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Field Experiments and Numerical Prediction on Dynamics of a Light Floating Structure Moored in Deep Ocean

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ABSTRACT

A floating structure for fish-gathering has been developed and moored in the deep sea south of Okinawa Island. The depth of the sea in this area is 1300 m. The structure is moored with a composite mooring line of wire rope and chain; its displacement is about 94 tons. To establish a design for the small floating structure, a series of field experiments was carried out in which motions of the structure, current velocity and wave height were measured with motion sensors, a current meter and a wave rider buoy. Motions of the structure obtained from the field experiments were compared with numerical simulations. The dynamics of the mooring line were calculated using a lumped mass technique. Hydrodynamic coefficients used in the numerical simulations were obtained from theoretical calculation and model experiments in a wave tank. The design method for a small floating structure moored in deepsea was confirmed through the field experiments.

INTRODUCTION

Designing a floating offshore structure requires theoretical and experimental studies to determine the anticipated performance and safety. In the final stage of the design, performance under working conditions and safety under survival conditions should be confirmed using numerical simulation programs developed on the basis of these studies.

Establishment of a numerical simulation method for analyzing the dynamics of a small floating structure for fishery or ocean observation is necessary, yet the difficulties confronted are much more serious than for a large oil rig: The incident wave height is relatively large in comparison with the scale of the floating structure, which leads to strong nonlinear effects. The computer program developed for the numerical simulation of the motions of a small floating structure must therefore be validated by experiments, as has been done by many researchers over the past 20 years for a large offshore structure.

In the case of deep-sea mooring of a small structure, another difficulty is that, because the mass of the mooring line is large compared to that of the floating structure, interference between the dynamics of this line and that of the structure itself must be considered; this interference is small enough to be neglected except for the phenomenon of so-called slow drift oscillation for an oil rig with mass of more than 10,000 tons.

The results of field experiments on the motion of a structure moored in a 1300-m-deep sea area south of Okinawa Island are reported here; the results will be compared with those of numerical simulation.

OBJECT STRUCTURE OF STUDY

Fig. 1 shows a conceptual view of the structure and the mooring line; the structure was built to gather tuna and other fish. Its advantages for the fishing industry have already been confirmed by an investigation carried out by the Okinawa Prefectural Fisheries Experiment Station. The total displacement is 94 tons, which includes the 30ton weight of the suspended line in water.

The mooring line is composed of chain and wire rope sections. Fig. 1 shows the layout and dimensions. The total length is 1807 m, including the section laid on the sea bottom. The diameter of the main deck at the water surface is 7 m, and that of the column connected under the main deck is 1.9 m. A hexagonal footing is fixed at the lower end of the column at a depth of 7 m. This is intended to increase the fish-gathering capability and to serve as viscous damping for motion; it is composed of frame cylinders and nets as shown in Fig. 1.

THEORETICAL MODEL

Motions of Floating Structure

The coordinate systems used to describe the motion of the floating structure and mooring line are shown in Fig. 2, where X and Z are the horizontal and vertical axes, θ the pitching angle, and β_i the angle of the line between M_i and M_{i+1} to the X axis. The origin of the axes for the structure is fixed at its center of gravity and the cable is modeled based on the lumped mass method (Thresher and Nath, 1975); each mass in the figure is denoted by M_i. In this study, motions of the structure and cable were assumed to be confined to two dimensions. As mentioned, the nonlinear effects on hydrodynamic forces are significant and the viscous force in particular has a great effect on the motion of the floating structure. The most popular means of describing the viscous force is based on the relative velocity concept (RVC) (Koterayama and Nakamura, 1988a). Under RVC the drag force F_D written in a modified form of the Morison equation is:

$$F_D = \frac{1}{2}\rho C_D A_x \left(\dot{X}-u\right)\left|\dot{X}-u\right| \tag{1}$$

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KEY WORDS: Field experiment, motions, moored floating structure, simulation technique.