Experimental study of dynamic displacement estimation of oscillating floaters based on measured accelerations

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ABSTRACT

As a critical component of wave energy power generation devices, the heave displacement of the oscillating float is particularly important. However, it is difficult to measure the dynamic displacement of the oscillating float in an actual marine environment, and the direct integration of the measured acceleration will lead to an estimated dynamic displacement that produces a drift term. Therefore, in this study, a displacement estimation method was developed to eliminate the baseline drift of the sensor to accurately estimate the heave displacement of the oscillating float. The physical model experiment of the oscillating float under the action of regular and irregular waves was carried out in the wave pool of the Ocean University of China. The top of the oscillating float is equipped with an acceleration sensor and a 6-DOF laser displacement sensor to measure the different rules. The acceleration and heave dynamic displacement of the oscillating float under the action of regular and irregular waves were measured, and the results were analyzed. The experimental results show that this method can accurately estimate the heave displacement of an oscillating float, and has significant application potential.

KEY WORDS: Acceleration; Displacement; Oscillating float; Model test;

INTRODUCTION

Wave energy has been widely used as a renewable energy source because of its advantages such as energy intensity, large reserves, and high predictability. It is estimated that the global ocean energy reserves are approximately 75 billion kW, of which the wave energy that can be developed is 2-3 billion kW (Boyle et al., 2004). In remote islands, wave power generation costs less than $0.05/(kW·h) under medium waves, whereas traditional power generation costs are typically greater than $0.19/(kW·h) (Falcão et al., 2010). Among the many wave energy capture methods, the oscillating float type has attracted the attention of many wave energy developers because of its low cost and high efficiency (Mohamed et al., 2011; Titah-Benbouzid et al., 2015), and has become an active area of focus for wave energy development. However, owing to the long-term effects of the harsh marine operation environment, the structure will inevitably be destroyed. The heave displacement of the oscillating float can reflect the real operation state of the structure, which plays an important role in vibration control (Ning et al., 2019; Ning et al., 2018) and structural monitoring (Dong et al., 2018; Dong et al., 2019). However, owing to the lack of a fixed reference point, it is almost impossible to measure the heave displacement in a real marine environment. Compared with the displacement, the measurement of structural acceleration is easier to perform, and the accuracy is higher; the modal parameter identification for offshore structures has been implemented based on the measured structural acceleration (Liu et al., 2019).

In theory, the dynamic displacement can be estimated by performing two integrations on the measured acceleration. However, because of the baseline drift, random error of the sensors, unknown initial conditions, and recording errors, film or paper warping, background noise, recording system noise, baseline drift, and baseline uncertainty due to an incomplete accelerogram in an analog recording (Trifunac et al., 1971; Trifunac and Lee et al., 1974; Hudson et al., 1979), a nonphysical drift appeared in the reconstructed displacement. Trifunac and Lee (1973) introduced high-pass filtering to remove drift terms in the integrated displacement. Park (2005) proposed an initial condition estimation method to estimate the actual displacement using the measured acceleration.

However, in the above methods, an important issue is ignored, that is, the data error caused by the baseline drift of the acceleration sensor itself. In this study, a method for estimating the heave displacement of an oscillating float was developed. First, the acceleration baseline is fitted by the least-squares method before filtering, then the Butterworth polynomial is introduced for the elimination of the low-