Nonlinear Network Dynamic Characteristics of Multi-Module Floating Airport with Flexible Connectors

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ABSTRACT

The floating airport consisting of multi-modules with flexible connectors forms a complex dynamic network. A generalized network model is formulated based on the models of single floating module, linear hydrodynamic model, mooring constraints and elastic connectors with geometric nonlinearity. We study the synergistic dynamic behaviors of the floating airport by using network theory. The phenomenon of amplitude death, a collectively weak oscillatory state, is investigated which is especially important for global stability design of the floating airport in waves. Numerical simulations illustrate the occurrence of amplitude death in a parameter domain spanned by wave period and connector stiffness. The paper presents a new methodology for nonlinear dynamics prediction of very large floating structures.

KEY WORDS: floating airport; network dynamics; amplitude death; nonlinear dynamics.

INTRODUCTION

Very large floating structures (VLFS) have been used to land reclamation from the sea in order to ease the pressure on existing heavily-used land space due to their relatively simple construction and ease of maintenance offering distinct advantages. The design and construction of an effective VLFS in terms of safety and desired responses are the key element for their successful implementation, operation and further development. Some applications require a stringent tolerance on the deformation of floating structures. For example, in the Mega-float project used as an floating airport in Tokyo Bay, the slope of the structure in the longitudinal direction should be less than one degree(Suzuki, 2005). So the prediction of dynamic characteristics of VLFS is significant for its design and construction.

The VLFS investigated during the past decades are commonly divided into two basic types, the box shaped pontoon type and the semi-submersible type. The hydroelastic theory has been applied to analyze the dynamics characteristics due to the small draft comparing to its length for the pontoon type VLFS. A common approach is to model the entire floating structure by a single plate based on the classical thin plate theory(Aoki, 1997; Hamamoto, 1994; Kashiwagi, 1998; Khabakhpasheva and Korobkin, 2001). On the other hand, for the larger draft to length ratios as opposed to the mat-like VLFS, this necessitates the modeling of the floating modules as a thick plate according to the Mindlin plate theory(Watanabe et al., 2006). The floating structures discussed above are all viewed as a single module and their responses are obtained by using linearized modal superposition or finite element discretization method. In general, however, since the VLFS has large horizontal dimensions compared to the vertical one, it is usually constructed by connecting multiple standardized modules with connectors addressing easy construction, transportation and deployment (Watanabe et al., 2004). So the connection problem is significant and the single beam or plate model can not disclose characteristics of the floating structures reasonably. More recently, Fu et al.(2007) and Wang et al.(2009) proposed the use of hinge or semi-rigid connectors instead because they found that the non-rigid connectors are more effective in reducing the hydroelastic response as compared with the rigid ones. Xia et al. (2000) dealt with the VLFS as a two-dimensional articulated plates connected by idealized connectors that are considered as two independent vertical and rotational springs. They showed that the hydroelastic dynamics are strongly dependent on the stiffness of the connectors and the incoming wave frequency. Gao et al.(2011)’s study examined the effect of the location and the rotational stiffness of a flexible line connection on the hydroelastic response. Hinge and semi-rigid line connections were found to be effective in reducing hydroelastic response of the VLFS as well as the stress resultants, depending on the wavelength.

The semi-submersible type is an optimal choice in order to reduce the hydrodynamics responses in the deep sea area. To determine its hydroelastic response, two models are required, a structural model to include the elasticity of the structure, and a hydrodynamic model to determine the fluid forces. Kim et al.(1999) developed a three-dimensional hydroelastic model of a multi-module linked floating structure under regular waves with arbitrary propagating direction by using FEM for structures and WIMIT program for the fluid in which the connector was represented by a linearized stiffness matrix with respect to the displacements at the module connection points. However, a detailed finite element structural model is actually more difficult to construct. There is, therefore, motivation to use a simpler structural