THE 5TH ASIAN COMPUTATIONAL FLUID DYNAMICS
BUSAN, KOREA, OCTOBER 27~30, 2003

Numerical Simulation and Visualization of The Flow Around Savonius Rotor

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Abstract

Flow around Savonius rotor is studied by means of the numerical simulation. Three-dimensional incompressible Navier-Stokes equations are solved numerically. Overgrid system is employed in order to enable the flow calculation of complex geometry. The basic equations in each region are solved by using the standard MAC method. The physical quantities such as the velocity and the pressure among each region are transferred through the overlapping region which is common in each region. Some numerical results of static and rotating rotor will be presented.

Keyword: *Savonius rotor, Numerical Simulation, Incompressible Flow*

1. Introduction

The Savonius rotor [1] (Fig 1) is a vertical axis rotor driven by drag forces. It has low rotational speed but it has high torque. Therefore, it is suitable for labor works such as pumping water for irrigation, agitating water for aeration of ponds, and starting up Darrieus rotors. Experimental studies on Savonius rotors have been reported various researchers. All these studies investigated the effects of various design factors on the rotor performance. The main design configuration factors are aspect ratio, overlap ratio, separation gap ratio, profile of bucket cross section, number of buckets, bucket endplates and bucket stacking. We investigate the effect of these configurations by numerical simulation.

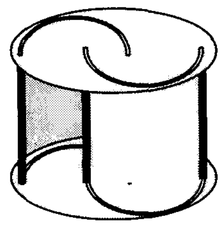
Fig 1. Savonius rotor

2. Numerical Method

For the numerical simulation of rotating body, it is convenient to use the rotating coordinate system, which rotates with the same speed. However, if there is another body that is not rotating or if there are many rotors that rotate at different position and with different speed, it is very difficult to choose one special rotating coordinate system.
In these situations, it is natural to use many coordinate systems separately, which are suitable for the flow simulation around each rotor and connect these coordinates adequately. Therefore, we use domain decomposition method in which the whole computational region is divided into several domains and they are connected adequately (Fig 2).
Since the rotational frequency is low enough, the flow around the Savonius rotor is assumed as incompressible. The basic equations are

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u}\cdot\nabla)\mathbf{u} = -\nabla p + \frac{1}{\mathrm{Re}}\nabla^2\mathbf{u}$$

$$\nabla\cdot\mathbf{u} = 0$$

where Re is the Reynolds number.
We use two computational domains. One domain includes the rotating rotor and another includes the whole domain. Since the shape of the Savonius rotor is semicircular, it is convenient to use a semicircular region. The region including rotors consists of two semicircular regions

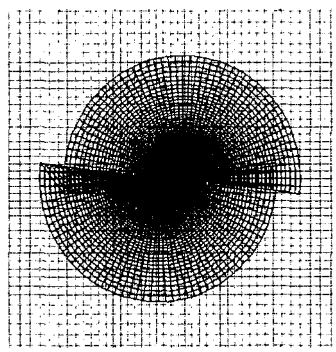
Fig 2. Overlapping grid

whose centers are located at different positions. These two regions are connected by one line which passes two centers. In the outer region, the Cartesian coordinate system is used and the non-uniform rectangular grid is employed.
The grid points don't coincide with each other. The computations in the two domains which have the overlapping region are performed alternatively at every time step. The physical quantities are exchanged through the common overlapping region.

3. Result

Fig 3 is the time averaged power coefficients for various tip speed ratios. The tip speed ration is changed from 0.4 to 1.8. The power coefficient has its maximum value where the tip speed ratio is around 1.0. Pressure contours are presented in Fig. 4.

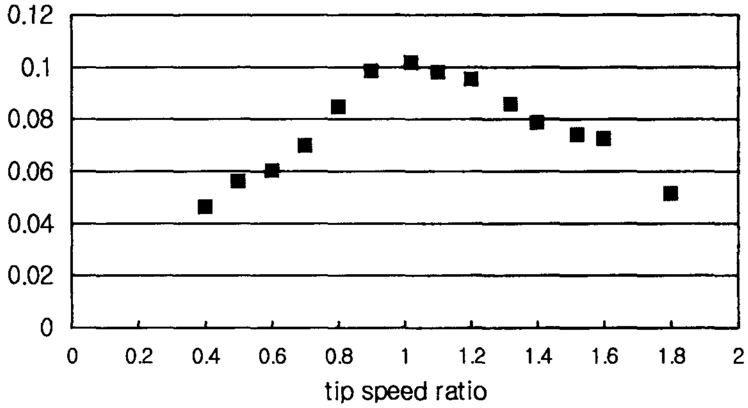

Fig. 3 Power coefficient for various tips speed ratios

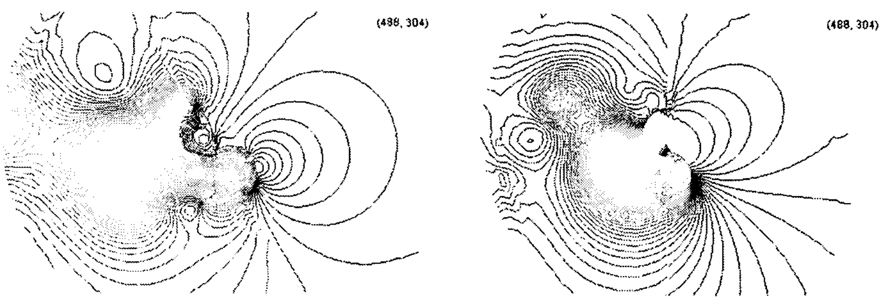

Fig. 4 Pressure contour (attack angle=60 and 90)

References

[1] Sheldahl, R. E., Blackwell, B. F. and Feltz, L. V. " Wind Tunnel Performance Data for Two-and Three-Bucket Savonius Rotors", J.Energy, 2-3, (1978), pp. 160-164