THE EVALUATION OF DRILLING PIPES DURABILITY AT ASYMMETRICAL CYCLE

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ABSTRACT: The different application methods of material fatigue properties investigation leads to construction of dissimilar fatigue curves. The calculation of durability at transit from one method of construction endurance curve to another are observed. The coefficients for recalculation of limited durability corresponded to investigations by different methods were offered.

The examined of different scientific sources testifies about three methods of fatigue curves construction at asymmetrical cycle. These methods don't depend on kind of loading (extension, stress, torsion, flexure etc.)

1-st method. Fatigue curve is constructed at constant average loading σ_m or τ_m. [1-3]

2-nd method. Fatigue curve is constructed at constant minimum loading σ_m or τ_m. [4]

3-rd method. Fatigue curve is constructed at constant coefficient of cycle asymmetry $r = \sigma_{min}/\sigma_{max}$.

The superficial inspection of scientific data testifies about application of different method in researches.

In fact, the application of different methods leads to construction of dissimilar fatigue curves. The variable physical value is taken into account as a constant parameter.

Example. The two fatigue curves are constructed by the 1-st method at different average stresses $\sigma_m=S_1$, $\sigma_m=S_2$. The relation between failure stress and cycle number logarithm is constructed as linear. The equations of durability lines for the 1-st and the 2-nd curves are given:

$$\sigma_1 = P_1 - K_1 \ln N_1 \qquad (1)$$

$$\sigma_2 = P_2 - K_2 \ln N_2 \qquad (2)$$

σ_1,σ_2 – maximum stresses,

N_1,N_2 – cycle numbers before failure,

P_1,P_2,K_1,K_2 – constants.

The equations (1) and (2) correspond the investigation results conducted at monotonically variation of σ_m value. The durability values can be found on lines circumscribed by (1) and (2) equations that correspond investigations at σ_{min} = M. The well-known relation can be taken into account.

$$\sigma = 2\sigma_m - \sigma_{min}$$

and the following durability values can be gained:

$$\lg N_1 = \frac{P_1 - M - 2S_1}{K_1}; \lg N_2 = \frac{P_2 + M - 2S_2}{K_2} \quad (3)$$

The stresses that correspond the durabilities circumscribed by equations (3), can be determinated as:

$$\sigma_1 = 2S_1 - M; \sigma_2 = 2S_2 - M \quad (4)$$

The line of limited endurance at constant σ_{min} = M of given material can be constructed across two points. These points were found on two curves. The line is circumscribed by the following equations:

$$\tau = P_{12} - K_{12} \ln N \quad (5)$$

$$K_{12} = \frac{2(S_1 - S_2)}{a_{12} - b_{12}} b_{12} \quad (6)$$

$$P_{12} = \frac{(2S_1 - M)a_{12} - (2S_2 - M)b_{12}}{a_{12} - b_{12}} \quad (7)$$

$$a_{12} = \frac{1}{K_2}(P_2 + M - 2S_2) \quad (8)$$

$$b_{12} = \frac{1}{K_2}(P_1 + M - 2S_1) \quad (9)$$

The line of limited endurance that corresponds to another methods can be found with the help of two lines of limited endurance constructed at different asymmetry. The satisfactory precisions of calculation provided by definite statistic trustworthiness of two experimental lines of limited durability. The endurances for coefficients K and P that necessary for recalculation of durability lines at transition from one method to another are shown in the table 1.

Table 1 – The coefficients for recalculation of limited durability corresponded to investigations by different methods.

Index of Recacalculation*	K	P	a	b
12	$K_{12} = \frac{2(S_1 - S_2)}{a_{12} - b_{12}}$	$P_{12} = \frac{(2S_1 - M)a_{12} - (2S_2 - M)b_{12}}{a_{12} - b_{12}}$	$a_{12} = \frac{1}{K_2}(P_2 + M - 2S_2)$	$b_{12} = \frac{1}{K_1}(P_1 + M - 2S_1)$
13	$K_{13} = \frac{2(S_1 - S_2)}{(a_{13} - b_{13})(r+1)}$	$P_{13} = \frac{2(S_1 a_{13} - S_2 b_{13})}{(a_{13} - b_{13})(r+1)}$	$a_{13} = \frac{P_2(r+1) - 2S_2}{K_2(r+1)}$	$b_{13} = \frac{P_1(r+1) - 2S_1}{K(r+1)}$
21	$K_{21} = \frac{M_2 - M_1}{a_{21} - b_{21}}$	$P_{21} = \frac{(2S - M_1)a_{21} - (2S - M_2)b_2}{a_{21} - b_{21}}$	$a_{21} = \frac{1}{K_1}(P_2 + M_2 - 2S)$	$b_{21} = \frac{1}{K_1}(P_1 + M_1 - 2S)$
23	$K_{23} = \frac{M_1 - M_2}{r(a_{23} - b_{23})}$	$P_{23} = \frac{M_1 a_{23} - M_2 b_{23}}{r(a_{23} - b_{23})}$	$a_{23} = \frac{P_2 r - M_2}{K_2 r_2}$	$b_{23} = \frac{P_1 r - M_1}{K_1 r_1}$
31	$K_{31} = \frac{2S(r_2 - r_1)}{(a_{31} - b_{31})(r_1+1)(r_2+1)}$	$P_{31} = \frac{2S[a_{31}(r_2+1)] - b_{31}(r_1+1)}{(a_{31} - b_{31})(r_1+1)(r_2+1)}$	$a_{31} = \frac{P_2(r_2+1) - 2S}{K_2(r_2+1)}$	$b_{31} = \frac{P_1(r_1+1) + 2S}{K_1(r_1+1)}$
32	$K_{32} = \frac{M(r_2 - r_1)}{r_2 r_1(a_{32} - b_{32})}$	$P_{32} = \frac{M r_2 a_{32} - M r_1 b_{32}}{r_1 r_2(a_{32} - b_{32})}$	$a_{32} = \frac{P_2 r_2 - M}{K_2 r_2}$	$b_{32} = \frac{P_1 r_1 - M}{K_1 r_1}$

* The first figure of double index means method number of constructed experimental fatigue curves, the second figure means method number of calculating coefficient values. In corresponded with designations:

1 - investigation at σ_m=const

2 - investigation at σ_{min}=const

3 - investigation at r=const

The result of investigation at cycle torsion of 60XC steel can be observed by example.

Table 2 – Compositions of 60XC steel (Wt %)

C	Cr	Si	Mn	Ni	S	P
0,58	0,86	1,35	0,62	0,10	0,006	0,021

The investigations were conducted by resonance machine [5] at frequency 40Hz on samples ∅6 mm. Steel 60 XC was chilled at 860^0C after law tempering (2 hours, at 100^0C). The investigation were conducted by the 1-st method at τ_m = 60MPa; τ_m = 0 (symmetrical cycle). The results are shown on fig.2. Statistic calculation [6] of results gives opportunity to construct correlative relations of limited endurance (lines 1 and lines 2):

$\tau_1 = 130{,}7 – 14{,}93\ N_1\ (\tau_m = 0)$,

$\tau_2 = 181{,}7 – 15{,}53\ N_2\ (\tau_m = 60\ MPa)$.

Line of limited durability at constant minimum stress τ_{min} = 5 MPa can be found. The recalculation is conducted from the 1-st method to the 2-nd method. Equations situated in the first line of table 1 must be used.

Equation of durability line at τ_{min}=5 MPa is shown (fig.2, line 3):

$\tau = 224{,}44–25{,}01\ lgN$.

We conduct fatigue investigations of 60XC steel at τ_{min} = 5 MPa for examination of trustworthiness of calculation curve and construct fatigue curve (line 4). The correlative relation of experimental curve is shown:

$\tau^I = 216{,}17 – 23{,}66\ lg\ N$.

Maximum departure of bearing ability $\Delta\tau$ from calculation value takes place at $N \cong 2 \bullet 10^6$ cycles and doesn't exceed 2MPa. That follows from lines on fig.2.

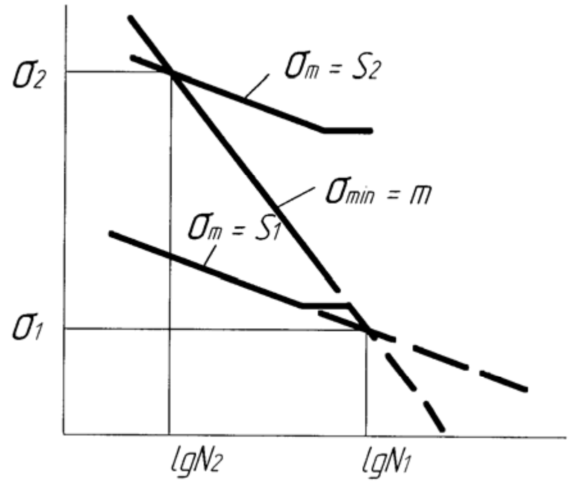

Fig. 1. The diagram for calkulation of durability at transit from endurance curves are constructed at σ_m = const to curve constructed at σ_{min} = const

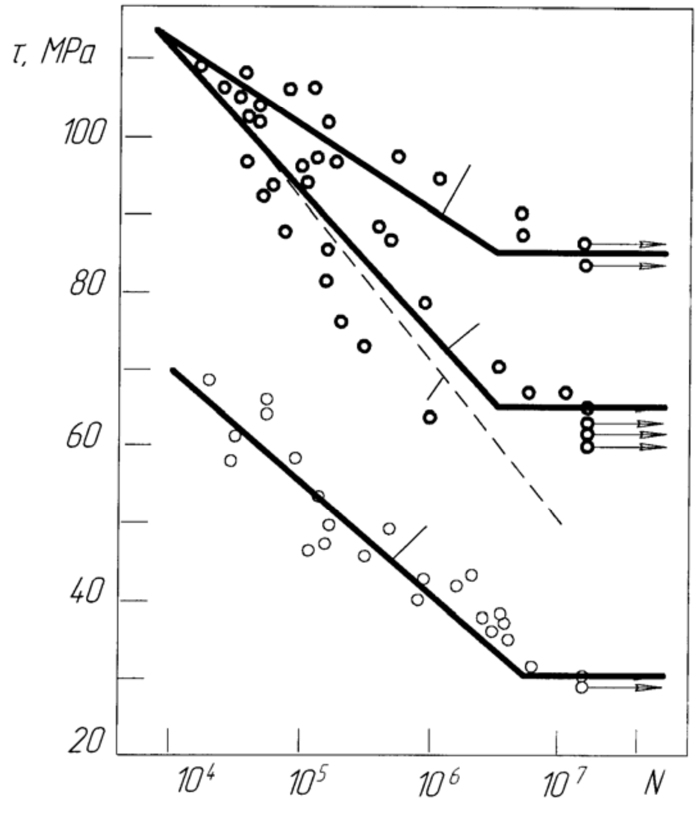

Fig. 2. Fatigue curves of 60XC steel atorsion:

1 – $\tau_m = 0$ (symmetrrical cycle)

2 – $\tau_m = 60$ MPa

3 – culculation curve for $\tau_{min} = 5$ MPa

4 – experimental curve for $\tau_{min} = 5$ MPa

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