Numerical Study of the blade dynamics for a cross-flow turbine

Yuko Sato [1], ***Tetuya Kawamura*** [2]

1. Graduate school of humanities and sciences, Ochanomizu university, 2-1-1 Ootsuka, Bunkyo-ku, Tokyo, 112-8610, JAPAN, Tel:+81-3-5978-5397, Fax:+81-3-5978-5705, yuko@ns.is.ocha.ac.jp

2. Graduate school of humanities and sciences, Ochanomiz, university, 2-1-1 Ootsuka, Bunkyo-ku, Tokyo, 112-8610, JAPAN, Tel:+81-3-5978-5397, Fax:+81-3-5978-5705, kawamura@is.ocha.ac.jp

Corresponding author ***Yuko Sato***

Abstract

Two and three-dimensional flows around a cross-flow wind turbine are investigated by the numerical simulation. The turbine studied in this paper has cylindrical shape with many small blades along its periphery. Incompressible Navier-Stokes equation is used for this simulation. A rotating coordinate system, which rotates at the same speed of the turbine, is used in order to simplify the boundary conditions on the blades of the turbine. Additionally, a boundary fitted coordinate system is employed in order to express the shape of the blades precisely. A third order upwind scheme is chosen for the approximation of the non-linear terms. When the number of blades is about 10, the highest torque is obtained.

Keyword: *cross-flow, wind turbine, vertical axis*

1. Introduction

Recently, wind energy has received much attention as a natural energy source. A wind turbine is one of the best candidates for getting wind energy. While there are many kinds of wind turbines, they can be classified into two types, i.e. the wind turbines which are rotated by the lift acting on the blades and those rotated by the drag. Since we are interested in environmental problems in arid land, we focus on the turbine of drag-type which can be used for irrigation.

In this study, we look at a cross-flow turbine of cylindrical shape with many blades along its periphery. Since this turbine has a lot of blades, it has less dependence on the wind direction. Despite of the potentiality of the cross-flow turbine, investigations about this turbine are quite few. We proceed to conduct numerical simulations of the flow fields around the cylindrical turbine, and estimate the torque and power coefficients. These information will give us fundamental data for the design of turbines.

2. Computational Method

Since the drag-type wind turbine rotates rather slowly, the flow is governed by the incompressible Navier-Stokes equation. The fractional step method is used for solving these equations. Finite difference method is used to integrate these differential equations. In order to express the shape of the rotor exactly, boundary-fitted coordinate system is employed. The rotational coordinate system is also used so as to include the rotation of the blades naturally. The non-liner term is approximated by the third order upwind scheme since it can compute the flow field stably even at high Reynolds number without any turbulent models

3. Results

Fig.1 shows the cross-flow wind turbine used in this study. Fig. 2 is the present computational grid. Fig. 3 is an example of the flow field around the cross-flow turbine of 12 blades. Fig.4 and fig.5 are the effect of blade number on torque and power coefficient respectively.

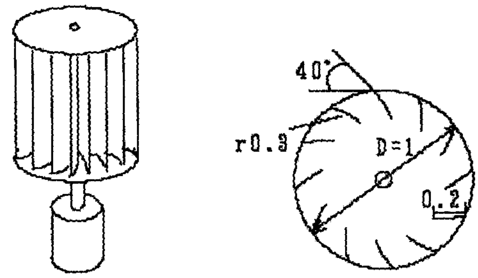

Fig. 1. Schematic figure of cross-flow turbine

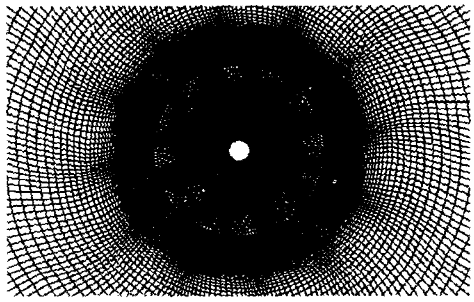

Fig. 2. computational grid

(a) pressure contour (b) velocity vector

Fig. 3. Typical flow fields around cross-flow turbine

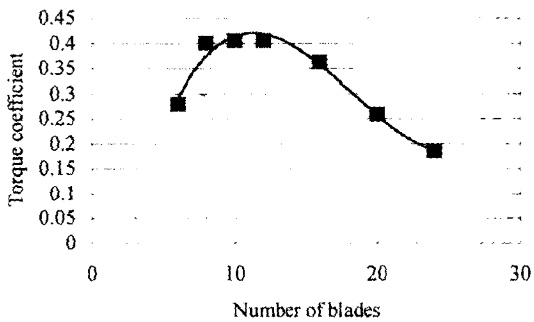

Fig. 4. The effect of blade number on torque coefficient

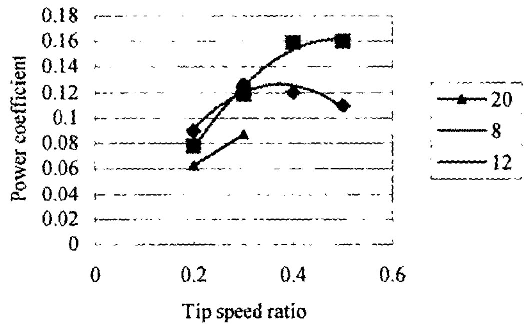

Fig. 5. The effect of blade number on power coefficient

4. Conclusions

In this study, the flow and blade dynamics for cross-flow wind turbine are investigated. Some numerical techniques are examined to treat the complex flow field. The main scientific innovation and relevance are as follows:

(i) To show the effectiveness of numerical method on the study of wind turbines;
(ii) To visualize and understand complex flow field around the turbine;
(iii) To obtain fundamental data for the purpose of the design.

References

[1] M.J. Holgate, et al., "A cross-flow wind turbine", *Proc. International. Symposium*, Wind Energy Systems, B29 (1976), pp 29-38.

[2] T. Kawamura, A. Shinohara, Y. Sato, and M. Kan, "Numerical study of the flow around a cross-flow turbine", *Theoretical and applied mechanics*, Vol. 51(2002), pp 231-240.