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Analysis Of Drilling Speed Of Cine Drill Bits

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ABSTRACT

The article discuss methods of the calculating speed of drilling with cone bits and compare with the real drilling speed on the mine. The methods of determining the drilling speed of different researchers are considered. The method of calculating the speed with the most approximate indicators from the practical drilling indicators is studied. A table of comparisons of drilling speed indicators determined by formulas and by reference is compiled.

KEYWORDS

Drill Bit, Speed Of Drilling, Axial Load, Rotation Speed, Rock Strength.

INTRODUCTION

For greater penetration of bits with the same operating parameters of the drilling machine, it is important to choose the right armament of the cones. The features of the armament include the material, the shape of the teeth of the cone, the relative location of the crowns of the teeth, their frequency of location in each row, the protrusion of the teeth from the body of the cone.

Currently, there are a large number of techniques for determining the performance of drilling machines for drilling. At the same time, there is no sufficiently formalized methodology that unambiguously shows the nonlinear dependence of the drilling speed on the rotation frequency of the drilling bit. Experimental and experimental data clearly show that the drilling speed has been increasing almost linearly for some time, but gradually it ceases to increase [1]. The cone bit, in principle, has a mechanism of cyclic action of individual teeth on the bottom of the well. A number of physical and mechanical

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characteristics, which can be combined into two groups, characterizes the rock: structural and strength. The rock at a particular point in the massif has a certain set of properties that determine a certain amount of mechanical work that needs to be done by the drilling rig, by means of another tooth of the cone, in order to destroy a certain volume of this rock [2].

MATERIALS AND METHODS

An analysis of the technical literature shows that in order to determine the drilling speed with cone bits, many factors affecting the operation of cone bits have been studied in full and determined. The principle of determining factors of one type or another when using a roller bit for certain drilling purposes gives a different type of calculation that does not show the real drilling speed in mineral deposits.

The drilling speed with cone bits has a variety in different technical literatures. Since G.M.Kiryukov gives a formula for calculating the drilling speed with cone bits [3]:

$$v_{drill} = nk_2h_D \qquad (1)$$

where: n - bit rotation speed, s^{-1};

k_2 – the coefficient depending on the degree of destruction of the rock at the bottom in one revolution of the bit and the average pitch of the teeth t on the crowns of the cones;

h_D – the depth of tooth insertion into the rock, m:

$$h_D = \left(\frac{k_1P_{a.l.}}{\xi_1\sigma_{s.c.}}\right)^{2/3} \qquad (2)$$

where: k_1 - coefficient depending on the degree of cleaning of the bottom of the well from the sludge;

$P_{a.l.}$ - axial load on the bit, N;

ξ_1 - the parameter calculated from the geometric parameters of the bit and the cones, $m^{0,5}$;

$\sigma_{s.c.}$ - stresses corresponding to intensive fine crushing of the rock under the bit tooth and depending on the rock strength coefficient f, Pa.

Under these conditions, according to A.A. Tsuprikov, the drilling speed, without taking into account energy losses for rock deformation and heat generation, can be determined from the expression [4]:

$$v = \frac{8n_{rot}P_{a.l.}K_P}{D_1^2\sigma_{sfe}k_{vol.des}} \qquad (3)$$

where: n_{rot} – rotation frequency of the cone bit, s^{-1};

D_1 – diametr of cone drill bit, m;

$P_{a.l.}$ – axial load, N;

K_P – proportionality factor equal to the cone bit radius, m;

$k_{vol.des}$ – the coefficient of volumetric destruction, which characterizes the fracturing of the rock, its ability to be crushed into pieces, up to a powdery state;

σ_{sfe} – surface free energy density of the substance of the rock material, N/m^2.

$$\sigma_{sfe} = \frac{F_{force}}{Sk_{vol.des}} \qquad (4)$$

F_{force} – the force of structural destruction of the rock, N;

S – the cross-sectional area of the destroyed rock, m^2.

According to Poderni R.Yu., the drilling speed can be determined from the expression [5,6]:

$$v = \frac{40P_{a.l.}n_{rot}}{P_{drill}D_1^2}, \text{ м/ч.}, \quad (5)$$

Where: $P_{a.l.}$ – axial load on bit, MN;

n_{rot} – rotation frequency of the drilling bit, s^{-1};

D_1 – diameter of drill bit, m;

P_{drill} – drillability indicator:

$$P_{drill} = 0,07\cdot(\sigma_{com} + \sigma_{shear}) + 0,7\gamma = \frac{\sigma_{sfe}k_{vol.des}}{7,2\cdot 10^3 K_p} \quad (6)$$

σ_{com} – the ultimate strength of rock under uniaxial compression, MPa,

σ_{shear} – shear strength of rock, MPa;

γ – rock density, t/m^3;

According to the method of Eygels R.M. and Sterlakov R.V., the drilling speed is determined based on the following indicators [7]:

$$v = \frac{H}{T + t_{op}} \quad (7)$$

where: H – the amount of penetration, m:

$$H = \frac{v_0}{1-\beta}\left[(1+T)^{1-\beta} - 1\right] \quad (8)$$

T – bit's working time, hour;

$$T = \frac{k}{nG^{\alpha}} \quad (9)$$

t_{op} – time of descent and lifting operations, hour.

v_0 – starting drilling speed, m/hour;

v_k – drilling speed at the end of the working time, m/hour;

β - coefficient that takes into account the change in drilling speed:

$$\beta = \frac{\ln\frac{v_k}{v_0}}{\ln(1+T)} \quad (10)$$

But the calculated data showed that the drilling speed depends on the axial load and the rotation frequency of the cone bit.

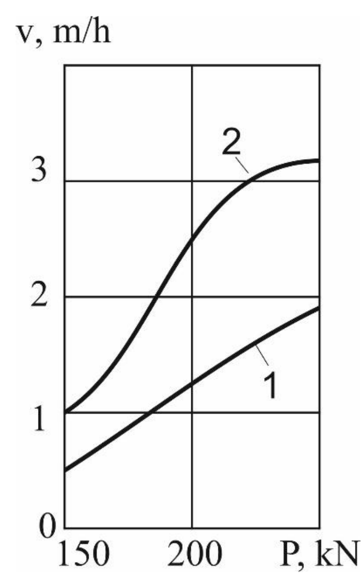

Fig.1. Calculated dependences of the drilling speed on the axial load: 1 – n=40 rpm, 2 – n=100 rpm

THE MAIN PART

The method of V.N. Tryupin and others gives the drilling carried out to determine the drilling speed, give complex mathematical formulas with numerous coefficients, many of which need to be determined empirically. There are no parameters in the formulas that characterize the fracturing of the rock massif.

It is very difficult to use these formulas to determine the drillability index of rock massifs, but the drillability index can be used to determine the degree of rock explosion and the effective parameters of drilling and blasting operations to obtain high-quality crushing of the massif. At the same time, the basic law is the conservation of energy [8].

According to the law of conservation of energy, the kinetic energy (E_k) of the embedded teeth of the cone, taking into account the axial force and torque (M), is spent on elastic-plastic deformations and destruction of the rock massif (E_{des}):

$$E_k + M = E_{des}. \qquad (11)$$

Using the basic regularities of the mechanical interaction of the teeth of a cone bit with a fractured rock, the dependence of the drilling speed according to the formula is obtained:

$$v_{drill} = \frac{\pi^2 P_{a.l.} n N_3 d_3^2}{2\left[\frac{\sigma_s^2}{8E}\left(\frac{1-v}{v}\right)^2 F d_e \pi d_d^2 - M\right]} \qquad (12)$$

where: $P_{a.l.}$ – axial load, N;

n – rotation frequency of the drilling bit, rpm;

d_d – diameter of drill bit, m;

N_3 – the number of teeth of the cone bit simultaneously embedded in the face, pieces;

d_3– diameter of teeth, m;

σ_s – tensile strength of rock, Pa;

v – Poisson 's coefficient;

E – modulus of elasticity of the rock;

F – index of fracturing of the rock mass;

d_n – the size of natural isolation.

Physical and mechanical properties of rocks have a high variation and rather difficult to determine in production conditions. Therefore, research was carried out and the connection of physical and mechanical properties with the strength coefficient according to M.M.Protodiakonov was established [9]. Numerical analysis of the formula (12) modified taking into consideration the strength coefficient and comparison with the practice data on the speed of drilling allowed us to establish it in the form of:

$$v_{drill} = \frac{5 P_{a.l.} n d_3^2}{1000\, f d_e F d_d^2 - M} \qquad (13)$$

Analysis of the formulas (12) and (13) shows, that increasing of the rotation speed of the bit, axial load, number of teeth which inject into rock at same time, diameter of the teeth and torque increase the speed of drilling. With an increase in the strength or the strength coefficient of the rock, the parameters of the fracturing of the array and the diameter of the bit, the drilling speed decreases. In many works carried out on the study of drilling speed, the change in drilling speed is confirmed in accordance with the given formulas (12), (13) parameters, which indicates the validity of the formulas obtained.

An important task in the processes of mining production is to determine the degree of explosiveness of the rock mass to obtain a given crushing quality. The explosiveness is determined by the strength (strength coefficient) of the rock and the parameters of the fracturing of the massif. On the other hand, the drilling speed significantly depends on the strength and fracturing parameters of rock massifs [10,11,12]. Then from (13) it is possible to determine the indicator of drilling difficulty in the form:

$$P_{drill} = f d_e F = 5 \cdot 10^{-3} \frac{P_{a.l.} n d_3^2}{v_d d_d^2} + 10^{-3} \frac{M}{d_d^2} \qquad (14)$$

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Table 1
The speed of drilling wells depending on the strength and strength coefficient of rocks (drilling rig SBSh – 250 MN, d_A = 244,5 mm):

Category of drillability of rocks on the CBNT scale	Compressive strength σ_{com}, *MPa*	Strength coefficient *f*	Speed of drilling $\upsilon_\delta, 10^{-3}$, *m/s*	
			By reference [10]	Calculated by (13)
IX	45	3	10	13,6
X	60	4	8,2	9,1
XI	75	5	6,7	6,9
XII	90	6	5,5	5,5
XIII	110	7	4,6	4,6
XIV	130	8	3,8	3,9
XV	150	10	3,2	3,1
XVI	170	12	2,7	2,5
XVII	200	14	2,3	2,1
XVIII	230	16	1,9	1,8
XIX	260	18	1,6	1,7
XX	300	20	1,4	1,5

Calculations according to the formula for determining the ib were carried out at average parameters: $P_{a.l.}$= 150 103N; M = 2.1 103 N m; d_3 = 0.009 m; d_d= 0.25 m; d_p= 0.5 m; F = 73; n = 1s^{-1}.

CONCLUSION

According to the results of research on determining the speed of cone drill bits, the following conclusions can be drawn that the higher the drilling speed, the greater the difference between the calculated and reference drilling speed indicators. The determination of the drilling speed not only depends on the axial load and rotation speed, but also it is necessary to determine how many revolutions the drilling cone completely hits the bottom of the well.

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