Comparative Study of Wave-induced Motion for Two Types of Floating Pendulum Wave Energy Converters

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ABSTRACT

We comparatively investigated wave-induced motions of two floating pendulum wave energy converters (WECs): one designed to reduce motion response via a damping plate and the other designed to reduce motion response via a large water-plane area. The motion responses were compared through model tests under operational and survival wave conditions and were numerically analyzed through a higher-order boundary element method (HOBEM) using the wave Green function. From experimental and numerical data, 6-DOF motion responses were compared under survival conditions. The WEC efficiency was estimated from the relative angular motions of the pendulum. An optimal WEC design was proposed by considering seakeeping performance and efficiency.

KEY WORDS: Wave energy; Pendulum; Model experiment; Floating pendulum wave energy converter; Boundary element method;

INTRODUCTION

A floating pendulum wave energy converter (WEC) uses pendulum motion in an open-mouthed water chamber to capture wave energy. The WEC has a high operational rate and low installation cost; however, it must be able to withstand repetitive extreme waves that cause large wave motions. The shape of the floater significantly affects the wave motion; thus, investigating its stability and survivability is essential. Recently, the Korea Research Institute of Ship and Ocean (KRISO) in Daejeon, Korea, has investigated a floating pendulum WEC by numerically studying its wave-induced motion characteristics (Nam, 2012). Furthermore, 1/20 scale-model tests were performed to analyze the wave responses of the water chamber and the motions of the floating device in a two-dimensional wave tank (Park, 2011). The addition of motion-reduction structures to the WEC to change its size, shape, and position resulted in satisfactory motion-reduction performance (Park, 2013).

In the present work, we comparatively studied the wave-induced motion of two types of floating pendulum WECs in which one was designed to reduce the motion response using a damping plate and the other to show small motion response via a large water-plane area. The six-degree-of-freedom (DOF) responses of both models were compared, and their respective efficiency was estimated by the relative angular motions of the pendulum. An optimal floating pendulum WEC design was proposed, which considers the seakeeping performance and efficiency.

FLOATING PENDULUM WAVE ENERGY CONVERTER

Fig. 1 shows the initial design of the floating pendulum WEC, designated as model A. It consists of a floating body (the mother ship with water chamber), a pendulum to absorb the incident wave energy, and a motion-damping plate installed behind the body to reduce the motion of the floating body. Fig. 2 shows this model along with a modified model called model B. Model A has a motion-damping plate, which increases the damping force and lengthens the total device length to cancel out the wave pressure exerted on the body. Therefore, surge, heave, and pitch motions can be reduced. In comparison, model B does not have a motion-damping plate; however, it has sloped side walls to increase the restoring force through the water-plane area. To maintain the same displacement as that of model A, model B features a lengthened floating body. Because model B has a simpler floating body shape, it is easy to manufacture and is stronger than model A whose motion-damping plate may be structurally weak. Both models have a displacement of ~1600 tons and similar breadths and heights. Table 1 lists the full-scale specifications of both models. Using these models, we conducted experimental and numerical simulations and compared their performance in terms of wave-induced motion and survivability.

Fig. 1 Floating pendulum WEC