UDC 622.692.4

Calculation models aspect for pipelines joint welds evaluation for the purpose of their endurance life increasing

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The main internal load, which is taken up by the pipe walls, is operating pressure load. Depending on the characteristics and purposes of the gas pipeline, the gas flow mode may be of two types: stationary and transient. Such pressure time oscillations lead to cyclic loading change in pipe walls at the frequency that approximately corresponds to the daily load cycle period. These loads may be considered as low-frequency cyclic loads.

In order for joint of this type to have permanent characteristic fatigue resistance, it makes sense to assume the confidence probability value $\gamma = 1 - \alpha$ as constant, independent from type of design and its purpose. At the same time, it would not be reasonably to maintain the corresponding design fatigue resistances the same for all the designs. Depending on the degree of design compliance, the probability of joints survival should be accepted as different.

The confidence probability is suggested to be accepted as equal $\gamma = 1 - 0,1 = 0,9$. In this case, a formula that determines the design fatigue resistance of joint weld with accepted confidence probability $\gamma = 0,9$ and survival probability P is of the form

$$R_r(P) = R_r^H - \Delta R(P) = [\sigma_r - \Delta\sigma_r] - \Delta R(P)$$

The limit of endurance σ_r is determined experimentally or by extrapolating up to $5 \cdot 10^6$ cycles. The values $\Delta\sigma_r$ and $\Delta R(P)$ may be calculated by known mean square deviation of endurance strength assuming normal law of its distribution and adequacy of the amount of conducted fatigue tests.

The method of load step change provides the stable values σ_r, $\Delta\sigma_r$, $\Delta R(P)$. In accordance with this method, at least 40-50 samples are tested in fatigue curve asymptotic area. Approximately 50% of these samples undergo number of tests without destruction [2]. However, it is difficult to execute such amount of experimental work considering the variety of explored joints and the need to repeat all the tests for each joint type at different cycle characteristics. In this regard, the possible ways of σ_r, $\Delta\sigma_r$, $\Delta R(P)$ evaluation should be considered according to testing data of limited number of samples.

When the tests are carried out in the field of a limited durability, these parameters dependence on the type of connection and cycle characteristics can be set by means of extrapolation using previously mentioned fatigue curve equation

$$\sigma = \sigma_r e^{\frac{m}{N+B}}$$

By taking the logarithm and replacing of coordinates $\frac{m}{N+B} = y$ and $\ln\sigma = x$, the equation $\sigma = \sigma_r e^{\frac{m}{N+B}}$ is reduced to the linear equation of the form

$y = b(x - c)$,

where $b = \frac{1}{m}$ and $c = \ln\sigma_r$.

The equation parameters b and c were determined when $B = 21\cdot10^4$ using correlation analysis of fatigue test results, which are indicated above the joints. After calculating of the average values of variables

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \text{ i } \bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i ,$$

their dispersions are

$$S_x^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$$ and

$$S_y^2 = \frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2 ,$$

and also of correlation coefficient

$$r_{xy} = \frac{1}{n-1}\frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{S_x S_y}$$

The values b and c, according to least square method under conditions of life dispersion independence from the stress level, are determined from the equations

$$b = r\frac{S_y}{S_x} \text{ and } c = \bar{x} - \frac{\bar{y}}{b}$$

The limited dependence of life dispersion from the stress level has been proved be testing results of 160 samples with crossing welds for the stage of crack formation. The homogeneity evaluation, which was conducted by Romanovsky and Bartlett, showed that the dispersion is homogeneous in the case when the criteria for testing completion is the initial stage of crack development. If the tests are carried out to complete breakdown, the dispersion is not homogeneous.

The target values $\Delta\sigma_r$, $\Delta R(P)$ are determined by equations

$$\Delta\sigma_r = \sigma_r - (\sigma_r)^C$$

$$\Delta R(P) = (\sigma_r)^C - (\sigma_r)^P$$

where $(\sigma_r)^C$ - the lower confidence interval of endurance limit average value; $(\sigma_r)^P$ - endurance strength lower limit, which corresponds to survival probability P.

The values $(\sigma_r)^C$ were determined in accordance with

$$\ln(\sigma_r)^C = c - \frac{t_\alpha(f)S}{b\sqrt{n}} = c - \frac{t_\alpha(f)S_y\sqrt{1-r_{xy}^2}}{b\sqrt{n}}$$

where S - dispersion that characterizes the measure of experimental data x_i and y_i spread relatively to straight line; n – tests number; $t_\alpha(f)$ - Student critical distribution; $f = n - 1$ - the number of free stages.

The values $(\sigma_r)^P$ were determined from equation

$$\ln(\sigma_r)^P = c - \frac{k_d S_y\sqrt{1-r_{xy}^2}}{b}$$

where k_d - coefficient, which depends on the probability of a given distraction. Its values are tabulated in the Table of bilateral tolerance limits.

Table 1. The main values, which determine the target values $\Delta\sigma_r$, $\Delta R(P)$

Equations parameters	Joints and cycle characteristics

	Butt r=-1	Surface r=-1	Surface r=0	Junction with crossing welds r =-1
n	20	20	20	20
$\overline{x}$	2,2887	1,9414	2,3850	2,5273
S_x	0,2072	0,3772	0,2169	0,1543
$\overline{y}$	$0,1415 \cdot 10^{-5}$	$0,1610 \cdot 10^{-5}$	$0,1217 \cdot 10^{-5}$	$0,2167 \cdot 10^{-5}$
S_y	$0,7666 \cdot 10^{-6}$	$0,8671 \cdot 10^{-6}$	$0,5907 \cdot 10^{-6}$	$0,9757 \cdot 10^{-6}$
r_{xy}	0,9765	0,9633	0,9574	0,9766
m	276778	451555	383530	161993
b	$0,3613 \cdot 10^{-5}$	$0,2414 \cdot 10^{-5}$	$0,2607 \cdot 10^{-5}$	$0,6173 \cdot 10^{-5}$
$S_y \sqrt{1-r^2}$	$0,1645 \cdot 10^{-6}$	$0,2324 \cdot 10^{-6}$	$0,1707 \cdot 10^{-6}$	$0,2099 \cdot 10^{-6}$
c	1,8871	1,2142	1,9182	2,1763
σ_r	6,60	3,37	6,81	8,81
$(\sigma_r)^c$	6,48	3,22	6,64	8,69
$\Delta\sigma_r$	0,12	0,15	0,17	0,12
$(\sigma_r)^P = 0,95$	5,99	2,69	5,91	8,19
$(\sigma_r)^P = 0,975$	5,88	2,57	5,76	8,08
$(\sigma_r)^P = 0,995$	5,67	2,36	5,46	7,86

As in this case, the one-sided dispersion limit is of interest only to corresponding probability, the value of such probability P is associated with tabulated probability ratio P_m.

$$P = P_m + \frac{1-P_m}{2}$$

Conclusions

It is impossible to set the dispersion lower limit of endurance strength of total population when such determining of value σ_r .At that, on the basis of the noted above statistical analysis, the lower and upper limit the stress can be found, where one of the described test cases is possible if significant probability β of their occurrence is set. Obviously, with the sufficient accuracy for practice, the occurrence probability of each of the two test results under consideration may be accepted as significant, which allow the equation $\beta \geq 0,05$. Then the average value of the endurance limit will be between lower and upper dispersion limits in the range the stress. For them, the probability of each of these test results is less than 0.05 ($\beta \leq 0,05$).

References

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