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An experimental study on improvement of Savonius rotor performance

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Abstract For solving the world energy problem and the bad effect of conventional sources of energy on environment, great attention allover the world is paid towards the use of renewable energy sources. Special interest is paid towards wind energy because of its competitively.

Savonius rotor is a vertical axis wind turbine which is characterized as cheaper, simpler in construction and low speed turbine. This makes it suitable for generating mechanical energy in many countries especially in Egypt.

In this work different geometries of Savonius wind turbine are experimentally studied in order to determine the most effective operation parameters. It was found that, the two blades rotor is more efficient than three and four ones. The rotor with end plates gives higher efficiency than those of without end plates. Double stage rotors have higher performance compared to single stage rotors. The rotors without overlap ratio (β) are better in operation than those with overlap. The results show also that the power coefficient increases with rising the aspect ratio (α). The conclusions from the measurements of the static torque for each rotor at different wind speeds verify the above summarized results of this work.

1. Introduction

Wind energy is very important as one of clean energy resources. Wind rotors are the most important tool of the wind energy. Savonius wind rotor is one of the vertical axis wind turbines. It is simple in structure, has good starting characteristics, relatively low operating speeds, and an ability to capture wind from any direction. But it has a low aerodynamic efficiency. Savonius wind rotor is constructed simply of two vertical half cylinders, as shown in Fig. 1. The ratio between rotor height (H) and rotor diameter (D) is called the aspect ratio (α). Another parameter that affects the performance of Savonius rotor is the overlap ratio (β) which is expressed as: $\beta = (e - a)/d$, where e is the overlap, a is the shaft diameter and d is the blade diameter.

The performance of Savonius rotor has been studied by many researchers from 1977 until 2010 in order to determine

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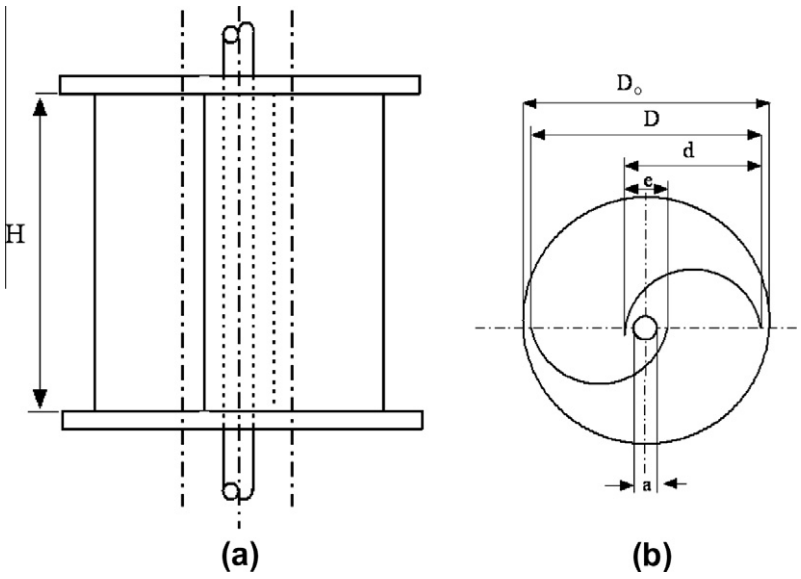

Figure 1 Scheme of a single-stage Savonius rotor: (a) elevation view; (b) plan view.

the optimum design parameters of this rotor. In the following, the main trends in these studies are summarized and discussed.

The effect of blade aspect ratio, blade overlap and gap besides the effect of adding end extensions, end plates and shielding were tested by Alexander and Holownia [1]. The test was carried out in a wind tunnel on a number of Savonius rotor geometries with wind speeds ranging from 6 to 9 m/s. They concluded that, there is an improvement in rotor performance with increasing the aspect ratio. The tests for three and four bladed geometries gave appreciably lower values of efficiency than two blades rotor. They used four values of the extensions and found that the efficiency increases with the increase of the extension. They concluded also that the efficiency for the rotor with end plate and shielding is greater than that with end plate and without shielding. Furthermore, the efficiency obtained for a rotor with end plate and without shielding is greater than that of rotor without end plate. They found also that, increasing the rotor overlap ratio increases the rotor efficiency. Modi et al. [2] reported that the optimum values of the aspect and overlap ratios are 0.77 and 0.25 respectively. Mojola [3] examined the performance of Savonius wind rotor under seven values of the rotor overlap ratio namely 1/8, 1/5, 1/4, 1/3, 1/2, 3/4 and 7/8. He concluded that the effect of overlap ratio on rotor performance depends on its tip speed ratio ($\lambda = \omega R/V$) where ω is the angular speed, R is the rotor radius = $D/2$ and V is the wind speed. The aerodynamic performance and the flow fields of Savonius rotors at various overlap ratios have been investigated by Nobuyuki [4]. The static torque performance of the rotor, specially of the returning blade, is improved by the presence of the overlap and the best value of the overlap is 0.15. Menet [5] aimed to construct a prototype of Savonius turbine to charge a battery. He used blades from plastic tube (PVC) and steel shaft. He utilized a rotor with aspect ratio of 4 and overlap of 0.25. He found that starting velocity was 3 m/s, velocity for maximum production is 13 m/s and the mean efficiency between 5 and 10 m/s was found to be 29%. The range of speed rotation was 200–800 rpm. Kamoji et al. [6] examined helical Savonius rotors in an open jet wind tunnel. From their results, the helical rotors with shaft have lower power coefficient than the helical rotors without shaft. Saha et al. [7] carried out a comparison between Savonius rotor with different geometries. They reported that, the optimum number of blades is two for the Savonius rotor whether it is single-, two- or three-stages. Twisted geometry of the blade profile has a good performance as compared to the semicircular blade geometry. Two-stages Savonius rotor has better power coefficient as compared to the single- and three-stage rotors. Altan et al. [8] studied the curtain arrangement using two plates, one in the upper end of rotor and the second at the rotor lower end. This arrangement is used to prevent the air leakage from the concave side. They concluded that the arrangement increases the rotor performance. They used three curtaining arrangements by changing the two plate lengths and its angle on the horizontal axis. The results showed that the curtaining which has longest plates is better and the optimum angel is 15° on the horizontal axis for the upper plate and 45° for the lower one. Altan et al. [9] examined the parameters in Ref. [10] and compared the measurements with the numerical results. Gupta et al. [10] made a combination between Savonius wind rotor and Darrieus wind rotor. They compared the results obtained with those of conventional Savonius rotor. They observed that there is a retable improvement in the power coefficient for the combined Savonius–Darrieus rotor. Kamoji et al. [11] studied the effect of the overlap ratio, blade arc angle, aspect ratio and Reynolds number on the performance of Savonius rotor. They found that, the modified Savonius rotor without overlap ratio, with blade arc angle of 124° and with an aspect ratio of 0.7 has a maximum power coefficient of 0.21 at Reynolds number of 150,000. The obtained value of the power coefficient is higher than that of conventional Savonius rotor. Roth [12] tested the effect of both aspect ratio and overlap ratio. He reported that the best values are 0.77 and 0.22 respectively. Blackwell et al. [13] reported that the two-stages geometry has better aerodynamic performance than the three-stage one, with the exception of starting torque. They decided also that, the increase in the aspect ratio improve the rotor performance. Shankar [14] tested both two-blades and three-blades geometries. He