AERODYNAMICAL CHARACTER OF MULTI BLADES WINDMILL

Rep. Fac. Sci. Kagoshima Univ., (Math., Phys. & Chem.)
No. 24, p. 43-46, 1991.

AERODYNAMICAL CHARACTER OF MULTI BLADES WINDMILL

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(Received September 10, 1991)

Abstract

According to the worldwide recognition to the[1)] environmental crisis, utilizing of renewable energy such as wind power is increasing. However, windmill now working are almost propeller type suitable for big size in high average wind speed. Our study was done to get the knowledge of multi blades type windmill used for small decentral energy source in low wind speed area.

1 Aerodynamical character of ideal windmill

Wind power is kinetic energy. As well known, kinetic energy of air E with air mass M and flow speed V is

$$E=\frac{1}{2}MV^2$$

In this case, we don't think the fluctuation of wind speed. M depends to flow speed V. M is given as

$$M=\rho V$$

where ρ is density of air. Kinetic energy of air is expressed as

$$E=\frac{1}{2}\rho V^3$$

When wind pass through a windmill, the windmill gets rotating torque and gets pressure toward downstream. Upper stream speed V_1 is decreased to Vm when wind is passing through the windmill. Final down stream speed is V_3. We show the behavior of air current in Fig. 1. But we can't convert all the energy to rotational movement from the wind. From the momentum theory, maximum energy P get from the wind is

$$P=\frac{8}{27}\rho V^3$$

It means any windmill cannot get more than 16/27 of the energy from the wind.

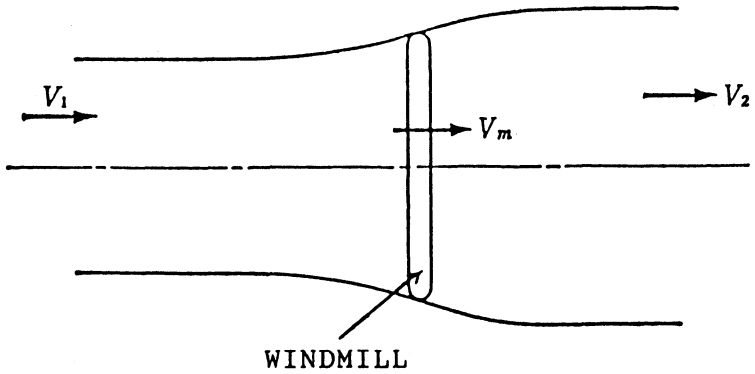

Fig. 1 The behavior of air current. Upper stream wind speed V1 is decreased to Vm when wind is passing through the windmill. Final down stream speed is V3.

2 Problems of windmill technology

From view point of pure aerodynamical efficiency, we can say, closer to the ideal value, it's better windmill. Using low solidity blade with high lift coefficient and low drug coefficient airfoil propeller type mill, we can reach around 0.5. Character of propeller type mill is high rotating speed and low torque. The output power of electro-magnetical generator depends on the velocity when coil run across magnetic field, so propeller type windmill is essentially fit for generation use.

Though propeller type mill has many excellent points on the aerodynamical character, it has many technical problems. Practical propeller type mill needs relatively high wind speed for starting. This means wind speed below cut in speed is not used. This is one of the problem for utilizing in low wind speed area like most of Japan.

On the contrary, multi blades type windmill starts relatively low wind speed and runs high torque with low speed. From the view point of safety, high speed propeller type has latent danger, if man live there like most part of Japan. If we want to spread decentralized energy in Japan, safety is very important factor. Low solidity means few slim blades should withstand the pressure from the wind. Force par every blade is divided by the number of blade. Blade of multi blade type should not be so strong like one of propeller type. Human feeling is also important. Many people don't like a windmill designed only for mechanical efficiency.

Theoretical character of propeller type mill has been investigated[2]. But we have no accurate investigation on that of multi blade type yet. Our study is an experimental work on the quantitative character of multi blade type windmill.

3 Method of experiment

We used whirling device for our experiment. Model windmill was fixed at the top of the arm. Some points are changed or improved since our study of digital type wind speed meter for experimental use[3]. Whirling speed was regulated by feedback system. Time integrated torque meter was newly developed for our experiment. Time integrated data

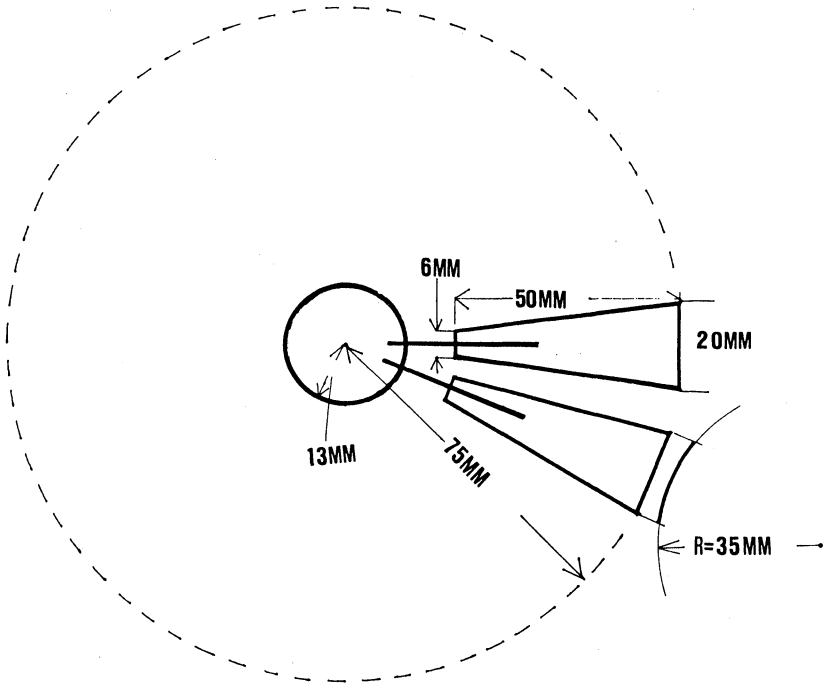

Fig. 2 The shape and size of the model. We used simple none twist 16 blades (constant pitch) with camber of 35 mm radius.

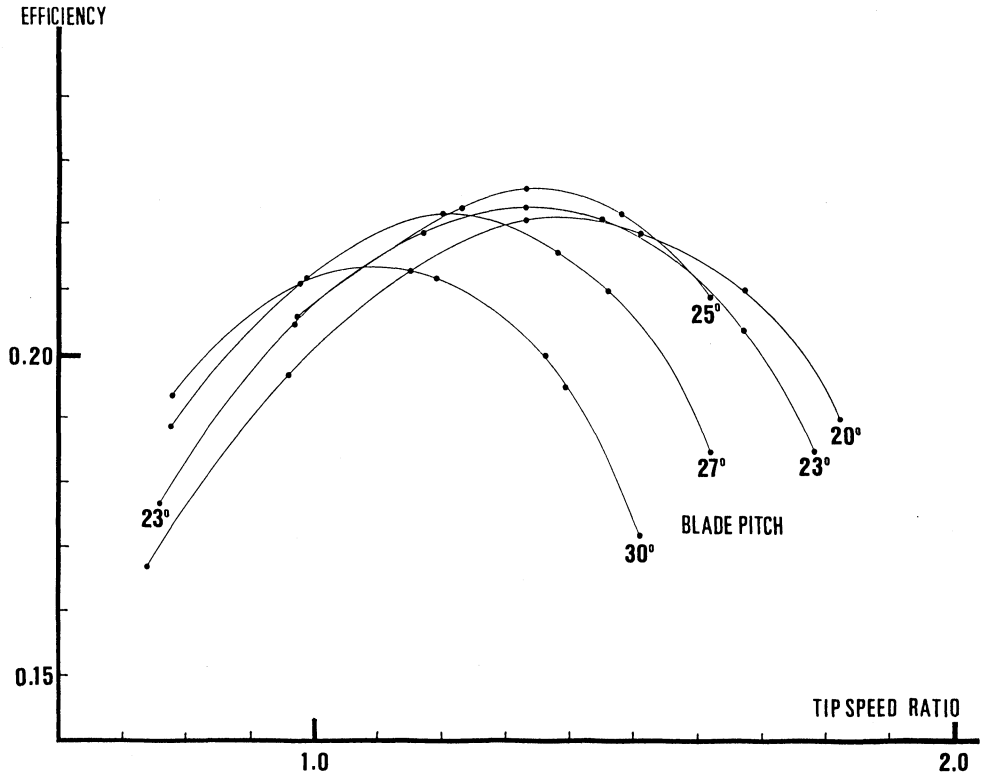

Fig. 3 Characteristic curves of efficiency. Blade pitch is angle in degree between blade plane and sweep plane. Tip speed is velocity of wing tip. Tip speed ratio is the value of tip speed by wind speed.

about rotating speed, torque, whirling speed and elapsed time are expressed on digital display panel. After the measurement, we can calculate time average data on the character of model windmill.

The shape and size of the model is shown in Fig. 2. For our first stage experiment we used simple none twist 16 blades (straight pitch) with camber of 35 mm radius. Many actual working windmills like water pumping mill have similar shape to the model. Tip speed is velocity of wing tip. Tip speed ratio is the value of tip speed devided by wind speed. If a windmill has maximum efficiency at high tip speed ratio, the mill means high speed type. Fig. 3 shows characteristic curve of our model. Blade pitch is angle in degree between blade plane and sweep plane.

4 Discussion

Main purpose of our first stage experiment is to check our newly developed whirling system. Though our system is small, low cost and simple compared to conventional wind tunnel, measured results were satisfactory. We see similar curve to ours in many reports. Our system can be used for study of windmill design. Also, it's useful to decide best wing shape and impedance matching between windmill rotor and load.

Acknowledgments

The author would like to express his sincere gratitude to Mr. M. Matoba, former student of Kagoshima University, for his help in our experiment and in drawing figures.

References

1) T. Hashizume, *Trials for alternative technology about the energy problem,* Rep., Fac., Sci., Kagoshima Univ., No. 14.
2) B. Sørensen, *Renewable Energy,* p. 416–428, Academic Press.
3) T. Hashizume and I. Kawano, *Digital Type Wind Speed Meter for Experimental Use,* Sci. Rep., Kagoshima Univ., No. 33, 1984.