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Dynamic deformation of the floating collar of a net cage under the combined effect of waves and current

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A R T I C L E I N F O

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A B S T R A C T

In this study, a numerical model was established to simulate the dynamic behavior of a floating net cage in waves and current, based on the finite element method. To validate the numerical model, we considered a case based on the motions of the net cage under regular waves and current, where we calculated and compared the simulated results. The comparison of the results indicated good agreement. We calculated the dynamic deformation of the floating collar of the net cage under regular/irregular waves and current, and we analyzed the effects of the net, strong waves and current, and the length of the mooring line on the cage collar deformation. The results indicated that the deformation of the floating collar with a net was much greater than that without a net. The collar deformation became larger as the wave height or current velocity increased. Therefore, in order to reduce the risk of local collar failure due to plastic deformation, adding a casing pipe in the position of the mooring line connection point on the floating collar could greatly enhance the bearing capacity of the cage collar under severe sea conditions. In addition, increasing the length of the mooring line would help to decrease the mooring line tension and further reduce deformation of the cage collar.

1. Introduction

Cage aquaculture is a major marine culture method that has developed rapidly over the past 10 years in China, where the total production obtained from this method was 572,355 metric tons in 2015, which accounted for about 50% of all marine fish farming (Fisheries Bureau, 2016). However, due to various environmental issues and coastal zone resource conflicts in recent years, cage aquaculture has been increasingly developed in more exposed sea water where the water depth exceeds 20 m and the water quality is much better. Unfortunately, the prevailing typhoons each year may cause serious deformation of the floating collar for cage systems due to strong waves and current, thereby severely undermining the integrity of the cage collar under strong sea loads. Therefore, the dynamic deformation of cage collars is a very important problem that requires investigation.

In general, a gravity net cage mainly comprises the floating collar, fishing net, sinker weights, and mooring system. The floating collar is responsible for providing buoyancy to ensure cage drifting and an operational platform for farm workers, but it also has a significant role in resisting impacts due to sea loads. To make their calculations simple and convenient, many researchers have conducted numerical studies of the hydrodynamic behavior of net cages based on the assumption that the load-bearing component floating collar is rigid, and it undergoes no deformation (Huang et al., 2007; Zhao et al., 2007; DeCew et al., 2010; Tang et al., 2011; Xu et al., 2013; Lee et al., 2015). In addition, model testing has been used widely as an effective method for understanding the hydrodynamic properties of fish cages. However, investigating the deformation of a floating collar in hydrodynamic experiments of fish cages under the influence of waves and a current is generally difficult because the deformation of a small-scale cage collar is too small to be observed easily as the stiffness similarity is not likely to be appropriate for a small-scale, prototype cage collar. Therefore, a small-scale cage collar in a water tank is basically a rigid body. Previous experimental studies of the deformation of fish cages have focused mainly on net deformations (Lader and Enerhaug, 2005; Ding et al., 2007; Moe et al., 2010; Kristiansen and Faltinsen, 2015; Stranda et al., 2016). Furthermore, the floating collar is usually fixed when focusing only on net deformations during the physical testing of fish cages, especially in a

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0144-8609/

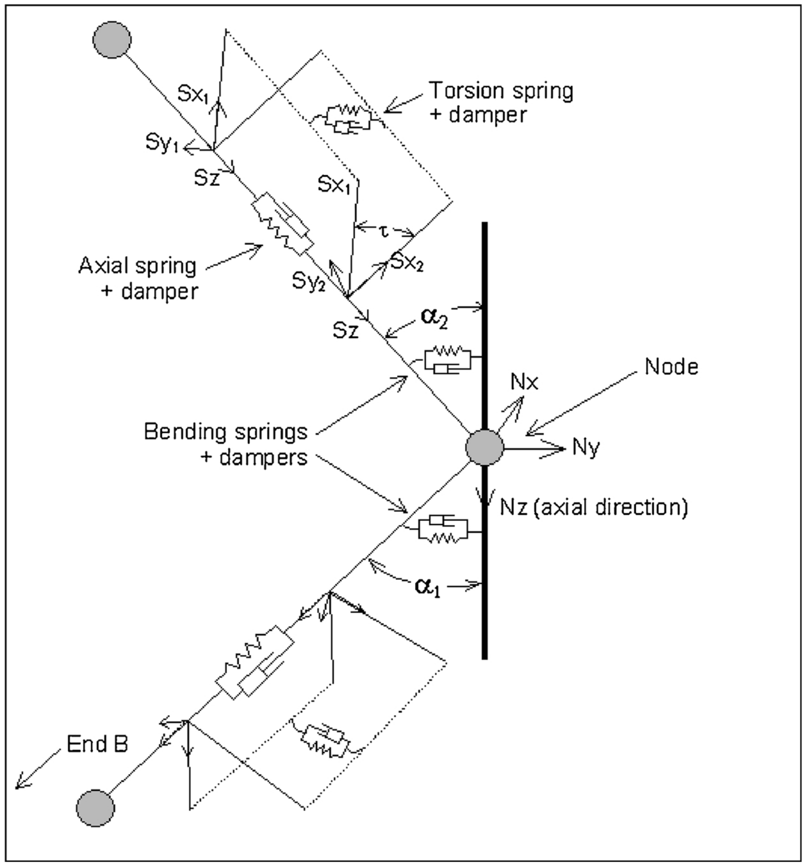

Fig. 1. Detailed representation of line model.

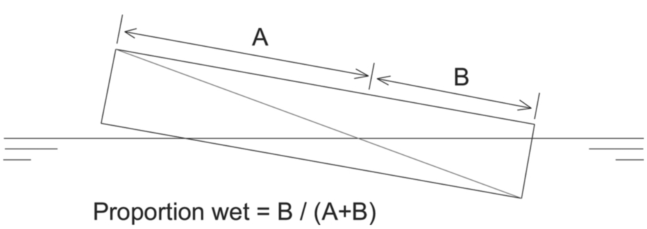

Fig. 2. Proportion wet for a surface-piercing segment.

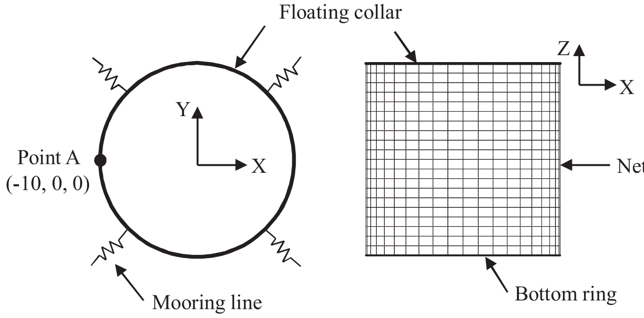

Fig. 3. The net cage model used for the calculations.

state with a uniform flow (Lader and Enerhaug, 2005; Stranda et al., 2016).

In practice, strong waves and currents act on a net cage fixed in the open sea, where a cage collar made of high-density polyethylene (HDPE) may undergo large deformation at the connection with the mooring system. Site observations have confirmed that the deformation of larger fish cages is more severe than that of smaller cages. In recent years, the deformation of fish cage collars has attracted the interest of researchers in the marine aquacultural community (Fredriksson et al., 2007; Hao, 2008; Li et al., 2013; Huang et al., 2016; Bai et al., 2016). For example, Li et al. (2013) studied the dynamic responses of a semi-immersed floater and a fish cage system comprising a floater and nets in waves and currents, where large geometric deformation and motions were observed in both the floater and nets. Huang et al. (2016) investigated the deformation and forces for a floating fish cage collar in regular waves based on the finite element modeling method and analyzed the effects of the collar dimensions. Bai et al. (2016) conducted fatigue assessment for the floating collar of a fish cage using the Palmgren–Miner cumulative damage theory together with the deterministic method.

The dynamic deformation of a floating collar is related closely to the fishing net and mooring system, as well as the waves and currents that impact on net cages. According to this consideration, the objective of this study is to analyze the dynamic deformation of a floating collar for a net cage under the combined influence of waves and the current in order to help optimize the design to increase the bearing capacity of a net cage. The remainder of this paper is organized as follows. Section 2 introduces the finite element numerical model of a net cage. To validate the numerical model, we simulate the floating fish cage in regular waves and current described by Li et al. (2013), and comparisons of the results are presented in Section 3. In Section 4, the numerical model is used to simulate the dynamic deformation of the floating collar under strong waves and a current, and a measure for increasing the safety and reliability of the cage collar is proposed according to the simulation results. In addition, the effects of the fishing net and the mooring line length are analyzed. Finally, we give our conclusions in Section 5.