A STUDY ON WIND TURBINES WORKING ON THE PRINCIPLE OF MAGNUS EFFECT

BY

W.R.G.A. WIJESUNDARA

B.Sc. Eng. (Hons.) (Sri Lanka) ; C.Eng ; M.I.E. (Sri Lanka)

A thesis submitted in fulfillment of the

requirements for the

Degree of Master of Philosophy

DEPARTMENT OF MECHANICAL ENGINEERING

FACULTY OF ENGINEERING TECHNOLOGY

THE OPEN UNIVERSITY OF SRI LANKA

NAWALA, NUGEGODA, SRI LANKA

OCTOBER 2000

ABSTRACT

Conventional wind turbines have been used in many locations in Sri Lanka for harnessing wind energy for many applications, out of which rural electrification is the most important. Wind potential in Sri Lanka is high in the coastal belt and in the Dry Zone and hence these areas are very prospective for wide spread use of wind turbines.

This thesis presents a study for developing a horizontal axis wind turbine working on Magnus effect, incorporating rotating cylinders, to overcome some of the problems in conventional wind turbines, especially problems associated with starting. The design parameters have been selected in such a way that the wind turbine could be used even in regions where low to moderate wind velocities are available. A rotor was designed for a small scale wind energy system with battery charging facility. A theoretical model was developed for the present design and model testing was carried out in a wind tunnel.

The theoretical model was developed based on the momentum theory and blade element theory, as for the case of conventional rotor with aerofoil profile blades. However the conventional theory had to be modified in order to apply for the present design, because instead of local blade angle and chord length the governing parameters were the local radius of the cylinder and its rotational speed. The theoretical analysis indicated that an optimum rotor cannot be obtained with rotating cylinders as in the case of conventional rotors, where the blade angle and chord length can be varied along the span of the blade for the optimum performance. Out of the corresponding parameters, rotational speed of the cylinder and its radius, only the radius can be changed along the span but not the rotational speed of the cylinder. Therefore an "optimum" rotational speed was selected for the performance of the rotor. Further, a rotating cylinder of constant radius was employed for simplicity. The performance of the rotor was predicted through the theoretical model, where the variation of power coefficient with tip speed ratio was given for different velocity ratios (velocity ratio is the ratio between the circumferential velocity of the rotating cylinder and wind speed) . The curves

indicated typical behaviour of wind turbine rotors. The optimum tip speed ratio was found to be 1.5 and the optimum velocity ratio was around 2.7 – 3.

Although the design was targeted for the battery charging application with permanent magnet generator, the results indicated that rotor speed was too low such that a step – up gearing was necessary, which leads to further losses. Therefore, this design is more suitable for high torque, low speed applications. Since the lift coefficient is a function of the velocity ratio, the rotor can be made to start at relatively low wind speeds by rotating the cylinders faster. A maximum value of 9.2 can be obtained for the lift coefficient at velocity ratios greater than five, which is higher than for conventional profiles. Relatively easy construction of the rotor and simpler rotor speed control in high winds are the advantages of the design while the necessity to supply external power to rotate the cylinder is a disadvantage.