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Use of Oscillation Constraints in Providing a Reaction for Deep Water Floating Wave Energy Devices

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ABSTRACT

This paper studies a method for absorbing wave energy via the relative oscillation between a floating body and an onboard, actively controlled motion-compensated platform. One feature of such a system is that the floating device does not need a reaction from the sea bottom or another floating/submerged body. Frequency-domain analysis is used to investigate practical energy absorption strategies for a heaving point absorber utilizing a compensator. In particular, to prevent the oscillations of one of the system elements from being too large, constrained optimal control is applied. Calculations indicate that the oscillations of the interacting masses and the required control forces could be restricted to realistic amplitudes, in exchange for some loss in the absorbed power.

INTRODUCTION

Onshore and near-shore devices in which the sea bottom provides a reaction for primary converter oscillations (e.g. Whittaker et al., 1995; Hotta, 1995; Falcão, et al., 1995; Randlov, et al., 1995; Sjostrom, 1995) have probably received the most attention in wave energy research so far. However, there is generally greater energy in deeper waters, and floating devices experience reduced impact loads in extreme waves. Because it is difficult to obtain a reaction from the sea bottom in deep water, in some cases, a deeply submerged plate/sphere is provided for this purpose. In others (Washio et al., 1998), the primary converter reacts against a floating hull. The relative motion is used in energy absorption, often, at the cost of conversion efficiency.

The system examined in this paper absorbs wave energy via relative motion between the floating body and an onboard motion-compensated platform. The basic operating principle is similar to that of dynamic vibration absorbers used in machinery vibration isolation (Meirovitch, 1986). Applications of this system were investigated in Korde (1998a, b) and in Pizer and Korde (1998).

Ideas utilizing an internal mass for energy conversion were examined by Parks (1980), French and Bracewell (1985), Korde (1990) and Chaplin et al. (1995). The present method differs from these authors' methods in that the internal block here is held stationary, using springs and a smaller, controlled, undamped internal spring-mass system (Fig. 1).

For floating wave energy devices, it was found that the control force on the oscillator (M_m, k_m) can be derived such that the block (M_c) remains stationary over a wide frequency range (Korde, 1999). It was also noted that under this condition, a "complex conjugate" load (applied on the hull from the stationary block) leads to optimal power absorption.

However, frequency-domain calculations under optimal control show the oscillations of M_m to be very large, especially at low frequencies. With a view to practical implementation, this paper investigates a method for constrained optimal control that aims to keep the oscillations and forces in check while maximizing the absorbed power within that constraint.

All work in this paper is carried out in the frequency domain. It is worth noting that control of the force F_m (Fig. 1) to cause motion compensation of M_c is not difficult to achieve in real time in real seas. However, real-time control of the force F_L for optimal power absorption will require prediction of the float oscillation of the future (Falnes, 1995). This question is not addressed in this paper.

SINGLE-MODE DEEP-WATER DEVICE

We investigate the use of an onboard heave compensator to provide a reaction for a three-dimensional heaving float in deep water. We assume a hydraulic ram/cylinder type power takeoff capable of applying resistive and reactive loads on the float and operating between M_c and M_s (Fig. 1). Small, predominantly heave motions are assumed. Details of the treatment in this section can be found in Korde (1999). Let the control force F_m on M_m be such that:

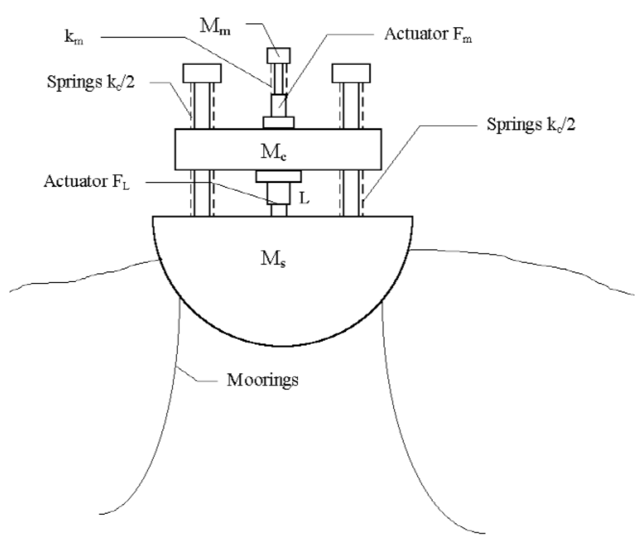

Fig. 1 Schematic of compensator system in heave

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