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Practical Calculation of Parabolic Overtopping Wave Energy Converter

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ABSTRACT

Overtopping Wave Energy Convertor (OWEC) is an offshore wave energy convertor for collecting the overtopping waves and converting the water pressure head into electric power through the hydro turbines installed in the vertical duct which is fixed in the sea bed. The numerical wave tank based on the commercial computational fluid dynamics code Fluent is established for the corresponding analysis. The Reynolds Averaged Navier-Stokes and two-phase VOF model are utilized to generate the 2D numerical linear propagating waves, which has been validated by the overtopping experiment results. Several incident wave conditions and shape parameters of the overtopping device are calculated. The straight line type and parabolic type of the sloping arm are compared in the optimal designing investigation of the overtopping characteristics and discharge for OWEC device. The numerical results demonstrate that the parabolic sloping arm is available for wave running up and the overtopping discharge increasing.

KEY WORDS: Renewable energy; overtopping wave energy convertor; VOF model; numerical wave tank; straight type; parabolic type; overtopping discharge.

INTRODUCTION

Among various ocean renewable resources, wave energy is most abundantly available and applicable in most coastal and offshore areas. Due to the advantages of simple converting techniques and producing cost over other types of ocean energy, the wave energy conversion system is feasible to be established for the commercial power production. Plenty of wave energy absorption devices and plants have been invented, and several of them have been utilized in the electricity generation. Recently, the oscillating water column type has been widely employed in the application for the wave energy conversion. The disadvantage of this type is the low wave energy converting efficiency.

Overtopping Wave Energy Convertor (OWEC) has the sloping walls and reservoirs to lift water waves to the levels above the average surrounding ocean. The released reservoir water is used to drive hydro turbines or other converting devices. OWEC has some distinct advantages over other types of wave energy converting devices. It produces a relatively small fluctuation in the derived electricity because it converts wave energy to potential energy in the calm water of the reservoir. Furthermore, OWEC is more feasible economically since it can be combined with other coastal facilities such as break waters.

TAPCHAN is a prototype onshore generator which was installed on a remote Norwegian island in 1985 described by Falnes et al. (1991) and has been functioning ever since. The name is an abbreviation of "tapered channel", which describes the basic idea behind the device. TAPCHAN consists of a reservoir built into a cliff a fewer meters above the sea level. A tapered channel, which is wide at the mouth and open to the sea, becomes narrower as it penetrates the reservoir. Incoming waves increase in height as they move up the channel, eventually overflowing the lip of the channel and pouring into the reservoir. Kofoed et al. (2006) proposed a floating wave energy convertor of the overtopping type, Wave Dragon. It consists of two patented wave reflectors focusing the wave towards the ramp, linked to the wave reservoir. The wave reflectors have the verified effects of increasing the significant wave height substantially and thereby increasing the energy capture. Waves focused by the reflectors overtop the ramp and fill the reservoir, which is situated at a higher level than the surrounding sea.

The numerical simulation has become a very useful tool in the investigation of the wave propagation and overtopping, especially in recent years. Hu et al. (2000) presents a one-dimensional high-resolution finite volume model based on solving the non-linear shallow water equations capable of simulating storm waves propagating in the coastal surf zone and overtopping at the sea wall. With the development of computer technology and computational dynamics methods, it is feasible to directly solve the Naiver-Stokes equations coupled with VOF model for the simulation of many problems, including the wave breaking and overtopping processes. The wave breaking and running up over the structures by using the donor-acceptor VOF scheme are simulated by Isobe et al. (2001). As mentioned by Lin and Liu (1998), breaking waves in a surf zone by using a VOF based model are calculated to compare with the experimental data. Hieu et al. (2004) proposed a numerical two-phase flow model for incompressible viscous fluid utilized in the simulation