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Performance effects of attachment on blade on a straight-bladed vertical axis wind turbine

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A R T I C L E I N F O

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A B S T R A C T

Recently, many straight-bladed vertical axis wind turbines (SB-VAWT) are installed in community, urban and high mountain areas as an independent power supply. However, in cold climates, icing, snow and other attachments on the blade surface may affect turbine performance. In this study, the condition of rime-type icing on the leading edge of blade surface was simulated by clay, and the effects on the rotation and power performance were measured by wind tunnel tests and discussed. The results show that the attachment reduced the steady revolution and power coefficient of the SB-VAWT, and the reduction rate increased as the weight of the attachment and wind speed increased.

1. Introduction

Recently, there has been a resurgence of interest in straight-bladed vertical axis wind turbine (SB-VAWT) [1]. Researchers in many universities and institutions have investigated the lift type VAWT, especially in Canada and Japan [2,3], etc. It is usually installed in community, urban and high mountain areas as an independent power supply. This is not only for its advantages of simple design, but also its independence on wind direction as compared to the horizontal system. However, when it is installed in cold regions, the icing, snow and other attachments on the blade surface affect its performance [4]. Therefore, it is important to make the icing mechanism clear and find a way to prevent icing. Experience indicates that the whole blade surface is prone to icing when the wind turbine is immobile; in contrast, the leading edge is prone to icing easily during operation. Although it is known that the types of icing mainly include rime ice, glaze ice and mixed ice, icing on blade surface is very complex and affected by many factors [5]. In this study, rime-type icing on the leading edge of blade surface was solely considered because the situation of rime ice is rather simple and uniform as compared to the glaze ice. Icing on blade surface can be thought of as a kind of attachment; thus, icing was simulated by clay due to its good adhesion and deformability. Wind tunnel tests were performed, and the effects of the attachment on the rotation and power performance were measured and discussed.

2. Experimental details

2.1. Test model

A small model of SB-VAWT with three straight blades was designed and made in this study for wind tunnel test. The NACA0018 aerofoil blade was used. The chord, length of span and rotor diameter was 0.07 m, 0.325 m and 0.3 m, respectively.

2.2. Attachment

Considering that the icing or attachment changed both the blade weight and the blade airfoil, it is necessary to make clear the degree of effect between the two factors on the performance of SB-VAWT. Therefore, it was decided to attach the clay to the blade in one of two possible ways. The condition of clay attached on blade is shown Fig. 1. In the first way, clay was pasted to the surface of the leading edge along span direction. Ten points were selected to measure the shape and thickness so as to ensure an even distribution of clay. In the second way, clay with the same mass as that attached to the blade surface was inserted inside the blade – half at each side of blade. In this case, only the blade weight changed and the blade airfoil kept original shape. For both of the two ways, the clay was solely attached on single blade in this

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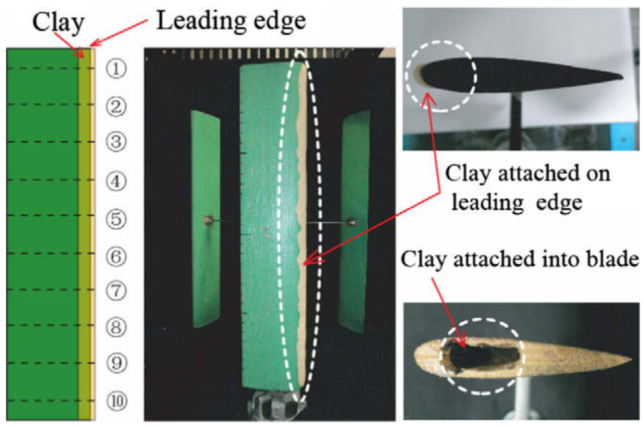

Fig. 1. Position of clay attached on or in blade.

Table 1
Clay attached on or in blade.

Position	Weight (g)	Thickness (mm)
Surface	15 (25% of blade weight) 30 (50% of blade weight)	2 (3% of chord) 4 (6% of chord)
Inner	7.5 at each side (total 15) 15 at each side (total 30)	– –

study. Further, the weight and thickness of clay were two kinds for comparison and listed in Table 1.

2.3. Experimental methodology

Wind tunnel tests were carried out in the Faculty of Regional Sciences of Tottori University in Japan. The wind tunnel is an open type one with an outlet of 0.4×0.4 m. Fig. 2 shows a schematic diagram of the experimental system. The test model was placed at the same center of the wind tunnel outlet and 0.5 m downstream from the outlet. Torque was measured by a digital torque detector which was located between the test model and an induction motor. The main tests included: (1) the effects of attachment on the rotation performance at different wind speeds (U = 5, 5.5, 6, 6.5 and 7 m/s); (2) the effects of attachment on the power performance at the wind speed U = 6 m/s.

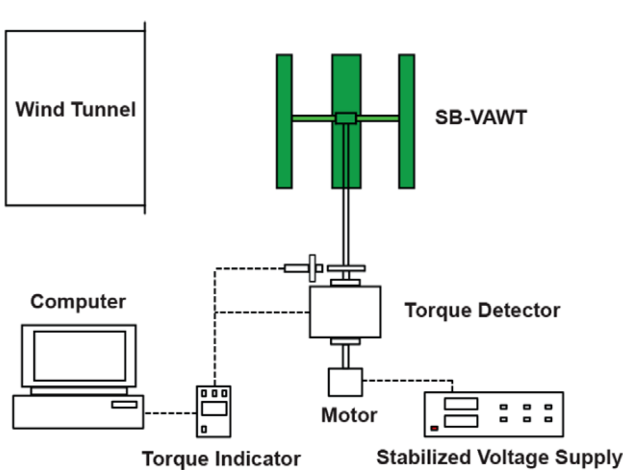

Fig. 2. Schematic diagram of experimental system.

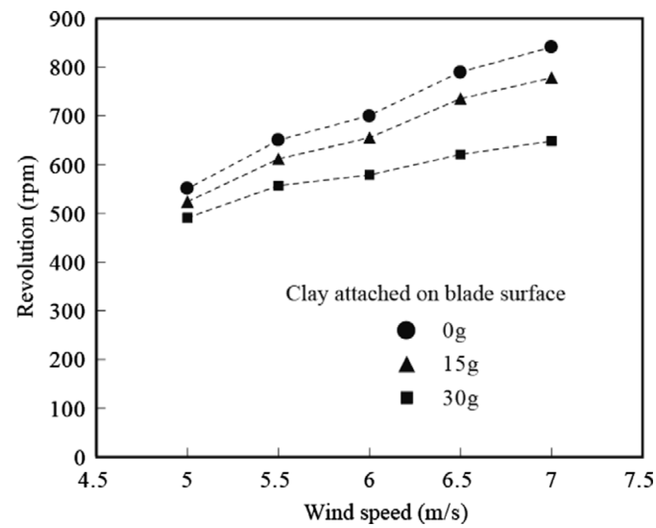

Fig. 3. Steady revolution at different wind speeds.

3. Results and discussions

3.1. Rotation performance

Usually, a wind turbine can generate electric power only when it reaches certain revolution. Therefore, it is important to study the effects of attachment on rotation performance.

Fig. 3 shows the steady revolutions of the rotor with attachment on blade surface at all test wind speeds. The steady revolutions were the averaged value of five tests. Obviously, the steady revolution of the rotor without attachment is the largest at each wind speed compared with the rotor with attachment. Further, although the steady revolutions of the rotor with attachment increased as wind speed increased, the rate of increase fell in the presence of an attachment, and this behavior grew clearer as the mass of clay increased.

As an example, the revolution changes from stop to steady rotor rotation with or without attachment are shown in Fig. 4. The revolution curves of the three cases are similar. However, it is clear that it took longer for the rotor with attachment to reach steady revolution than for the rotor without attachment, and the time delay increased with the clay mass increased.

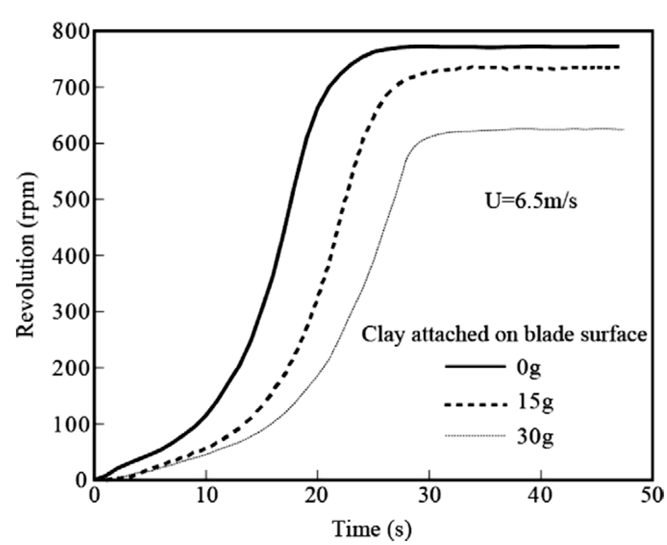

Fig. 4. Revolution changes at wind speed U = 6.5 m/s.