nov, G.G. Psaras and V.K. Rubajlo), and monograph «Magnetic Control of Weld Formation in Arc Welding» by A.D. Razmyshlyaev, stamped by the Ministry of Education and Science, were prepared and published during the last three years.

During the 65 years period the team of the Chair educated about 6000 engineers, including for the countries of Europe, Asia, Africa and Latin America, and 42 candidates and 8 doctors of technical sciences defended their theses. The Chair published over 30 manuals and monographs, and 760 scientific papers. Over 280 developments are covered by the author's certificates and foreign patents.

Graduates of the Chair A.D. Chepurnoj, T.G. Kravtsov, V.Ya. Zusin, V.I. Shchetinina and V.N. Kalianov successfully defended their doctoral theses. Many graduates became recognised specialists in the field of welding production and headed industrial enterprises of Ukraine, Russia and other countries: A.V. Savchuk, Doctor of Economic Sciences and Chairman of the Board of «Azovmash»; Doctor of Technical Sciences A.D. Chepurnoj, L.P. Khadzhinov, Director General of «Zaporozhtransformator», K.Kh. Kazmiridi, Director General of «Pozhzashchita», etc.

At present, three professors — doctors of technical sciences, ten associate professors — candidates of technical sciences, one senior teacher and one assistant are working at the Chair. The Chair has been accredited as corresponding to level IV by the Commission of the Ministry of Education and Science of Ukraine. It trains specialists in professions «Technology and Equipment for Welding» and «Welding Units».

Specialists of the Chair take part in activities of International Association «Welding». Along with traditional cooperation with chairs of the higher education institutes of Moscow, St.-Petersburg, Chelyabinsk, Yekaterinburg, Tbilisi, Minsk, Mogilyov and other cities of the former Soviet Union countries, the Chair has established contacts with higher education institutes and organisations of «far-foreign» countries, such as the Institute of Welding in Gliwice (Poland), University of Miskolc (Hungary), Harbin Institute of Technology (China), etc.

The Chair meets its 65th anniversary with active and creative work on improvement of training of the staff for national economy of the country and development of research in the field of welding and related processes and technologies.

INFLUENCE OF HARDFACING TECHNOLOGY AND HEAT TREATMENT ON STRUCTURE AND PROPERTIES OF METAL DEPOSITED ON CARBON STEEL BY LN-02Kh25N22AG4M2 STRIP ELECTRODE

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Possibility for improvement of structural state of fusion zone metal in hardfacing of carbon steel by LN-02Kh25N22AG4M2 strip electrode was investigated. The recommendations on selection of heat treatment modes were provided for improvement of structure and properties of this zone.

Keywords: *arc hardfacing, strip electrode, carbon steel, bimetal, corrosion-resistant layer, fusion zone, microstructure, thermocyclic treatment, mechanical properties*

Bimetal structures are widely used in manufacture of equipment for chemical machine building. One of the traditional methods of obtaining of bimetal billets is automatic arc hardfacing of corrosion-resistant layer on low-carbon steel, performed by single strip electrode of 0.5–0.8 mm thick at the width of 60 mm with fraction of the base metal not more than 15–20 %.

Presence of the residual stresses and structural inhomogeneity in fusion zone are specific peculiarities of the hardfaced bimetal. These factors promote appearance of new or development of existing microcracks that can result in loss of working capacity of the part under hard operation conditions of equipment in chemical industry.

Selection of reasonable modes of hardfacing and heat treatment of the deposited metal can help to achieve specific positive effect on reduction of the residual stresses and homogenizing of the chemical composition.

The aim of present study is to investigate influence of modes of hardfacing and heat treatment on structure and mechanical properties of the bimetal layer.

Electric arc hardfacing was carried out on templates from steel 20 of 400 × 600 × 15 mm size by LN-02Kh25N22AG4M2 strip electrode of 0.5 × 60 mm section with 48-OF-10 flux without preheating at current of hardfacing I_{hf} = 750–800 A and arc voltage

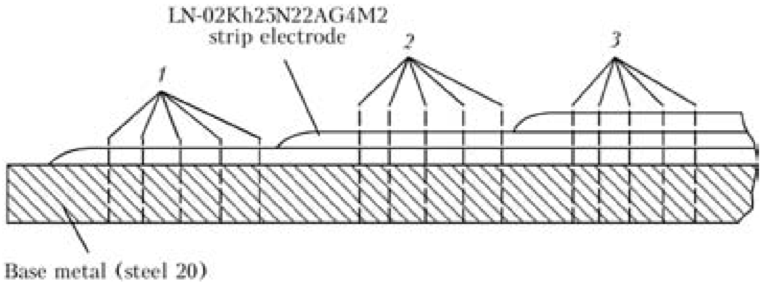

Figure 1. Scheme of hardfacing of one-, two- and three-layered specimens *1*–*3*

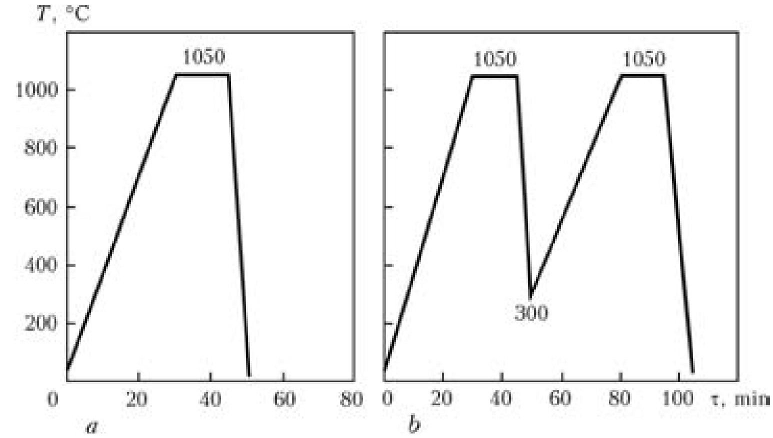

Figure 2. Modes of heat treatment of deposited specimens: *a* — high-temperature normalization; *b* — HTTCT; τ — time of HT

U_a = 28–30 V. Deposited layer contained the areas of different heights, from which test specimens were cut out (Figure 1). At that, effect of the subsequent layers on mechanical properties and structure of the base metal and HAZ can be evaluated. Influence of the heat treatment (HT) on distribution of the structural constituents across section of the deposited metal (modes of HT are given in Figure 2, cooling in air) was also investigated.

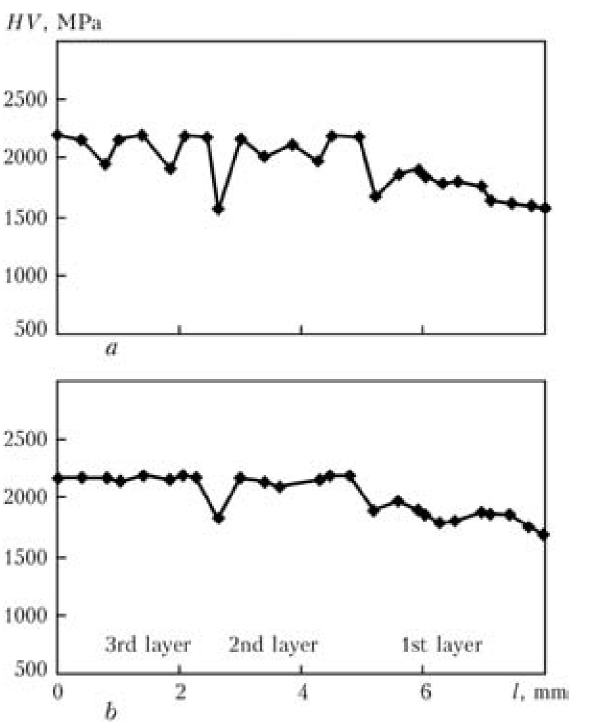

Figure 3. Change of microhardness across the section of deposited layer after hardfacing without HT (*a*) and after HTTCT (*b*): *l* — distance to the surface

Application of HT mode on variant, provided in Figure 2, *a*, does not allow grain refining in the base metal since heating to 920 °C and cooling in air (1050 °C for stainless chromium-nickel steels) are provided for standard normalization of steel 20. Spreading in the microhardness values (Figure 3, *a*) can be well explained for high-alloyed steels tending to segregation at solidification under the non-equilibrium conditions. Similar microhardness measurements were carried out after high-temperature thermocyclic treatment (HTTCT) (Figure 3, *b*). Positive effect of HTTCT indicted in many studies [1, 2] since such a treatment promotes grain size refinement, formation of more developed substructure, intensification of diffusion processes and increase of chemical homogeneity of the metal. This results in increase of impact toughness and improvement of complex of mechanical properties in whole.

Dendrite segregation in different layers of deposit occurs in structure of the deposited layer. Thus, austenite structure with obviously etched grain boundaries and carbides (Figure 4, *a*) is formed in the first layer, and dendrite segregation (Figure 4, *b*) is noticed in the second layer of the double-layered specimens. Similar segregation takes place in the second and third layers of three-layered specimen.

Coarse grains and mixed ferrite-pearlite (F-P) structure with separate Widmanstaetten zones are formed in the HAZ, that indicates significant overheating relative to A_{c_3} point and tendency to brittle cracking. Simple F-P banding with elongated lines of

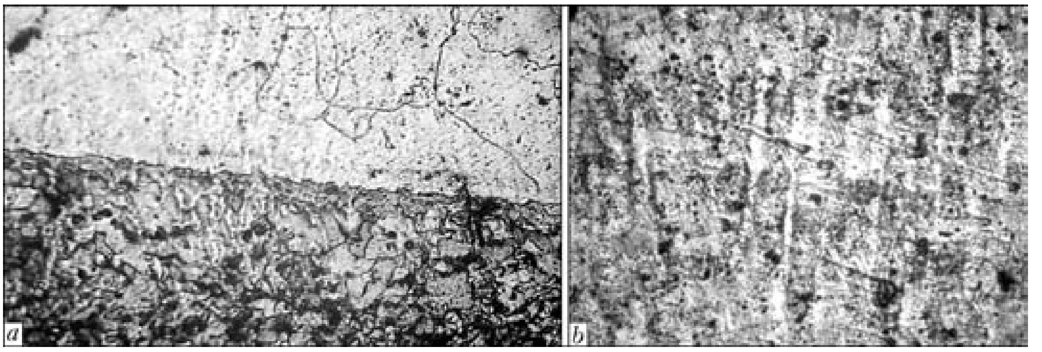

Figure 4. Microstructures (×600) of corrosion-resistant layer of double-layered deposited specimen: *a* — fusion zone with base metal; *b* — dendrite segregation in the 2nd deposited layer

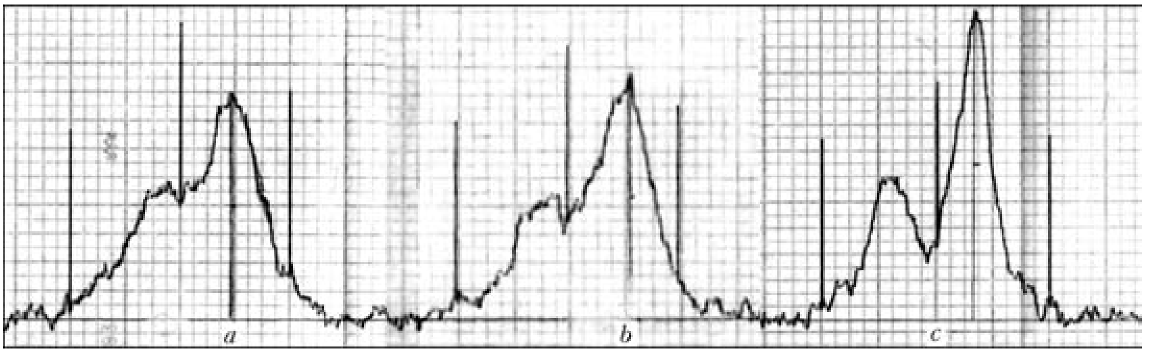

Figure 5. Diffraction patterns of the specimens with 1st (*a*), 2nd (*b*) and 3rd (*c*) deposited layers

Table 1. Mechanical test results of base metal

Base metal	σ_t, MPa	$\sigma_{0.2}$, MPa	δ, %	*KCU*, J/cm^2
As delivered	400	225	26	65
After hardfacing	345	185	19	40
After high-temperature normalization	350	210	20	52
After HTTCT	380	255	24	84

Table 2. Calculated data on elastic microstresses

Version of technology	Amount of deposited layers	Elastic microstresses, MPa
In the hardfaced state without HT	1 2 3	86.0 107.5 112.0
After high-temperature normalization	1 2 3	71.5 76.0 75.0
After HTTCT	1 2 3	57.0 54.5 59.0

sulfides character for hot-rolled metal occurs out of the HAZ.

Positive effect of HTTCT was observed in testing of mechanical properties of the base metal (Table 1), namely values of tensile strength ρ and yield strength $\sigma_{0.2}$ as well as elongation δ after HTTCT were close to initial ones, but impact toughness index was 30 % higher after HTTCT (38.4 % reduction after hardfacing).

X-ray structure analysis of the specimens was carried out. It was based on registration of the distortions in crystal lattice of the metal using X-ray irradiation. The level of elastic stresses of the second order rising in the metal was determined by calculations based on these values. At that, standard calculation technique from study [3] was used.

Investigations of elastic microstresses in the deposit layer showed that the largest distortions take place after hardfacing of three-layered specimens (Figure 5 and Table 2), high-temperature normalization promotes decrease of these stresses to 71–76 MPa and HTTCT — to 54–56 MPa.

CONCLUSIONS

1. Structural inhomogeneity in the fusion zone and high level of residual stresses, which are proportional to amount of deposited layers, take place in electric arc hardfacing of carbon steel by LN-02Kh25N22AG4M2 strip electrode.

2. Heat treatment of hardfaced billets is recommended for correcting of the structure, improvement of mechanical properties and elimination of tendency to brittle fracture. Double-cycle HTTCT is preferred for bimetal billets.

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