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Research Status and Prospect of Downhole Acceleration Technology Based on Drill String Vibration

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Abstract. Drilling acceleration technology has been a research hotspot in the field of drilling engineering. It is an important research direction in the field of ultra-deep well acceleration to find new energy available underground and develop a matching energy conversion method to improve rock-breaking efficiency. In this paper, the characteristics of downhole available energy are analyzed, and the concept of using vertical vibration energy of drill string to increase the speed of rock breaking assisted by jet pressure of downhole drilling fluid is expounded. This paper summarizes the structure and advantages of the developed downhole drilling string vibration reduction and pressurization device and multi-effect synergistic speed-increasing drilling device, and looks forward to the future development direction of deep-well speed-increasing equipment. The acquisition and rational utilization of downhole energy is an important research direction for the development of speed-up tools in the future.

1. Introduction

With the development of deep strata oil and gas resources, there are more and more deep and ultra-deep wells in the new and old exploration areas, and the drilling depth is getting deeper and deeper. Using downhole devices to improve drilling speed is the most important means to speed up today^[1-4]. The developed speed-increasing tools mainly include downhole power drilling tools, rotary percussion drilling tools, downhole pulsed cavitation jet generator, downhole torsional percussion drilling tools, etc. Whatever tool it is, it takes energy to work.

If the energy source is not guaranteed, it is difficult for the speed-up tool to work properly. It is found that although the acceleration mechanism of commonly used tools in the field is different, most of them have the same characteristics. Drilling practice shows that with the increase of well depth, the pressure consumption of drilling circulating medium increases, and even the circulation medium can only meet the phenomenon of circulating rock carrier in extremely deep wells^[5-13]. Based on the analysis of downhole available energy characteristics, the research status of downhole acceleration technology of drill string vibration is described in detail, and the future acceleration technology is prospected in order to be a deep well and an ultra-deep well. The development and technical development of drilling speed increasing equipment provide reference.

2. Analysis of downhole available energy characteristics

Drill pipe is the main source of rock-breaking energy for downhole drill bit, but to improve drilling speed, other energy must be found on the basis of pressure and torque transmitted by drill pipe. According to the downhole working condition analysis in the drilling process, the energy available at



the bottom of the well includes two categories, the energy transmitted to the underground through the media and original underground energy. There are three types of media that transmit energy down the hole, drill pipe, cable or cable buried in the drill pipe, drilling circulation media and underground portable energy. There are two main types of underground energy, drill string vibration in drilling and Underground geothermal energy. Various energy application processes show the following characteristics.

2.1 Cables or embedded cables in drill pipe transmit energy

Cable is one of the most effective ways to transmit energy from the well to the underground. Currently, downhole tools using this method include electric drilling tools, electric percussion rotary drilling tools, laser drilling tools, etc. In the field application process, the underground cable transmission energy shows the following advantages.

(1) The energy transmission process is not affected by well depth, drilling fluid displacement and characteristics.

(2) Directly control the working state of downhole tools by controlling the upper energy source.

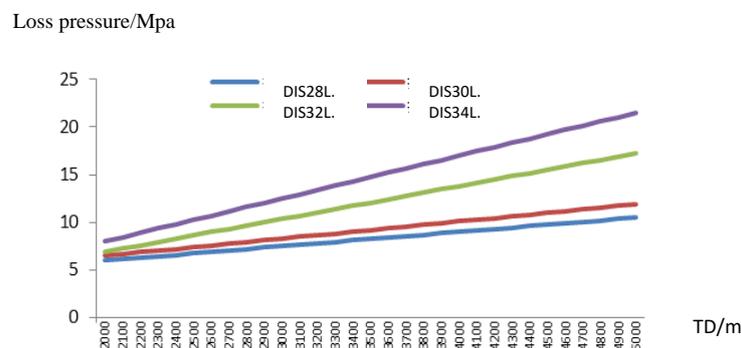
(3) Could provide greater energy, provide energy stability and no limit to the working time. However, its disadvantage is that the existence of cable makes drilling state complicated, which increases the probability of failure and the cost of operation.

2.2 Portable downhole energy source

The downhole tools that use the portable energy source include rotary steering drilling system and new electric percussion rotary drilling tools. This kind of energy is mostly used to control the flow area of the drilling fluid passage and cause the change of drilling fluid energy distribution to promote the operation of tools, but it is difficult to be used as the direct energy to drive tools.

2.3 Use drilling fluid to transfer energy

This method is currently the most widely used, and tools developed based on this principle are more numerous, including downhole screw drill, turbodrill, hydraulic rotary impact drill, torque impact drill and so on. the main problem is that with the increase of well depth, pressure consumption increases and available energy decreases significantly. Figure 1 shows the variation curve of drilling cycle pressure consumption with well depth under different displacement. We can be seen from figure 1, the circulating pressure consumption increases linearly with the increase of well depth. Therefore, it is limited for deep well drilling to improve the drilling speed by relying on the energy of drilling fluid. Factors such as well depth, drilling equipment and drilling fluid performance should be fully considered in the design of tools.



FIGUER 1. The influence of well depth on pressure loss of drilling cycle

2.4 Geothermal energy

The scientific exploitation and utilization of geothermal resources in China originated in the 1970s, and so far, a geothermal resource exploitation and utilization pattern mainly focused on direct utilization of heating, bathing and power generation has been formed [14-15]. However, the application of geothermal energy directly underground in the process of oil and gas drilling has not appeared. Practice concluded that formation temperature with depth increases, the depth increase about 33m, ground temperature increase 1 °C, according to the calculation, 7,000m of super deep well temperature over 210°C, if we can convert this energy into mechanical energy, we will certainly can achieve the purpose of improving drilling rate, and the energy can be increased with the increase of well depth increases, but so far does not appear to use geothermal drilling devices and equipment.

3. Research status of downhole acceleration technology based on drilling string vibration

3.1 Vibration reduction and pressurization device of downhole drill string and its advantages

The high frequency and large change of bit pressure acting directly on the bit will cause the cutting tooth of the bit to bear great impact force instantaneously, which will cause the cutting tooth to crack. However, the installation of spring and damping structure in the middle of the drill string and the upper part of the drill bit will transfer the drilling pressure to the drill bit through the spring and damping structure, then the fluctuation of the drilling pressure will be converted into the elastic potential energy and damping work of the spring, the fluctuation range of the drilling pressure will be greatly attenuated, the action time of the impact force will be prolonged. Therefore, the reaction of internal liquid pressure during the operation of the plunger pump structure is used as damping to attenuate the fluctuation of bit pressure, and the damping work can be converted into the internal liquid pressure of the plunger pump structure, so as to realize the increase of liquid pressure discharged by the plunger pump.

The prominent advantages of drilling string vibration reduction and pressurization device are the combination of drilling string vibration reduction and drilling fluid pressurization enables the vibration energy of drilling string which is easy to cause fatigue damage of drilling string to be converted into the pressure energy of drilling fluid to realize downhole pressurization, improve rock-breaking efficiency, turn harmful into beneficial. At the same time, the device does not need to change the existing drilling technology and equipment, does not affect the normal circulation and drilling operations.

3.2 Structure and advantages of vibration absorption underground hydraulic pulse generator

By transferring the vibration energy of drill string to some drilling fluids, the ultra-high pressure jet can accelerate rock breaking. If the vibration energy of the drill string is transferred to all drilling fluids in the circulation, the purpose of pulse pressurization of the circulating drilling fluid can be achieved. The vibration-absorbing hydraulic pulse generator uses the reaction of liquid pressure inside the plunger pump structure to act as damping to attenuate the fluctuation of bit pressure, and converts damping work into liquid pressure inside the plunger pump structure, so as to realize the lifting of liquid pressure of plunger pump discharge.

The vibration-absorbing hydraulic pulse generator utilizes the longitudinal vibration of drill string and the fluctuation of bit pressure. Through the relative movement between the drill string linkage and the drill string component of the pulse generator, the internal plunger pump generates relative periodic movement. The high-pressure pulse jet generated by the drilling fluid in the compressed plunger cylinder is used to improve the stress state at the bottom of the well and the effect of rock cleaning, so as to improve the drilling speed and achieve rapid drilling.

The advantages of this device are: it can effectively compress and pressurize all drilling fluids at the bottom of the well periodically, and realize the pulse jet modulation of the jet, and the pulse amplitude is high. The average pressure of pulsed jet generated is higher than the average pressure

without the device, and the rock breaking and carrying capacity is enhanced, which reduces the difficulty of rock breaking.

The energy source of the device increases with the increase of well depth, and the tool is more effective. The pulsed jet generated by this device can be applied to any drill bit. Because of the large pulsation of the flow field at the bottom of the well, it can alleviate the mud balling of the drill bit, especially when the drilling speed is low due to the difficulty in increasing the displacement..

3.3 The structure and advantages of multi-effect cooperative speed-increasing drilling device

Drilling practice shows that the underground strata are different, and if the drilling speed is improved, it is difficult to apply the same acceleration mechanism to multiple strata. Therefore, it is great significance to develop acceleration tools that utilize new energy and cooperate with multiple acceleration mechanisms. Multi-effect synergetic speed-increasing drilling device can introduce annulus fluid to increase the displacement of drilling fluid at the bottom of the well, and at the same time introduce the energy of drill string vibration to realize pulse jet modulation, which can not only improve the rock-breaking efficiency, but also enhance the rock-carrying effect at the bottom of the well, thus improving the drilling speed.

In the process of drilling, the longitudinal vibration of drill string will be caused by the friction between drill string and borehole wall and the bit jumping at the bottom of the well. When the drill string vibrates, the drill string vibration continuous assembly produces relative motion with respect to the bottom hole static vibration bearing assembly, and the motion speed presents periodic change. When it vibrates downward, the relative motion speed accelerates from 0 to a certain speed, and then the speed decreases until it returns to 0, and the downward vibration ends. When the upward vibration starts, the relative motion velocity accelerates from 0 to a certain velocity in the opposite direction, and then the velocity decreases until it returns to 0, and then the downward vibration starts, and so on. Compared with existing technologies, multi-effect synergetic speed-increasing drilling device can increase the displacement of bottomhole drilling fluid, introduce annulus fluid, introduce energy other than drilling fluid and realize pulsed jet modulation, which can not only improve the rock-breaking efficiency, but also enhance the rock-carrying effect of bottom hole. The device does not need to change the structure of the drill string and is independent of the type of drill bit applied.

3.4 New progress in speed increasing technology based on drill string vibration

Drill string vibration provides a new source of energy for tools. Different mechanical structures will be used to convert this energy, and different speed-increasing technologies will be realized. Based on this thought, the authors and their research team have developed three kinds of drilling hydraulic drill string vibration energy can be converted to the device, and designed the drill string vibration energy can be converted to axial impact mechanical downhole vibration absorbing impact drilling tool and drill string vibration energy can be converted to "underground torsion shock excitation device" to reverse the impact speed equipment, such as in deep well acceleration field provides a new way of thinking. With the development of the idea of utilizing the vibration energy of drill string, more kinds and better acceleration tools will be developed to serve the drilling field.

4. Technical outlook

At present, with the development of oil and gas fields, the well types used have changed a lot. Directional wells, horizontal wells and other special technology wells have become the main well types. In addition, the borehole length is significantly longer than before. With the increase of the borehole extension length, the formation encountered by a single well will also increase. In the future, speed-increasing technology should pay more attention to the development characteristics of drilling engineering. Based on the analysis of current drilling engineering status and speed-increasing tools, we believe that future speed-increasing technologies should solve the following problems:

1) The energy source of acceleration tool. Today's speed-increasing tools are basically at the expense of drilling fluid energy. As the well depth increases, the drilling fluid energy is decreasing, and the speed-increasing effect is bound to be affected. Therefore, it is an important direction to search available energy in the well and develop application methods.

2) Rationalization of underground energy utilization. If the energy that can reach the bottom of the well can be used reasonably, it will play a more prominent role. For example, the screw drill tool converts the drilling fluid hydraulic energy into the bit speed, which improves the drilling speed and does not affect the drilling construction. Rotary drilling tool converts the hydraulic energy of drilling fluid into axial impact on the drill bit, which improves the drilling speed. It can be seen that the reasonable use of downhole energy can improve the drilling speed, but how to use these energy to ensure the normal drilling, and increase the drilling speed to the best are the topics that need to be studied.

3) Diversified ways to speed up. Different failure characteristics, speed up the formation rock is different, the same strata at the same time accelerated the use of a variety of ways, such as power tool + churn is the effect of rock fragmentation. How many speed way organic fusion is a key problem for the present study.

4) Simplification of acceleration tool structure. Downhole space is limited, the conditions are harsh, complex mechanical structure is very easy to fail, so on the basis of ensuring the realization of its function, simplifying the existing structure of speed or designing new speed increase tool with simple structure is another important direction of tool research and development field.

5) There is no risk in the whole process of acceleration. Downhole tools have limited service life and often face the problem of accidental failure. When the tool is in normal use, the drilling speed can be accelerated. However, after tool failure, how to prevent it from affecting normal drilling is also very important to control the occurrence of risks, which is also an important research direction of future acceleration technology.

6) General application of speed-increasing technology. A speed-increasing technique should be able to be applied to different working conditions and well types before it can be widely used.

5. Conclusion and suggestions

The advancement of deep oil and gas development and geothermal energy development requires the development of supporting technology put forward higher request, the problem of low drilling speed in deep formation of all kinds of resources in the development process, one of the main challenges facing the should fully, reasonable and effective use of underground can take advantage of all the energy to improve the efficiency of rock drilling.

For downhole tool used in the process of drilling energy source are mainly using the underground cable transmission energy, hydraulic energy of drilling fluid, and bottom drill string vibration energy geothermal energy, some of these energy has been a wide range of applications, some is just beginning, the drill string vibration is used to improve the drilling speed of technology offers a new way for downhole energy use to be more reasonable.

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