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Impulse Turbine with Self-Pitch-Controlled Guide Vanes for Wave Power Conversion: Guide Vanes Connected by Links

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ABSTRACT

Experimental investigations directed towards improving the performance of the impulse turbine with self-pitch-controlled guide vanes for wave power conversion are reported. The turbine presented and tested here has an upstream and a downstream guide vane row connected by links. The behavior of guide vanes in the reciprocating flows is shown in connection with the axial flow velocity. The results show that a high-efficiency impulse turbine can be developed by using guide vanes connected by links. Furthermore, it is found that the running and starting characteristics of this turbine in the reciprocating flow can be estimated from the performance of the turbine with fixed nozzle and diffuser vanes in a unidirectional steady flow.

NOMENCLATURE

b : blade height
C : hub clearance
C_A : input coefficient
C_T : torque coefficient
f : frequency of wave motion
I : moment of inertia
l_g : chord length of guide vane
l : chord length of rotor blade
Q : flow rate
γ_R : mean radius
γ_t : tip radius
S : nondimensional frequency = $\gamma_R f / Va$
t : time
t^* : nondimensional time = tf
T : output torque
T_L : loading torque
U_R : circumferential velocity at γ_R
v_a : mean axial velocity
V_a : maximum value of v_a
X_I : nondimensional moment of inertia = $I/(\pi\rho\gamma_R^5)$
X_L : nondimensional loading torque = $T_L/(\pi\rho\gamma_R^3 Va^5)$
Δp : total pressure drop between settling chamber and atmosphere
η : turbine efficiency
$\bar{\eta}$: mean turbine efficiency
η_m : peak value of η
θ : pitch angle
θ_1 : setting angle of upstream guide vane
θ_2 : setting angle of downstream guide vane
μ : viscosity
ρ : density of air
ϕ : flow coefficient = v_a/U_R
Φ : flow coefficient V_a/U_R
ω : angular velocity of rotor
ω^* : nondimensional angular velocity = ω/f

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KEY WORDS: Fluid machine, guide vane, natural energy, ocean wave, impulse turbine, wave power generator, link.

INTRODUCTION

A Wells turbine is a self-rectifying air turbine expected to be widely used in wave energy devices with an oscillating water-air column. Several reports describe the performance of the Wells turbine both at starting and running conditions (Inoue et al., 1986; Kaneko et al., 1987; Setoguchi et al., 1990). According to these results, the Wells turbine has inherent disadvantages: lower efficiency and poorer starting characteristics in comparison with a conventional unidirectional turbine.

In order to overcome these weak points, the authors proposed an impulse turbine with self-pitch-controlled guide vanes (Kim et al., 1988). The basic design data such as optimum conditions of the turbine rotor geometries were presented with various fixed guide vanes and setting angles under unidirectional steady flow conditions (Kim et al., 1988, 1990; Maeda et al., 1994). This turbine was expected to be superior to the Wells turbine at starting characteristics as well as at design rotor speed. In a reciprocating flow, however, the performance was below what we expected. (Setoguchi et al., 1993).

The objective of this paper is to propose a new type of impulse turbine, one suited for wave energy conversion. The experimental investigations directed towards improving the performance of the impulse turbine with self-pitch-controlled guide vanes are reported. A new type of guide vane arrangement connected by links is presented and tested.