

Application Research of Borehole Cleaning Evaluation System Based on Cuttings Weighing

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Abstract: Due to complex working conditions and cuttings migration mechanism and other factors, cuttings bed is easy to form in deviated well section and extended reach horizontal well section, and too high cuttings bed is easy to cause a series of complex downhole accidents, such as bit mud bag, wall collapse, stuck drilling and holding in drilling. The borehole cleaning evaluation system based on cuttings weighing can collect the cuttings returned in real time. The system combines the real-time cuttings flow rate, theoretical cuttings volume, actual cuttings volume and other data to evaluate the borehole cleaning situation and provide guidance for field drilling construction. At the same time, the drilling optimization analysis module is designed in the system. The module adopts the combination of comprehensive logging data and geological logging data, combining the advantages of comprehensive logging and geological logging, which can realize the real-time drilling time optimization analysis to the maximum extent. In this paper, the evaluation system of borehole cleaning based on cuttings weighing is studied and corresponding engineering application examples are given. It has high practical application value for borehole cleaning monitoring and evaluation, drilling aging optimization analysis and reducing non-productive time.

Keywords: Borehole cleaning, Cuttings weighing, Drilling optimization.

1. Introduction

Borehole cleaning monitoring is always a very important problem in drilling and logging. In horizontal well drilling and logging, the returned cuttings provide the basis for well cleaning monitoring [1]. Drilling optimization analysis is also a very important direction in the drilling process. Therefore, it is very important to combine borehole cleaning monitoring with drilling optimization analysis to reduce drilling accidents and improve drilling efficiency in the process of drilling and logging [2,3].

According to the literature reviewed, there are mainly the following monitoring methods for cuttings return: expert experience, downhole engineering sub and surface cuttings weighing device [4]. Expert experience is too subjective, so this method has limitations on well cleaning and horizontal logging. The annulus pressure is measured by the downhole engineering nipple, and then the annulus cuttings concentration is calculated according to the annulus pressure to analyze the borehole cleaning condition. However, this method has high cost of downhole tools and is not conducive to widespread popularization. The cuttings weighing device is installed at the discharge port of the vibrating screen. Real-time cuttings flow measurement is the most common method at present, Xiao Jingtao, Ren Zhonghong, Wang Qiang, Cui Zhongfeng, Li Yanfeng, Li Fukai, Hu Fengbo proposed a wireless cutting-flow measuring device and its application [5]; Zeng Yongwen, Wang Dongsheng, Zhang Jijun, and Zhang Liang proposed a cuttings volume balance calculation method and analysis process for horizontal well cleaning analysis [6]; Jing Wenming, Ni Pengbo, Mao Min and Qin Tianbao introduced the latest generation of intelligent comprehensive

logging system developed by the French Geological Service Company, and carried out the application research of the system in optimizing drilling engineering [7].

At present, the research on directly measuring the cuttings flow and then evaluating the wellbore cleaning in China remains more in the experimental stage, and the application research on the wellbore cleaning evaluation system based on the cuttings weighing is less. In this paper, the wellbore cleaning evaluation system based on cuttings weighing is applied to the field. The results show that the system is of great significance for real-time monitoring of borehole cleaning, optimization of drilling efficiency and reduction of non production time.

2. Wellbore Cleaning Evaluation System Based on Cuttings Weighing

The overall design scheme of wellbore cleaning evaluation system based on cuttings weighing is shown in Figure 1. The system collects rock cutting flow data through the rock cutting weighing device installed at the outlet of the shale shaker, and combines the data of the comprehensive logging instrument to form a rock cutting flow data record with time, depth, rock cutting weight and other records; The system calculates the actual cuttings return flow, cuttings volume concentration, rock carrying efficiency and other data through cuttings flow calculation and correction method for wellbore cleaning evaluation; In order to realize real-time optimization analysis of drilling, the statistical method while drilling and optimization analysis method of drilling efficiency combined with comprehensive logging data and geological logging data are studied to provide guidance for shortening drilling time and improving production efficiency.

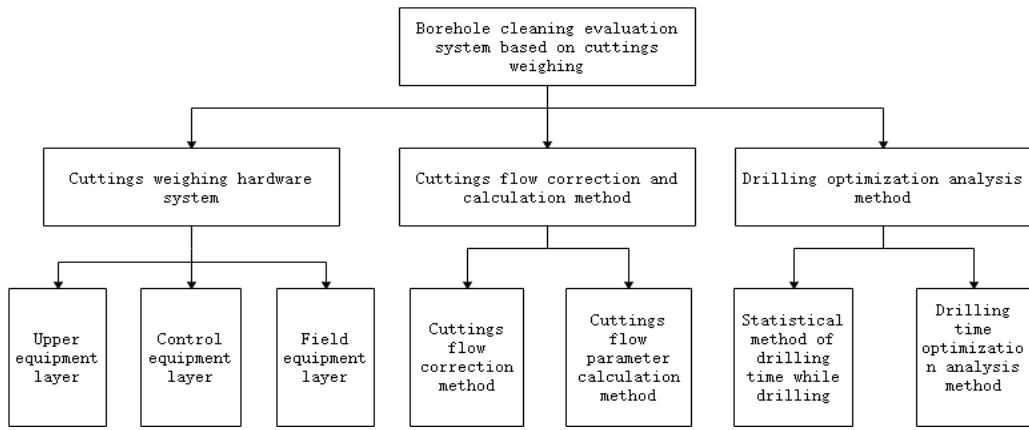


Figure 1. Overall design of wellbore cleaning evaluation system based on cuttings weighing

2.1. Cuttings weighing hardware system

The hardware system of rock cuttings weighing is divided

into field equipment layer, control system equipment layer and upper equipment layer from bottom to top^[8,9], As shown in Figure 2.

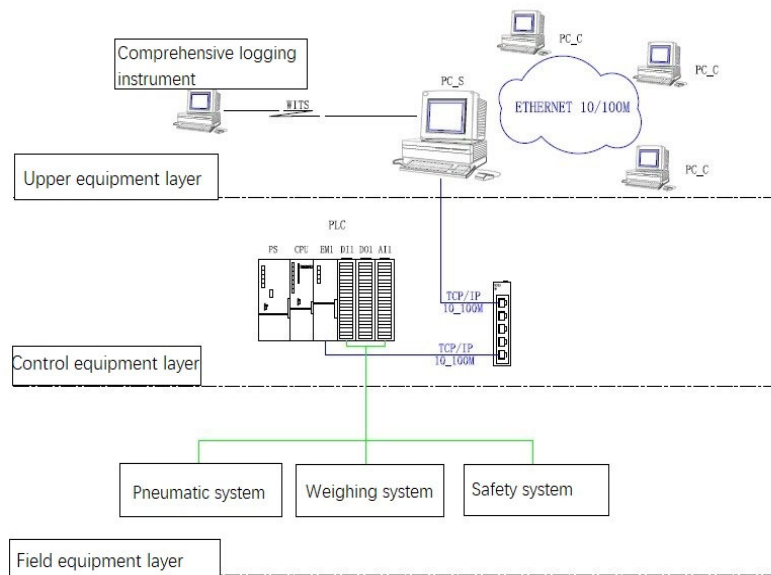


Figure 2. Hierarchical Structure of Rock Cutting Weighing Hardware System

1. Upper equipment layer

The upper device layer is mainly composed of PC_S (field server) and several PC_C (client server). PC_S server is used to communicate with the control equipment layer to obtain cuttings flow data and comprehensive logging instrument data, to display real-time curve of instantaneous, whole meter and column cuttings flow [10], and to evaluate borehole cleaning status. The main function of PC_C is to process the data forwarded by PC_S in real time through user Ethernet. By setting proper operation permissions, the PC_C can not only read the relevant data of field devices in real time, but also operate field devices in real time.

2. Control equipment layer

The control equipment layer is mainly composed of Siemens PLC and MOXA industrial Ethernet switch. Its main function is to collect the real-time data of the field equipment, according to the user's program to achieve manual and automatic control mode, at the same time, the relevant data will be transmitted to the upper server in real time.

3. Field equipment layer

The field equipment layer is mainly composed of pneumatic system, weighing system and safety system. The

main function is to complete the collection, measurement, dumping, hanging sweep, weighing and other functions of returned cuttings [10].

The three-dimensional and physical drawings of the hardware system for weighing cuttings are shown in Figure 3 and 4.

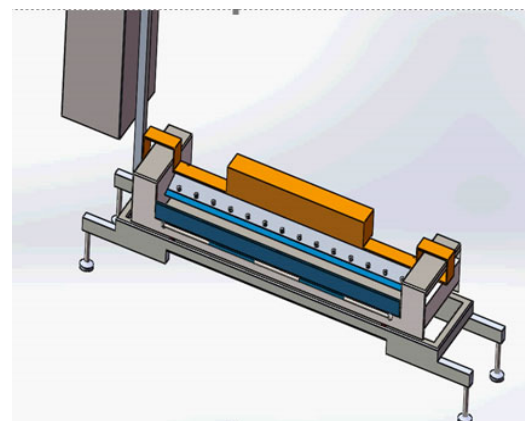


Figure 3. Three-dimensional diagram of chip weighing hardware system



Figure 4. Physical picture of hardware system for weighing cuttings

2.2. Cuttings flow correction and calculation method

1. Cuttings flow correction method

Due to the tipping and hanging sweep of the cuttings weighing device, the cuttings receiving is interrupted, and the continuous recording of cuttings weight data cannot be realized. Polynomial correction method is used to predict the flow value during the interrupt period according to the historical flow parameters. Due to the lack of depth mark in cuttings flow data, the late well depth is extracted by using real-time parameters of engineering logging to form cuttings flow data records with time, depth and cuttings weight records.

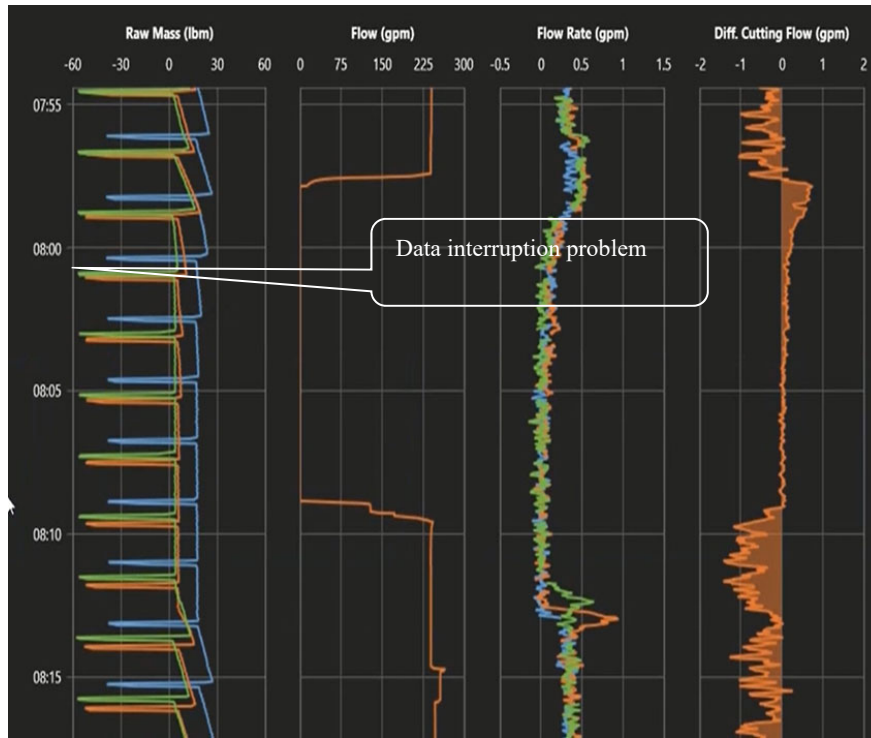


Figure 5. Interruption of original cuttings weight data

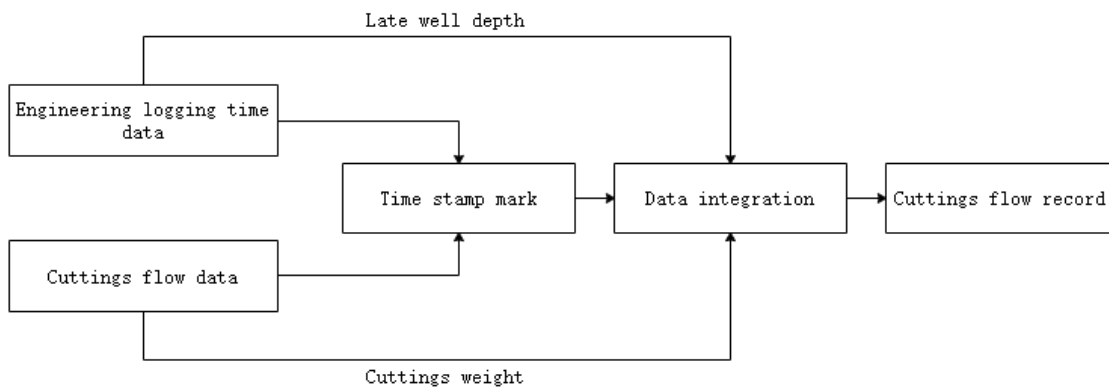


Figure 6. Flow chart of cuttings flow data recording

2. Cuttings flow parameter calculation method

The actual cuttings volume is calculated as follows:

$$V_{\text{actual}} = \sum_{i=h_0}^h \left(\frac{\eta_i \times \mu_i}{\rho_{ci}} + LGS_i \times Q_i \times t_i - \frac{Q_i \times t_i \times MBT_i}{\rho_{bi}} \right)$$

V_{actual} , Volume of dry cuttings returned per meter: m^3

h_0 , Calculate the starting well depth: m

h , Calculated end well depth: m

η , Weight of cuttings per meter measured: kg

ρ_c , Cuttings density: kg/m^3

ρ_b , Bentonite density: kg/m^3

In order to compare with the actual cuttings volume, the

theoretical cuttings volume is calculated as follows:

$$V_{\text{theory}} = \frac{\pi d^2 (1 + \theta)}{4} \times (h - h_0)$$

V_{theory} , The theoretical volume of cuttings produced: m^3

d , Hole diameter: m

θ , Hole expansion rate: %

h_0 , Initial depth: m

h , Drill the depth of the well: m

2.3. Drilling optimization analysis method

1. Statistical method of drilling time while drilling

Comprehensive logging data can automatically identify drilling, reaming, tripping and other dynamic drilling conditions in real time. Geological logging data (mainly referring to drilling conditions logs) can record both dynamic and static drilling conditions. Integrated logging instrument and geological data acquisition instrument are connected on site to realize automatic statistics and accurate calculation of drilling aging, and real-time quantitative display of aging analysis results is helpful to reduce non-productive time and improve drilling construction efficiency.

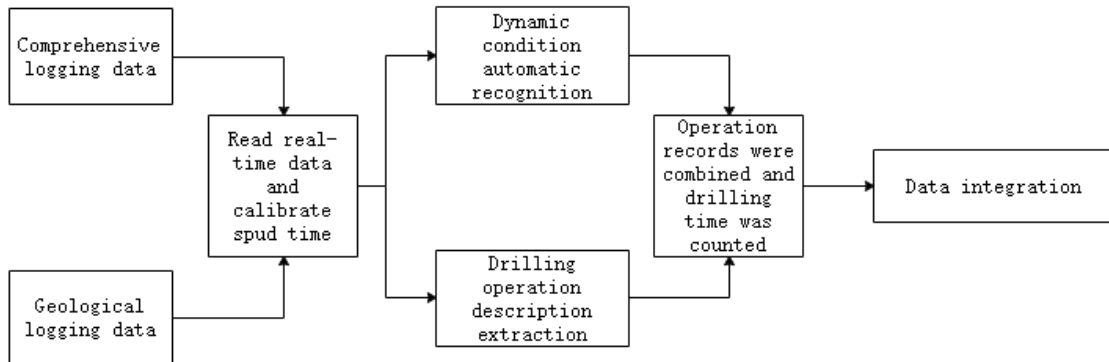


Figure 7. Statistical data flow chart of drilling aging while drilling

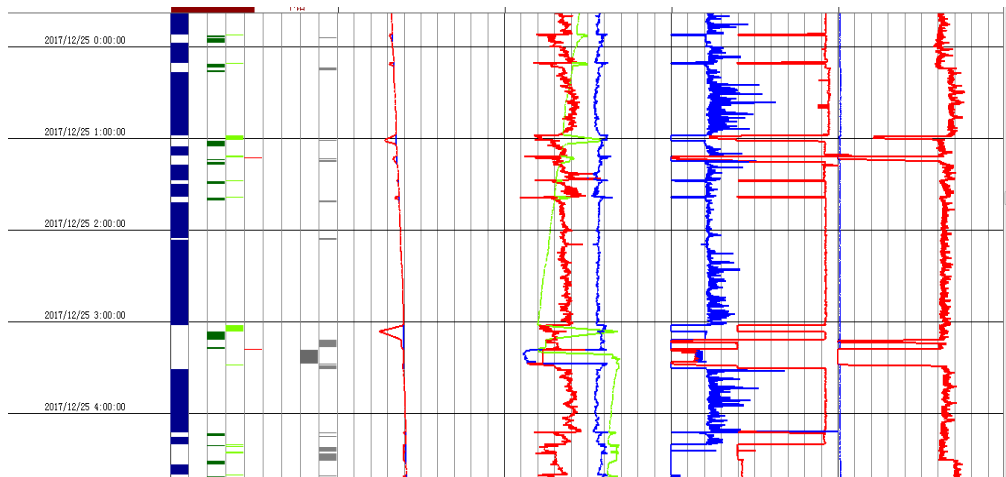


Figure 8. Automatic analysis module of rig status

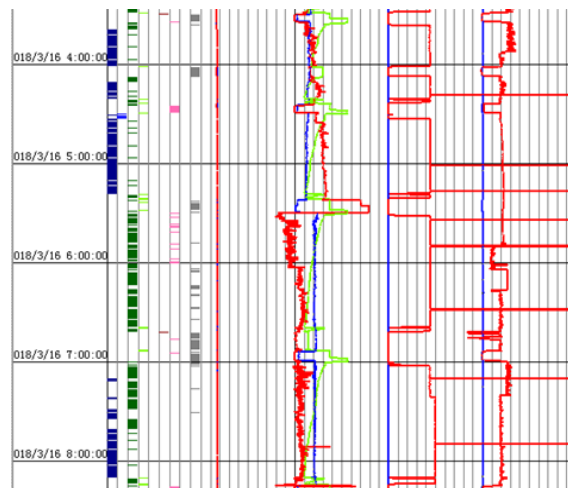


Figure 9. Drilling aging automatic statistics module

2. Drilling time optimization analysis method

According to the actual and theoretical cuttings volume

relationship, the cuttings bed and the stability of the shaft wall are judged. Combined with the cuttings return situation of the

column, the operation of pulling times, cycle time, tripping and thickening plug are decided.

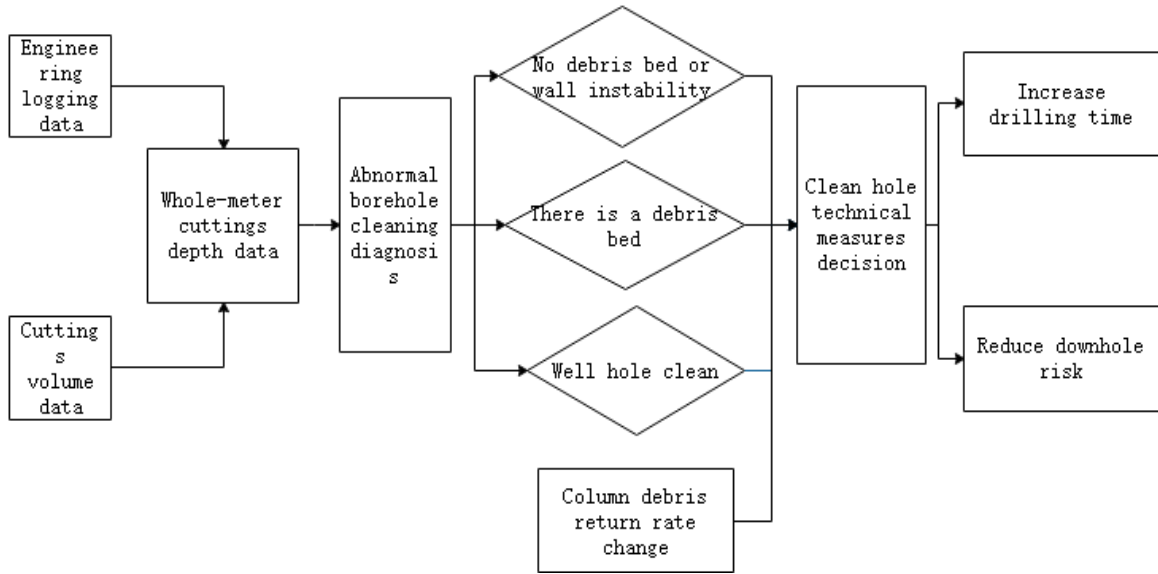


Figure 10. Flow chart of application of cuttings return evaluation data

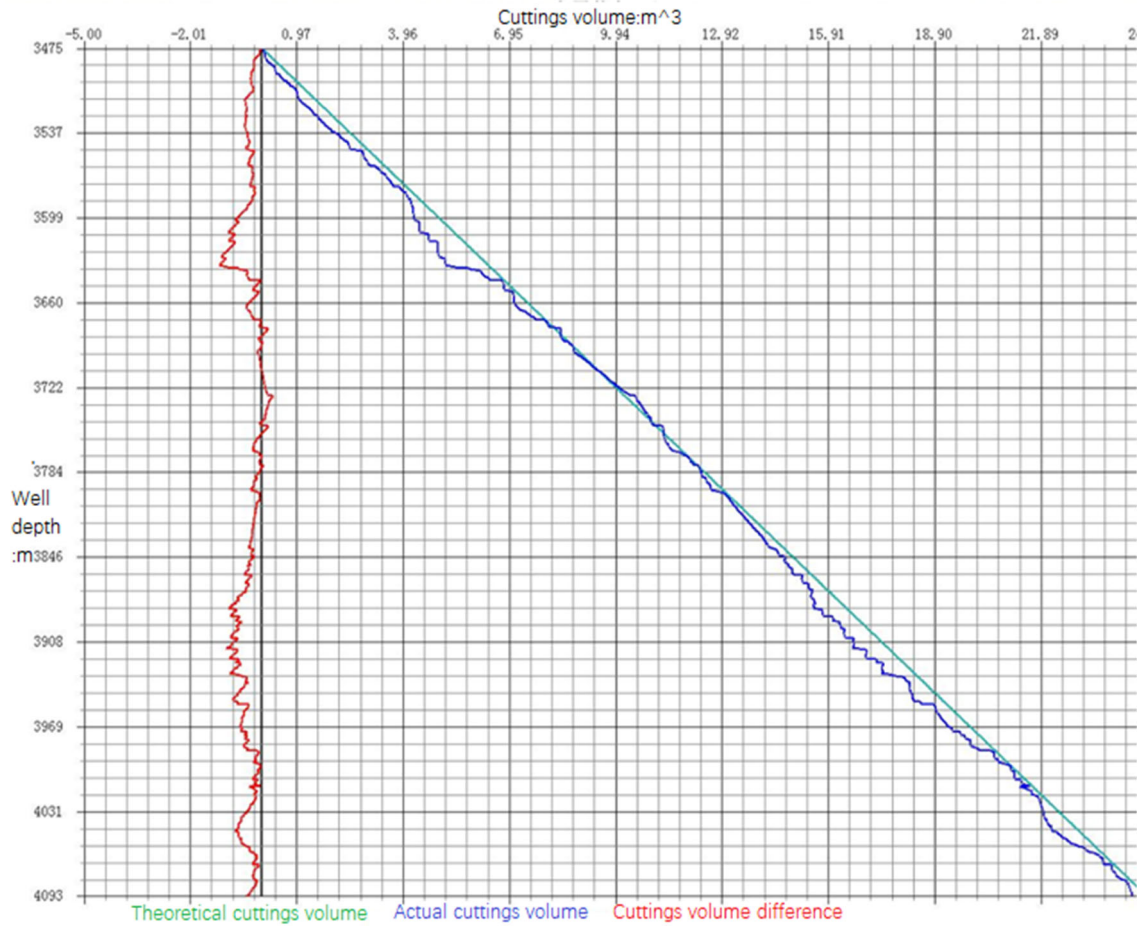


Figure 11. Cuttings volume tracking while drilling

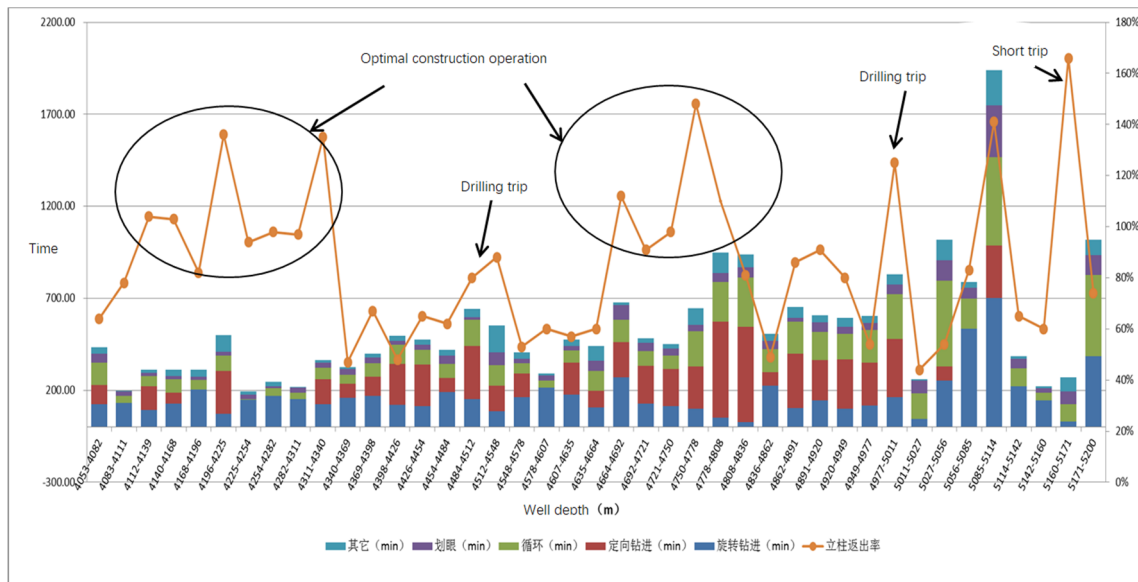


Figure 12. Relationship between borehole cleaning aging and cuttings return

3. Application Case of Wellbore Cleaning Evaluation System Based on Cuttings Weighing

The designed well depth of YX well is 6186.00m (vertical depth 3976.00m), which belongs to horizontal well. The well cleaning evaluation system based on cuttings weighing started trial operation at the well depth of 3910.00m, and was officially put into operation at the well depth of 4030.00m.

Online monitoring technical services began, and data collection was completed at the well depth of 6230.00m (completion of drilling). One warning occurred. Figure 13 shows the correction and comprehensive calculation diagram of cuttings volume flow parameters, including the theoretical cuttings return volume, actual cuttings return volume, cuttings return rate, cuttings volume density, mud adsorption coefficient and other parameters of the whole monitoring section.

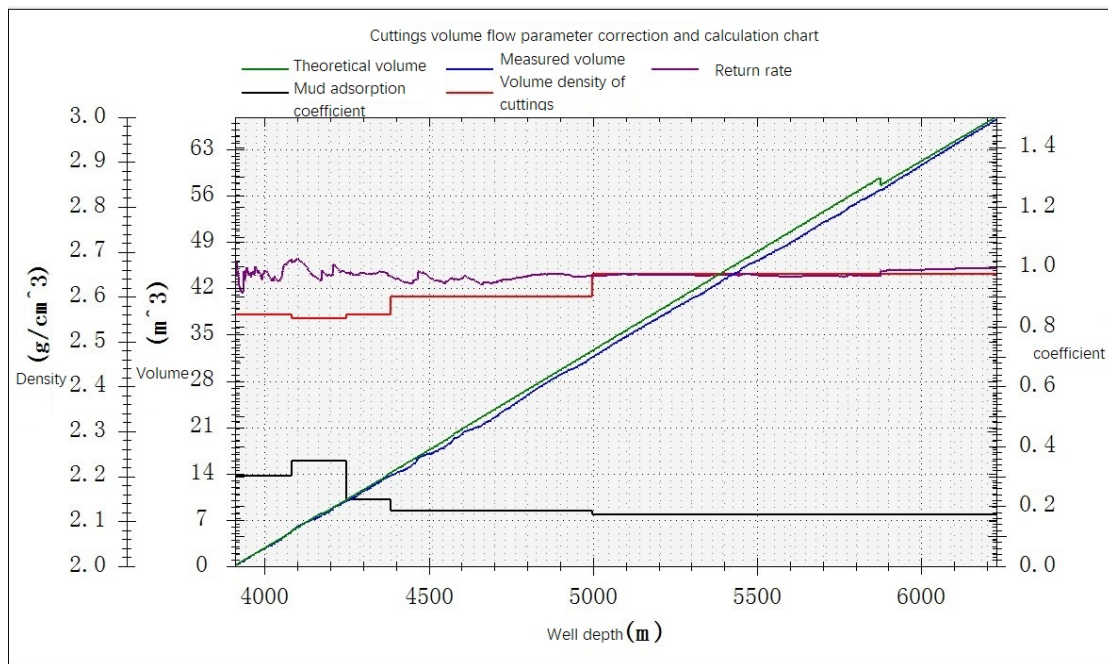


Figure 13. Cuttings volume flow parameter correction and comprehensive calculation diagram

Monitoring report: When drilling to 4537.00 m, due to the faster drilling time (1.2min/m-3.3min), there was a trend of cuttings retention, as shown in the red mark in Figure 14. When drilling to the depth of 4648.00m, the cuttings retention rate of single column rose to 42%, as shown in the red column in Figure 15 below. It was preliminarily determined that there was more sand settling in the bottom hole.

Recommended measures: Increase the drilling frequency,

control the drilling time, adjust mud performance, lengthen the cycle time, and improve the well cleaning capacity.

Implementation effect: The mud performance was adjusted to improve the rock-carrying ability. When drilling to 4727.00m, the cuttings return rate gradually returned to the normal range (as shown in FIG. 16 below), effectively avoiding potential sticking risks.

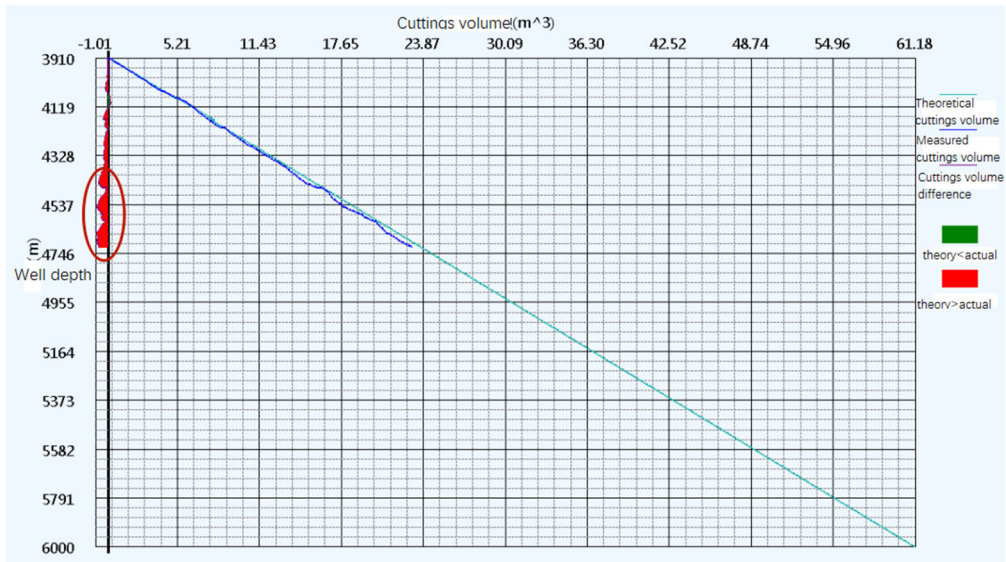


Figure 14. Whole-meter cuttings return in well interval 3910m ~ 4617m

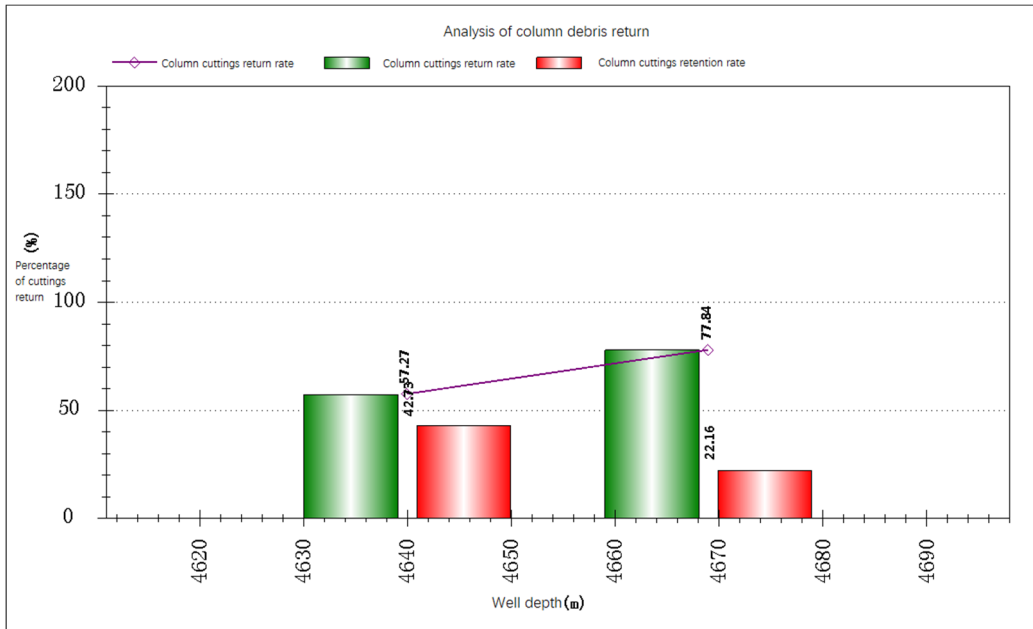


Figure 15. Cuttings return diagram of column in 4630m ~ 4660m well section

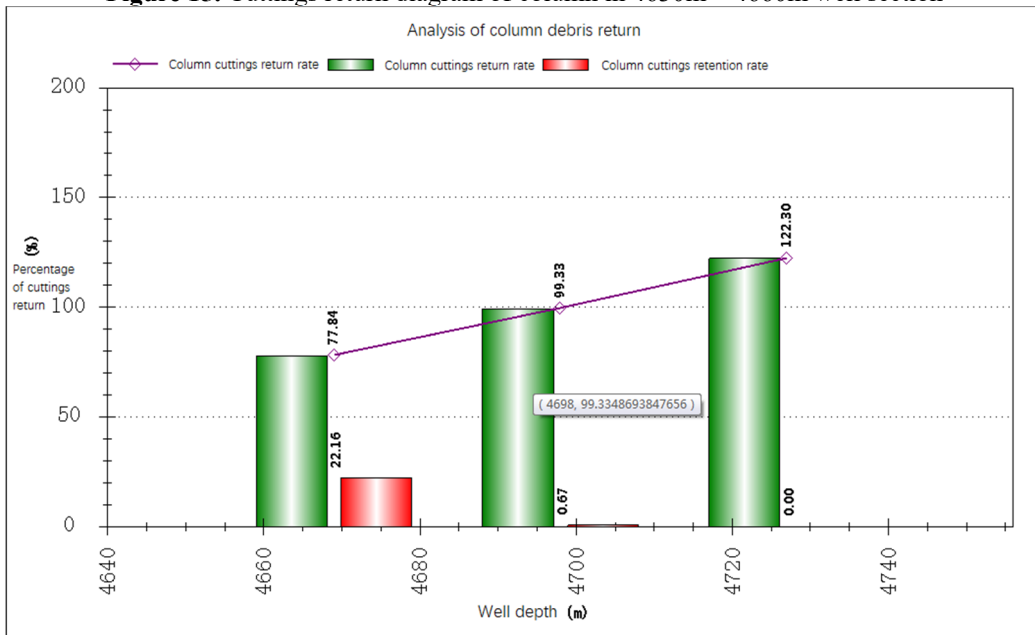


Figure 16. Cuttings return of well column 4660m ~ 4720m

4. Conclusion

The cuttings weight-based borehole cleaning evaluation system can detect poor borehole cleaning in a timely manner, optimize and analyze drilling timeliness in real time, and help reduce risks and non-productive time in deviated Wells and extended reach horizontal Wells. This kind of equipment has been widely applied in foreign countries and achieved good economic benefits, with high application value. It is suggested to strengthen the research on the software and hardware of borehole cleaning evaluation system in China so as to provide better technical support and service for the market.

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