PECULIARITIES OF RESISTANCE WELDING OF COPPER WITH ALUMINIUM ALLOYS USING NANOSTRUCTURED FOIL OF Al–Cu SYSTEM

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Peculiarities of formation of welded joints of AD1 aluminium alloy with M1 copper using nanostructured foil of Al–Cu system as an insert are considered. Microstrucutre and chemical heterogeneity of welded joint metal were studied and mechanical rupture testing of welded joints was performed.

Keywords: *resistance butt welding, nanostructured foil, eutectics, microstructure, intermetallics*

Welding of aluminium with copper is applied in industry for manufacture of current conducting elements and units of electric machines, transformers, current conductors, busbars, power-consuming machines, chemical vessels and other products. The main problem in producing welded joints is formation of intermetallics of Al–Cu system in a weld which have con-high hardness and brittleness, thus significantly deteriorating mechanical and electric characteristics of the products. The negative influence of intermetallics is especially noticeable if thickness of their layer is more than 7–8 μm [1]. To decrease the thickness of layer of intermetallics one should minimize the time-temperature parameters of welding process and provide more concentrated heating.

In the present work the process of resistance welding of aluminium with copper was studied using nanostructured foil of Al–Cu system as embedded elements, which is featured by the formation of melt of eutectic composition in the joint zone at minimal heat input. Besides it was established in the works [2, 3] that application of such foils provides highly-concentrated uniform heating of parts being joined.

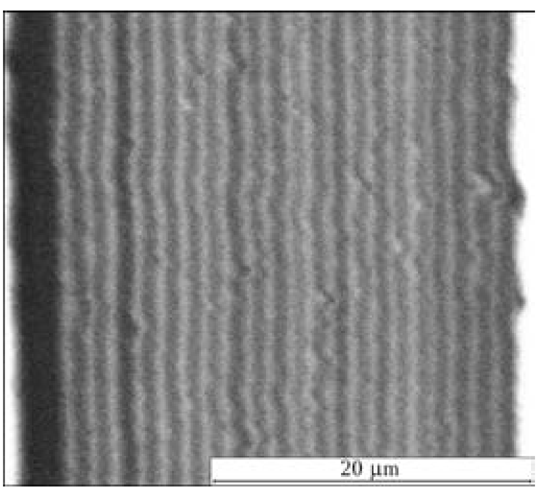

Figure 1. Microstructure of nanolayer foil of Al–Cu system

The welding of specimens of 5 × 14 × 140 mm was performed using updated butt welding machine of the K766 type. The pressure during heating was 3–4 MPa, during upsetting it was 7.5–8.0 MPa, time of welding — 1.5–2.0 s.

The manufacture of nanostructured foils using method of electron beam evaporation with subsequent condensation of components was mastered at the E.O. Paton Electric Welding Institute [4]. The microstructure of a nanolayer foil of Al–Cu system (78 wt.% Al and 22 wt.% Cu) produced using micro X-ray spectral analysis is presented in Figure 1.

The analysis of microstructure and determination of chemical heterogeneity of the joints was performed using optical microscope «Neophot-32» and scanning electron microscope JSM-840 (Japan) with microanalyzer «Link-systems». The evaluation of strength properties of the joints was performed by investigation of microhardness using the LECO microhardnesss meter and performing mechanical rupture tests.

The experiments on resistance welding of aluminium alloy of the grade AD1 with copper M1 and comparative metallographic investigations were performed using foil of Al–Cu system and without it. In microstructure of transition zone of a joint produced without using foil, the width of a weld is not uniform (varied in the range of 1–10 μm). At 1–2 μm width of transition zone the structure of weld metal is homogeneous, the boundary with aluminium is wave-shaped (Figure 2, *a*, *b*). There is a shelf on the curves of distribution of copper and aluminium in the area located near the boundary with aluminium; a curve of distribution of copper grows gradually while that of aluminium is falling.

It is known that copper is not dissolved in aluminium at a room temperature and solubility of aluminium in copper reaches 7.6 wt.%. Al–Cu system is characterized by the presence of some intermetallic compounds, among which $CuAl_2$ is the nearest to aluminium.

Based on the diagram of state (see Figure 3) [5] it can be assumed that transition zone is composed of

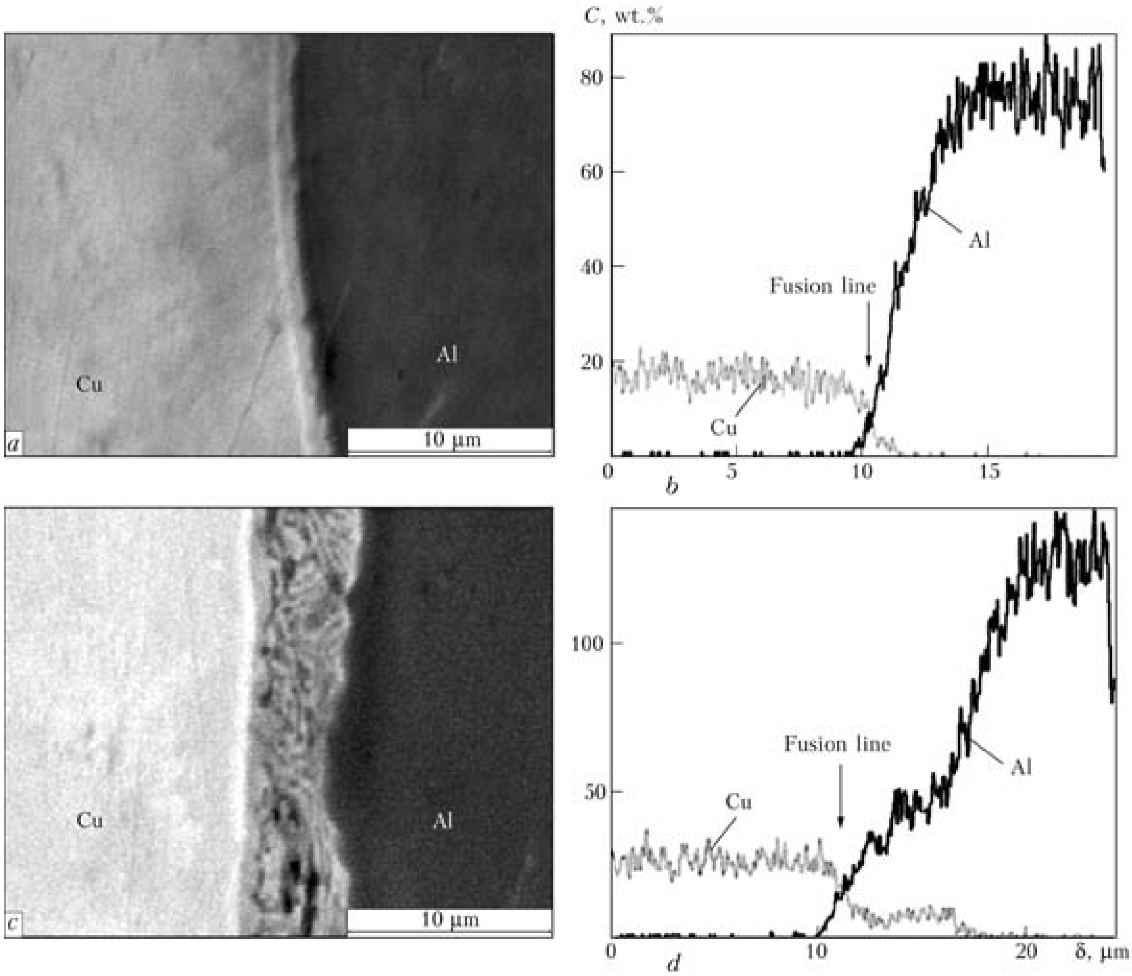

Figure 2. Microstructures (*a*, *c*) and curves of distribution of copper and aluminium content *C* (*b*, *d*) in transition zone of the joint, produced using resistance butt welding without using foil, on the zones of the width δ = 1–2 (*a*, *b*) and 10 (*c*, *d*) µm

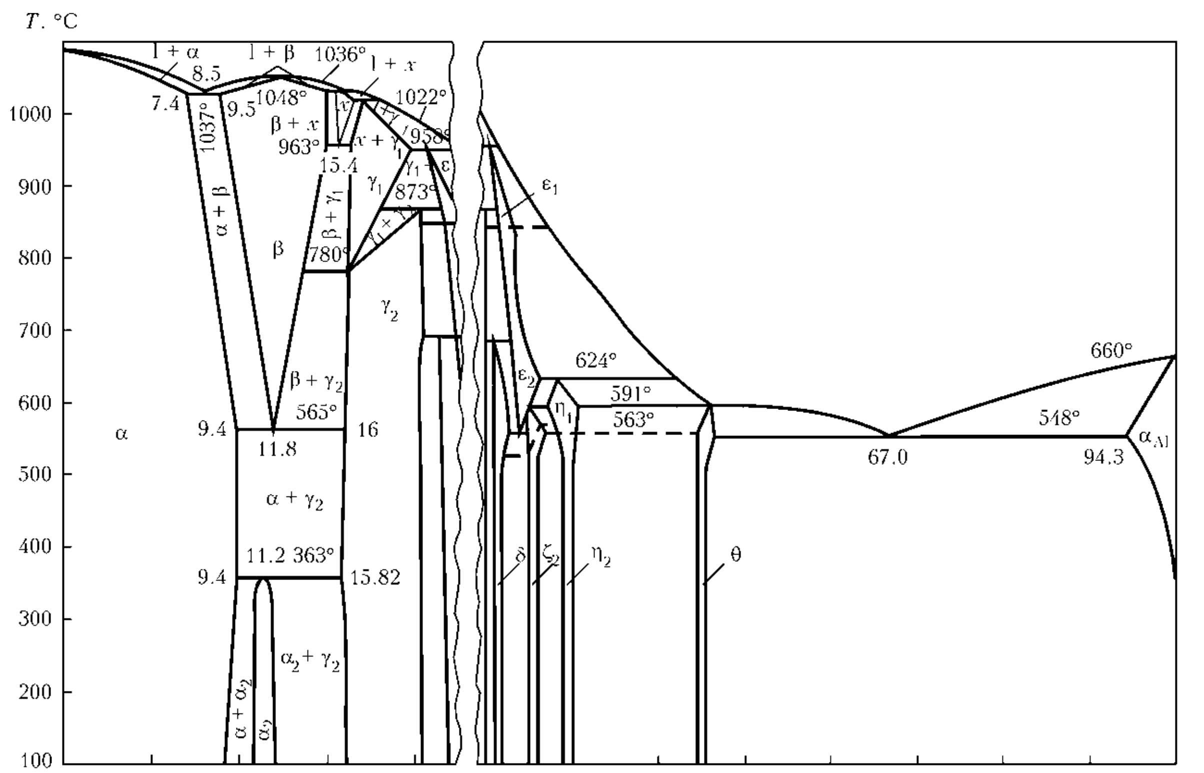

Figure 3. Temperature diagram of state of Al–Cu system

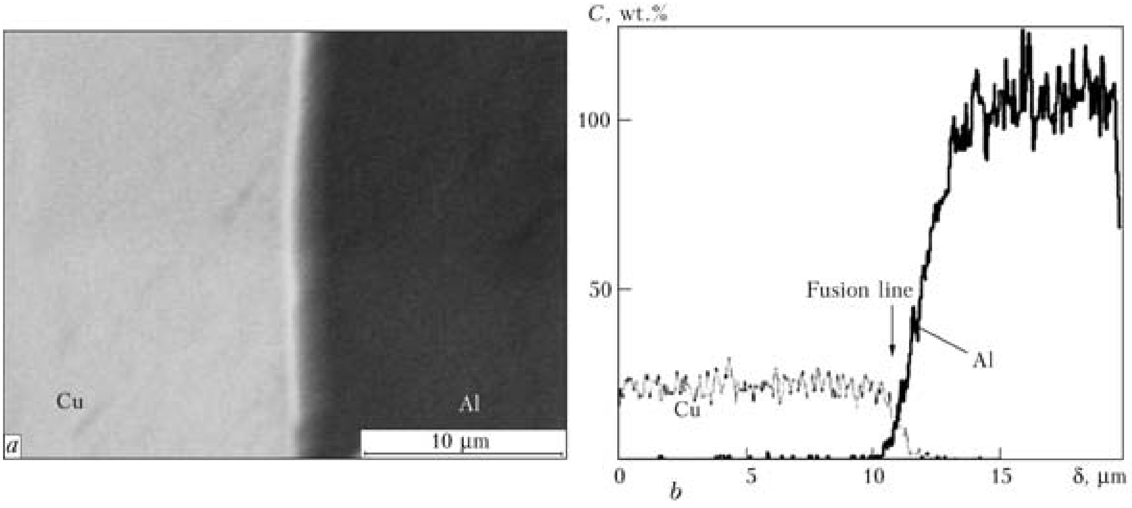

Figure 4. Microstructure (*a*) and curves of distribution of content of copper and aluminium (*b*) in transition zone of the joint produced by resistance welding using nanostructured foil of Al–Cu system

diffusion zone of copper and a layer of θ-phase (solid solution based on $CuAl_2$).

With increase in width of a weld to 10 μm the dendrites, growing from the boundary with copper, and eutectic colonies are formed in its metal (see Figure 2, *c*, *d*). The shelf corresponds to the eutectic colonies on the curves of distribution of aluminium and copper, in the area of dendrites a curve of distribution of copper is gradually falling and a curve of distribution of aluminium grows. In this case the transition zone is composed of eutectics Al + θ-($CuAl_2$) and dendrites of α-phase (solid solution of aluminium in copper).

A weld produced using resistance butt welding using foil of Al–Cu system (Figure 4) has a width of 2–3 μm. The shape of the curves of distribution of aluminium and copper in the transition zone of width of above 1.5 μm evidences the gradual change of content of these elements. If intermetallic compounds are not detected, the eutectics is absent.

Mechanical rupture tests showed that maximal strength of specimens of welded joints produced using resistance butt welding with nanostructured foil was 75 MPa (the average value was 65–70 MPa). The fracture of specimens occurred along the near-weld zone on the side of aluminium. The maximal strength of welded joints produced without using foil was 50 MPa. During the tests the specimens were fractured along the weld.

Thus, the use of aluminium with copper in resistance butt welding and nanostructured foil of Al–Cu system as an embedded element prevents the formation of brittle intermetallic phases in weld metal and allows producing welded joints of equal strength.

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