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Wind Tunnel Test of Shielded Flat Plant Wind Rotor

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Summary
A rectangular flat plate rotor was tested inside a wind tunnel. The plate was half shielded by semi - cylindrical cover so that the wind strikes one half of the plate. The power coefficient and output torque were found experimentally for value of the tip speed ratio ranging from zero, when the output is sufficient to stop the turbine, to the maximum free running value when the output torque is zero.

1.**Introduction**

Various methods are used to assess the performance of vertical axis wind turbines [1,2,3.5.9]. One of the best methods of assessing wind turbine performance is testing a model in a wind tunnel, [1,2,4,6,7,9]. Measurements are made of the output torque applied at the rotor shaft and the speed of rotation at known air speed. An important parameter which must be accounted for is the ratio of blockage area (i.e the ratio of the turbine rotor swept area to the cross section of the wind tunnel). According to Pop and Harper [8] , the tunnel blockage correction factor (e) is given by the following equation:

$$e = 1\backslash 4\ (\text{Model frontal area} \backslash \text{Test section area}) \qquad \text{……… (1)}$$

The model chosen for this investigation had an area ratio of about (1\8) and hence (e=3%) the measured air velocity upstream of the model (which was obtained from measurement of working section reference pressure and the wind tunnel calibration curve prepared when the model was present in the section [8]) was corrected by multiplying by a factor equal to (1.03).

The performance of a wind turbine is usually represent by a relation between the power coefficient (which is a measure of it's efficiency) (C_p) and tip speed ratio () where:

$$Cp = T * w \backslash 0.5 * \rho * v^3 * A \qquad \text{………… (2)}$$

Where : T: output torque, w: angular velocity, A: projected (or swept) area.

$$\lambda = w * R \backslash v \qquad \text{……… (3)}$$

where R: rotor radius .Another important characteristic is the output torque vs. λ. Experience shows that the output turbine power (p) and torque (T) depend on air velocity, air density and viscosity, size of given turbine and it's angular velocity. Performing the dimensional analysis the out put power is given by

$$p = \rho v^3 R^2 \quad f(R_e, \lambda) \qquad \text{………… (4)}$$

$$T = \rho v^2 R^3 \quad f(R_e, \lambda) \qquad \text{………… (5)}$$

For the range of Reynolds number encountered in normal operation it is usually accepted that it's effects are negligible. Thus the output torque and power are mainly functions of tip speed ratio. Dynamic similarity between model and prototype can be achieved if they both have the same tip speed ratio. The torque coefficient C_T is defined by the equation:

$$C_T = T \backslash 0.5 * \rho * v^2 * R^3 \qquad \text{………….(6)}$$

2. Experimental set-up

The details of the model are shown in Fig (1). The semi-cylindrical shield was fixed to the wind tunnel wall while the flat plate rotated about a steel shaft which protruded through the tunnel wall and was rigidly fixed to a small pulley which was used for torque measurement. The torque was also measured by a torque transducer in order to check the accuracy of the small pulley dynamometer which proved to be quite accurate. A stroboscope was used to measure the rotational speed. A magnetic pick-up method was also used (an electrical signal is created once every time the pick-up is approached by tooth of a rotating tooth wheel attached to the dynamometer pulley. The succession of signal is converted electronically into rotational speed). From the measurements of torque and angular velocity, for several air velocities, relations were obtained between the power and output torque with the tip speed ratio. For each air velocity the output torque applied at the rotor shaft was varied from zero to a value close to the breaking torque where the angular velocity was close to zero.

3. Results and discussion

The power coefficient relation with (λ) is shown in Fig (2) for three values of Re. No. (129000, 152000, 173000) based on undisturbed air velocity and rotor diameter. It can be observed that the effects of Reynolds number are negligible range. A similar comment can be made about the torque coefficient in Fig (3)

The measurement of out put torque using thread round a pulley proved to be quite simple and accurate.
The power coefficient of this rotor is low (less than 0.16) however it has advantage of being very simple and cheap in construction. A wind turbine is normally used in open air where air velocity varies and fluctuates. However it's performance may be found easily when tested inside a wind tunnel where the air velocity is controlled at a desired constant value.

4. **Conclusions**

1- Wind tunnel test of wind turbine models are easy to carry out. They give the power and torque coefficient.
2- The flat plate rotor is very efficient but is simple to make.
3- The required measurement are few, namely air velocity rotor rotational speed and output torque.

5. Reference

[1]- Savonious, S. J, (1931). The S- rotor and it is Appliutions. *Mech. Eng*. 53.
[2]- Ahmedi, G.,.(1978). Some preliminary results on the performance of a small vertical axis cylindrical wind turbine. *Wind Engineering*. 1, 2, 74.
[3]- Sivasgaram, S., (1977). Design parameter Affecting the performance of vertical axis rotor. *Wind Engineering*. 1, 3, 207-217.
[4]- Sheldahi, R. E., balackweel, B.F., and L.V. (1978). Wind tunnel performance data for two and three bucket savonious rotor. *Jour of energy*. 2, 3, 160-164.
[5]- Nguyen, D.(1980).Experimental study for the optimization of the performance of the filippini vertical axis wind rotor. *Wind Engineering*. 4, 1, 43-47.
[6]- Khan, H.M.(1978). Model and prototype performance characteristics of savonious rotor windmill. *Wind Engineering*. 2, 2, 75-85.
[7]- Modi, V.J., Roth, N.J., pittal wala A. (1983) . Blade configuration and performance of the savonious rotor with application to an irrigation system in Indonesia. *Trans, ASME*. 105.,
[8]- Pop, A., and Harper, J.J, (1966). Low speed wind tunnel testing. *John Wily, New York*.
[9]- Modi, V.J., Frenado, M.S.U.K.(1989). One the performance of the savonious wind turbine. *Trans, ASME*. 111, 71-81.

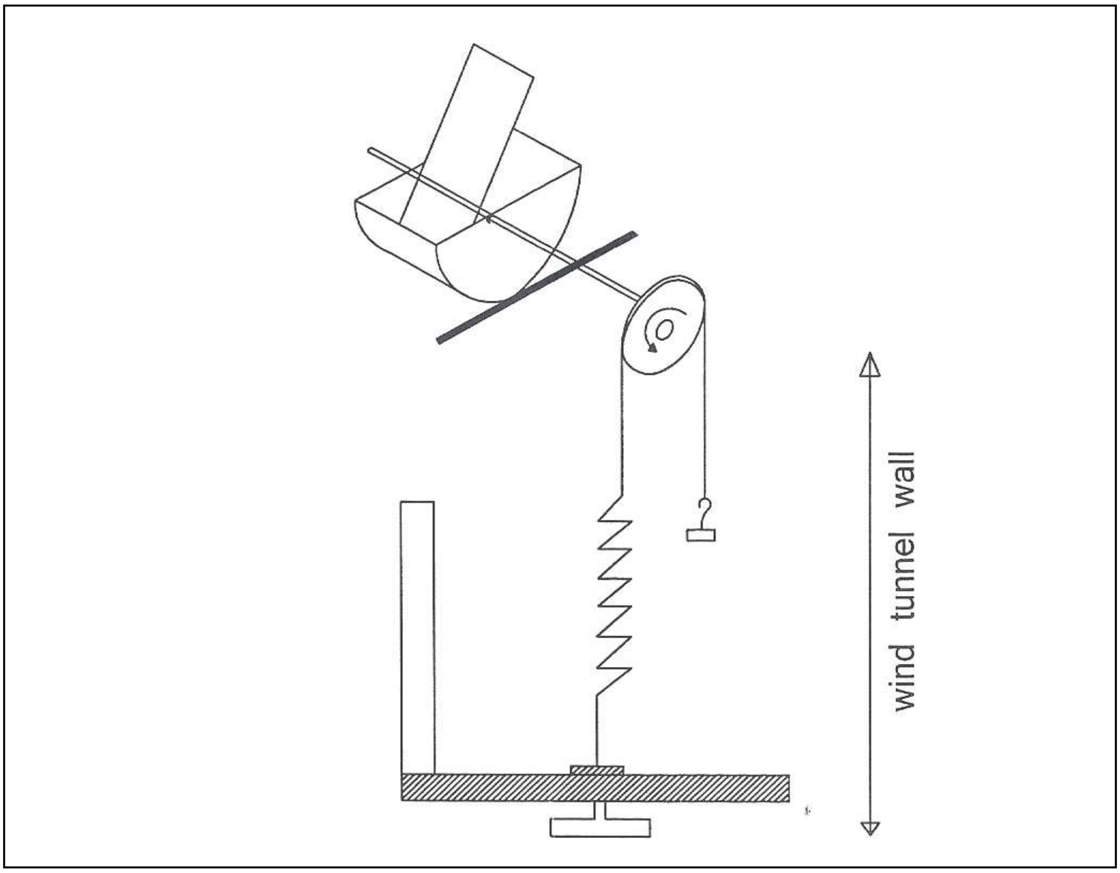


Figure 1. Wind rotor in side wind tunnel

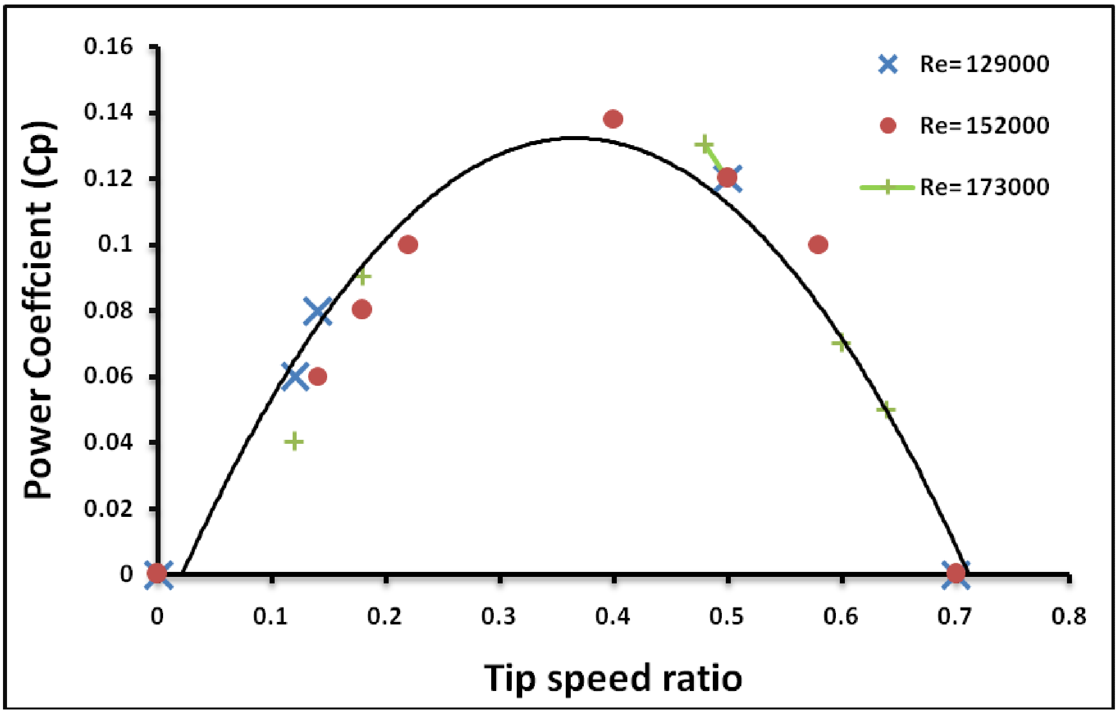
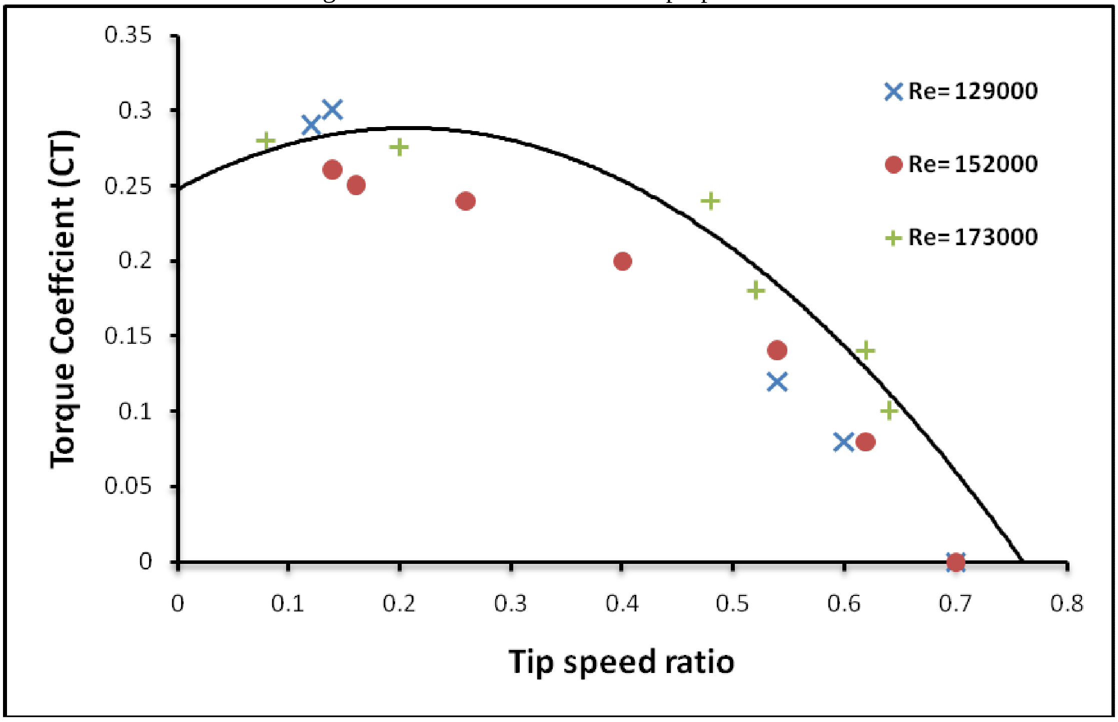


Figure 2. Power Coefficient vs. Tip Speed Ratio



Figur 3. Torque Coefficient vs. Tip Speed Ratio