Increasing the efficiency of rocks distribution tools in air-assisted well drilling

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Abstract. One of the main ways to ensure the normal temperature regimes of the rock crushing tool is to cool the temperature of the cleaning compressed air delivered to the well, that is, to eliminate the heat spread in the rock crushing tool by transferring the cooled air. However, the experience of drilling wells with compressed air shows that in order to effectively regulate the temperature regimes of the rock-breaking tool, it is necessary to provide optimal drilling regimes together with the cooling of the compressed air temperature.

1 Introduction

Today, in order to eliminate the burning of the rock crushing tool under the influence of high temperatures, methods are used to control the operation of the circulation system, control the hermeticity of the drilling shell, and select the optimal consumption of cleaning compressed air, however, the contribution of the burning of rock crushing tools is significantly higher, shows the low efficiency of these methods [1-3].

A study of the temperature regimes of rock crushing tools showed that when the temperature of diamond gear tools reaches 600 °C, its teeth wear out (grinding), and when it exceeds 800 °C, it cracks and breaks off. When the temperature reaches 450 °C, deformation of the matrix, erosion and falling of the teeth are observed in hard alloy rock breakers (Figure 1). High temperatures of the drilling bit cause accidents such as burning of the bit, and to eliminate these accidents 8-10% of the total drilling time is spent.

One of the main ways to ensure the normal temperature regimes of the rock crushing tool is to cool the temperature of the cleaning compressed air delivered to the well, that is, to eliminate the heat spread in the rock crushing tool by transferring the cooled air. However, the experience of drilling wells with compressed air shows that in order to effectively regulate the temperature regimes of the rock-breaking tool, it is necessary to provide optimal drilling regimes together with the cooling of the compressed air temperature.

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Fig. 1. Erosion of the teeth of a three-pointed dolot under the influence of high temperatures.

2 Materials and methods

Based on expressions (1) and (2), a mathematical model of the temperature regimes of the ring-shaped drill bit and the three-point bit was created in mathcad graphics program in order to determine the initial temperatures of the cleaning compressed air and the influence of the drilling mode on the temperature regime of the rock-breaking tool.

$$t_T = \frac{2K_pN}{\pi\sqrt{\lambda_1(\alpha_1 D_1+\alpha_2 D_2)(D_2^2-D_1^2)}} + \frac{K_pN}{2Gc_p} + t_1\ , \quad ℃ \tag{1}$$

$$t_s = \left[\left(\frac{h}{\lambda_1 f_ц} + \frac{1}{\alpha f_л}\right)\frac{k_1k_2}{m} + \frac{1}{2G_г c_p}\right]N - \frac{\Psi`\Delta W}{2c_p} + t_1, ℃, \tag{2}$$

When creating a mathematical model of the temperature regimes of the annular drilling bit based on expression (1), the following parameters were selected: λ_1 – thermal conductivity coefficient of the bit material, W/ch (m·°C); α_1ва α_2 – heat transfer coefficients, (in the gap between the crown and the core; in the gap between the crown and the walls of the well), W/(m^2·°C);– D_1ва D_2 inner and outer diameter of crown ring, m; t_1 – initial temperature of compressed air, °C; N - power generated at the bottom of the well, (W); G -mass consumption of cleaning compressed air, (kg/s); cp – specific mass heat capacity of air, J/(kg·°C), Kr – dimensionless coefficient of diffusion of heat flows.

Calculations of the temperature modes of the annular drilling bit using the expression (1) were carried out in the mathcad graphic program, during the calculations, the value of the initial temperature of the compressed air (t_T) was changed from -20 °C to +80 °C, the storage power was 2500 W, and the consumption of the cleaning compressed air was It was set at 0.12 kg/s. The results of the calculations are presented in Figure 2

The results of calculating the temperature regimes of the annular drilling bit show that the temperature of the bit working in the reservoir depends on the temperature of the cleaning compressed air, that is, as the temperature of the cleaning compressed air (t_T) increases, the temperature of the bit working in the storage (t_T) increases.

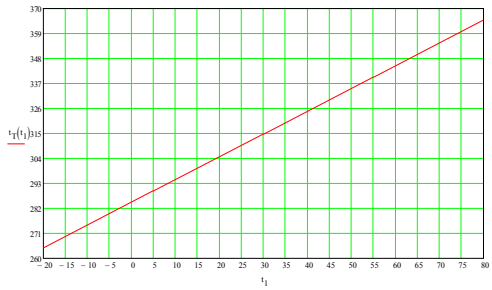

Fig. 2. Results of calculation of temperature regimes of annular drilling bit.

When creating a mathematical model of the temperature regimes of a three-cornered dolat using expression (2), the following parameters were selected: h – average thickness of the dolat paw along the axis of the tsapfa, м; f_s, f_l – cross-sectional surface of the outer surface and base of the spindle, м^2; λ_1 – thermal conductivity coefficient of the crown material, *Wt/h* (м· ℃); α – temperature conductivity coefficient, – м^2/s; t_1 initial temperature of compressed air, °C; sr– specific mass heat capacity of cleaning air, *J/kg*·°C; G_g–;air mass consumption, kg/s; kg/s; k_1, k_2 – dimensionless coefficients of power loss due to frictional force on supports and heat flow distribution in bearings, in the unit of contribution; *N* – the power in the battery, *W*; m - the number of sharoshkas; PS`– specific heat of vaporization, *J/kg*; Δ*W*,– humidity, in units of contribution.

Calculations of the temperature regimes of the three-point valve using the expression (2) were also carried out in mathcad graphics software, during the calculations, the value of the initial temperature of the compressed air (t_T) was changed from -20 °C to +80 °C, and the storage power was 2500 W. and the consumption of cleaning compressed air was set at 0.21 kg/s. The results of calculations are presented in Figure 3.

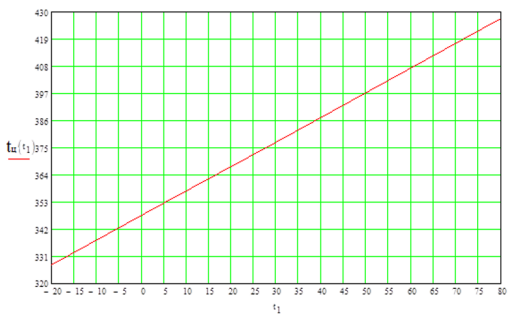

Fig. 3. The results of calculating the temperature regimes of the three-layer dolot.

Based on the results of the research of the temperature regimes of the three-chamber machine, it can be concluded that the temperature of the cleaning compressed air has a significant effect on the temperature of the machine working in the tank.

The results of the calculations based on the expressions (1) and (2) given above show that the temperature regimes of the rock breaker are influenced by the temperature of the cleaning air and the size of the reservoir power ($N_{slaughter}$) at the bottom of the well. That is, in order to effectively regulate the temperature conditions of the rock breaker working at the bottom of the well, it is necessary to ensure a rational size of the storage capacity.

Measuring the storage capacity during the operation of the rock-breaking tool at the bottom of the well is technically complicated, the storage capacity depends on the type of the rock-breaking tool and the drilling modes.

$$N_{slaughter} = 5{,}3 \cdot 10^{-4} \cdot P \cdot n \cdot D_{mid.cr.}\,(0{,}137 + \mu), \qquad \text{(W)} \tag{3}$$

There, P – reading pressure applied to the rock breaker, N; n – the frequency of revolutions of the crown, min^{-1}; $D_{mid.cr.}$ – the average diameter of the crown, м; μ– the coefficient of friction of the crown teeth against the bedrock (values of μ for different bedrock are given in [4]).

For a diamond-toothed drill bit:

$$N_{slaughter} = 2 \cdot 10^{-4} \cdot P_{axis} \cdot n \cdot D_{mid.cr.}\,, \qquad \text{W}, \tag{4}$$

For sharoshka dolotas:

$$N_{slaughter} = 10^{-3} \cdot \mu \cdot P_{axis} \cdot n \cdot D, \qquad \text{W} \tag{5}$$

Where D is the diameter of the dolot, m.

The temperature of the rock breaker operating in the wellbore can be calculated using expressions (1) and (2), but in order to ensure the optimal temperature regimes of the rock breaker, rational drilling modes, i.e., the reading pressure force (P_{shaft}) given to the rock breaker, rotations it is necessary to select the frequency (n) and consumption of washing liquid (G).

In order to determine the rational drilling modes, i.e., the …. pressure force (P_{shaft}) and the frequency of rotations (n) in order to normalize the temperature regimes of the rock-breaking tool during the air-cleaning drilling of wells, the value of the storage power (N) at the bottom of the well presented in expressions (1) and (2) indicator was specified using expressions (3), (4) and (5).

In this case, the expression (6), which allows to calculate the temperature of the ring drill bit, has the following forms (7).

For hard alloy drill bits:

$$t_T = \frac{K_p 5{,}3 \cdot 10^{-4} \cdot P_{axis} \cdot n \cdot (D_1 + D_2)(0{,}137 + \mu)}{\pi\sqrt{\lambda_1(\alpha_1 D_1 + \alpha_2 D_2)(D_2^2 - D_1^2)}} + \frac{K_p 5{,}3 \cdot 10^{-4} \cdot P_{axis} \cdot n \cdot (D_1 + D_2)(0{,}137 + \mu)}{4Gc_p} + t_1 \tag{6}$$

The expression (2) that allows you to calculate the temperature of the three-point dolota comes to the following form (7):

$$t_T = \left[\left(\frac{h}{\lambda_1 f_{ц}} + \frac{1}{\alpha f_{л}}\right)\frac{k_1 k_2}{m} + \frac{1}{2G_{г}c_p}\right] 10^{-3} \cdot \mu \cdot P_{o`q} \cdot n \cdot D - \frac{\Psi`\Delta W}{2c_p} + t_1, \ ℃. \tag{7}$$

Given above (6) and expressions (7) allow not only to determine the temperature of the rock-breaking tool during air drilling of wells, but also to select the rational values of drilling modes, that is, the reading pressure force (P_{axis}) and the number of revolutions (n) [5-9].

3 Results and Discussion

Temperature regimes of rock breakers can be normalized not only by lowering the temperature of the cleaning compressed air, but also by correctly selecting the reading pressure (P_{axis}) and the number of rotations (n), i.e., the parameters of the drilling mode, given to the rock breaker. In order to confirm these opinions, using its graphical interface in the mathcad program, based on expressions (6) and (7), the temperature of the rock-

breaking tool was determined as a function of the temperature of the drilling modes, the reading pressure force (P_{axis}) and the number of revolutions (n) [10,11].

Figures 4 and 5 below show graphs of the temperature of a hard alloy (t_T) drill bit as a function of the pressure force (P_{axis}) and the number of revolutions (n).

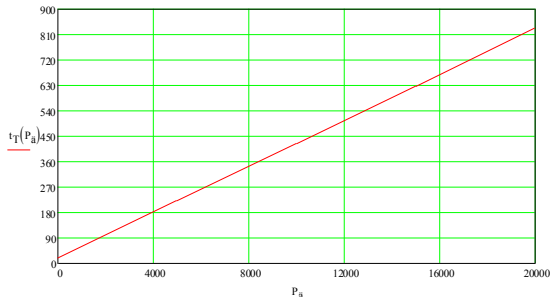

Fig. 4. The graph of the temperature (t_t) of the hard alloy ring drill bit and the pressure force (P_{axis}) (n=60 min^{-1}).

When calculating the dependence of the temperature of the hard alloy annular drilling bit shown in Figure 4 on the pressure force, the consumption of cleaning compressed air (G) is 400 kg/h, the number of revolutions of the bit is 60 min-1, and the coefficient of friction of the bit teeth against the rock (μ) is 0.4 were selected, calculations were made for rocks with hardness coefficient (f) equal to 8 categories.

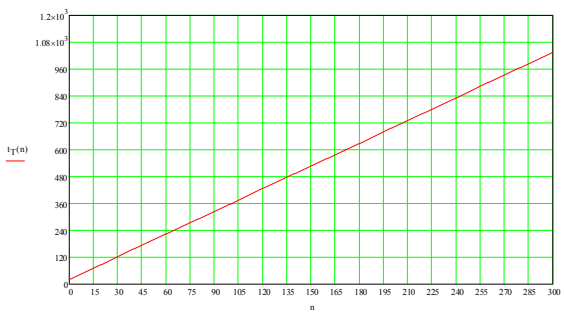

Fig. 5. A graph of the temperature (t_T) of a hard alloy annular drill bit versus the number of revolutions (n) (P_{axis}=5 кН).

When calculating the temperature of the hard alloy ring drill bit shown in Fig. 5 as a function of the number of rotations of the bit, the same values were selected as above, where only the axial pressure force applied to the bit was 5 kN. Also, the dependence of the temperature of the three-cornered dolot on the axial pressure force and the number of revolutions (n) was modeled using the expression (7). In this case, the diameter of the three-point blade is 76 mm, the consumption of cleaning air (G) is 600 kg/hour, and the initial temperature of the air is 20 °C. In the study of the temperature dependence of the three-point dowel, the number of revolutions of the dowel was 500 min^{-1}, and the dowel pressure was increased from 0 to 20 kN. The result of the calculations carried out for the study of the dependence of the temperature of the three-cornered dolot on the reading pressure force

It is presented graphically in Figure 6.

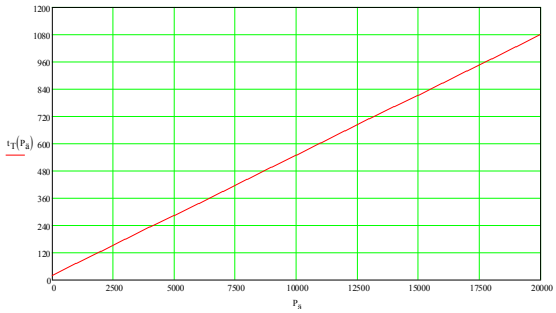

Fig. 6. Graph of dependence of the temperature (t_T) of the three-pointed dolot on the pressure force(P_{axis}) (n=300 min^{-1}).

In the study of the temperature dependence of the three-point tool on the number of revolutions of the tool, the number of revolutions of the tool was increased from 0 to 800 min-1, and the axial pressure force was 10 kN. The results of the calculations are presented in Figure 7

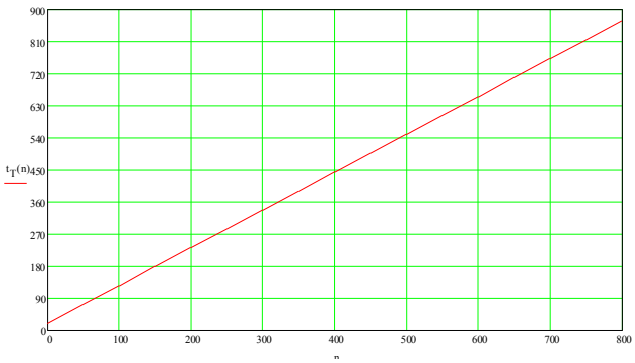

Fig. 7. The temperature of the three-cornered dolota (t_s) to the number of revolutions (n) dependence graph (P_{axis}=10 кN).

As can be seen from the graphs presented in Figures 2-7 above, the temperature of rock breakers during clean drilling of wells using compressed air depends not only on the initial temperature of the clean air, but also on the drilling modes. In order to moderate the temperature of the rock crushing tool, it is necessary to select the rational indicators of the number of rotations and the reading pressure force applied to the dolot along with lowering the temperature of the cleaning compressed air supplied to it.

4 Conclusion

A mathematical model was developed to determine the temperature of the rock-breaking tool during air-cleaning drilling of the wells and to determine the rational values of the drilling modes for normalizing the temperature regimes.

The mathematical model developed above allows to determine the rational indicators of the drilling mode, which ensures that the temperature regimes of the rock-breaking tool are not exceeded when drilling wells using air. When the axial pressure force (Paxis) applied to the three-point drill bit is 10 kN, and the number of rotations (n) of the drill bit is provided in the range of 100-300 min^{-1}, the surface temperature does not exceed the maximum of

255 °C, thereby reducing the workability of the drill bit due to high temperatures. Is eliminated.

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