Geometry Effects of an Oscillating Wave Surge Converter on its Energy Absorption

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Abstract
In this study six different shapes for oscillating wave surge converter are introduced and their energy absorption in a specific wave is investigated. This research is done by numerical simulation of a typical wave flume that operates in six seconds and the transferred energy is absorbed by each OWSC. Due to using structured grid mesh, simulation of different shapes is fairly fast. The results show that geometry of OWSC plays a significant role in energy absorption. The effect of restoring force and power take off system is also investigated by considering the forces as a body force in numerical simulation.

Keywords: *Oscillating Wave Surge Converter-Geometry-Wave Energy Converter-Energy absorption.*

Introduction

Oscillating wave surge converter (OWSC) is an instrument used for harvesting surface wave energy in near-shore areas. Many researches have studied about OWSC but all of the numerical and analytical studies assume the OWSC as a simple flat wall. In the study of Henry et al. [1] the OWSC shape with obstacles was tested experimentally but even in that study comparison between OWSC shapes was not investigated.

Many numerical studies were performed like Wei et al. [2] or another part that study by Wei et al. [3] that was based on the assumption of simple plane wall. For simulation of OWSC with different shapes a structured mash based method was used and in this study only the effect of shape on energy absorption of OWSC is investigated.

In the first part the motion and method of harvesting energy from waves are explained. Then the computational domain and different design of OWSCs which are compared are introduced. In the next step a short summary about the simulation method is available and at last some results are shown.

Theory of OWSC Motion

OWSC pitches seaward and landward by the wave force and during this periodical motion it extracts energy. The equation of its motion is present in Eq. (1).

$$(I + I_{added})\ddot{\theta} + (C + C_{damp})\dot{\theta} + K\,\theta = M_{water} \qquad (1)$$

Where I is the inertia about the pitching axis and θ is angle of OWSC. I_{added} is the added inertia due to the motion of OWSC in the water. C is drag coefficient and C_{damp} is the added drag force which is due to power take off system (hereafter we call it power take off stiffness). M_{water} is the torque exerted on the OWSC by water (including wave force, buoyancy, etc.). Due to maintenance of its periodical motion a restoring force is needed. In real wave farms by reduction of OWSC density restoring force is provided but in this study because we aim to compare different shapes of OWSC, if the density decrease restoring force changes. Therefore it is assumed that a spring which its stiffness coefficient is K is used to provide restoring force. Density of OWSC is the same as density of water so we have no restoring force by buoyancy. For unifying all the parameters except geometry, I is fixed to amount of 0.9Kgm^2.

Computational Domain

In this study a two dimensional wave flume with a wave maker and two damping zones is simulated numerically. The wave flume is 5.6m long and 0.46m high. Wave maker is set in 1m from one side and 3.5m from that side is the position of OWSC. OWSC pitches about an axis 0.05m above the flume floor. Different OWSCs with different shapes that is designed to compare is shown in the fig. 1. In fig.1 for each design left side is seaward and right side is landward. All the designs are surface pierced and their inertia is similar.

The wave maker generates a typical wave with the amplitude of 0.06m and period of 1.9s in the water depth of 0.305m. Wave maker begins from the still water situation and its amplitude rises up to its maximum within 1.9s.

Simulation Method

Method of simulation is volume of fluid (VOF) with the structured grid mesh which makes the simulation of various shapes so easy and fast. The method proposed by Glowinski et al. [4] and modified by Mirzaii and Passandideh-Fard [5]. External forces like restoring force or power take off force are simulated by incorporating them to the body force in Navier-Stokes equations. This method was used by Anbarsooz et al. [6]. Validation of the method was proved by comparison to the experimental data of Wei et al. [2].

Results and Discussion

Fig. 2 shows some parts of the results of a huge amount of experiments that has been done by computational simulation. Even in the first glance it indicates the importance of OWSC shape. The difference between absorbed energy for different shapes of OWSC differs up to around 60% which is not negligible. As it is clear from the figure the larger seaward obstacles makes the OWSC more efficient (e.g. design A versus design F or design B versus design C). But for the landward obstacles by increasing its size a small reduction of efficiency is observed (e.g. design C versus design D). Fig. 2 also indicates the effect of restoring force coefficient (K) and power take off stiffness (C_{damp}).

Conclusion

Many results have been extracted for specific generated wave. In genera some of the conclusion remarks are:

- Effect of OWSC geometry is not negligible and plays a very important role in harvesting.
- The larger obstacles in the seaward side of OWSC results more absorbed energy up to 60%.
- The smaller obstacles in the landward side of OWSC results a bit more harvested energy.
- By increasing the restoring force absorbed energy increases. Also by increasing power take off stiffness absorbed energy increases up to a specific value.

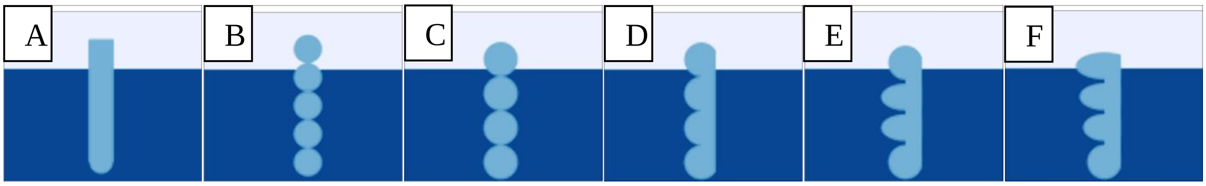

Fig. 1 : Six proposed geometries for OWSC. A to F represent Design A to Design F respectively. In all designs inertia is 0.9Kg.m^2

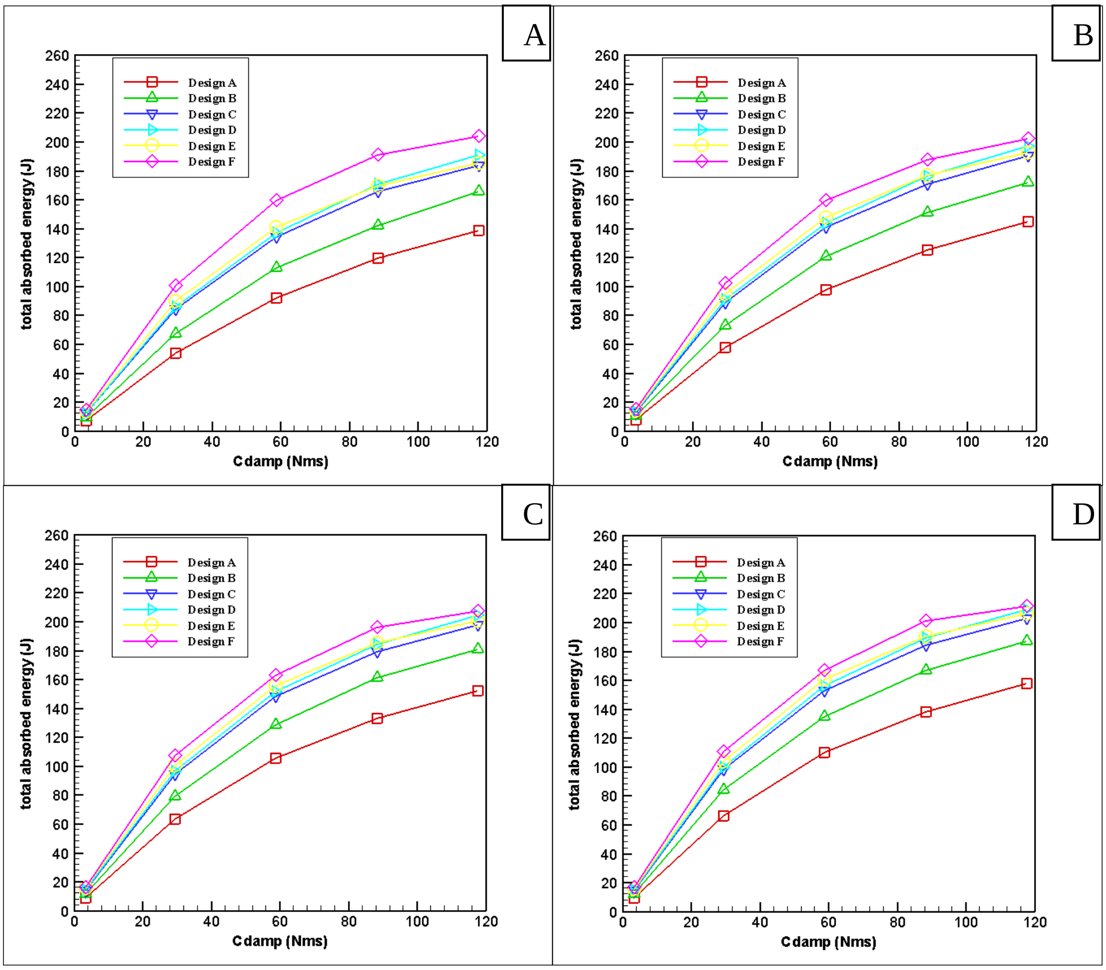

Fig. 2 : Total absorbed energy in 6s operation of wave maker that starts from still water for a 1m width OWSC in 6 different designs shown in fig. 1 versus damping coefficient. A: K= 10.5Nm/rad , B: K=105Nm/rad , C: K=210Nm/rad , D: K=280Nm/rad

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