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Experimental Study on Interaction Between Flow Current and Cage Structure

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In this study, the experiments of a 1:30-scale model of a flexible, circular net cage with mooring system are conducted in the circulating flume. For geometry and motion measurements, a nonintrusive stereo imaging method is employed, which uses 3 CCD camera systems to take the 2-dimensional photos and then transform them to 3-dimensional visional sketches. Experiment results show a highly mutual dependency between the tension force and the deformation of a flexible net structure. Further investigated are the evolution change of 3-D deformation and the motion of the net cage.

INTRODUCTION

As the world's population increases, so does the demand for seafood, including marine finfish. Landings of marine finfish are beginning to plateau, however, with nearly 50% of the major stocks fully exploited (Food and Agriculture Organization of the United Nations, 2000). While the capture fisheries are reaching their full potential, aquaculture continues to expand. Today, marine cage aquaculture is expected to play an increasingly important role in the fish production industry worldwide. Marine aquaculture has been undertaken predominantly in protected near-shore waters (Panchang et al., 1997). In Taiwan, as well as in other countries, this has resulted in an increasing number of fish farms installed in near-shore areas. Despite recent activity in cage aquaculture development in Taiwan, significant biological, engineering and socio-issues need to be resolved before cage aquaculture is chosen instead of inland fisheries. A major constraint to marine aquaculture development in Taiwan is suitable water space. Because of environmental and ecosystem issues existing near-shore aquaculture facilities, aquaculture operations need to be moved into more exposed sites. Thus, the feasibility of extending operations into the energetic open ocean has recently been addressed. However, such a transition is not a minor matter, as the suitable species and technologies for this energetic environment are not yet developed to a viable economic scale.

In contrast to most oil and gas facilities, aquaculture installations are highly flexible hydroelastic structures. Hydrodynamic forces acting on such a structure affect the shape of the structure, and the altered shape affects the hydrodynamic forces. This complex interaction between load and shape is a typical feature of hydroelastic motions. The primary forcing mechanisms due to ocean currents and waves are important in the modeling of open-ocean aquaculture systems. Ocean currents induce both normal and tangential steady-state drag forces on the structure components. The nets on the fish cage are often the largest component and have been the focus of drag forcing research. Using theoretical and model test methods, Aarsnes et al. (1990) determined force and blockage characteristics for individual net types. Colbourne and Allen (2001) conducted a field experiment measuring waves—mooring system loading and cage motion response of a gravity-type net pen—and compared the results with physical models. Further, because in an aquaculture application the internal volume of the net structure influences the fish health and well-being, it is important to study the volume reduction due to the hydrodynamic forces exposure. Huang et al. (2006) utilized the single-point-mooring (SPM) marine cage and numerical solution to investigate its dynamic response of the testing field. They proved the numerical solution could predict the tension from typhoon attacks as long as the current and wave conditions are accurately predicted. Zhao et al. (2007) used a numerical model to simulate the dynamic response of the gravity cage to waves combined with currents. A numerical method was presented for simulating the hydrodynamic behavior of the gravity cage in combined wave-current flow. They show good agreement with physical modeling tests under different current velocities and wave conditions. This numerical model thus has established a foundation for simulating practical net-cage systems in wave-current conditions. Until now, however, an estimate for the 3-D geometry of a net cage exposed to hydrodynamic force has not been well established in field investigation or even in experimental study.

In this study, the experiments of a 1:30-scale model of a flexible circular net cage with mooring system are conducted in the circulating flume. Hydrodynamic force and net deformation are investigated under a different uniform current. For geometry and motion measurements, a nonintrusive stereo imaging method uses 3 CCD camera systems to take 2-D photos, with the relationship between 2-D imaging coordinates and 3-D visional sketches to be obtained by matrices transformation. The submersible load cell is used to investigate the tension force of anchor systems.

EXPERIMENTAL SETUP

The experiments were conducted at the circular flume at the Tainan Hydraulics Laboratory (20 m × 1 m × 1.5 m) (THL) of the National Cheng Kung University, Taiwan. This tank is a vertical-type circular water channel driven by a screw pump, with an observation section 2.3 m long × 1 m high × 1 m wide (Fig. 1). Maximum velocity of generating uniform flow is 28 cm/s (153.4 cm/s in prototype).

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