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PROGRESS IN THE INVESTIGATION OF MARINE DEEPWATER DRILLING FLUID SYSTEMS

S.Z. Lim
Faculty of Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.

Abstract: With the development of the petroleum industry, offshore oil and gas resources have become a key area of petroleum development. As one of the key technologies in current deepwater oil and gas exploration and development, deepwater drilling technology is related to the success or failure of drilling operations. The technical problems of marine deepwater drilling are analyzed: well wall stability, drilling fluid rheology adjustment at low temperature, natural gas hydrate generation and formation decomposition, wellbore cleaning, etc., and the research progress of marine deepwater drilling fluid systems is reviewed, including water-based drilling fluids. system, oil-based drilling fluid system, synthetic-based drilling fluid system.
Keywords: Deepwater drilling; Deepwater drilling fluid; Well wall stability; Constant rheology

1 TECHNICAL DIFFICULTIES FACED BY OFFSHORE DEEPWATER DRILLING

In recent years, the exploitation of land and offshore oil and gas resources in various countries around the world has been close to saturation. The development of oil and gas resources has gradually turned to the ocean, especially the exploitation of deep-sea oil and gas resources, which has gradually become the top priority in the current field of petroleum development [1]. my country's marine oil and gas resources are abundant. Petroleum geological resources account for approximately 19.01% of the country's oil and gas resource reserves, and natural gas geological resources account for approximately 23.14%, most of which are contained in deep water. The development of deepwater oil and gas resources requires high drilling technology, and the current deepwater drilling fluid system still has many problems that need to be improved. In view of this, the author provides a reference for the study of deepwater drilling fluid systems on the basis of analyzing the technical problems of ocean deepwater drilling.
Ocean deepwater drilling is different from shallow water drilling. There are more technical issues that need to be considered during the drilling process, including poor stability of loose wellbore walls in seafloor mud shale, rheology adjustment of drilling fluids at low temperatures, and natural gas hydrate generation that blocks pipes and wellbores. The cleaning rock carrying strength is not enough [2-6]. These problems often affect the normal development of on-site operations, and also put forward higher requirements for drilling technology. Therefore, an overview of the progress in developing efficient and rapid drilling technology is intended to improve the performance of offshore deepwater drilling fluid systems and high-performance The marine deepwater drilling fluid system is one of the important issues that need to be solved urgently in current marine deepwater drilling.

1.1 Well Wall Stability Issues

In the oceanic deepwater drilling area [7], due to the complexity of the formation, the difference in rock deposition speed and water content, some rock layers are replaced by seawater, making the rocks in this formation extremely active. However, oceanic deepwater drilling areas are often far away from the coast, and seawater The sediment carried is not enough to compact the ground layer, so the cementation properties of the rock layer are poor, and it is easy to disperse and expand. A large number of solid particles combine with the drilling fluid, thus seriously affecting the performance of the drilling fluid.
During actual drilling operations, in China, appropriate amounts of inorganic salts, polymeric alcohols with cloud points, and polyamine inhibitors are generally added to inhibit the hydration and dispersion of shale; while abroad, synthetic-based drilling fluids are used to enhance the stability of seafloor rocks. In deepwater drilling areas, there is often a thick siliceous soft mud layer in the shallow part of the seabed. The water content is generally above 50%. Its shear strength is low and its bearing capacity is poor. The formation fracture pressure is similar to the pore pressure, which will lead to the density window of the drilling fluid. Therefore, it is necessary to rationally use and develop efficient lost circulation materials to solve the problem of lost circulation in deep sea drilling.

1.2 Drilling Fluid Rheology Adjustment Issues at Low Temperatures

The temperature of the seafloor gradually decreases with the increase of depth. The temperature of the mud-liquid line on the deep seabed is generally about 4°C. The low temperature causes the rheology of the drilling fluid [8-9] to go out of control, which brings hidden dangers to on-site drilling operations. Experiments have shown that in the range of 4 ~ 65 °C, the rheology of water-based drilling fluid is difficult to accurately control, especially under low temperature (below 4 °C) conditions. In a low-temperature environment, the viscosity and shear force of water-based drilling fluids will increase significantly, and the thickening effect of oil-based mud will be even more obvious, resulting in excessive equivalent circulation density and increasing the risk of lost circulation; at the same time, at low temperatures Under high-pressure environments, the probability of natural gas hydrate formation increases, leading to pipeline blockage and safety accidents.

In response to the above problems, the problem of rheology adjustment of drilling fluid at low temperature is generally solved by using a constant rheology drilling fluid system. At the same time, the equivalent circulation density should be detected to avoid the occurrence of underground safety accidents.

1.3 Issues of Natural Gas Hydrate Generation and Formation Decomposition

As deep-sea drilling depth advances, the seafloor temperature drops below 0°C and the static pressure reaches over 30MPa, providing good conditions for the generation of natural gas hydrates [10]. On the one hand, when the dissolved natural gas hydrate near the wellhead re-condensates in pipelines such as risers and kill pipes due to the cooling effect, it will block the pipelines, hinder normal downhole pressure monitoring, and even cause serious downhole accidents. In order to control the formation of natural gas hydrates, natural gas hydrate thermodynamic inhibitors (such as NaCl, KCl, etc.) are generally used at work sites to inhibit the formation of natural gas hydrates. On the other hand, during drilling operations, when the drill encounters a gas hydrate formation, the temperature and pressure changes caused by the agitation of the drilling tool and the invasion of drilling fluid cause a large amount of natural gas hydrate to decompose, and a large amount of gas and water to be analyzed, increasing the The pore pressure between the formations is reduced, which reduces the strength of the formation, easily causes the instability of the well wall, and increases the risk of well collapse. Therefore, it is extremely important to develop and optimize a high-performance marine deepwater anti-collapse drilling fluid system.

1.4 Wellbore Cleaning Issues

During deep sea drilling, due to the large diameter of the riser pipe, the annulus area is large, making it difficult for the mud to maintain a high flow rate when returning, and cannot achieve the purpose of cleaning the wellbore, especially when the well deviation is large. obvious. In order to increase the drilling fluid displacement and improve the cuttings carrying capacity of the mud, the drilling fluid is generally required to have a high viscosity while maintaining a low shear rate. This requires optimizing the rheological parameters of the drilling fluid. For water-based Drilling fluids can be added with polymer flow pattern regulators to effectively improve the mud's rock-carrying capacity. Compared with water-based drilling fluids, oil-based/synthetic-based drilling fluids have better rock-carrying and wellbore cleaning capabilities. However, deep-sea drilling fluids generally require larger quantities and higher costs. Once leakage occurs downhole, the drilling fluid will be damaged. Handling and accident handling are even more disadvantageous.

2 CURRENT STATUS OF RESEARCH ON MARINE DEEPWATER DRILLING FLUID SYSTEMS

2.1 Deepwater Water-Based Drilling Fluid System

Compared with oil-based/synthetic-based drilling fluid systems, water-based drilling fluid systems are environmentally friendly and low-cost, and are widely used in deepwater drilling. Currently commonly used deepwater water-based drilling fluid systems include: high-salt/PHPA polymer drilling fluid system, CaCl2/polymer drilling fluid system, silicate drilling fluid system, and high-performance water-based drilling fluid system. High-performance water-based drilling fluid systems are generally composed of polyamine strong inhibitors, coating agents, plugging agents, fluid loss agents, environmentally friendly lubricants and other treatment agents. Their performance is similar to that of synthetic-based drilling fluid systems. Through multiple The combination of the two treatment agents has the characteristics of strong inhibition, superior lubrication performance, increased drilling speed, and stable well wall.

ULTRADRILL drilling fluid system [11-12] is a high-performance deepwater water-based drilling fluid system launched by the foreign company M-ISWACO. It was first put into use in China's Bohai Oilfield in 2004. The system is mainly composed of the strong inhibitor Ultrahib, the coating agent Ultracap, the lubricant Ultrafree, the speed-increasing agent Ultrafree, etc. It has strong inhibitory effect, superior lubrication performance, can effectively solve the problem of mud ball coating, is easy to maintain, and is environmentally friendly. Friendly and other characteristics, it has good on-site application effects for high-activity mud shale and complex drilling environment strata.

The Hydro-Guard drilling fluid system [13] is a high-performance water-based drilling fluid launched by the foreign company Halliburton Baroid that has properties close to those of oil-based drilling fluids. The system is mainly composed of polyamine inhibitor BORE-HIB, coating agent EZ-MUD DP, blocking agent BARO-TROLPLUS, etc. It does not contain soil phase, can effectively inhibit the hydration and dispersion of shale, and can withstand high temperatures of 150°C., and the mud is easy to discharge, making it suitable for environmentally sensitive areas. The Hydro-Guard drilling fluid system has been successfully used in deepwater wells in Brazil and Angola.

The HEM drilling fluid system [14-15] is a high-performance deepwater water-based drilling fluid system developed by CNOOC Oilfield Chemical Division. The inhibitor is PF-UHIB, the coating agent is PF-UCAP, and the lubricant is PF-HLUB, supplemented by flow pattern regulator, fluid loss agent, NaCl and other materials, is suitable for complex formations and formations with high environmental performance requirements. The formula of this system is: seawater+Na2 CO3+PF-FLO+XCH+PF-UHIB+ PF-HLUB+KCl+PF-UCAP+NaCl+barite. In 2011, the HEM drilling fluid system was successfully applied to 15 wells in the South China Sea, with the deepest operating depth of 1,300 m, the deepest well depth of 4,239 m, and the lowest mudline temperature of 3°C. It effectively solved the problem of difficult to control the rheology of water-based drilling fluids at low temperatures. Problems such as narrow density window and downhole leakage.

Zhao Xin et al. [16] aimed at problems such as the difficulty in adjusting the rheology of deepwater drilling fluids at low temperatures and the formation of natural gas hydrates. They synthesized a strong polyamine inhibitor SDJA through the polymerization of polyetherdiamine and ethylene oxide, and constructed it by optimizing treatment agents. A set of high-performance polyamine deepwater water-based drilling fluid system was developed. The formula of this system is: 3% seawater bentonite slurry+0.15%XC+3%SDJA+ 0.1%KPAM+4%SD-101+1%JLS-1+1%SD-505+ 1.5%FT-1+20% NaCl. Indoor experiments have shown that this system has good rheology at 2°C and 25°C, can withstand high temperatures of 150°C, and can basically meet the requirements of drilling operations at a depth of 1500m. It has good suppression performance, superior environmental protection performance, and good anti-pollution ability.

Gao Han et al. [17] analyzed the effects of temperature and pressure within a specific range on the rheology of drilling fluid, and combined with the rheological model, initially proposed the rheological mechanism of constant rheology water-based drilling fluid and the "structural compensation-performance" based on molecular morphology. "Controlled release" structure-activity relationship, and introduced the T/P factor into Casson's initial equation, established a dynamic rheology equation suitable for constant rheology water-based drilling fluids, and revealed the constant rheology nature of water-based drilling fluids.

Geng Tie et al. [18] used acrylamide, alkyl quaternary ammonium salts and 2-acrylamido-2-methylpropanesulfonic acid as monomers and used aqueous solution polymerization to synthesize low molecular weight polymer coatings for deepwater drilling. agent, and on this basis, a set of water-based drilling fluid system with high temperature resistance and strong inhibition was constructed by optimizing other treatment agents. The formula of the system is: 5% seawater bentonite slurry + 0.2% Na2 CO3 + 0. 2% NaOH + 1. 0% flow pattern regulator FLOTROL + 1.0% high temperature fluid loss agent HTFL + 0.5% new coating inhibitor Cap+ 3.0% blocking agent FT-1+1.0% polyamine inhibitor+2.0% high temperature stabilizer STBHT+3.0% lubricant+5.0%NaCl+10.0% potassium formate+barite. This system has good suppression performance, good rheological properties at low temperatures, and can withstand high temperatures of 160°C. It has been successfully used in four wells in a deepwater oil field in the South China Sea. The construction was smooth, the wellbore was more stable, the drilling cycle was short, and no downhole complications occurred.

2.2 Deepwater Oil-Based Drilling Fluid System

Compared with water-based drilling fluids, oil-based drilling fluids [19] have better temperature resistance and rheological controllability, and can still maintain good drilling fluid performance under a narrow density window. Different from land drilling, offshore deepwater drilling areas are generally environmentally sensitive areas, requiring oil-based drilling fluids with low toxicity and environmental protection. Therefore, offshore deepwater oil-based drilling fluids generally use base oils with low aromatic content (such as white oil, gas to oil) to minimize the impact of the drilling fluid system on marine life.

Since oil-based drilling fluids tend to become viscous and even gel at lower temperatures, how to maintain good rheological properties of deepwater drilling fluids in the special low-temperature environment of the deep seabed is an important step in ensuring the success of deepwater drilling operations.. Patel et al. first proposed the concept of "constant rheology" as an indicator to test the performance of deepwater drilling fluids. "Constant rheology" means that the AV and PV values of deepwater drilling fluid are relatively stable in the range from low temperature to high temperature. In 2015, Knox et al. [20] of the British BP company gave detailed technical indicators for the ocean deep water constant rheology system: PV (4.4 ℃) <2.5PV (49 ℃), Gel (10 min) <1. 7Gel (10s), Gel (30min) <1. 3Gel (10 min), YP (4. 4 ℃) < 1. 2YP (49 ℃). Compared with traditional oil-based drilling fluid systems, deepwater oil-based drilling fluid systems [21] mainly control the rheological properties of the drilling fluid system by adjusting the amount of organic soil and using flow pattern regulators. Since oil-based drilling fluid systems cause great damage to the marine environment and are costly, and there is a large gap between domestic deep-water oil-based drilling fluid systems compared to foreign countries, deep-water oil-based drilling fluid systems are rarely used in China. With the gradual development of easily recoverable oil reserves on land and the increase in offshore deepwater drilling depth, the development of offshore deepwater oil-based drilling fluid systems has become an inevitable trend in the exploration of oil and gas resources.

Xing Xijin et al. [22] constructed a deepwater constant-rheology oil-based drilling fluid system through indoor optimization of several base oils and treatment agents. This system mainly achieves the constant rheology characteristics of oil-based drilling fluid through the use of an amide thermosensitive polymer and organic soil. The formula is: refined white oil + 4.0% emulsifier + 2.0% wetting agent + 3.0 % calcium chloride aqueous solution + 0.5% calcium oxide + 2.0% cutting agent + 2.0% tackifier + 3.0% fluid loss agent + 1.5% organic soil + barite. Indoor rheological tests show that the rheological values of this system do not change much in the range of 4~65°C.

Hu Sanqing et al. [23] used white oil as the base oil and added an appropriate amount of treatment agent to construct a low-toxic oil-based drilling fluid system suitable for deep water. The formula of this system is: base oil (white oil: CaCl2 aqueous solution = 70:30) + 3.0% main emulsifier + 0.5% auxiliary emulsifier + 1.5% wetting agent + 1.5% organic soil + 3.0% fluid loss agent + 1.0 % alkalinity regulator + aggravating agent. This system can still maintain good rheological properties at 5°C, and has strong salt resistance, high temperature resistance, and strong reservoir protection capabilities.

2.3 Deepwater Synthetic-Based Drilling Fluid System

The synthetic-based drilling fluid system is an inverse emulsification drilling fluid system composed of artificially synthesized organic matter as the continuous phase, brine as the dispersed phase, and adding treatment agents such as emulsifiers and fluid loss agents. The synthetic-based deepwater constant rheology drilling fluid system is obtained by adding a polymer flow pattern regulator to the original synthetic-based drilling fluid and then combining it with organic soil. Its viscosity and shear force fluctuate less within a certain temperature range. The synthetic-based drilling fluid system is similar to the oil-based drilling fluid system in terms of inhibition performance. It has strong high-temperature resistance, is environmentally friendly, and is easy to discharge. It is especially suitable for use in marine deepwater and ultra-deep water wells. It is a relatively mature deepwater drilling fluid in recent years.

Rheliant drilling fluid system [24-25] is a constant-rheology synthetic-based drilling fluid system in a wide temperature range launched by Schlumberger MISWACO. The system is mainly composed of the main emulsifier SUREMUL, the auxiliary emulsifier SUREWET, the flow pattern regulator Rheflat, etc. It has excellent rock-carrying ability, strong wellbore cleaning ability, and can effectively solve the problem of downhole leakage.

Accolade drilling fluid system [26] is an environmentally friendly synthetic-based drilling fluid system launched by Halliburton Baroid Company. The base fluid is a mixture of esters and internal olefins, which can be completely degraded in the ocean. It has good rheological properties and is equivalent to The circulation density is low, the wellbore cleaning ability is strong, and it can effectively perform deepwater drilling operations. When operating in deep water areas in Mexico, the application effect was good and there were basically no underground accidents.

Yue Qiansheng et al. [27] found that emulsifier type, oil-water ratio, organic soil addition, etc. are the main factors affecting the low-temperature rheology of gas-to-oil synthetic-based drilling fluid systems.

Luo Jiansheng and others constructed a deepwater FLAT-PRO synthetic-based drilling fluid system using low-viscosity gas-to-liquids as the base fluid. The formula is: gas-to-liquids + 0.8% primary emulsifier PF-FSEMUL + 1.0% auxiliary emulsifier PF- FSCOAT+1.0% wetting agent PF-FSWET+25%CaCl2 solution+2.5% organic soil PF-FSGEL+0.5% flow pattern regulator PF- FSVIS+3.0%CaO+2.5% fluid loss agent PF-FSHFR+barite. Indoor tests show that this system has basically unchanged dynamic shear force, static shear force and Φ6 value in the range of 4~65°C, has good rheological properties, and the emulsion has good stability and is not prone to settling. It has good application results in an oil field in the western South China Sea. It has strong rock-carrying ability and small ECD value, which meets the needs of downhole operations in low-density windows.

Zhao Jingfang et al. [28] developed an environmentally friendly synthetic base fluid BIO-OIL. The basic physical and chemical properties, viscosity-temperature characteristics, carbon number distribution, biological toxicity, and emulsion microrheology of this base fluid and conventional base fluids were studied indoors. etc., and constructed a set of deep water synthetic base drilling fluid with this base fluid. Indoor tests show that this system basically meets the needs of on -site drilling and has good biodegradability. When applied in three wells in the western South China Sea, the wellbore was stable, the rheological properties were good, the rock carrying capacity was strong, and no downhole complications occurred.

Hu Wenjun et al. [29] used Saraline185V gas-to-liquid as the base oil, and constructed a set of FLAT-PRO deep water constant rheology synthetic base drilling fluid suitable for deep water drilling by optimizing emulsifiers, organic soils, fluid loss agents and other treatment agents. system, its formula is: Saraline185V + (0. 8% ~ 1.0%) FSEMUL + (1.0% ~ 1.2%) FSCOAT + 1.2% FSWET + 2% organic soil FSGEL + 25% CaCl2 + 2.5% PF- MOALK + 2% PF - HFR+0.1%FSVIS+barite, oil to water ratio is (70:30) ~ (85:15). Indoor tests show that this system has good rheological properties in the range of 4~65°C, meets constant rheological characteristics, has strong rock-carrying ability, is easy to discharge, and has strong reservoir protection capabilities. The application effect is good in the LS-A ultra-deep water well in the South China Sea. The ECD value is small, the well hole is regular, tripping is smooth, and the drilling cycle is short.

3 CONCLUSION

Marine deepwater drilling faces technical requirements such as drilling fluid rheology adjustment, well wall stability, wellbore cleaning, and natural gas hydrate generation at low temperatures, which puts forward higher requirements for the performance of deepwater drilling fluid systems. Deepwater water-based drilling fluids should focus on the development and research of core treatment agents, focusing on the development of modification additives based on natural polymer materials and agricultural and sideline products. It should ensure that the drilling fluid system has both good performance and superior Environmentally friendly performance. Deepwater oil-based/synthetic-based drilling fluids should pay attention to the screening of base fluids, try to select low-toxic, non-toxic, and environmentally friendly base fluids, and pay attention to the development of major additives such as emulsifiers and flow regulators to enhance the resistance of treatment agents. Research on temperature and salt resistance and performance of deepwater and ultra-deepwater well drilling fluids.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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