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Safety of dynamic positioning operations on mobile offshore drilling units

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Abstract

Dynamic positioning of mobile offshore drilling units for drilling operation (termed as DP drilling operation) is analyzed in this paper. A safety modeling approach based on the barrier concept is developed. Safety of DP drilling operation is modeled in terms of three main barrier functions, i.e. barrier functions to prevent loss of position, to arrest vessel movement and to prevent loss of well integrity, respectively. Analyses of each barrier function are performed. The associated barrier elements are identified, their existing deficiencies are revealed based on operational experience on the Norwegian Continental Shelf (NCS), and recommendations to strengthen each barrier element are proposed. These recommendations could improve safety of DP drilling operation on the NCS. They are also valid to DP drilling operations worldwide.

Keywords: Dynamic positioning; Barrier; Mobile offshore drilling units

1. Introduction

1.1. Background

A dynamically positioned (DP) mobile offshore drilling unit (MODU) performing drilling operation is illustrated in Fig. 1. This is termed as DP drilling operation in this study. The dynamic positioning means to automatically maintain vessel's position (fixed location or predetermined track) exclusively by means of thruster force [1]. There are generally four major components involved in DP operations, i.e. power system, thruster system, DP control system, and key DP personnel. The DP control system mainly consists of DP software and computers, sensors and reference systems and operator stations. The key DP personnel generally include DP operators, Masters, Chief Engineers, engine room operators, electricians and instrument technicians.

In normal operations a MODU should be positioned within a green zone inside the yellow limit. When the vessel loses the capability to maintain position by means of thruster force, she may have an excursion beyond the

Abbreviations: BOP, blowout preventer; CCTV, closed-circuit television; DGPS, differential global positioning system; Diff link, refer to the differential techniques applied in order to improve the accuracy of GPS; DP, dynamic positioning; DPO, DP operator; Drift-off, insufficient thruster force so that vessel is drifted away from the target position by the environmental forces; Drive-off, abnormal thruster force so that vessel is driven away from the target position; DUBE, operations committee of drilling companies in Norwegian shipowners association; EQD, emergency quick disconnect (system); FMEA, failure mode and effect analysis; GPS, global positioning system; GLONASS, global navigation satellite system; HDOP, horizontal delusion of precision; HPR, hydroacoustic position reference system; HIL, hardware-in-the-loop; IMCA; International Marine Contractors Association; IMO, International Maritime Organization; LMRP, lower marine riser package; MODU, mobile offshore drilling unit; NCS, Norwegian Continental Shelf; NMD, Norwegian maritime directorate; NTNU, Norwegian University of Science and Technology; NSA, Norwegian Shipowners Association; PRS, position reference system; PSA, petroleum safety authority (of Norway); PSF, performance shaping factor; RPM, rotation per minute; SDS, safe disconnect system; Vessel owner, The company that operates drilling semi-submersibles and/or drill ships; Vessel, A term refers to both semi-submersible drilling rig and drill ship; VDU, visual display unit; WSOG, well specific Operational guideline

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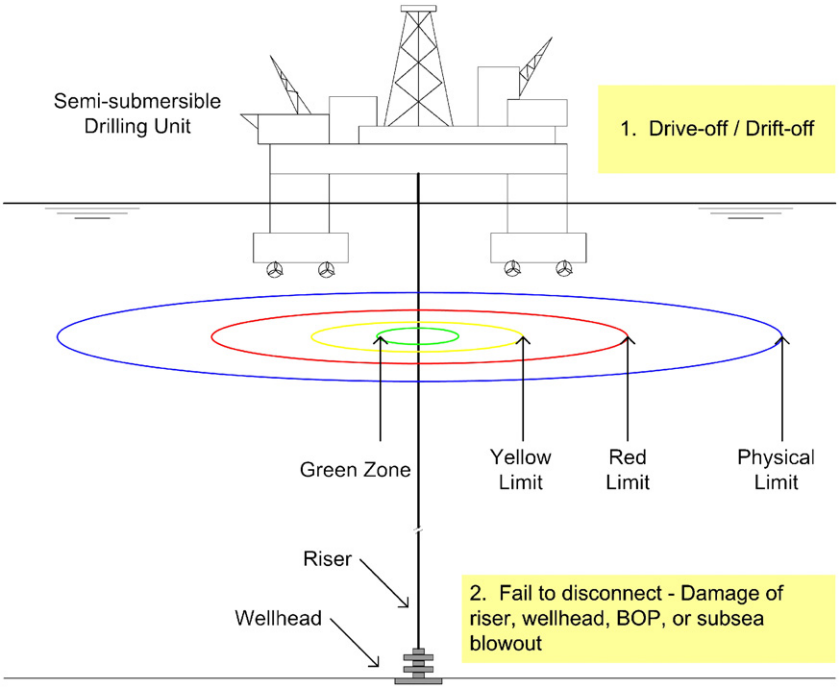

Fig. 1. DP drilling operation (the excursion limits: yellow, red, physical are not to scale).

yellow or even the red limit. This condition is denoted drive-off or drift-off event, which is generic to all DP vessels. If the vessel passes the yellow limit, the drilling operation must be stopped and driller starts to prepare for disconnection. If the vessel passes the red limit, emergency disconnection must be initiated in order to disconnect riser/LMRP (lower marine riser package) and shut in the well. Failure of disconnection may result in damage of riser, wellhead or BOP (blowout preventer). This could cause significant financial losses and vessel downtime, and in worst case could escalate into a subsea blowout.

During 1994–2004 five MODUs had contributed to the DP drilling experience on the Norwegian Continental Shelf (NCS). Some had been in operation on the NCS for their entire operational lives, i.e. *West Venture* and *Stena Don*, while others just had periods of time working in the region, i.e. *Ocean Alliance* and *West Navigator*. There was also one vessel (*Scarabeo* 5) that had been operated alternatively in DP mode and mooring mode.

A unique feature that characterizes the DP drilling operations on the NCS was that most of the operations had been performed in water depths of less than 500 m. While in other parts of the world, DP drilling operations are generally carried out in much deeper water. Operational statistics showed that approximately 82% of DP drilling time on the NCS (up to 1 May 2004) was accumulated from operations in water depth of less than 500 m.

1.2. Motivation and objective

In 2003 Norwegian Petroleum Directorate (NPD, now called Petroleum Safety Authority in Norway) published a report of trends in risk level on the NCS [2]. One of the recommendations from the report to the offshore industry was to improve the safety of DP operations. In the light of NPDs recommendations, Norwegian Shipowners Association's drilling contractor group (DUBE) established a dedicated work group working on the safety of DP operations on MODUs since August 2003. At the same time the Centre for Ships and Ocean Structures (CeSOS) at Norwegian University of Science and Technology (NTNU) also initiated research activities on further development of safety modeling approaches for marine operations. A study was carried out to look into safety of DP operations on mobile offshore drilling units. The two initiatives from DUBE and CeSOS were united in November 2003, and this resulted in a 2-year joint industry research project.

The main goal of the project was to improve the safety of DP operations on mobile offshore drilling units on the Norwegian Continental Shelf. The results in this project were subject to reviews from a large reference group that includes representatives from most key players in the DP drilling field, namely oil companies (Statoil, Norsk Hydro), drilling contractors at DUBE, DP vessel owners (Smedvig Offshore, Stena Drilling, Saipem, Prosafe Offshore), system vendor (Kongsberg Maritime), regulators (petroleum safety authority (PSA), HSE, Norwegian Maritime Directorate (NMD)), classification society (DNV), and DP operator training organization (Ship Manoeuvring Simulator Centre in Trondheim).

1.3. Structure of paper

This paper presents the safety modeling approach and main findings from this study. The contents are structured