International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 30, No. 4, December 2020, pp. 427–436; https://doi.org/10.17736/ijope.2020.sh29

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Experimental and Numerical Investigation of Influences of Connector Stiffness and Damping on Dynamics of a Multimodule VLFS

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This paper investigates the connector characteristics of a multimodule very large floating structure (VLFS). The VLFS is composed of three modular semisubmersible structures, each of which is 300 m in length. Two kinds of connectors are considered: the pitching free articulated connector and the flexible connector. The load characteristics of connectors and their influence on the relative motion of the modules in various environmental conditions are analyzed. To further study these influences, a numerical model is established and experimentally verified. The factors affecting connector performance are then numerically analyzed in detail. The results show that the connector load and module motion were significantly influenced by connector stiffness and damping characteristics. A connector with appropriate stiffness can constrain relative motion well, and it can release part of its relative motion to reduce its load. Some conclusions are summarized that provide a reference for the design of VLFS connectors.

INTRODUCTION

In recent decades, as a result of advances in very large floating structure (VLFS) technology, the connector design for VLFSs has drawn substantial attention from researchers. In 1999, Kværner Co. (Zueck et al., 2000) proposed a conceptual design for a flexible connected semisubmersible VLFS. The VLFS consists of three semisubmersible modules, each 235 m in length. Modules are connected by a 410 m flexible connection bridge. The capacity of this kind of VLFS is small, because the flexible connection bridge generally cannot bear the carriages.

The articulated connectors pitch freely, and the rest of the degrees of freedom are completely rigid. Under certain environmental conditions, the relative pitch is limited by the hinged connector, and the module can pitch freely to a certain extent. The relative motion of the module is constrained well by this design, and the longitudinal load of the connector itself is alleviated (Derstine and Brown, 2000). During docking, the sensor can precisely monitor the relative distance between adjacent modules, thus ensuring that the bolt can insert into the hinge smoothly and complete the connection process. In extreme conditions, it is easy to quickly release the hinge pin and thus separate adjacent modules. This kind of connector has a simple mechanical structure and high stability. However, some problems persist. First, this articulated connector is very weak in VLFS modules' pitch constraint. When the VLFS is in extreme conditions, its connectors must be disconnected, which is difficult and dangerous. Second, articulated connectors have a high requirement on the middle axis, as a result of material wear and fatigue resistance. Finally, with the increase in the number of VLFS modules, the difficulty and risk of pitch constraint increase rapidly. For these reasons, the advantages of the articulated connector are reduced, and the disadvantages are prominent.

There has been a long-term technological trend from the simple articulated connector to a flexible connector. These have a six-degrees-of-freedom (6-DOF—namely, surge, sway, heave, roll, pitch, and yaw) stiffness that can be adjusted according to environmental conditions, which allows the relative motion of VLFS modules (relative roll, pitch, and yaw) and reduces connector loads (Derstine and Brown, 1999). Compared with simple rigid connectors, flexible connectors are powerful and simple; however, the system design is more complicated (Haney, 1999).

The flexible connector can provide stiffness in some degrees of freedom to maintain VLFS smoothness (such as relative heave and roll) while permitting larger relative motion in other degrees of freedom (i.e., relative pitch and surge). A flexible connector makes up for the shortcomings of a rigid connector and an articulated connector. Upon selecting the appropriate stiffness and damping, the connector can constrain the relative motions of adjacent modules and reduce its own bearing loads.

Wang et al. (1991) calculated the hydrodynamic and wave load of a VLFS using three-dimensional hydroelastic theory, and they found that the maximum impact on the VLFS module motion and connector load was from the connector stiffness. Riggs and Ertekin (1999) analyzed the stiffness of flexible connectors in various sea conditions and analyzed the response rules. They found a substantial resonance response on the connector loads in some sea conditions.

Fu et al. (2007) studied the hydroelastic problem of a two-module connected VLFS and showed that, to a large extent, both the stiffness of the connector and the module determine the hydroelastic response of the structure. Furthermore, Gao et al. (2013) studied the function of connectors from the perspective of hydroelastics. They compared a set of connectors and found that a flexible connector can effectively reduce the hydroelastic response of a VLFS.

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Received August 21, 2018; revised manuscript received by the editors October 26, 2019. The original version was submitted directly to the Journal.

KEY WORDS: Very large floating structure (VLFS), flexible connector, articulated connector, stiffness, damping.