

The Analysis of Wave-Induced Dynamics of Ocean Platforms by Hybrid Integral-Equation Method

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ABSTRACT

A reliable and economical numerical method is proposed for predicting wave-induced dynamic responses of ocean platforms of complex geometry. This is based on the hybrid integral-equation method, which combines a direct boundary element solution of the fluid region close to the body with an eigenfunction representation of the far field behaviour. To achieve accuracy and economy, the boundary surfaces are discretised into quadratic isoparametric elements. The validity and accuracy of the proposed method are demonstrated through several numerical examples, including the results for the ITTC semisubmersible. It is shown that the use of quadratic isoparametric elements leads to significant improvement of accuracy and efficiency of the hybrid integral-equation method, compared with classical boundary integral approaches based on constant element idealisations.

INTRODUCTION

The design of huge ocean platforms depends critically upon the analysis of wave-induced loads and motions. Thus, over the last 15 years, substantial efforts have been devoted to the development of reliable and economical methods for predicting these effects. Computer programs based on three-dimensional diffraction theory are now available for evaluating the hydrodynamic coefficients, loads and motions for structures of practical form. For large bodies with relatively simple geometry such as a vertical cylinder or sphere, these programs generally provide accurate predictions that compare well with analytical solutions and model test results. Recent surveys for the ITTC (Takagi et al., 1985) and the ISSC (Eatock Taylor and Jefferys, 1986), however, suggested that this was not the case for more complicated structures such as a semisubmersible and tension leg platform (TLP).

The ITTC Ocean Engineering Committee has performed a comparative study of motions of a semisubmersible, which has been published by Takagi et al. (1985). Predictions from 34 computer programs were compared among themselves and with model test results from three organisations. While most computer programs provided reasonable predictions of measured surge and sway, the computed results for the other motions showed substantial scatter about the experimental data. The three-dimensional diffraction programs seemed to overestimate the heave added mass, leading to longer natural periods than those predicted by Morison's formula or experiment. The survey for the ISSC, republished by Eatock Taylor and Jefferys (1986), also demonstrated significant and disturbing variability between the hydrodynamic loads and motions predicted for an example TLP by 17 diffraction programs.

Most of the participating organisations employed a source-sink distribution or direct boundary integral formulation, with an as-

sumed constant distribution of the governing variable (source strength or potential) over each surface panel. It would therefore not be surprising if a large number of panels were required to represent the complex geometry of the semisubmersible or TLP, and the complexity of associated wave flows accurately. Indeed, Korsmeyer et al. (1988) adopted up to 12,608 constant source panels to analyse another TLP with 6 columns. Jefferys (1987) studied the same TLP configuration with different mesh arrangements, and cautioned that the constant source panel method did not necessarily lead to correct answer, as the number of panels was increased without limit.

The present work is motivated by the need to investigate more reliable and economical numerical methods for predicting wave-induced dynamic responses of ocean platforms of complex geometry. One such method proposed herein is the hybrid integral-equation method involving the use of quadratic isoparametric surface elements. To describe the complexity of body geometry and associated wave flows accurately, it appears adequate to adopt higher-order elements (e.g., linear or quadratic). To the best of our knowledge, higher-order panels have never been used in conjunction with the classical boundary integral formulation, due to the difficulty in integrating Green's function and its gradients multiplied by the higher-order shape functions over each element. The difficulty may be overcome by introducing a free-space Green's function (i.e., a Rankine source) instead of the complete Green's function. This hybrid integral-equation method is based on combining a direct boundary element solution of the fluid region close to the body with an eigenfunction representation of the far field behaviour. The formulation based on a constant panel idealisation has been given by Yuen and Chau (1987), and Matsui, Kato and Shirai (1987), and it is extended herein to adopt quadratic isoparametric elements. (In our experience, the use of linear elements does not necessarily lead to the improvement of accuracy.) Because of the simplicity of the free-space Green's function, no additional difficulty arises in employing higher-order elements. Following a brief review of the mathematical formulation, the validity and accuracy of the proposed method are demonstrated

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KEY WORDS: Hybrid integral-equation method, wave diffraction, wave radiation, hydrodynamic load, wave-induced motion, ocean platform.