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An Overview on the Stress Analysis of Drillstring without Riser under Platform Motion

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Abstract: The mechanical behavior of drill string under the condition of no riser involves many external loads, including the movement of the platform, waves, tides, ocean currents and other marine environments, as well as the drilling pressure of the dynamic drill string. Among them, the motion of the platform is the main research object, because the motion process is complex nonlinear motion, and the coupling between different motion forms cannot be described by linear equation. This paper researches on the nonlinear motion response of the floating body of the platform and introduces the main results briefly. In addition, It also overview that the research results of drill string stress in the environment without riser in recent years and summarizes the deformation and reliability of drill string under different load conditions. In view of the current research results, this paper proposes that the research direction may become a hot topic in the future.
Keywords: No marine riser; platform motion; nonlinear; drill string stress.

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1. INTRODUCTION

In recent years, although the degree of onshore oil exploitation is higher than before, there are many problem such as the newly discovered oil and gas fields are small in scale, low in production, high in extraction difficulty coefficient, and unable to recover the cost in the short term. Therefore, the exploitation of offshore oil and gas resources have been become the main trend of energy development. Compared with onshore oil and gas fields, offshore oil and gas fields that are found in large scale and high production not only the proportion of oil and gas production to the global total production is increasing, but also the scope and depth of the sea area for exploration and development are expanding continuously[1]. With the continuous development of offshore oil and gas resources, more advanced drilling platforms (ships) are required to complete the exploration and development of oil and gas. There are many countries are concerned about the exploration and development of deep water oil and gas resources now. In contrast to shallow water, both drilling platforms (ships) and drilling equipment in deep water must have specific capabilities to achieve stable offshore drilling. There are two kinds of semi-submersible drilling platforms and offshore drilling vessels which are mainly used in deep-water drilling. However, it is bound to be affected by the Marine environment, such as

wind, waves, currents, tides and storm surges no matter which kind of equipment works in the marine environment. Therefore, it is helpful to ensure the stability of drilling equipment and significantly improve drilling efficiency in drilling work by studying the motion patterns of drilling platform (ship) under various sea conditions. In addition, the deep water drilling operation includes many riser-free procedures, such as jet downpipe, surface hole drilling and surface casing running [2], and riser-free drilling fluid recovery technology. Unlike drilling operations with risers, the drill string is exposed directly to the sea in this environment, which causes the drill string to move, vibrate, sway and other complex motions along with the movement of the platform while being affected by the marine environment, under the action of force also will produce the corresponding deformation, thus for deep water drilling safety crisis. Therefore, in-depth research on the movement of drilling platform (ship) and drilling string stress is of great significance to ensure the safety and reliability of riser-free drilling.

2. RESEARCH STATUS OF DRILLING PLATFORM (SHIP) MOTION

Floating drilling equipment floating on the sea surface will produce movement in six degrees of freedom due to the impact of the marine environment load, these movements are generally divided into two categories, one is the movement, including advance and retreat, transverse drift and heave, the other is rotation, including roll, pitch and yaw. The study of these motions is not only helpful to realize the stability of the platform (ship) but also important to the drilling equipment connected with the platform. Offshore drilling platforms can be divided into two categories according to whether they can be moved include fixed drilling platforms and mobile drilling platforms. In shallow waters, fixed drilling platforms can be used, while only mobile drilling platform is used in deep water. With the continuous development and progress of marine undertakings, the development and utilization of the ocean have been gradually developed from the offshore to the far sea, from the shallow to the deep sea in China.

The higher requirements must be put forward for the platform to ensure its safe and effective operation at sea in order to cope with the impact of adverse marine environment due to the increase of water depth. Therefore, the research on the motion of semi-submersible drilling platform and drilling ship which are unique to deep water drilling has become an important aspect of the research on riser, drill string and the stability of underwater wellhead [3]. It is necessary to carry out corresponding experimental or numerical simulation methods to study the motion response of the platform (ship).

In 2008, Pan Zi hui [4] analyzed that the motion response of semi-submersible drilling platform by using three-dimensional potential fluid theory and experimental. There are numerical simulation used as the means of analysis according to the correlation between semi-submersible drilling platform and mooring system and nonlinear time-domain coupling method, the motion response of semi-submersible drilling platform is analyzed by Moses software. The results show that the motion response of semi-submersible drilling platform can be predicted [5,6]. There are a large number of studies have shown that among the six degrees

of freedom motions of ships, rolling motion has the greatest impact on the stability of ships, so the research on rolling motion of ships has been become a hot issue.

Roberts[7]of the United Kingdom adopted the stochastic theory and Markov process to analyze the nonlinear roll of ships in the ocean, and also determined the probability model of ship's stable roll motion; Santos T.A[8]analyzed the nonlinear rolling differential equation of the ship, and then determined the damping moment coefficient by using the phase plane and Runge-Kutta fourth-order method combined with the quantitative analysis method, and obtained the equivalent linear damping coefficient of the ship in the case of nonlinear rolling. However, the above are all the analysis and research of the ship's motion of a single degree of freedom -- roll. In fact, the motion of other degrees of freedom will also affect the roll motion, such as pitch and heave. Therefore, the study of ship roll coupled with these motions have gradually developed along with the study of stability. In 1955, Kerwin [9] proposed that pitch is one of the important reasons for the occurrence of rolling according to the change of initial stability height of ship in longitudinal waves. Gabriele, Francesentto and Ribeiro[10-11]take ship rolling motion under irregular and regular waves as the research object, and consider the influence of dynamic and hydrodynamic forces on ship motion response, and then propose a method for the dynamic stability of ships facing waves. The movement of the platform (ship) in the sea is affected by many factors, such as the coupling of the platform, riser and anchorage system. Therefore, this has become an important part of people's research.

In 2004 Roveri [12] considered that platforms between the riser and the mooring system of semi-submersible drilling platform is established under the condition of numerical model, the coupling analysis of hydrodynamic calculation model and pipeline (chain, riser) finite element model, and uses the Prosim program for nonlinear time domain dynamic analysis. It is founded that coupling analysis results mainly include platform movement and chain and the response of the riser. With the increase of water depth, the number of finite elements will increase significantly, the calculation amount will become quite large, since the anchor chain and riser are divided into many finite elements in the coupling analysis and the complete integral calculation is carried out on each step at the same time, Therefore, it is difficult to achieve fully coupled computation at this stage, so the partially coupled hybrid method is still commonly used [13].

3. RESEARCH STATUS OF DRILL STRING FORCES WITHOUT RISER

In offshore drilling operations without risers, the drill string or casing is exposed directly to the sea water, without the protective effect of the outer layer of the riser, and the upper end of the drill string is directly connected to the big hook, which will affect the deformation and stress of the drill string during the movement of the upper platform. The drill string is connected to the drill string assembly and the drill bit, and its movement and deformation will also affect the force and stability of the wellhead. Therefore, it is necessary to analyze the stress of drill string or casing without riser, study its influencing factors and its strength limit, which will help to drill safely and save time.

Zhang hui of China university of petroleum (east China)[14]and others in 2010 analyzed the process of installation by studying the deep catheter injection tubing string mechanics, the string deformation curve under the condition of different shift of drilling ship is obtained, and most dangerous section of the drill string is found out through the analysis, including the migration situation under different maximum tensile stress distribution of the section, column top so as to facilitate the preset position of drilling ship and mobile, saving the wellhead positioning time, at the same time also can install catheter, these are avoided because of the tensile properties of the drill string itself, cannot install the catheter in place, and even lead to the tube's stuck phenomenon. The calculation process of this research is all realized by computer programming. When drill string unit is fine, the deformation curve of pipe string is more precise.

In 2012, Gao Deli [15] and others studied the mechanics analysis of pipe string without riser, and applied computer program to solve the equations, taking into account all kinds of factors that affect the stress of pipe string. including the deflection and heave motion of the platform, the longitudinal and transverse bending deformation of the pipe string under the action of marine environmental load, the change of the top stress, and the displacement of the pipe string caused by the heave motion of the drilling ship are solved. These provide important basis for mechanical behavior and control of pipe string in deep water drilling without riser.

Su Kanhua [16], from Chongqing university of science and technology, used finite difference method to solve the mechanical model of drill string in time domain in 2013, and calculated it by computer programming, and then study the stress and vibration of drill string without riser.This study is mainly to analyze the effects of platform drift and wave current force on the dynamic response of drill string, the size of drill string and the weight below the mud line. The results show that the platform drift will have an effect on the stress and deformation of drill string. Under the condition of satisfying the strength requirement, the drill string with small diameter should be selected as far as possible, and the appropriate measures should be taken when the drill bit is just below the mud line to avoid over loading the drill string.

RobelloSamuel [17] proposed and verified a correction model for predicting the serious damage vibration of drill string, and analyzed the damage of down hole dynamic drilling tools and related tools caused by the vibration of drill string in drilling operations. The dynamic analysis model is based on Fourier transform to solve the resonance frequency. Through the analysis of input parameters and results, the author proves that the vibration of drill string c an be avoided by controlling the three-dimensional vibration effect, and the distribution o f bending stress, shear stress and lateral stress can be obtained. Based on the above study, the results shown that various parameters will affect the vibration of drill string, such as mud line depth, well deviation from the center, borehole inclination, curvature, borehole torsion, and deflecting angle when entering the wellhead. This provides an important basis for reasonable selection of drilling parameters to reduce or avoid down hole drilling tool damage. In 2014, Wang Guodong [18] and others analyzed the axial vibration of string of drilling fluid recovery system without riser in deep water, according to different boundary conditions. The

axial vibration model of the drilling fluid recovery system considering seawater damping was given, and the general solution of the model was obtained. This provides direct practical significance for the application of deep water riser free drilling fluid recovery system.

4. CONCLUSION

At present, the research on the mechanics of riser-free pipe string is not mature enough, and only in the last five years relevant literatures have been involved in this direction. However, there are few related documents to study the deformation and reliability of pipe string by taking platform motion into account. However, the research on the motion of the six degrees of freedom of the platform (ship) has started from long time ago. People have concluded that rolling will be the most important factor that affecting the stability of the platform (ship), and the influence of other degrees of freedom on the rolling has also been taken into account and the movement of the platform under coupling of the two degrees of freedom has also been summarized. However, the research on random parameter mechanism of rolling is still in the qualitative stage, and there is no quantitative calculation method. In addition, researches on the stability of the platform only focus on the stability of the platform itself, and do not involve the influence of roll, pitch, heave and other steady-related motions on the stress of the pipe string in the environment without risers. In the future, the research on the stress analysis of riser string related to platform (ship) stability will become another hot topic and be paid more attention on offshore drilling riser archers.

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