Hydrodynamic Evaluation for Spar Platform Subjected to Mooring Line Failure

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ABSTRACT

The changes of dynamic response for a spar platform due to mooring lines failure are evaluated. The wave and low frequency responses are displayed in motion and tension spectrums. The development of the hydrodynamic behaviour subjected to the heaviest load on the mooring lines is quantitatively assessed by comparing response spectrums and statistical results. It is shown that the changes vary greatly for different structure motions and line tensions under various environment loads or line failure situations, though the dynamic responses tend to increase significantly.

KEY WORDS: Spar; mooring line failure; hydrodynamic response; coupled analysis.

INTRODUCTION

As exploitation activities for offshore energy move into deeper seas, various innovative floating offshore structures have been proposed and developed to comply with these severe environments. Among these, a spar platform is an attractive design solution due to its excellent hydrodynamic performance. A typical spar platform system consists of a cylindrical structure, a station keeping system consisting of several spread mooring lines. The spar hull generally has helical strakes to prevent VIV (vortex induced vibration) in current (Rho et al., 2002). Owing to its deep draft and small water-plane area, its natural frequencies are quite different from the peak frequency of an incident wave.

The failure of mooring lines and riser is liable to occur due to overload, fatigue and corrosion in severe ocean environments. After one single line failure, the optimum configuration of the station keeping system is disturbed and the remaining lines are overloaded in sequence. This is quite like the so-called “knock-on” effect resulting in more lines failing. Multiple line failures always lead to a complete loss of station keeping.

The natural periods, typically 160s for surge, 60s for pitch and 30s for heave (Converse and Bridges, 1996), of classical spar platforms are longer than wave frequencies. However, the second-order wave effects can excite large-amplitude slowly varying resonant motions and the corresponding riser and mooring line loading. When a platform undergoes large heave motion, say, up to 8~10 times the incident wave amplitude (Rho et al., 2002), the contribution of the second-order wave loads to the motions and tensions plays a dominant role in platform design and safety assessment.

A spar hull is integrated with mooring lines and risers to resist severe environment loads. Although the dynamic interaction among different parts makes it quite complicated to evaluate the entire load and motion for the floating structures, many methods have been available. They can be divided into two categories: uncoupled and coupled. The first one, like static or quasi-static method, assumes mooring lines/risers responding statically to the motion of the hull (Chai et al., 2002; Huang and Vassalos, 1993; Ogawa, 1984; Smith and MacFarlane, 2001). The inertia effects and hydrodynamic loading on mooring lines and risers are partially neglected. The slender member only provides the hull with restoring stiffness. After hull motions are evaluated, the slender part response can be independently investigated by imposing the fairlead motion. The mutual effect is actually ignored in every time step. However the drawback of this method has been mentioned concerning the dynamic response. The static and quasi-static uncoupled analysis tends to over-predict the surge amplitude due to an inaccurate evaluation of the drag force acting on the mooring system (Heurtier et al., 2001). Mooring/riser dynamic tension can be greatly over-predicted when uncoupled method used (Arcandra and Kim, 2003). The drag forces of mooring lines are comparable in magnitude with the damping force acting on the hull of the floating structure, The amplitude of slow drift oscillation is overestimated if hydrodynamic forces acting on mooring chains are ignored (Nakamura et al., 1991). Additionally the hydrodynamic drag in moorings can be a major source of damping, up to 80% of total damping (Huse and Matsumoto, 1989), which significantly reduces the vessel response and line tensions.

Moreover, as the water depth increases, the coupling effect becomes significantly important for dynamic assessment of the floating structure. It has been shown (Arcandra and Kim, 2003; Kim et al., 2001a, 2001b, 2002, 2005; Ma et al., 2000; Ormberg et al., 1997, 1998; Paulling and Webster, 1986; Ran and Kim, 1997) that reliability and accuracy of the uncoupled approach for various offshore structures will