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Air Turbine with Self-Pitch Controlled Blades for Wave Energy Conversion

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ABSTRACT

The unsteady characteristics of an air turbine with self-pitch-controlled blades have been investigated by the use of turbine test equipment in which the sinusoidally reciprocating flow conditions are simulated. The results have been compared with those of the Wells turbine. As a result, it has been clarified that the turbine presented here is superior to the Wells turbine both in running and starting characteristics.

NOMENCLATURE

b : blade height
C_A : input coefficient = $2\Delta p_0 Q/\{\rho(v_a^2+U_R^2)blv_a^z\}$
C_T : torque coefficient = $2T_i/\{\rho(v_a^2+U_R^2)blRz\}$
f : frequency of wave
I : moment of inertia of rotor
l : blade chord length
Q : flow rate
R : mean radius of rotor
S : dimensionless frequency = fR/V_a
t : time
t^* : dimensionless time = tf
T_i : output torque
T_L : loading torque
U_R : blade speed at mean radius
v_a : mean axial flow velocity
V_a : maximum value of v_a
X_I : dimensionless moment of inertia = $I/(\pi\rho R^5)$
X_L : dimensionless loading torque = $T_L/(\pi\rho R^3 V_a^2)$
z : number of blades
α : angle of incidence
γ : setting angle
Δp_0 : total pressure drop between settling chamber and atmosphere
$\overline{\eta}$: mean turbine efficiency
θ : pitch angle
v : hub-to-tip ratio
ρ : density of air
σ : solidity
ϕ : incidental flow coefficient = v_a/U_R
Φ : flow coefficient = V_a/U_R
ω : angular velocity
ω^* : dimensionless angular velocity = ω/f

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KEY WORDS: Fluid machinery, wave power conversion, axial flow air turbine, self-pitch-controlled blades, ocean wave, unsteady characteristics.

INTRODUCTION

One of the so-called renewable energy sources which attracts attention especially in Europe and Asia is energy contained in ocean waves. There are various techniques for extracting energy from waves. Some are based on a power train system of hydro-pneumatic-mechanical-electrical energy conversion in which an air turbine is an essential element. A typical example of these techniques is wave energy conversion using an oscillating water column (OWC).

In 1976, Dr. A.A.Wells proposed a form of self-rectifying, axial-flow air turbine, the so-called Wells turbine, as a device suitable for wave energy conversion in an OWC. Many reports investigate the performance of the Wells turbine both on starting and running characteristics (Gato et al., 1994; Inoue et al., 1986a, Raghunathan et al., 1989). According to these results, the Wells turbine has inherent disadvantages: lower efficiency, poorer starting and higher axial thrust in comparison with conventional turbines. Newly devised self-rectifying air turbines have been proposed to overcome these points (Kaneko et al., 1992; Setoguchi et al., 1993).

On the other hand, several types of variable pitch air turbines for wave energy conversion have been presented so far (Sarmento et al.,1987; Salter,1993). The authors have also proposed an air turbine with self-pitch-controlled blades shown in Fig. 1 (Inoue et al.,1989). The air turbine consists of several symmetrical air blades which change the pitch angle by aerodynamic force so as to obtain higher torque in a reciprocating air flow. The turbine is simpler geometrically and inexpensive to manufacture in comparison with the turbines proposed by Sarmento et al. (1987) and Salter (1993). In Inoue et al. (1989), the experimental investiga-

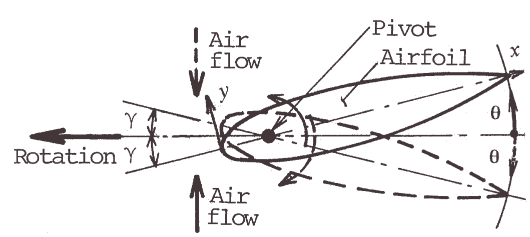

Fig. 1 Scheme of air turbine with self-pitch-controlled blades