Proceedings of the Eighth (2008) ISOPE Pacific/Asia Offshore Mechanics Symposium
Bangkok, Thailand, November 10-14, 2008

ISBN 978-1-880653-52-4

Dynamic Responses of Marine Risers/Pipes Transporting Fluid Subject to Top End Excitations

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ABSTRACT

This paper deals with the dynamic responses to top end excitation of marine risers/pipes conveying internal fluid. The marine riser is often used as a flexible link between undersea bore head and subsurface offshore platform. The tidal waves and the changes of sea level consistently excite its top end connected to a floating vessel. In order to carry out the performance-based design of the marine risers, the evaluation of their dynamic responses to top end excitations is imperative. In this study, the marine riser is simulated using two-dimensional beam elements. Energy functional of the marine risers conveying fluids is derived from variational principle. Nonlinear equations of motion influenced by the nonlinear Morison waveform are obtained through Hamilton's principle. Investigation of the dynamic responses of marine risers to top end excitation is achieved using the finite element method and Newmark Average Acceleration Method. Interestingly, either beating or resonant phenomenon can be observed from the responses. It is also found that the top tension plays a major role in the increment of undamped frequencies of marine risers, while either the internal flow rate or the external hydrodynamic drag force remarkably affects the displacement amplitudes of the marine risers' dynamic responses.

KEY WORDS: Marine risers; pipes; dynamic response; top end excitation; internal fluid; finite elements; direct integration.

INTRODUCTION

There are a number of different types of offshore platforms, which are depending on the functional uses. All of the offshore structures are generally designed against the dynamic load actions due to the severe wind and wave interactions. Marine risers/pipes are part of the offshore platform, generally attached to the platform structures or floating vessels as a transportation means for the hydrocarbon resources underneath the sea bed e.g. crude oil, natural gas, and so on. Generally, the dynamic excitations acting on the marine risers/pipes are due to the ocean waves resulting in the complicated movements of the vessels. Sen (2006) described the movements, which comprise of high frequency response to the tidal waves and low frequency excursion (slow drift). In particular, these forces are acting at the top end of the marine risers in both horizontal and vertical directions, while the hydrodynamic drag force acts along the riser. Most vulnerable to excessive stresses are the flexible pipelines at the dynamic mode shape inflexion points subject to the corresponding resonances (Kaewunruen et al., 2005). It is widely accepted that even a small damage of the offshore structural components could lead to significantly detrimental effect to environment, human lives, and assets. It is thus imperative for structural offshore engineers to carry out the analytical simulations to determine the effects of those top end excitations on the dynamic responses and behaviour of the marine risers/pipes transporting the internal fluid.

The marine risers have been first used since 1949 in Mohole Project in the US. In general design perspective, the marine risers are considered to carry their own weight and subjected to a static offset. They are also designed to confront the nonlinear hydrodynamic drag forces, internal and external fluid pressures, surface waves, undersea turbulences, and vortex induced vibrations. It is found that although there are a number of investigations related to the dynamic responses of the marine risers or pipes, the dynamic effect due to top end excitation has not been addressed yet. The previous research topics of interest have included both linear and nonlinear problems. Those key parametric studies have covered the effects of internal flow, bending rigidity, axial extensibility, top tension, Poisson's ratio, and even radial deformation.

A recent step stone in riser static analysis has been carried out by Athisakul et al. (2002) whereas the large strain and large sag (higher order geometric nonlinearity) have been considered using a variational approach. To obtain the analytical results, the shooting method has been employed and the results were compared against the nonlinear finite element analyses. It was found that the large extensible strain and the bending rigidity have little effect on the static equilibrium. However, a highlight is that the bending moment envelope of the risers increases as the static offsets (Monprapassorn, 2002; Chucheepsakul et al., 2003).

In relation to dynamic analysis of marine risers/pipes, Irani et al. (1987) used energy and finite element methods to investigate the effects of internal flow and nutation damping on the dynamic responses of the marine risers to linear hydrodynamics. It was found that the internal