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Impulse Turbine with Self-Pitch-Controlled Tandem Guide Vanes for Wave Power Conversion

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ABSTRACT

Experimental investigations directed towards improving the performance of the impulse turbine with self-pitch-controlled guide vanes are reported. Two types of tandem guide vanes are presented and tested: those with variable-pitch flat-plate and those with variable-pitch splitter. The results show that an impulse turbine of higher efficiency can be developed through the use of the splitter. It is found that, in this case, the upstream guide vanes act as a slotted nozzle blade row and the downstream vanes as a tandem diffuser blade row by changing the pitch angle of the splitter automatically in a reciprocating flow. It is also found that the running and starting characteristics of this turbine in the reciprocating flow can be evaluated from the performance of the turbine with fixed nozzle and diffuser vanes in a unidirectional steady flow.

INTRODUCTION

The Wells turbine is a self-rectifying air turbine which is expected to be widely used in wave energy devices with oscillating water-air column. Several reports describe the performance of the Wells turbine both at starting and at running conditions (Inoue et al., 1986; Kaneko et al., 1986; Raghunathan et al., 1982; Sarmento et al., 1987; Setoguchi et al., 1990). According to these results, the Wells turbine has inherent disadvantages: lower efficiency and poorer starting 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 (monovane type shown in Fig. 1). The basic design data such as optimum geometries of the turbine were obtained by model testing of the turbine rotor with various fixed guide vanes and setting angles under unidirectional steady flow conditions (Kim et al., 1988, 1990; Kaneko et al., 1992). This turbine is superior to a Wells turbine in both starting characteristics and design rotor speed, and is less complicated and expensive to design than either a system of rectifying valves proposed by NEL of Glasgow, U.K., or a system using the McCormick turbine (Richard et al., 1986). However, the performance was not so superior to the Wells turbine in a reciprocating flow, contrary to our expectation. This was due to the deterioration of diffuser efficiency caused by the movement of downstream guide vanes in the process of changing axial flow velocity (Setoguchi et al., 1991).

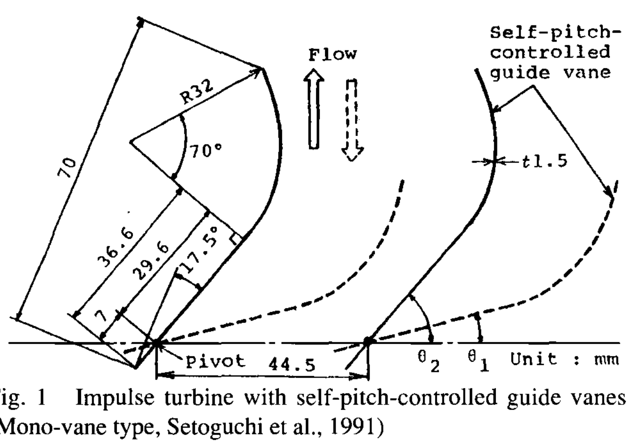

Fig. 1 Impulse turbine with self-pitch-controlled guide vanes (Mono-vane type, Setoguchi et al., 1991)

The objective of this paper is to propose a new type of impulse turbine which is 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. Two types of impulse turbine with tandem guide vanes are presented and tested: those with variable-pitch flat-plate and those with variable-pitch splitter.

EXPERIMENTAL METHOD AND PROCEDURE

The test rig consists of a large piston-cylinder, a settling chamber and a 300-mm-dia test section with a bell-mouth entry and a diffuser exit. The details are shown in Setoguchi et al., (1991). The impulse turbine rotor with hub-to-tip ratio of 0.7 was placed at the center of the test section and tested at a constant rotational speed under the condition of sinusoidal change of axial velocity. The flow rate evaluated by integrating the flow velocity over a cross-sectional area was measured by a Pitot tube survey. The overall performance was evaluated by the torque T, the flow rate Q, rotor angular velocity ω and the total pressure drop between settling chamber and atmosphere Δp. Tests were performed with Δp in the range of 200 to 800 N/m^2, ω up to 370 rad/s, and Q up to 0.63 m^3/s. The Reynolds number based on the blade chord was approximately equal to 0.4×10^5 at peak axial velocity. The uncertainty of mean efficiency $\bar{\eta}$ (the definition will be shown later) is about ±2%.

Two types of self-pitch-controlled tandem guide vanes tested are illustrated in Figs. 2a and b. One has a configuration similar to

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KEY WORDS: Fluid machinery, guide vane, wave, impulse turbine, tandem blade, wave energy, wave power generator.