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A static position-adjustment method for the motion prediction of the Flexible Floating Collision-Prevention System

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ABSTRACT

The Flexible Floating Collision-Prevention System (FFCPS), used to prevent collision between uncontrolled ships and non-navigational bridges, comprises cable chains, floating structures and mooring system. Its main working principle is to use the sliding of the mooring systems in the role of energy dissipation. It can convert the kinetic energy of the ship into internal energy, and thus achieve the effect of avoiding a ship collision. The force relationships between various components of the system and ensuing simplified numerical models are firstly established in order to study the movement of the FFCPS. Subsequently, using suitable assumptions, the method of position adjustment to approach equilibrium condition is introduced. This method is based on the concept of statically determinate equilibrium in each step. The feasibility of the method proposed in this paper is verified by comparing the calculated results with model test measurements and published reference predictions. From these comparisons it is concluded that this method can be used in the preliminary design stage of the FFCPS.

1. Introduction

As accidents involving ship collisions occur more frequently, more and more scholars and researchers are involved with the ship-bridge collision problems. There have been many studies focusing on collision risk assessment [1–5]. The application of Integrated Bridge Systems incorporated on a ship and the corresponding new methods for determining safe ship trajectory [6–8] increase the safety of navigation. Nevertheless, these solutions cannot thoroughly prevent the ship-bridge collision, hence, the design of ship-bridge collision avoidance system have been paid more attentions [8,9]. In these studies, simulation based on finite element analysis is one of the most frequently used methods [10–13]. .

There are many new types of anti-collision devices for protecting bridges. Lei et al. [14] analyzed various aspects of the bridge-collision problem, putting forward the key principles of the “initiative anti-collision” concept and presenting a corresponding simplified model. Zhu et al. [15] proposed a simplified energy-based analysis method to estimate the lateral deflection of the flexible pile-supported protective structures that are subjected to a given impact energy. Chang et al. [16] analyzed buoys and their anti-collision features, and provided several theoretical suggestions for the design of anti-collision buoys. Wu et al. [17] designed an “energy consuming collision-prevention system of long distance anchor moving”, which is installed at a suitable distance away from the bridge to prevent the collision between ship and non-navigational bridge. This system, namely the Flexible Floating Collision-

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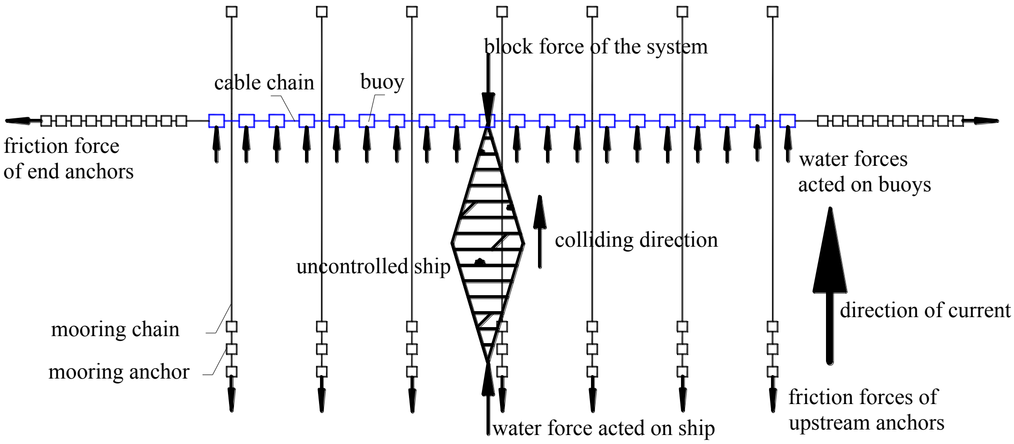

Fig. 1. Schematic diagram of Flexible Floating Collision-Prevention System.

Prevention System (FFCPS), is made up of buoys, connection cables and mooring system, as shown in Fig. 1. Chen et al. [18–20] studied the methods for simulating the motion of the system when collided with uncontrolled ships. The kinetic energy and potential energy of the moored collision-prevention system, when collided with a ship, were calculated through the kinetic energy theorem and the mooring force equation. Then the approximately static equations are solved by a numerical iterative calculation method for the FFCPS. Xie and Li [21] proposed a system made up of independent anti-collision piers, interception rope chains, steel floating bodies and anchor ingot sink block. It is similar to FFCPS and it has been applied in the Hangzhou Bay Sea-Crossing Bridge of China. Based on position adjustment to approach equilibrium condition, a new method for the motion analysis of the FFCPS is presented in this paper. The numerical model based on this method is similar to the model proposed in Ref. [20], but there are some differences between them. In Ref. [20], the position of each component is adjusted simultaneously in each micro-time step, while the elements are adjusted locally during each micro-displacement in this essay. By comparing the numerical results obtained from the proposed method with those from published numerical and experimental results, its feasibility for application in the preliminary design process is verified. Furthermore, the proposed model can obtain faster convergence rate.

FFCPS comprises the water surface blocking system and mooring system. The former consists of buoys and the connecting cable chains, which are floating on the water surface to prevent the colliding ship. The mooring system is composed of mooring chains and anchors. Before collision, except for the internal loads of connecting cables and mooring lines etc., the water forces acting on the buoys and the friction forces of anchors shown in Fig. 1 are the external forces acting on FFCPS. When a ship collides with the system, the block force of the system acting on the ship has the same value (but opposite direction) with the push force that the ship exerts on the system. At the same time, the water force related to the relative velocity between the ship and current is another external force acting on the ship, as shown in Fig. 1.

Fig. 2 illustrates how the FFCPS functions in a model test. In most cases, the current is generated and causes the ship to drift. When the uncontrolled ship collides with the system, firstly the water surface components of the system will move with the ship. When the horizontal force component of a mooring chain reaches the maximum friction force between the anchor and the sea bed, the anchor will slide on the sea bed under the action of increased mooring force induced by the collision. The mooring system, through the sliding of the anchors, absorbs the energy of the colliding ship, including the initial kinetic energy and the work obtained from the current in the later process. It should be stated that a small part of the kinetic energy and work might also be transformed into the potential energy in the mooring system, kinematic energy of the buoys and cable chains and strain energy of the structure, but they are not be considered in this paper. If the summation of the friction forces of the anchors, namely the maximum block force, is bigger than the total current force (as well as wind and wave force, if relevant, but not considered in this paper) acting on the ship and buoys, the ship will be controlled under the block force of the FFCPS in the end. The maximum block force and the duration of the

Fig. 2. Model test of FFCPS.

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