The Heave and Pitch Power Output of a Vertical Cylindrical Wave Energy Converter in Finite-Depth Water

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ABSTRACT

We study the power output contributed from the heave and pitch modes of a wave energy converter in regular and irregular waves. The device is a vertical truncated circular cylinder allowed to oscillate in the vertical plane in finite depth water. Our results focus on the share of the pitch power from the total power. The results also highlight the effects of some parameters such as the buoy radius, height and floatation level on the power output. The results in regular waves indicate that the contribution from the pitch mode is highest at high frequencies and radii. The power per unit mass in irregular waves is found to admit a maximum at a fixed buoy height-to-radius ratio.

KEY WORDS: Ocean Wave Energy; Cylindrical Buoy; Heave; Pitch.

INTRODUCTION

It is a well known fact (Falnes, 2002) that the theoretical maximum power that can be absorbed from an axisymmetric body oscillating in heave or pitch only is limited by the energy transport per unit frontage of the incident wave divided by the wave number. This maximum becomes three times higher when the modes: surge, heave and pitch are allowed. It might seem advantageous to employ all three modes simultaneously in a wave energy converter. This does not have to be the case as the power extracted is mostly less than the theoretical maximum unless some control strategy is considered (Bjarte-Larsson & Falnes, 2006). In general, it is difficult to implement a controller (Falcao, 2008) and in its absence, it is difficult to tell for a generic body whether allowing more degrees of freedom will help.

It is the purpose of this work to show how much more power is actually extracted by employing the added modes to a vertical truncated circular cylindrical body in shallow water. The body considered is connected to the ocean bottom using a loose mooring cable and power is extracted from the heave and pitch modes using two power takeoff mechanisms (PTOs). Numerical methods such as the FEM or the BEM are usually used to compute the hydrodynamics for complicated geometries or for fully nonlinear problems (Wu, Ma & Eatock Taylor, 2001a&b). For the simple linear case considered here, analytical methods are more appropriate. The radiation forces on the cylinder have been studied in (Yeung, 1981) and (Sabuncu & Calisal, 1981) using an eigenfunction expansion method. The excitation forces and moments have also been investigated analytically in (Miles & Gilbert, 1968, Garret, 1971) and numerically in (Black, Mei & Bray, 1971). The problem of finding the power itself from the heave mode has been presented in (Ricci, Saunier & Falcao, 2007) and (Tabaei & Hariri Nokob, 2010).

Generally speaking, the forces on the PTOs are nonlinear and their treatment requires a time domain analysis (Yu & Falnes, 1995). For simplicity and to keep our analysis within the frequency domain, the PTOs are modeled by linear translational and rotational dashpots for the heave and pitch modes respectively.

In what follows, we solve for the power output of the system described using optimum values for the PTO dampers. We present the power and power per unit mass results and show the power contribution from the pitch mode. The power output in irregular waves described by a Pierson-Moskowitz spectrum is also presented for different geometries.

THEORY

![Figure 1: System Schematic Diagram](image-url)