Wave Frequency Dependent Added Mass and Hydroelasticity of Flexible Floating Structures

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ABSTRACT

In this paper, the significance of the inclusion of the wave frequency dependent added mass, additionally, to the hydrostatic-gravitational stiffness in the hydroelastic analysis of flexible Floating Structures (FSs) is demonstrated and investigated. The numerical approach includes the application of a 3D structural model (eigenvalue analysis), a 3D frequency domain hydrodynamic model (hydroelastic analysis) and an iterative procedure (direct inclusion of the frequency dependent effect of the incident waves). The results of this approach for two kinds of FSs are compared with the corresponding ones obtained from a “dry” and a modified (inclusion of infinite wave frequency added mass) numerical approach and the importance of the present methodology in the hydroelasticity of FSs is clearly demonstrated.

KEY WORDS: Hydroelastic analysis; wet modes; dry modes; floating structures; added mass; floating breakwater.

INTRODUCTION

Floating Structures (FSs) present nowadays one of the most characteristic types of offshore and coastal structures, which can be utilized in the sea environment in order to develop modern and sophisticated projects that address new trends and needs and satisfy new requirements. The climate change, the requirement of sustainable development in all aspects of human life, the problem of land scarcity, the necessity of the usage of renewable energy sources in conjunction with the well-known advantages of these structures (i.e. reduced environmental impact, reallocation ability, etc) have enforced the significance of the FSs and have redefined their role. Floating island cities, floating entertainment facilities and emergency bases, floating storage bases of oil or water, floating airports and heliports, floating offshore wind turbines and/or sea water desalination plants, floating bridges and breakwaters represent characteristic current and future potential projects, where the design and construction of effective FSs in terms of safety, desired performance and cost is the key element for their successful implementation.

In most of these projects, FSs are characterized by considerable structural deformations, i.e. great flexibility, since they have very large horizontal dimensions and/or they consist of flexibly interconnected modules. Consequently, the application of an appropriate hydroelastic analysis is a very important factor for an accurate and realistic design of these structures. This fact in combination with the aforementioned significance of the flexible FSs, have led to the extensive investigation of the performance of these structures by many researchers, through the development and the application of various numerical approaches, which enable the inclusion of hydroelasticity in the corresponding analyses.

The concept of hydroelastic analysis has been introduced by Bishop and Price (1979), who considered symmetric and anti-symmetric modes for a ‘beam-like’ hull with the use of 2D hydrodynamic strip theory. Thenceforth, many other investigators developed and applied analytical formulations for the calculation of the structural deformations (deformational displacements which cause strains) and utilized numerical methods for the implementation of the hydroelastic analysis (Newman, 1994; Wu et al., 1995; Taylor and Ohkusu, 2000; Taylor, 2003; Fu et al., 2005; Taylor, 2007; Senjanovic et al., 2008a and Diamantoulaki et al., 2008). Other researchers, like Riggs et al. (2000), Chen et al. (2003), Taghipour et al. (2006), Fu et al. (2007) and Senjanovic et al. (2008b, 2008c) utilized structural models based on the Finite Element Method (FEM) in order to calculate the eigenmodes and the structural deformations of the floating body through the solution of the eigenvalue problem, considering the absence of incident waves. The calculated eigenmodes present the “dry” modes of the FS and the corresponding structural deformations are then inserted in appropriate hydrodynamic numerical models in order to perform the hydroelastic analysis. In all these investigations, the effect of the incident waves on the structural deformations is achieved only in the hydrodynamic model, through the appropriate modification of the mass and the structural stiffness matrices that correspond to the “dry” modes of the FS, which are augmented in order to include the added mass and the hydrostatic-gravitational coefficients. Therefore, the effect of the incident waves (added mass and hydrostatic-gravitational stiffness) on the eigenvalue results of the structural model is considered indirectly. The terms “dry” and “wet” modes were introduced by Bishop and Price (1976) and were also referred by Taylor (2003) in order to express the exclusion or the inclusion of the effect of the incident waves on the calculated eigenmodes and eigenfrequencies of the FS that correspond...