Numerical investigation on dynamic performance of a fixed OWC wave energy device under solitary wave

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ABSTRACT

The oscillating water column (OWC) wave energy converter (WEC) was widely applied to capture the wave energy due to its structural simplicity and reliability. However, there are few published literatures on its survivability under extreme sea conditions. This paper presents the dynamic performance of a typical land-fixed OWC device under solitary waves. The 3D numerical model is established based on the open-sourced code, i.e., OpenFOAM. The Navier-Stokes equation is solved by PIMPLE algorithm and the VOF (Volume-of-Fluid) technique is applied to track the free surface between air and water. The numerical model is validated with the experiments carried out at a wave flume at Dalian University of Technology. It is found that there are two peak crests and one fluctuation in the time-history of the total horizontal wave force on the OWC device. The second peak crest induced by the overflow phenomenon is slightly larger than the first one caused directly by the solitary wave action. The total horizontal force increases with incident wave heights ($H$) and has a turning point at $H = 0.12m$ due to the occurrence of the overtopping.

KEY WORDS: OWC; solitary wave; numerical simulation; VOF; wave force.

INTRODUCTION

A tsunami disaster is one of the most devastating natural hazards which propagates onshore in a variety of waveforms (Kawashima and Buckle, 2013). It not only causes loss of life, but also destroys infrastructures near the coast. There are substantial researches related to the interaction between the tsunami and coastal structures (e.g. the breakwater (Saelevik et al., 2013), monopiles used in wind industry (Mo et al., 2013)). Nevertheless, the influence of tsunami on the oscillating water column (OWC) wave energy converters (WECs) has not been well established to the author known.

A typical OWC device mainly consists of a hollow chamber which is partly submerged in water (Ning et al., 2016). The water column enclosed by the chamber moves up and down periodically, then it drives the air flown in/out through the turbine to generate the electric power. The main difference between the OWC-WECs and other traditional marine energy structures is the existence of the air chamber. This means that the strong nonlinear aerodynamic loads have the significant influence on the device. The previous studies on OWC devices mainly consisted of following aspects, the design of structures (Delauere and Lewis, 2001; Ning et al., 2015), the turbine optimization (Falcao, 2002; Lopez et al., 2014) and the dynamic wave loads under the normal sea conditions (Koo and Kim, 2010; Wang et al., 2020) etc. For example, a sloshing mode and a significant increase of hydrodynamic pressure on a stationary cylindrical-type OWC-WEC were excited by the resonance of second-order component. This effect cannot be ignored at low frequency long waves (Zhou et al., 2021). The hydrodynamic performance of a fixed OWC-WEC under various wave conditions and geometric parameters was tested experimentally by Ning et al. (2016). It is found that the opening ratio $S_i/S_o$ (where $S_i$ is the area of the air orifice, $S_o$ the area of back wall above the static