Parametric Vibration of Top-tensioned Risers with Internal Flow

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ABSTRACT

This paper studies the effects of internal fluid on the stability of parametric vibration of a top-tensioned riser (TTR), where the effects of internal flow on the parametric instability charts are analyzed. Results show that both the internal flow density (mass per unit length) and velocity exert an influence on the instability charts. The internal flow density has more influence on the instability region. As the internal flow density changes, the shape and the position of the instability charts will change.

KEY WORDS: top-tensioned riser; TTR; parametric vibration; internal flow; instability analysis; Hill equation.

INTRODUCTION

As the offshore oil and gas industry moves into deeper waters, where the difficulty of the exploration of oil and gas increases dramatically, it puts forward higher requirement for deep-water production equipment. As a key equipment linking the floater and subsea production system, the vibration characteristics of a top-tensioned riser (TTR) become a popular issue in engineering design. In the marine environment, a TTR is subjected to various loads including top floater motion, internal fluid, sea current and so on. Due to the large slenderness ratio, the riser may undergo large motions under the actions of adverse loads, even though a certain tension is applied at the top end of the riser. Therefore, it is essential to explore the vibration response analysis of the riser.

The parametric vibration of a TTR will occur in the horizontal direction due to the effects of the platform’s heave motions, which will lead to the destruction of risers. Parametric resonance of marine cable was propose and analyzed for the first time by Hsu (1975), where the effects of the velocity square damping of the fluid to decrease the amplitude growth in unstable case are studied. Based on using a direct solution approach to solve the differential equations, Chung and Whitney (1981) studied the heave induced dynamic loads on an 18,000-FT ocean mining pipe. And then they investigated the effect of axial deformation to deep-ocean pipe and found that it is significant to dynamic behavior of the low flexible riser (Chung et al. 1994a; Chung et al. 1994b). Patel and Park (1995) examined the combination of the forcing and parametric excitation for tethers of tensioned buoyant platforms, in different water depths. By using a numerical method, Chatjigeorgiou and Mavrakos (2002) researched vertical the non-linear dynamic response of marine risers, which are subjected to parametric excitation due to motions of marine structure. And then, effects of damping on riser stability for risers subjected to parametric excitation have been studied by their subsequent works (Chatjigeorgiou 2004; Chatjigeorgiou and Mavrakos, 2005). Based upon using finite element method, Park and Jung (2002) investigated the response of risers under combined parametric and forcing excitations. In their numerical works, the relative amplitudes of this kind of combination to an isolated forcing excitation for various water depths, environmental conditions and vessel motions are considered. Chandrasekaran et al. (2006) studied the dynamic response of tethers and TLPs, assuming that tension varies along the tether length. Aiming at deep-water risers, Brugmans (2005) compared the difference of the parametric vibration instability of three boundary models in detail, and developed simple formulae to predict platform heaving frequency corresponding to different instability regions under parametric excitation of riser system. By using Floquet theory, Kuiper et al. (2008) investigated riser instability under parametric excitation and obtained instability mechanisms of two kinds of parametric vibrations. The first is induced by periodic time variation of the axial tensions. The another one is due to large motions of the platform. Xu et al. (2008) investigated the instability of TLP tethers by considering the coupled motion of surge and heave of TLPs. And then, they study parametric instability of long slender marine structures by using the Lyapunov-Poincarepe method, the modified Lyapunov-Poincarepe method and the harmonic balance method (Xu et al., 2011). Chung (2010) presented the full-scale measurements for 5,000-m-long hanging pipe and the theoretical prediction of its end’s dynamic behavior. Fujiwara et al. (2011) studied the response of riser Vortex-Induced Vibration under parametric excitation using experiment methods. By using a multi-frequency excitation, Yang et al. (2013) gave a prediction for the parametric instability of TTRs under the action of irregular waves. A frequency domain method was proposed by Lei et al. (2014) to investigate the