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DYNAMIC CHARECTERISTICS OF A VERTICAL AXIS VANE TYPE WIND TURBINE

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ABSTRACT
A Vertical axis Vane type wind turbine is a drag based wind turbine. In the present analysis, an extensive experimental investigation of the dynamic performance characteristics of four/five and six bladed Vertical Axis Vane Type rotors has been carried out in the subsonic wind tunnel at different tip speed ratio with different Reynolds number. The theoretical analysis of the present work has been done using momentum theory and Blade element theory. It is found that the value of maximum power coefficient increases with increasing the Reynolds number. It is also observed that the calculated results of aerodynamic characteristics of Vertical Axis Vane Type wind turbine is comparable with other vertical axis rotor like semi cylindrical Savonius rotor, S shaped Savonius rotor. Finally, the calculated results of the wind turbine have been compared with the existing experimental results. It is found that there is a good correlation between the present experimental results and the existing predicted results.

Keywords: Vertical Axis Wind Turbine, Reynolds Number, Tip Speed Ratio, Dynamic Characteristics.

1. INTRODUCTION

Recent research and development in the field of power exploitation from wind, place wind energy as a reliable sector of renewable energy source. Still people are doing research to find more efficient and cost effective way to exploit wind energy. Now-a-days both horizontal and vertical axis wind machines of different kinds have been developed in different parts of the world. For the present study attention has been focused on vertical axis wind machines only. Vertical axis Vane Type Wind Turbine is a drag based slow running wind machine and has relatively lower efficiency. Still it is being used in the developing countries because of its simple design, easy and cheap technology for construction and good starting torque characteristics at low wind speed. It is independent on wind direction and also works even at low wind speed. For the efficient utilization many researchers worked on to improve the dynamic characteristics of Vertical Axis wind rotor.

2. EXPERIMENTAL SETUP AND PROCEDURE

The schematic diagram of the experimental set-up of the present investigation is shown in Figure: 1. An open circuit subsonic type wind tunnel was used to develop the required flow and the rotor was positioned at the exit section of the wind tunnel. The tunnel was 5.93 m long with a test section of (490mm $\times$ 490mm) cross-section. The central longitudinal axis of the wind tunnel was maintained at a constant height from the floor. The converging mouth entry was incorporated into the system for easy entry of air into the tunnel and maintains uniform flow into the duct free from outside disturbances. The induced flow through the wind tunnel was produced by two-stage rotating axial flow fan of capacity 18.16 m^3/s at a head of 152.4 mm of water and 1475 rpm with each of the fans connected to a motor of 2.25kW capacity and 2900 rpm. A butterfly valve, actuated by a screw thread mechanism was placed behind the fan and was used to control the flow. A silencer was fitted at the end of the flow controlling section in order to reduce the noise of the system. The diverging and converging section of the wind tunnel was 460 mm long and made of 16 SWG black sheets. The angle of divergence and convergence was 7°, which was done with a view to minimizing expansion and contraction loss and to reduce the possibility of flow separation. Other three outlet square (610 mm each) sections were used to make the flow straight and uniform.

At first, the velocity was measured without the model turbine at the sections which was placed in front of the rotor at different locations and average velocity was measured directly. The experimental set-up is shown in Figure 2. Non-contact electrical tachometer was used to measure the speed of the model wind turbine at different loading conditions. Wind speed behind the rotor was measured by a digital anemometer and the speed of the model wind turbine shaft having 4, 5 and 6 bladed rotor at different Reynolds number were determined using a non-contact digital tachometer at different loading condition.

1. CONVERGING MOUTH ENTRY
2. PERSPEX SECTION
3. RECTANGULAR DIVERGING SECTION
4. FAN SECTION
5. BUTTERFLY SECTION
6. SILENCER WITH HONEYCOMB SECTION
7. DIVERGING SECTION
8. CONVERGING SECTION
9. RECTANGULAR SECTION
10. FLOW STRAIGHTNER SECTION
11. RECTANGULAR EXIT SECTION

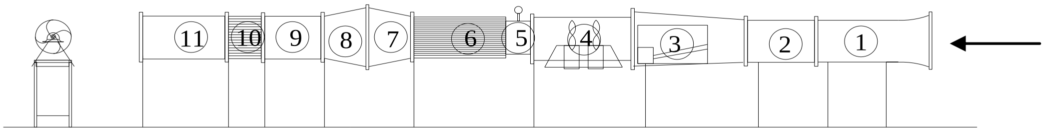

Fig. 1: Schematic diagram of wind tunnel

Fig 2. Pictorial diagram of the experimental set up.

Fig. 4. Five bladed rotor.

Fig. 3. Four bladed rotor.

Fig 5. Six bladed rotor.

2.1. CONSTRUCTIONAL DETAIL

The constructional detail of the Four, Five and Six bladed vane type rotor are shown in figure 3, 4 and 5 respectively. The rotor were made up of four, five and six half cylinders (blade) of diameter,d = 65 mm and height, H=340 mm respectively. Rotor diameter, D was 200 mm to maintain d/D ratio as 1/3.

The cylinders were made of PVC material. Both the top and bottom ends of the rotor were fitted with end caps. The whole rotor was fixed on an iron frame by using a through shaft that was inserted into it and by two ball bearings. A pulley was attached at one end of shaft. A strip whose one side was tied to a spring balance and other side to a load carrying plate was prepared for passing over that pulley. A radium sticker was attached to that side of shaft. The spring balance was attached to the iron frame. The whole experimental set-up is shown in Figure 2.

3. RESULTS AND DISCUSSION

The dynamic performance charecteristics i.e power coefficient and torque coefficient of three rotors with different number of blades at different Reynolds number as well as different loading conditions are determined. In addition a comparative study of the existing research work (predicted) and present investigation of dynamic characteristics are also analyzed.

Effect of number of blades or solidity have been taken into consideration in the present experimental investigation. A wind rotor can only extract power from the wind, because it slows down the wind. The maximum power extraction is reached when the wind velocity in the wake of the rotor is 1/3 of the undisturbed wind velocity. If the wind speed increases the power also increases. The variations of result for changing the Reynolds number in terms of Cp versus λ are shown in Figures 7 to 9. However, the maximum power coefficient is affected by changing the Reynolds number as well as by number of blades.

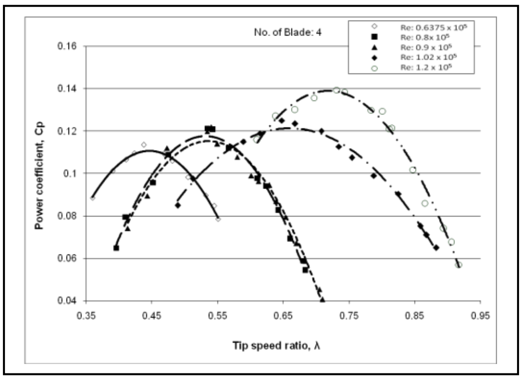

Fig. 6. A comparison of power coefficient vs tip speed ratio for four bladed rotor at different Reynolds number.

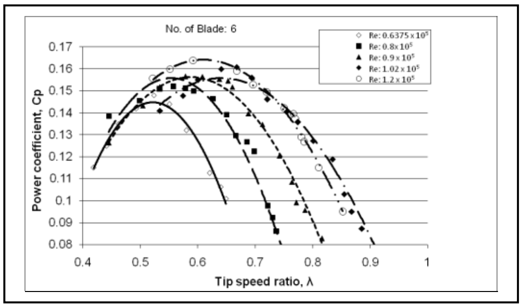

Fig 7. A comparison of power coefficient vs tip speed ratio for six bladed rotor at different Reynolds number.

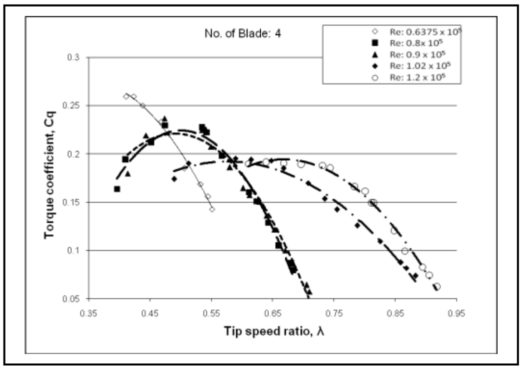

Fig 8. A comparison of torque coefficient vs tip speed ratio for four bladed rotor at different Reynolds number.

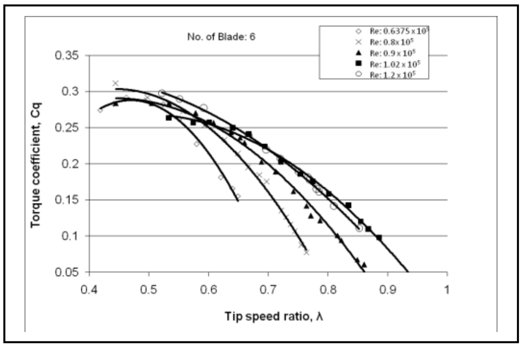

Fig 9**.** A comparison of torque coefficient vs tip speed ratio for six bladed rotor at different Reynolds number.

The variation of results for changing the Reynolds number in terms of Cp vs λ are shown in Figure 6 and 7 for four and six bladed vane type rotor respectively. For both case the power coefficient increases with increasing the Reynolds number. Again the variation of result in terms of Cq vs λ are shown in figure 8 and 9 for four and six bladed rotor respectively. From these graphs it is apparent that for higher Reynolds number the value of maximum torque coefficient is lower and it is shifted to the higher values of tip speed ratio.

3.1 Comparison of the Results with Earlier Experimental Data

A comparison of the experimental results of power coefficient of wind turbines having four bladed rotor and other Savonius rotor are made in figure 10. It can be observed from this figure that the nature of curves for all type of vertical axis rotor (Vane type and Savonius) is identical. The value of power coefficient increases with incteasing the tip speed ratio and after a certain point the value of power coefficient decreases with further increasing the tip speed ratio. In case of present experimental analysis the value of maximum power coefficient is achieved at tip speed ratio approximately 0.5 but all other predicted maximum power coefficient is occurred at tip speed ratio around 1.

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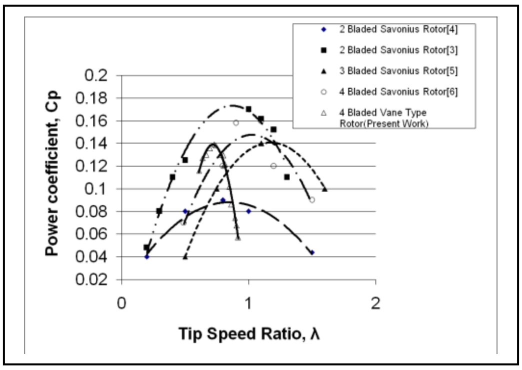

Fig. 10. A comparison of power coefficient vs tip speed ratio for different type of vertical axis rotors.

4. CONCLUSION

In regards to the present experimental investigation of the vertical axis vane type wind turbine the following conclusions can be drawn:

1. For higher values of Reynolds number the value of power coefficient is higher and it shifts to the region of high tip speed ratio.
2. For same Reynolds number, with increasing the number of blades, the maximum value of power coefficient also increases.
3. At higher Reynolds number the value of maximum torque coefficient is slightly lower.
4. At the same Reynolds number, the rotor having higher number of blades, the value of maximum torque coefficient is also higher.
5. The value of power coefficient of the vertical axis vane type wind turbine are comparable to those with other vertical axis wind turbine like Savonius rotor or S shaped Savonius rotor.

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6. NOMENCLATURE

Symbol	Meaning	Unit
Cp	Power coefficient	
Cq	Torque coefficient	
Re	Reynolds number	
Λ	Tip speed ratio	
D	Rotor diameter	mm
d	Blade diameter	mm
H	Rotor Height	mm

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