Progress in Research on Drilling Safety of Natural Gas Hydrate Formation

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Abstract: With the development of its economy and society in recent years, China’s demand for energy is increasing. Traditional energy such as coal and petroleum can no longer meet the needs of China’s economic development, because it is very easy to cause environmental pollution in the process of traditional energy reuse. In recent years, China has begun to explore, develop and utilize marine natural gas hydrates, which can achieve better energy effects in use and reduce environmental pollution. However, there are great difficulties in the exploration and development of marine natural gas hydrates and safety issues in the process of drilling the formation. In the process of research, based on the extensive research on the safety of marine gas hydrate drilling at home and abroad, this paper discusses and summarizes the safety problems encountered in Dacheng drilling, and organizes the research on the drilling safety issues of marine gas hydrate formation, providing reference for future research.

1. Introduction

Marine gas hydrate is a kind of clean energy, and has a large amount of storage in the seabed, which can provide an effective solution to the energy shortage problem of China's current economic development. It can be said that natural gas hydrate is an important way for the world's energy utilization in the future, and it has very important research and development value. Countries all over the world have carried out exploration and exploitation of marine gas hydrate. In the process of mining, formation drilling is required, which is an important means to make full use of marine gas hydrate. After recent years of exploration and development, there are currently more than 240 areas in the world where natural gas hydrates are distributed. However, the overall distribution of natural gas hydrates is very uneven and it is affected and controlled by the geological structure of the seabed bringing great difficulties to the exploration and mining. Formation drilling is more difficult than conventional oil and gas drilling, and safety problems are also prone to occur during construction, which seriously affects the quality of engineering construction and the lives and health of construction personnel. The process of drilling exploration will cause changes in the temperature and pressure of the hydrate formation. If not properly controlled, it will lead to marine geological disasters and environmental disasters. Therefore, the drilling of marine hydrate formations is a highly difficult project. In this paper, we mainly organize and analyze the previous research reviews, which is conducive to further research and provides reference for the exploration and exploitation of natural gas hydrate in China.

2. Safety issues easily caused by the decomposition of natural gas hydrate
2.1 Borehole wall losing stability in formation drilling
Before the process of drilling and mining, the bottom of the seabed is in a balanced state. During the drilling process, the formation will be destroyed and the formation stress will be released. It will cause the borehole wall of the top drilling to lose stability and affect the security of the entire exploration work. This is mainly because the uncoupled weighing of the marine natural gas mixture under exploration will decompose, causing the seabed stratum to loosen, and the originally stable structure between the stratum granular structure loosens, which affects the safety and stability of the borehole wall of the formation drilling, which will also affect the safety of the formation drilling process.

2.2 Drilling fluid easily penetrating into the formation
During the drilling process of marine gas hydrate, the hydrate will decompose under certain pressure conditions, which will affect the mechanical stability of the borehole wall. During the drilling process, drilling fluid is a very common drilling material. In the process, the pressure of the drilling fluid will be too high, which will directly intrude into the formation. When drilling continuously, the drilling fluid will continue to deepen and affect the overall stability of the formation. After the drilling fluid penetrates into the formation, it will cause further decomposition of natural gas hydrate, increasing the penetration rate. The penetration of drilling fluid will affect the overall stability of the formation, thereby seriously affecting the safety of the large-scale drilling process.

2.3 Wellhead subsidence in formation drilling
There are great difficulties in the exploration and drilling of marine gas hydrates. During the drilling process, it will cause the destruction of the submarine stratum, the loss of the submarine bearing capacity, and the subsidence of the submarine foundation, which seriously affects the safety and stability of the drilling. If the wellhead sinks during drilling, the drilling equipment, especially the casing pipes, will be flattened. Under the continuous influence of pressure, the upper inlet of the casing pipes will tilt due to the loss of sufficient pressure support, which will affect the safety and stability of the drilling. In severe cases, safety accidents such as blowouts will be caused, causing great losses.

2.4 Gas leakage in formation drilling
Marine natural gas mixture will lead to mixture leakage during drilling in formation. Once leakage occurs, it will lead to a large amount of methane gas leakage. After methane gas leakage, it will rise to the sea level, resulting in loss of sea surface buoyancy, thus affecting the safety and stability of drilling equipment, resulting in equipment tilting, which will affect the safety of drilling. At the same time, it will cause corrosion of drilling equipment on the seafloor, affect the service life of equipment and bring unnecessary losses to the whole exploration work.

2.5 Seafloor landslide in formation drilling
During the drilling process, it will affect the seafloor formation, and in serious cases will lead to seafloor landslide. Because a large amount of seafloor hydrate will be decomposed in the process, affecting the seafloor support effect and carrying capacity. Once seafloor landslide occurs, it will directly affect the safety and stability of submarine cables, drilling equipment and oil pipelines, and in serious cases will cause serious damage to mechanical equipment.
Figure 1 Principle of drilling safety problems in seafloor formations

3. Drilling safety issues easily caused by natural gas hydrate formation

3.1 Destruction of drilling equipment
Marine gas hydrate will lead to drilling fluid leakage after being drilled and exploited. When drilling fluid is mixed with natural gas hydrate, it will be further affected by seafloor temperature and pressure, which will further affect wellbore and pipeline of drilling equipment, lead to equipment corrosion and pipeline blockage and seriously affect normal drilling process. If the decomposition of hydrate occurs during exploration, safety accidents such as well blowout will occur, which will seriously affect the influence of underground subsea equipment.

3.2 Influence on drilling fluid performance
Drilling fluids are the important foundation to ensure the safety and stability of the whole drilling process. Drilling fluids will penetrate into the formation and lead to the loss of drilling fluids during drilling exploration. At the same time, the problem that seawater and sediment are mixed into drilling fluids will occur during drilling. The entry of impurities will consume water in drilling fluids, thus affecting the performance of drilling fluids, resulting in increased friction between mechanical equipment during drilling and causing damage to mechanical equipment. The decrease of drilling fluid performance of drilling equipment will result in a significant increase in viscosity and shear force of fluid pressure, which seriously affects the safety and stability of drilling and the wall-building
performance of drilling fluid.

4. Safety issues arising from marine gas hydrate drilling projects

At present, many countries have carried out marine gas hydrate drilling projects. In the process of drilling exploration and exploitation, many have adopted test exploration. In the process of mining, there are various degrees of safety issues, which affect the safety and stability of the entire mining process and the service life of mechanical equipment. At present, in the process of drilling and exploitation, the following problems mainly arise: drill pipe bending, drill pipe collapse, wall collapse, hydrate decomposition, methane leakage and so on. These problems will seriously affect the safety and stability of drilling. During BP (British Petroleum) drilling, the platform exploded severely and caused a fire, which caused the entire platform to sink. Crude oil leakage occurred in the process of drilling, and heat release and pressure relief changes occurred during operation. These changes directly led to the decomposition of hydrate, and at the same time, methane gas leakage gradually rose to sea level, causing an explosion when the leaked methane diffused the drilling platform.

| Voyage number | Time | Survey area | Purpose | Drilling-related problems | Water depth/m |
|---------------|------|-------------|---------|---------------------------|---------------|
| OPD 164       | 1995 | Submarine plateau Blake in USA | Prospecting | Drill pipe bending | 2567          |
| OPD 204       | 2002 | South of sea ridge hydrate in USA | Prospecting | Drill pipe collapse, borehole wall collapse and stuck drill pipe | 1210          |
| JIP-I         | 2005 | Gulf of Mexico, USA | Prospecting | Insufficient drilling cuttings transportation capacity, blocked annulus and expanded wellhead | 1290          |
| IODP-311      | 2005 | North of sea ridge hydrate in USA | Prospecting | Serious sand production, stuck drill pipe and damaged equipment | 1306          |
| GMGS1         | 2007 | Shenhua sea area, South China Sea | Prospecting | Expanded borehole wall and hydrate decomposition | 1500          |
| MC-252        | 2010 | Northern Gulf of Mexico | Oil extraction | The heat release and pressure drop during cementing cause hydrate decomposition, releasing methane gas and causing explosion. | 1522          |
| MH21          | 2012 | South China trough, Japan | Pilot production | There is no obvious drilling problem, but sand production is serious. | 1000          |
| GMGS2         | 2013 | East China Sea area of Pearl River Mouth Basin, South China Sea | Prospecting | Methane leakage on the sea floor, borehole wall collapse | 869           |

5. Experimental study on drilling safety issues in marine gas hydrate formation

5.1 Experimental study on drilling fluid performance

In the process of drilling, all countries study the performance of drilling fluid by experiment. Through the corresponding research, we can ensure that the drilling fluid can be maintained at a reasonable
density level. At the same time, it can ensure good chemical stability of the borehole wall, and has adjustable well control ability. In the process of production, it can reduce the leakage of drilling fluid and meet the requirements and needs of drilling environmental protection. In the process of carrying out the experiment, the main experimental forms include density test experiment, viscosity test experiment, etc. In the process of experiment, we can develop drilling fluid system with excellent performance such as polymer system and formate system, so as to better serve the drilling work and exploration and production work. For example, Saikia et al. extracted a glycoprotein from the pancreas of pigs as hydrate inhibitor to prepare hydrate drilling fluid. The experimental results show that this drilling fluid has good hydrate formation inhibition effect and can be used as a natural gas hydrate drilling fluid additive with excellent performance.

5.2 Experimental study on disturbance of marine hydrate formation physical properties during drilling

The process of drilling will cause instability of the seafloor and its destruction. During the drilling experiment, the entire process is often simplified to a static or quasi-static standard for research. Applying this experimental method can analyze the impact on the formation during the drilling process. During the drilling experiment, the corresponding parameter changes are measured by the corresponding sensors, so as to evaluate the safety and stability of drilling in the hydrate formation. China University of Geosciences has developed a set of experimental equipment to carry out research on drilling fluid intrusion during drilling. It mainly uses resistivity changes to determine the frontier position of hydrate decomposition. At present, there are very few experimental equipments that can simulate drilling into hydrate formations. Dou Bin et al. of China University of Geosciences designed and built a set of equipment for synthesizing natural gas hydrate and conducting micro-drilling experiments, which can simulate and study the temperature field changes of hydrate formations near the borehole wall during drilling. The results show that the increase in the rotation speed of the drill pipe will speed up the decomposition of hydrate, but when the rotation speed increases to a certain extent, the decomposition rate will be affected by the thermal conductivity of the hydrate and increase slowly.

6. Numerical simulation research on safety problems of offshore gas hydrate drilling

In the process of conducting research, many researchers have conducted research through corresponding numerical values and models. They have found that the main factors affecting the safety of drilling are heat transfer factors, mass transfer factors, and mechanical characteristics.

| Mode | Reference | Time | Considerations | Coordinate |
|------|-----------|------|----------------|------------|
| Self-built NING FULONG | 2005 | Thermal convection | Heat transfer, Gas, liquid | Square |
| FREJ-AYOU B et al. | 2007 | Heat conduction | Heat transfer, Gas, liquid | Square |
| KHABIBULLIN et al. | 2011 | Heat conduction and throttling compression | Gas | Square |
| SHEN HAICHAO et al. | 2012 | Thermal convection | Heat transfer, Gas, liquid | Square |
| LI LINGDONG et al. | 2012 | Thermal convection | Heat transfer, Gas, liquid | Square |
| LEE et al. | 2015 | Thermal | Heat transfer, Gas, liquid | Square |
convection liquid dimensional rectangular
GOLMOHA MMADI et al. 2015 Heat conduction Gas - - Cylinder
GAO et al. 2017 Heat conduction - - - Two dimensional rectangular
ZHANG et al. 2018 Thermal convection Gas, liquid Kim model ¬ Two dimensional rectangular
YU et al. 2018 Heat conduction Gas, liquid Kamath model - Cylinder
WEI et al. 2019 Heat conduction Gas, liquid, solid Kim model - Two dimensional rectangular

Mathematical analysis is used to solve the temperature field and pressure field around the production well in hydrate formation. The model considers the throttling effect and adiabatic effect in the process of fluid seepage in the heat transfer term. On this basis, Khabibullin et al. simulated the dynamic effect of gradually drilling into the formation by continuously adjusting the boundary conditions in the grid, and obtained the temperature distribution around the borehole wall during the drilling process and related data information of gas production over time.

7. Safety issues and suggestions for marine gas hydrate drilling
At present, there are still many shortcomings in the research on the safety issues of marine gas hydrate drilling. This is mainly because the geological environment in seafloor is very complicated in the process of drilling, and the depth and soil composition of the seabed in different regions are quite different. Therefore, before drilling and mining, detailed data understanding, model construction and analysis should be carried out. Further basic research should be carried out to understand the specific geological parameters for seafloor drilling and exploration under complex conditions. In the process of experimental research on drilling fluids, it is necessary to develop a hydrate drilling fluid system with the characteristics of reservoir protection ability, hydrate formation inhibition ability, environment-friendly, low consumption, low cost, easy access, safe and stable, so as to meet China's demand for mineral exploration and mining of natural gas hydration as soon as possible. At the same time, in the process of further research, the number of experimental equipment and measurement accuracy should be further improved. In the process of research, mathematical models should be used flexibly to understand the corresponding parameters of the seafloor location. In the process of experimental scientific research, we should use pure models for research, which, however, is not mature at present. In addition, it is necessary to develop a multi-dimensional large-scale mathematical model or professional software that can simulate the dynamic process of drilling into the formation on the basis of the current quasi-static model. Hopefully, the model or software can predict borehole wall instability, gas leakage, submarine landslide and equipment damage.

8. Conclusion
In conclusion, this paper mainly explored the research progress of the drilling safety issues of marine gas hydrate drilling during the research process. Natural gas hydrate is a kind of future clean energy with high reserves. All countries attach great importance to the exploration and exploitation of marine natural gas hydrate, which requires formation drilling. Corresponding research shows that during the
process of formation drilling, the main problems such as drilling fluid penetration, wellhead subsidence and seafloor landslide will cause the damage of drilling equipment and change the nature of the drilling fluid. Scholars have carried out experiments on drilling safety issues in marine gas hydrate formation. These studies have analyzed the properties of hydrate drilling fluid and the interference and influence of drilling process on marine hydrate formation. At the same time, numerical simulation of safety problems is used to develop research, and the basic principle construction and model review are carried out. Through the study of drilling safety issues in marine gas hydrate formation, the following conclusions are drawn as follows. In the process of marine gas hydrate exploration and exploitation, due to the complex seafloor conditions, it is necessary to focus on improving the accuracy of hydrate formation identification and evaluation. At the same time, the drilling fluid with high performance should be used. During the design of drilling machinery and experimental equipment, high pressure and low temperature conditions should be created to generate hydrate, and the change of hydrate morphology should be timely mastered. Only in this way can we better carry out offshore gas hydrate formation drilling, and further provide help for China's energy development.

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