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Effects of Shape Parameters of OWC Chamber in Wave Energy Absorption

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ABSTRACT

Oscillating wave amplitude in a bottom-mounted OWC chamber designed for wave energy converter is investigated by applying characteristic wave conditions in Korean coastal water. The effects of shape parameters of OWC chamber in a view of wave energy absorbing capability are analyzed. Both experimental and numerical approaches are adopted and their results are compared to optimize the shape parameters which can result in a maximum power production under given wave distribution. The experiment was carried out in a wave flume under 2-D assumption of OWC chamber. In numerical scheme, the potential problem inside the chamber is solved by use of the Green integral equation associated with the Rankine Green function, while outer problem with the Kelvin Green function taking account of fluctuating air pressure in the chamber. Air duct diameter, chamber width, and submerged depths of front skirt and back wall of chamber changes the magnitude and peak frequency of wave absorption significantly. We applied the approach to OWC chamber design of Chagwi-Do wave energy converter which is planned to be installed in Jeju, one of the most promising wave power generation sites in Korean coastal water.

KEY WORDS: Oscillating water column; wave energy absorption; air chamber; pneumatic damping; wave resonance

INTRODUCTION

The efficiency of wave energy conversion is one of the most important criteria in the successful development of wave energy converters. The pneumatic device with oscillating water column (OWC) has been widely used in wave energy conversion in recent years, and its efficiency greatly relies on effective wave energy absorption in an air chamber. Since the OWC type wave energy converter utilizes the wave resonance in air chamber to maximize air flow and the resonance is closely related to incident wave conditions, the shape of air chamber should be optimized by considering wave climate in an installation site.

The primary objective of optimal design of OWC air chamber is to maximize the total extraction of wave energy from a distributed incident wave field. Thus, an optimal air chamber requires not only a high peak of resonance amplitude but also a broad bandwidth of efficient wave frequency. The theory of wave energy absorption by the oscillating water column (OWC) devices was developed by Evans (1982) and Sarmento and Falcão(1985) for fixed devices. Hong et al.(2004) extended it to the floating device. Experimental verification based on scaled models was carried out by Sarmento(1993) and Holmes et al.(1995). Folley and Whittaker(2001) performed a small scale experiment on LIMPET and then they identified the difference between LIMPET's performance and prediction by linear wave theory(Folley and Whittaker, 2002). While most efforts in numerical modeling of OWC hydrodynamics(Evans and Porter, 1995; Brito-Melo et al., 1999; Wang et al., 2002) employed linear wave theory, Clement(1996) applied nonlinear numerical modeling to quantify the nonlinear hydrodynamics of OWC chamber as a function of shape parameters. Also, Mingham et al.(2004) suggested two-fluid modeling of OWC free surface motion. Recent studies of Weber and Thomas(2004) and Falcão(2004) concentrated on the optimal design of OWC chamber for maximum production with respect to stochastic sea states.

The internal wave motion in air chamber is governed by its shape parameters such as chamber width, depth and thickness of front skirt, size of air duct, slope of bottom and pneumatic volume of air chamber. In present study we investigated effects of shape parameters of bottom-fixed OWC chamber in terms of internal wave amplitude and converted wave power both experimentally and numerically. In numerical approach, the oscillating surface pressure in the OWC chamber is represented by a product of the air-flow velocity and an equivalent linear damping coefficient. In principal, the equivalent linear damping should be given as a function of the air-turbine characteristics which cause a nonlinear pressure drop. An iterative solver can be applied to consider the nonlinear effect correctly by updating the damping parameter. In this paper, instead of the iteration scheme, the equivalent linear damping is given as a parameter for numerical tests. The time-mean internal wave amplitude, absorbed power and reflection coefficient of the device are then calculated for various values of the linear damping parameter. The absorbed powers are calculated by both the near-field and far-field methods.