Hydrodynamic Behavior of a Gravity Cage with Frame Anchor System in Irregular Waves

T.J. Xu, G.H. Dong, Y.P. Zhao* and Y.C. Li
State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology.
Dalian, Liaoning, China

C.P. Chen
Civil Engineering, Dalian Fisheries University.
Dalian, Liaoning, China

F.K. Gui
Marine Science and Technology School, Zhejiang Ocean University.
Zhoushan, Zhejiang, China

ABSTRACT

In this study a typical gravity cage with frame anchor system is presented and a set of equations of motion for this flotation structure are derived using lumped mass method. The purpose of this study is to investigate the gravity cage dynamics under irregular wave conditions using numerical model. The numerical results are discussed focusing on the motions of the float collar and the maximum mooring-line forces. The results show that the mooring lines located upstream are most loaded, and the spectra of wave elevation, surge and heave motion response of float collar have a same dominant frequency.

KEY WORDS: Gravity cage; numerical simulation; wave forcing; spectrum analysis.

INTRODUCTION

Global shortage of seafood is becoming more serious. To satisfy the global need for seafood, the marine aquaculture is becoming very popular all over the world. The expansion of near-shore aquaculture is becoming more difficult due to coastal multi-use issues and environmental impact concerns. In the future, more fish farms will be located at the offshore area, but current and severe waves may cause some trouble. This means an increase the necessary of engineered technology employed in the design of net cage.

To investigate the performance and reliability of the open ocean net cage, there were several research efforts on net cage involving numerical modeling, scaled physical modeling and field measurements. To our knowledge, Kawakami (1964) proposed relative reliable semi-empirical formula to calculate the drag force acting on net. The formulation includes the drag force caused by flow velocity, mesh size of net and material characteristics. Aarsens et al. (1990) further divided the external forces on net cage into drag force and lift force, considering the angle between normal direction of net plane and current velocity, based on both theoretical work and comprehensive model tests. Their work has laid a foundation for further study of the net cage dynamics. Lader et al. (2003) and Lader and Enerhaug (2005) conducted a series of experiments to investigate the force and deformation on a net cage in a uniform flow and discussed the computational model of the circle 3D net structures exposed in waves and current, in which the net was dispersed into a super element structure. Tsukrov et al. (2003) investigated the dynamic behavior of the net by using finite element method with consistent net element concepts and applied it to the tension leg net-cage successfully. In Tsukrov et al. (2005), the numerical model was improved by the addition of the nonlinear elements. Fredriksson et al. (2003) carried out the research on fish-cage and mooring-system dynamics, using physical and numerical models with field measurements. The field data collected have helped researchers to understand numerical and physical modeling approaches and to make improvements. Li et al. (2006a, b) investigated the gravity cage dynamics by physical model tests, and obtained a promising result. Lee et al. (2008) proposed a mathematical model for analyzing the performance of a fish cage system influenced by currents and waves.

Based on the above analysis, the research on the net cage dynamics is mainly focused on the net cage in either steady flow or regular waves. However, in reality, the sea-state is mainly composed of irregular waves. Therefore, a need exists to investigate the hydrodynamic behavior of gravity cage in irregular waves. In the meantime, the frame anchor system is a kind of widely used and important mooring system, where there are various types of mooring lines, such as anchor lines, grid lines and bridle lines. It is necessary to investigate the distribution of tension forces in the mooring lines. Thus, this paper simulates the motion and load response of gravity cage with frame anchor system in irregular waves by numerical model. The motion response (in surge and heave) of the float collar and the tension response in the mooring line are analyzed in the time and frequency domain. Besides, the transfer