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

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

A composite body composed of laminations of magnesium and aluminum is possessed of numerous important advantages in the electrical, mechanical and chemical arts because of the relative and diverse characteristics possessed by aluminum and magnesium which particularly fit them respectively for use as coating and core metals in a composite metal structure. Thus aluminum 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 aluminum, 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 dead load of moving parts and structures, etc., magnesium is a highly desirable body material, but no entirely satisfactory way for protecting magnesium from corrosion has so far been suggested; while both metals are strong and have very similar melting temperatures, coefficients of expansion and contraction, etc., aluminum has higher electrical and thermal conductivity, greater reflectivity, is more resistant to abrasion, chemical reaction, corrosion, etc.

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

It is an object of this invention to provide a method whereby magnesium may be satisfactorily used for the fabrication of a wide variety of articles where weight is important.

Another object of this invention is to provide a method whereby magnesium may be suitably protected against corrosion.

Another object of this invention is to produce laminated magnesium and aluminum 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 aluminum and 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 a magnesium core and a coating lamina of aluminum on one or more faces thereof with a substantially uniform alloy bond between the magnesium and aluminum throughout the contiguous surfaces thereof.

Another object of this invention is to produce rolled plates, sheets, foils, etc., of aluminum coated 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 magnesium as a core metal and of the aluminum as a surfacing metal.

Another object of this invention is to provide a magnesium body which is completely and permanently coated with a corrosion-preventing envelope and which can therefore be widely used where decreased weight or increased strength or stiffness or decreased cost per unit of cross sectional weight are desirable.

Another object of this invention is to produce aluminum coated 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 aluminum coated magnesium which while preserving the desirable characteristics of the magnesium as a core metal and the aluminum as a surfacing 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 associ-

ation of these two metals into 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 aluminum and magnesium is formed by effecting a substantially uniform alloy bond between the two metals. To this end an alloy of zinc and aluminum is first created at the surface of the aluminum which is to be united to the 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 magnesium. Then magnesium is fused to said alloy, establishing an alloy bond of zinc, magnesium and aluminum between the magnesium and aluminum. 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 magnesium and aluminum, 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 magnesium and aluminum is established throughout the contiguous surfaces thereof, and as the depth of said bond may be nicely controlled, 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 an aluminum 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 magnesium core. Furthermore, while it is preferred to cast the magnesium in an aluminum 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 aluminum is united to a 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 aluminum that is coextensive with opposed faces thereof.

The preferred procedure is as follows:—Aluminum 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 in the ultimate product, etc. As aluminum and magnesium have closely similar melting temperatures and like rolling temperatures, the envelope may be relatively thick. The envelope must not be so thin, in comparison with the volume of magnesium to be used in the core, that the relative heat capacities of the two metals are such as to cause the alloying of the magnesium with the aluminum to extend through to the outer surface of the aluminum. If the magnesium core is sufficiently thin or small or the temperature relations between the magnesium and aluminum are otherwise suitably controlled, however, this does not prevent the aluminum 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 aluminum to 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 aluminum envelope is preferably formed from hot rolled sheets, as this provides an envelope which is well annealed and has a relatively clean surface. However, cold rolled aluminum sheets may be employed if preferred, provided the sheets are sufficiently annealed and the surface thereof is properly cleaned to enable the carrying out of the process as herein described.

The face of the sheet or sheets which, when the envelope is assembled or formed, is to be united to the magnesium is then provided with a substantially uniform layer of zinc aluminum alloy of predetermined depth. The preferred procedure is to heat the aluminum sheet to a temperature at least as high as the eutectic melting point of the aluminum zinc binary system. Zinc is then applied to that face of the aluminum sheet which is to be united with the core in such a way as to assure a uniform break down and detachment of the aluminum oxide film on the aluminum sheet and to obtain the desired depth of alloy. To this end the aluminum sheet may first be treated with a zinc chloride or any other suitable flux that will break down the aluminum oxide, but I prefer to use abrasion of the aluminum surface, as with any suitable wire brush, after the molten zinc, which may be melted by the temperature of the aluminum plate, has been spread over the surface of the aluminum so that it is applied uniformly thereover, working the brush through the coating of molten zinc to break down the oxide film while the zinc coating protects the aluminum surface from contact with the oxygen of the air. 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 magnesium is cast into said envelope as hereinafter explained.

The depth of the alloy formed can be varied depending upon the temperature of the aluminum and the time and character of the mechanical or chemical work which are used in breaking down the aluminum oxide film and assuring a penetration of the zinc into the aluminum. Ordinarily, a relatively thin layer of alloy is desired, deep penetration of the zinc into the aluminum being undesirable because the alloy is less ductile than either the aluminum or magnesium. The molten zinc goes into solution with the aluminum and establishes a zinc aluminum alloy, and this alloy when formed as heretofore described is substantially uniform in thickness and of controlled thickness throughout the surface of the aluminum 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 magnesium 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 a position for a casting operation and, where necessary, complete the cavity between the elements of the envelope for reception of the molten magnesium.

Magnesium is then cast into the cavity of the mold at any suitable temperature. Ordinarily, the usual pouring temperature employed in the casting of magnesium billets may be used, but higher degrees of superheat may be employed depending upon the depth of alloy bond desired. The molten magnesium melts the zinc aluminum alloy upon contact therewith, producing surface fusion of the alloy and forming a fused bond between said alloy and the magnesium, which bond is composed of an alloy of magnesium, zinc and aluminum. By suitably controlling the temperatures of the two metals with respect to the heat capacities of their respective volumes, the depth of alloy bond may be nicely controlled. Thus by heating the aluminum or by having such heat capacities due to the volume of 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 magnesium into the aluminum is undesirable, and therefore the temperature relationship between the aluminum envelope and the magnesium cast therein, with respect to the relative heat capacities of the two, must be predetermined to avoid undue penetration of the zinc and magnesium into the aluminum. 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 previous 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 aluminum and magnesium is usually desirable. The break down passes are preferably carried out at a temperature between 550° F. and 900° F., but thereafter the further rolling operations may be carried out at any suitable temperature, depending upon the characteristics desired in the ultimate product.

Aluminum coated magnesium plates or sheets of suitable thickness 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 the lighter weight magnesium as a body or core material, while the magnesium is properly encased and protected by the corrosion-resistant aluminum.

The envelope may be composed of pure aluminum or a wide variety of aluminum base alloys depending upon the character of coating desired, and the core may be composed of pure magnesium or any suitable magnesium alloy. Ordinarily, for economy in the use of scrap, the core is preferably a magnesium base alloy with a small percentage of aluminum therein, the presence of the aluminum also giving desirable characteristics to the core metal. Therefore, it is to be expressly understood that when aluminum or magnesium are referred to herein it is intended to embrace within such terms any suitable alloy of aluminum for the coating metal and any suitable alloy of magnesium for the core metal.

The present invention therefore provides billets and other bodies of aluminum coated magnesium wherein the magnesium and aluminum 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 aluminum as a coating metal and 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 two 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 as 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. Therefore the composite metal of this invention can be applied to many uses in the electrical, mechanical and chemical arts where the light weight of the magnesium makes use thereof desirable.

While the preferred procedure has been described with considerable particularity, it is to be expressly understood that the invention is not restricted thereto, as various departures therefrom will now suggest themselves to those skilled in the art. Other methods of securing the alloy layer or of fusing the magnesium core to the alloy layer may be used for example, and any other suitable metal may be used for effecting the alloy layer, provided an alloy bond as herein disclosed is established between the magnesium and the aluminum. 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 aluminum coated magnesium which includes the steps of substantially destroying the oxide film at the surface of the aluminum to be united to the magnesium by forming an alloy of zinc and aluminum at the inner face of an aluminum envelope, and casting magnesium into said envelope into direct contact with said alloy to form therewith a substantially continuous alloy bond between said magnesium and aluminum.

2. The method of forming laminated billets

and other bodies of aluminum coated magnesium which includes the steps of forming a coating sheet of aluminum, substantially destroying the oxide film at the surface thereof to be united to the magnesium while alloying zinc therewith, and uniting a magnesium core thereto by establishing a substantially uniform aluminum zinc magnesium alloy bond between the contiguous surfaces of the magnesium and aluminum.

3. The method of forming bodies of corrosion-resistant magnesium which includes the steps of forming a coating sheet of aluminum, substantially destroying the oxide film at the surface thereof to be united to the magnesium while alloying zinc therewith, and fusing the alloyed face of said coating sheet to a magnesium core by a substantially uniform alloy bond which is substantially continuous and co-extensive with the contiguous faces thereof.

4. The method of forming laminated billets and other bodies of aluminum coated magnesium which includes the steps of forming an envelope of aluminum which has a substantially continuous predetermined layer of zinc aluminum alloy adherent to the inner face of said envelope with substantial uniformity, and fusing to said layer a core of magnesium to establish a substantially uniform alloy bond between said metals.

5. The method of forming laminated billets and other bodies of aluminum coated magnesium which includes the steps of forming a sheet of aluminum, forming an alloy layer at the face of said sheet which is to be united to the magnesium, and fusing to said alloy layer a magnesium core to form an alloy bond of substantially uniform character and predetermined depth throughout the contiguous surfaces of said metals.

6. The method of forming laminated billets and other bodies of aluminum coated magnesium which includes the steps of substantially destroying the oxide film at the surface of the aluminum to be united to the magnesium by alloying zinc to said face of the aluminum to provide a relatively thin alloy layer, and fusing to said layer a core of magnesium.

7. The method of forming laminated billets and other bodies of aluminum coated magnesium which includes the steps of substantially destroying the oxide film at the surface of the aluminum to be united to the magnesium by alloying zinc to said face of the aluminum to provide a relatively thin alloy layer, and casting molten magnesium into contact with said layer to form a fused bond with said alloy layer.

8. The method of forming laminated billets and other bodies of aluminum coated magnesium which includes the steps of substantially destroying the oxide film at the surface of the aluminum to be united to the magnesium by forming an alloy of zinc and aluminum at the inner face of an envelope sheet of aluminum and uniting said alloyed face of said aluminum envelope sheet to a fused magnesium core by forming a substantially uniform alloy bond therebetween while controlling the relative temperatures of said metals to predetermine the depth of the bond so formed.

9. The method of forming laminated billets and other bodies of aluminum coated magnesium which includes the steps of applying molten zinc to aluminum while breaking down the aluminum oxide film on said aluminum to form a predetermined layer of zinc aluminum alloy, forming the aluminum into an envelope, and then fusing a core of magnesium to said alloy within said envelope.

10. The method of forming laminated billets and other bodies of aluminum coated magnesium which includes the steps of applying molten zinc to aluminum while breaking down the aluminum oxide film on said aluminum to form a predetermined layer of zinc aluminum alloy, forming the aluminum into an envelope, and then casting into said envelope a core of molten magnesium to fuse the surface of said alloy and establish a substantially uniform alloy bond between the aluminum and magnesium.

11. The method of forming laminated billets and other bodies of aluminum coated magnesium which includes the steps of applying molten zinc to aluminum while breaking down the aluminum oxide film on said aluminum to form a predetermined layer of zinc aluminum alloy, forming the aluminum into an envelope, and then casting into said envelope a core of molten magnesium to fuse the surface of said alloy and establish a substantially uniform alloy bond between the aluminum and magnesium while controlling the relative temperatures of said aluminum and magnesium with respect to their relative heat capacities so as to predetermine the depth of alloy bond so formed.

12. The method of forming laminated billets and other bodies of aluminum coated magnesium which includes the steps of forming an envelope of aluminum having alloyed to the inner face of said envelope a thin coating of zinc, and then fusing a core of magnesium to said thin coating to unite said magnesium to said aluminum by a magnesium-zinc-aluminum alloy.

13. The method of forming laminated billets and other bodies of aluminum coated magnesium which includes the steps of forming an envelope of aluminum having alloyed to the inner face of said envelope a thin coating of zinc, and then casting a core of molten magnesium into said envelope to form a fused bond with said thin coating and unite said magnesium to said aluminum by a magnesium-zinc-aluminum alloy.

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

15. A malleable ductile aluminum coated magnesium body composed of a relatively thin aluminum coating sheet having a zinc aluminum alloy layer at its inner face united to a magnesium core by a substantially continuous bond of controlled thickness, said bond being composed of a relatively thin layer of aluminum, zinc and magnesium alloy substantially coextensive with the contiguous surfaces of the magnesium and aluminum and uniformly bonded to both of said metals.

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