IMPROVEMENT OF SERVICE LIFE OF RESISTANCE WELDING MACHINE ELECTRODES IN WELDING GALVANIZED STEEL

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Existing methods for manufacture of high-temperature copper alloys were analyzed, and service durability of different electrode materials in spot welding of galvanized steel was evaluated. The effect of composition of electrode materials on their hardness at increased temperatures was studied.

Keywords: *resistance spot welding, resistance welding machines, electrode material, galvanized steel, service durability of electrodes, bimetal electrodes, alloy structure and hardness*

Steels with anticorrosion coating, in particular galvanized steels, are ever wider accepted in modern mechanical engineering, particularly in automotive industry and carriage engineering, as well as other industries. Resistance spot welding is the main technological process for joining these materials. Operating life of resistance welding machine electrodes in welding galvanized steels is 10–20 times lower (depending on electrode material, welding speed, etc.) compared to welding of uncoated steels. Therefore, development of new high-temperature materials on copper base with increased softening temperature and minimum adhesion of electrode material to molten zinc is an urgent task.

At present manufacturing of high-temperature copper alloys is mainly concentrated in metallurgical production, powder metallurgy, in productions with electron beam evaporation. Welding fabrication processes, namely arc surfacing, can also be used.

In metallurgical production mainly alloys of the type of chromium and chromium-zirconium bronze are manufactured, which have been the most widely accepted in different countries as material for resistance welding machine electrodes [1, 2]. Recently dispersion-strengthened composite materials (DSCM) based on copper (with additives of refractory compounds) produced by powder metallurgy method, have been ever wider accepted instead of dispersion-hardening chromium and chromium-zirconium bronzes produced by casting. Featuring a range of unique properties (high hardness, strength, electrical conductivity), which are preserved also at high temperature, they essentially increase the service durability of welding tools [3]. The most efficient method of adding oxides to the metal matrix is internal oxidation [4]. This method was realized by OMG Americas (USA) at development of Cu + Al_2O_3 DSCM under GlidCop trade name [5]. However, application of electrodes from GlidCop Al-60 material in the world practice is restrained by a quite high cost of this material, which is due to a complex technology of its manufacturing.

Recently TsNIIMT DISKOM Ltd. (Cheboksary, Russia) developed a nanocomposite material S16.102 DISKOM, which has a heterogeneous dispersion-strengthened structure and is characterized by high recrystallization temperature, high-temperature strength, electrical conductivity and service durability due to application of reaction mechanical alloying in high-energy and high-speed attritors, processes of granule metallurgy and hot pressing (extrusion) [6].

Also interesting are locally produced condensed dispersion-strengthened materials (CDSM) based on copper and molybdenum, which also have high hardness and electrical conductivity [7]. Their main advantage is high thermal stability — recrystallization temperature reaches 1000 °C [8]. They are made both with bulk distribution of molybdenum (CDSM), and with microlaminate distribution when copper and molybdenum layers alternate (CMLM).

In recent years PWI developed technologies of manufacture of bimetal electrodes for resistance spot welding by the method of nonconsumable electrode inert-gas arc surfacing using flux-cored filler wire [9].

Materials the physical properties of which are given in the Table, were selected to assess service durability of the current electrode materials made by different processes, at resistance spot welding of galvanized steel. «Cap» type electrodes were made from the above materials. Electrode with the working part from CDSM and CMLM was made by welding plates from these materials to a copper billet by percussion welding in vacuum. Procedure of accelerated testing of service durability of electrode materials in resistance spot welding of galvanized steel allowing saving of steel being welded was developed.

It consists in the following. Spot welding of low-carbon steel with anticorrosion coating applied by hot galvanizing is performed. Thickness of zinc coating in this case is 2–3 times greater than that of the coating deposited by electrochemical method. As is known

Physical properties of copper-based high-temperature materials manufactured by different processes [1–9]

Material	Hardness *HRB*	Electrical conductivity of copper, m/(Ohm·mm^2)	Recrystallization temperature, °C
Chromium bronze BrKh	55–65	80–85	475
Chromium-zirconium bronze of Cu–Cr–Zr type	70–83	75–85	550
CDSM based on copper with 2.5–12.0 wt.% Mo	50–87	82–64	> 850
Dispersion-strengthened copper produced by the method of internal oxidation GlidCop Al-60 (USA)	78	78	860
Copper-based DSCM produced by mechanical alloying	97–112	45–48	> 700
DISKOM produced by reactive mechanical alloying	89	80	850
Metal deposited with special filler wire #30 (PWI)	66–69	70–75	–

from [10], the greater the zinc coating thickness, the lower is the electrode resistance. In addition, the copper «end piece» on which the «cap» is put on, is made without a cooling channel, which also lowers its resistance in spot welding of galvanized steel. Testing was conducted in resistance spot welding machine of MT-22 model. Before welding and after the end of testing, the diameter of the electrode surface working part imprint was measured by the imprint on white paper using carbon paper (durability characteristics is the number of spots welded before increase of working surface initial diameter by 20 %). After welding every 20 spots, cast nugget diameter was measured by welding a reference spot weld on samples from the same galvanized steel 40 mm wide and tearing one plate from the other one in one direction by the method of twisting in a parallel plane. After completion of testing, graphs of the change of the cast nugget depending on the number of welded spots were plotted for each electrode material. In our opinion, measurement of the cast nugget diameter is a more objective criterion than measurement of the diameter of electrode working surface.

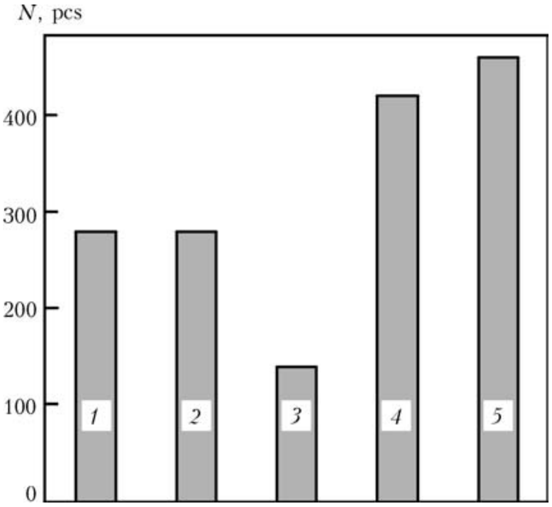

Figure 1. Durability of different electrodes (up to the first resharpening) in resistance spot welding of hot galvanized steel 0.5 mm thick (without cooling channel in the electrode); *1*, *2* — chromium-zirconium bronze manufactured in Germany and South Korea, respectively; *3* — BrKhTsr («Krasny Vyborzhets», RF); *4* — nanocomposite material S16.102 DISKOM; *5* — bimetal electrode #30 (PWI); *N* — number of spot welds

Figure 1 shows the results of comparative testing of different electrode materials for spot welding of hot galvanized steel 0.5 mm thick (coating thickness of 20–30 μm) in the following mode: I_w = 4.5–5.0 kA; t_w = 5–6 cycles; compressive force of 200 MPa; welding speed of 35 spots/min. Lowering of welding parameters compared to the standard ones is related to absence of cooling channel in the «end piece». As is seen from Figure 1, durability of electrodes from chromium-zirconium bronze (Cu–Cr–Zr) produced in South Korea and Germany is the same and is higher than that of electrodes from BrKhTsr produced by «Krasny Vyborzhets» plant (Russia). In our opinion, this is related to its higher content of zirconium (about 1 wt.%) compared to BrKhTsr (0.06 wt.% Zr). Bimetal (surfaced) electrodes demonstrated the highest durability. Durability of electrodes from nanocomposite material S16.102 DISKOM is only slightly inferior to that of surfaced electrodes.

Preliminary testing of electrodes from DSCM (mechanical alloying) showed that a considerable transfer of electrode metal to galvanized steel is observed in welding, which, apparently, is what accounts for their low resistance (100 spots).

Evaluation of service durability of bimetal electrodes the working part of which is made of CDSM — CDSM and CMLM — was performed earlier. Figure 2 shows the results of testing obtained at resistance spot welding of hot galvanized steel 0.8 mm thick using uncooled electrode. It is determined that resistance of an electrode with working part from CDSM is higher than that of electrode from CMLM.

Results of the conducted testing showed (Figure 3) that electrode material structure can considerably influence its service durability. A.A. Bochvar expressed his opinion on the advantage of the cast structure compared to deformed metal [11].

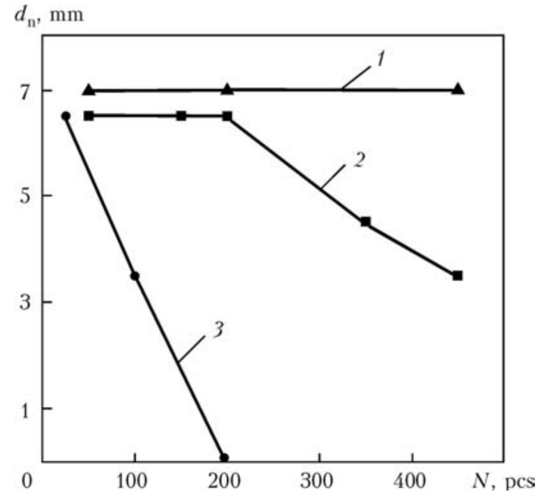

Figure 2. Dependence of spot weld nugget diameter d_n on number of welded spots N in resistance spot welding of hot galvanized steel 0.8 mm thick: *1, 2* — bimetal electrode with working part from CDSM and CMLM, respectively; *3* — electrode from chromium bronze BrKh

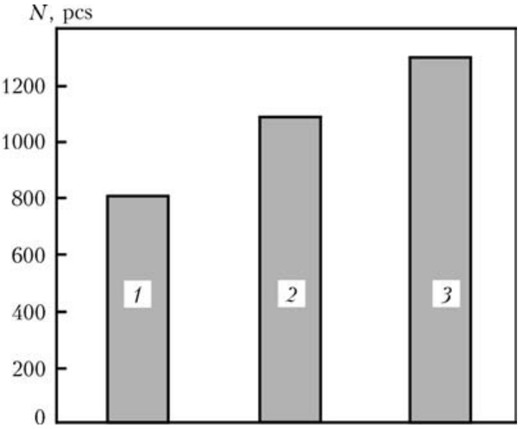

Figure 4. Durability of different electrodes (up to first resharpening) in resistance spot welding of cold galvanized steel 0.8 mm thick (with cooling channel in the electrode): *1* — Cu–Cr–Zr (Germany); *2, 3* — bimetal electrode #30 and 057, respectively (PWI)

It should be noted that testing of bimetal electrodes under the conditions of cooled electrode at resistance spot welding of cold galvanized steel 0.8 mm thick (coating thickness of 30–60 μm) showed their higher service durability (cast nugget diameter is determined after welding every 100 spots) (Figure 4). Welding was performed in the following mode: I_w = 8.8–9.5 kA; t_w = 8–9 cycles; compressive force of 280–300 MPa; welding speed of 35 spots/min.

Considering the higher service durability of bimetal electrodes, experiments were conducted on selection of an optimum alloying system and composition of deposited metal, satisfying the following requirements: high hardness at increased temperature; required electrical conductivity of bimetal electrode; cellular substructure of deposited metal; good welding-technological properties of surfacing wire.

Test flux-cored wires with different alloying system were made, which were selected on the basis of theoretical analysis of physical properties of elements. They were used for surfacing copper billets with their subsequent heat treatment. After that samples were made for metallographic investigations and hardness measurement at elevated temperature in Lozinskii microhardness meter.

Figure 5 gives the results of hardness measurements of surfaced electrodes with various microalloying ad-

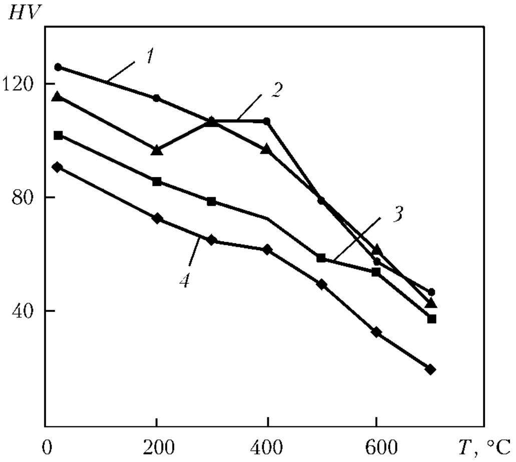

Figure 5. Dependence of hardness of test surfaced electrodes on testing temperature: *1* — #66; *2* — #72; *3* — #30; *4* — #03

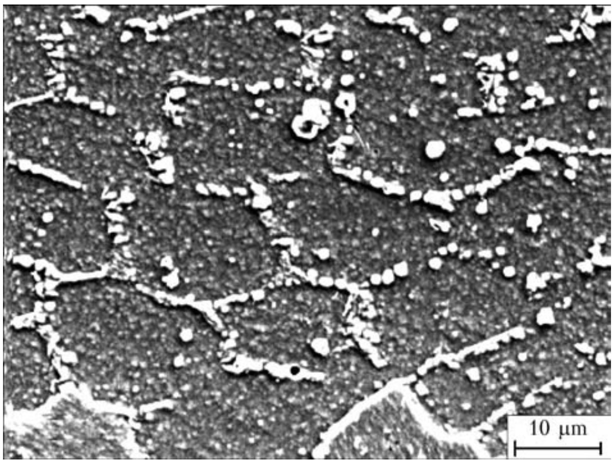

Figure 3. Microstructure of an electrode with cellular substructure of grains, the boundaries of which are decorated by strengthening phase (scanning electron microscope)

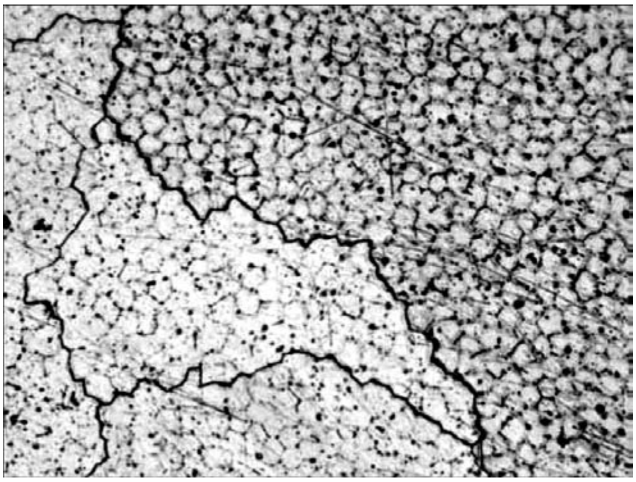

Figure 6. Microstructure (×200) of an electrode surfaced with wire #66

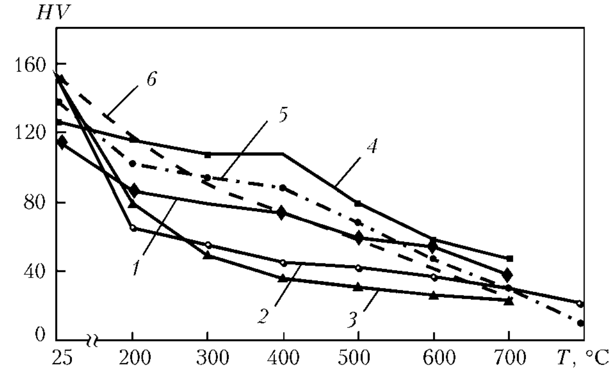

Figure 7. Dependence of hardness of electrodes from different materials on test temperature: *1* — bimetal (surfaced) #30 (PWI); *2* — GlideCop Al-60 (USA); *3* — nanocomposite material S16.102 DISKOM; *4* — bimetal (surfaced) #66 (PWI); *5* — Cu–Cr–Zr (Germany); *6* — BrKhTsr («Krasny Vyborzhets», RF)

ditives, and Figure 6 shows the cellular substructure of the electrode surfaced with wire #66.

As is seen from Figure 7, bimetal (surfaced) electrodes have higher hardness at elevated temperatures. A correlation is found between electrode hardness at elevated temperature and their service durability (see Figures 1 and 7).

To ensure efficiency and stability of the quality of bimetal electrodes it is rational to apply automatic surfacing with solid wire. Improvement of nanocomposite material composition to increase its hardness at elevated temperature is also promising. Such work is currently conducted in cooperation with TsNIIMT DISKOM.

Thus, it is established that electrodes made by arc surfacing and those from nanocomposite material have the highest service durability.

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INFLUENCE OF GETTER ADDITIVES ON HYDROGEN EMBRITTLEMENT OF WELDED JOINTS OF STRUCTURAL MATERIALS OF NPP EQUIPMENT

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The paper gives analysis of literature data on searching for getter materials, which can be recommended for creation of hydrogen traps by introducing them into structural materials and welded joints of NPP equipment. Hydride-forming alloys and compounds based on zirconium, titanium and vanadium are considered as the most promising ones. Rare-earth metals and their alloys, binary compounds of rare-earth metals with transition metals of VIII group are proposed as materials of getter additives to create hydrogen traps in structural materials and welded joints of NPP equipment.

Keywords: *structural materials, service life, physical simulation, weld metal, hydrogen, getter additives, nuclear-physics research*

Hydrogen is known to be one of the most harmful and hazardous impurities in metals and alloys. Practical experience and almost all experimental investigations of hydrogen influence on the processes of embrittlement, strengthening, long-term strength and thermal stability, static and cyclic fatigue, fatigue strength, fatigue resistance, creep in metals and alloys reveal its negative role in these processes. A sufficiently high content of hydrogen in structural materials under certain operation conditions can lead to significant embrittlement of these materials, and, as a result, mark-