Numerical Investigation of the Hydrodynamic Performance of the Dual-chamber Oscillating Water Columns

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ABSTRACT

The dual-chamber oscillating water column (OWC) is considered in this study. The device has two sub-chambers with a shared orifice. A fully-nonlinear numerical wave flume based on the potential-flow theory is applied for the simulation. At various wave conditions, effects of the chamber geometry (i.e. the draft and breadth of two chambers) on the hydrodynamic efficiency of the OWC device are investigated numerically. The hydrodynamic efficiency of the dual-chamber OWC is compared with that of the single-chamber one. The dual-chamber device shows a higher efficiency near the resonant frequency. Then, effects of the breadth and draft of two sub-chambers are discussed. It is observed that a proper set of two sub-chambers can increase the general hydrodynamic efficiency of the OWC device.

KEY WORDS: OWC; Dual-chamber; HOBEM; Hydrodynamic Efficiency; Fully nonlinear.

INTRODUCTION

Due to their non-polluting nature and environment friendliness, renewable energies have gained great deal of attention and deserve a substantial body of research. The wave energy as an important type of renewable energy has drawn people’s attention for several decades (Dizadji and Sajadian, 2011). Thousands of prototypes of Wave Energy Converters (WECs) have been developed for many decades now for exploiting the energy of the ocean waves (Vyzikas et al., 2017). Featured by high efficiency and structural simplicity, the OWC device becomes one of the most favorable wave energy converters (Delauré and Lewis, 2003).

In recent decades, a great volume of researches has been carried out to investigate the efficiency of OWCs analytically (McCormick, 1976; Evans, 1978; Falcão and Sarmento, 1980; Evans, 1982), numerically (Zhang et al., 2012; Luo et al., 2014; Ning et al., 2015) and experimentally (Morris-Thomas et al., 2007; Falcão and Henríques, 2014; Murakami et al., 2016; Ning et al., 2016a), most of which focus on the single chamber device. For the single chamber OWC, it has been recognized that the maximum power absorption occurs only when the frequency of incident waves is close to the resonance frequency of the OWC chamber (Morris-Thomas et al., 2007; El Marjani et al., 2008; Sahinkaya et al., 2009; Iturrioz et al., 2015). To enhance the performance of the OWC devices, the multi-chamber OWC concept has been proposed. The principle of double chamber OWC device’s operation has been extensively studied by Boccotti, (2007), Boccotti et al. (2007) and Wilbert et al. (2014). They observed that relative opening depth along with asymmetry value have strong effects on hydrodynamic energy conversion capacity of the device. Rezanejad et al. (2013) and Rezanejad et al. (2015) analytically and numerically analyzed the hydrodynamic efficiency of a dual-chamber OWC placed over stepped bottom. They found that by considering dual-chamber OWC device on the stepped sea bottom, the performance of the device can be improved significantly in wide range of frequencies, as compared with the single chamber case.

This paper considers a dual-chamber OWC by a fully nonlinear numerical model. The device has two chambers with a shared orifice as shown in Fig. 1. At various wave conditions, effects of the chamber geometry (i.e. the draft and breadth of two chambers) on the hydrodynamic performance of the OWC device are systematically investigated. The following contents are organized as follows. The numerical model is described in section 2. The relating results and discussions are given in section 3. Finally, conclusions are shown in section 4.

NUMERICAL MODEL

To investigate the hydrodynamic performance of the proposed dual-chamber OWC device, the two-dimensional fully nonlinear numerical model based on the potential theory and the time-domain HOBEM by Ning et al. (2015) is extended here to simulate the interaction of the wave and the dual-chamber OWC device by adding a barrier wall in the single chamber device. The sketch of the flume is shown in Fig. 1. A Cartesian coordinate system Oxz is used with its origin on the still water level, and the z-axis pointing upward. The averaged water depth is denoted by h. h1 and h2 are two chamber breadths. c1 and c2 represent thicknesses of two barrier walls. d1 and d2 are chamber draughts. Ls is the length of the sponge layer. Sc is the breadth of the orifice, and hc is the height of the chamber above the still water level.