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FURTHER DEVELOPMENTS IN THE TAYLOR 'V' TYPE VAWT CONCEPT

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ABSTRACT

This paper describes the development of the Taylor 'V' Type Vertical Axis Wind Turbine (V-VAWT) which was first described at the 1983 ISES Solar Energy Congress in Perth, Australia.

The aerodynamic performance prediction model VAWTTAY has been enhanced in VAWTTAY6. Further wind tunnel tests have been carried out using two-bladed models, and two of these are described. These tests have produced results which are close to the values predicted by VAWTTAY6, and results which have demonstrated that power control of the V-VAWT can be achieved by varying the pitch of the blade tips.

The design of a prototype 5kW machine, that utilises lightweight, composite blades, and the continued development of the V-VAWT concept is discussed.

KEYWORDS

'V' type Vertical Axis Wind Turbine; Double Actuator Disc Theory; Dynamic Stall; VAWTTAY6 Aerodynamic Performance Model; Tip Pitch Control; Wind Tunnel Tests; Wind Energy; Taylor V-VAWT.

INTRODUCTION

Wind energy promises to be one of the first renewable energy sources to be cost-competitive with conventional fuels, but to fulfill this promise wind turbines will need to be reliable and low in cost.

The 'V' type vertical axis wind turbine (V-VAWT) was conceived by Derek Taylor at the Open University, and first described by Sharpe and Taylor [1]. The turbine has an inherent simplicity which could lead to an inexpensive machine that is easy to maintain and highly reliable, Fig. 1.

As well as the usual advantages of VAWTs over horizontal axis wind turbines, the V-VAWT has some additional favourable features. The rotor uses two, or three, straight blades mounted in the form of a 'V' on a short tower (just 3 or 4 metres high), and supported by bracing cables from a central pylon. The blades are straight, untwisted and the planform may be tapered or untapered. The turbine is self starting, which is unusual for vertical axis machines. Aerodynamic control devices such as spoilers, flaps or variable pitch tips can be used to regulate power. This simple arrangement avoids the use of heavy cross arms, a tall tower or curved blades, and allows easy access to the generator, transmission and the rotor itself.

AERODYNAMIC PERFORMANCE

The prediction of the aerodynamic performance of the V-VAWT uses the computer program VAWTTAY [1], which embodies Sharpe's extended multiple streamtube theory and dynamic stall effects [2]. This computer model has been enhanced with VAWTTAY6 to take account of blade inclination, blade shape, blade taper, blade pitch (and twist) and blade tangential offset. A study of the effects of these features on overall performance has been made by Sharpe and Taylor [3] to establish the optimum aerodynamic configuration.

WIND TUNNEL TESTS

A number of model V-VAWTs have been tested in the exit of a straight through, blowdown wind tunnel at Queen Mary College, London. One of these models has been used to check the aerodynamic performance predictions of VAWTTAY6, and one to investigate the variation of tip pitch on overall turbine performance.

The well established acceleration method [4] was used to derive values of rotor torque and power from measurements of rotational velocity in constant wind speed conditions. The test results presented here have been corrected for cable drag, bearing friction and tunnel blockage. Cable drag was the most significant of these corrections and was measured separately.

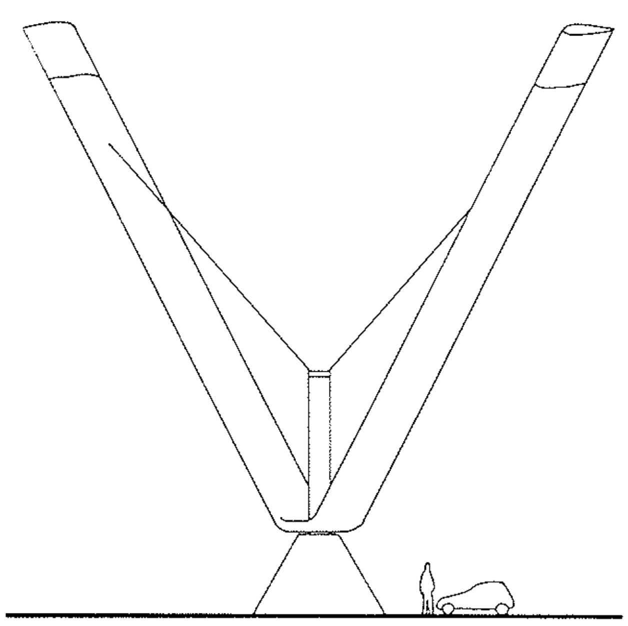

Fig. 1 Two-bladed Fixed Geometry 100kW V-VAWT

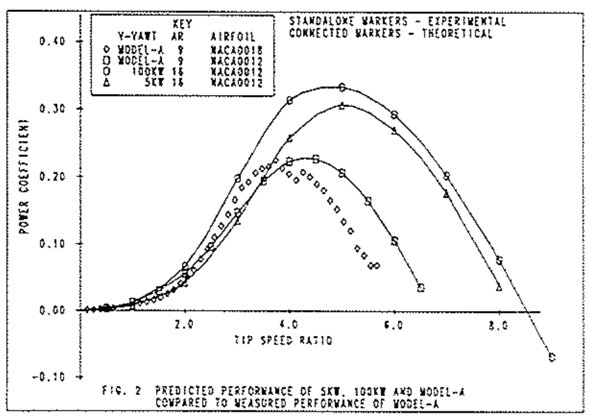

Fig. 2 Measured Cp of Model-A and predicted Cp of 5kW, 100kW and Model-A

The first of these recent models (model-A) had two blades of uniform 60mm chord and were 500mm in length, giving an aspect ratio of nine. Each blade was held at an inclination of 45 degrees to the vertical by a pair of cables attached 120mm from the tip. The blades had a NACA0018 aerofoil cross section.

The wind tunnel test results for model-A at a wind speed of 13.7 m/s are shown in Fig. 2. These are compared with theoretical predictions based on NACA0012 aerofoil data (data for the NACA0018 section has not yet been compiled for use with VAWTTAY6). The small difference between the theoretical and experimental results is due, in part, to the different aerofoil sections. The superior post-stall behaviour at the lower tip speed ratios and the higher profile drag at the higher tip speed ratios of the 18% section is clearly illustrated. A similar difference has been demonstrated by Sharpe and Taylor [3].

These test results were regarded as encouraging and established the aerodynamic prediction model as a useful design tool. Predictions for 5kW and 100kW V-VAWTs using VAWTTAY6, Fig. 2, show that power coefficients in excess of 0.3 can be achieved. The difference between the three theoretical predictions shown in Fig. 2 is due primarily to Reynold's Number effects.

The second model (model-B), Fig. 3, was constructed with two blades of uniform, 80mm chord and a length of 665mm. Each blade was held at an inclination of 45 degrees to the vertical by a pair of cables attached 115mm from the tip. For strength the blades had a NACA0025 aerofoil cross section. Additionally, each blade had a moveable tip portion measuring either 5%, 10% or 15% of the blade area. The pitch angle of each tip portion was adjustable and could be pre-set with either positive, 'nose-in' pitch or negative 'nose-out' pitch. Using this model it was possible to study the effect of the variation of both tip pitch and tip area on overall performance.

The results of the wind tunnel tests are plotted in Fig. 4, and show how tip pitch for tip to blade area ratios of 5%, 10% and 15% affects the performance of the turbine. The results clearly show that 'nose-in' pitch encourages the stall condition, thereby decreasing the developed power of the turbine. Figure 5 shows how the loss of developed power increases as the tip area increases, for a +5 degrees nose-in pitch position.

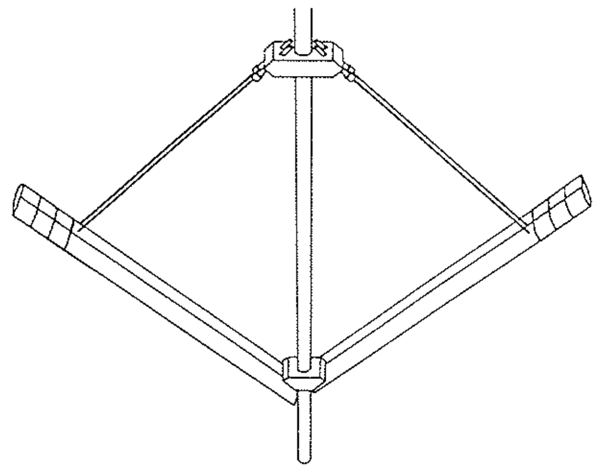

Fig. 3 Model-B: Wind tunnel V-VAWT with pitching tips

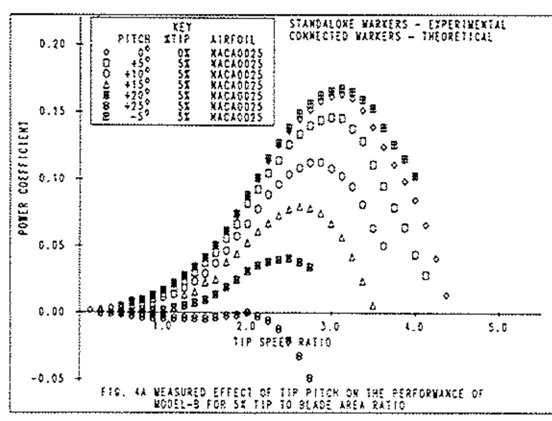

Fig. 4a Measured effect of tip pitch for 5% tip area ratio

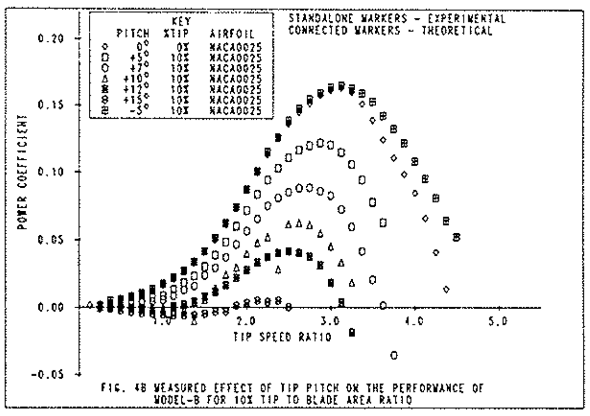

Fig. 4b Measured effect of tip pitch for 10% tip area ratio

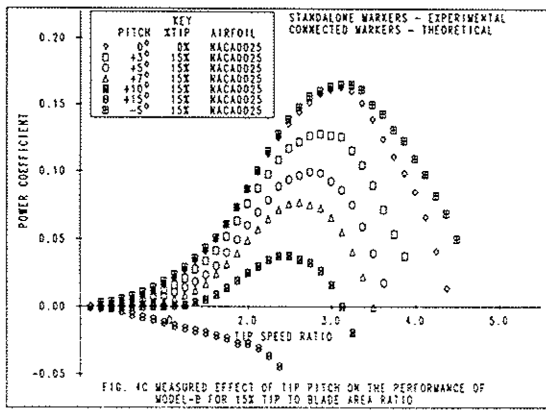

Fig. 4c Measured effect of tip pitch for 15% tip area ratio

It appears that developed power can be increased by small nose-out pitch settings, since in such positions the stall condition is delayed at low tip speed ratios, and drag decreased at high tip speed ratios. From the results for all three tip areas (though not all reproduced here), a nose-out pitch of -5 degrees seems to maximise the developed power. These nose-out results are compared to those for nose-in pitch settings in Fig. 4.

Predictions of turbine performance for different tip pitch positions have been derived from the theoretical model using NACA0012 aerofoil data (data for the NACA0025 section has not yet been compiled for use with VAWTTAY6). While it is not possible to match these predictions to the rest results because of the different aerofoil sections, the effects of nose-in pitch, nose-out pitch and tip area are demonstrated, Fig. 6.

The high starting torque developed by the V-VAWT has been predicted by the theory and confirmed by the results of the wind tunnel tests, Fig. 7.
Also it seems an increase in starting torque is possible with small negative, nose-out pitch positions.

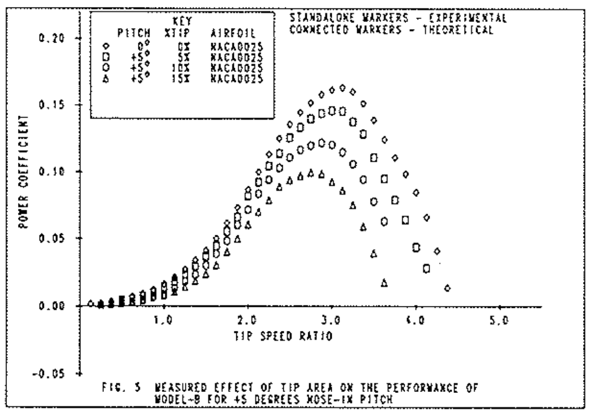

Fig. 5 Predicted effect of tip pitch for +5 degrees nose-in pitch

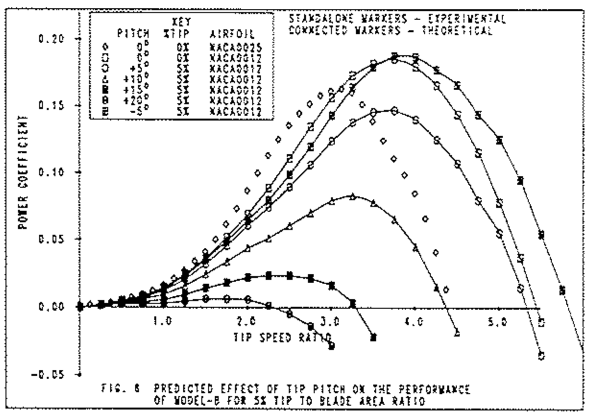

Fig. 6 Predicted effect of tip pitch for 5% tip area ratio

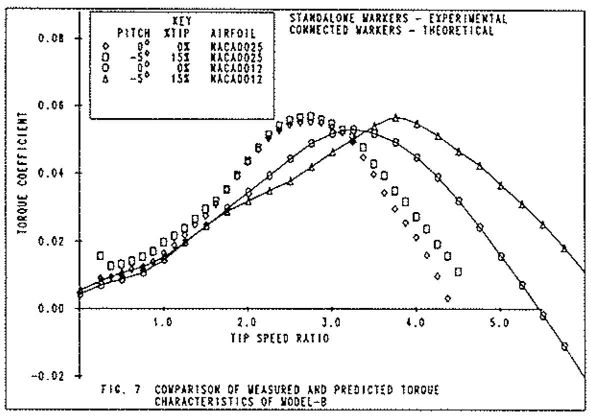

Fig. 7 Measured and predicted torque coefficient of Model-B

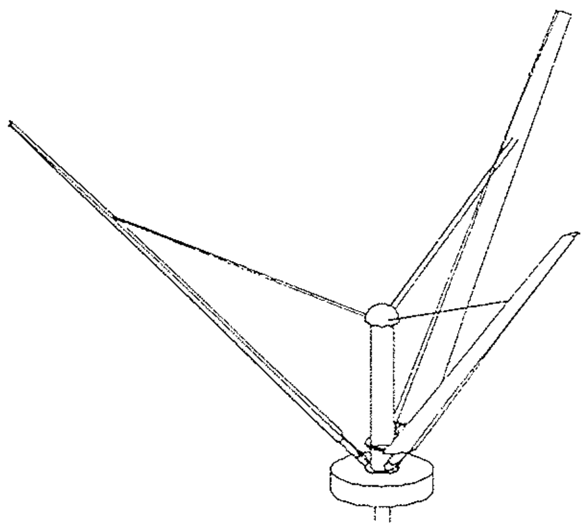

Fig. 8 General view of three-bladed 5kW prototype V-VAWT

FIVE KILOWATT V-VAWT

A 5kW prototype, Fig. 8, has been designed and is scheduled for erection in October 1985. The 5.5 metre blades for this machine are being manufactured by Gifford Technology Limited, at their own cost, from composite materials. The predicted performance of this machine is shown in Fig. 2.

CONCLUSIONS

Recent wind tunnel tests of the Taylor 'V' type vertical axis wind turbine have shown the aerodynamic performance prediction model to be a useful and valid design tool, and that further tests have demonstrated that both overspeed control and power regulation can be achieved by variation of tip pitch. These results are being used for the further development of this VAWT concept, which includes the design and erection of a 5kW prototype V-VAWT.

ACKNOWLEDGEMENTS

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