Hydrodynamic Modelling of Heaving Buoy Wave Energy Conversion System with Liquid Metal Magnetohydrodynamic Generator

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ABSTRACT

In this paper, we present numerical studies of waves interacting with a semisubmerged sphere point floater that is directly driving a Liquid Metal Magnetohydrodynamic (LMMHD) generator. By using potential theory, the waves are assumed inviscid, irrotational, incompressible and homogeneous fluids when considering the wave/floater interaction. The generator is modeled as a viscous damper. The power capability of the system has been studied for both regular waves and irregular waves, which with a spectral distribution of Pierson-Moskowitz type.

KEY WORDS: LMMHD generator; wave energy; irregular waves; modelling.

INTRODUCTION

The global wave energy (include the energy on open oceans) is in the order of $10^{13}$W, a quantity that is comparable with the world’s present power consumption (Johannes Falnes, 2007). Until now, inventors have proposed many different devices for utilizing wave energy for human purposes. In recent years, it has become more specific. There is a wide variety of wave energy technologies, resulting from the different ways in which energy can be absorbed from the waves. Such as oscillating water column (OWC) device (Bønke K, 1986); oscillating body device Pelamis (Pizer DJ, 2005); overtopping device Tapchan (Mehlum E Tapchan, 1986), and etc. Traditionally, high speed rotating generators are used for energy conversion. This requires a system that converts the slow linear/rotation motion of the wave energy absorber to a high speed rotating motion. Hydraulic systems or turbines are used for this purpose. Such a solution gives a complex system with many moving parts (M. Eriksson, 2005).

In this paper we consider a concept for electric energy extraction from waves based on Liquid Metal Magnetohydrodynamic generator (Yan Peng et al, 2008; Lingzhi Zhao et al, 2009). The LMMHD generator is connected by a shaft to a floater, semisubmerged in the waves and to a spring around the shaft. The LMMHD generator is fixed by the mooring system (see Fig.1). The hydrodynamical action of waves forces the floater and thereby the shaft to move with a heave motion. The shaft drives the liquid metal passing through the channel, which is equipped with permanent magnets; induces currents in the channel according to Faraday’s law of induction. In this way, a part of the wave energy can be converted into electric energy. In this paper we present a study of the hydrodynamic of harmonic waves with the floater-generator system, using linear potential theory.

In order to calculate the exciting force (diffraction force) and hydrodynamic parameters for the semisubmerged floater, we assume, for simplicity, the floater to be a sphere moving in heave. For this purpose we make use of analytical expressions (Hulme, 1982; M. Rahman, 2001). These expressions are derived using variable separation and multipole expansions of the velocity potential in spherical coordinate system $(r, \theta, \psi)$.

This paper is intended to give an estimate of different parameters, such as floater radius, spring constant and generator damping coefficient in order to obtain high power capture ratio. The characteristics of the system have been simulated in harmonic waves and irregular waves with a spectral distribution of Pierson-Moskowitz type.

GOVERNING EQUATIONS

Equations of motion

We assume that the fluid is homogeneous, inviscid and incompressible and the fluid is irrotational. The waves are also assumed to be of small amplitude. A rigid floating body has six degrees of freedom, three translational and three rotational. We will restrict the discussion to heave motion only. This is reasonable since our interest lies in modelling wave energy converters with a point floater tethered directly above a LMMHD generator. By assuming that the length of the shaft is much larger than the floater motion only the heave motion will