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EFFICIENCY OF APPLICATION OF FILLER METAL CORED WIRE IN TIG WELDING OF COPPER*

V.M. ILYUSHENKO, A.N. BONDARENKO, E.P. LUKIYANCHENKO and **T.B. MAJDANCHUK**
E.O. Paton Electric Welding Institute of the NAS of Ukraine
11 Kazimir Malevich Str., 03150, Kyiv, Ukraine. E-mail: office@paton.kiev.ua

The experience of the E.O. Paton Electric Welding Institute in creating a metal cored wire for helium arc TIG welding of copper and its alloys was described. The deposited metal of the wire contains not more than 0.35 wt.% of alloying additives and is characterized by a high electrical and heat conductivity. Examples of the effective use of the developed wire in welding rotors of electric machines and in repair of gas-oxygen copper chambers of arc steel melting furnaces are given. 2 Ref., 4 Figures.

Keywords: *TIG welding, helium shielding, copper and copper alloys, metal cored wire, electrical and heat conductivity, efficiency of application*

Welding in shielding gases is one of the main technological processes of joining non-ferrous metals. This is largely predetermined by the simplest solution to the problem of protecting weld pool metal from the surrounding atmosphere, the possibility of visual observation of welding process, and the simplicity and reliability of the process automation. Welding of copper abroad is mainly performed using this method.

In domestic practice, especially, for metal of small and medium thicknesses (up to 10 mm), welding with a nonconsumable electrode, TIG process, becomes widely used. In a much smaller volume, mainly due to the lack of special welding wires, a consumable electrode welding, MIG/MAG-process, is used.

Welding of copper in shielding gases together with the noted advantages encounters also serious difficulties, namely, the need to apply preheating and also concurrent heating in case of large thicknesses, which significantly complicates the welding process. Copper is also prone to the formation of pores in the welds, which occur during the weld pool crystallization as a result of gases evolution.

As shielding gases for welding copper, argon, helium, nitrogen and their mixtures are used. Taking into account the special thermophysical properties of copper, when selecting the optimal protective environment, the preference should be given to helium and nitrogen, providing a higher efficiency factor of the process. However, it is still necessary to take into account the negative effect of nitrogen on the porosity of welds when welding copper and some of its alloys. The earlier opinion about nitrogen inertness with respect to copper is erroneous. Recent studies have established that under the conditions of welding heating, nitrogen is absorbed by liquid copper and during the weld pool crystallization it can lead to the formation of gas porosity. Producing dense welds in nitrogen-arc welding is possible with the use of filler materials containing elements that bind nitrogen to stable nitrides.

Taking into account the fact that the main cause of porosity in copper welding is the formation and evolution of water vapors from weld pool metal as a result of interaction of hydrogen with oxygen, the main measure for prevention of porosity is the active deoxidation of the weld pool metal. Therefore, the required quality of welds during welding in shielding gases is achieved primarily by the correct selection of filler material [1]. The analysis of application of wires for welding copper, which are produced by industry according to GOST 16130-90 (MNZhKT 5-1-0.2-0.2; BrKMts3-1; BrKh0.7; BrKhNT, etc.) shows that the presence of such active deoxidizers and nitride-forming elements like titanium, silicon, manganese, etc. in the wires, provides metallurgical treatment of the pool and producing dense defect-free welds. However, despite the satisfactory welding and technological properties, these wires do not provide the necessary thermophysical properties of welded joints: their thermal and electrical conductivity is at the level of

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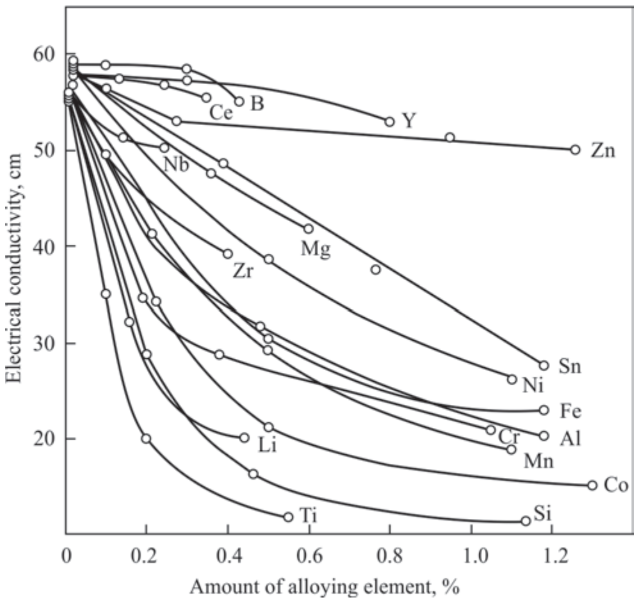

Figure 1. Effect of additives on the electrical conductivity of copper (according to the «Tsvetmetobrabotka» Institute)

20–30 % of the level of those for metal being welded. In practice, these materials are unsuitable for welding products that require high electrical and thermal conductivity of welds.

As experience shows, the same low values of thermophysical properties are also provided by the wire OK Autrod19.12 (ERCu/AWSA5.7) produced abroad, which has the following typical chemical composition of the deposited metal, wt.%: 0.2 Si, 0.2 Mn and 0.8 Sn.

For many years, E.O. Paton Electric Welding Institute, together with the «Tsvetmetobrabotka» Institute, developed welding wires of optimal chemical compositions for welding of copper and its low-alloyed alloys, which meet the complex requirements of welding-technological properties in welding with both consumable and nonconsumable electrode, and also providing the necessary thermophysical properties of welded joints. The wires of grades Sv.ML0.2; Sv.MBMg, Sv.MLMgB; Sv.MLKhMg were developed, containing not more than 0.1–0.4 % of effective deoxidizers and nitride-forming elements (lithium, magnesium, boron). As is seen from Figure 1, such small additives provide high electrical conductivity of copper (75–85 % of that for pure copper). However, the technology for manufacturing these wires is quite complicated: melting in vacuum furnaces using master alloys, pressing of rods under high heating, annealing and drawing to the required diameter, therefore their production is set up only in an experimental manner [2].

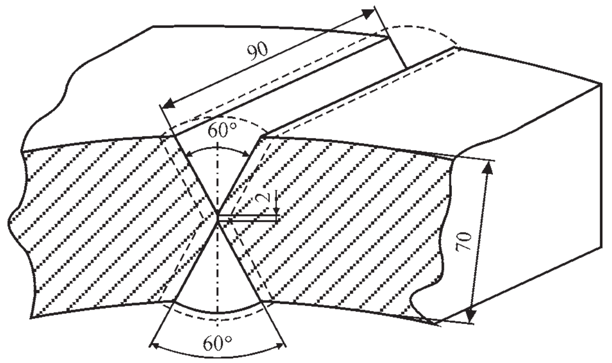

Figure 2. Preparation of butt for double-sided welding of rings

It is simpler and economically more rational to develop electrode material of the flux-cored wire type, applying copper strip as a sheath. Using a strip with a thickness of 0.8–1.0 mm and a width of 12–15 mm, and a copper powder as the main filler of a core, we can produce a metal flux-cored wire as a result, into the composition of which a dosed amount of deoxidizers and, if necessary, slag-forming components are easily introduced. As a result of experimental studies, a metal cored wire of the grade PP-ANM1 was developed, which provides the deposited metal with a content of not more than 0.35 % of alloying additives. Such a deposited metal has an electrical and thermal conductivity, which is 2.5–3.0 times higher than that during welding with the standard wires.

The most effective was the use of filler metal flux-cored wire in helium-arc welding. This technology was successfully applied in the production of rotors of large electric machines.

The basic design of rotors represents two copper rings made of rectangular section copper bars. The di-

Figure 3. Typical defects of copper chambers after operation

Figure 4. Appearance of restored gas-oxygen chamber

ameter of the rings, depending on the type of motor is in the range of 600–1000 mm. The cross-section of workpieces is min 60×20 mm; max is 90×70 mm. The rings are made on rolling units, and then, depending on the diameter, they are welded with one or two butt welds. Figure 2 shows the shape of the butt edge preparation of the workpiece with a section of 90×70 mm.

Helium-arc welding is performed with the use of filler metal cored wires of the grade PP-ANM1, which provides a minimum reduction of the electrical conductivity in the welded joint. The butt joint of the section, shown in Figure 2, is made with a double-sided weld in 5–6 passes on each side. The electrical conductivity of the weld metal is not less than 60–70 % of the electrical conductivity of copper. The developed welding technology was mastered at the Large Electric Machines Plant (Novaya Kakhovka).

The use of this cored wire in the repair of copper gas-oxygen chambers of arc steel melting furnaces (ASF) is highly effective. These parts are worn out during operation as a result of extremely complex operating conditions (thermal, chemical and mechanical effect). At the end part of the chambers, deep cracks are initiated, a local burning-out of copper occurs up through burn-outs of walls of water-cooling channels (Figure 3), which leads to the appearance of leaks. In the presence of leaks, the chambers are rejected and subjected to replacement by new ones. Taking into account the high cost and scarcity of these products (supplied by import), the task of extending their service life is very urgent.

The studies on the selection of a rational technology for repairing gas-oxygen chambers showed that for these purposes the helium-arc welding with the use of filler metal cored wire PP-ANM1 is preferable. Providing a dense metal in multilayer surfacing, the process allows restoring the edge surface of the chamber to the desired size in height. Here, the thickness of the deposited layer can amount up to 20 mm. The presence of a very small amount of slag-forming additives in the filler wire, as a rule, does not require the removal of slag between the passes, which is a significant advantage over welding with coated electrodes.

Figure 4 shows the appearance of the restored ASF chamber. As was shown by the industrial tests of the restored chambers at the Metallurgical Plant «Dneprosteel LLC», their service life increased by 60–80 %. At the same time, an experience of already two-time repair of gas-oxygen chambers is available.

It should also be emphasized that this technology, providing high electrical and thermal conductivity of welded joints, is very promising for welding of busbars and electrical networks of different purposes.

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