INVESTIGATION OF TRANSITION ZONE OF LOW-CARBON STEEL JOINT WITH HIGH-ALLOYED Cr–Ni DEPOSITED METAL

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Causes for fracture of repair layer deposited with electrodes of E-08Kh20N9G2B type on the surface of St3sp (killed) steel lining of water wheel chamber of HPS hydraulic unit are analyzed. It is established that its failures (cracking, delamination) arise as a result of lower chromium content (less than 12 %) and formation of martensite phase in the transition zone between steel St3sp and high-alloyed deposited metal. State of transition zone between St3sp and deposited metal of E-10Kh25N13G2, E-11Kh15N25M6AG2 and 10Kh28N14G2 type at welding current variation in the range of 80–140 A has been studied. It is shown that sufficient content of chromium (less than 12 %) and absence of martensite in the transition zone can be ensured in the case of application of electrodes of 10Kh28N14G2 type for repair surfacing at limitation of I_w to not more than 90 A. 6 Ref., 5 Figures, 1 Table.

Keywords: *coated-electrode manual arc welding, low-carbon steel, high-alloyed deposited metal, transition zone, structural and chemical inhomogeneity, martensite, microhardness, cracks, corrosion*

Dissimilar steel welded joints are widely applied in chemical engineering. Their performance is largely determined by the state of transition zone (its structure and chemical inhomogeneity), which undergoes degradation in structure service as a result of the effect of higher temperatures and pressure, cyclic mechanical loads, thermal cycling and aggressive media, and initiates metal delamination. The main regularities, determining the inhomogeneity of chemical composition and structure in the fusion zone of dissimilar metals, are associated with appearance of interlayers conditionally named «solidification» ones [1–4].

In enterprises of petrochemical industry and power generation repair operations with application of different kinds of arc welding are performed. So, in hydro-power engineering, in order to maintain generating capacity of units, repair of damage of lining of water wheel chambers (WWC) from St3sp (killed) steel is periodically performed by restoration of its design dimensions and subsequent deposition of high-alloyed cavitation- and corrosion-resistant metal layer on the working surface. Deposition of the latter is most often performed with TsL-11 electrodes of E-08Kh20N9G2B type.

During investigations of fragments of damaged metal of WWC lining in one of the hydraulic units, the authors found that failure of the layer deposited with TsL-11 electrodes occurs through cracking, delamination and corrosion (Figure 1), that is due to formation of martensite phase with microhardness of 3100–3850 MPa and lower content of chromium (up to 9 %) and nickel (up to 4 %) in the transition zone between St3sp steel and high-alloyed metal. According to [5], minimum content of chromium, ensuring corrosion resistance in humid atmosphere and various low-aggressive solutions, should be not less than 12 %.

Thus, requirements of high enough corrosion resistance, limited content of δ-ferrite (its excess can lead to ductility lowering), as well as minimum formation or elimination of martensite phase, should be made of transition zone metal.

This work is devoted to investigation of the possibilities of minimizing structural inhomogeneity in the fusion zone due to variation of deposited metal composition and welding cur-

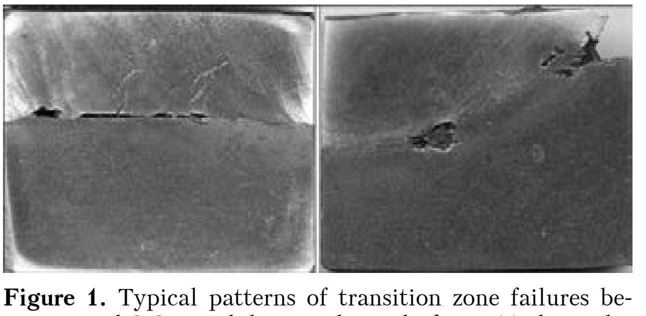

Figure 1. Typical patterns of transition zone failures between steel St3sp and deposited metal of TsL-11 electrodes

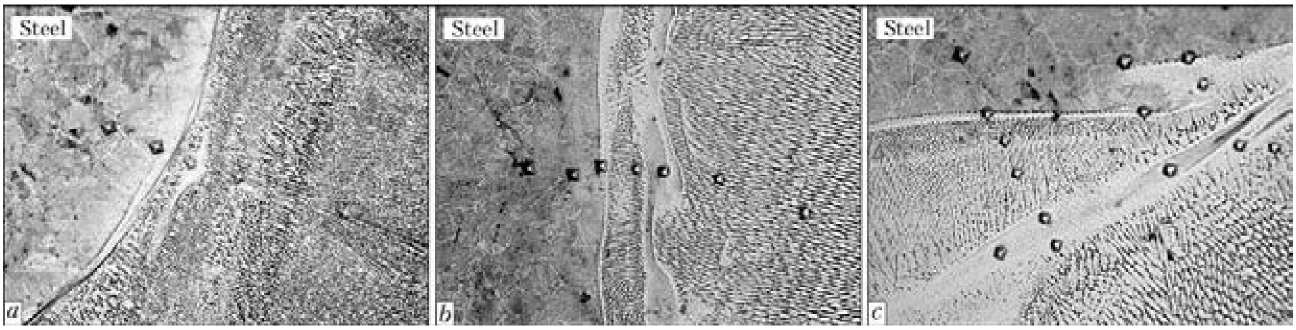

Figure 2. Microstructure (×200) of transition zone between St3sp steel and deposited metal of E-10Kh25N13G2 type at I_w = 80–90 (*a*), 100–110 (*b*) and 130–140 (*c*) A

rent. For this purpose, single-layer deposits were made on St3sp steel plates by electrodes of E-10Kh25N13G2, E-11Kh15N25M6AG2 and 10Kh28N14G2 type with varying degrees of austenicity at welding current variation in the range of 80 to 140 A. Metallographic investigations were performed on the respective microsections.

Microhardness of structural components was determined with metallographic microscope PMT-3 at 100 g load on the indentor, quantity of magnetic phase — with Ferritgehaltmesser 1.053 ferritometer, and microstructure of transition zone metal — with Neophot-32 microscope. Data on composition of transition zone metal were obtained using energy-dispersive X-ray microanalyzer of Camscan microscope. Transition zone profile was detected by combined chemical and electrolytic etching.

At the first stage of the work it was established that in all the studied samples the transition zone has a wavy profile, and its width varies within 2 to 135 μm, that is in good agreement with the results of [6].

Microstructure of deposited metal of electrodes of E-10Kh25N13G2 type at I_w = 80–90 A consists of austenite + 5 % of ferrite and martensite (Figure 2, *a*; the Table), and martensite microhardness in the transition zone is equal to 3250 MPa.

At increase of welding current to 100 and 140 A, respectively (Figure 2, *b*, *c*; the Table) quantity of ferrite and martensite in the deposited metal rises, that is due to greater penetration of low-carbon steel and lowering of chromium and nickel content to 9.7 and 5.5 %, respectively. Microhardness of martensite in the transition zone (see the Table) at I_w = 100 A reaches 3250–3940 MPa, and at I_w = 140 A it is 3310–4140 MPa.

Data on the influence of welding current on the structure and microhardness of deposited metal and transition zone at application of E-11Kh15N25M6AG2 type electrodes is given in the Table and in Figure 3. It follows from the given data that despite increased nickel content in the transition zone, martensite phase with microhardness of 3720–3840 MPa formed at $I_w \geq$ 100 A. Its X-ray microprobe analysis showed that its chromium content is equal to 4.5–8.0 % and that of nickel is 7.4–11.3 %. Such a low content of chromium in it in the transition zone regions can initiate corrosion attack on metal in service.

Thus, to ensure sufficient corrosion resistance of the transition zone, it is necessary to increase chromium content here. To check the validity of

Influence of welding current on structure and properties of deposited metal and transition zone

Deposited metal type	I_w, A	Microhardness, MPa			Deposited metal microstructure
		Transition zone	Deposit middle	Deposit top	
E-10Kh25N13G2	80–90	2180–3250	1980–2080	2250–3110	A + F
	100–110	3250–3940	2320–3120	2480–3720	A + F
	130–140	3310–4140	2780–3310	2860–3720	A + F
E-11Kh15N25M6AG2	80–90	2120–3140	2160–2480	2180–2530	A
	100–110	2020–3720	1800–2160	1760–2530	A
	130–140	2160–3840	2120–2780	1975–2080	A
10Kh28N14G2	80–90	1595–2580	1688–1780	1875–1940	A + F
	100–110	1942–3600	1900–2120	1900–2200	A + F
	130–140	2380–3840	1971–2080	1800–2080	A + F

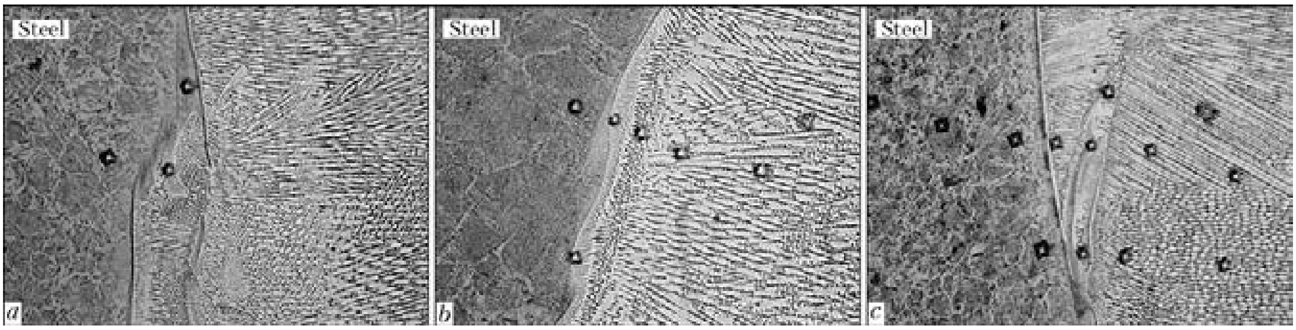

Figure 3. Microstructure (×200) of transition zone between St3sp steel and deposited metal of E-11Kh15N25M6AG2 type at I_w = 80–90 (*a*), 100–110 (*b*) and 130–140 (*c*) A

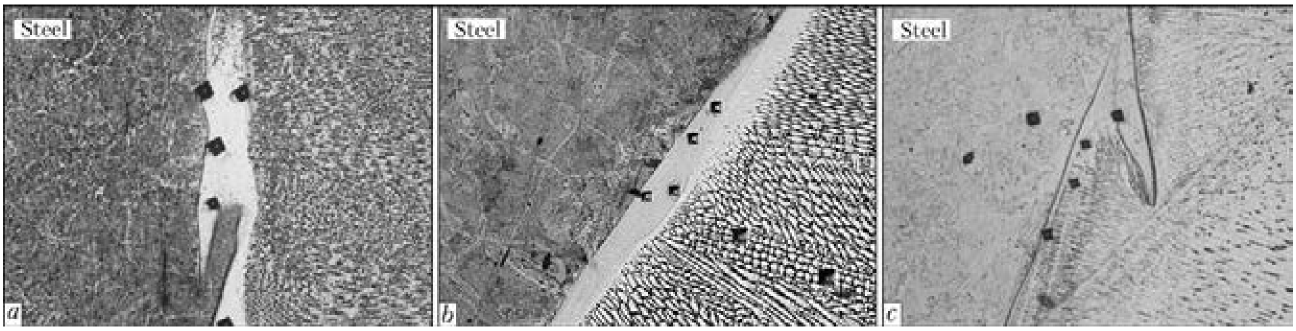

Figure 4. Microstructure (×200) of transition zone between St3sp steel and deposited metal of 10Kh28N14G2 type at I_w = 80–90 (*a*), 100–110 (*b*) and 130–140 (*c*) A

this statement, the transition zone of test electrodes of 10Kh28N14G2 type was studied. Microstructure and microhardness of deposited metal of these electrodes, depending on welding current, are given in Figure 4 and in the Table. As is seen from the Table, at I_w = 80–90 A microhardness of all the transition zone regions was equal to 1595–2580 MPa, except for one of ~40 μm length, where it reached 3050 MPa. In this section energy dispersion analyzer was used to determine chromium and nickel content. Nickel content in it was equal to 7.85 %, and that of chromium was 15.16 %, i.e. microstructure of the transition zone in this case consists of austenite + 3.5 % of ferrite, and chromium content is quite sufficient to ensure the corrosion resistance. At I_w increase to 100–140 A, microhardness in the transition zone rises (3600–3840 MPa), and alloying element content decreases significantly (8.2–12.3 % Cr, 4.8–6.8 % Ni), i.e. a phase with martensite component formed here alongside austenite.

Thus, for electrodes of 10Kh28N14G2 type welding current increase above 90 A increases the structural and chemical inhomogeneity of transition zone metal, that may lead to lowering of its ductility and corrosion resistance. Generalized pattern of the influence of deposited metal type and welding current on the quantity of martensite in the transition zone is given in Figure 5.

Comparative analysis of the results of metallographic, durometric and X-ray microprobe analyses shows that in surfacing St3sp steel with E-10Kh25N13G2 type electrodes a martensite structure forms in the transition zone metal and chromium content drops below 12 %, that is insufficient to ensure the corrosion resistance. An optimum variant is application of electrodes of 10Kh28N14G2 or E-11Kh15N25M6AG2 type, which at I_w = 80–90 A provide the highest quality of transition zone metal. On the other hand, it should be noted that electrodes of 10Kh28N14G2 type are more cost-effective (1.5 times less expensive).

At testing of samples of metal deposited by test electrodes of 10Kh28N14G2 type and TsL-11

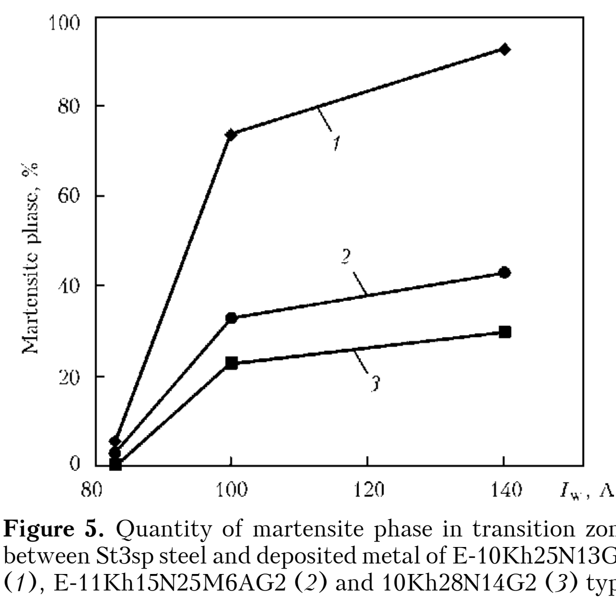

Figure 5. Quantity of martensite phase in transition zone between St3sp steel and deposited metal of E-10Kh25N13G2 (*1*), E-11Kh15N25M6AG2 (*2*) and 10Kh28N14G2 (*3*) type

electrodes of E-08Kh20N9G2B type conducted in the test facilities of the Laboratory of Hydrogas Systems of National Aviation University it is established that in the first case cavitation wear resistance is 2 times higher, and hydroabrasive wear resistance is higher by 10–15 %.

Conclusions

1. Failure of metal, deposited with TsL-11 electrodes of E-08Kh20N9G2B type on working surface of lining of hydrounit WWC from steel St3sp, is due to martensite phase formation in the transition zone and lower chromium content, that initiates cracking and delamination of the deposited high-alloyed layer.

2. Methods of metallography, durometry and X-ray spectrum microprobe analysis were used to study the state of transition zone between steel St3sp and deposited metal of E-10Kh25N13G2, E-11Kh15N25M6AG2 and 10Kh28N14G2 type at welding current variation in the range of 80 to 140 A. It is established that sufficient corrosion resistance of transition zone metal can be ensured and martensite phase formation here can be avoided at surfacing with electrodes of 10Kh28N14G2 type and welding current limitation to not more than 90 A.

3. It is proposed to apply new welding electrodes of 10Kh28N14G2 type for deposition of cavitation-resistant metal layer on the working surface of hydrounit WWC lining, which ensure the high quality and cost-effectiveness of repair-welding operations.

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