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RISK OF COLD CRACKING IN WELDING OF STRUCTURAL HIGH-STRENGTH STEELS

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Mathematical model of the risk of cold cracking in welding of structural high-strength steels is considered. The model is based on distributed data on the state of microstructure, content of diffusible hydrogen and stressed state in elementary volumes within the welded joint zone. It is shown that the model makes it possible to more precisely evaluate the local conditions of cold cracking on the basis of the above parameters.

Keywords: *arc welding, low-alloy high-strength steels, brittle fracture, cold cracks, diffusible hydrogen, microstructure, stressed state, probability model*

It is a known fact that the presence of quench structures, diffusible hydrogen and tensile stresses [1] are conditions that induce cold (hydrogen) cracks in welding of structural steels. As to the quantitative characteristics of the specified conditions, at present it is possible just to approximately evaluate critical values of the corresponding characteristics, allowing for locality of cold cracking processes, presence of a significant gradient of changes of these characteristics in a zone of welding heating, their strong mutual effect and other factors, by limiting their extreme demonstrations with almost no account for their mutual effects. Meanwhile, development of the methods (experimental and calculation) for determination of distributed parameters of the above characteristics in welding of different joints on structural steels, as well as the trends to optimization of the techniques to prevent cold cracks require development of more precise criteria of the risk of their formation.

It can be shown that many recent approaches [1] based on such integral characteristics as carbon equivalent in the HAZ [1], content of hydrogen in filler metal, degree of restraint and thicknesses being welded, used as the quantitative conditions for microstructure, diffusible hydrogen and effective stresses are of a very general character. They are far from providing an ambiguous determination of the quantitative characteristics of the conditions causing cold cracking at certain parameters of welding heating. It has been proved in recent decades, due to the development of the «Sysweld» and other types of computer systems, which help to obtain the calculation information on the distributed characteristics in the weld and HAZ metals regarding the cold cracking conditions, that zones of potential cold cracks do not always have the most extreme combinations of volumes of quench microstructures, content of diffusible hydrogen and level of tensile stresses. Often the zones with a maximum volume of martensite and content of diffusible hydrogen are within the compressive zones, or the zones with high tensile stresses have a purely bainitic microstructure and low level of diffusible hydrogen, i.e. they are not potential centers of cold cracks. In other words, the proper, physically substantiated criteria that quantitatively connect, on the level of the distributed parameters, the necessary conditions for cold cracking to occur in welding heating of structural steels under consideration, are required.

An approach for development of such criteria, based on the following factors, is given below:

- probability assessment of the risk of cold cracking is performed in a specified area of a welded joint (certain region of the fusion zone or HAZ);
- initiation and propagation of cold cracks take place by the brittle fracture mechanism, i.e. determined by correspondent normal stresses $\sigma_{jj}(x, y, z)$ at a point with coordinates x, y, z, acting in an area with normal j and corresponding characteristic of resistance of a material, $A_j(x, y, z)$, to brittle fracture formation.

A_j is a function of microstructural state and content of diffusion hydrogen for a given steel.

The probability of brittle fracture in specific volume V, in compliance with the Weibull theory, is determined by dependence

$$P_j(V) = 1 - \exp\left[-\int_V \left(\frac{\sigma_{jj} - A_j}{B_j}\right)^{\eta} dV/V_0\right], \quad (\sigma_{jj} > A_j). \qquad (1)$$

In (1), integration is carried out only with respect to elementary volumes dV, where $\sigma_{jj} > A_j$, and A_j, η and $B_jV_0^{1/\eta}$ are the Weibull distribution parameters. As a rule, $\eta = 4.0$, and A_j and $\bar{B}_j = B_jV_0^{1/\eta}$ are determined experimentally.

The values of $\bar{B}_j$ depend on the size of the volume V along the section with normal j (Figure 1). If stresses σ_{jj} and material resistance A_j in length l_j of this volume change but slightly, then a change of $dV = l_jdF$ can be made in integral of expression (1), where F is the cross-section area of volume V.

Accordingly, the following will be obtained instead of (1):