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Bit feed principles and operations of slide drilling

Zifeng Li*, Changjin Wang

Petroleum Engineering Institute of Yanshan University, Qinhuangdao 066004, China

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ABSTRACT

Slide bit feed is often used in the drilling of directional and horizontal wells. How the surface intermittently feeding of drill pipe into the well transfers to down hole drill bit pushing? How to reduce the WOB error due to slide friction between the drill string and the borehole wall? What are the advantages and disadvantages of the existing sliding drilling bit feed technologies? In order to answer these questions, this paper first introduces bit feed principles of the down hole drill string elasticity, the hydraulic oscillator and the hydraulic thruster. Then, introduces the relationships between surface drilling parameters and bottom hole drilling parameters for slide feeding technology of the BHA only with motor, and it also with hydraulic oscillator or it also with hydraulic thruster. Finally, these three technologies are compared. The best is the slide feeding technology of BHA with the hydraulic thruster, WOB is smooth and adjustable, the hydraulic thrusters can be used in tandem and the upper part of the drill string can make short trip while the bit is drilling. Two potential devices facilitating slide feeding are introduced.

1. Introduction

Slide bit feed is often used in the drilling of directional and horizontal wells to change borehole direction, to build angle or drop angle. Sometimes, slide drilling is used in vertical section. In slide drilling, the friction force between drill string and borehole wall leads to the decrease of the hook load do not equal to WOB (Weight on bit) (Johansick, 1983; Li et al., 1995; Li, 2008). The reduction of the hook load is part for the friction between the drill string and the borehole wall, and the remainder is applied on the bit. The phenomenon that the WOB is less than the reduction of the hook load is referred to as backing force problem in the slide drilling (Hu et al., 2012). And in the process of trip in, the relieving of the stuck between the drill string and the borehole wall and the friction state converting from static friction to dynamic friction, result in the sudden release of the drill string's elastic energy and uneven slide down, sometimes the bit hits the bottom suddenly, which even leads to the bit and the down hole motor damaged. The phenomenon that the drill string elastic energy sudden releases resulting in the drill string uneven slides down is referred to as drill string stick-slip motion (Wang et al., 2012). In order to reduce the backing force, in addition to wellbore trajectory optimization, well trajectory control (Li and Li, 2008), drilling fluid system optimization and drilling fluid properties maintaining, special tools are used. These special tools include hydraulic thruster (Matthias et al., 1995; Li, 1997; Liu et al., 2009; Wang et al., 2012) and hydraulic oscillator (Shi et al., 2012). This paper discusses the bit feed principles and technologies of slide drilling, and evaluates the hydraulic thruster and hydraulic oscillator, introduces two potential devices facilitating slide feeding: oval sleeve pipe string friction and torque reduction device and axial vibration crawling device.

2. Down hole bit feed principles of slide feeding

Viewing from the drill floor, slide drilling is tripping in the drill string intermittently. But from the bottom of the well, what are the principles of bit feeding? What are the bases of the using of hydraulic thruster or hydraulic oscillator? These questions are discussed below.

2.1. Principle of drill string elasticity bit feeding

For the drilling assembly with down hole motor and without the hydraulic thruster or hydraulic oscillator, while the bit is sent to the bottom of the well and WOB is applied, bit feed is paused on the surface. At this time, the drill pipe movement has stopped viewing from the drill floor, whether the bit is stopped drilling down hole? Obviously not, then what pushes the bit forward? It is the drill string elasticity. The principle of drill string elasticity bit feeding is shown in Fig. 1.

In Fig. 1(a), the drill string that length is L moves to the right (the bottom of the well) in the action of thrust F, the distribution of sliding friction force f_0N, and the weight on the bit W_0. Then the whole drill string stops, stress is frozen. Although the coefficient of static friction between the drill string and the borehole wall is rising with the increase

* Corresponding author.
E-mail address: zfli@ysu.edu.cn (Z. Li).

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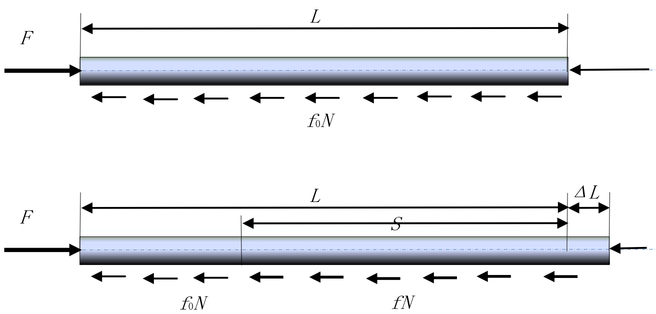

Fig. 1. The principle of drill string elasticity bit feeding.

of still time, because stress is frozen, sliding friction force distribution remain f_0N

$$F = W_0 + f_0NL \tag{1}$$

where,F is the thrust, W_0 is the initial WOB,f_0 is the friction coefficient in tripping in, $N$is the line contact force between the drill string and the borehole wall,$L$is the drill string length.

Fig. 1(b) shows, with the development of rock breaking, bit drilled space allows WOB drop to W, the WOB drop makes the drill string elongation for ΔL, the length of drill string moving forward powered by elastic releasing is S, the friction coefficient between the drill string and the borehole wall is increased from f_0 to f at S section at this time

$$F = W + f_0N(L - S) + fNS \tag{2}$$

where,W is the instantaneous WOB,S is the length of the elastic elongation section,f is the instantaneous slide friction coefficient.

From Eqs. (1) and (2).

$$S = \frac{W_0 - W}{N(f - f_0)} \tag{3}$$

According to the material mechanics

$$\Delta L = \frac{(W_0 - W)^2}{2EAN(f - f_0)} \tag{4}$$

where,E is the elastic modulus, A is the area of the string cross section.

From Eq. (4), the larger initial WOB, the longer drilling footage can be achieved during each bit feed; the instantaneous sliding friction coefficient f is more close to the bit feed friction coefficient f_0, the longer footage can be achieved during each bit feed. In addition, the larger the initial WOB, the greater the drilling rate.

The conventional sliding drilling technology without any special delivery drilling tools is based on the principle of drill string elasticity bit feeding. This principle has been generally applied in directional wells, horizontal wells and long reach wells.

2.2. Principles of hydraulic oscillator bit feeding

The hydraulic oscillator reduces the friction between the drill string and the borehole wall by longitudinal vibration; improves the effectiveness of the WOB transfer during drilling. The tool is mainly composed of three parts: power part, valve and bearing system, supporting facilities (Shi et al., 2012). Frequency range: 9–26 Hz. Instant impact acceleration range: 1–3 times of the gravitational acceleration.

Essentially, the hydraulic oscillator itself cannot feed bit, its role is to reduce the growth rate of instantaneous sliding friction coefficient f during drill string elasticity bit feeding, and try to close to f_0(the friction coefficient during tripping in), therefore can improve the footage of each bit feeding.

The application results of the tool in the SU36-8-18H well (Shi et al., 2012) are that it provided an effective and real WOB, increased drilling rate, shorten the drilling cycle. It is used to conduct a trial to improve drilling rate in Xinsha 21–28 H well, Xinchang gas field, western Sichuan Basin (Xu et al., 2013), and the results shows that sliding drilling ROP (rate of penetration)increased by 45.16%, the composite drilling penetration rate increased by 30%.

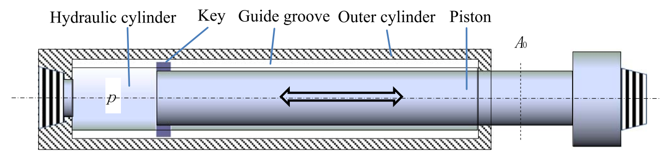

Fig. 2. The principle of hydraulic thruster.

2.3. Principles of hydraulic thruster bit feeding

The hydraulic thruster connects within the BHA (bottom hole assembly). It is a hydraulic cylinder-piston sub. Fig. 2 shows the principles of hydraulic thruster (Li, 1997). The piston is driven by the fluid pressure inside the hydraulic cylinder, producing WOB. The torque is transmitted by guide groove on the outer cylinder and keys on the piston end.

Working WOB of the hydraulic thruster

$$W_t = pA_0 \tag{5}$$

where,W_t is the working WOB of the hydraulic thruster, p is the dynamic pressure inside the hydraulic cylinder, A_0 is the outer circle area of the piston elongation end.

If $W > W_t$, the hydraulic thruster is in a fully contracting state, invalid. If $W = W_t$, the hydraulic thruster is in working condition. If $W < W_t$, the hydraulic thruster is in fully extended state, invalid. The main technical parameters of the hydraulic thruster are working WOB and stroke.

The hydraulic thruster has gained wide range of applications. The application effects in Hua 79-6 well group and Yun'an 15 well (Huang et al., 1998) are that it can apply weight on the bit smoothly, can reduce the vibration transmitted to the drill string above it, reduce the fatigue of the drill collar and the drill pipe, improve the life of the drill string and drill bit, reduce drilling costs. The hydraulic thruster effects in Qili 19 well (Lin et al., 2003) include: (1) has a significant effect of shock absorption and protection of the drill string; (2) significantly improve the life of the bit, and ROP increased by 15–20%; (3) bit teeth are protected, fewer broken teeth, teeth and tooth claw gage wear smaller, drill footage and using time significantly longer. The hydraulic thruster effects in Shen 20 wells (Liu et al., 2013) are: WOB applied smoothly, improved ROP and drilling quality, significantly reduced the drill string vibration, and extended drill string life.

3. Bit feeding of slide drilling

How to apply WOB to the bit more accurately in sliding drilling? How to add and restoring WOB after WOB drops? How to correctly use the hydraulic thruster or hydraulic oscillator? Let us discuss these questions.

3.1. Slide feeding of conventional BHA with motor

In the directional well and horizontal well drilling, due to the continuous change of friction force between the drill string and the borehole wall, it is difficult to accurately apply the design WOB to the bit. So, is there a relatively feasible way which makes WOB as far as possible close to the design WOB? Yes, using directional well drilling technology software for guidance. Specific steps are as follows:

(1) For different well depths and different friction coefficients, calcu-