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An experimental study on performance of curved-plate bladed rotor

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ABSTRACT

This paper reports author's experiences of technical assistance for developing countries.

The authors proposed a curved-plate bladed rotors based on the design concept of an appropriate technology. From the wind tunnel test, the highest power coefficients both 3-bladed and 5-bladed rotors are around 0.35 as the same value for high performance solid propeller type bladed rotor. Thus, the proposed curved-plate bladed rotors will have good prospect not only for developing countries, but also for educational materials.

1. Introduction

The world population is expected to grow to some 9 billion around the year 2050. The rapid expansion of the population will bring increase in demand for food, explosion in energy consumption, and pollution of the environment. Therefore, a priority issue for the 21st century is to assure enough energy and water in the developing countries needed for increased agricultural output and to stop population increase at the same time.

From our previous experiences, in technological support for developing countries, there is a concept that can be called "appropriate technology" (AT) which is best fitted to the environment and conditions of the regional society and in answering the needs there. Therefore, the receptive technologies best fitted to the actual conditions in a given developing country must be selected, transferred, and diffused. However, the countries that require technological assistance have multitudes of different conditions and a success of a given country does not assure success in a different country.

For example, when planning to generate electricity using wind turbine, the combination of wind turbines and generators to use will depend on the wind conditions, topological conditions, and the energy needs of the site. Furthermore, the technological level of the region, the available types of windmills or wind turbines, and even the practices and traditions of the local people could affect the design.

As described above, AT does not exist as a universal one as there are no common appropriate technologies applicable to all developing countries. Thus, AT can be traditional or modern, small scale or large scale. Its only quality is that it is perfectly applicable to the individual conditions of the people of the region who need the technology.

Thus, in general, AT means 1. simple design, 2. sing indigenous material, 3. low cost 4. O&M are maintained by local people.

In this paper, the authors present a case of simplified wind rotor based on the concept of the appropriate technology design.

2. Tested blades and rotor

Tested blades were made based on the concept of appropriate technology. Blades were made by aluminum plate of 0.5 mm thickness. The plate were cut by scissors and then bended. Rotor diameter is 600 mm and chord-length at blade tip of two kind of inversely tapered blades, as shown in Fig. 1 of 100 mm (A100) and Fig. 2 of 120 mm (A120).

Numbers of blades were changed 3-bladed rotor or 5-bladed one.

Moreover, the setting angle of each blade were changed from 10° to 25°.

Fig. 3 shows the apparatus for the setting angle with the protractor.

3. Experimental apparatus and method

Figs. 4 and 5 show the experimental apparatus for the rotor test section and the layout of experimental apparatus of the wind tunnel test. The wind tunnel used was of the open-circuit type and has a square exit of cross section 1050 mm × 1050 mm.

The wind speed can be varied in the range from 2 m/s to 20 m/s with a variable speed motor. In order to avoid blockage effect, the

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Nomenclature[1]

A	swept area of the rotor [m^2]
D	rotor diameter [mm]
V	wind speed [m/s]
N	rotational speed [rpm]
P	power [W]
β	blade setting angle [deg]
λ	tip speed ratio [-] [$= \pi ND/(60V)$]
ρ	air density [kg/m^3]
C_p	power coefficient [-] [$= P/(1/2)\rho AV^3$]

[1] Main symbols and units used in this paper are listed below.

Fig. 1. A100 type bladed rotor.

tested rotor was placed about 1 m downwind from the exit of the wind tunnel.

For measuring the wind speed, a Betz type manometer was used at the wind tunnel exit. The load for the wind rotor was connected to the 3 phase 200 V induction motor with 4poles and 6poles. A synchronized frequency was controlled by the inverter. The torque and rotational speed correspond to arbitrary frequency were measured by the torque converter and the revolution counter.

Finally, the torque coefficient, the power coefficient, and the tip speed ratio were calculated from the measured data of the torque and the rotational speed.

4. Experimental results and considerations

The experimental tests in the wind tunnel were conducted by changing the chord-length at blade tip of the blades and the number of the blades. Moreover, the blade setting angle were also changed. Wind speeds were changed from 4 m/s, 6 m/s, to 8 m/s.

4.1. Effect of number of blades and tip chord-length

Figs. 6 and 7 show that the operating range of the tip speed ratio for 3-bladed rotor was higher than that of 5-bladed one.

Fig. 2. A120 type bladed rotor.

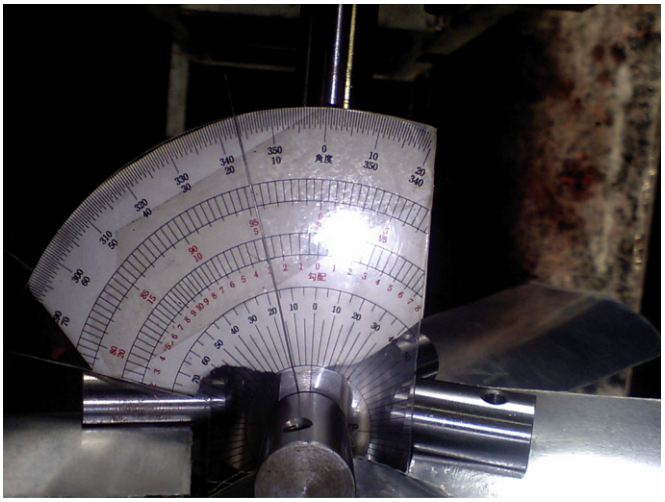

Fig. 3. Apparatus of changing for setting angle.

As for A100 type blades, the maximum power coefficient C_{pmax} for 5-bladed type is a little higher than that for 3-bladed one. On the other hand, as for A120 type, the higher the wind speed, the higher become the C_{pmax} in case of 5-bladed rotor.

4.2. Effect of blade setting angle

Figs. 8–11 show the effect of the setting angle of the blade on the power coefficient of the tested rotor.

As for 3-balded rotor, the highest power coefficient were obtained for setting angle between 13° and 15° among all wind speed of 4, 6, 8 m/s.

On the contrary, as for 5-blade rotor, the optimum blade setting angles were a little larger than 3-balded cases.

There were clear difference between A100 3-bladed rotor and A120 5-bladed rotor.

Then, Figs. 12 and 13 show the effect of the blade setting angle β on the maximum power coefficient C_{pmax}.

As for the 3-bladed A100 type rotor, the larger the blade setting angle β, the lower become the maximum power coefficient C_{pmax}.

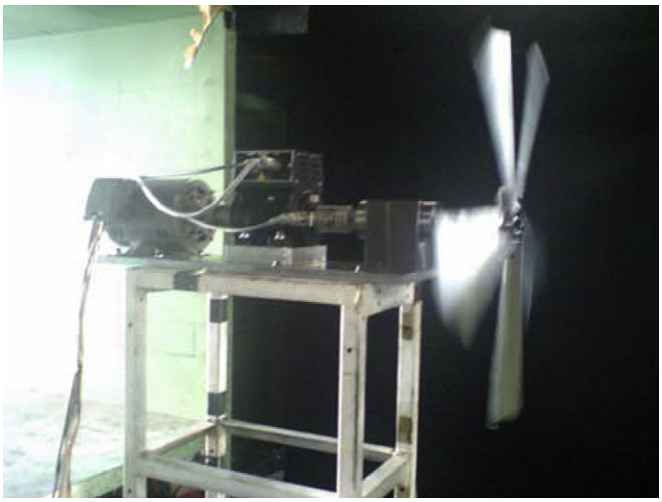

Fig. 4. Experimental apparatus of tested rotor.