Analysis of a Piston-type Porous Wave Energy Converter

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ABSTRACT

This paper investigates wave reflection characteristics induced by a piston-type porous (PTP) wave energy converter, consisting of a solid wall, a vertical porous plate, a transmission bar, a rigid block constrained by rollers, a spring and a damper. The work also researches the force exerted on the porous plate and the response of the PTP wave energy converter.

This study subjects the wave energy converter to a dynamic loading external source from the wave attack and uses a mathematical model with a single degree of freedom (SDOF) system to simulate the dynamic system. A linear wave theory governs the whole fluid domain, divided into two regions by the vertical porous plate. Darcy’s law is also applied in the porous plate. Finally, this investigation employs eigenfunction expansion to obtain the solution.

The current study conducts a series of numerical experiments, including the reflection coefficient, the added-mass coefficient, wave force acting on the porous plate, and converter responses.

KEY WORDS: Porous plates; SDOF systems; PTP wave energy converters; reflection.

INTRODUCTION

An important characteristic of sea waves is their high energy density, which is the highest among renewable energy sources. To capture energy from sea waves, it is necessary to intercept waves with a structure that will react in an appropriate manner to wave forces applied to it. Previous researchers have developed different wave energy converters to use this energy. Recent decades have seen an increased interest in using permeable structures to control waves.

Chwang (1983) investigated free surface gravity waves produced by a horizontally oscillating porous plate. This work has been applied to several recent studies on porous breakwaters. Chwang and Dong (1984) linearized the problem of wave reflection by a thin barrier of fine pores and solved it by the method of matched eigenfunction expansion. They found that the reflected wave amplitude reduced to its minima, if the distance between the porous barrier and the chamber end wall was equal to a quarter–wavelength plus a multiple of half–wavelength of the incident wave. Twu and Lin (1991) extended Chwang’s method to evaluate wave reflection from a wave absorber containing a finite number of porous plates possessing various porosities. The wave absorber is more efficient if the porosity magnitude of plates is arranged in a progressively decreasing order from the front to the back of the absorbers. Wang and Ren (1993) presented a theoretical model to study surface wave scattering by a flexible, porous and thin beam – like breakwater held fixed in the seabed. They observed that the general hydrodynamic force decreases with reduced barrier rigidity. Wang and Ren (1994) studied wave trapping due to a flexible and porous barrier backed by an impermeable vertical seawall. The seawall is located behind the barrier by a distance of $B$. They observed that the distance $B$ between the barrier and the seawall, at which the minimum reflected–wave amplitude reaches, is in the range of $(2n+1)L/4$ to $(3n+2)L/6$ for barriers with different rigidity and permeability. Örör and Ozdamar (2007) experimentally examined the efficiency of a submerged plate wave energy converter for different opening ratios, with and without a triangular or vertical wall under the horizontal plate. The present study investigated wave reflection characteristics induced by a piston–type porous (PTP) wave energy converter, consisting of a solid wall, a vertical porous plate, a transmission bar, a rigid block constrained by rollers, a spring and a damper. The study also researched the force exerted on the porous plate and the response of the PTP wave energy converter.

PROBLEM FORMULATION

This work considered the interaction between a piston-type porous (PTP) wave energy converter and a gravity wave train. The PTP wave energy converter consists of a solid wall, a vertical porous plate, a transmission bar, a rigid block constrained by rollers, a weightless spring and a damper. The transmission bar horizontally connects the vertical porous plate and the rigid block. The weightless spring of stiffness $k$, (per unit width) and damper $c$, (per unit width) were both planted between the solid wall and the rigid block. A semi-infinite fluid region of constant depth, $h$, connects with the PTP wave energy converter. Figure 1 shows a sketch of such a configuration. A single degree of freedom (SDOF) system was used to simulate the dynamic...