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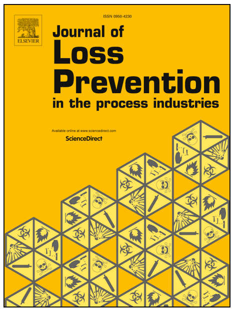

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Xiangkun Meng, Guoming Chen, Jihao Shi, Gaogeng Zhu, Yuan Zhu

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STAMP-based analysis of deepwater well control safety

Xiangkun Meng, Guoming Chen, Jihao Shi, Gaogeng Zhu, Yuan Zhu[1]
(Centre for Offshore Engineering and Safety Technology, China University of Petroleum (East China), No.66, Changjiang West Road, Qingdao, China

Abstract: The complexity of a deepwater well control system makes defining appropriate safety requirements with traditional safety analysis methods difficult. Hence, there is a need for a complex systems approach for better understanding the development and prevention of accidents during deepwater drilling. Differing from traditional methods based on reliability theory, we use the system-theoretic accident model and process (STAMP) and system-theoretic process analysis (STPA) methods to establish a hierarchical control and feedback loop model of a well control system. In view of the characteristics of complexity and dynamism, the safety analysis is regarded as a system control and feedback problem in this work. Using this model, the systematic hazards and safety-related constraints are firstly defined, the safety control structure (SCS) is then established, the inappropriate control actions (ICAs) are identified in the next step, and the key factors that contribute to ICAs are finally determined. Guided by the STAMP/STPA, we construct the process of well control to simulate the consequences of ICAs during deepwater drilling by using the dynamic multiphase simulation software, OLGA. The simulation takes the lack of control actions and the provided control actions of a late shut-in as examples. The STAMP/STPA method proves to be an effective solution for evaluating the safety of deepwater well control from the perspectives of control and constraint. By modeling the process of a well kick, shut-in, and well killing, it was quantitatively indicated that the rational control actions within a certain time period can prevent accidents from occurring and escalating, thereby ensuring the safety of the system. The differences between traditional methods and STAMP/STPA are compared in this paper, and the limitations that need to be solved in the future are pointed out.

Key words: Deepwater well control; Safety analysis; Constraint; STAMP; STPA; OLGA

Abbreviations: BOP, blowout preventer; BP, British Petroleum; BT, Bow Tie; ET, event tree; FMEA, failure mode and effects analysis; FT, fault tree; HAZOP, hazard and operability analysis; ICA, inappropriate control action; PC, programmed computer; MPD, managed pressure drilling; OIM, offshore installation manager; PWD, pressure while drilling; RCD, rotating control device; SCS, safety control structure; STAMP, system-theoretic accident model and process; STPA, system-theoretic process analysis

1. Introduction

Offshore operations have always been faced with technological and operational complexities in combination with extreme marine environments (Tamim, et al., 2017). Deepwater drilling, in which a narrow pressure window is applied, is often challenging with respect to the well control issues. A kick will occur if the bottom-hole pressure drops below the pore pressure, which can potentially escalate into a blowout (Khakzad et al., 2013). A blowout, which is considered one of the most severe types of accidents, may lead to property damage, loss of life, and environmental contamination (Xue et al., 2013). For instance, the Deepwater Horizon catastrophe in the Gulf of Mexico resulted in 11 deaths and the spillage of 4.9 million barrels of crude oil (Pranesh et al., 2017). It will cost over 68 billion dollars for British Petroleum (BP) to deal with the environmental pollution and ecological destruction.

Complex systems almost always fail in complex ways (Summerhayes, 2011). Different from the simple system accidents triggered by component failures, accidents of complex systems such as blowouts usually result from a complex combination of deficiencies including coincide—technical or operational failures, inadequate safety controls, and improper organizations and managements. Nevertheless, developing a safety assessment model that tallies with the actual situation is difficult because of the highly correlated components and complicated operations. Risk factors of a well control system are related and

Corresponding author.
E-mail address: offshore@126.com (G. Chen)

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