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Effect of Turbine Geometry on the Performance of Impulse Turbine with Self-Pitch-Controlled Guide Vanes for Wave Power Conversion

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ABSTRACT

This paper concerns the development of an impulse turbine with self-pitch-controlled guide vanes, which was proposed by the authors to be used as a wave power generator. In order to clarify the effects of the rotor blade profile and guide vane pitch/chord ratio on the characteristics of this turbine, experimental investigations were performed using a small-scale turbine. These include three types of turbine blade rotors with different blade inlet angles γ and two types of guide vanes, that is, the splitter type and mono-vane type. The results show that a high-efficiency impulse turbine can be achieved for a rotor blade profile with $\gamma = 60°$. It is also found that, in this case, the optimum pitch/chord ratio of the guide vane (Sg/lg) is about 0.8 for the splitter type, and $Sg/lg < 0.65$ for the mono-vane type.

INTRODUCTION

A Wells turbine is a self-rectifying air turbine which is expected to be widely used in wave energy devices with an oscillating water-air column. The Wells turbine has, however, inherent disadvantages: lower efficiency and poorer starting in comparison with a unidirectional turbine (Inoue et al., 1986; Kaneko et al., 1986; Raghunathan et al., 1982; Setoguchi et al., 1990).

In order to overcome these weak points, a number of impulse turbine for wave power conversions have been presented so far. The McCormick turbine is one of them. It was constructed and tested (Richard et al., 1986), and the average efficiency near 0.3 appears to have been attained. Furthermore, the authors proposed an impulse turbine with self-pitch-controlled guide vanes (mono-vane type). The basic design data for the turbine were obtained by model testing of the turbine rotor with fixed guide vanes and setting angles under unidirectional steady flow conditions (Kim et al., 1988, 1990; Kaneko et al., 1992). According to these results, this turbine is superior to the Wells turbine in both starting characteristics and design rotor speed. However, its performance was not so superior to that of a Wells turbine in a reciprocating flow. This was due to a deterioration of diffuser efficiency in the process of changing axial flow velocity(Setoguchi et al., 1991). In order to overcome the weak point, a new type of impulse turbine using a tandem guide vane was proposed and tested by the authors (Setoguchi et al., 1992). The results showed that a high-efficiency impulse turbine could be developed through the use of tandem guide vanes with a variable-pitch splitter. As the results were obtained for a rather high pitch/chord ratio of guide vane in these studies (Setoguchi et al., 1991, 1992), it is necessary to investigate the effect of the pitch/chord ratio. Furthermore, the following investigation is required from the viewpoint of the rotor blade profile. According to Kim et al. (1990), the elliptic profile, which has the wider flow passage at midchord portion than at the inlet and outlet portions, is superior to the simple profile with constant passage width between the neighboring blades. But the effect of blade angle has not been clarified.

The objective of this paper is to clarify the effects of the guide vane pitch/chord ratio and rotor blade profile on the characteristics of the impulse turbine with self-pitch-controlled guide vanes. The experiments were carried out by model testing of the turbine rotor with fixed guide vanes under unidirectional steady flow conditions, since the performance of this turbine in a reciprocating flow can be evaluated by quasi-steady analysis (Setoguchi et al., 1992).

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 bellmouthed entry and diffuser exit (Maeda et al., 1994). 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 steady flow conditions. The overall performance was evaluated by the torque T, the flow rate Q, the rotor angular velocity ω and the total pressure drop Δp from the settling chamber to the atmosphere. 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

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