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Equation of rotation speed for bit under compound drilling condition

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Abstract: *In order to reduce the influence of bit rotation speed on the development of drilling work and the evaluation of oil and gas reservoir, and improve the accuracy of bit rotation speed equation of composite drilling, the standardized calculation equation of bit rotation speed of composite drilling was studied. Considering the influence of the performance of the screw drill, WOB, deviation and other factors, combined with the mechanism of rock breaking, the standardized calculation equation of the bottom hole bit speed was proposed. By introducing the transmission model of planetary gear train, combining with the standardized prediction equation of bottom hole bit rotation speed and wellhead rotary table rotation speed, the standardized equation of bit rotation speed in composite drilling was preliminarily established, which improves the prediction accuracy of standardized calculation equation of bit rotation speed. In order to verify the correctness and practicability of the established equations, the formulas was applied in well 723 and well 6-2x, and the prediction results are basically consistent with the actual bit speed, proving the accuracy of the speed prediction equation and indicating that the prediction equation can meet the engineering needs. The establishment of the equation provides a theoretical basis for optimizing the application of drilling technology in the drilling process.*
Keywords: *Bit; Invasion theory; Rock breaking; Bit rotation speed equation*

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I. Introduction

The scale and total amount of drilling ranks first in the world, but there is still a gap between the level and efficiency of drilling in developed countries[1]. At present, the compound drilling method of screw and rotary table is an important method for down hole drilling[2]. The existence of factors in the compound drilling method, such as screw drilling tool performance, well deviation and weight-on-bit, greatly affect the calculation of the drill bit speed[3]. Therefore, it is extremely necessary to establish the formula for calculating the speed of the drill bit under compound conditions.

Some scholars analyzed the influence of well deviation and weight-on-bit some factors on drill string dynamics, and established a new three-dimensional drilling rate equation model[4,5]. Another scholars have conducted experiments with PDC bit, and studied the rock breaking mechanism of PDC bit cutters through experiments on PDC bit cutting granite and marble[6].

In this paper, the rock breaking mechanism of the drill bit was investigated firstly. Then, combining with the performance of the screw drilling tool, the inclination and the drilling pressure, a model of the coupling of logging parameters-bit-stratum was established, and finally the calculation equation of the compound drilling bit speed was obtained.

II. Analysis of crushing rock by drill bit

2.1 Analysis of the rock breaking mechanism of the drill bit

The drill bit is pressed into the rock under the action of axial load and then rock is cyclically crushed to generate the micro-cracks [7]. A part of the micro-cracks were extend from inside of rock to the rock surface, causing the intact rock into crushed block. In addition, some of the micro-cracks were extend to the deeper interior of rock to crush the rock.

After the drill bit is pressed into the rock, it cuts the rock under horizontal load. The rock at the tip of the drill bit is crushed first, and small shear cracks are generated at the same time[8,9,10]. As the horizontal load continues to increase, the small shear cracks will continue to extend until the rock is crushed.

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2.2 Mechanical analysis of rock breaking by drill bit

The mechanical analysis of the drill bit during the drilling process shows that the drill bit is axially subjected to two vertical forces of lifting force F_1 and weight-on-bit F_2 applied to the ground; horizontally subjected to the torque force T generated by the screw drilling tool. The cut rock produces frictional forces F_{s1} and F_{s2} and their reaction forces F_N (F_{N1} and F_{N2} are the component forces of F_N). The force analysis was shown in Fig. 1.

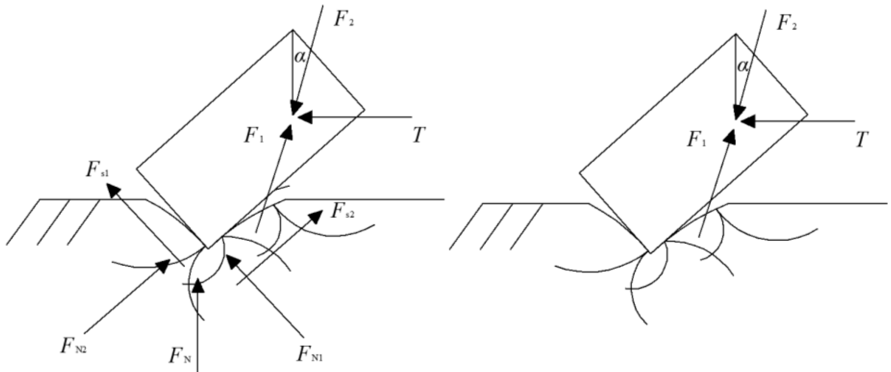


Fig. 1. Schematic diagram of bit force analysis

III. Compound drilling bit speed equation

Based on the force analysis, the momentum theorem was introduced to establish the drill bit rotation model, seeing Eq. (1).

$$\frac{d}{dt} M_0(mv) = M_0(F) \quad (1)$$

$$M_0(F) = \frac{1}{2\pi R} \Delta P q \eta_m d_m \quad (2)$$

$$M_0(mv) = \frac{1}{60} mR^2 \pi n \quad (3)$$

Eqs. (2) - (3) were substituted into Eq. (1), and then Bottom hole bit speed equation (Eq.(4)) was obtained:

$$n = \frac{30 q \eta_m}{\pi^2 Rm} \Delta P \quad (4)$$

The inlet and outlet pressure drop ΔP can be obtained by Eq. (5) [6]:

$$\Delta P = \left(\frac{Q}{Q_0}\right)^{1.8} P_0 + k(aF_2 + bF_2^2)^f \quad (5)$$

Combining Eqs. (4) and (5) to get the bottom hole bit speed Eq. (6):

$$n = \frac{30 q \eta_m}{\pi^2 Rm} \left[\left(\frac{Q}{Q_0}(1-\mu)\right)^{1.8} P_0 + k\left(a(F_2 \cos \alpha_j) + b(F_2 \cos \alpha_j)^2\right)^f \right] \quad (6)$$

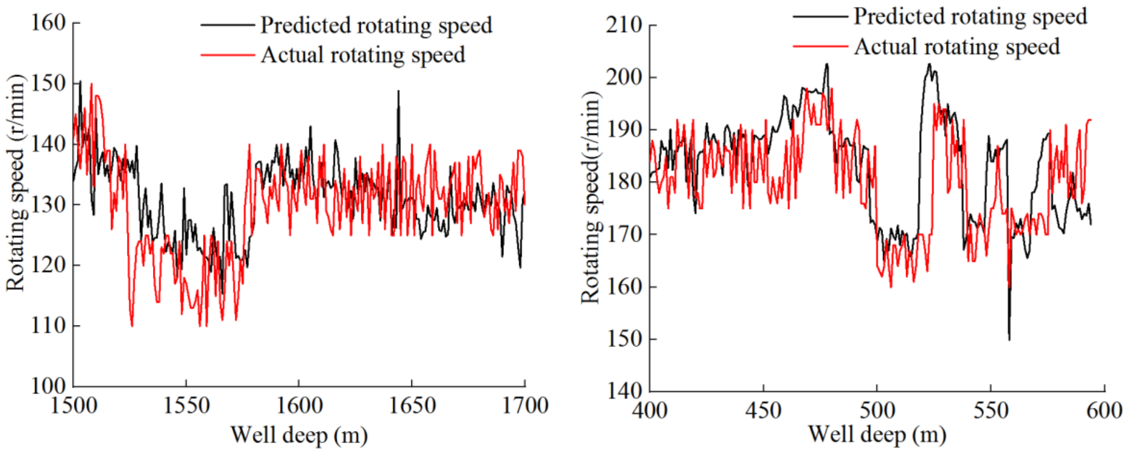
During the compound drilling process, the motor speed is the rotation speed, and the turntable is the revolution speed. Therefore, the compound drilling bit speed prediction formula was shown in Eq.(7).

$$n_f = \frac{R\left(\frac{30 q \eta_m}{\pi^2 Rm} \left[\left(\frac{Q}{Q_0}(1-\mu)\right)^{1.8} P_0 + k\left(a(F_2 \cos \alpha) + b(F_2 \cos \alpha)^2\right)^f \right] + n_1\right) + n_1 e}{R + e} \quad (7)$$

where F is horizontal force generated by the torque of the screw drilling tool; m is mass of the drill bit; ΔP is pressure drop at the inlet and outlet of the screw motor; q is displacement per revolution of the screw motor; η_m is mechanical efficiency; P_0 is pressure drop when the screw drill tool is idling at the maximum displacement; Q is Drilling fluid displacement, Q_0 is Maximum allowable displacement of the screw drill tool, F_2 is weight on bit, a, b, f, k is Regression structure parameter; μ_f is leakage coefficient, generally 0.2-0.4; $\Delta\delta$ is screw motor interference and gap value difference.

IV. Examples and application of compound drilling bit rotation speed

In order to verify the accuracy of the compound drilling bit speed prediction equation, wells 6-2X and 723 were taken as an example. The Eq. (7) was used to analyze the drill bit speed at the 1.5km-1.7km section in Well 6-2X and at the 0.4km-0.6km section in Well 723. The screw drilling tool model used in the two wells was 5LZ120×7.0V, the borehole radius was 0.108m, the rotating speed of the 6-2X well was 0r/min, and the rotating speed of the 723 well was 60r/min.



(a) Well Ⅰ **(b) Well Ⅱ**

Fig. 2. The comparison chart of predicted speed and actual speed of drill bit.

As shown in Fig.2, the predicted rotational speed of the composite drilling bit in Well 6-2X and Well 723 is basically consistent with the theoretical rotational speed, validating the accuracy of the composite drilling bit rotational speed equation and indicating the proposed equation can be used in drilling engineering.

V. Conclusions

(1) This paper comprehensively considers the effects of screw drill tool performance, weight-on-bit, and well deviation on drill bit rotation speed, and establishes a standardized calculation equation for bottom hole drill bit rotation speed prediction based on the mechanism of intrusive rock fragmentation.

(2) This paper introduces the transmission model of the planetary gear train, and initially establishes the standardization equation of the drill bit rotation speed in compound drilling, and improves the prediction accuracy of the standardization calculation equation of the drill bit rotation speed. The establishment of the standardized calculation equation for the speed of the compound drilling bit has laid the foundation for the development of drilling optimization.

(3) The compound drilling bit speed prediction equation is verified, and the predicted speed is basically consistent with the theoretical speed, combined with actual drilling data.

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