Removal of Fluid Contents in a Cavity under the Effect of A Propagating Solitary Wave

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ABSTRACT

This study is aimed to investigate, as a solitary wave propagating past a cavity; the motion of fluid particles inside a bottom cavity. A model formulated with stream function and vorticity is applied and the governing equations are solved using the finite-analytic method. In order to reveal the small eddy motion in a cavity, a boundary-fitted grid system combined with fine overset grids is adopted. The simulated motions of fluid particles at various times are shown to be similar to the experimental observations. The present model is demonstrated to be capable of capturing the motion of the fluid particles. Furthermore, the effect of incident wave height on the patterns of fluid-particle motion and the removal displacement along the vertical and horizontal directions are analyzed and the results are presented and discussed.

KEY WORDS: solitary wave, cavity, particle motion, numerical simulation, visualization.

INTRODUCTION

Wave induced current as it passes over an uneven bottom (natural topography or artificial structures) tends to deform the free surface and generate vortices in the regions with changing water depth. This study focuses on modeling the propagation of an incident solitary wave past a rectangular cavity (trench). The kinematic motions of the particles within a cavity is also investigated.

The cavity related problems can be widely identified in the natural or engineered systems. The easy deposition of materials into the cavities can be a major concern. Numerous studies of flow over cavities without a free surface have been motivated by a fundamental interest in the phenomenon of separated flow. For examples, in the processing industry, the residues of industrial manufacturing processes can give rise to an accumulation of deposits in cavities of rough surfaces and consequently a corresponding degradation of quality in the processed material may be observed (Fang et al. 2003). In aerodynamics, constituents (such as pollutants, nutrition, toxic materials, and sediments) frequently settle down in a concave terrain. As a result, the clear maintenance to the sediment in dredged navigation channels is important in coastal engineering (Ting and Raichlen, 1986). In recent years, the transportation of near-shore sediments by wave induced currents has gained great attention (Tao and Tao, 2006). Furthermore, the existence of the Chagos trench prevented the Diego Garcia, a southernmost island in the Chagos Archipelago, from greater damage by the Andaman Tsunami of 26 December, 2004. The trench is a 640 kilometer long, underwater canyon that ranges in depth from less than 100 meters below the surface to depths that plunge to over 5,000 meters. It can be seen the damage caused by waves differs greatly depending on the undersea topography. According to an inferred report, the favorable ocean topography minimized the tsunami’s impact on the atoll. This event makes the study of tsunami over a trench an interesting one, although a simplified trench is considered in this study.

The study of wave-trench problem can be traced back to Lassiter (1972), who investigated the reflection and transmission coefficients for a normally incident linear wave in cases of asymmetric problem (with different depths on the two sides of the trench). In analytical approaches, the matching conditions are usually employed on discontinuity sections. Unlike Lassiter’s vertically dividing regions, Lee and Ayer (1981, hereafter LA) investigated the symmetric trench problem setting the matching line in the trench mouth with horizontal boundary using the transformed method. The next development was done by Miles (1982), who considered especially for linear long wave. Kirby and Dalrymple (1983) extend the results of LA to the case of obliquely incident wave. Recently, Jung et al. (2008) derived an analytical solution for waves propagating over an asymmetric trench with variable shapes. Only wave reflections and transmissions were concerned in those papers. Ting and Raichlen (1986) extended LA’s method to study the velocity distribution in a trench. At the same time, Liu et al. (1986) also used LA’s theory to examine the wave interactions with a sediment trench. The above described studies on wave diffraction by a trench are limited to fluids propagating over an asymmetric trench with variable shapes. Only wave reflections and transmissions were concerned in those papers. Ting and Raichlen (1986) extended LA’s method to study the velocity distribution in a trench. At the same time, Liu et al. (1986) also used LA’s theory to examine the wave interactions with a sediment trench. The above described studies on wave diffraction by a trench are limited to fluids propagating over an asymmetric trench with variable shapes.