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Field Test of Straight-bladed Vertical Axis Wind Turbine with a Directed Guide Vane Row

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ABSTRACT

A straight-bladed vertical axis wind turbine with a directed guide vane row has been proposed and tested by the authors, in order to overcome the disadvantages of vertical axis wind turbine. However, field test of the proposed wind turbine has not been carried out so far. In the study, performance of straight-bladed vertical axis wind turbine with a directed guide vane row was investigated experimentally in field. The tested wind turbine has some straight rotor blades with a profile of NACA0018, a chord length of 100 mm, a diameter of 1.0 m and a height of 1.5 m. The rated power is 500W.

KEY WORDS: Fluid machinery; natural energy; vertical axis wind turbine; guide vane.

NOMENCLATURE

A	Projected area = $2HR$
C	Chord length of guide vane
C_p	power coefficient = $P/(\rho A V^3/2)$
H	rotor blade height (m)
N	rotational speed of rotor (rpm)
P	power output (W)
R	radius of rotor (m)
U	circumferential velocity of rotor = $R\omega$ (m/s)
V	wind velocity (m/s)
Greek symbols	
λ	rotational speed ratio = U/V
ρ	density of air (kg/m^3)
ω	angular velocity of rotor = $\pi N/30$ (rad/s)

INTRODUCTION

Floating offshore wind farms are being considered for Japanese waters. In such case, in order to control behavior of the float, it is very important to use a vertical axis wind turbine which has low center of gravity. As such wind turbine, a straight-bladed vertical axis wind turbine (this is named "S-VAWT" in the study) has been developed and investigated so far. This turbine consists of several aerofoil vertically mounted on a rotating shaft (Fig. 1). Although the turbine needs a bearing at the top of the structure and has complicated aerodynamic interaction between the downwind blades and the wakes of the upwind blades, it has some advantages in comparison with a horizontal axis wind turbine (HAWT): (1) The center of gravity is relatively lower because the generator and gearbox can be placed on the ground. (2) A yaw mechanism to turn the rotor against the wind is not necessary for the turbine system. On the other hand, however, there are substantial drawbacks of S-VAWT. That is, the power coefficient and self-starting characteristic of S-VAWT are less than those of HAWT.

According to previous studies, the performances of drag-based vertical axis wind turbines, such as Savonius wind turbine and cross-flow wind turbine, can be improved by setting guide vanes around the rotors because the guide vanes in upstream of the rotor work as nozzle and increase torque (Shimizu et al., 1998; Sivasegaram and Sivapalan, 1983). However, it may be considered that the guide vanes in downstream of the rotor prevent airflow from the rotor. In order to overcome the disadvantages of S-VAWT mentioned above, a straight-bladed vertical axis wind turbine with a directed guide vane row has been proposed and tested by the authors (Fig. 1) (Takao et al., 2007; Kuma et al., 2008). The guide vane which consists of arc plate rotates around the rotor and is directed to the wind by aerodynamic force generated by tail vane, so as to put the guide vane in upstream of the rotor. According to previous studies, it was clarified that the performance of the straight-bladed vertical axis turbine can be improved by means of the directed guide vane row (Takao et al., 2007). Furthermore, it has been found by CFD that since the guide vane generates wake in its downstream and increases the whirl velocity of inlet flow to the rotor, as shown in Fig. 2, where red and green dots show clockwise and counter-clockwise vortex elements, respectively (Kuma et al., 2008). However, field test of the proposed wind turbine has not been carried out so far.

In the study, performance of straight-bladed vertical axis wind turbine with a directed guide vane row was investigated experimentally in field. The tested wind turbine has some straight rotor blades with a