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INVESTIGATION OF THE METHODS OF MODIFYING THE STRUCTURE OF AUSTENITIC WELDS AND THE ZONE OF THEIR FUSION WITH PEARLITIC BASE METAL

K.A. Yushchenko, O.V. Bulat, G.V. Svyagintseva, V.I. Samoilenko and **Yu.M. Kakhovskyi**
E.O. Paton Electric Welding Institute of the NAS of Ukraine
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine. E-mail: office@paton.kiev.ua

Investigation of the effect of nitrogen alloying and yttrium and zirconium oxide additives to the weld pool on the structure of an austenitic weld and its microhardness in the zone of its fusion with pearlitic base metal was studied for the case of joints of dissimilar steels (austenitic with pearlitic), made by coated-electrode arc welding. It is shown that nitrogen alloying of weld metal of Kh20N9G6 type through the electrode coating practically does not affect the dendrite dimensions, but lower the microhardness (risk of martensite formation) in the zone of fusion with pearlitic base metal. In the case of yttrium or zirconium oxide additives to the austenitic metal of Kh15N25M6AG2 type through the coating, its dendrite structure is refined significantly, and metal microhardness in the fusion zone drops to the level that is indicative of martensite absence. 8 Ref., 2 Tables, 4 Figures.

Keywords: arc welding, coated electrodes, austenitic deposited metal, transition zone with pearlitic metal, structure, microhardness

Structure refinement and prevention of transcrystallinity in multipass welded joints of high-alloyed austenitic steels enable improving their technological strength and service properties [1, 2]. Known are the techniques of structure refinement due to electromagnetic impact on the molten metal, pulsed melting or welding wire feeding, adding metal powders or master alloys to the weld pool can be implemented at automatic welding. Under the conditions of coated electrode arc welding (MMA), a positive effect can be obtained by modifying the weld metal through the electrode coating by refractory metals (Zr, Ti, Nb, Mo) [3], as well as oxides (Cr, Zr, REM) [2].

In welding dissimilar steel joints by austenitic electrodes, in addition to structure refinement, it is also necessary to minimize or exclude the formation of martensite in the zone of fusion with pearlitic base metal. This is due to the fact that the low-ductility martensite is the source of stress concentration and premature failure of the joint. Martensite formation can be prevented by increasing the nickel content in the austenitic weld and lowering the energy input in welding [4, 5].

More over, use of nickel-based electrodes can not only prevent formation of martensite in the fusion zone, but also prevent development of stresses and strains as a result of a considerable difference in TEC between the austenitic and pearlitic metal [4, 5]. In a number of cases, particularly, during performance of repair operations, use of nickel-base electrodes allows welding equipment from heat-resistant pearlitic steels without preheating or final heat treatment. At the same time, it is not rational to use such electrodes for joints exposed to temperatures of up to 450 °C in service.

Under these conditions electrodes of Kh20N9G6S or Kh15N25M6AG2 types are used [4]. Meanwhile, as was shown in [6], only in the case of electrodes of Kh15N25M6AG2 type at welding current limitation below 80 A, it is possible to avoid martensite formation in the zone of fusion of austenitic weld metal with pearlitic base metal. For the conditions of automatic welding of such joints by Sv08Kh20N9G6S wire the authors of [7] determined that martensite formation can be essentially limited due to weld metal alloying by nitrogen through the gas phase.

The objective of this work consists in studying the techniques of improvement of the quality of welded joints of dissimilar steels (austenitic with pearlitic) due to application of nitrided manganese (nitrogen alloying), as well as yttrium and zirconium oxides (modifying by refractory particles) in the welding electrode coating.

The influence of nitrogen alloying was studied using 3 mm test electrodes of Kh20N9G6 type, in the

K.A. Yushchenko — https://orcid.org/0000-0002-6276-7843, O.V. Bulat — https://orcid.org/0000-0003-2237-5260,
G.V. Svyagintseva — https://orcid.org/0000-0002-6450-4887, V.I. Samoilenko — https://orcid.org/0000-0001-6370-277X,
Yu.M. Kakhovskyi — https://orcid.org/0000-0002-9520-2996

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Table 1. Chemical composition of deposited metal of test electrodes of 10Kh20N9G6S type

Electrode designations	Weight fraction, % in the deposited metal*							Ferrite phase content, %
	N	Cr	Ni	Mn	Si	S	P	
C1	0.07	21.3	9.1	7.1	0.70	0.015	0.025	4–5
C2	0.32	20.0	10.0	6.6	0.65	0.016	0.024	1–1.5
C3	0.44	20.4	9.8	6.2	0.62	0.015	0.022	0.8
*Content of other elements in the deposited metal: 0.09 % C; 0.40 % Mo; 0.30 % Cn.								

coating of which the content of nitrided manganese was varied instead of that of metal manganese (C1–C3 electrodes in Table 1).

Before that these electrodes were used to make eight-layer deposits to determine the chemical composition of the deposited metal by the methods of X-Ray microprobe, chemical and gas analysis. The results are given in Table 1.

Then, 3 mm test electrodes C1–C3 were used to make single-layer deposits on a plate from 10 mm steel St3sp(killed) at I_w = 90–100, U_a = 26–28 V; v_w = = 9 m/h; from which sections were cut out for metallographic studies. The structure of the transition zone and deposited metal was revealed by combined chemical and electrochemical etching. Martensite formation was recorded by measuring the microhardness of the transition zone, using microhardness meter PMT-3. Here, it was assumed that microhardness values above 3000 MPa correspond to martensite formation. Obtained results are given in Figure 1, from which one can see that increase of nitrogen content in the deposited metal from 0.07 up to 0.32 % leads to microhardness lowering in the fusion zone from 3380 to 3000 MPa. Further increase of nitrogen content up to 0.44 % increases the microhardness in this area up to 3320 MPa. Average microhardness in the deposited metal rises from 1814 up to 2732 MPa, that is indicative of increase of strength and is in agreement with the data of [2, 8].

Nitrogen effect at its concentration of 0.32 % is attributable to the fact that it is an interstitial impurity, similar to carbon, and blocks carbon diffusion from pearlitic metal into the austenitic deposit. Due to that in the transition zone austenite decomposes at cooling by γ→γ + α reaction instead of γ→γ + M + α. Microhardness increase at additional alloying of the

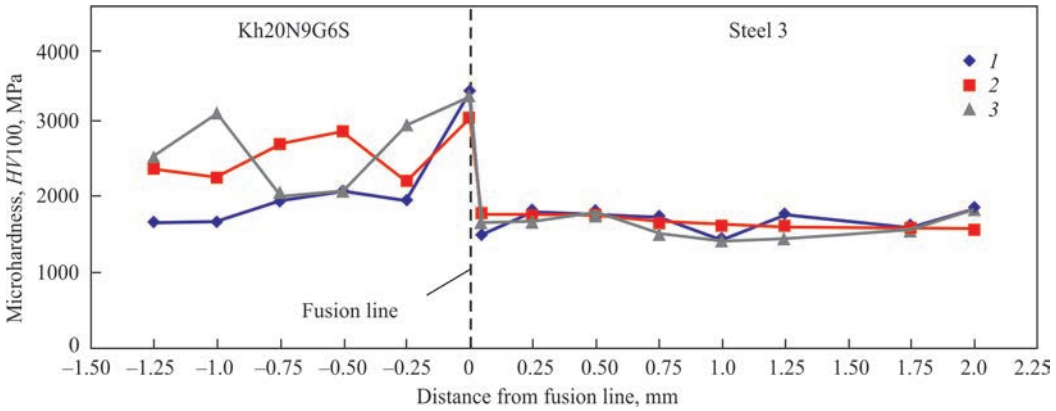

Figure 1. Effect of nitrogen alloying on microhardness in the joint of austenitic deposited metal of 10Kh20N9G6S type with pearlitic base metal: *1* — [N] = 0.7; *2* — 0.32; *3* — 0.44 %

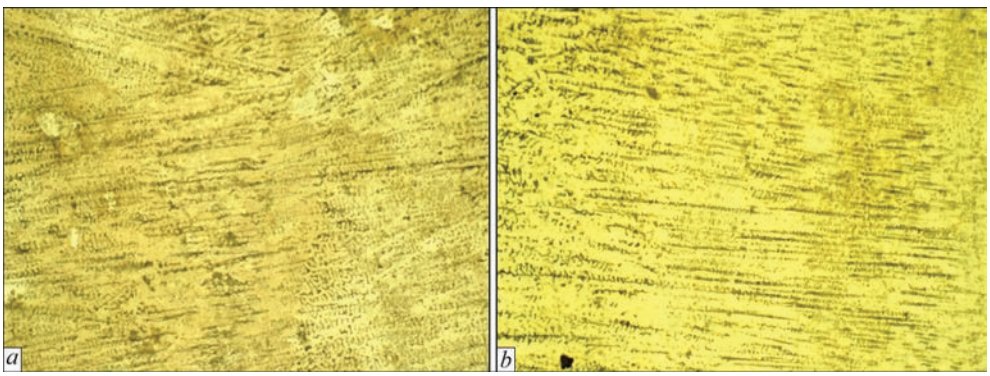

Figure 2. Dendritic structure (×200) of deposited metal of 10Kh20N9G6S type: *a* — unalloyed by nitrogen; *b* — alloyed by 0.32 % of nitrogen

Table 2 Chemical composition of the deposited metal of test electrodes of 10Kh15N25M6AG2 type

Electrode designations	Description and number of modifiers in the coating	Weight fraction of test electrodes								
		Cr	Ni	Mo	Mn	Si	N	C	S	P
C4	–	15.3	24.8	6.2	2.1	0.35	0.18	0.10	0.017	0.024
C5	Y_2O_3, 1%	15.1	24.2	6.0	2.0	0.34	0.18	0.09	0.019	0.025
C6	ZrO_2, 1 %	15.4	25.0	6.2	1.8	0.36	0.17	0.11	0.017	0.026
C7	ZrO_2, 2 %	15.4	24.5	6.4	1.9	0.39	0.17	0.10	0.018	0.026

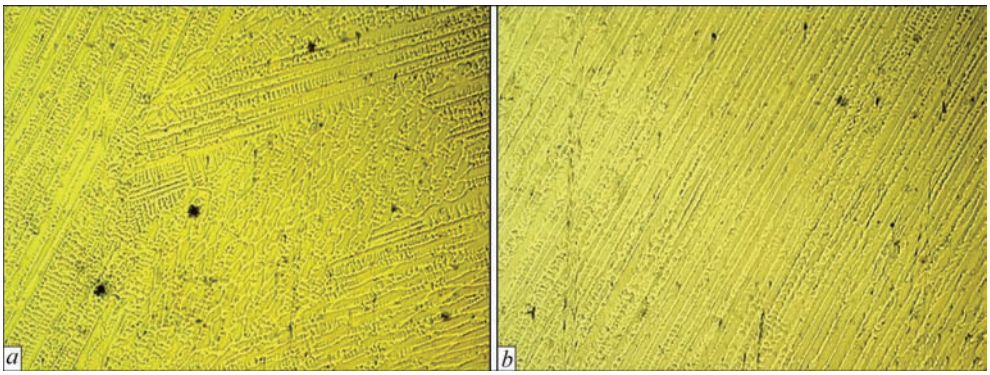

Figure 3. Dendritic structure (×200) of deposited metal of 11Kh15N25M6AG2 type: *a* — without ZrO_2 in the coating; *b* — with 2 % ZrO_2 in the coating

deposited metal by nitrogen (up to 0.44 %) is attributable to formation of chromium, manganese and silicon nitrides during solidification, which strengthen the austenitic matrix. Studying the structure of the deposited metal of C1–C3 electrodes using Neophot-32 microscope showed that irrespective of nitrogen content, the dendrite dimensions remain practically unchanged (Figure 2) and are equal to 7–8 in the lower and 13–14 μm in the upper part of the deposit.

The next stage was to study the possibility of refining the structure of austenitic weld of Kh15N25M6AG2 type and lowering the microhardness in the zone of its fusion with pearlitic base metal due to application of electrodes with yttrium or zirconium oxides in the coating. The powders of these materials with particle dimensions less than 100 μm were added to the coating of 3 mm test electrodes C4–C7 through the rutile concentrate.

Results of determination of the chemical composition of the deposited metal of these electrodes are given in Table 2.

C4–C7 electrodes of 3 mm diameter were used to perform single-layer deposition on the surface of plates from St3sp steel 10 mm thick. Here, the deposition mode remained the same as in the previous test series. Metal structure in the respective sections was revealed by a similar procedure. Metallography of the produced sections using Neophot-32 microscope was used to determine (Figure 3) that the maximum reduction of the average width of dendrites from 20.97 to 11.39 μm is achieved in the deposited metal of C7 electrodes which contain 2 % ZrO_2 in the coating. Refinement of the austenitic structure of the deposited metal of Kh15N25M6AG2 type at its modification by zirconium oxide can be explained by that the surface dissolution of these particles in the molten met-

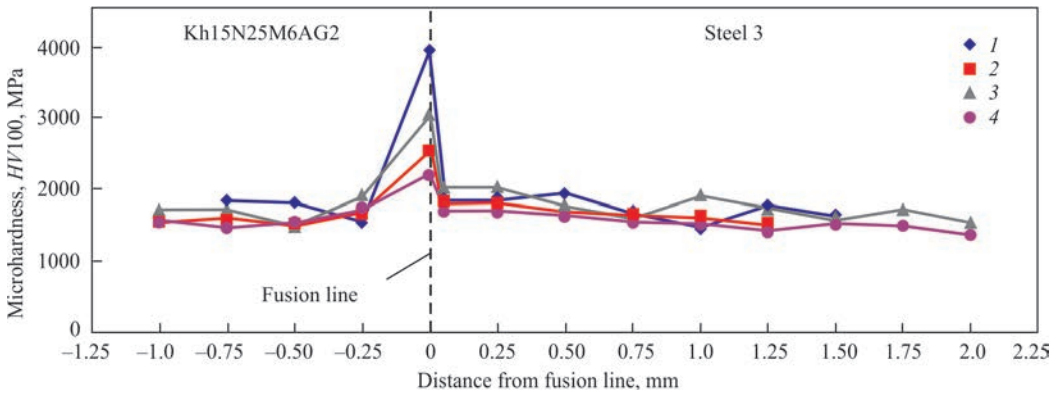

Figure 4. Effect of yttrium and zirconium oxides on microhardness in the joint of austenitic deposited metal of 11Kh15N25M6AG2 type with pearlitic base metal: *1* — without modifiers; *2* — 1 % Y_2O_3; *3* — 2 % ZrO_2; *4* – 2 % ZrO_2

al volume proceeds with heat absorption. Due to that the weld pool temperature decreases, and it solidifies faster. Investigations of microhardness of the transition zone between the pearlitic base and the deposited metal of C4–C7 electrodes, made using PMT-3 microhardness meter (Figure 4), revealed that the minimum microhardness is ensured in the transition zone of the metal deposited with C7 electrodes. This effect is somewhat lower in the case of C5 electrodes which contain 1 % Y_2O_3 in the coating. Unlike the previous test series, addition of refractory oxides to the deposited metal did not lead to increase of its average microhardness (strength).

Conclusions

1. Alloying of the deposited weld metal of Kh20N9G6S type by nitrogen up to 0.32 % due to nitrided manganese in the electrode coating composition, lowers the microhardness in the zone of fusion with the pearlitic base metal from 3250 to 3000 MPa and practically does not affect the dimensions of dendrites in the weld metal structure.

2. Modification of weld metal of Kh15N25M6AG2 type by yttrium or zirconium oxides through the electrode coating leads to microhardness lowering in the zone of fusion with the pearlitic base metal from 3950 to 2500 and 2200 MPa, respectively, as well as a considerable reduction of the dimensions of dendrites in the weld metal structure.

3. Nitrogen alloying and modifying of high-alloyed austenitic weld metal by particles of refractory oxides allows reducing the risk, or preventing martensite formation in the joined dissimilar steels (austenitic and pearlitic).

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