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Air Turbine with Staggered Blades for Wave Power Conversion

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ABSTRACT

In a self-rectifying air turbine for wave energy conversion, it is reported that the rotor encountered different maximum velocities between the inhalation and exhalation processes of the oscillating water column. This paper describes the development of an efficient turbine suitable for such actual asymmetric flow conditions. The air turbine with staggered blades has been presented and investigated experimentally by model testing under steady flow conditions. The running and starting characteristics under pseudo-sinusoidal oscillating flow conditions were then clarified by using a quasi-steady analysis. As a result, it is found that the air turbine with staggered blades is superior to the Wells turbine, and a suitable choice of design factor has been suggested for the preset angle of the rotor.

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 column (OWC). Many reports describe the performance of the Wells turbine, including both starting and running characteristics (Gato and Falcão, 1988; Inoue et al., 1986a and b, 1988; Raghunathan and Tan, 1982; Setoguchi et al., 1998; Takao et al., 2001, White, 1995). According to these results, the Wells turbine has inherent disadvantages in comparison with conventional turbines: lower efficiency, poorer starting and higher noise level. In order to overcome these disadvantages, new turbines for wave power conversion have been developed and studied in some countries, including Japan.

Conversely, a number of wave energy plants based on an OWC has been constructed and tested in Japan, India and other countries (Falcão et al., 1993; Miyazaki, 1993; Santhakumar et al., 1998; Thorpe, 2001; Washio et al., 2000). Observation in some of the plants led to the report that the maximum value of axial airflow velocity during exhalation (i.e., flow from air chamber to atmosphere) was higher than that during inhalation (i.e., from atmosphere to air chamber). Fig. 1 shows the flow rate Q measured with time in the wave energy plant of the National Institute of Ocean Technology of India (NIOT) (Santhakumar et al., 1998). The positive sign Q corresponds to exhalation. This phenomenon means that the supply of pneumatic energy during exhalation is higher than that during inhalation at the wave energy plants. In this case, it is not necessary that the self-rectifying turbine have symmetrical configuration with respect to the plane perpendicular to the rotor axis. It can be considered that the performances of an air turbine with staggered blades as shown in Fig. 2 (i.e., $\gamma > 0°$) may be superior to those of the Wells turbine (i.e., $\gamma = 0°$) under realistic flow conditions, because it is possible to obtain high turbine efficiency during exhalation if $\gamma > 0°$. However, the performances of the turbine with staggered blades have not yet been clarified.

In this study, in order to improve the performance of the Wells turbine in the asymmetric reciprocating flow, the air turbine with staggered blades has been investigated experimentally by model testing. The experimental investigations have been performed under steady flow conditions. Then, the running and starting characteristics under asymmetric reciprocating flow conditions were then clarified by a computer simulation using a quasi-steady

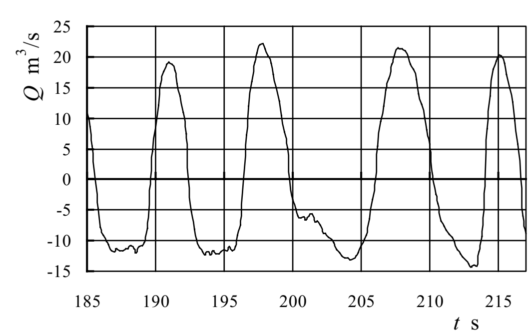

Fig. 1 Time series data for flow rate at wave energy plant constructed by National Institute of Ocean Technology, India (Santhakumar et al., 1998)

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