DEVELOPMENT OF TECHNICAL SOLUTIONS PREVENTING COMPLETE ABSORPTION OF DRILLING FLUID DURING WELL DRILLING

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https://doi.org/10.5281/zenodo.13985117

Abstract

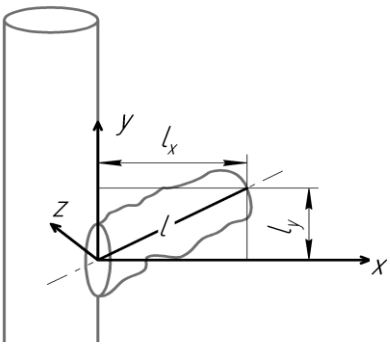
Timely elimination and prevention of accidents and complications during drilling operations are among the main factors that help reduce the time spent exploring and prospecting a field and the operation of technological and technical wells. In the process of drilling wells, preventing downtime associated with the absorption of drilling mud allows reducing the cost and timing of drilling operations, which in turn leads to an increase in the productivity and efficiency of drilling operations. In this article, a mathematical model has been developed that allows calculating the volume of the cavity, taking into account the geometric parameters of the pores and cracks in the walls of the sound design of a drilling tool has been developed that allows covering individual sections of the well with a casing pipe, absorbing the washing solution. The results of an experimental study of the developed drilling tool are presented.

Keywords: drilling, well, absorption of drilling mud, bits, drilling tool, crack, pores, casing pipe, expander

Determining and assessing the intensity of drilling fluid absorption creates specific difficulties, leading to increased labour and expenses for eliminating absorption [1].

The intensity of drilling fluid absorption and the determination of an effective method for eliminating absorption depend on the fracturing, porosity, and pore volume in the borehole wall. A mathematical model has been developed for the preliminary determination and calculation of pore volume.

The primary absorption in fracturing is caused by the volume of cracks and the difference in pressure in the cracks and the borehole. An essential parameter for determining this phenomenon is the horizontal angle of the crack or the angle formed between the crack and the horizon. In this case, the functional dependence of the area of fluid absorption on the coordinates of the length of the cracks $\omega = f(x, y)$ is determined. Fig. 1 below is an illustration of the location of the well cavity along the axes.



l – length of cracks; l_x – length of cracks along the abscissa axis; l_y – length of cracks along the ordinate axis

Fig. 1. Illustration of the location of colors at the well bottom along the access

$$\begin{cases} l_x = l * \cos\alpha \\ l_y = l * \sin\alpha \end{cases} \quad (1)$$

where α – angle of cracks relative to the abscissa axis.

If 1. $\cos\alpha = 0^0$; 2. $\cos\alpha = 45^0$; 3. $\cos\alpha = 90^0$ non-existent condition, 4. $\cos\alpha = -45^0$; $-l_x = l_y$, then:

$$\omega(x,y) = \frac{4\rho_0}{E}\sqrt{(x_f^2 - x^2) + (y_f^2 - y^2)} = \frac{4(1-v^2)}{E}\sqrt{x_f^2 - x^2 + y_f^2 - y^2}$$

$$= \frac{4(1-v^2)}{E} \cdot \sqrt{x_f^2 + x^2 - y_f^2 - y^2}; \quad (2)$$

where ρ_0 – internal crack pressure, (P_a); E – crack wall deformation modulus, (P_a); $X_f =$ crack width along the ordinate axis, (m); X – width of crack length along the abscissa axis, (m); *"X"* – crack length width along the ordinate axis, (m); v – Poisson's ratio.

The length and location of the crack formed in the well cannot fully determine the absorption capacity of this crack, so it is important to determine the initial surface of the crack formed in the well, for this we introduce a general equation, taking into account that the crack line is curved:

$$A \cdot x^2 + 2\beta * xy + Cy^2 + 2Dx + 2Ey + F = 0; \quad (3)$$

1. If A= C, then a circle;
2. If A$\cdot C > 0$ and A≠C, then it is an ellipse;
3. If A$\cdot C$<0, that's hyperbole;
4. If A$\cdot C = 0$, $A^2 + C^2 \neq 0$, then it's a parabola.

Based on the above conditions, in order for the crack shape to be close to circular or ellipsoidal, we introduce equations based on conditions 1 and 2:

$$Ax^2 + 2\beta xy + Ay^2 + 2D_x + 2E \cdot y + F = 0; \quad (4)$$

$$A(x^2 + y^2) + 2(Bxy + Dx + E \cdot y) + F = 0; \quad (5)$$

$$x^2 + y^2 = R^2 \quad (x^2 + y^2) = \frac{-2(Bxy + D_x + E_y) - F}{A}; \quad (6)$$

$$x^2 + y^2 = \frac{(-2(Bxy + D_x + E_y) + F)}{A} = R^2 (\text{a circle}); \quad (7)$$

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 2z \text{ Parabolic equation,} \quad (5)$$

where $2 \cdot z$ – is the length of the crack. Using the above equations, we form the following expression:

$$\frac{4 \cdot (1-v^2)}{2 \cdot E} \cdot \sqrt{x_f^2 + y_f^2 - x^2 - y^2} = \frac{x^2}{2 \cdot a^2} + \frac{y^2}{2 \cdot b^2}. \quad (9)$$

Taking into account the above, the volume of cracks will be:

$$V_f = \omega(x,y) \cdot S_{пл};$$

$$V_f = \frac{4(1-v^2)}{E} \cdot z \cdot (P_0 - S_h)\sqrt{x_f^2 + y_f^2 - (l\cos\alpha)^2 - (l\sin\alpha)^2}. \quad (10)$$

For an equation not to be equal to zero, the following conditions are valid:

$l > l_x$ $l > l_y$ $P_0 > S_n$ $z > 0$;

$X_f \geq l_x$ $y_f \geq l_y$ $\frac{\pi}{2} > a > 0$.

Provided that the area of the well diameter

If we analyze the given formula with the condition that the area of the crack entrance is mathematically not greater than the diameter of the well, then it is necessary that $R > x_f$, $R > y_f$.

Accordingly: $V_f = f(x,y,z)$;

Vf = f (x,y,z)+ qe.

Let us express the volume of cracks by the lengths of three coordinates:

$$V_f = \frac{4(1-v^2)}{E} \cdot z \cdot (P_0 - S_h) \sqrt{x_f^2 + y_f^2 - (l\cos\alpha)^2 - (l\sin\alpha)^2} + \frac{C \cdot A}{\sqrt{t-T}} =$$

$$= \frac{4(1-v^2)}{E} \cdot z \cdot (P_0 - S_h) \sqrt{x_f^2 + y_f^2 - (l\cos\alpha)^2 - (l\sin\alpha)^2} +$$

$$+ \frac{x_f y_f 2}{\sqrt{t-T}} \cdot 0.172 \sqrt{\frac{k(P_W - P_P)\Phi}{\mu}}. \qquad (11)$$

Generalizing the expression, we obtain an expression for determining the crack volume:

$$V_f = \frac{4(1-v^2)}{E} z(P_0 - S_h) \sqrt{x_f^2 + y_f^2 - (l\cos\alpha)^2 - (l\sin\alpha)^2} +$$

$$+ \frac{x_f y_f 2 \cdot 0{,}172}{\sqrt{(t-T) \cdot \mu}} k(P_W - P_p)\Phi, \qquad (12)$$

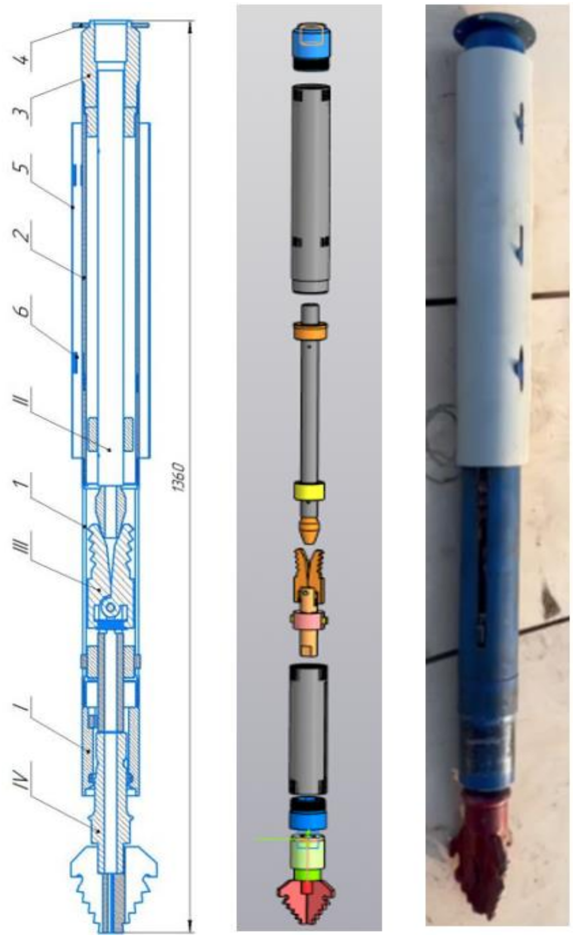
where z – coordinate of fracture height change; S_h - he pressure generated in the fracture, (Pa); t is the total drilling time, sec; T – the time of fracture filling with liquid, μ- the viscosity coefficient of the liquid entering the fracture; k is the conductivity of the rock; Φ - the degree of porosity; P_0 is the pressure at the bottom of the well, (Pa); P_W - the fracture pressure, (Pa); P_p - the pressure inside the fracture, (Pa).

When determining the volume of the absorbing medium, a mathematical model with three unknowns was obtained. This makes it possible to determine the shape and volume of the absorbing section, close to the actual ones, by entering intermediate values for the corresponding coordinates [2].

If the drilling fluid is absorbed catastrophically during well drilling as a result of large pores and cracks, the section of fluid absorption in the well is sealed with a separate casing pipe. However, in this case, the diameter of the well is reduced by the wall thickness of the installed casing pipe, which in turn causes several technological difficulties [3].

A drilling tool design has been developed that allows closing the absorption zone during well drilling, in the case of complete, i.e. catastrophic, absorption of the drilling fluid, by the casing pipe while maintaining the initial diameter of the well. Fig. 2 shows the developed drilling tool design.

IBAST ISSN: 2750-3402



I-sleeve; II-rod; III-expander; IV-rock-breaking tool;
1-adapter; 2-expanding pipe; 3-head; 4-connecting part; 5-shell; 6-ears

Fig. 2. The design of a drilling tool that allows the strengthening of individual sections of the well

An experimental study of the drilling tool design that allows blocking individual sections of a well with a casing pipe was conducted in the Geological Exploration Expedition of the Navoi Mining and Metallurgical Combine Joint-Stock Company. In this case, large-scale cracks encountered at 107 meters in a 160-meter-deep well with a diameter of ∅ 112 mm and a rock strength coefficient of f = 8 were reinforced with an expanding casing pipe 2 meters long. The proposed expander made it possible to expand the healthy diameter from ∅ 112 mm to ∅ mm at 107-108 meters of the well. Then this section was closed with a casing pipe, the diameter of which was expanded in the same section of the well from ∅ 104 mm to ∅ 122 mm.

Experimental studies have found that the new design of the drilling reamer, which can expand and contract, and the drilling tool with an expanding casing pipe, which allows covering the pores and cracks of individual sections of the well along the entire depth, eliminates the catastrophic absorption of the drilling fluid.

When using the design of the drilling tool, allowing the covering of individual sections of the well with a casing pipe, lowering the pipe to the absorption section, and ensuring its reliable fixation after lowering is a complex task. At the same time, the resistance force exerted by the narrowing of the expansion pipe is an important indicator. Since the expansion pipe is made of a galvanized profile sheet, its resistance force to compression depends on the thickness.

IBAST | Volume 4, Issue 10,October

When observing the absorption of drilling fluid in small-diameter wells, using an expanding pipe made of a thick profile sheet is very difficult. It is preferable to use a thick sheet as an expansion pipe since, due to its high compressive strength, it is firmly attached to the wall of the well and is highly reliable. However, lowering and placing such a pipe to the bottom of the well is very difficult, there is a high risk of opening such a pipe during lowering, drilling and expansion, so it is advisable to use profile sheets with a thickness of 0.3-0.45 mm as an expanding pipe.

In large-diameter wells, the opposite is observed, with a small thickness of the profile sheet, due to the large diameter of the well, the value of its compressive resistance force is small for opening the pipe, in addition, the expansion pipe is not firmly attached to the wall of the well.

After processing the results of experimental tests on the optimal selection of the wall thickness of the expanding casing pipe depending on the diameter of the well, a dependence of the wall thickness of the expanding profile pipe on the diameter of the well was established; this dependence is shown in Fig. 3.

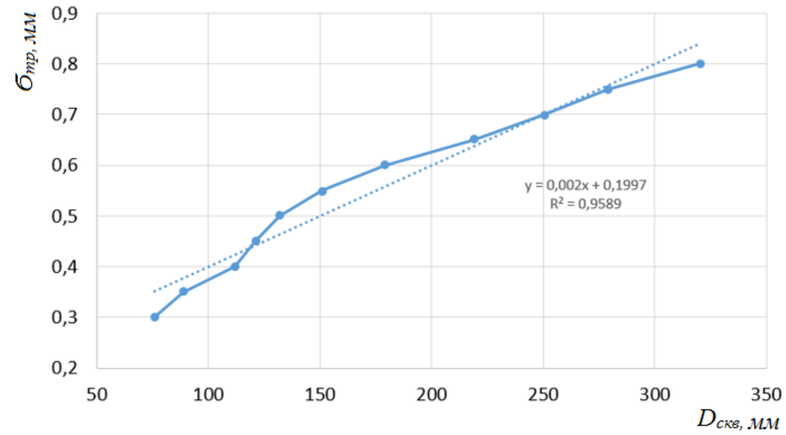


Fig. 3. Dependence of the wall thickness ($6_{тр}$) of the expanding pipe of the drill string, allowing to cover of individual sections of the well with the casing, on the diameter of the well ($D_{скв}$)

Having carried out an analytical, correlation and statistical analysis of the results of the conducted experimental studies and the indicators shown in Fig. 3, an expression was obtained for determining the optimal wall thickness of the expansion pipe of the drilling tool, strengthening individual sections of the well when observing the absorption of the drilling solution during the drilling process:

$$6_{тр} = k \times D_{скв} + b \qquad (13)$$

where $6_{тр}$- expansion pipe wall thickness, mm; $D_{скв}$ – well diameter, mm; b – correction factor (at $D_{скв}$ 76÷151 mm b=0,1997; at $D_{скв}$ 179÷320 mm b=0,21).

In the obtained results, a function was created by setting the value of the variable $f(x)$ as the thickness of the expanding pipe wall $6_{тр}$, the argument x as the diameter of the well $D_{скв}$ and real numbers k and b equal to 0.002 and 0.1997.

Thus, as a result of the conducted research and experimental work, a design of a drilling tool was developed that allows blocking individual sections of the well that absorb drilling mud with a casing pipe, and a dependence was obtained that allows choosing the optimal wall thickness of the expansion profile pipe intended to strengthen the wellbore, depending on the diameter of the well.

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