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METHOD OF BONDING ALUMINUM TO STEEL

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The present invention relates to an improved bimetallic article and a method of producing the same. It is especially directed to an article consisting of a layer of steel and a layer of aluminum or aluminum alloy firmly bonded together in such a manner that the article is capable of withstanding severe bending, forming, or rolling without rupture of the bond.

It is a recognized fact that molten aluminum is very reactive with most metals and forms intermediate brittle phases upon solidification. This is especially true when heavy coatings of molten aluminum are in contact with relatively heavy layers of steel since the temperature cannot be lowered in sufficient time by known conventional methods to prevent the formation of detrimental brittle phases. Many attempts have been made in the past to provide means for coating ferrous base metals with aluminum by using various other metals such as copper, tin, zinc, and the like as bonding agents, but in most of these prior methods the metal used did not prevent reaction between the aluminum and ferrous base metal. Other methods have been proposed, whereby the ferrous base metal was coated with a metal which in turn was contacted with molten aluminum and which acted as a barrier layer to prevent reaction between the ferrous base metal and the aluminum. Such a process is described in application Serial No. 769,616, filed August 20, 1947, now Patent No. 2,611,163, dated September 23, 1952. In this application there is described a bimetallic article having a ferrous base metal, a barrier layer of nickel or cobalt and a relatively thick layer of aluminum or aluminum alloy bonded securely together.

As the thickness of the steel or the molten aluminum or its alloys increases, the time of heat removal is correspondingly increased. Since the reaction rate between the molten metal and the barrier layer is proportional to the temperature and time of contact, the heavy gauge steels and heavy sections of molten aluminum or its alloys will allow the formation of brittle intermediate phases of nickel or cobalt with aluminum which in turn minimize the ductility of the bond and reduce the ability of the bimetal article to withstand mechanical work. The present invention contemplates using layers of cobalt or alloys of cobalt with iron or nickel and a subsequent layer of mercury on a ferrous base metal in combination with a layer of aluminum to give a strong, ductile bond capable of severe mechanical distortion and rolling.

It has been found that, by applying a layer of

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mercury over cobalt or its alloys on a heavy steel section and then casting a thick layer of aluminum or aluminum alloy upon it and quenching in the conventional manner, the bond strength can be controlled to obtain a resulting product capable of severe mechanical distortion or rolling. In the casting process the mercury dissolves completely in the molten aluminum or the aluminum alloy. The exact role of mercury on cobalt or its alloys to enhance the bond strength and ductility between the aluminum and steel, is unknown.

It has been found that cobalt alloyed with iron or nickel is satisfactory in place of pure cobalt. The only explanation of why this is possible is associated with the relationship of the metals in the Periodic Table. Thus cobalt alloyed with other metals in the iron group 8A and mercury used in combination with aluminum and steel as previously described will give a strong, ductile product.

In carrying out the present invention, strip, sheet or plate steel is first electroplated with a layer of cobalt approximately .0001 to .0005 inches thick, although the upper limit is largely determined by economics, which layer is then covered with a layer of mercury of .00005 to .0002 inches thick before the cobalt oxidizes. Then the plated strip is heated to approximately 1350° F. in a nonoxidizing atmosphere and a molten aluminum alloy at approximately 1350° F. is cast upon the plated surface. The material is quenched at a rate of approximately 100° F. per second until a temperature of approximately 1000° F. is reached, to solidify the aluminum. Below this temperature the rate of quench is immaterial. Alloys of cobalt with iron or nickel may be substituted for the cobalt layer.

In order to evaluate the ductility of the bond between the steel and aluminum layers, a chisel test, a bend test, and a rolling test have been used. The chisel test consists of using a cold chisel and a hammer and attempting to separate the aluminum from the steel by pounding the chisel at about a 30° angle to the surface of the material between the layers. The bend test consists in bending a blank at 180° upon itself with the aluminum layer on the outside. The rolling test consists of reducing the composite by rolling in conventional rolling equipment to a minimum reduction of 25%. Material made in accordance with the invention will withstand the ductility tests described above and in addition can be annealed at temperatures up to 1000° F. in a neutral atmosphere for a conven-

tional period of time without affecting the bond strength or ductility, which is not possible with other bonding media for aluminum and steel. If the material passes these three tests it is considered satisfactory for complex forming and fabricating processes. Previously known bonding combinations, especially when there is a relatively thick layer of aluminum and of steel, will not withstand these tests without rupture of the bond.

The following is a specific example of one method of carrying out the invention. Low carbon cold rolled steel strip such as S.A.E. 1010 approximately 4.5 inches wide by 0.131 inches thick was properly cleaned and pretreated according to regular commercial plating practice and was then electroplated with a layer of cobalt approximately .0002 inches thick. This plating operation was carried out in a standard electroplating bath by conventional methods. The strip was then dipped in mercury and wiped free of excess mercury before oxidation of the cobalt. Following this the steel strip was heated in an atmosphere furnace containing approximately 90% nitrogen and 10% hydrogen to a temperature of 1350° F. and had cast upon the mercury surface a molten aluminum alloy consisting of approximately 1.5% silicon, 6.5% tin, 1% copper, 0.5% nickel, balance aluminum with normal impurities at 1350° F. The strip was then quenched with water, as described in application Serial No. 769,616, now Patent No. 2,611,163, dated September 23, 1952, from the ferrous side. This material withstood the tests indicated above for bond strength.

An example of the other barrier layers includes alloys of cobalt and iron or nickel in the ratio of approximately 50% each.

It has been found that the invention is particularly advantageous when used with steel thicknesses in excess of .080 inches and layers of aluminum in excess of .020 inches thick when the cooling rate is approximately 100° F. per second. Below these thicknesses the invention is also advantageous but generally the heat can be extracted from thinner sections fast enough to prevent formation of the undesirable intermediate phases.

Steel in the form of sheet, strip, tubing, or the like which is prepared with a layer of cobalt or its alloys and a layer of mercury as described and which is subsequently cast with aluminum or an aluminum alloy will produce a bimetallic article having greatly improved bond strength over present known combinations.

We wish it to be understood that we do not confine ourselves to the precise details herein set forth in the preferred manner of carrying out our invention as it is apparent that many changes and variations may be made by those skilled in the art without departing from the spirit of the invention or exceeding the scope of the appended claims.

We claim:

1. A method of making a bimetallic material composed principally of a ferrous layer and a layer of aluminum or aluminum alloy which consists of electrodepositing a layer of a metal selected from the iron group or its alloys in which cobalt is at least 50% of the alloy and successively coating upon this layer a second layer of mercury before the first metal oxidizes and lastly casting upon said second layer a layer of aluminum.

2. The method of making bimetallic material composed principally of a layer of ferrous material and a layer of aluminum or aluminum alloy integrally bonded thereto which consists of plating a metal barrier layer selected from the group consisting of iron, cobalt, nickel or their alloys in which cobalt is at least 50% of the metal and subsequently coating said barrier layer with mercury before the metal barrier layer oxidizes and casting upon said mercury layer molten aluminum.

3. A method of making a bimetallic material composed principally of steel upwards of 0.80 inches thick and aluminum or aluminum alloy upwards of 0.20 inches thick which consists of plating upon said steel layer a metal barrier layer selected from the group consisting of cobalt, nickel, iron or their alloys provided cobalt is at least 50% of the metal and coating said barrier layer with a second layer of mercury before said first metal barrier layer oxidizes and casting upon said second layer a layer of aluminum in a reducing atmosphere composed principally of nitrogen and a small percentage of hydrogen and subsequently quenching the aluminum to minimize the reaction between the molten aluminum and the barrier layer.

4. A method of making a bimetallic material composed principally of a layer of ferrous material more than .080 inches thick and a layer of aluminum or aluminum alloy more than .020 inches thick which consists of plating upon said ferrous material a metal barrier layer selected from the group consisting of cobalt, nickel, iron and alloys thereof wherein cobalt is at least 50% of the material from .0001 to .0005 inches thick and coating said barrier layer with a layer of mercury from .00005 to .0002 inches thick before the metal barrier layer oxidizes and casting upon said strip at a temperature of about 1350° F. in a reducing atmosphere a layer of molten aluminum or aluminum alloy and quenching said strip from the ferrous side of the strip to solidify the aluminum at at least 100° F. per second.

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