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Effect of Guide Vanes on the Performance of a Wells Turbine for Wave Energy Conversion

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ABSTRACT

In order to improve the performance of a Wells turbine, the effects of the gap between rotor and guide vanes and the solidity of the guide vane have been investigated by model testing. The results have been compared with those of the case without guide vane. It is found that the overall characteristics of the turbine are considerably improved by the guide vanes. A suitable choice of design parameters such as the gap and solidity of the guide vane has been suggested.

NOMENCLATURE

AR : aspect ratio of rotor blade
b : blade height
C_A : input coefficient
C_T : torque coefficient
D : drag
D_t : tip diameter of rotor
f : frequency of wave
G : gap between rotor and guide vane
I : moment of inertia of rotor
l_g : chord length of guide vane
l_r : chord length of rotor blade
L : lift
Q : flow rate
r_R : mean radius of rotor
S : dimensionless frequency $= fr_R/V_a$
SPL : sound pressure level
t : time
t^* : dimensionless time $= tf$
T : output torque
T_L : loading torque
U_R : blade speed at mean radius
v_a : mean axial flow velocity
v_1 : absolute velocity at inlet
v_2 : absolute velocity at exit
V_a : maximum value of v_a
w_1 : relative velocity at inlet
w_2 : relative velocity at exit
X_I : dimensionless moment of inertia $= I/(\pi\rho r_R^5)$
X_L : dimensionless loading torque $= L/(\pi\rho r_R^3 V_a^2)$
z : number of rotor blades
α : angle of attack
β_1 : absolute inlet flow angle
γ : stagger angle
Δp : total pressure drop between settling chamber and atmosphere
$\overline{\eta}$: mean turbine efficiency
ν : hub-to-tip ratio
ρ : density of air
σ_{gR} : solidity of guide vane at mean radius
σ_{rR} : solidity of rotor blade at mean radius
ϕ : flow coefficient $= v_a/U_R$
Φ : flow coefficient $= V_a/U_R$
ω : angular velocity
ω^* : dimensionless angular velocity $= \omega/f$

Subscripts: 1, inlet; 2, exit; a, axial; g, guide vane; r, rotor; R, mean radius.

INTRODUCTION

Several of the wave energy devices currently studied in the United Kingdom, Japan, Portugal, India and other countries make use of the principle of the oscillating water-air column for converting wave energy to low-pressure pneumatic energy which in turn can be converted into mechanical energy by a Wells turbine. This turbine rotates in a single direction in an oscillating airflow and therefore does not require a system of nonreturn valves. Several reports describe the performance of the Walls turbine and factors which influence the performance (Inoue et al., 1986; Kaneko et al., 1986; Setoguchi et al., 1986; Raghunathan et al., 1987, 1994). According to these results, turbine efficiency is lower in comparison with that of the usual turbines. In this case, the guide vanes before and after rotor may be one of the most effective equipment to improve turbine performance.

The performances of the Wells turbine with guide vanes were studied theoretically (Sturge, 1977; Gato et al., 1990) and experimentally (Inoue et al., 1985; Arakawa et al., 1987) under steady operating conditions. But there are many unknown aspects about the favorable configurations of guide vanes.

In this paper, in order to clarify the performance of the Wells

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KEY WORDS: Fluid machinery, guide vane, natural energy, Wells turbine, wave energy conversion, ocean energy.