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Design Of A New Self-Cleaning And Efficient Circulation System For Drilling Fluid

Yuandong Liu, Wenling Liao
School of Intelligent and Manufacture
Chengdu Technological University
Chengdu, China
lwlcdtu18@163.com

Xianfeng Shi
Technical Equipment Department
Changqing Drilling Corporation
Xian, China

Guorong Wang
School of Mechanical and Electrical Engineering
Southwest Petroleum University
Chengdu, China

***Abstract*—Drilling fluid is the "blood" of drilling engineering, and its stable performance and circulation efficiency directly determine drilling safety, cost, and quality. In response to the problems of low installation and disassembly efficiency, low slurry mixing efficiency, difficulty in removing sand accumulation, and serious leakage pollution in traditional drilling fluid circulation tank systems, efforts have been made to optimize the layout of the drilling fluid circulation system, innovate the internal structure, design the process flow, and conduct on-site application testing. The results showed that the overall disassembly and transportation efficiency of the new drilling fluid circulation system was improved by 30%, the manufacturing efficiency was increased by 36%, and the manufacturing cost was reduced by 23.8%; The online monitoring and intelligent control system has increased the slurry mixing efficiency by more than three times, the drilling fluid reuse rate has increased to 95%, and the sand cleaning efficiency has increased by 100%.**

***Keywords*—Drilling fluid, circulation tank system, innovative design**

I. INTRODUCTION

As the "blood" of drilling engineering, drilling fluid plays a core role in carrying rock debris, balancing formation pressure, lubricating and cooling drilling tools, and protecting wellbore walls. The performance of its circulation system directly determines wellbore safety, drilling efficiency, and operating costs [1]. As global oil and gas resource development extends to deep wells, ultra deep wells, and shale gas long horizontal sections, drilling conditions exhibit characteristics of "high temperature, high pressure, and high sand content". The technical shortcomings of traditional drilling fluid circulation systems are becoming increasingly prominent: 1) incomplete removal of solid particles below 10 um leads to abnormal increase in drilling fluid viscosity, causing "differential pressure sticking" accidents; 2) The recovery rate of drilling fluid is only 60%-70%, and the amount of new slurry added to a single well exceeds 100m³. At the same time, a large amount of waste drilling fluid is generated, which not only increases the economic burden but also violates the requirements of green drilling [2-3]; 3) The system relies on manual regular cleaning of vibrating screens, cyclones, and other components, with a single shutdown time of 0.5-2 hours, and non-production time accounting for over 15%, severely restricting drilling efficiency [4]. Therefore, the development of new systems with self-cleaning capabilities and efficient circulation characteristics has become a key technological direction for solving complex well drilling problems and promoting cost reduction and efficiency improvement in oil and gas development.

Researchers have conducted extensive simulation and experimental testing work to optimize the drilling fluid circulation system. Schramm et al. [5] proposed a series scheme of "high-frequency vibrating screen cyclone", which improves the removal rate of solid particles above 75 um to 92% by optimizing the vibration frequency and cyclone inlet pressure. However, the system has a separation efficiency of less than 60% for fine particles between 10-75 um, and the screen mesh needs to be manually cleaned every 4 hours due to rock debris adhesion blockage, making it difficult to adapt to the continuous operation needs of long horizontal wells. The intelligent cyclone unit developed by Equinor in Norway monitors the bottom flow pressure in real time through pressure sensors. When the pressure difference exceeds the inlet pressure by 10%, the slag discharge valve automatically opens to achieve automatic bottom flow slag discharge. However, its inner wall has not been treated with wear-resistant treatment. After running continuously for 300 hours in drilling fluid with a sand content of 5%, the inner wall wear reaches 0.8mm, resulting in a 20% decrease in separation efficiency [6]. The ceramic membrane filtration system launched by M-I SWACO company can remove some colloidal particles and reduce the solid content of drilling fluid to below 3%. However, the membrane components have weak resistance to oil-based drilling fluid pollution. After running in oil-based slurry for 100 hours, the membrane flux decreases by 50%, requiring frequent replacement of membrane components, resulting in poor economy [7]. The automatic slurry mixing system developed by Halliburton achieves precise addition of viscosity reducers and weighting agents through the linkage of density sensors and viscosity sensors. However, the system does not cooperate with the separation module. When the solid content suddenly changes, the slurry mixing adjustment lags by more

than 10 minutes, which can easily lead to loss of control of drilling fluid performance [8]. Li Wei and others have developed a composite system of "vibrating screen horizontal spiral centrifuge", which improves the recovery rate of drilling fluid to 85% by optimizing the differential speed of the centrifuge spiral pusher. However, the system does not integrate a self-cleaning module, and the inner wall of the centrifuge drum needs to be manually flushed every 8 hours. Moreover, the removal rate of colloidal particles below 10 um is less than 50%, and it still relies on chemical flocculants for assistance, increasing the cost of drilling fluid [9]. Zhang Jie et al. [10] proposed the "Ultrasonic Cyclone" coupling design, which uses ultrasonic waves to break down fine particle aggregates and optimizes the flow field of the cyclone to improve the separation efficiency of 10-75 um fine particles by 15%. However, this technology is only applicable to a single unit of the cyclone and is not linked to units such as vibrating screens and membrane filtration, which cannot form a complete system separation loop. Moreover, the ultrasonic probe is prone to damage due to drilling fluid corrosion and has a service life of less than 500 hours. The "Drilling Fluid Intelligent Circulation Control System" developed by China Petroleum Engineering Technology Research Institute is based on PLC control to achieve preliminary linkage between the separation equipment and the slurry system, but the control logic is only for a single parameter and does not consider the coupling effects of multiple parameters such as drilling fluid viscosity and water loss [11]. In addition, Zhao Fushun et al. developed a wear-resistant cyclone using $Al_2O\propto$ ceramics. Although the equipment life was extended to 1000 hours, the problem of clogging at the bottom flow port of the cyclone was not solved, and manual intervention for slag removal was still required in drilling fluids with a sand content of 8% [12].

In summary, although existing research has made progress in optimizing single separation equipment and intelligent zing local functions, there are still some shortcomings: 1) low system integration and lack of full process closed-loop design such as "pretreatment grading separation self-cleaning intelligent conditioning"; 2) The level of intelligence is limited, mostly relying on single parameter control or local unit linkage, lacking a system wide collaborative response mechanism; 3) Lack of shared operation mode for drilling fluid, resulting in low utilization rate of drilling fluid. Based on this, this article designs a new type of self-cleaning and efficient circulation system for drilling fluid, carries out work such as optimizing the layout, innovating the internal structure, and designing the process flow, and conducts on-site application testing.

II. Design Scheme and Effect

A. Modular Design Scheme

Adopting modular and lightweight collaborative design methods, the topology structure of the circulation system is reconstructed, and a fast and flexible connection device is developed, which is combined with hydraulic locking mechanism and standardized interface design. The schematic diagram of modular design and connection scheme for the circulation tank system is shown in Figure 1, and the on-site assembly effect is shown in Figure 2. Data shows that modular design increases production efficiency by 36%, reduces single unit manufacturing costs by 33.2%, and improves on-site disassembly and transportation efficiency by 30%.

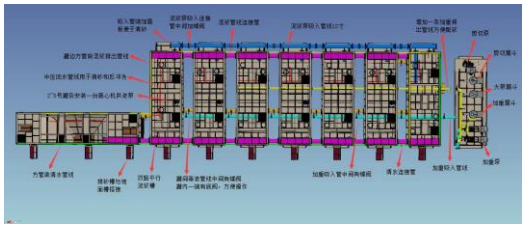

Figure 1 Modular Connection Diagram

Figure 2 On site assembly effect of circulating tank system

B. Automatic Feeding and Slurry Preparation Scheme

Aiming at the safety risk of injury caused by manual cutting of bags with cutting tools, a high solid phase multi-media slurry design scheme of "automatic bag breaking with four edges cutting knife-dual axis multi blade convection shear mixing" is proposed, which realizes mechanical bag breaking and rapid mixing. At the same time, by combining jet, shear, and mixing, a three in one efficient slurry mixing technology is constructed, which increases the slurry mixing efficiency by more than three times and reduces the frequency of personnel exposure to chemical dust by more than 90%.

Figure 3 Schematic diagram of automatic cutting device and feeding and slurry preparation

C. Efficient Closed Sand Cleaning Solution

The sand settling induction alarm is designed to be located at the four corners of the tank surface, and the rotating spray gun is located next to the sand settling induction alarm. The strong water repellent sloping tank bottom is high outside and low inside, with a

certain inclination angle. The liquid supply pump is connected to the rotating spray gun to generate high-pressure hydraulic action, driving the drill cuttings to be discharged into the closed sand discharge tank outside the tank. The drilling cuttings generated by the solid control equipment and the drilling cuttings carried by the drilling fluid during the tank cleaning process are transferred to the sand discharge tank through a dual control sand cleaning door. The automatic sprinkler sprays high-pressure cleaning fluid to flush and transfer the drilling cuttings to the buried tank. The liquid supply pump pumps the solid-liquid mixed drilling cuttings to the vibrating screen for secondary filtration, thus forming a closed-loop process and improving the sand cleaning efficiency by 100%. Figure 4 shows a comparison of the on-site performance between the new and traditional solutions. Obviously, the new solution is more conducive to sand discharge in the circulation tank system, reducing blockages and corrosion caused by mud and sand.

Figure 4 Comparison of the effects of two schemes

D. Dual drilling rig shared operation plan

The circulation tanks are connected in a straight line, sharing an external water supply pipeline. There are multiple aqueducts inside the tanks, and any adjacent straight line is connected to form a circulation path. Through the aqueducts, dual circulation solid control is achieved, meeting the requirement of two drilling rigs sharing one set of circulation tanks to achieve simultaneous operation of dual drilling fluid systems. The reuse rate of drilling fluid is increased to 95%.

Figure 5 Dual drilling rig shared operation

E. Intelligent control scheme

Based on multi-source perception fusion technology, an online monitoring and prediction method for drilling fluid performance was proposed, and a multi parameter online monitoring device for drilling fluid was developed; Breakthrough the dynamic slurry control algorithm and achieve real-time control of six core indicators, including pH value and rheological parameters; Build a closed-loop control model of "online monitoring abnormal alarm automatic adjustment", combined with the propagation mechanism of wellbore pressure waves, establish a three-level warning system for well surge and leakage, form a technical chain of "monitoring warning disposal" for well control risks, and achieve unmanned operation of the circulation system. As shown in Figure 6, the automatic control system for drilling fluid performance can control the circulation tank system based on real-time monitoring data of drilling fluid performance. The online monitoring device for drilling fluid performance is shown in Figure 7.

Figure 6 Intelligent system control system

Figure 7 Online monitoring of drilling fluid performance

III. Conclusion

This work focuses on the problems of low installation and disassembly efficiency, low slurry mixing efficiency, difficult sand removal, and serious leakage pollution in traditional drilling fluid circulation tank systems. A new type of self-cleaning and efficient circulation system for drilling fluid is designed. The design and testing results show that the overall disassembly and transportation efficiency of the new drilling fluid circulation system has been improved by 30%, the manufacturing efficiency has been increased by 36%, and the manufacturing cost has been reduced by 23.8%; The online monitoring and intelligent control system has increased the efficiency of slurry preparation by more than three times, the reuse rate of drilling fluid has increased to 95%, and the sand removal efficiency has increased by 100%, promoting cost reduction and efficiency improvement in oil and gas development.

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