INDIVIDUAL FATIGUE LIMITS DEFINITION USING MODERNIZED WEIBULL EQUATION PARAMETERS

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Abstract: The relation for determination of an individual fatigue limit based on the modernized Weibull equation was obtained. The assessment of the comparative evaluation of individual fatigue limit for two selected S-N curve models was carried out.

The experimental verification of the proposed relation was done using specimens made from grade Steel 35 (GOST 1050-88).

Key words: fatigue limit, endurance, S-N curve parameters

1. PROBLEM STATEMENT

The experimental methods of fatigue limit determination are divided into two groups. To the first group refer methods in which parameters of a S-N curve are obtained by performing fatigue tests for similar objects fabricated from the same grade. In that case these methods are considered as verification (controlling) methods.

To the second group refer methods based on correlation relations between parameters of a S-N curve and fatigue limit [1, 2]. Not high accuracy of second group methods constraints their application by necessity of the prior fatigue limit assessment. As for the methods of the first group, they have reserves of increasing their precision due to the ability of more strict definition of S-N curve parameters by means of using different mathematical models.

2. RESEARCH OBJECTIVE

To get the relation for individual fatigue limit definition, based on the

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modernized Weibull equation, and carry out an experimental approval of obtained solution.

3. EXPOSITION OF THE MAIN STUFF OF THE RESEARCH

It was proposed [3] to use the Weibull equation for description of the experimental results of the fatigue tests in which the fatigue limit was replaced by the variable parameter. This parameter was defined from the maximum condition of the correlation coefficient

$$(\sigma - \sigma_{\mathrm{R}})^{m_W} \cdot N = 10^{C_W} \tag{1}$$

$$(\sigma - A)^{m'_W} \cdot N = (\sigma_R - A)^{m'_W} \cdot N_{\mathrm{GW}} = 10^{C'_W}, \tag{2}$$

where σ_R – fatigue limit; σ and N – current stress cycle amplitude and endurance; N_{GW} – endurance that corresponds the fatigue limit; m_W, m'_W, C_W, C'_W and *A-S-N* curve parameters.

Having evaluated from the equation (2) σ_R, we obtain

$$\sigma_R = A + \left[\frac{(\sigma - A)^{m'_W} \cdot N}{N_{GW}} \right]^{1/m'_W}. \tag{3}$$

In this equation the mean values of parameters are used. For the individual fatigue limit definition from equation (3) it was assumed that m'_W and N_{GW}, which correspond to the S-N curve of an average probability, are similar for all group of test specimens. For the comparative evaluation of fatigue limit values that have been obtained based on two selected models of S-N curve let's appeal to test data [4]. The test results for grade Steel 35 (GOST 1050-88) specimens that were undergone to pure bending, fatigue limits, S-N curve parameters, correlation coefficients and mean square deviation of the fatigue limits are given in the table 1.

Table 1. **Experimental and calculated parameters for the grade Steel 35 (GOST 1050-88) specimens**

N specimen	**σ, MPa**	***N*, cycle**	**Evaluation (1)**				**Evaluation (3)**			
			R	σ_{Ri}, **MPa**	δ_{σ_R}, **%**	S'_{σ_R}, **MPa**	σ_{Ri}, **MPa**	***R***	δ_{σ_R}, **%**	S''_{σ_R} **MPa**
(σ_R =190 MPa; m_W =1,2; C_W =7,5; m'_W =4,9; C'_W =16,8; A = 55 MPa; S_{σ_R} =7,3 MPa)										
1	320	62300	0,9438	140,7	-25,9	14,0	181,9	0,9720	-4,3	7,5
2	320	81900		177,2	-6,7		189,2		-0,4	
3	320	86100		183,0	-3,7		190,6		0,3	
4	320	91400		189,7	-0,2		192,2		1,2	

N specimen	**σ, MPa**	***N*, cycle**	**Evaluation (1)**				**Evaluation (3)**			
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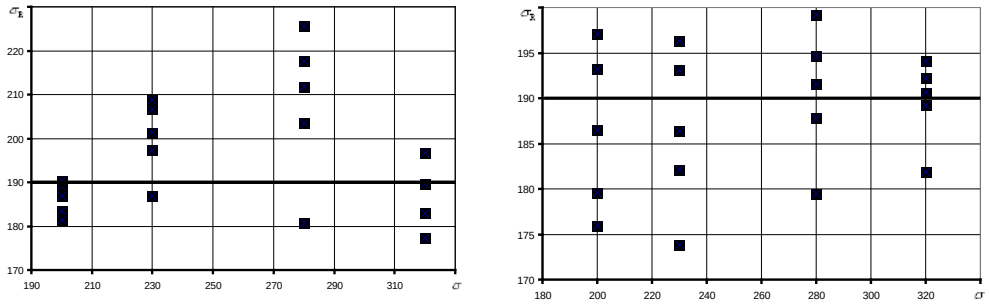
(σ_R =190 MPa; m_W =1,2; C_W =7,5; m'_W =4,9; C'_W =16,8; A = 55 MPa; S_{σ_R} =7,3 MPa)										
5	320	97800		196,8	3,6		194,1		2,2	
Mean value for the stress level				177,5	6,6		189,6		-0,2	
6	280	126700		180,7	-4,9		179,5		-5,5	
7	280	173200		203,5	7,1		187,8		-1,2	
8	280	198600		211,7	11,4		191,5		0,8	
9	280	221300		217,6	14,5		194,6		2,4	
10	280	260100		225,5	18,7		199,2		4,9	
Mean value for the stress level				207,8	9,4		190,5		0,3	
11	230	344500		186,8	-1,7		173,8		-8,5	
12	230	563400		201,4	6,0		186,4		-1,9	
13	230	479200		197,2	3,8		182,1		-4,2	
14	230	719800		206,6	8,7		193,1		1,6	
15	230	805400		208,7	9,8		196,3		3,3	
Mean value for the stress level				200,1	5,3		186,3		-1,9	
16	200	941600		181,3	-4,6		175,9		-7,4	
17	200	1094000		183,5	-3,4		179,6		-5,5	
18	200	1423000		186,8	-1,7		186,5		-1,8	
19	200	1816000		189,2	-0,4		193,2		1,7	
20	200	2085000		190,4	0,2		197,1		-1,4	
Mean value for the stress level				186,2	-2,0		186,5		-2,9	
Generalized mean value				192,9	1,5		188,2		-1,2	

The following signs are used in the table: R - selective calculated correlation coefficient; S_{σ_R}, S'_{σ_K}, S''_{σ_R} - mean square deviation of the fatigue limits that were found by using "up-and-down" (staircase) method; δ_{σ_R} - evaluation error for a fatigue limit. The relation $\sigma_{Ri}(\sigma)$ from the table 1 is shown on the fig. 1 for the pictorial presentation of the individual fatigue limit distribution versus its mean probability.

4. CONCLUSION

Mean square deviation of the fatigue limits S'_{σ_R}, that were calculated based on Weibull equation, does not correspond to its real value and exceeds it several times. At the same time S_{σ_R} and S''_{σ_R} are very close to each other.



a b

Fig. 1. The distribution of the specimen individual fatigue limits for the grade Steel 35 (GOST 1050-88) specimens in according to stress levels
a – under equation (1); b – under equation (2)

In the case of modernized Weibull S-N curve using fatigue limit definition error for all cases is lower, then in the case of using of traditional Weibull equation which is specified by higher correlation coefficient of equation (2). For small endurance the individual fatigue limit errors, that have been calculated based on Weibull equation, were found the highest. That fact shows us that in this area Weibull equation fits poorly with the test results;

In the case of individual fatigue limit calculation based on the equation (3) its scattering for every stress level were founded as practically equal, i. e. real. And in the case of using traditional Weibull equation its growth is observing with the increasing of the stress level σ.

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