

Determining the bending intensity that ensures the free passage of the curved conductor assembly through the curvilinear barrel

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Abstract. In the article, in order to determine the free passage of the drilling tool through the curved interval of inclined wells, taking into account its elasticity, the intensity of the increase in the zenith angle was calculated accordingly.

Key words: zenith angle, flexibility, drilling tool, interline interval.

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1. Introduction. The geometrical dimensions and the diameter of the bit along with the drill collar of the curved transmission downhole motor allow to determine in advance the minimum curvature radius of the well or the minimum bending intensity. When you start bending the vertical well with this assembly, it stops in the position shown in figure 1. In this case, the body of the engine or the drill collar rests on the upper wall of the well at point S and exerts pressure on it with the force F_S . However, as the zenith angle increases, after reaching a certain value, the body of the engine or the drill collar breaks off (separates) from the upper wall at point S of the well due to its own weight and sits on the lower wall at point D and exerts pressure on it with the force F_D . Depending on the seating of the drill collars on the upper and lower walls of the well, the expected value of the bending intensity that ensures the normal passage of the indicated system through the inclined well pipe will also be different.

2. Methodological part. In the first case, that is, when the tool touches the wall of the well at point S, let's determine the value of the bending intensity that ensures the normal transition of the curved conductive assembly. For this, let us assume that the bit 1, the downhole motor 2, the drill collar 4 placed on it touch the well wall 5 at points A, B and S and the zenith angle DBO has an increasing tendency along the circular arc.

Therefore, the increase of the zenith angle in the interval from point D to point B will be $\Delta\alpha_0$, and in the drilling interval BO will be $\Delta\alpha_l$.

We assume that the well wall is absolutely rigid against lateral forces, and the shape of the elastic bits of the assembly in the interval from the bit to the point where the drill collar touches the wall is as shown in Figure 1.

To solve this problem, the lower part of the bent-conductor fuel assembly can be viewed as a flexible beam mounted on three roller bearings.

Let's assume that the zenith angle accumulation intensity is $\Delta\alpha_k$.

The principle diagram of the transition of a curvilinear node from a curvilinear barrel

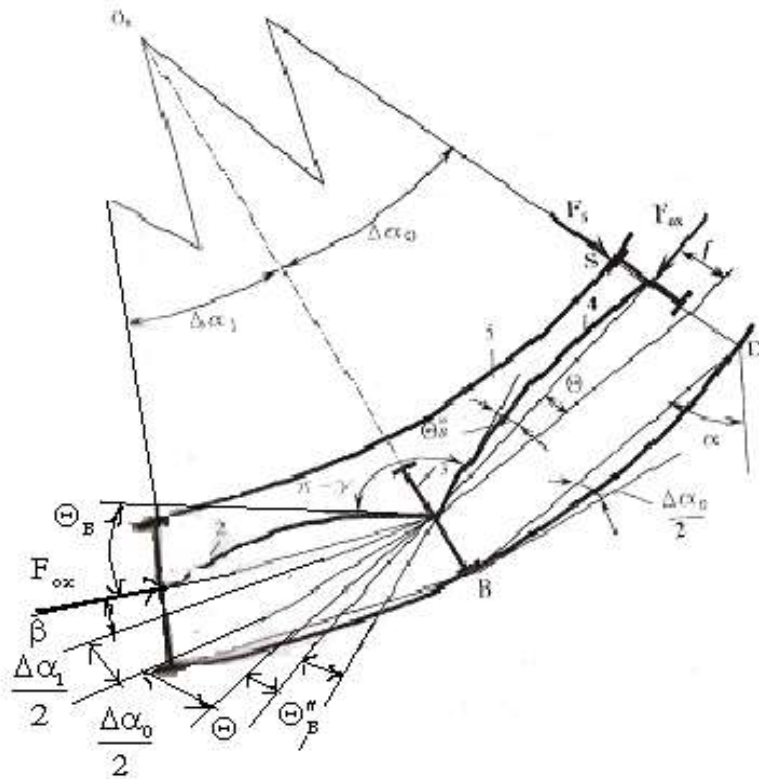


Figure 1.

In Figure 2, the following dependence can be written between the angles resulting from the deformation of the lower part of the drilling tool on the geometric dimensions of the assembly, the bending intensity and the curvature of the fuel in the section where the assembly is located with a curved conductor:

$$\theta'_B + \beta + \frac{\Delta\alpha_1}{2} + \frac{\Delta\alpha_0}{2} + \theta + \theta''_B \quad (1)$$

here, $\beta = \frac{D-D_x}{2L_T}$, $f = D - \frac{D_y+D_x}{2}$ D, D_x – the outer diameter of the bit and the curved conductor (mechanism), respectively, or if the downhole motor touches the wall of the well;

β - the inclination angle of the downhole motor with respect to the well bits;

L_T – the length of the downhole engine with the bit to the bending mechanism;

L – the distance from the curved conductor to where the assembly touches the wellbore wall, α - zenith angle;

$\Delta\alpha_1$ – and $\Delta\alpha_0$ properly the increase of the zenith angle in the L_T and L interval;

γ - the angle of curvature of the curved conductor;

θ , θ'_B $\vee$ θ''_B - O and B are the rotation angles of the bits of assembly at the supports.

Assuming that $\Delta\alpha_1 = \Delta\alpha_k \cdot L_T$ $\vee$ $\Delta\alpha_0 = \Delta\alpha_k \cdot L$ depending on the bending intensity ($\Delta\alpha_k$) and if we substitute the values of these quantities in the expression (1) to determine the bending intensity ($\Delta\alpha_k$) we get this equation:

$$\Delta\alpha_k = \frac{2}{L_T+L}(\gamma - \beta - \theta - \theta'_B - \theta''_B) \quad \text{degrees/meters} \quad (2)$$

Since the quantities L , γ , θ'_B , θ''_B and θ in expression (2) are unknown, they must be determined.

Let's determine the quantities L , γ and θ for the case where the assembly with a curved conductor is located in a vertical barrel.

3. Results and discussion. When the shown system is located in a vertical wellbore, it undergoes elastic deformation and as a result, the bit is pressed against the well wall by the forces F_y and the drill collar by F_s . As a result of the presence of a curved conductor in the assembly and the arrangement of the assembly in a barrel with a limited diameter, an elastic moment M occurs in the section with a curved conductor, which causes the system to undergo elastic deformation. In this case, the situation where the assembly is located in the vertical wellbore can be considered as shown in figure 2. Taking the lower part of the assembly as a beam sitting on three absolutely rigid supports of different levels, determining the elastic moment M generated in the B-B section, the distance (L) from the bending plane to the point of the curved conductor, the fuel force F_y pressing the bit against the wall of the well, and the forces F_s pressing the drill collar against the wall can. If we consider the well wall to be absolutely rigid, then the value of the elastic bending moment M caused by the loads placed on the left side of the section B-B can be found with very little error from the following equation [79].

$$M = F_y L_T = F_s L \quad (3)$$

here, F_y – is the driving force (the force that presses the bit against the wall).

Layout of the bending assembly in a vertical well

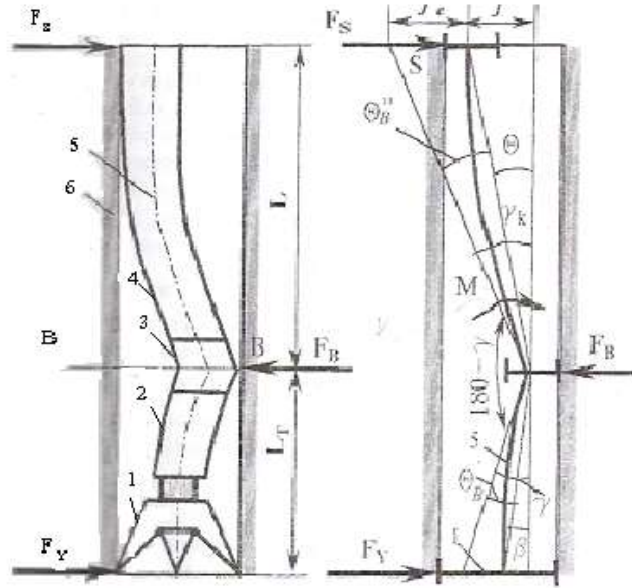


Figure 2. 1 – bit; 2 – well bottom engine; 3 - curved conductor; 4 – drill collar; 5 – elastic bits of assembly; 6 – well wall

To determine the driving force on the bit, the following relationship can be written between the angles of rotation resulting from the forces acting on the beam to the right and left of the B-B section and the angles resulting from the difference in the levels of the beam supports (i.e. for the case $\Delta\alpha_k = 0$).

$$\theta_B' + \theta_B'' = \gamma - \theta - \beta \quad (4)$$

here, θ_B' , θ_B'' -B-B are the turning angles of the beam on the left and right sides. If we ignore the weight of the downhole motor and the drill collar in the vertical barrel and the effect of the bit load applied to the bit, the turning angles θ_B' , θ_B'' can be determined by the following formulas using known research works (4).

$$\begin{cases} \theta'_B = \frac{ML_T}{3E} \\ \theta''_B = \frac{ML}{3EJ_0} \end{cases} \quad (5)$$

here, EJ and EJ_0 – respectively the bending stiffness of the downhole motor and the drill collar placed on top of it; α - is the zenith angle.

To determine the distance L from the plane of curvature of the curved conductor to the point where the drill collar touches the top wall of the well, we write the equation of the beam angle θ at the support.

$$\theta = tg\theta = \frac{ML}{6EJ_0} = \frac{f}{L} \quad (6)$$

If we solve equations (6) – (7) together, we get:

$$L = \frac{3f}{2\gamma_k} + \sqrt{\left(\frac{3f}{2\gamma_k}\right)^2 + \frac{2mfL_T}{\gamma_k}} = \frac{3f}{2\gamma_k} \left(1 + \sqrt{1 + \frac{8m\gamma_k L_T}{9f}}\right) \quad (7)$$

$$M = \frac{6EJ_0 f}{L^2} = \frac{6EJ_0 \gamma_k}{3L + 2mL_T} \quad (8)$$

here, $\gamma_k = \gamma - \beta$; $m = \frac{EJ_0}{EJ}$; $f = D - 0,5(D_y + D_x)$

To determine the angle of curvature of the bending mechanism (bend conductor), let's look at the parts BO and BS of the assembly as cantilever beams and use the deformation equations of the angles of rotation of the ends

$$\gamma_k = tg\gamma_k = \frac{F_y L_T^2}{2EJ} = \frac{ML_T}{2EJ} \quad (9)$$

$$\gamma_k = \frac{F_s L^2}{2EJ_0} = \frac{ML}{2EJ_0} \quad (10)$$

here, F_s – is the force pressing the pipe against the wall at point S.

We can solve the equations (8) - (10) together and determine the curvature angle of the curved conductor.

$$\gamma = \beta + \frac{3f}{mL_T} = \frac{1}{L_T} \left[\frac{D - D_y}{2} + \frac{3}{m} \left(D - \frac{D_2 + D_x}{2} \right) \right] \quad (11)$$

Substituting the value of the actual bending moment in the expression (11), we get the following equations to determine the propellant force F_y generated in the bit and the force F_s pressing the drill collar against the wall at point S.

$$F_y = \frac{M}{L_T} = \frac{6EJ_0 f}{L_T L^2} \quad (12)$$

$$F_s = \frac{M}{L} = \frac{6EJ_0 f}{L^3} \quad (13)$$

4. Conclusions. In order to determine the free passage of the drilling tool through the curved interval of inclined wells, taking into account its elasticity, the intensity of the increase in the zenith angle was calculated accordingly. Based on certain calculations, the free passage of the drilling tool through the curved interval is ensured.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research.

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