Fully Coupled Dynamic Analysis of Rigid Lines and Floater Behaviours in Deep Water

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ABSTRACT

The paper deals with the numerical modelling of the fully coupled behaviour of rigid risers and floaters in deep water. After a brief review of the main risers/floater configurations proposed for production in deep water, uncoupled models used for the dynamic analysis of risers and floaters are described. Details are given on their theoretical bases. Based on these models, a new numerical model DEEPLINES, performing the fully coupled dynamic analysis both in frequency domain and in time domain, was developed. The model includes 1st and 2nd order wave loads on the floaters, hydrostatic restoring loads, drag loads on the hull, mooring lines and risers, static and dynamic structural response of the risers and mooring lines. A typical application to a TLP in deep water is described in the last part of the paper.

KEY WORDS: Hydrodynamics, Risers, Floater, Coupled analysis.

INTRODUCTION

The gas and oil production in very deep waters is a major challenge for the offshore architect. New concepts are based on multi-structures systems including floaters and complex mooring and risers systems. However in deep water the large number of lines and risers can induce the main contribution to the hydrodynamic loads on the FPS. Then the hydrodynamic analysis of such concepts requires methods taking into account the coupling effects between the floater and the rigid risers and mooring lines.

Typical riser configurations in deep water

A large variety of floaters can be used, depending on the field conditions: FPSO on SPM, turret or spread mooring, TLP, deep draft floater (spar and emis). For drilling or offloading operations, floaters motions can interact. The same phenomenon may occur for risers configurations which can include taut rigid risers, catenary steel risers, flexible risers (catenary, lazy wave, lazy s,...), hybrid risers.

In some conditions (towage, installation, disconnection, export line) the pipe can be in particular configurations (free hanging, subsurface arch) increasing the coupling effects with the floater behaviour. In deep water the dynamic behaviour of such systems is quite different from those in limited depth due to an increasing influence of the hydrodynamic loads on the mooring lines and risers. Coupled frequency effects between floater and risers modes can be observed in their response spectra. Particularly critical configurations appear when the drag forces on the mooring lines and risers become important compared to those on the floater. If the wave frequency motion is of the same order of magnitude than the low frequency motion the viscous low frequency damping formulation is coupled with the wave frequency motion. In addition if the floater displacement is sufficiently small the wave frequency motion can be dominant with a significant part coming from the nonlinear drag loads.

For these reasons, the mooring restoring loads can not be always approximated by a linear stiffness or quasi-static approach. For example, for TLPs the dynamic bending deformations of the tethers may have an influence on the restoring forces. In case of a catenary lines system using steel cables or synthetic ropes the stiffness laws become greatly non linear.

General considerations

The dynamic behaviour of FPS concepts including a floating structure and deep water risers and mooring lines can be performed within different levels of approximation. In the uncoupled approach, the motions of the floater are computed, in frequency or in time domain, including the mooring lines and risers from a quasi-static assumption. Preliminary static computations are performed to estimate the restoring loads. The hydrodynamic loads on the lines, assumed rigid, are evaluated in an independent way from Morison formulations. Then the external excitation at the top level of each line and riser are deduced from the floater motions and used in a finite element model to analyse their dynamic behaviour.

In fact, in deep water, dynamic coupling effects may have a major influence.