

Dynamic simulation of the fish cage net and floating collar subjected to currents and waves

Chun W. Lee^a, Gun H. Lee^b, M Youl. Choe^b, Mi K. Lee^b

^aDivision of Marine Production System Management, Pukyong
National University, Busan, South Korea

^bDepartment of Fisheries Physics, Pukyong National University
Busan, South Korea

ABSTRACT

The fish cage system consists of netting, mooring ropes, a floating collar, floats, sinkers and anchors. Whole elements of the cage system were modeled on the mass-spring model. The modeling method was applied to the dynamic simulation of the actual fish cage system simultaneously influenced by the current and waves in order to evaluate their practicality. Computer-based simulation provides a method to quantitatively analyze the environmental forces acting on fish cage systems and thereby provides valuable information necessary for designing an optimal structure.

KEY WORDS: Dynamic simulation; mathematical model; fish cage; floating collar; mass-spring model.

INTRODUCTION

In recent activity in fish cage systems, the increased attention is being focused on extending operations into the open ocean in order to avoid conflicts in the near-shore areas. To design reliable systems that can withstand the severity of open ocean, stricter design criteria and novel engineering methods specific to open ocean environments are needed. Such methods include mathematical modeling of the dynamic responses of structures placed in high energy open ocean areas and 3-D simulation of the ocean environmental loads that would act on aquaculture systems. Fish cage systems consist of netting, mooring lines, a floating collar, floats, and sinkers. Netting, ropes, and a floating collar are the basic components of marine cage structures. Much research has been devoted to understanding the hydrodynamic coefficients and the behavior of the nets in different operating conditions (Aarsnes et al., 1990; Bessonneau and Marichal, 1998; Lee et al., 2005; Kim et al., 2007). Recently, many researchers have conducted computer-aided behavior analysis of fish cage systems (Tsukrov et al., 2003, 2005; Fredriksson et al., 2003, 2007; Lader and Enerhaug, 2005; Haung et al., 2006, 2007; Li et al., 2006; Zhoa et al., 2007).

In this study, we propose a mass-spring model to describe the whole elements of a fish cage system, including the floating collar. We performed a mathematical calculation to interpret the dynamic behavior of the actual fish cage system when influenced by currents and waves. Dynamic simulation was conducted with the current velocity at 0.25m/s, 0.5m/s, 0.75m/s, and wave height at 6m. Finally, when the velocity is

0.8m/s and waves are at a height of 6m simultaneously, fatal damage of the fish cage system by breaking the mooring line was simulated.

MATERIALS AND METHODS

Equation of Motion

The cage system was modeled based on the mass-spring model. In this model, the nettings and ropes are regarded as flexible structures and the floating collar as an elastic structure. The structures of the cage are divided into a finite number of elements and mass points are placed at the mid-point of each element; the mass points are connected by springs without mass. Applying this method to the netting, which takes up most of the cage structure, the mesh knots in the netting can be considered as the mass points and the mesh bars can be considered as the springs connecting the mass points (Fig.1). To reduce the calculation loads we used the approximation method, in which several actual meshes are bundled together into a virtual mathematical mesh having the same physical properties. For the mooring line, we divided the line into constant lengths, and mass points were placed at the mid-point of each element; the mass points were connected by springs (Lee et al., 2005; Kim et al., 2007).

The floating collar consists of one big floating tube or two small tubes connected in parallel to form the circular upper structure, with a hand rail installed on top of it. For convenience of analysis, we modeled one floating tube without the hand rail. For the mass points of the floating collar, a rectangular parallel pipe, similar to the original 3D structure, was constructed, and mass points were placed on each corner. The spring was placed along the edges and diagonally to make sure that the structure maintained its shape even if external forces were applied in several different directions (Fig. 1).

The equation of motion for each mass point can be described as follows:

$$(m + \Delta m)\ddot{\mathbf{q}} = \mathbf{F}_{\text{int}} + \mathbf{F}_{\text{ext}}, \quad (1)$$

where m is the mass of the mass points; Δm is the added mass; $\ddot{\mathbf{q}}$ is the acceleration vector; \mathbf{F}_{int} is the internal forces applied between the mass points; and \mathbf{F}_{ext} is the external forces applied to the mass points. The added mass of the mass points is given by:

$$\Delta m = \rho_w V_n C_m, \quad (2)$$