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Numerical Simulation of Hydrodynamic Behaviors of Gravity Cage in Current and Waves

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Knowledge of the hydrodynamic behavior of a net cage under the action of waves and currents is the basis of the design and management of net cages in the open sea. Techniques used to investigate the net cage have typically included the use of scaled physical and numerical models, and, where possible, field measurements. Comparing model tests and field measurements, the numerical simulation method is low in cost, easy to manage and a time-saver. In this paper, a numerical model has been developed by rigid body kinematics and the lumped mass method to investigate the dynamic response of the gravity cage in current and waves. Using the numerical model, the motion, net deformation and mooring line forces of the gravity cage were calculated under current only, waves only and combined wave and current flow, respectively. A series of physical experiments was carried out to evaluate the validity of the numerical model. The results of our numerical simulation are all in close agreement with the experimental data. This study shows that our model is valid for the simulation of the net cage in current and waves.

INTRODUCTION

Exposed net cages in the open sea are subjected to wave and current action. From an engineering perspective, net cage systems need to be designed to cost-effectively withstand extreme conditions while providing a suitable growing environment. Thus, knowledge of their hydrodynamic behavior under the action of waves and currents is important for the design and management of net cages in the open sea. The main methods used to investigate the net cage have typically included the scaled physical tests, numerical simulation and, where possible, field measurements.

Many research studies have been conducted to better predict the dynamic performance and reliability of the net cage while subjected to wave and current forces. Kawakami (1964) has proposed relatively reliable semi-empirical formulas for a flexible net subject to the effect of currents. The formulation includes the drag force caused by the material properties, mesh size of net and current velocity. Aarsnes et al. (1990) proposed a calculation method for determining the shape and internal forces on supple net cages. In their theory, the 3-dimensional effects were neglected. The cage thus consists of net panels discretized with line-finite elements in the plane of symmetry. The calculation of hydrodynamic forces comes from test models. These works have laid a good foundation for the estimation of the external forces on an offshore net-cage system. Lader et al. (2003) and Lader and Enerhaug (2005) have conducted a series of experiments investigating forces and deformation on a net cage in a uniform current. They concluded that the total force on a flexible net cage and its deformation are mutually dependent, since different areas in the net structure have different effective angles of attack, and the effective solidity may be altered due to the deformation of the net cage. They also estimate the discrepancy of global forces on a flexible net structure using complicated drag formulas derived from stiff net panel experiments when compared with experimental measurements. This leads to a numerical model called the super-element method, which can be used to predict the global forces on a flexible net sheet. Tsukrov et al. (2003) described the theoretical models and calculation methods of nets, using the consistent net element method, compared the results of previous research with those of the models he described, and applied them to interpreting the movement of the cage system. In Tsukrov et al. (2005), the numerical model was improved upon by the addition of nonlinear elastic elements, such as ropes, rubber tethers and feed hoses. Fredriksson et al. (2003) adopted not only the finite element method, but also a stochastic approach to analyze the motion response characteristics of an in-situ fish cage and the mooring line tension response to wave forces. The results provided valuable information concerning the dynamical processes of the fish cage under environmental forces. Takagi et al. (2004) described the dynamic behavior of fishing nets using the computer-aided simulation NaLA, a system developed for determining net shape and load. Suhey et al. (2005) have worked on the cage structure's numerical modeling using the finite element method and proved that the inflated structure has sufficient stiffness to be used as the structure support within a fish cage. DeCew et al. (2005) performed an extensive set of experiments in a wave tank using regular and random waves to investigate the dynamic response of a modified gravity cage system. Frequency analysis was performed. The RAO results exhibited no resonant condition peaks within the wave excitation range (0.05–0.45 Hz) and it was concluded that the kind of fish cage is a highly damped system, which is favorable for the open sea farming sites. Li et al. (2006a, b) developed a lumped mass method to simulate the hydrodynamic behaviors of both plane fishing nets and gravity cages in steady current.

There are many types of net cages, of which gravity cages are the most popular. In this paper, to investigate the gravity-cage dynamics in waves and current conditions, a numerical model was

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