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COMPOSITE BODY OF COPPER AND ALUMINUM OR COPPER AND MAGNESIUM, AND METHOD OF MAKING SAME

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This invention relates to the production of composite bodies of copper and aluminum or copper and magnesium.

A composite body composed of laminations of copper and aluminum is possessed of numerous important advantages in the electrical, mechanical and chemical arts because of the relative and diverse characteristics possessed by copper and aluminum which particularly fit them, respectively, for use as coating and core metals in a composite metal structure. Thus copper is more resistant to galvanic action than aluminum and tends to preserve itself at the expense of aluminum; aluminum is of lower specific gravity than copper and therefore a body composed of these two metals is of lighter weight per unit of cross sectional area, or of greater stiffness and strength per unit of cross sectional weight; the copper is a better conductor of electricity than aluminum, but aluminum is a good conductor of electricity, and a copper coated aluminum, because of the arrangement of the copper on the surface, disposes the relative conductivity of the coating and core metals in a particularly advantageous way for use in the electrical arts; copper is also a desirable coating metal where advantage is to be taken of its adaptability to soldering or brazing operations, its appearance, its low coefficient of friction, its resistance to corrosion and certain forms of chemical reaction, etc.

Similarly a composite body composed of laminations of copper and magnesium is possessed of numerous important advantages in the electrical, mechanical and chemical arts because of the relative and diverse characteristics possessed by copper and magnesium which particularly fit them, respectively, for use as coating and core metals in a composite metal structure. Thus copper is more resistant to galvanic action than magnesium and tends to preserve itself at the expense of magnesium; magnesium has a substantially lower specific gravity than copper, and therefore where lighter weight per unit of cross sectional area or greater stiffness and strength per unit of cross sectional weight are desirable, as in the saving of weight, lowering of costs, reduction in the dead load of moving parts or structures, etc., magnesium is a highly desirable body material.

The bonding of copper to aluminum or magnesium has heretofore presented grave practical difficulties. The high surface tension, tenacity and resistance to rupture of the aluminum oxide film and the magnesium oxide film which exist on these metals in the presence of air render difficult the adhesion of copper to aluminum or magnesium, even though an effort be made to roll the two metals together under relatively high pressure and at an elevated temperature, because of the difficulty in breaking through the tenacious oxide film. Therefore, so far as I am aware, no commercially feasible procedure has heretofore been suggested for producing laminated copper and aluminum or laminated copper and magnesium because of the absence of a method which will assure a substantially uniform bonding between the laminations of the diverse metals.

It is an object of this invention to produce laminated copper and aluminum or laminated copper and magnesium by a procedure which assures a substantially uniform alloy bond throughout the contiguous surfaces of the laminations.

Another object of this invention is to provide a method for producing laminated bodies of copper and of aluminum or magnesium wherein the depth of the alloy bond connecting the laminations may be controlled so as to secure a predetermined depth as well as a substantially uniform character of bond.

Another object of this invention is to provide a method of the type characterized which is of such character that it may be efficiently and economically performed in large scale commercial operations.

Another object of this invention is to produce a billet, ingot, block, or other body composed of an aluminum or magnesium core and a coating lamina of copper on one or more faces thereof and having a substantially uniform alloy bond between the laminations and throughout the contiguous surfaces thereof.

Another object of this invention is to produce rolled plates, sheets, foils, etc., of copper coated aluminum or magnesium, wherein the laminations are united by a substantially uniform alloy bond throughout the contiguous surfaces thereof and in which at the same time are preserved the desirable characteristics of the aluminum or the magnesium as a core metal and the copper as a surfacing metal.

Another object of this invention is to provide an aluminum or magnesium body which is completely and permanently coated with an envelope of copper and which can be widely used where decreased weight or increased strength or stiffness or decreased cost per unit of cross sectional weight are desirable or, in the case of copper coated aluminum, where advantage can be taken of the desirable electrical, physical and other charac-

teristics of copper as a surfacing material and aluminum as a core or body material.

Another object of this invention is to produce copper coated aluminum or magnesium which can be readily drawn, rolled, pressed, shaped and otherwise worked, and therefore fabricated into a wide variety of articles and applied to a wide variety of uses but with assurance that the alloy bond between the laminations will not be destroyed.

Another object of this invention is to produce copper coated aluminum or magnesium which while preserving the desirable characteristics of the copper as a surfacing material and the aluminum or magnesium as a core metal also secures various advantages to be derived from their association in laminations, the character and thickness of the alloy bond between the laminations being such as not to interfere with or detract from the characteristics to be desirably obtained from the association of these metals in a laminated structure.

Other objects will appear as the description of the invention proceeds.

In conformity with the present invention a composite metal body of copper and aluminum or magnesium is formed by effecting a substantially uniform alloy bond between the component metals. To this end an alloy of zinc and copper is first created at the surface of the copper which is to be united to the aluminum or magnesium, said alloy being formed under such conditions as to assure a substantially uniform character and depth of the alloy throughout the surface which is to be united to the aluminum or magnesium. Then aluminum or magnesium is fused to said alloy, establishing an alloy bond of copper, zinc and aluminum or copper, zinc and magnesium between the copper and the core metal. Thereby are avoided the discontinuities and irregularities of bond which would exist if the metals were rolled or otherwise pressed together. By suitably controlling the relative temperatures of the copper, on the one hand, and the aluminum or the magnesium, on the other hand, with regard to the heat capacities of the volumes of the respective metals employed, the thickness of the alloy bond may be controlled and predetermined. By this procedure a substantially uniform alloy bond between the copper and the aluminum or the magnesium is established throughout the contiguous surfaces thereof, and as the depth of said bond may be controlled and predetermined, the laminated body can be given the desired characteristics suitable for the use to which the laminated metal is to be put.

For most purposes it is preferable to have the coating metal substantially coextensive with the outer face of the ultimate product, but it is within the contemplation of the present invention to provide a copper coating on one face only, or on less than all of the faces of billets, ingots, blocks, or other bodies where such is sufficient, and therefore the term "envelope" as herein used is to be interpreted as embracing a covering on one or more faces of the aluminum or magnesium core. Furthermore, while it is preferred to cast the magnesium or aluminum in a copper envelope which will produce composite metal in the form of a billet, ingot, block, or the like, it is to be expressly understood that the invention is not restricted thereto, as the composite metal may be formed in conformity with the present invention in other shapes, including tubes, bars, etc., or in fact in any suitable form that is appropriate for the ultimate product to be produced, and therefore the invention is not restricted to the formation of billets, ingots, blocks, etc., but the term "billet" as used herein is to be construed as a term generic to any suitable form in which the copper is united to an aluminum or magnesium core as herein explained. For purposes of illustrating the invention, however, it will be assumed that the composite metal body is to be formed as a billet or the like with a coating of copper that is coextesive with opposed faces thereof.

The preferred procedure is as follows:— Copper in a form to provide a suitable envelope is first provided. The thickness of said envelope may be varied within relatively wide limits depending upon the use to which the composite metal is to be put, the desired characteristics of the ultimate product, etc. The envelope must not be so thick that the alloy bond is destroyed during the "breaking down" passes through the rolls, and an upper limit of three to four-sixteenths of an inch of thickness is probably as large as practicable. The envelope must not be so thin, in comparison with the volume of aluminum or magnesium to be used in the core, that the relative heat capacities of the two metals employed are such as to cause the alloying of the copper with the aluminum or magnesium to extend through to the outer surface of the copper. If the core is sufficiently thin or small or the temperature relations between the metals are otherwise suitably controlled, however, this does not prevent the copper envelope from being only a few thousandths of an inch thick if desired. Between these limits the thickness of the envelope may be selected with regard to the percentage of copper to aluminum or magnesium desired in the ultimate product, which will vary with the use to which the composite metal is to be put and the characteristics desired.

The copper envelope is preferably formed from sheets of clean annealed copper and the face of the sheet or sheets which, when the envelope is assembled or formed, is to be united to the aluminum or magnesium is then provided with a substantially uniform layer of zinc copper alloy of predetermined depth. The preferred procedure is to heat the copper sheet to a temperature at least as high as the eutectic melting point of the copper zinc binary system. Zinc is then applied to that face of the copper sheet which is to be united with the core in such a way as to assure a uniform alloy layer which penetrates the surface of the copper to a uniform and predetermined extent and breaks down and detaches from the copper any surface film thereon. To this end the copper sheet may first be treated with any suitable flux, but I prefer to use abrasion of the copper surface, as with any suitable wire brush, after molten zinc, which may be melted by the temperature of the copper plate, has been spread over the surface of the copper so that it is applied uniformly thereover, working the brush through the coating of molten zinc to break down any film on the copper while the surface of the copper is protected by the molten layer of zinc. This procedure also avoids the presence of foreign material that may have to be removed to avoid formation of gas or other interference with the establishment of a uniform bond between the core and envelope when aluminum or magnesium is cast into said envelope as hereinafter explained.

The depth of the alloy formed can be varied depending upon the temperature of the copper

and the time and character of the mechanical and chemical work which are used in breaking down any existing film and assuring penetration of the zinc into the copper. Ordinarily, a relatively thin layer of alloy is desired to hold the zinc content to a minimum. The molten zinc goes into solution with the copper and establishes a copper zinc alloy, and this alloy when formed as heretofore described is substantially uniform in thickness and of controlled thickness throughout the surface of the copper sheet.

The envelope is then assembled or formed with the alloy surface on the inside. For example, it may be composed of a plurality of sheets suitably assembled so as to form a core cavity, but where the billet is to be subsequently rolled into plates, thin sheets, foils, and the like, I preferably form the envelope by bending the sheet into U form with the alloy layer on the inside so that the parallel legs thereof are spaced at the distance predetermined for the thickness of the core, the connection between said legs helping to maintain said legs at the predetermined spacing, and where the envelope is sufficiently stiff supporting and retaining the side sheets at that spacing. The envelope is mounted in any suitable mold, by which term is to be understood any suitable form which will properly retain the envelope in position for a casting operation and, if necessary, complete the cavity between the elements of the envelope for reception of the molten core metal.

Aluminum or magnesium is then cast into the cavity of the mold at any suitable temperature. Ordinarily, the usual pouring temperature employed in the casting of aluminum or magnesium billets may be used, but higher degrees of superheat may be employed depending upon the depth of alloy bond desired. The molten aluminum or magnesium melts the copper zinc alloy bond upon contact therewith, producing surface fusion of the alloy and a fused bond between said alloy and the aluminum or magnesium, which bond is composed of an alloy of copper, zinc and aluminum or of copper, zinc and magnesium.

By suitably controlling the temperature of the two metals with respect to the heat capacities of their respective volumes, the depth of alloy bond may be controlled and thus by heating the copper or by having such heat capacities due to the volume of aluminum or magnesium present, the depth of alloy bond may be increased over that established by the initial formation of the alloy during the preceding step, and the depth of this bond may thus be widely varied and accurately controlled. Excessive penetration of the zinc and core metal into the envelope metal is undesirable, and therefore the temperature relationship between the copper envelope and the aluminum or magnesium cast therein, with respect to the relative heat capacities of the two, must be predetermined to avoid undue penetration of the core metal into the copper envelope. To this end the mold may be water cooled if desired, such being ordinarily desirable where the molds are to be used at frequent intervals and it is desirable to withdraw therefrom at least some of the heat resulting from the casting operation.

Assuming that the billet is to be rolled into plates, sheets, or foils, the billet may be passed to the rolls as soon as it has cooled to a suitable rolling temperature. I prefer to roll the billet hot, to avoid drastic strain hardening of the composite metal. The temperature at which the composite metal is rolled, however, may vary within relatively wide limits, depending upon the desired characteristics of the ultimate product. Ordinarily, the temperature should not be so high as to cause substantial dispersion of one metal into the other and thereby unduly increase the depth of the alloy bond, but a temperature which gives a considerable degree of plasticity to the component metals is usually desirable. The breakdown passes are preferably carried out at a temperature between 650° F. and 950° F. for copper coated aluminum, and between 550° F. and 900° F. for copper coated magnesium, but thereafter the further rolling operations may be carried out at any suitable temperature, depending upon the characteristics desired in the ultimate product.

Copper coated aluminum or magnesium plates, sheets, tubes, bars, wires, etc., may thereby be formed for fabrication into a wide variety of articles, and the composite metal so provided possesses the advantages derived from the use of copper as a surfacing material and the aluminum or magnesium as a body or core material.

The envelope may be composed of pure copper or of a wide variety of copper alloys suitable for the rolling operations, depending upon the character of coating desired, and the core may be composed of pure aluminum or pure magnesium, or any suitable aluminum or magnesium alloy. Therefore, it is to be expressly understood that when copper or aluminum or magnesium are referred to herein it is intended to embrace within such terms any suitable alloy of copper for the coating metal and any suitable alloy of aluminum or magnesium for the core metal, within the limitations of suitable metals for the carrying out of the procedure herein referred to.

The present invention therefore provides billets and other bodies of copper coated aluminum or magnesium wherein the component metals are united throughout their contiguous surfaces by a substantially uniform alloy bond of predetermined depth. The composite metal is possessed of the various desirable characteristics inherent in the use of copper as a coating metal and aluminum or magnesium as a core metal without detraction from their respective characteristics by the manner in which the composite metal is formed. The method of the present invention also assures the establishment of a substantially uniform alloy bond of substantially uniform depth between the component metals under conditions which may be readily carried out in large scale operations. Therefore, the composite metal of the present invention, because of the characteristics thereof when produced by the method disclosed, may be put to a wide variety of uses and a wide variety of objects may be made therefrom without destroying the alloy bond between the laminations. Hence the composite metal of this invention can be applied to many uses in the electrical, mechanical and chemical arts where the relative characteristics of copper and aluminum as coating and body materials, or the relative characteristics of copper and magnesium as coating and body materials, are desirable.

While the preferred procedure has been described with considerable particularity, it is to be expressly understood that the invention is not restricted thereto, and various departures therefrom will now suggest themselves to those skilled in the art. Other methods of securing the alloy layer or of fusing the aluminum or magnesium core to the alloy layer may be used, for example, and any other suitable metal, such as a zinc alloy, tin, etc., may be used for effecting the alloy layer, providing an alloy bond as herein disclosed is es-

tablished between the copper and the core metal. Reference is therefore to be had to the claims hereto appended for a definition of the limits of the invention.

What is claimed is:—

1. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of forming an alloy of zinc and copper at the inner face of a copper envelope, and casting aluminum or magnesium into said envelope into direct contact with said alloy to form therewith a substantially continuous zinc alloy bond between said copper and said aluminum or magnesium.

2. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of forming a zinc alloy on the face of a sheet of copper which is to be united to the aluminum or magnesium, forming said sheet into an envelope with said alloy at the inner face of said envelope, and fusing an aluminum or magnesium core directly to said alloy layer to establish a substantially uniform alloy bond composed of said zinc and the envelope and core metals.

3. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of forming an alloy on the face of a sheet of copper which is to be united to the aluminum or magnesium, forming said sheet into an envelope with said alloy at the inner face of said envelope, and fusing an aluminum or magnesium core directly to said alloy layer by casting molten aluminum or magnesium into said envelope into direct contact with said alloy layer to establish a substantially uniform alloy bond between said metals.

4. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of forming an alloy on the face of a sheet of copper which is to be united to the aluminum or magnesium, forming said sheet into an envelope with said alloy at the inner face of said envelope and fusing directly to said layer a core of aluminum or magnesium to establish a substantially uniform alloy bond between said metals.

5. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of alloying zinc to the inner face of a copper coating sheet to provide a relatively thin alloy layer and fusing directly to said layer a core of aluminum or magnesium.

6. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of alloying zinc to the inner face of a copper coating sheet to provide a relatively thin alloy layer and fusing an aluminum or magnesium core directly to said layer by casting molten aluminum or magnesium directly into contact with said alloy layer to form a fused bond with said alloy layer.

7. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of alloying zinc to the inner face of a copper coating sheet to provide a relatively thin alloy layer and casting molten aluminum or magnesium directly into contact with said alloy layer to form a fused bond with said alloy layer while controlling the relative temperatures of said metals to predetermine the depth of the bond so formed.

8. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of applying molten zinc to copper while abrading the surface of the copper to form a predetermined layer of zinc copper alloy, forming the copper into an envelope with said alloy layer on the inside thereof, and then fusing a core of aluminum or magnesium to said alloy within said envelope.

9. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of applying molten zinc to copper while abrading the surface of the copper to form a predetermined layer of zinc copper alloy, forming the copper into an envelope with said alloy layer on the inside thereof, and casting into said envelope into direct contact with said layer a core of molten aluminum or magnesium to fuse the surface of said alloy and establish a substantially uniform alloy bond between the component metals.

10. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of applying molten zinc to copper while abrading the surface of the copper to form a predetermined layer of zinc copper alloy, forming the copper into an envelope with said alloy layer on the inside thereof, and casting into said envelope into direct contact with said layer a core of molten aluminum or magnesium to fuse the surface of said alloy and establish a substantially uniform alloy bond between the component metals while controlling the relative temperatures of the component metals with respect to their relative heat capacities so as to predetermine the depth of alloy bond so formed.

11. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of forming an envelope of copper having alloyed to the inner face of said envelope a thin coating of zinc, and then fusing a core of aluminum or magnesium directly to said thin coating.

12. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of forming an envelope of copper having alloyed to the inner face of said envelope a thin coating of zinc, and then casting a core of molten aluminum or magnesium into direct contact with the coating of said envelope to form a fused bond with said thin coating.

13. The method of forming laminated billets and other bodies of copper coated aluminum or magnesium which includes the steps of forming an envelope of copper having alloyed to the inner face of said envelope a thin coating of zinc, and then casting a core of molten aluminum or magnesium into direct contact with the coating of said envelope to form a fused bond with said thin coating while controlling the relative temperatures of the component metals with respect to their relative heat capacities to predetermine the depth of alloy bond formed between said metals.

14. The method of forming laminated bodies of copper coated aluminum or magnesium which includes the steps of forming an envelope of copper having an inner face of zinc-copper alloy, fusing said alloy layer directly to an aluminum or magnesium core to form a substantially uniform alloy bond therebetween, and hot rolling said body to

reduce the cross section thereof and extend the surface area thereof.

15. A copper coated body having a core composed of a metal from the group composed of aluminum and magnesium and having a copper envelope fused to said core by a substantially continuous alloy bond including a third metal which interpenetrates both of said core and envelope metals, said alloy bond being substantially coextensive with the contiguous surfaces of the copper and aluminum or magnesium.

16. A malleable and ductile copper coated body having a core composed of a metal from the group composed of aluminum and magnesium and having a relatively thin copper envelope fused to said core by a relatively thin and substantially continuous alloy bond comprising zinc and said envelope and core metals, said alloy bond being substantially coextensive with the contiguous surfaces of the copper and aluminum or magnesium.

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