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Responses of a Spar Platform in Random Waves and Currents (Experiment Vs. Theory)

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ABSTRACT

The response characteristics of a large slack-moored floating spar in regular waves, bichromatic waves, and unidirectional irregular waves with or without sheared currents are investigated by experiment and numerical method. The experiment with 1:55 scale model was conducted in the Offshore Technology Research Center (OTRC) three-dimensional wave basin at Texas A&M University. A time-domain nonlinear motion analysis computer program was developed to numerically simulate the performance of the spar for various wave and current conditions. It was found that the linear wave-body interaction theory alone was not adequate, and the second-order wave-body interaction theory including the effects of viscous and wave drift dampings had to be used for the reliable motion prediction of a spar. The complete first- and second-order diffraction/radiation programs for bichromatic, bidirectional waves were developed using the higher-order boundary element method (HOBEM), and the viscous drag forces were computed from the Morison drag formula based on the relative velocity squared. The wave drift damping was computed using the modified drift gradient method. The two-term Volterra series was used to calculate the time series of nonlinear potential excitations in random seas. The resulting numerical results agreed well with our measured data. It was seen that the low-frequency surge and pitch responses were in general greater than the wave-frequency responses, and the slowly varying responses were appreciably reduced in the presence of currents. The total response amplitudes were found to be practically acceptable in the survival condition characterized by a 100-year storm sea.

INTRODUCTION

Numerous oil and gas discoveries have recently been made in water depths ranging from 2,000 ft to 6,000 ft. Those deep water reserves, however, have not been actively developed yet, mainly because of high development cost and technological uncertainties. In this regard, an innovative, reliable, and cost-effective platform concept needs to be explored to justify such investment and the risk involved in ultra-deepwater development.

The spar (Fig. 1) is a new, reliable and cost-effective platform concept that seems economically feasible to a depth as deep as 10,000 ft (Perryman and Beynet, 1994). It is a deep-draft, large-diameter, straight-sided, hollow-cylindrical vessel that can support drilling and production equipment and store plenty of oil in its hull (Glanville et al., 1991). Its deep draft gives it excellent motion characteristics in the most severe sea states, which has already been proved through the successful operation of a similar floating instrument platform, FLIP, in the North Pacific. The spar also has a number of other attractive features compared to existing platforms, such as low-cost construction, installation and relocation, insensitivity to water depth, higher riser protection, early cash flow and so on.

The natural frequencies of all the compliant modes of the spar are typically smaller than the frequencies of appreciable wave energy. This implies that the linear wave-body interaction theory alone *cannot* adequately predict the resonance phenomena (Kim and Yue, 1990). The second-order difference-frequency wave loads in this case are likely to be the most important contribution to the low-frequency large-amplitude resonant motions (Kim and Ran, 1993). Furthermore, in this low-frequency region, the wave damping is in general smaller than the viscous and higher-order wave-drift dampings. Therefore, it is very important to include those nonlinear effects for the reliable motion prediction and optimum design of a spar.

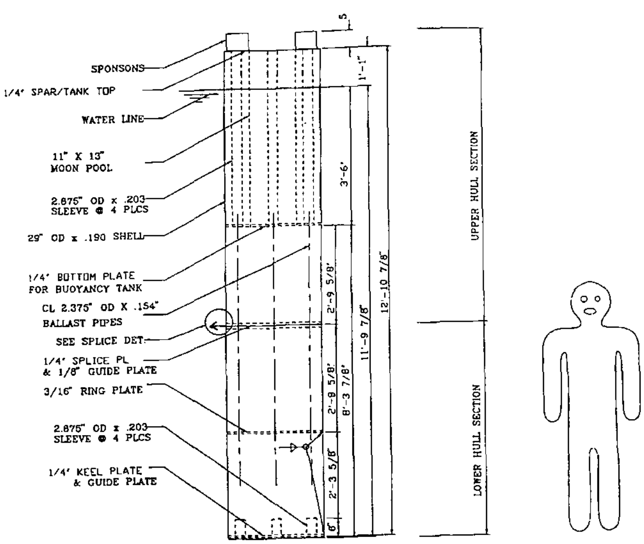

Fig. 1 Particulars of the JIP spar platform in model scale

This paper investigates the motion characteristics of this new platform concept in storm waves and currents. Recently, a number of oil companies formed a Joint Industry Project (JIP) for the

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KEY WORDS: Spar platform, slowly varying coupled responses, bichromatic waves, random waves, shear currents, second-order diffraction, large-scale experiment, time-domain simulation.