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CALCULATING THE FATIGUE OF A WELDED JOINT IN MOTINE CONDITIONS

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Machine parts are calculated by the method of permissible but stresses, elements of building structures - by the method of limit states.

The propagation of stress waves in welded joints is considered in order to assess the stress concentration in the weld zone depending on its geometrical and physical parameters. If these temporary stresses do not exceed the yield point of the material, then by the time of complete cooling, the temperature stresses will disappear and residual stresses will not arise.

Analysing the operational, structural and technological loading of the welded units of individual bases, we can conclude that some of the welded units of individual bases are perceived only by compressive alternating stresses and the usual calculations for static strength can be decisive for them, while other welded units are under conditions of asymmetric alternating bending and torsion.

Keywords: machine parts, stresses, welded joints, hydraulic structures, fatigue, coefficient, strength

Introduction

The article deals with improving the quality of welded joints of parts with a large difference of thickness on the basis of theoretical and experimental studies of conditions and the process of their connections and develop new methods and technology of welding processes.

Welding, as well as other technological processes in mechanical engineering and construction (casting, pressure treatment, cutting, heat treatment), causes the appearance of residual stresses in the details and parts of structures [1-3]. The reason for this is unequal linear or volumetric deformations of adjacent metal volumes.

Materials and methods

When calculating machine parts for strength and determining the bearing capacity of structural elements, fatigue testing of welded joints is carried out according to nominal stresses and is reduced to establishing an inequality where $N < R$, and N - is the calculated effect of external variable loads; R - is the calculated bearing capacity of the welded joint under fatigue conditions.

This general starting point does not exclude, however, differences in the methods for cal-

culating fatigue joints. The calculation methods adopted in individual branches of mechanical engineering and construction differ not only in form, but also in approaches to establishing N and R in terms of using the probabilistic aspects of their assessment, as well as taking into account the non stationarity of loading, the influence of cycle asymmetry, residual stress, stages of development of fatigue cracks, etc. etc.

Additional differences are associated with the peculiarities of calculation methods established in mechanical engineering, the oil industry and in the construction of offshore hydraulic structures. Machine parts are calculated according to the method of permissible stresses, elements of building structures - according to the method of limit states.

Results

Typical for machine parts is the calculation method recommended by the design and manufacturing standards for locomotive bogies. The calculation is based on the operating conditions of the welded bogie frames without fatigue damage during the entire service life of the locomotive (20–30 years). The endurance of the structure is estimated by the value of the safety factor:

$$n = \frac{\sigma_{-1}}{k\sigma_v + \psi\sigma_m} \geq 2,0 \quad (1)$$

where n – margin of safety; σ_{-1} – endurance limit of a standard sample at a symmetrical cycle; σ_m – average cycle voltage; σ_v – cycle voltage amplitude; $\psi = \frac{2\sigma_{-1} - \sigma_0}{\sigma_0}$ – coefficient

taking into account the influence of the asymmetry of the cycle; k – effective coefficient taking into account the reduced resistance of a part to fatigue failure.

Amplitude σ_v , is established according to the results of processing oscillographic records of the alternating voltages acting in the frame. Calculated value σ_v , is found either by sampling the maximum swing, or as a result of statistical processing of waveforms using the swing-to-swing method. In the latter case, the calculated value of the amplitude is taken equal to:

$$\sigma_v = \bar{\sigma}_v + 3S_v \quad (2)$$

where $\bar{\sigma}_v$ – statistical mean amplitude; S_v – amplitude standard deviation.

Confirmation

The effective K coefficient is recommended to be established on the basis of bench tests or by assessing the degree of influence of individual factors that determine it:

$$K = \beta_k \frac{k_1 k_2}{\gamma \cdot m} \eta \quad (3)$$

here β_k – effective stress concentration factor;
 k_1 – coefficient for material heterogeneity;
 k_2 – coefficient taking into account internal stresses in the material of the part;
 m – coefficient taking into account the state of the surface of a part;
 γ – a coefficient that takes into account the influence of the scale factor;

η – an effective coefficient that takes into account the impact of a possible deviation from the established technology.

For an approximate choice of the coefficient K and evaluation of the use of welded joints it is allowed to determine its value based on the effective stress concentration coefficients given in the reference literature K_σ , using the following dependency:

$$K = \frac{K_\sigma}{\xi} \quad (4)$$

where ξ – the proportionality coefficient, for the main beams of the frame, is assumed to be equal to 0.5-0.6.

The recommended method is consistent with the general form of calculations for fatigue of machine parts [1-2]. At the same time, it is obvious that for the calculation of welded joints with high residual stresses, it requires some clarifications.

The formula (1) for calculating the safety factor is obtained based on the schematized diagram $\sigma_m, \sigma_{\max}$ (fig.) under the assumption of

the constancy of the relation: $\frac{\sigma_a : (\sigma_a)_{\text{conn}}}{\sigma_{-1} : (\sigma_{-1})_{\text{conn}}}$ –

without taking into account the influence of residual stresses.

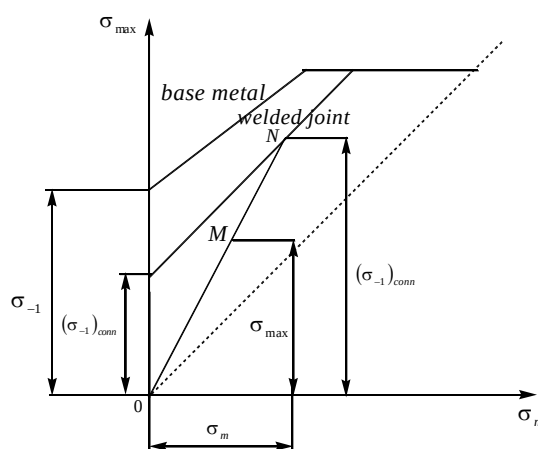


Fig. Diagram for determining the strength reserves of a welded joint with high residual stresses. The strokes indicate the current coordinates

When significant residual stresses act in the region of the welded joint, it is more reasonable to proceed from the fact that the value $(\sigma_a)_{conn}$ is constant. In this case, the equation of the line of limiting stresses of the welded joint takes the form:

$$(\sigma'_r)_{conn} = \sigma'_m + (\sigma_{-1})_{conn} = \sigma'_m + \frac{\sigma_{-1}}{K_\sigma} \quad (5)$$

here: $(\sigma'_r)_{conn}$ – endurance limit of a welded joint at an asymmetric cycle; σ'_m – average cycle voltage; K_σ – effective stress concentration factor, dashes indicate current coordinates.

If a given stress state is expressed by a point M with coordinates σ_m, σ_{max} , then the limiting stress of the welded joint under simple loading, as well as the required safety margin, is most simply determined by jointly solving the equations for the line of limiting stresses and the beam ON . Since the equation for ON has the form:

$$\sigma'_m = \frac{\sigma_{max}}{\sigma_m} \sigma'_m \quad (6)$$

and for point N

$$\sigma'_m = (\sigma'_r)_{conn} = (\sigma_r)_{conn} \quad (7)$$

the joint solution of equations (4) and (5) gives:

$$(\sigma_r)_{conn} = \frac{(\sigma_r)_{conn} \sigma_m}{\sigma_{max}} + \frac{\sigma_{-1}}{K_\sigma} \quad (8)$$

From here

$$(\sigma_r)_{conn} = \frac{\sigma_{max} \sigma_{-1}}{K_\sigma (\sigma_{max} - \sigma_m)} = \frac{\sigma_{-1} \sigma_{max}}{K_\sigma \sigma_v} \quad (9)$$

The safety margin will be determined:

$$n = \frac{(\sigma_r)_{conn}}{\sigma_{max}} = \frac{\sigma_{-1}}{K_\sigma \sigma_v} \quad (10)$$

As you know, metal structures of offshore hydraulic structures are in a complex stress state, depending on various force effects, namely:

stresses in the welded joints of the structure from the own weight of the elements of the metal structure;

stresses in welded joints of the structure from the weight of oil equipment located on separate bases;

technological stresses arising during the assembly and installation of the base;

technological stresses arising from the operation of machines;

stresses arising from wind and wave pressure;

stresses arising from changes in ambient temperature.

It should be noted that some of these efforts, such as the own weights of individual elements of the metal structure and located on the bases of machines and mechanisms, as well as technological stresses arising during the assembly and installation of the bases, can be attributed to constant stresses.

The stresses arising from the specific features of the operational equipment, forces, inertia, wind and wave pressure, as well as from changes in the ambient temperature, can be attributed to voltages that are variable in time.

Analyzing the operational, structural and technological loading of the welded joints of individual bases, it can be concluded that some of the welded joints of individual bases perceive only compressive alternating stresses and conventional calculations for static strength may be decisive for them, while other welded joints are in conditions of asymmetric alternating bending tension and torsion.

As is known, the analytical expression for the endurance limit in asymmetric loading cycles has the form [3-6]:

$$\sigma_{\max} = \sigma_{-1} + (1 - \psi)\sigma_m \quad (11)$$

where ψ – cycle asymmetry sensitivity coefficient;

$\sigma_{\max}, \sigma_m$ – maximum and average cycle voltage.

Coefficient ψ is determined by the formula:

$$\psi = 2\sigma_{-1} - \frac{\sigma_{-1}}{\sigma_0} \quad (12)$$

where σ_0 – endurance limit with pulsating stress cycle;

σ_{-1} – endurance limit at symmetric loading cycle.

Amplitude of asymmetric loading cycle:

$$\sigma_a = \sigma_{\max} - \sigma_m = \sigma_{-1} - \psi\sigma_m \quad (13)$$

By introducing the correlation coefficient β_{corr} , taking into account the effect of corrosion and referring it to the variable component of the cycle, that is, to the amplitude of alternating stresses, we can write:

$$\sigma_r = \sigma_{\max} = \frac{\beta_{corr}}{\sigma_a} + \sigma_m = (\sigma_{-1} - \psi\sigma_{\max})\beta_{corr} + \sigma_m \quad (14)$$

In the presence of tensile stresses in the welded assemblies $\sigma_{\max} > 0$ from the ratio:

$$tg\beta = \frac{\sigma_{\max}}{\sigma_m} = 2 \frac{\sigma_{\max}}{\sigma_{\max} + \sigma_{\min}} = \frac{2}{1 + R} \quad (15)$$

and taking into account:

$$\sigma_m = 1 + \frac{R}{2\sigma_r} \quad (16)$$

the expression for determining the endurance limit becomes:

$$\sigma_r = \frac{2\beta_{corr}\sigma_{-1}}{\psi\beta_{corr}(1-R) - (1-R)} \quad (17)$$

where R – cycle asymmetry coefficient.

Conclusions

Introducing the safety factor S , the value of the permissible voltage can be determined by the formula:

$$[\sigma_r] = \frac{2\beta_{corr}\sigma_{-1}}{[\psi\beta_{corr}(1+R) + (1-R)] \cdot S}.$$

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DƏNİZ ŞƏRAİTİNDƏ QAYNAQ BİRLƏŞMƏSİNİN YORĞUNLUĞA HESABLAMA METODİKASI

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Məqalədə, maşın hissələrinin buraxılabilən gərginliklər, inşaat konstruksiyalarının elementləri isə həddi vəziyyətlər üsulu üzrə yerinə yetirildiyi göstərilmişdir.

Dalğaların yayılması ilə qaynaq birləşmələrində gərginlik konstruksiyasının qiymətləndirilməsi, qaynaq tikişi zonasında onun həndəsi fiziki parametrləri nəzərə alınmaqla öyrənilir. Bu zaman müvəqqəti gərginliklərin qiyməti materialın axıcılıq həddini aşmır, tam soyuma anına qədər temperatur gərginlikləri yox olur və qalıq gərginliklər yaranmır.

Nəticədə ayrı-ayrı hissələrin qaynaq tikişlərin istismarına, konstruksiya və texnoloji yüklənməsinə baxılır. Əsas qaynaq düyünlərinin bir hissəsi ancaq sıxıcı dəyişən gərginlikləri qəbul edir, onlar üçün statik möhkəmliyə adi hesablamalar istifadə edilir. Başqa qaynaq tikişləri isə asimmetrik dəyişən dartılmada əyilmə və burulma şəraitində olur.

Açar sözlər: maşın hissələri, gərginliklər, qaynaq birləşmələri, hidrotexniki tikintilər, yorğunluq, möhkəmlik

МЕТОДИКА РАСЧЕТА СВАРНОГО СОЕДИНЕНИЯ НА УСТАЛОСТЬ В МОРСКИХ УСЛОВИЯХ

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В данной статье рассмотрен расчет деталей машин, рассчитывающихся по методу допускаемых напряжений, а элементов строительных конструкций—по методу предельных состояний.

Изучается распространение волн напряжений в сварных соединениях для оценки концентрации напряжений в зоне сварного шва с учетом зависимости от его геометрических и физических параметров. При условии, что временные напряжения не превзойдут предела текучести материала, к моменту полного остывания температурные напряжения исчезнут и остаточные напряжения не возникнут.

Анализируется эксплуатационная, конструкционная и технологическая нагруженность сварных узлов отдельных оснований, в результате чего можно заключить, что часть сварных узлов оснований воспринимают только сжимающие переменные напряжения и определяющим для них могут явиться обычные расчеты на статическую прочность, другие же сварные узлы находятся в условиях асимметричного переменного растяжения изгиба и кручения.

Ключевые слова: детали машин, напряжения, сварные соединения, гидротехнические сооружения, усталость, прочность