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EXPLOSION WELDING OF COPPER-ALUMINIUM PIPES BY THE «REVERSE SCHEME»

P.S. Shlyonskyi
E.O. Paton Electric Welding Institute of the NAS of Ukraine
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine. E-mail: office@paton.kiev.ua

Explosion welding by the «reverse scheme» of pipe billets from copper and aluminium with 36 mm outer diameter and 200 mm length was studied. For welding by this scheme, a steel rod of smaller diameter than that of inner (copper) pipe was used as the filler-support for this pipe, and the gap was filled by a low-melting Wood's alloy. 6 Ref., 4 Figures.

Keywords: *explosion welding, «reverse scheme», bimetal pipes, copper, aluminium*

Current-conducting copper-aluminium elements, made by explosion welding (EW) by the parallel scheme cannot be applied for joining multiconductor (flexible) electric cables from dissimilar materials (copper-aluminium) [1].

Manufacture of bimetal products by explosion welding is widely demanded in the global industry. EW can be used to manufacture products of both plane and cylindrical shape [2]. Problems of producing copper-aluminium bimetal by the parallel schematic are quite well studied [3, 4], while the features of producing bimetal copper-aluminium pipes are practically not described in publications.

The objective of this work was experimental study of the possibility of producing copper-aluminium pipe billets by the method of explosion welding by the «reverse scheme», in particular, for manufacturing the transition pieces for joining copper and aluminium cables.

Tubes from AD1 aluminium with 6 mm wall thickness were used as the cladding layer, and tubes from M2 copper of 19×1.5 mm size were the base.

It is obvious that in the case of external cladding of a thin-walled copper tube by a thick-walled aluminium tube, the filler (material inside the copper tube), which acts as a support for the latter, has an important role.

Known is the application of metal shot as the support for cladding curvilinear surfaces of turbine blades [5], and metal shot with liquid to obtain two-layer pipe billets with an inner corrosion-resistant layer from 08Kh18N10T stainless steel [6]. Filling the space between the shots by liquid allows lowering the shot pressure in the zone of its contact with the product that reduces the depth of shot imprints on the pipe inner surface.

Considering that copper is quite ductile, and presence of dents on the inner surface of the copper pipe will reduce the area of contact with the cable, it will adversely affect the product serviceability on the

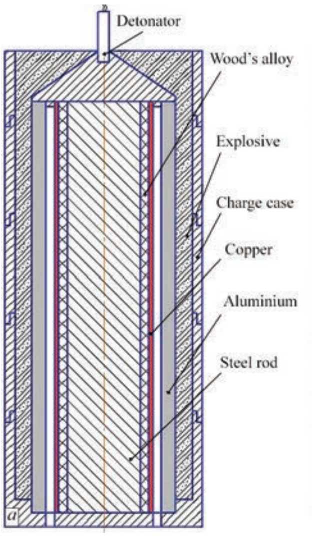

Figure 1. Scheme of assembly for explosion welding in order to produce a bimetal pipe billet (*a*) and billet for explosion welding with a steel rod, covered by Wood's alloy inside the copper tube (*b*)

P.S. Shlyonskyi — http://orcid.org/0000-0002-3566-1752

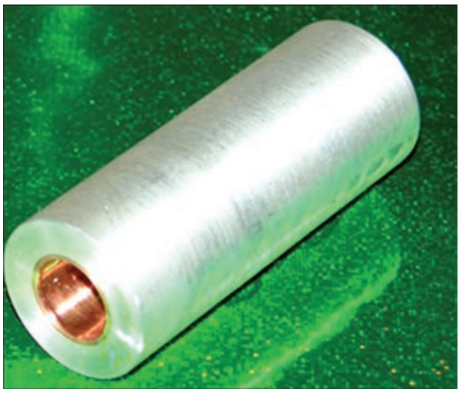

Figure 2. Sample of a bimetal pipe billet (AD1 — outer layer, M2 — inner)

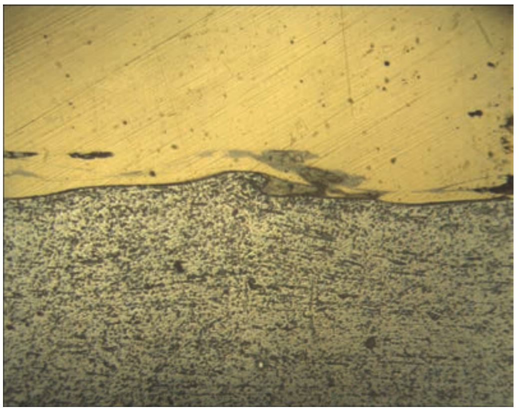

Figure 3. Microstructure (×100) of the joint produced in the optimum mode

whole, and, therefore, application of filler from metal shot is inacceptable for this material.

After conducting experimental work, it was determined that the optimum scheme of external cladding for pipe billets from ductile materials, in order to prevent their deformation under the impact of explosion and to obtain smooth inner surface, is the scheme (Figure 1, *a*) with application of a steel rod, which was inserted with a 1 mm gap into the copper tube, prefilled by molten Wood's alloy (Figure 1, *b*).

Thus, it eliminates the gap between the tube and the rod, and after explosion welding it enables easily removing the rod by heating up to approximately 70 °C.

Test bimetal copper-aluminium billets with an inner copper layer from 1.5 mm copper were produced by the results of optimizing the modes (Figure 2).

Metallographic investigations were conducted using MMO-1600NA microscope after microsection etching by aluminium in sodium hydroxyde solution. Figure 3 presents the microstructure of the joint produced in the optimum mode.

Figure 3 shows a weak wave profile that for the case of welding copper to aluminium is indicative of the fact that the energy is enough, and a clearly defined zone of the joint with a small amount of intermetallic inclusions.

As the standard procedures for assessment of tearing strength of layers of a bimetal ring cut out of the pipe billet, are absent, qualitative evaluation of the adhesion strength of the layers was performed using the known procedure of flattening testing of a bimetal ring (Figure 4), and the ring was cut out of a bimetal pipe billet. Testing was conducted with the purpose of revealing cracks and delaminations in the joint zone under the impact of the load.

Figure 4 shows that no delamination occurred in the joint zone after compression of the bimetal ring.

As a result of the conducted studies, it was shown that in order to lower the deformation of the welded billets under the impact of explosion and to obtain a smooth inner surface of the thin-walled pipe, on which another pipe is applied, in explosion welding by the «reverse scheme» it is rational to use a metal rod of a smaller diameter with gap filling by Wood's alloy.

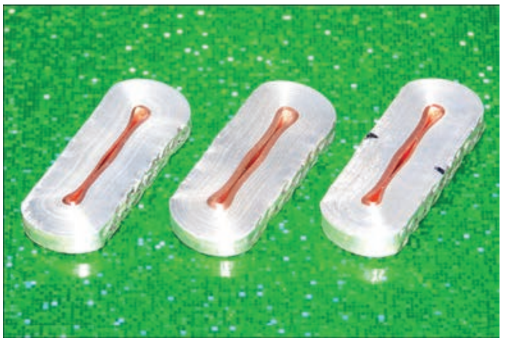

Figure 4. Samples of rings cut out of a bimetal pipe billet after flattening

1. Chugunov, E.A., Kuzmin, S.V., Lysak, V.I. et al. (2001) Energy saving composite elements of current-conducting assemblies of electrical power circuits. *Energetik*, **9**, 13–15 [in Russian].
2. Lysak, V.I., Kuzmin, S.V. (2005) *Explosion welding*. Moscow, Mashinostroenie [in Russian].
3. Chuvichilov, V.A. (2005) *Investigation and development of technology of explosion welding manufacture of electrotechnical purpose composites with two-sided symmetrical cladding*: Syn. of Thesis for Cand. of Techn. Sci. Degree. Volgograd [in Russian].
4. Peev, A.P. (2001) *Development of technological processes of explosion welding manufacture of copper-aluminium elements of current-conducting assemblies for power engineering and electrometallurgy enterprises*: Syn. of Thesis for Cand. of Techn. Sci. Degree. Volgograd [in Russian].
5. Konon, Yu.A., Pervukhin, L.B., Chudnovsky, A.A. (1987) *Explosion welding*. Moscow, Mashinostroenie [in Russian].
6. Malakhov, A.Yu., Sajkov, I.V., Pervukhin, L.B. (2016) Peculiarities of explosion welding of pipes by «reverse scheme». *Vestnik Tambov. Un-ta. Ser: Estestvennye i Tekhnicheskie Nauki*, 21(**3**), 1139–1141 [in Russian].

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