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Measurement and analysis of the interaction between internal solitary wave and submerged slender body in a stratified fluid tank

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Abstract

A measurement technique of hydrodynamic load of internal waves in a stratified tank was developed. By means of accurately measuring slight variations of internal wave forces exerted on a slender body in the tank, their interaction characteristics were determined. It is shown that through establishing the similarity between the model scale in the stratified fluid tank and the full scale in the numerical simulation the obtained measurement results of internal wave forces are confirmed to be correct.

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Keywords: Internal solitary wave; stratified fluid; slender body; interaction

1. Introduction

A series of surveys have also proved some important facts that the large-amplitude internal soliton with abruptly strong current can bring about destructions to oil-gas exploitation equipments at sea and disasters to submerged vehicles. The theory and methods for interactions of linear or nonlinear water waves with objects in the homogeneous fluid have been widely applied in the density stratification fluid, so that many hydrodynamic properties of interactions of internal waves with bodies have been revealed. Recently, great progress in both theory and application for interactions of large-amplitude internal waves with objects has been made [1]. Wei et al. developed an edge-layer theory in the stratified fluid [2], which was proposed in the homogenous fluid by Sugimoto et al., and analytically described nonlinear characteristics of both transmitted and reflected internal solitary waves on

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a submerged floating barrier. Cai et al. [3] calculated the force and torque exerted by internal solitons in shear flows on cylindrical piles using the in-situ measured data and showed that this action is one of the serious threats against the security of ocean engineering structures.

The physical simulation in laboratory is an indispensable method for investigating marine environment and internal waves, and is also a reliable means of safety evaluation in the field of naval architecture and ocean engineering. The quantitative measurement of interactions between internal wave and architectural object is currently facing a major difficulty in model experiments. Although progress has been made in the associated techniques and methods [4], the measuring error of internal wave forces in laboratory is still very large. Because the cross section of the stratified fluid tank is too small to confine the size of testing model, the interaction between the internal wave and the model is very weak. At present, it is not possible to provide the reliable test data of hydrodynamic forces due to internal solitary waves with large amplitude in model experiments, so both efficient estimation and reliable analysis of the influence of actual internal waves on underwater architectural objects are always restricted.

In this study, we will work on establishing a measurement system for internal wave loads in our stratified fluid tank and finding out hydrodynamic forces of internal waves exerted on a submerged slender body. Furthermore we will verify the reliability of the model-scale experiments in the stratified tank through comparison with the full-scale numerical simulations.

2. Measurement system and method

The principle of measuring internal wave forces is sketched in Figure 1. The relevant experiments were still conducted in the present tank, in which the new wave-maker and the wedge-shaped absorbing-wave device were installed at the upstream and downstream ends of the tank respectively. The force-measuring sensor was connected to the test model through a sword-shaped rigid rod functioning as force -transferring portion of the system. The model fixed in horizon was a slender gyral-body of 80.0 cm in length and 9.0 cm in diameter respectively. A three-component force-measuring sensor was used to measure the force or torque exerted by internal waves on the model, and three corresponding non-dimension parameters were calculated as follows:

$$c_x = \frac{F_x}{\rho g A \cdot D}, \qquad c_z = \frac{F_z}{\rho g A \cdot D},$$

where F_x and F_z denote the forces in the horizontal and vertical directions respectively (N) , ρ and D are the density (kg m^{-3})and the total depth (m)of fluid respectively, g the gravitational acceleration (m s^{-2}) and A the horizontal windward area (m^2).

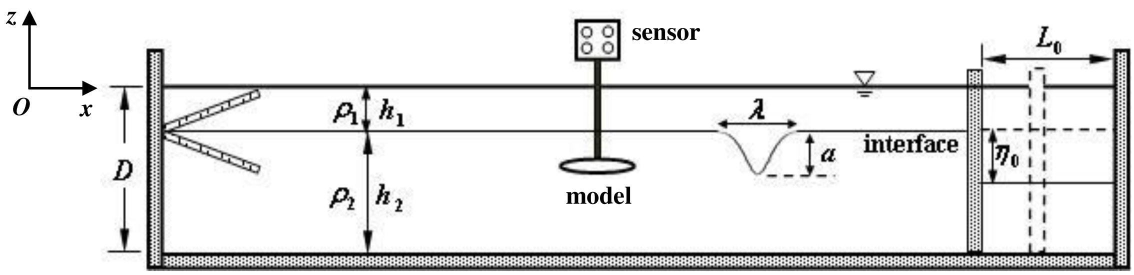

Fig. 1. Experimental schematic diagram