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Numerical Methods for the Analysis of Mooring Systems in Deep Water

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ABSTRACT

An investigation on the wave-induced motion responses of a FPSO stationed in Schiehallion field approximately 140km to the west of the Orkney Islands UK is presented. The Schiehallion FPSO and her turret mooring system are subject to harsh North East Atlantic weather conditions. In this study, a frequency-domain method and a fast time-domain technique are employed to estimate wave-induced extreme excursions and the resulting tensions on the mooring lines. Both the first-order and second-order motions are considered. The calculated results of wave frequency and low frequency motions of the FPSO and the corresponding maximum line tensions by these methods are compared and discussed.

KEY WORDS: FPSO; Wave spectrum; time domain; frequency domain; motion equation; mooring system; low frequency motion; irregular waves.

INTRODUCTION

A floating production storage and offload (FPSO) vessel is constantly stationed at the oil field for her service life even in extremely hostile weather conditions. The floating vessel requires a mooring system to maintain her position and control excursions within imposed operational limits. Therefore, it is vital to determine a possible range of vessel excursions and mooring line tensions, along with possible failure modes, such as line failure, the dragging or uplift of an anchor. In analyzing a mooring system, suitable mathematical and numerical techniques are required to assess its integrity and station-keeping capability. The mooring analysis may be performed by means of a static, quasi-static or dynamic approach.

The static method applies the total steady environmental force to the load-excursion curve of the mooring system to find the static offset of the vessel and then use the resultant of the static offset and dynamic offset caused by the first-order and second-order waves on the line-excursion curve of the most loaded line to find the corresponding maximum tension. The dynamic offset may be estimated statically from coarse estimation of wave forces and the system stiffness. This method is often carried out at an initial stage of mooring system design and has a disadvantage that the important features of dynamics such as the effects of added mass, damping and wave excitations are absent and large safety factors are required for taking uncertainties into account.

If the motion responses of a moored vessel are outside the wave exciting frequency range of the mooring system, the dynamic behavior of the lines are negligible and the mooring lines will only response statically to the motions of the vessel. Under this condition, a quasi-static approach that the dynamic motion responses of the vessel coupled with the static catenary mooring system are sought can be employed and hence the resulting maximum line tension can be found (Ansari 1980, Schellin et al 1982). The quasi-static method may be performed in the frequency domain or time domain. However, this method ignores the effect of line dynamics which may be significant if the line inertia is important.

In dynamic approach, the equations of motion of line dynamics is formulated and numerically solved to develop tension-displacement characteristics, which is then used as non-linear restoring forces in the motion response analysis of the moored vessel (Ansari and Khan1986). This kind of analysis is performed in the time domain and is time-consuming.

Time-domain simulations of motion responses of a moored vessel in irregular seas are computationally intensive even in quasi-static mooring analysis since the equations of motion are integrated in the time domain and a number of test cases must be considered due to the random nature. In the present study, a frequency-domain technique and a practical and fast time-domain simulation method for coupled wave-induced motions and mooring analysis are developed and implemented to predict the first-order wave-induced motions and slow-drift motions of a FSPO vessel operating in Schiehallion field 140km to the west of the Orkney Islands, UK, and to estimate the resulting maximum tensions on her turrent-mooring system. Comparisons between the