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A Review Study on Vertical axis Wind Turbines(lift and drag type) for Optimizing the Aerodynamic and Structural Performance

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Abstract: *Vertical axis wind turbines (VAWT) are omnidirectional in nature. Lift type work on the conditions of lift produced on blades. Drag type harness power from wind by the effect of drag force. VAWTs require no yaw mechanism to continuously orient towards the wind direction. This work deals with the review study of vertical axis lift and drag type rotors and identifying various performance parameters to increase the power performance. It is observed that helical rotor has self starting capacity at low wind speeds. The egg beater shape has better stress bearing capacity as compared to other shapes, but generated insufficient torque for self starting nature. Number of blades for optimal performance for tip speed ratios between three to five were adequate when taken as three. Whereas for tip speed ratios less than three, four blades are optimal. For drag type rotors, it has been concluded that helical blades are more inclined towards self starting nature than conventional bucket type shapes. It was concluded that better power performance were obtained for two bladed rotors at different rotor angles.*
Keywords: *Aspect ratio, Darrieus rotor, Savonius rotor, Power coefficient(Cp), Tip speed ratio(TSR), solidity.*

I. Introduction

With the advent of the modern era the energy demands needed to fulfil today's needs are increasing. The way energy is generated plays an important role in its production and distribution. Until few years back energy has been generated only through conventional sources of energy. Conventional sources of energy are the sources which have been found till then to meet the energy demands of human society. Energy extracted from these sources is not the only final product in energy generation process. But these also include emission of harmful gases that add up to atmosphere causing depletion and devastation of the world we are living in. These sources being limited in nature cannot be used in an uncontrolled manner to meet our energy requirements and if used will definitely lead to a world with no sign of these. Thus new ways of energy generation which are environment friendly and are abundant in nature have to be developed. The sources are called renewable sources of energy. Of many Renewable Sources wind energy is selected in this study. Vertical Axis wind turbine being omnidirectional in nature can harness energy from the wind flowing in any direction. VAWTs are of two types: lift type and drag type. Recent studies have shown that the efficiency is of these turbines can be improved to harness maximum energy from the wind. The optimum operating conditions depend upon tip speed ratio and rotor solidity for lift type rotor. Tip speed ratio is a function of angular velocity of rotor. In design of vertical Axis wind turbine it is crucial to optimise the Aerodynamic performance off the rotor. By optimising the power Coefficient curve at varying tip speed ratio the annual energy production can be optimised. The Darrieus wind turbine was patented by G.J.M. Darrieus with egg beater shaped, H shaped and V-shaped rotors, but other geometries is have since been developed with the aim of optimising Aerodynamic performance and structural performance. lift driven vertical Axis wind turbines has advantages like insensitivity to yaw angle, low noise due to low tip speed ratio. a more complex and optimised design is Gorlov rotor with helical blades. The egg beater shape was further optimised due to low torque at ends of the blades. blades having egg beater shape were at low induced structural stresses. set of obtained was typically low due to blades converging at the ends. considering this loophole straight blade vertical axis when turbine was introduced with straight blades. as the radius of the turbine was uniform the torque induced on blade by air was same throughout. this lead to the new geometry which is termed as H-shaped rotor. This lead to the new geometry which is termed as H-shaped rotor. This Rotor though had problem with self starting ability at low wind speeds.

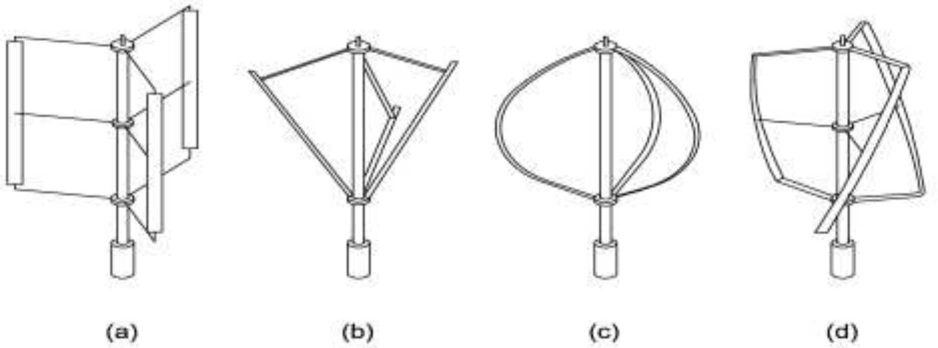

Fig 1. Possible variants of Darrieus VAWT: H-type (a), V-type (b), Troposkien type (c), and Gorlov (helical type, d) .

Helical shaped Rotor was found to be most stable in fluctuating wind speeds and was found to have Sun starting ability at low wind speeds. Drag type rotors work due to difference in drag force on semi spherical blades depending on whether the wind is striking the concave part or the convex part. These are used worldwide due to their simplest design, less manufacturing cost and good starting torque independent of the direction of wind. Torque coefficient, drag coefficient and power coefficient are found out by aerodynamic study of rotor. The power Coefficient and torque coefficient can be improved by a change in geometry of the blades. Helical blades were introduced to have improved torque coefficient and power coefficient at different angles of twist, mainly 60^0, 90^0 and120^0.

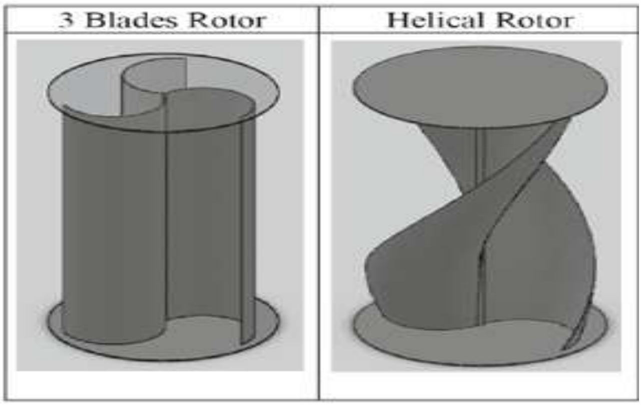

Fig 2. Possible variants of Savonius VAWT: simple 3 blades rotor (a), Helical rotor (b)

The number of blades can be changed to face wind more efficiently by the blades. But with increase in number of blades it was observed to have decreased torque and power coefficients and unstable operation generating noise and vibrations.

II. Lift type rotors

2.1 Egg beater shape

The egg beater shape is also called torposkien shape. It is the most famous type vertical axis wind turbine. It is characterised by its C shaped rotors which give it its egg beater appearance. It is normally build with number of blades as two or three. Due to decreasing rotor radius from maximum at centre to least at ends it loses its self starting ability and hence is not favoured when self starting is desired. Therefore either high wind speed or some other mechanism is needed for self starting. The blades of this rotor can withstand high centrifugal force. Therefore, the blades could be made slender, light and low cost via relatively simple extrusion manufacturing method.

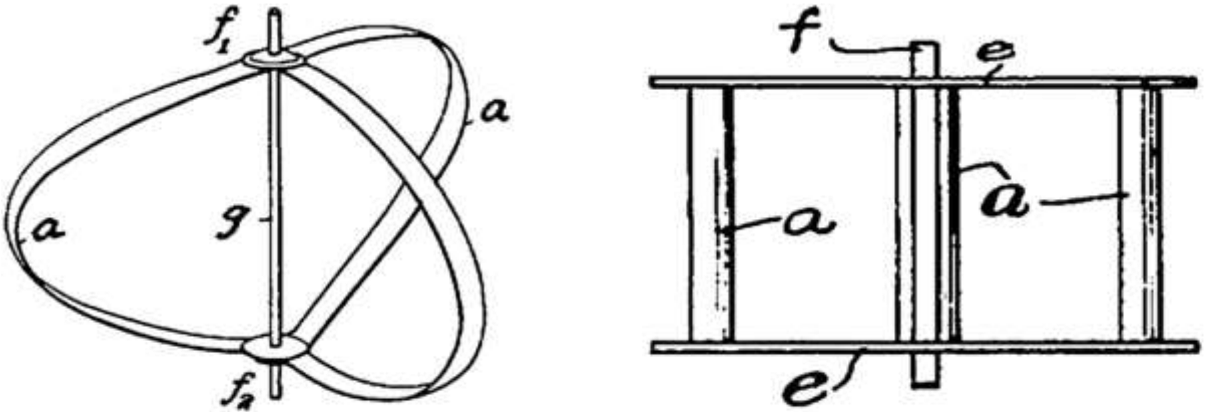

Fig. 3. Original illustrations by G.J.M. Darrieus in 1931 patent: curved blades (left) and straight blades (right). Annotations in the figure: (a) blades, (e) supporting plates, (f1) and (f2) ¼hubs, (f) and (g) rotor shaft .

In term of H/D ratio, pure troposkien shape has the H/D ratio of about 0.9. As the aspect ratio is low the torque generated is also low due to low Reynolds number and hence low power generating capacity. Number of blades are kept either two or three which expects this rotor to rotate at high angular velocities than rotors with more number of blades, typically four. Overall this shape is not considered favourable for urban use for power generation due to its low coefficient of torque and low power coefficient.

2.2 H-Shaped rotor

It is an advancement of Darrieus egg beater shape for optimising aerodynamic characteristics aiming at optimised power coefficient. The blades of this rotor are straight having uniform radius throughout. The torque induced upon the blades hence is uniform throughout causing uniform stresses on the blades. Number of blades can vary from two to five depending upon the wind speed. solidity is one of the main parameters dictating the rotational velocity ay which the turbine reaches its maximum performance coefficient. With experimental studies he compared the behavior of a two and three bladed VAWT, and demonstrated that the two bladed generates an higher power than the three bladed and the peak power is obtained for higher values of tip speed ratio. For a three, four and five bladed rotor, solidity values are respectively 0.5, 0.67 and 0.83.

$$\sigma = N c / R \quad (1)$$

σ – rotor solidity
N – Number of blades
R – rotor radius

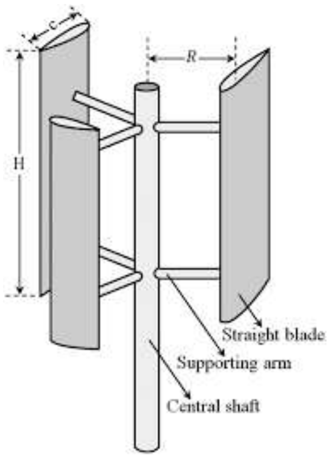

Fig 4. Straight blade vertical axis wind turbine

The peak of power coefficient lowers with the increase of rotor solidity, while it moves to lower tip speed ratio. This shows that more number of blades reaches the maximum power coefficient for lower angular speeds, but are penalized as far as efficiency is concerned.

2.3 Helical rotor

The oscillating torque produced by straight and curved blade VAWT contributes to vibrations that are transmitted to the foundations of the system. The oscillations due to the loading on the blades can lead to increased fatigue on rotor structure. For reducing this unwanted effect, blades are helically twisted around the rotational axis. The torque, and consequently the power output, of vertical-axis wind turbines with helically twisted blades is relatively steady, thus decreasing the stress on the turbine system, reducing the vibration transmitted into its supporting structure, and thereby increasing the design life of the turbine. The straight- and curved-bladed turbines exhibit significant unsteadiness in power coefficient over the duration of a single turbine revolution. The oscillations in the power coefficients of the straight- and curved bladed turbines have three coherent peaks close to 90◦, 210◦ and 330◦ azimuth; this reflects the location of the peak in the variation of the torque of each single blade close to 90◦ azimuth.

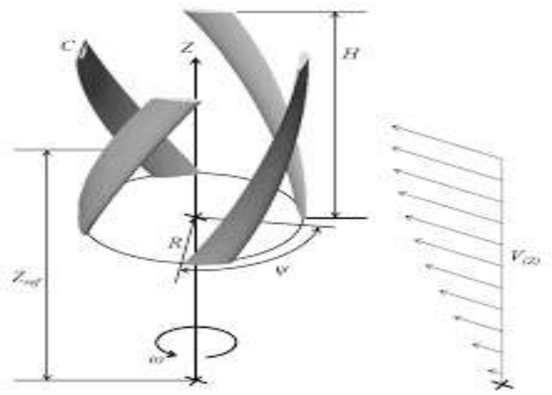

Fig 5. Helical blade rotor

The Reynolds number and the number of blades have the major effect on the pulsating loads. Higher number of blades decreases both thrust and torque oscillations. Design with three blades was found to be more stable and generated power at low wind speeds.

III. Drag type rotors

The power coefficient and torque coefficient of two blades helical Savonius rotors are evaluated from CFD analysis at 60°, 90° and 120° twist angles. Also, the power coefficient and torque coefficients of 90° twist two bladed and three-bladed rotors were evaluated at 30°, 90° and 180° rotor angles. The results are compared with two-bladed and three-bladed 90° twist helical Savonius rotors. The power coefficient and torque coefficient were evaluated at 60°, 90° and 120° twist angles and at different TSR, after which these power and torque coefficients were compared at different TSR for the said twist angles. From these comparisons, it was found that a 90° twist helical Savonius rotor is more efficient in terms of power coefficient and torque coefficient. - For the helical Savonius rotor at different twist angles, high dynamic pressure cocentrations and velocity were found near the front bucket blade. The pressure and velocity magnitude contours depend on the twist angle. In the case of distinct rotor angles, static pressure and velocity also depend on rotor angle and on the number of blades.

From comparisons between two-bladed and three-bladed helical Savonius rotors, it was found that the maximum power coefficient (Cp=0.53) is high for the two-bladed rotor compared to the three-bladed (Cp=0.36) helical Savonius rotor. The maximum power coefficient is obtained at 0°, 180° and 360° rotor angles for the two-bladed helical Savonius rotor, and the maximum power coefficient was obtained only at the 60° rotor angle for the three-bladed helical Savonius rotor. For two blades in three rotor angles and for three blades in one rotor angle only, a maximum power coefficient was obtained. Thus, the two-bladed helical Savonius rotor was found to be more efficient. - Positive power and torque coefficients were obtained at all rotor angles in one revolution (360°) for both the two-bladed and the three-bladed helical Savonius rotor.

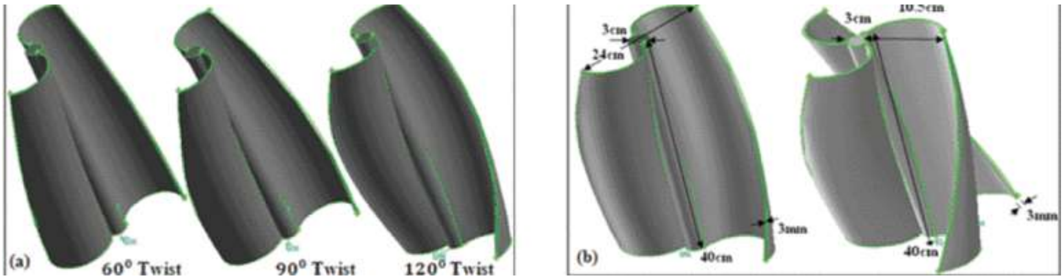

Fig 6. (a) Helical savonius rotors at different twist angles, (b) Helical savonius rotors with different number of blades.

IV. Conclusion

Three-bladed lift type wind turbines showed better performance characteristics compared to two bladed ones. As a result, a higher thrust is also registered. A lower variation of both torque and thrust also emerges when it is compared to a two-bladed rotor. Such behaviour could represent a great advantage for three-bladed small VAWT architectures, for which the increased manufacturer and installation costs are not so important as for large rotors. As the fatigue life of VAWTs is often considered as important as power production, helical shaped rotors are advantageous because they reduce the cyclic oscillations of the aerodynamic loads, thus boosting the turbine life and reducing its vibrations during operation. It also appears as the most efficient architecture for the wind energy exploitation. However, the operation of the helical turbine at initial Tip speed ratios(TSR) appears less efficient, the blade manufacturing cost is actually higher than the straight blade type and more experimental tests have still to be carried out, in order to clarify the actual potential and limits of Gorlov turbines.On comparing two-bladed and three-bladed helical Savonius rotors, it was found that the maximum power coefficient (*Cp=0.53*) is high for the two-bladed rotor compared to the three-bladed helical Savonius rotor(0.36). The maximum power coefficient is obtained at 0°, 180° and 360° rotor angles for the two-bladed helical Savonius rotor, and the maximum power coefficient was obtained only at the 60° rotor angle for the three-bladed helical Savonius rotor. For turbine with two blades in three rotor angles, a maximum power coefficient was obtained. Thus, the two-bladed helical Savonius rotor was found to be more efficient.

Conflict of interest the authors declare that there is no conflict of interests regarding the publication of this paper.

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