is the rotor rotational speed and V is the wind speed. A tachometer is used to obtain the rotational speed of the rotor. Wind turbine with the electrical system and a loading device are presented in Fig. 1.

Savonius VAWT was designed based on the information extracted from previous studies [4]. The height and the aspect ratio are set to be 20 cm and 2/4, respectively. This turbine was designed with 2 blades and 2 stages. It also has upper and lower endplates as well as a mid-plate. The overlap between the blades is 20% of the blade diameter. The 3D printer device is utilized to construct the rotor blades. The plates are constructed using plexiglass.

Darrieus VAWT is a straight blade turbine with 3 blades. Aspect ratio and height of the turbine are 1 and 20cm, respectively. NACA0021 is used as the airfoil type of the blades. The solidity of the turbine is set to be 75% [3]. Each blade is constructed by 20 separable pieces. Using this innovation, the effect of two parameters, i.e. the aspect ratio and the vertical position of the blades struts can be assessed using one experimental set-up. For this purpose, the Darrieus turbine was tested with three different aspect ratios including 0.8, 0.9 and 1. Also, two struts are located in three different vertical positions which are the tips of the blades, middle of blades and 25% of the blade height from the tips.

3. Results and Discussion

Fig. 2 presents the power coefficient with respect to TSR for the Savonius VAWT at three different wind speeds. It can be seen that by increasing the wind speed, the power coefficient decreases.

Micro scale turbines are strongly influenced by resistance forces. By increasing of the rotational speed of wind turbine resistance forces increase and then power output decreases.

Fig. 3 shows the power curves for Darrieus turbines with three different aspect ratios. it can be seen the Darrieus turbine has the best performance with an aspect ratio equal to 1. The results are in accordance with previous investigations, though they have been mostly performed numerically [5]. The effect of the aspect ratio on the turbine performance is associated with the vortices, formed on the tips of the blades and influence the flow structure on the blade and consequently the turbine performance. For aspect ratios less than one, influence of these vortices increases and thus the power coefficient decreases.

Fig. 4 presents the power coefficient with respect to the TSR for the Darrieus turbines with 3 different positions of the blades struts. It's clear that the best position for the struts is the tips of the blades. A vortex flow, created by struts when the turbine is rotating, affects the flow structure on the blade. This effect is less when they are mounted on the blades' tips.

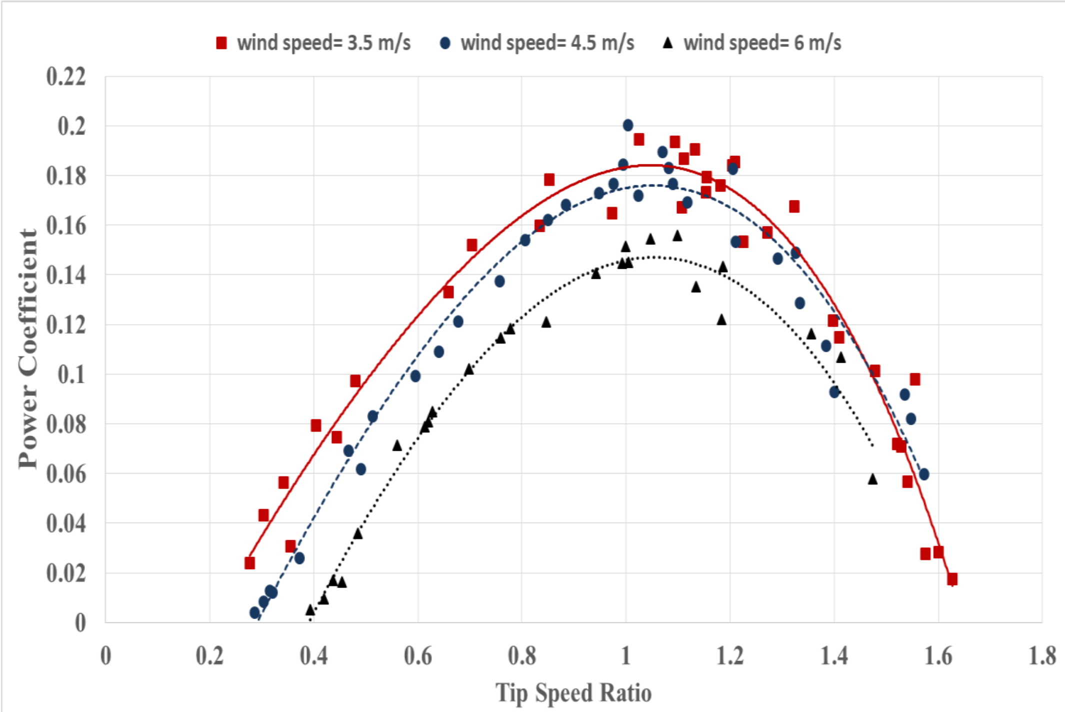

Fig. 2. Diagram of power coefficient in terms of tip speed ratio for Savonius wind turbine at different wind speeds.

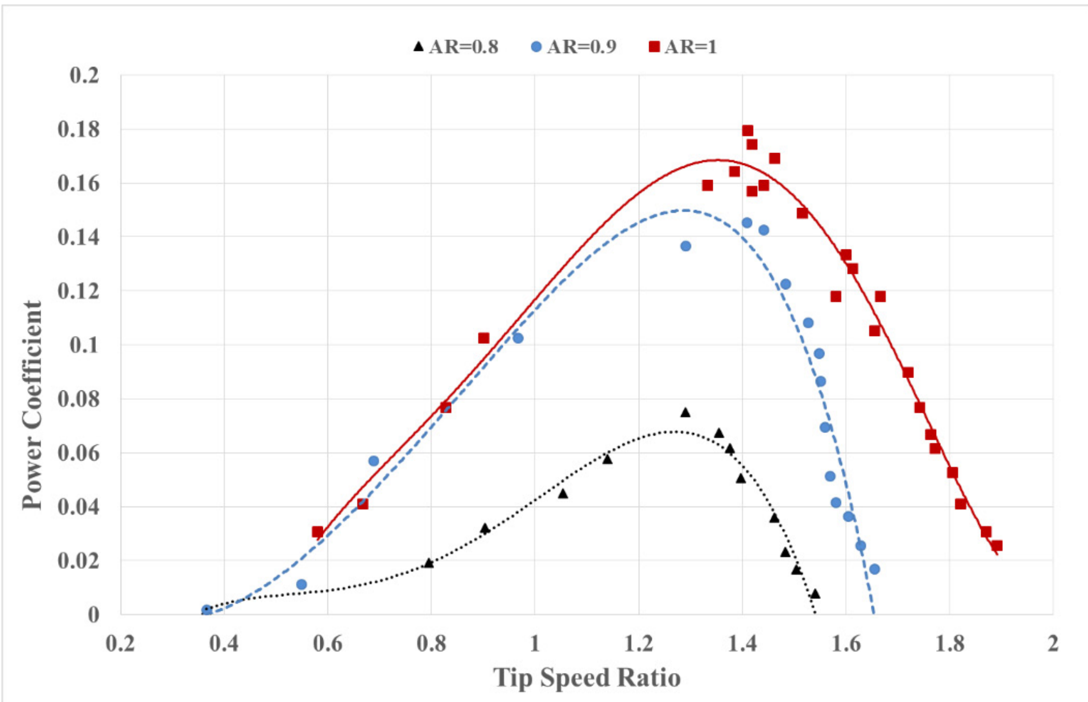

Fig. 3. Comparison diagrams of power coefficient in terms of tip speed ratio for different aspect ratios of Darrieus turbine.

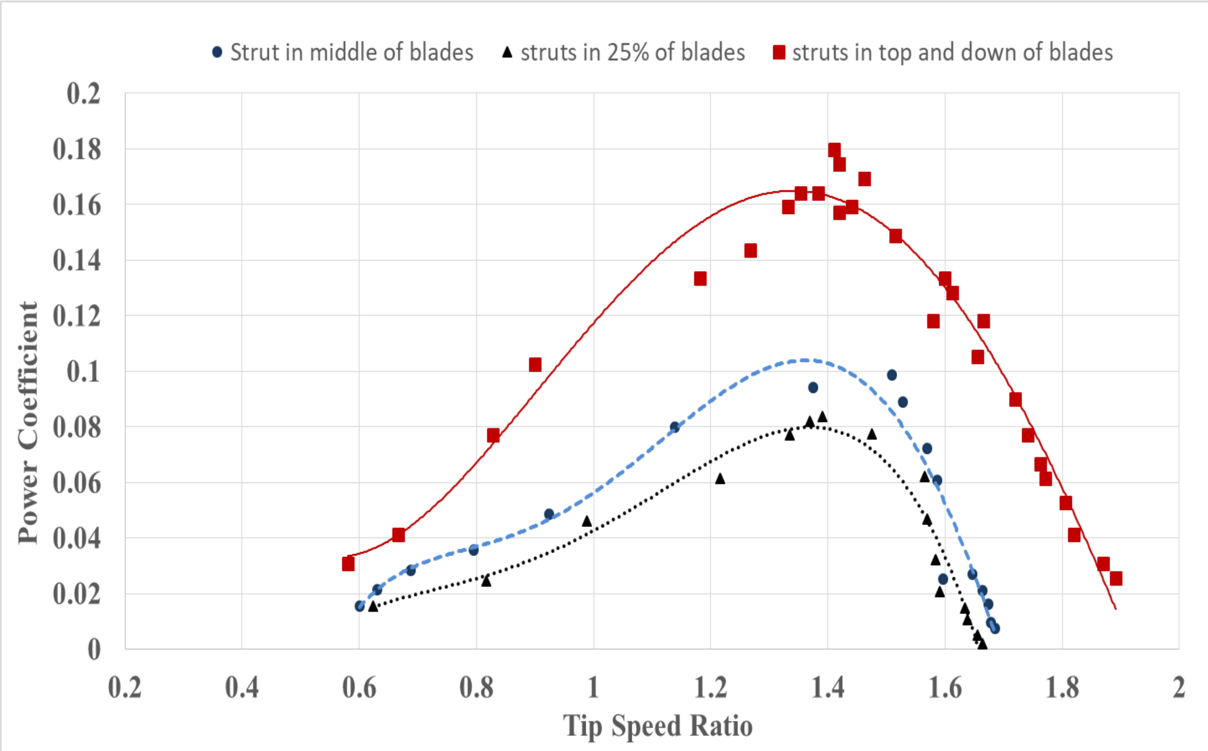

Fig. 4. Comparison diagrams of power coefficient in terms of tip speed ratio for different blade struts position.

4. Conclusion

In present research, the effect of some parameters on the performance of micro scale VAWTs was experimentally investigated. The results show that the Savonius turbine has a better performance in lower wind speeds. A straight blade Darrieus turbine is designed and constructed with blades comprising of 20 separable pieces. The turbine is used to investigate the effect of aspect ratio and the vertical position of blade struts on power coefficient. The results show that the maximum power coefficient is achievable when the aspect ratio is equal to one and when the struts are positioned at the tips of the blades.

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