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Experimental Investigation on the Dynamic Response of Density-Stratified Fluid in a Submarine Trench

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ABSTRACT

The dynamic response of the generated internal wave as surface water propagating over a submarine trench is investigated in a wave flume. The image processing technique is used to observe the response of density-stratified interface. Two typical distinct phenomena of internal waves were caught in the experiments, which are the traveling internal waves usually occurred as the density of lower layer fluid is higher, and the standing internal waves usually occurred as the density of lower layer fluid is lower. The quantitative results would be presented in the future.

KEY WORDS: density-stratified fluid; interfacial wave; trench

INTRODUCTION

When waves propagate across a submarine trench which is partially filled with heavier fluid, the generation of internal wave is an interesting topic on engineering. Such a situation may exist in navigational channels and harbors where bottom is composed of very fine sediment. It is observed that when the frequency of the incoming surface waves corresponds to the natural frequency of the internal waves in the trench, the amplitude of the internal waves becomes large compared to the amplitude of the surface waves. In these extreme events, the dense fluid in the trench will be excited in a mode of resonant oscillation. Therefore, large amplitude of internal wave results in large velocity near boundary hen enhances the process of erosion and affects ship maneuverability. An example of a harbor where this type of dense lower layer is present is Holland, where the bottom was defined as a region where the specific gravity of the fluid was larger than 1.2 (Marine Board National Research Council, 1983). The density-stratified fluid in these channels can have an influence on the kinematics around the perimeter of the trench as a result of internal waves generated in the trench.

The nature of the internal waves in the trench is a major interest in this study. Thorpe (1968) has made an extensive study, both theoretical and experimental, of standing internal waves at the interface of two fluids and in a continuously stratified fluid. For the two-layer problem, his method of analysis was similar to the perturbation scheme in Stokes waves. Thorpe (1968) represented the finite-amplitude wave solutions in the form of power series expansions with respect to the wave slope as the expansion parameter. The propagation of time-periodic water waves past a rectangular trench with a homogeneous fluid in the trench has been studied by Lee & Ayer (1981) and Kirby & Dalrymple (1983). Primary interests in those studies are related to the phenomenon of wave scattering, in which strong reflection of the incident waves can occur for suitable dimensions of the trench relative to the wavelength of the incident waves. It was found that for a particular symmetric trench where the water depths before and after the trench were equal, there existed an infinite number of discrete wave frequencies at which the incident wave energies were fully transmitted, the maximum and minimum values of the transmission and reflection coefficients appeared periodically, but the effect of the trench on wave energy transmission decreased monotonically as the wavelength decreased. Based on the formulation by Lee & Ayer (1981), Ting & Raichlen (1986) showed that the wave energies trapped within the trench were very small compared to the energies in the incident waves. The excitation of internal waves in a rectangular trench by normally incident surface waves has been studied experimentally and theoretically by Ting & Raichlen (1988). Their analysis dealt with small-amplitude waves and an inviscid two-layer fluid in the trench, whereas fresh water and salt water were used to create the density stratification in the experiments. It was observed that at resonance the amplitude of the internal waves was large compared to the amplitude of the surface waves, but the effects of the internal waves on the surface waves were not measurable. The theoretical solutions predicted the wave motions quite well even for relatively large amplitude waves in the trench.

The phenomenon of resonant excitation of internal waves in a rectangular trench by surface waves has been investigated experimentally and theoretically by Ting and Raichlen (1988) and Ting (1992). In the above studies, the stratified fluid in the trench was created using fresh water and salt water. It was found that the amplitudes of internal waves were much larger than those of surface waves when the frequency of surface waves coincided with the natural frequency of internal waves in the trench. An empirical formula is proposed to predict the resonant condition under particular geometrical length, density ratio, and wave number.