METHOD OF JOINING WIRE OF COMPOUND MATERIAL

Inventors: Carl Bergman; Erik Enroth, both of Vasteras, Sweden

Assignee: Allmanna Svenska Elektriska Aktiebolaget, Vasteras, Sweden

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ABSTRACT

In drawing wire of compound material with a core of aluminum and a casing of copper, in order to join two wire ends for continuous drawing, the copper close to the end of the wires is removed, and the adjacent portion is tapered downwardly. The two ends are then butt-pressure welded and the burr is cut off. The exposed area of aluminum at the burr and the adjacent parts of the wire are then provided by sputtering with a metallic material of good malleability and good electrical conductivity such as silver or gold.

6 Claims, 7 Drawing Figures
Fig. 1

Fig. 2

Fig. 3
METHOD OF JOINING WIRE OF COMPOUND MATERIAL

BACKGROUND OF THE INVENTION

1. Field of the Invention
The invention relates to the joining of wire of compound material.

2. The Prior Art
When drawing wire in a drawing bench for production of wire having smaller diameter, it is customary to join successive lengths of the thicker wire to each other in order to make the drawing process continuous and in order to make possible manufacture of the thinner wire in unlimited length. It is very desirable that it should be possible to apply this method when producing compound wire having a core of aluminium and a casing of copper, not least because it is practical to produce the first generation wire of this material having a diameter of 5 - 10 mm by means of hydrostatic extrusion. The material is obtained in limited lengths and must, for most uses, be drawn down to considerably smaller dimensions.

It has been found very difficult to join wire of aluminium having a copper casing in such a way that the wire can be drawn and that the joint after drawing will have satisfactory electrical, mechanical and physical properties. Joining by means of welding methods in which the wire is heated has been found to involve such alterations at and around the joint that the wire breaks during the drawing process. One of the main reasons for this is that hard and brittle alloys are easily formed between the components when the wire is heated. Therefore, methods involving heating of the wire to high temperature have been avoided. It is thus known to join wire of copper-clad aluminium by means of cold pressure welding of the aluminium cores in the wire ends which are to be joined, and to replace the copper which is removed from the joint in connection with the cold pressure welding with new copper. This is done by applying a sleeve of copper over the exposed aluminium surface and adjacent parts of the copper casing, and joining the sleeve to the aluminium core and the copper casing by means of blast welding. The explosive is then fitted as an outer casing around the copper sleeve, this having the same or somewhat larger thickness that the copper casing of the wire. It has been found out, however, that also the last mentioned method has certain drawbacks. In certain cases it may be difficult to obtain joints having a reproducible, good bonding between the copper laid on at the joint and the underlying aluminium. This can lead to the laid-on copper peeling off or flaking off during the drawing process. It can also be added that electrolytic laying on of copper at the joint gives a considerably worse result than the described method using blast welding since the bonding to the aluminium is quite unsatisfactory.

SUMMARY OF THE INVENTION
The present invention is based on the recognition that a copper layer which is considerably better anchored to the aluminium can be achieved by means of sputtering, after the cores at the wire ends have been joined together without being heated to a temperature which leads to the formation of brittle alloy layers. The sputtering process is also carried out below the harmful temperature mentioned. The improved bonding is attributed to the great energy content of the copper atoms on hitting the aluminium surface and the fact that the copper layer at each point is efficiently anchored to the underlying aluminium. In this way, a mechanical strain on the copper layer is evenly distributed along the whole extension of the joint. This means that the tendency of the copper layer to peel off or flake off during the drawing is considerably reduced. The sputtering method has also the quality that it makes it possible to achieve an arbitrary thickness in the laid-on copper layer. Thus it is possible, contrary to what it the case when using the blast welding method, to apply very thin copper layers when necessary. Such a thin copper layer, being firmly anchored to the underlying material, follows more easily a deformation in the underlying material without being damaged than a thicker layer.

The present invention relates more exactly to a method of joining wire of compound material having a core of aluminium and a casing of copper, two wire ends being joined, preferably by means of cold pressure welding so that the cores at the two wire ends form a homogeneous transition with each other, and the joint, after removing any bulge which may have been formed there, is coated with a coating material in the form of copper or other metallic material having good malleability and good electrical contact properties, such as silver or gold, characterised in that the coating metal is applied by means of sputtering. Besides cold pressure welding, the wire ends can be joined, among other things, by means of friction welding and electron-beam welding.

As mentioned, it is possible to use also other coating metals besides copper. The condition is that they are malleable so that they can follow the deformation of the wire when it is drawn down without breaking, and further that they have good contact properties so that they give a low transition resistance to a connection device. This implies that they are not covered with an insulating oxide layer when exposed to air and that they in themselves have sufficient electrical conductivity. Besides copper, which is preferred, among other things silver, gold, tin and several tin alloys having more than 50 per cent by weight tin are usable.

According to an advantageous embodiment of the invention, the copper casing is removed closest to the ends of the respective wire ends before the cores at the respective wire ends are joined to each other. It has been found particularly suitable for achieving a joint of good quality to shape the copper casing of each wire end, for example by means of working by cutting or grinding, with a thickness decreasing towards the end of the wire end before the coating metal is applied.

As is clear from the foregoing, the coating metal can be applied in the form of a thin layer. The layer can be considerably thinner than the casing of the wire. It may thus be advantageously applied in layers having a thickness of 0.1 – 100 microns. In many cases, a thickness of 0.1 – 10 microns is preferred. At least when using layers of coating metal which are considerably thinner than the thickness of the casing, it is advisable to upset the wire ends when they are joined so that the diameter of the core at the joint is at least as large as the original diameter of the wire, and that any parts projecting outside the original wire diameter are removed before the coating is applied.
BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described by means of an example with reference to the accompanying drawing, in which

FIG. 1 shows in longitudinal section two wire ends which are to be joined,
FIG. 2 the same wire ends which have been pre-treated for joining,
FIG. 3 the pre-treated wire ends inserted in a joining tool before joining,
FIG. 4 the joined wire ends removed from the tool,
FIG. 5 the same wire ends after-treated for laying-on of coating metal,
FIG. 6 the same wire ends coated with copper, and
FIG. 7 shows schematically a sketch of a sputtering equipment by means of which the laying-on can be carried out.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The two wire ends which are to be joined are shown in FIG. 1. Each of them has a core 1a and 1b of aluminum and a casing 2a and 2b of copper. In the example the diameter of the wire is 8 mm and the layer thickness of the casing is 0.3 mm. Before joining, the copper casing is removed, as appears from FIG. 2, closest to the end surface of each wire end so that an exposed aluminum surface 3a and 3b is obtained. Further the copper casing is bevelled in the area 4a and 4b closest to the exposed aluminum surface so that the thickness decreases successively in a direction towards the exposed aluminum surface.

After this, the two wire ends are placed, according to FIG. 3, in clamps 5a and 5b having gripping surfaces 6a and 6b. The wire ends are pressed against each other by means of the clamps with a pressure considerably exceeding the yield point for aluminum. The clamps are provided with cavities 7a and 7b which take care of the burr and edges 8a and 8b which cut off the burr. In the pressing, the cores 1a and 1b flow into each other and form a homogeneous transition with each other, which means that the core at the joint has as good strength as the core elsewhere at each wire end. At the same time, the cores of the wire ends are upset, as appears from FIG. 4, so that the joint 8 for the cores has a greater diameter than the wire itself. The joint is then made even, for example by using emery cloth, so that the joined wire has an even surface as appears from FIG. 5. The joined wire is now ready for application of coating metal. The coating metal, in the example consisting of copper, is applied on the joint 8 where the aluminum reaches the surface of the wire and on adjacent parts of the copper casing 2a and 2b by means of sputtering. The coating, designated 9 in FIG. 6, is very thin, having a thickness of a few microns. Its thickness is thus greatly magnified in the Figure. The increase in thickness at the joint is so insignificant that it does not affect the drawing of the wire in a drawing machine.

For application of coating metal, the sputtering plant schematically shown in FIG. 7 may be used. It comprises a chamber 10 containing argon under low pressure. In the chamber a target 11 and a substrate holder 12 are arranged, both being provided with connections 13 and 14 for electrical current. The target consists of the material which is to be sputtered, in this case copper, and of a holder for this material. On the substrate holder, the object 15 to be coated is placed, that is in this case the joined wire shown in FIG. 5. Said wire is wound on both sides of the joints on bobbins 16 and 17, these being rotatable by motors, not shown, in such a way that the wire inside the chamber 10 can turn round its axis. The wire is led through the walls of the chamber by means of vacuum tight lead-ins 18 and 19. Further a shutter 20 is arranged in the chamber, said shutter being displaceable so that it can be placed both in the area between the target and the substrate holder and outside this area. In the Figure, this has been shown by making the shutter turnable round a vertical axle 21 arranged in a vacuum tight lead-in 22.

The sputtering device works in such a way that the argon gas is ionized when a voltage is applied above the target 11 and the substrate holder 12. The positive ions produced are then attracted by the negatively charged target. From the target, atoms are released, in this case copper atoms. The copper atoms move across the chamber and hit the object 15, that is the joined wire which rests against the substrate holder 12. At the moment of their contact with the joint, the copper atoms give a coating of copper on the joint. By rotating the wire at least one turn, a coating is obtained round the whole joint.

During the process described above, the shutter 20 was not used. It is then displaced to a position outside the area between the target and the substrate holder. The shutter is used in the so-called ion etching (back sputtering), the sputtering being carried out inversely. During the ion etching the poles are reversed so that the substrate holder 12 is negative and the target 11 positive. The ions generated in the chamber instead bombard the object 15, dispersing impurities from its surface, for example oxides. The shutter, which during this process is displaced to its position between the target and the substrate holder, intercepts the impurities. When coating the joint according to the present invention, it is advisable to carry out an ion etching prior to the real sputtering process, in order to remove oxide from the aluminum at the joint. When the ion etching process is finished, the shutter 20 is removed from the area between the target and the substrate holder, and the poles are reversed so that the target is negatively and the substrate holder positively charged. In this way, the coating of copper on the joint is started, the joint being now free from impurities thanks to the preceding ion etching.

We claim:

1. In a method of joining wire of compound material having a core of aluminum and a casing of copper, welding the ends of two copper coated aluminum wires the cores in the two wire ends forming a homogeneous transition with each other and the core at the joint having as good strength as the core elsewhere, and coating the joint with a coating of metallic material having good malleability and good electrical contact properties by means of sputtering.

2. Method according to claim 1, which comprises removing the copper casing closest to the ends of the respective wire ends before the cores in the respective wire ends are joined to each other.

3. Method according to claim 2, which comprises shaping the copper casing of each wire with a thickness diminishing towards the end of the wire end before the coating material is applied.
4. Method according to claim 1, which includes upsetting the wire ends during the joining so that the diameter of the core at the joint is at least as large as the original diameter of the wire and removing any parts projecting outside the original wire diameter before the coating material is applied.

5. Method according to claim 1, in which the coating material is applied in a thickness of 0.1 – 100 microns.

6. In a method as claimed in claim 1, said metallic material being copper.

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