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UNSETTLED DISTRIBUTION OF CONTACT PRESSURE IN CONJUGATION OF A DIAMOND CROWN WITH BOTTOMHOLE

Abstract

It is defined the rule of unsettled distribution of contact pressure in conjugation of a diamond crown with the drilled rock. Starting distribution of pressure is assumed unsettled along the circumference of the butt-end of the tool. It is obtained the solution allowing to quantitatively appraise the influence of the parameters of the system on the process of re-distribution of contact pressure.

A contact pressure quantity in conjugation «the bit end - well bottom» has a great influence on the functioning of a drilling diamond instrument. Force and thermal loading of diamond grains and matrix, their wear intensity, effectiveness of the whole process essentially depend on a distribution law of contact pressure on the working surface of a bit.

The problems on the steady distribution of a contact pressure in conjugation «bit-bottom hole» have been considered in a series of papers [1,2 and others]. But the problems of unsteady distribution (redistribution) of contact pressure in indicated linking until were not formulated and investigated properly. It is known that as a result of presence of the end play of the bit, it holds a uniform initial distribution of contact pressure on the working surface of the tool [1]. In the process of well drilling, because of wear of the bit, this non-uniformity is removed gradually. In the paper we attempt to consider the mathematical model the indicated phenomena for the case, when the width of the working part of the impregnated bit is sufficiently small (column instrument). This admits essentially to simplify the solution of the stated problem, neglect the alternations of contact pressure depending on radial coordinates and investigate the process of redistribution of forces of bottom hole reaction only along the periphery of the bit end.

We must note that the end play of the bit may hold as a result of inevitable errors in preparation of the instrument (some sinousity of the end surface on periphery: non-perpendicularity of the end plane to the axis of the threaded joint of the bit; initial deviation of the axis of the drilling column bottom from straight line and etc.).

We assume that in the considered case the bit rotates around the fixed axis. We consider the axial load $\overline{Q}$ to be a constant quantity. From the balance condition we have

$$rs\psi\int_0^{2\pi} q(\alpha,\varphi)d\alpha - Q = 0\,, \tag{1}$$

where r is a mean radius of the working surface of the bit end ($r=\frac{r_1+r_2}{2}$; where r_1 and r_2 are internal and external radiuses of the bit); s is the width of the bit end $(s=r_2-r_1)$; ψ is a coefficient considering the presence of flushing groove $\left(\psi=1-\frac{b}{2\pi r}\right)$, where b - is a total width of flushing grooves on the periphery of the radius r; $q(\alpha,\varphi)$ is a contact pressure; α is a corner coordinate of an arbitrary point of the bit end (it is measured from some fixed point of the latter); φ is the corner of the bit rotation under its rotary motion.

We obtain from (I)

$$\int_0^{2\pi} q(\alpha,\varphi)d\alpha = \frac{Q}{rs\psi}. \tag{2}$$

The moving value of a longitudinal descent of the instrument may be defined by the formula

$$h(\varphi) = \Delta(\alpha) + \delta(\alpha,\varphi) + u_n(\varphi) + u(\alpha,\varphi), \tag{3}$$

where $\Delta(\alpha)$ is the function characterizing the deviation of the bit end from the plane, perpendicular to the rotation axis of the instrument; $\delta(\alpha,\varphi)$ is the thickness of removable stratum under the well drilling; $u_n(\varphi)$ is the thickness of removable stratum under well drilling; $u(\alpha,\varphi)$ is the wear of the bit end. We consider that a rock deformation at the given point is proportional to the contact pressure at this point, i.e.

$$\delta(\alpha,\varphi) = k_1 q(\alpha,\varphi), \tag{4}$$

where k_1 is a constant proportionality coefficient (coefficient of the rock compliance).

Differentiating (3) with respect to φ and considering (4) we find

$$\frac{dh(\varphi)}{d\varphi} = k_1 \frac{\partial q(\alpha,\varphi)}{\partial\varphi} + \frac{\partial u(\alpha,\varphi)}{\partial\varphi}. \tag{5}$$

According to the statements of the theory of conjugation wear, the wear intensity of the working surface of the bit end at its given point at the first approach we adopt as proportional to contact pressure [3,4] . Thus,

$$\frac{\partial u(\alpha,\varphi)}{r\partial\varphi} = k_2 q(\alpha,\varphi), \tag{6}$$

where k_2 is a constant, characterizing the wearability of the working surface of the bit end at the given conjunction (wear coefficient).

Considering (6), expression (5) may be represented in the form

$$\frac{\partial q(\alpha,\varphi)}{\partial\varphi} + \lambda r q(\alpha,\varphi) = \frac{dh(\varphi)}{k_1 d\varphi}, \tag{7}$$

where $\lambda = \frac{k_2}{k_1}$. Differentiating (2) with respect to φ we have

$$\int_0^{2\pi} \frac{\partial q(\alpha,\varphi)}{\partial\varphi} d\alpha = 0. \tag{8}$$

According to (7)

$$q(\alpha,\varphi) = \frac{1}{k_2 r}\frac{dh(\varphi)}{d\varphi} - \frac{1}{\lambda r}\frac{\partial q(\alpha,\varphi)}{\partial\varphi}. \tag{9}$$

Substitute (9) in (2):

$$\frac{\pi}{k_2 r}\frac{dh(\varphi)}{d\varphi} - \frac{1}{2\lambda r}\int_0^{2\pi}\frac{\partial q(\alpha,\varphi)}{\partial\varphi}d\alpha = \frac{Q}{2rs\psi}. \tag{10}$$

Whence with regard to (8) we find

$$\frac{dh(\varphi)}{d\varphi} = \frac{k_2 Q}{2\pi s\psi}. \tag{11}$$

The quantity $\frac{Q}{2\pi rs\psi}$ represents a mean contact pressure in conjunction, i.e. $\frac{Q}{2\pi rs\psi}=q_{cp}$. As a result, the differential equation (7) is reduced to the form

$$\frac{\partial q(\alpha,\varphi)}{\partial\varphi}+\lambda rq(\alpha,\varphi)=\lambda rq_{cp}. \tag{12}$$

The solution of the equation with regard to initial condition $q|_{\varphi=0}=q(\alpha,0)$ may be represented in the form

$$q(\alpha,\varphi)=q_{cp}+\left[q(\alpha,0)-q_{cp}\right]e^{-\lambda r\varphi}. \tag{13}$$

We see from the obtained solution that the parameter λ influences to the speed of running in of the bit, i.e. the wear coefficient relation of the instrument to the compliance coefficient of the rock. We analyze a partial case for definiteness, when the bit end is plane, but is not perpendicular to the rotation axis of the tool. In this case, the parallelism of the working surface of the bit end and of the bottom-hole surface is excluded.

Let at the initial moment, the bit end has a plane form and constitutes some angle γ with the plane, perpendicular to the rotation axis of the tool. Then, at the first approach, an initial distribution of contact pressure we can express by the formula:

$$q(\alpha,0)=q_0+\frac{1}{k_1}\delta_1(\alpha,0), \tag{14}$$

where q_0 is the least contact pressure in the conjunction at initial moment (corresponds to the point $\alpha=0$, i.e. $q_0=q(0,0)$); $\delta_1(\alpha,0)$ is the additional elastic deformation of a rock arising because of the end play of the tool. At this case $\delta_1(\alpha,0)$ may be defined from geometrical relations. We shall have

$$\delta_1(\alpha,0)=r(1-\cos\alpha)tg\gamma. \tag{15}$$

Consequently

$$q(\alpha,0)=q_0+\frac{r}{k_1}(1-\cos\alpha)tg\gamma. \tag{16}$$

Substituting (16) to the balance condition (I) and considering an expression of the mean contact pressure, we find

$$q_0=q_{cp}-\frac{r}{k_1}tg\gamma. \tag{17}$$

As a result we have

$$q(\alpha,0)=q_{cp}-\frac{r}{k_1}tg\gamma\cos\alpha. \tag{18}$$

Then according to (13) we get

$$q(\alpha,0)=q_{cp}-\frac{r}{k_1}e^{-\lambda r\varphi}tg\gamma\cos\alpha. \tag{19}$$

A partial case is possible, when $q_0=0$. In this case, according to (17) $\frac{r}{k_1}tg\gamma=q_{cp}$ and the definition $q(\alpha,\varphi)$ is reduced to the formula

$$q(\alpha,\varphi)=q_{cp}\left(1-e^{-\lambda r\varphi}\cos\alpha\right). \tag{20}$$

For comparative estimates and convenience of qualitative analysis, to use dimensionless contact pressure

$$\tilde{q}(\alpha,\varphi)=\frac{q(\alpha,\varphi)}{q_{cp}}=1-e^{-\lambda r\varphi}\cos\alpha\,. \tag{21}$$

turns out to be more appropriate.

It follows from the obtained solution that by increasing φ, i.e. in the course of time (under constant corner velocity of the tool, the angle φ is proportional to the time), contact pressure at the bit end is leveled. The values of the parameter λ (i.e. the relation of wear coefficient of the tool end to the coefficient of the rock compliance) and the mean radius of the working surface of the mean radius of the working surface of the bit have a great influence on the intensity of the process. The obtained solution allows qualitatively estimate the given influence.

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