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RESEARCH PAPER

Analyses and countermeasures of deepwater drilling riser grounding accidents under typhoon conditions

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Abstract: For deepwater drilling riser system facing grounding risk in the South China Sea, a mechanical analysis model of deepwater drilling riser grounding accident was established. Focusing on drilling riser grounding accidents of a deepwater floating drilling platform in the South China Sea, mechanical characteristics and grounding accidents of riser were analyzed. And the riser retrieving window was determined. The results showed that the shape of the riser system after riser grounding is catenary. The maximums of bending moment and von Mises stress are located at lower flex joint. Platform moon pool, tensioner and lower flex joint are damaged due to severe bending deformation in the upper and lower drilling riser system after riser grounding accidents. The riser may fracture if drilling platform continues to move toward shallow water. Drilling platform displacement and riser lift height must be within the riser operation window during riser retrieving, or else the riser may fracture and the LMRP may suffer further damage. Residual riser and LMRP can be retrieved in a fixed position when the drilling riser system is separated from seabed.

Key words: typhoon; deepwater; drilling; riser; grounding accident; accident analysis

Introduction

Deepwater riser is a major component of offshore drilling system connects drilling platform with subsea wellhead. The primary functions of deepwater risers are providing fluid passage between subsea wellhead and drilling platform, supporting auxiliary lines, guiding drilling tools into wells, and serving as running and retrieving string for the blowout preventer (BOP) [1–6]. As a flexible structure, deepwater riser is vulnerable to severe weather, particularly to the frequent typhoon in the South China Sea. In 2009, a deepwater floating platform was attacked by typhoon Koppu during drilling and completion in the South China Sea. The platform was not driven away from typhoon area and deepwater riser was not retrieved to platform in time. Then, the platform was pushed to shallow water by the typhoon and the deepwater riser grounded. The riser grounding accident caused huge losses, including damage of platform moon pool, tensioner, LMRP and lower flex joint, and postponing of operation schedule [7–9]. In this paper, the riser grounding accident of the deepwater floating platform was studied. Mechanical analysis model of the deepwater riser grounding accident was established. Riser mechanical characteristics after riser grounding accident were analyzed. Equipment failure causes and potential failure risk were identified. Countermeasures of riser grounding accident were proposed.

1 Mechanical analysis of deepwater riser grounding accident

1.1 Basic equations

Normally, the top end of riser is hanged on drilling platform via tensioner, and the bottom end of riser is connected to BOP and wellhead forming a complete riser system, as shown in Fig. 1. The riser system deforms laterally under the combined effect of wave, current and drilling platform offset. The riser system is near-vertical since the lateral deformation is small compare with the riser system length. Thus, small-angle deflection theory is applicable to the mechanical analysis of riser system in connected operation. And the mechanical analysis model of connected operation of the riser system is shown in Fig. 2.

According to small-angle deflection theory, both environmental loads and riser deformation are in horizontal direction. The dynamic analysis differential equation of riser is given as [10]:

$$f\left(x\right)\delta x=\frac{\mathrm{d}^2}{\mathrm{d}x^2}\left(EI\frac{\mathrm{d}^2y}{\mathrm{d}x^2}\right)-T\left(x\right)\frac{\mathrm{d}^2y}{\mathrm{d}x^2}-$$

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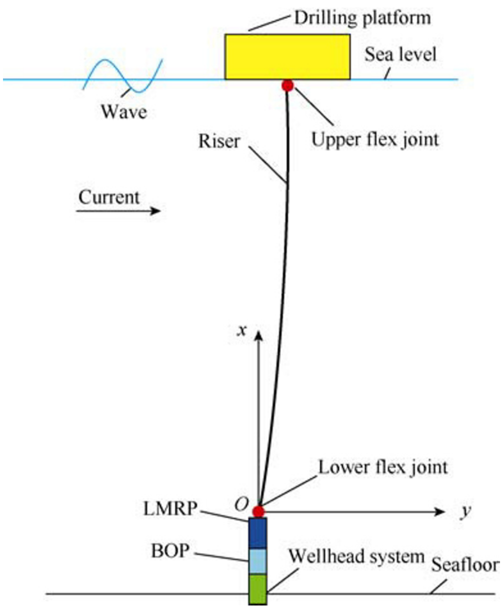

Fig. 1 Schematic diagram for connected operation of the riser system

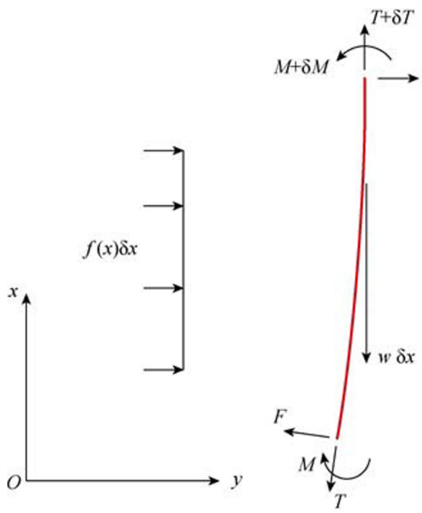

Fig. 2 Mechanical analysis model of connected operation of the riser system

$$w(x)\delta x\frac{\mathrm{d}y}{\mathrm{d}x}+ma\delta x \tag{1}$$

When typhoon is coming, drilling platform operators should unlock the connector between LMRP and BOP, and then move platform away from typhoon center with riser hanged on it. However, the platform did not leave typhoon center in time and moved to shallow water under the influence of typhoon. LMRP collided with seafloor, as shown in Fig. 3. After riser grounding accident, the bottom end of riser was near-horizontal, the top end of riser was attached to drilling platform in a specific angle with vertical direction. The angle of drilling riser system varied largely on the whole and large-angle deflection theory is applicable to mechanical analysis of the riser grounding. Mechanical analysis model of deepwater riser grounding is shown in Fig.4.

According to large-angle deflection theory, environmental loads are perpendicular to the riser. The dynamic analysis differential equation of drilling riser is given as [11]:

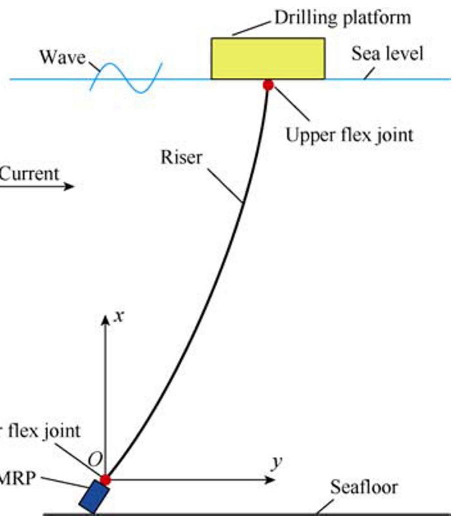

Fig. 3 Schematic diagram of deepwater riser grounding

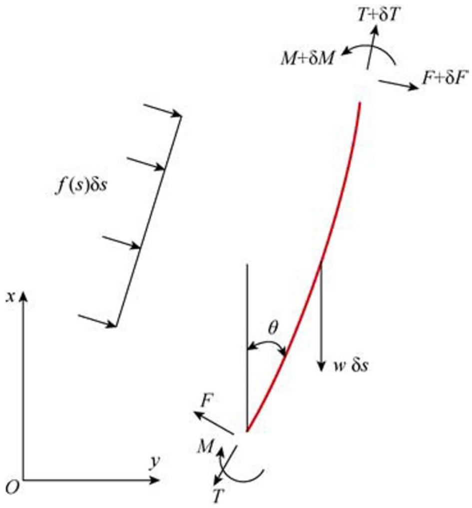

Fig. 4 Mechanical analysis model of deepwater riser grounding

$$f(s)\delta s=\frac{\mathrm{d}^2}{\mathrm{d}s^2}\left(EI\frac{\mathrm{d}\theta}{\mathrm{d}s}\right)-T(s)\frac{\mathrm{d}\theta}{\mathrm{d}s}-$$
$$w(s)\delta s\sin\theta+m\delta s a_{\mathrm{N}} \tag{2}$$

The axial force T in Eq. (2) varies continually along riser axial direction. The variation (see Eq. 3) can be obtained by establishing axial equilibrium equation according to mechanical analysis model of riser grounding.

$$\frac{\mathrm{d}T(s)}{\mathrm{d}s}=w(s)\cos\theta \tag{3}$$

The combined effect of wave and current is very complicated and the simple superposition of drag forces of wave and current is not advisable. The hydrodynamic loads on the riser are normally calculated by modified Morison's equation, which can be expressed as:

$$f(s)=\frac{1}{2}\rho C_{\mathrm{D}}D(v_{\mathrm{W}}+v_{\mathrm{C}}-v_{\mathrm{N}})|v_{\mathrm{W}}+v_{\mathrm{C}}-v_{\mathrm{N}}|+$$
$$\frac{\pi}{4}\rho C_{\mathrm{M}}D^2a_{\mathrm{W}}-\frac{\pi}{4}\rho(C_{\mathrm{M}}-1)D^2a_{\mathrm{N}} \tag{4}$$

1.2 Boundary conditions

The top end of riser is attached to drilling platform and its