COMPOSITE WIRE AND METHOD OF MAKING

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ABSTRACT
A composite creep-resistant metal wire having an aluminum core and having a copper cladding metallurgically bonded to the core is shown to embody aluminum and copper materials having selected properties and is shown to be processed in a selected manner to provide the wire core in substantially annealed condition and to provide the wire cladding in substantially work-hardened condition to permit easy wire bending and forming while minimizing wire creep under stress. Aluminum wire conductors cause difficulty in some applications in that aluminum materials tend to creep or deform excessively when subjected to stress for any substantial period of time. For example, when an aluminum wire conductor is wrapped tightly on a terminal post or the like to establish a selected contact pressure between the conductor and post, good electrical conductivity is initially established between the conductor and post but the conductor is subjected to significant stress. Over a period of time, the conductor then gradually undergoes some strain or deformation in response to this stress. This time dependent strain or deformation — called creep — tends to relieve the stresses in the aluminum material but also undesirably lowers the contact pressure between the aluminum conductor and the terminal post.

2 Claims, No Drawings
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It is an object of this invention to provide a novel and improved creep-resistant composite wire; to provide such a wire having a copper cladding on an aluminum core; to provide such a creep-resistant copper-clad aluminum wire which is easily bent and shaped and which displays adequate fatigue strength for most wire applications; to provide such a copper-clad aluminum wire which displays high electrical conductivity; to provide novel and improved methods for making such wire; and to provide such improved composite wire materials which are of inexpensive manufacture.

Briefly described, the improved composite metal wire of this invention embodies a core formed of an aluminum material having relatively high electrical conductivity and having a selected annealing temperature. The composite wire has a cladding formed of a copper material which has a high electrical conductivity and which has an additive therein adapted to raise the annealing temperature of the cladding material to a level above the lowest annealing temperature of the wire core material. Preferably a silver additive is incorporated in the copper material to provide the cladding with the desired annealing temperature while retaining the high electrical conductivity of the basic copper material. In accordance with this invention, the copper cladding is solid-phase metallurgically bonded to the aluminum core material to form a composite wire in the conventional manner, the interface between the core and cladding being substantially free of copper-aluminum intermetallic compounds. The bonded composite wire is then drawn to reduce size as required to establish the desired composite wire diameter and to place the materials of both the wire cladding in a substantially fully work-hardened condition. Finally, the composite wire is heated to a temperature above the lowest annealing temperature of the aluminum core material and below the annealing temperature of the copper cladding material, the wire being maintained at this temperature for a sufficient period of time for substantially fully annealing the wire core while leaving the wire cladding in a substantially fully work-hardened condition. In this way, it is found that the composite wire displays adequate bendability or formability and fatigue strength to be useful in most copper-aluminum wire applications. However, the work-hardened copper cladding of the wire minimizes creep of the wire under stress so that the composite wire is adapted for use substantially interchangeably with solid copper wire in many conductor applications.

Other objects, advantages and details of this invention appear in the following more detailed description of preferred embodiments of the invention.

In accordance with this invention, the aluminum wire core material preferably comprises any of the conventional aluminum materials generally utilized in electrical conductors. Such materials include aluminum materials with density of at least about 0.5 IACS and have minimum annealing temperatures of at least about 500°F. Preferably, no more than about 50% of IACS or more in substantially fully annealed condition. For example, the wire core materials used in this invention include the aluminum materials commonly designated as EC Alloy, commercially pure aluminum and the like. Commercially pure aluminum is also commonly identified by its government number as Alloy 1100. Preferably however, the aluminum wire core material comprises the aluminum alloys commonly identified as CK-74 and CK-76 Alloy. EC Alloy comprises 99.45% plus aluminum by weight with no more than 0.55% impurities therein. Alloy 1100 aluminum comprises 99.00% plus aluminum by weight with 1.0% (Max.) iron plus silicon, 0.20% (Max.) copper, 0.05% (Max.) manganese, 0.10% (Max.) zinc with no more than 0.005% (Max.) of any other element and with no more than 0.015% (Max.) total of other elements present as impurities therein. CK-74 aluminum alloy comprises 99.0% by weight aluminum with 0.85% iron, with 0.015% boron, and with the remainder impurities. CK-76 aluminum alloy comprises 99.0% aluminum by weight with 0.7% iron, 0.15% manganese, 0.015% boron, and with the remainder impurities. These named, commercially available, aluminum materials have electrical volume conductivities above 60% IACS in substantially annealed condition and are adapted to be substantially fully annealed with annealing times on the order of from a few seconds up to about 4 hours at annealing temperatures in the range from 400°F to 625°F.

The composite wire cladding materials used in this invention preferably embody the copper materials conventionally used in electrical conductors, these copper materials being modified by the use of selected additives adapted to raise the annealing temperatures of the copper materials to above the lowest annealing temperatures of the aluminum core materials to be used therewith in a composite wire. For example, the cladding materials preferably embody copper materials commonly designated as electrolytic tough pitch copper (ETP), deoxidized low phosphorus copper (DLP), or oxygen free copper (OF). These copper materials have electrical volume conductivities of at least about 100% IACS and are normally adapted to be annealed at temperatures in the range from about 500°F to 1200°F. In accordance with this invention, these high electrical conductivity copper materials are preferably modified by the addition thereto of small quantities of silver or other metal materials which are adapted to raise the annealing temperatures of the copper materials above about 550°F. Any conventional alloying process for preparing the modified copper materials can be used within the scope of this invention. Silver is preferably used as the additive material in that silver provides the resulting copper cladding material with the desired higher annealing temperature while retaining the full electrical conductivity of the basic copper materials. However, other additive materials such as nickel and zinc and the like can also be used for raising the annealing temperatures of the composite cladding materials if desired.

In preferred embodiments of this invention, the copper cladding materials used comprise any of the above noted copper materials modified by the addition of at least about 5 ounces of silver to each ton of the basic copper material. In this way, the resulting cladding materials display electrical volume conductivities of at least about 100% IACS and have minimum annealing temperatures of at least 550°F. Preferably, no more than about 15 ounces of silver is added to each ton of the basic copper material so that the resulting cladding material is adapted to be heat-softened at temperatures as low as about 950°F, to 1000°F, for a purpose which will be explained below. That is, the copper material preferably embodies silver additive comprising from about 0.015 to about 0.047 percent by weight of the resulting copper material.
In accordance with this invention, the copper-clad and aluminum core materials as above described are bonded together in any conventional manner to form a composite, copper-clad aluminum wire. Preferably, the cladding material is solid-phase metallurgically bonded to the entire periphery of the aluminum core in the manner described in U.S. Pat. No. 3,444,603 so that the interface between the core and cladding materials in the resulting composite wire is substantially free of copper-aluminum intermetallic compounds. Where the copper cladding materials have limited quantities of the noted additive materials therein as above described so that the copper cladding materials are adapted to be heat-softerned at temperatures as low as about 950°F. to 1000°F., the copper cladding materials are readily softened during the heat-treatment thereof as described in the noted patent, thereby facilitating bonding of the cladding material to the wire core. Note that where the thin copper cladding strips are heat-softerned at temperatures as low as about 950°F. to 1000°F. in being bonded to the aluminum core material which is at room temperature as shown in the noted patent, the copper cladding material is rapidly cooled against the aluminum material for forming the desired cladding-to-core bond without tending to form any substantial quantity of copper-aluminum intermetallic compound at the interface between the cladding and core materials.

Having formed a composite copper-clad aluminum wire in conventional manner with the copper-cladding material having an annealing temperature above the lowest annealing temperature of the wire core material, the composite wire is then drawn or otherwise deformed in any conventional manner for reducing the composite wire to a desired final diameter and for substantially work-hardening both the copper cladding material of the wire and the aluminum core material of the wire. For example, in a typical embodiment of this invention, a composite wire having an initial diameter of 0.560 inches as bonded and having approximately 10% of the cross-sectional area of the wire formed of the noted copper cladding material is drawn down to a total composite diameter of 0.312 inches without intermediate annealing of the wire materials. This drawing step places the wire core and the wire cladding materials in substantially fully work-hardened condition.

In accordance with this invention, the drawn and work-hardened composite wire is then heated to a temperature which is above the lowest annealing temperature of the wire core material and which is below the lowest annealing temperature of the wire cladding material, the composite wire being held at this temperature for a sufficient period of time for substantially fully annealing the wire core material while leaving the wire cladding material in substantially fully work-hardened condition. For example, in a preferred embodiment of this invention wherein the wire core material is formed of CK-76 Alloy as above described and the wire cladding is formed of ETP copper having 10 ounces of silver per ton added thereto, a composite wire having a wire diameter of 0.312 inches after drawing down from an initial diameter 0.560 inches and having approximately 10% of the wire volume formed of copper cladding material is heated to a temperature in the range from 450°F. to 525°F., preferably in a conventional bell annealer in the presence of a reducing or inert atmosphere, for a period of from 5 to 15 minutes. In this way the resulting composite wire has its core material in substantially fully annealed condition whereas the wire cladding is in substantially fully work-hardened condition. It is found that this wire has a tensile strength on the order of 58,000 psi. and a yield strength of approximately 55,000 psi. The wire is easily bent and coiled displaying adequate formability and fatigue strength for most composite wire applications. On the other hand, the composite wire displays minimal wire creep roughly equivalent to the wire creep displayed by an annealed, solid copper wire of a corresponding diameter. That is, retention of the wire cladding material in work-hardened condition, is found to permit bending and forming of the wire to the extent usually required in most wire applications but is found to substantially prevent the tendency of the wire core material to creep under stress.

It should be understood that although particular embodiments of this invention have been described by way of illustration, this invention includes all modifications and equivalents thereof which fall within the scope of the appended claims.

1. A composite metal wire comprising a core of aluminum material having a selected annealing temperature and a cladding of a copper material having an annealing temperature which is relatively higher than the lowest annealing temperature of said aluminum material, said core material being in substantially fully annealed condition, said cladding material being metallurgically bonded to the core and being in substantially fully work-hardened condition.

2. A composite metal wire as set forth in claim 1 wherein said aluminum core material is selected from the group of materials consisting of an aluminum material consisting essentially of 99.45% plus aluminum 99.2% weight with no more than 0.55% by weight impurities therein, an aluminum material consisting essentially of 99.0% plus aluminum by weight with 1.0% (Max.) iron plus silicon, 0.20% (Max.) copper, 0.05% (Max.) manganese, 0.10% (Max.) zinc with no more than 0.005% (Max.) of any other element and with no more than 0.015% (Max.) of other elements present as impurities therein, an aluminum material consisting essentially of 99.0% by weight aluminum, 0.85% iron, 0.015% boron and the remainder impurities, and an aluminum material consisting essentially of 99.0 aluminum by weight, 0.7% iron, 0.15% manganese, 0.015% boron, and the remainder impurities, and wherein said copper cladding material is selected from the group of materials consisting of electrolytic tough pitch copper, deoxidized low phosphorous copper, and oxygen-free copper, said selected copper material having a metal additive alloyed therewith to comprise from about 0.015 to about 0.047 percent by weight of said copper alloy to establish the minimum annealing temperature of said cladding material at least as high as 550°F.