

# 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
$\gamma_R$	: mean radius
$\gamma_t$	: 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 $\gamma_R$
$v_a$	: 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 = $T_L/(\pi\rho\gamma_R^3 Va^5)$
$\Delta p$	: total pressure drop between settling chamber and atmosphere
$\eta$	: turbine efficiency
$\bar{\eta}$	: mean turbine efficiency
$\eta_m$	: peak value of $\eta$

$\theta$	: pitch angle
$\theta_1$	: setting angle of upstream guide vane
$\theta_2$	: setting angle of downstream guide vane
$\mu$	: viscosity
$\rho$	: density of air
$\phi$	: flow coefficient = $v_a/U_R$
$\Phi$	: flow coefficient $V_a/U_R$
$\omega$	: angular velocity of rotor
$\omega^*$	: nondimensional angular velocity = $\omega/f$

## 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.

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