ESTIMATION OF RESIDUAL RESOURCE OF TOOL SCREWED JOINTS FROM VIEWPOINT OF DESTRUCTIVE MECHANICS

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The analysis of data given in [1] demonstrates, that the fair quantity of drilling string failures consists from failure of tool threads in latches (from 21,7 up to 39 %) and circa 75 % of these failures have fatigue nature. Usually fracture is propagated in dangerous section (DS), which is situated in a plain, which goes through the first thread coil of a nipple and is perpendicular to the axis of tool screwed joint (TSJ). Studies, held in papers [2, 3] demonstrate, that fatigue fractures (FF), which propagate in DS may have both ring-shaped and elliptical form. If propagation kinetics of the first kind fractures is widely highlighted in literature [4, 5, 6, 7 and others], than the second kind of fractures is not developed properly jet [3, 8]. Consequently the problem of residual resource estimation in TSJ with elliptical fracture remains actual.

As the durability of screwed joints in operating drilling string is determined by the rate of damage of DS by tiresome fracture, than it can be assessed the best way from the viewpoint of destructive mechanics.

Let's assume, that after N_1 cycles of loading elliptical FF has maximum coefficient of stresses intensity (CSI) along its front and is equal to K_{max1}. At N2, accordingly, the maximum value of CSI will be equal to K_{max2}. Apparently, that number of loading cycles and values K_{max} have certain dependence

$$K_{max} = f(N). \tag{1}$$

For further use let's write equation (1) the following way

$$N = f_1(K_{max}). \tag{2}$$

Using (2) let's find the number of TSJ loading cycles between two sequential stages of FF growth with maximum CSI, namely $K_{max,i}$, and $K_{max,i+1}$

$$N_d = N_{i+1} - N_i = f_1(K_{max,i+1}) - f_1(K_{max,i}) \tag{3}$$

If some extreme value CSI K_k, at which TSJ failures, or joint loses it's technological characteristics (for example airtightness), is substituted to expression (3) instead of $K_{max,i+1}$, we shall receive equation for estimation of a residual resource

$$N_\beta = f_1(K_k) - f_1(K_{max,i}), \qquad (4)$$

where $K_{max,i}$ is CSI value at the moment of registration.

For practical application (4) it is necessary to have an algorithm for calculation of maximum value of stresses intensity coefficient, digital value of K_k and dependence f_1, given in analytical kind.

To derive arguments, given above for certain TSJ Z-121 GOST 5286-75, let's use the results of experiment, held by author [4]. Nature of studies is following: a screwed joint was loaded by bending moment only with torsion on a testing machine IP-7 with nominal bending moment equal to 2070 Nm. During trials the loading on sample gradually moderated with the purpose to stop the growth of FF in nipple and to stop it's originating in the section of so-called "lines of front halting", which are indicated by arrows (figure 1). Due to this it was possible to establish more precise dependence of fracture arguments from number of loading cycles.

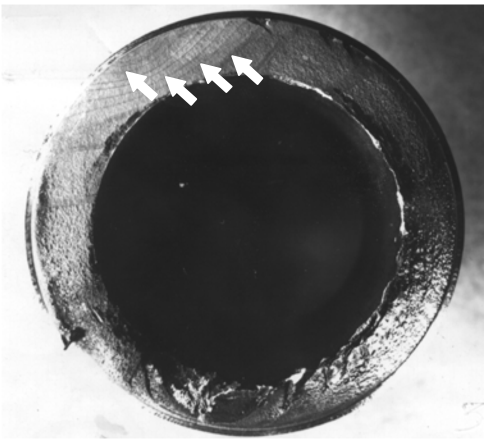

Figure 1 – Fractogram of dangerous section with elliptical fatigue fracture

For any FF front position, which coincides with "lines of front halting" the maximum value of CSI was calculated according to formula [9]

$$K_{max} = 1{,}13\sigma_{max} b^{\frac{1}{2}} \left[\frac{b}{a} \cdot \frac{2\Theta}{\pi} \left(\frac{b}{d} - 0{,}4 + 0{,}6\frac{b}{a} \right) + \frac{b}{a} \left(1 - 1{,}4\frac{b}{d} \right) + \right.$$
$$\left. + 0{,}62\lambda \left(1 - \frac{b}{a} \right) \left(\frac{b}{d} \right)^{-\frac{1}{2}} \sqrt{\left(1 - \frac{b}{d} \right)^{-3} - \left(1 - \frac{b}{d} \right)^{3}} \right], \qquad (5)$$

$$\lambda = \begin{cases} 1{,}15 - 60\left(\dfrac{b}{d}\right)^2, \text{при} \dfrac{b}{d} \langle 0{,}05 \\ 1, \text{при} \dfrac{b}{d} \rangle 0{,}05 \end{cases}$$

where Θ – is an angular coordinate, which determines the dot at the outline of fracture front; a – the size of large semiaxis of the ellipse ; b – the size of small semiaxis of the ellipse; d – exterior diameter of nipple at the cavity of a thread; σ_{max} – maximum stress of cycle, which is equal to sum of screwing stress and bending moment stress M [10]

$$\sigma_a = \frac{MY}{I} \qquad (6)$$

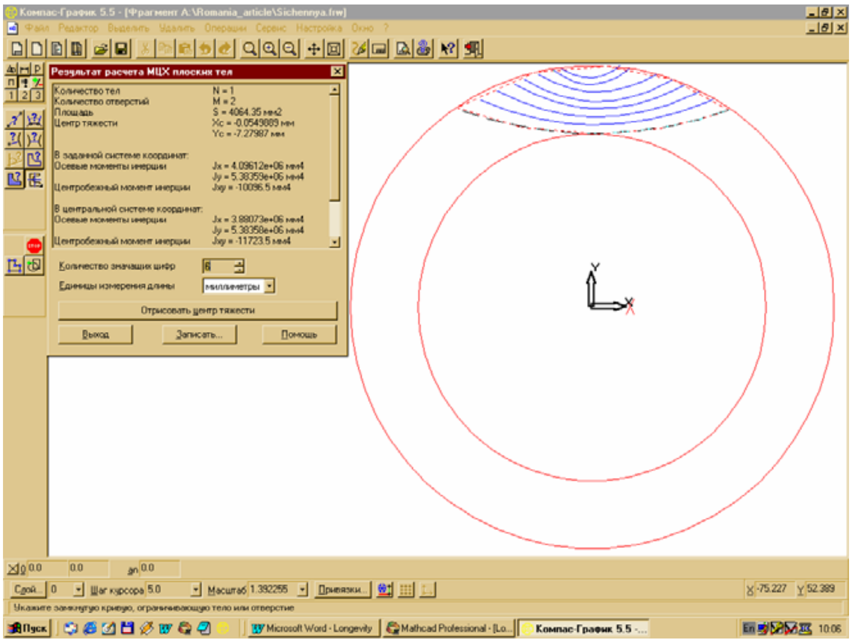

Figure 2 – Software environment "Compas 5.5", used to determine inertia moments in dangerous sections

Here Y – is the distance from central axis of a nipple to the point of FF front intersection with its exterior surface; I - inertia moment of DS, calculated by the mean of software package "Compass 5.5" (figure 2).

Obtained values of stresses intensity coefficients and corresponding operating time values are introduced at figure 3 as a plot. Having approximated values, we may write equation (2) as follows

$$N = -2{,}31 \cdot 10^5 + 352{,}58 K_{max},$$

and equation (4) as follows:

$$N_\beta = -2{,}31 \cdot 10^5 + 352{,}58 K_к - \left(-2{,}31 \cdot 10^5 + 352{,}58 K_{max}\right),$$

or having simplified

$$N_\beta = 352{,}58\left(K_к - K_{max}\right). \qquad (7)$$

Having replaced constant 352,58 in formula (7) by variable m we shall receive

$$N_{\beta} = m\left(K_{к} - K_{max}\right),$$

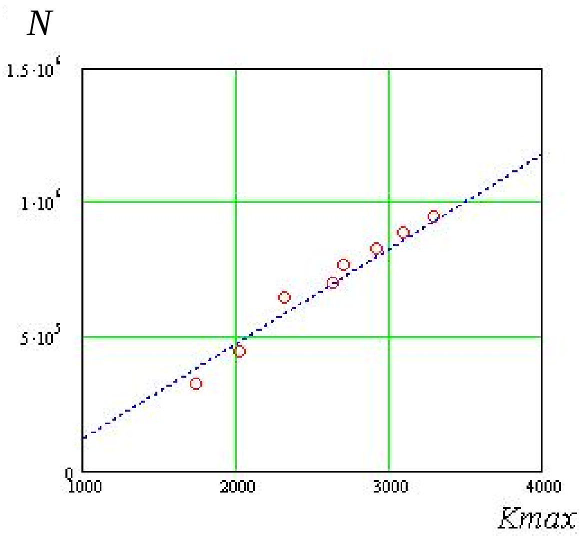

Figure 3 – Dependence of loading cycles number from maximum value of CSI

where $K_{к}$ – is the maximum value of CSI at reaching internal hollow of nipple by FF front; K_{max} – maximum value of CSI at the moment of registration; m – coefficient, which is considered as a constant for determined standard size of TSJ in case of DS damage by elliptical fracture (for example for Z-121 m=352,58).

Thus, received method of application resolves to assess residual resource of tool joints at drill-pipes, allowing not only standard size of TSJ and arguments of loading, but also geometrical and kinetic parameters of FF propagation, which is reason of failure.

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