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Three-Dimensional Hydroelastic Response of a Very Large Floating Structure

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ABSTRACT

A simplified analysis procedure based on 3-D hydroelasticity, which can be used to determine the motions and intermodule forces of a multi-module, very large floating structure (VLFS), is described. While the procedure is applicable to an arbitrary geometric layout of the modules, the modules are considered rigid, and hence all deformations occur in the module connectors. The procedure is used to analyze the response of a 5-module VLFS in both regular and irregular seas. The effect of fluid and structural coupling of the modules on the response is evaluated.

INTRODUCTION

Numerous proposals have been made for very large floating structures (VLFS). Proposed applications range from the visionary floating "city" to the more likely floating airport (Lemke, 1987); military bases (Bretz, 1988; Brahtz, 1989); wave power generators (Katory, 1977); and deep ocean mining platforms (Winkler et al., 1990). Many of these applications involve floating structures of a scale never before constructed. A floating airport, for example, would likely be several thousand m long and several hundred m wide, and it may be in an exposed ocean environment. By contrast, one of the largest floating structures ever constructed is the inland Hood Canal Bridge, which was approximately 2000 m long but only 15 m wide (Hartz, 1981), and the size of conventional floating platforms is on the order of 100 m x 100 m.

Although the scale of a VLFS may be an order of magnitude greater than previous floating structures, the basic technology required for their design and construction is available. It is likely that an important class of VLFS will consist of multiple modules, each of which will be a conventional-sized floater. For open-ocean applications for which motions must be restricted, the modules will likely be similar to the large semisubmersibles presently used in the offshore oil industry. It would appear, therefore, that the major technological issues which need to be addressed vis-a-vis this class of VLFS are i) the design and analysis of the connectors; and ii) analysis methodologies which can predict the motion and intermodule forces of such a large scale floating structure.

The size of a VLFS requires an alternative analysis methodology than that used for conventional floaters. For example, motions are almost always determined based on a rigid structure in the case of conventional floaters. This uncoupling of the hydrodynamics and the structural dynamics is often acceptable for conventional structures because the structural deformations are small compared to the rigid body motions. This is not necessarily true for a VLFS, however, and hydroelasticity theory must often be used, wherein the coupled hydrodynamics and structural dynamics problems are simultaneously solved in a unified manner.

Hydroelastic methods of analysis can be classified as either 2-D or 3-D. A typical 2-D theory of hydroelasticity uses strip theory of hydrodynamics and models the structure as a simple beam (see for example, Bishop and Price, 1979). This approach is most suitable for ships and floating bridges (Georgiadis, 1981; Langen and Sigbjornsson, 1980; Luft, 1981), but it has also been applied to other long VLFS (Okamoto et al., 1985; Masuda et al., 1987; Che et al., 1990; Ertekin et al., 1990; Riggs et al., 1991). It is clear that such an approach is not applicable to a general VLFS, in which the modules can have an arbitrary geometric layout. The alternative analytical approach is a 3-D theory. The most general linear theory in this category models the fluid flow with 3-D potential theory, while the structure is represented by a 3-D finite element model (Wu, 1984). This approach has been applied successfully to a variety of conventional-sized structures (Price and Wu, 1985; Bishop et al., 1985; Lundgren et al., 1988; Lee and Lou 1989).

Although general 3-D hydroelasticity could be used to determine the response of a VLFS, it is desirable to develop simplified methods of analysis, especially for use in preliminary design and for parametric studies. This paper presents such an approach to determine the 3-D hydroelastic response of a multi-module VLFS. In particular, it is assumed that the structure consists of multiple modules joined by connectors which are significantly more flexible than the modules themselves, and hence all deformation occurs in the connectors. This assumption results in a rigid module, flexible connector (RMFC) model, in which there are only 6 displacement degrees-of-freedom per module. A full 3-D source distribution method is used to determine the coupled structure-fluid-structure interaction problem. Although this approach is limited to flexibly-connected modules, it is considered to be particularly useful to study the motions, alternative geometric layouts, and connector forces for this class of VLFS.

The RMFC approach has been applied previously to VLFS by Che et al. (1990) and Ertekin et al. (1990), although in both references the hydrodynamic interaction between modules was ignored. Yoshida and Goo (1990) included the interaction, but they used an alternative hydrodynamic theory which is based on the multiple scattering and matrix theories of Kagemoto and Yue (1986). With the implementation of these theories, it is possible to use the Green function method for a single module and then determine the interaction between different modules without solving

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