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Study on an Impulse Turbine for Wave Energy Conversion

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ABSTRACT

The objective of this paper is to describe the performance of an impulse turbine with fixed guide vanes and to compare it with that of the Wells turbine with guide vanes. As a result, a suitable choice of the design factors for the impulse turbine was shown for the inlet angle of rotor blade and the shape of guide vane. Further, it was found that the running and starting characteristics of the impulse turbine were superior to those of the Wells turbine under irregular wave conditions.

NOMENCLATURE

A_c : air chamber cross-sectional area
A_t : turbine flow passage area
b : blade height
C_A : input coefficient (Eq. 4)
C_T : torque coefficient (Eq. 3)
f : frequency of wave motion
$\bar{f}$: mean frequency of wave motion = $1/\overline{T}$
f^* : nondimensional frequency = $f/\bar{f}$
h : wave height in air chamber
h^* : nondimensional wave height in air chamber = $h/H_{1/3}$
H : incident wave height
$H_{1/3}$: significant wave height
H^* : nondimensional incident wave = $H/H_{1/3}$
I : moment of inertia of rotor
l_r : chord length of rotor blade
l_g : chord length of guide vane
N : number of waves
m : A_t/A_c
K : nondimensional period = $r_R m/H_{1/3}$
Q : flow rate
r_R : mean radius
S^* : nondimensional spectrum of wave motion
t : time
t^* : nondimensional time in sinusoidal flow = t/T
$\bar{t}^*$: nondimensional time in irregular flow = $t/\overline{T}$
T : period of wave motion
T_o : output torque
T_L : loading torque
$\overline{T}$: mean period in irregular flow = $1/\bar{f}$
U_R : circumferential velocity at r_R
V : reference velocity = $H_{1/3}/(m\overline{T})$
v_a : mean axial flow velocity
v_a^* : nondimensional axial flow velocity = v_a/V
X_I : nondimensional moment of inertia = $I/(\pi\rho_a r_R^5)$
X_L : nondimensional loading torque = $T_L/(\pi\rho_a v_a^2 r_R^3)$, $T_L/(\pi\rho_a V^2 r_R^3)$
z : number of rotor blades
δ : camber angle of guide vane
Δp : total pressure drop between settling chamber and atmosphere
η : turbine efficiency under steady flow condition (Eq. 5)
$\bar{\eta}$: mean turbine efficiency under sinusoidal flow condition (Eq. 1)
$\tilde{\eta}$: conversion efficiency under irregular flow condition (Eq. 18)
$\tilde{\eta}^c$: efficiency of air chamber (Eq. 12)
$\tilde{\eta}^t$: mean turbine efficiency under irregular flow condition (Eq. 17)
θ : setting angle of guide vane
ν : hub-to-tip ratio
ρ_a : density of air
ρ_s : density of seawater
σ : solidity of rotor at r_R
ϕ : flow coefficient (Eq. 6)
Φ : flow coefficient (Eq. 2)
ω : angular velocity of rotor
ω^* : nondimensional angular velocity in sinusoidal flow = ωT
$\overline{\omega}^*$: nondimensional angular velocity in irregular flow = $\omega\overline{T}$

INTRODUCTION

Several of the wave energy devices currently studied in the United Kingdom, Japan, Portugal, India, China and other countries make use of the principle of oscillating water columns (OWC) for converting wave energy to pneumatic energy, which in turn can be converted into mechanical energy. In this case, the development of the bidirectional air turbine has been problematic. So far, a number of self-rectifying air turbines with different con-

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