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[54] **MANUFACTURE OF COPPER-CLAD ALUMINUM ROD**
5 Claims, 3 Drawing Figs.

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[51] Int. Cl. B21c 23/22
[50] Field of Search 72/47, 60, 258; 29/423, 474.3, 475, 494, 504

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ABSTRACT: Copper-clad aluminum rod in which the copper cladding is soundly metallurgically bonded to the aluminum core is made by surrounding a preformed billet of aluminum with a close fitting sheath of copper to form a cold composite billet, the contiguous surfaces of the aluminum and copper components of the composite billet being clean and substantially free of surface oxides, and directly extruding the cold composite billet so formed to effect a reduction in cross-sectional area of the composite billet. The reduction in cross-sectional area of the cold composite billet is preferably effected by hydrostatic extrusion.

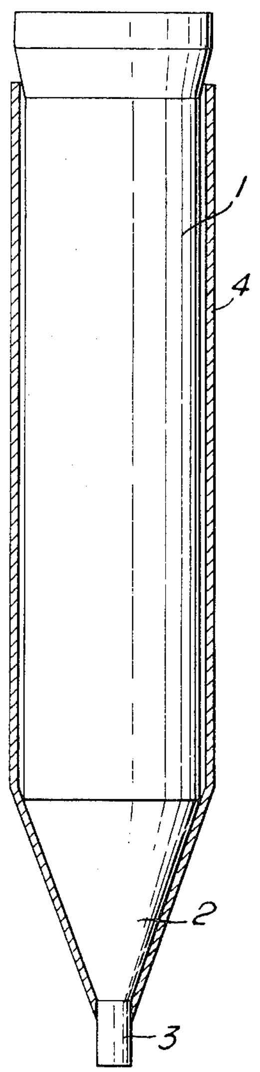

Fig. 1.

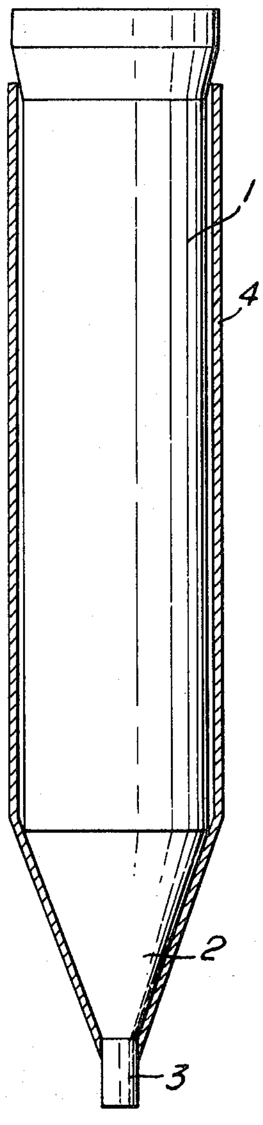

Fig. 2.

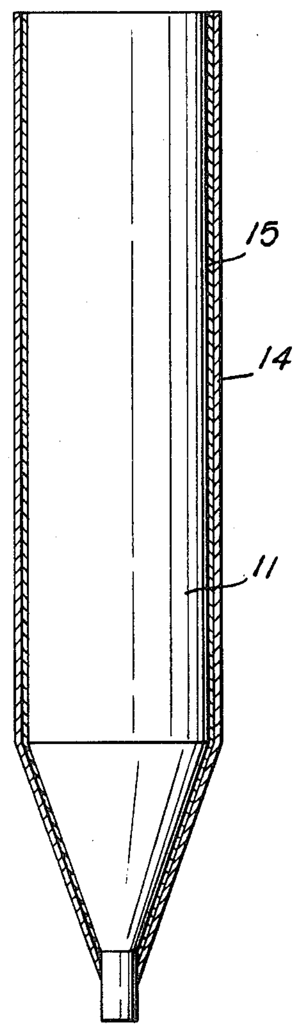

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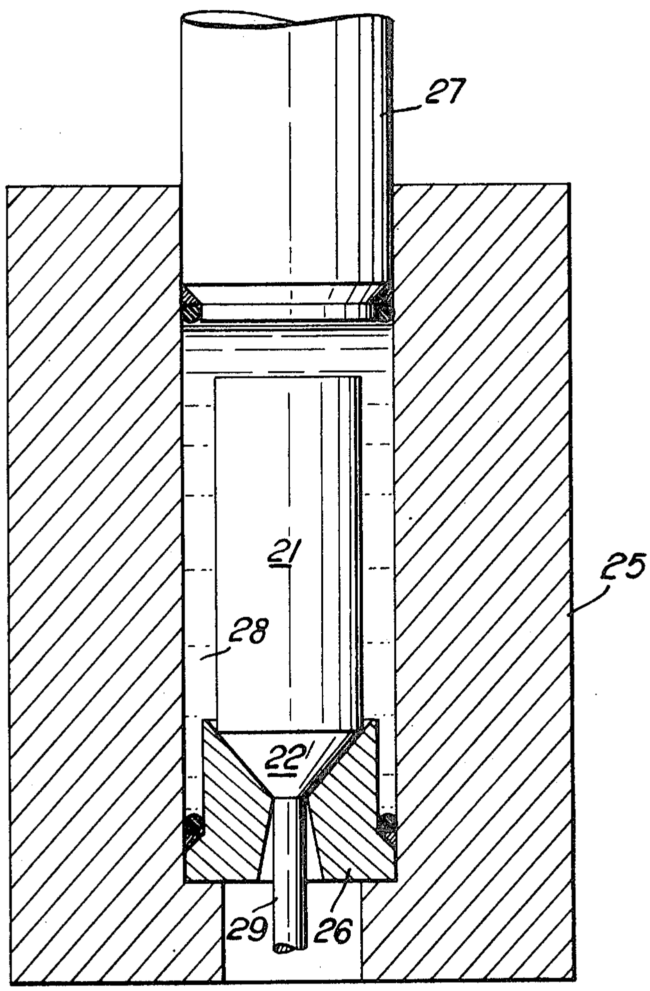
Fig. 3.



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MANUFACTURE OF COPPER-CLAD ALUMINUM ROD

The present invention relates to the manufacture of copper-clad aluminum rod and copper-clad aluminum wire. Copper-clad aluminum rod can be produced by making a composite start body by inserting a billet of aluminum in a tube of copper and rolling and/or drawing down the composite body to form rod which can be drawn to form copper-clad aluminum wire. However, when employing the rolling and/or drawing down technique it is difficult to produce copper-clad aluminum rod having very thin copper cladding, for instance composite rod in which the percentage by volume of copper is substantially less than 10 percent, with the result that the thickness of the copper cladding is often greater than is necessary, since the minimum wall thickness of the copper tube of the start body is dictated by the method of manufacture of the copper-clad aluminum rod rather than by the characteristics required in the copper-clad aluminum rod or wire produced.

Our invention resides in the discovery that copper-clad aluminum rod in which the copper is soundly metallurgically bonded to the aluminum core can be produced by direct extrusion of a cold composite billet comprising a preformed core of aluminum surrounded by a close fitting sheath of copper, to effect a reduction in cross-sectional area of the composite billet providing the contiguous surfaces of the copper and aluminum components of the composite billet are clean and substantially free of surface oxides.

By a "cold" composite billet we mean in this specification and in the claims which form part thereof a composite billet of which the temperature prior to and at the time of its insertion into the extrusion press is lower than the temperature at which copper and aluminum alloy when in contact.

Such a composite billet may be obtained by so machining or otherwise working the external surface of a billet of aluminum and/or the internal surface of a copper tube that the billet is a close fit in the tube, chemically and/or mechanically cleaning the whole of the mating surfaces of the aluminum billet and the copper tube to remove substantially all oxide and other contaminating films therefrom immediately before fitting the one in or on the other, fitting the one in or on the other and sealing the ends of the composite structure to prevent contact of the cleaned contiguous surfaces with the atmosphere. As a further precaution against oxidation the external surface of the aluminum billet and the internal surface of the copper tube may be purged with a nonoxidizing gas, for example nitrogen, during the cleaning and during the assembly of the two components to form the composite structure. Alternatively the cleaning operation may be carried out in an atmosphere of nitrogen or other nonoxidizing gas or under vacuum. When producing copper-clad aluminum rod from a composite billet formed from two such components it is necessary to effect a reduction in cross-sectional area of the composite billet of at least 70 percent in order to achieve a sound metallurgical bond between the copper sheath and the aluminum core.

In an alternative process of producing from a composite billet copper-clad aluminum rod in which the copper cladding is soundly metallurgically bonded to the aluminum core a composite billet is formed by electroplating a sheath of copper on to the surface of an aluminum billet. This may be effected after pretreating the surface of the aluminum billet either by the zincate process, by the so-called Alstan 70 process or by any other suitable pretreatment process. In the zincate process a layer of zinc is deposited on the circumferential surface of the aluminum billet before the sheath of copper is electroplated thereon. In the Alstan 70 process a layer of copper-based tin alloy is first deposited on the circumferential surface of an aluminum billet and thereafter a relatively thick layer of copper is deposited on the alloy layer. It will be appreciated that the electroplating method of building the composite billet permits of a reduction in the minimum proportion of copper present as compared with the copper tube method of building a composite billet.

Since the pretreatment of the surface of the aluminum billet by the zincate process, by the Alstan 70 process or by any other suitable pretreatment process results in the formation of a bond between the electrodeposited copper and the aluminum billet it is not necessary in carrying out the alternative process to effect a minimum reduction in cross-sectional area of the composite billet of 70 percent in order to achieve a bond between the copper sheath and the aluminum core of any rod or wire produced from the composite billet. However such plated composite billets may be extruded and drawn to wire in the same manner and to the same minimum extent as composite billets formed from copper tube and an aluminum billet, as such extrusion and drawing of plated composite billets merely consolidates the initial bond between the copper and the aluminum.

Extrusion of a cold composite billet to effect a reduction in cross-sectional area and yield an extrudate in which the copper and aluminum components of the billet are soundly metallurgically bonded at the interface can be effected by the process known as hydrostatic extrusion. In this process the billet in the press container is surrounded by a liquid, usually oil, through which are transmitted the forces necessary to deform the billet and force it through the extrusion orifice. Where hydrostatic extrusion is used to effect a reduction in cross-sectional area of a composite billet obtained by fitting an aluminum billet in a copper tube and sealing the ends of the composite structure so formed, the seals at the ends of the composite billet prevent ingress of the liquid between the mating surfaces of the composite billet.

In order that the invention may be more fully understood and readily put into practice two methods of manufacturing copper-clad aluminum rod in which the copper cladding is soundly metallurgically bonded to the aluminum core will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a sectional side elevation of a composite billet formed from copper tube and an aluminum billet,

FIG. 2 is a similar view of an electroplated composite billet, and

FIG. 3 is a sectional side elevation of an extrusion press for manufacturing copper-clad aluminum rod from a composite billet as shown in FIG. 1 or FIG. 2.

The composite billet shown in FIG. 1 comprises a preformed billet **1** of commercially pure aluminum which, over a major part of its length, has an overall diameter of approximately 1.29 in. (3.28 cm.) and which has at one end an integral substantially conical nose portion **2** tapering to a short cylindrical end portion **3** and, surrounding a major portion of the length of the billet, a length **4** of copper tube of similar shape which is sealed to the billet at each of its ends. Over the greater part of its length the copper tube **4** has an overall diameter of approximately 1.375 in. (3.49 cm.) and the copper of the tube constitutes approximately 10 percent by volume of the composite billet. In forming the composite billet the external surface of the aluminum billet **1** is so machined and the copper tube **4** is so worked that when the billet is fitted in the tube the billet will be a close fit with a radial clearance of approximately 0.0075 in. (0.19 mm.) and each end of the billet will tightly engage an end of the tube to form an effective seal. After the billet **1** and tube **4** have been so machined or otherwise worked the mating surfaces of the billet and tube are mechanically and/or chemically cleaned to remove substantially all oxide and other contaminating films from these surfaces and the billet is fitted in the tube until the ends of the billet tightly engage the ends of the tube to seal the composite billet against contact of the contiguous surfaces with the atmosphere and against ingress of the oil to be used in the hydrostatic extrusion process, the cleaning and assembling operations being carried out in an atmosphere of nitrogen. The ends of the billet **1** may alternatively, or additionally, be sealed to the ends of the tube **4** by means of rings or sleeves of elastomeric material or by use of suitable plastics sealing compound (not shown).

The composite billet shown in FIG. 2 comprises a preformed billet **11** of commercially pure aluminum of similar shape and dimensions to that described with reference to FIG. 1 on which is electroplated a sheath 14 of copper of a wall thickness of approximately 0.016 in. (0.41 mm.), the copper of the sheath constituting 5 percent by volume of the composite billet. In making this composite billet a thin layer 15 of copper-based tin alloy of approximately 0.0003 in. (0.0076 mm.) thickness is first deposited on the circumferential surface of the aluminum billet 11 and the relatively thick layer 14 of copper is deposited on the alloy layer.

In manufacturing copper-clad aluminum rod from each of the composite billets described with reference to FIGS. 1 and 2 use is made of the hydrostatic extrusion press illustrated diagrammatically in FIG. 3. The press comprises a tubular container 25 in one end of the bore of which is sealed an extrusion die 26 and in the other end of which bore a pressurizing ram 27 is in oiltight slidable engagement. A cold composite billet 21, from which copper-clad aluminum rod 29 is to be extruded, is placed in the container 25 with its nose portion 22 in the throat of the extrusion die 26 and is surrounded by oil 28 through which are transmitted the forces necessary to deform the billet and force it through the orifice of the extrusion die.

When using the extrusion press shown in FIG. 3 to form copper-clad aluminum rod from the composite billet shown in FIG. 1 an extrusion ratio of 20:1 was used, by which we mean that the ratio of cross-sectional area of composite billet to cross-sectional area of extrudate was 20:1 1. The product, a copper-clad aluminum rod of about 0.3 in. (7.62 mm.) diameter was successfully drawn down by conventional copper wire drawing practice, to composite wire of a diameter of 0.0076 in. (0.193 mm.) without any intermediate heat treatment. Using the same press to produce copper-clad aluminum rod from the composite billet shown in FIG. 2 an extrusion ratio of 17:1 was employed and, in this case, a copper-clad aluminum rod of about 0.3 in. (7.62 mm.) diameter was produced. This composite rod was successfully drawn down by conventional copper wire drawing practice to copper-clad aluminum wire of a diameter of 0.0076 in. (0.193 mm.) without any intermediate heat treatment.

The rod or the wire formed from both of the billets shown in FIGS. 1 and 2 could at any stage in the wire drawing process be bent around a mandrel of the same diameter as that of the rod or wire without peeling or fissure of the copper coating. Provided conditions are such that the formation of a brittle alloy at the interface does not take place to any substantial extent the rod or wire can be so heated that its ductility as measured by elongation under tensile load and its electrical conductivity are increased. Wire or rod so heat treated can be wrapped around a mandrel of the same diameter for six complete turns then completely unwrapped and again wrapped for six complete turns without its coating of copper fissuring or peeling off the aluminum core. Copper-clad wire drawn from copper-clad rod in which there is no metallurgical bond between the copper cladding and the aluminum core and copper clad produced by any other process which results in a brittle alloy layer at the interface cannot be bent to the same extent without fissure and peeling of the copper coating.

The method in accordance with the present invention has the important advantage that copper-clad aluminum rod can be produced in which the percentage by volume of copper is as low as 5 percent with the result that composite wire with a very thin coating of copper can be formed.

What we claim as our invention is:

1. A method of manufacturing copper-clad aluminum rod in which the copper cladding is soundly metallurgically bonded to the aluminum core, which method comprises forming a cold composite billet by so working the external surface of a preformed billet of aluminum and the internal surface of a copper tube that the billet is a close fit in the tube, cleaning the whole of the mating surfaces of the aluminum billet and the copper tube to remove substantially all oxide and other contaminating films therefrom and immediately fitting the aluminum billet in the copper tube and sealing the ends of the tube to the billet to prevent contact of the cleaned contiguous surfaces with the atmosphere, and directly extruding the cold composite billet so formed to effect a reduction in cross-sectional area of the composite billet of at least 70 percent.

2. A method as claimed in claim 1, wherein the external surface of the aluminum billet and the internal surface of the copper tube are purged with a nonoxidizing gas during the cleaning and during the assembly of the two components to form the cold composite billet.

3. A method as claimed in claim 1, wherein the cleaning operation is carried out in an atmosphere of a nonoxidizing gas.

4. A method as claimed in claim 1, wherein the cleaning operation is carried out under vacuum.

5. A method as claimed in any one of claims 1 to 4, wherein the reduction in cross-sectional area of the cold composite billet is effected by hydrostatic extrusion of the composite billet.

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