STUDY OF SIGMA PHASE EMERGENCE IN STAINLESS STEEL WELDS

O.Yu. Prokoshev[1], S.N. Petrov[1], M.L. Fedoseev[1], A.Kh. Islamov[2]

[1]*NRC "Kurchatov institute" – CRISM "Prometey", St. Petersburg, Russia*
[2]*Joint Institute for Nuclear Research, Dubna, Russia*

E-mail: npk3@crism.ru

Long-term aging of austenitic stainless steels (steel: 0.1% C, 18% Cr, 9% Ni, welding wire: 0.04% C, 17% Cr, 10% Ni, 2% Mo) at a temperature of 500-550° C leads to a decrease in ductility, impact toughness and crack resistance of the metal. This is due to the formation of secondary phases at intergranular, special and interphase boundaries, leading to a decrease in their adhesive strength.

To predict the degradation of the material for the entire service life of the equipment (up to 50 years), experimental data are not enough and the method of laboratory accelerated (simulation) aging at temperatures above operational temperatures were used. The temperature of laboratory aging was 700° C. The aging time was determined according to the Holomon parameter $P = T \cdot (5{,}15 + \lg\tau)$, where T – temperature, τ – time [1]. Welds were austenized (heat treatment for 30 min at 1050° C) to increase resistance to local fractures. Additional austenization after aging was done to reestablish the initial state of the welds.

Changes in the phase composition of the weld metal after laboratory aging and aging at the basic temperature were studied. X-ray and neutron diffraction, small-angle neutron scattering data on fine precipitates, impact bending test data (at a temperature of +20°C, which is most revealing) were used, see Fig. 1. A sharp drop in impact strength for a non-austenized weld occurs during the first 2000 hours, Fig. 1. This is in good agreement with the decay of the initial δ-ferrite, which was detected approximately in this range. The strongest decrease in impact toughness for an austenized weld occurs within 4000-6500 hours (Fig. 1), while this is not related to the decay of δ-ferrite, since it almost dissolved even before aging in the process of austenization. The state of the material after ~ 20,000 hours was also studied, using diffraction: a mixture of FCC-Fe with σ-phase is observed, no difference between the austenized and the non-austenized state was found.

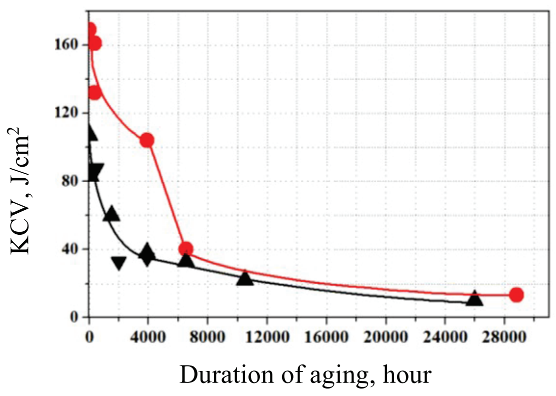

Fig. 1 Dependence of the impact toughness on the duration of aging for the weld metal:
● – austenized weld;
▲, ▼ – non-austenized weld;
●, ▲ – T_{ag} = 700 °C; ▼ – $T_{ag.}$ = 750 °C

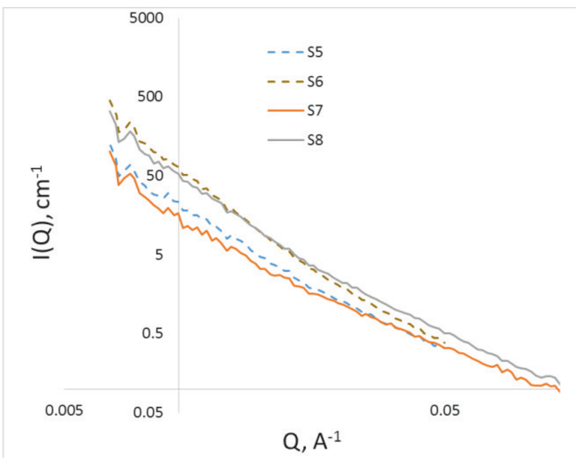

Fig. 2 Curves of small-angle neutron scattering of the initial state (s5, s7) and after aging (s6, s8), samples s5, s6, after laboratory aging, and s7, s8 after aging under basic conditions.

Fig. 2 shows the curves of small-angle neutron scattering of welds after laboratory aging and aging at operating temperature. The curves of the initial and the sample after aging

coincide for the two types of aging. The curves of the initial samples are below the curves after aging both for the given case and for other states.
Thus, the laboratory aging of the metal of austenized and non-austenized welds showed that thermal embrittlement occurs due to the formation and growth of brittle intermetallic σ- and χ-phases. Impact toughness at the initial stage of aging depends on the content of the δ-ferrite, the positive effect of austenization is explained by a decrease in its content. After a long time of aging, austenization does not affect the impact elasticity of these welds. The use of neutron instruments along with traditional methods of analysis provides additional data and allows for independent verification of the results obtained.
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