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# PROCESS OF MAKING ALUMINUM COATED FERROUS BODIES

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This invention relates to an improved method of coating ferrous metal articles, and more particularly to a method for controlling the formation of a bond between ferrous metal bodies and aluminum and its alloys.

When molten aluminum-containing metal is applied either as a coating or a layer to a ferrous metal surface under proper conditions, the aluminum-containing metal combines substantially at once with the ferrous metal surface. It is also recognized that a ferro-aluminum alloy is formed at the interface between the ferrous body and the layer or coating of the aluminum-containing metal, such alloy bonding the coating to the body.

While the formation of a ferro-aluminum alloy at the interface is necessary to obtain a permanent bond between the ferrous metal surface of the body and the coating or layer of aluminum-containing metal, we have now discovered that the presence of this alloy in large amounts impairs the strength of the resulting composite structure, and the control of the thickness of this bonding alloy is critical to the strength and permanence of the bond. In general, the bonding alloy formed at the interface is brittle in nature and the strength of the resulting bond, insofar as subsequent hot and cold working operations is concerned, is dependent to a large extent on the thickness of such alloy. We have found that for most conditions of rigorous working of the resulting laminate of ferrous metal and aluminum or aluminum alloy, that the thickness of the bonding alloy formed at the interface should not exceed about 0.6 mil and preferably should not be in excess of 0.5 mil. By limiting the thickness of the bonding alloy to not more than 0.5 mil we have observed that the resulting laminate can successfully withstand heat-treating and rolling operations which cannot be efficaciously carried out with laminates having a thicker bonding alloy at the interface. In accordance with the process of this invention, the depth of the bonding alloy may be controlled by incorporating into the ferrous metal body to be coated a small proportion of at least one of the metals of the sixth periodic group. In this group, molybdenum and tungsten have been found particularly effective. The selection of the particular metal or metals of this group to be employed is largely determined by the use to which the coated body is to be put. However, since the percentage of these heavy metals used for alloy control is relatively small, the irons and steels used in many arts can readily accommodate one of these metals in the small quantity required without impairing the utility of the article, and in fact many irons and steels utilizing such metals for their physical attributes can be coated with aluminum or aluminum-containing alloys according to this invention without requiring special addition of the alloy-controlling metal for that purpose. For instance, commercially available steels containing either molybdenum, tungsten, or both, for example up to 5% or more of molybdenum, or 20% or more of tungsten, may be successfully employed in the practice of this invention without the necessity of adding further amounts of such metals as in the case of low carbon or loy alloy steels.



In the case of low alloy steels containing about 1% of either molybdenum, or tungsten, the alloy bond thickness resulting from dipping such steel in molten aluminum of commercial purity has resulted in a bond alloy having a thickness not appreciably greater than about 0.4 to 0.6 mil, whereas a plain carbon steel dipped under the same conditions showed an undesirable alloy bond thickness of substantially 2.0 to 2.5 mils. Very small additions, i. e. from a trace to an amount not materially exceeding 1% of tungsten or molybdenum to a medium or low carbon steel resulted in a substantial reduction in the thickness of the alloy bond layer and for bodies which are to be subjected to subsequent rigorous treatment we have found that the thickness of the alloy bond should preferably be less than 0.4 mil, indicating that for many purposes the percentage of molybdenum or tungsten need not materially exceed 1% by weight of the steel.

While molybdenum and tungsten vary in efficiency in controlling the thickness of the bonding alloy the combination of these metals as alloy bond controllers may advantageously be employed. We have observed that although in certain molten aluminum-containing metals the bolybdenum tends to go into solution, nevertheless, molybdenum helps to control the thickness of the bonding alloy when coating molybdenum-containing steels designed for special purposes.

The term "aluminum" as used herein includes aluminum as well as aluminum-containing alloys, and particularly aluminum-base alloys, since the presence of the aforementioned metals in the steel article to be coated controls the alloying action between the ferrous metal of the body and the coating or layer of aluminum or aluminum alloy regardless of the presence of metals or non-metals that may be in the aluminum or aluminum alloy.

In carrying out the process of this invention, the ferrous metal body is alloyed with the indicated small percentage of molybdenum or tungsten, or combination thereof, whenever it is desired to control the thickness of the bonding alloy formed at the interface between the surface to be coated and the aluminum. The amount of the aforementioned bond-control metal determines the depth of the bonding alloy, without requiring the extremely accurate time and temperature control heretofore required for that purpose. For example, the temperature of the aluminum-containing metal can be maintained between the melting point of such metal and about 1350° Fahrenheit. With such alloy thickness control the strength of the bond is greatly augmented, since the bonding alloy is reduced in thickness and thus enables the composite metal article to be worked either hot or cold, or be subjected to wide temperature fluctuations, or both, without impairment of the bond.

Although a preferred method of controlling the depth of the alloy formation between the ferrous metal surface and aluminum-containing metals has been described herein, it is to be understood that the method of this invention may be used to control the depth of the alloying bond by proportioning the percentage of the alloy inhibiting metal in the steel so as to obtain an alloy at the interface of any desired thickness between that obtained without the use of the aforementioned heavy metals and that obtained with the maximum percentage which secures a bond of minimum safe thickness for rigorous treatment of the composite article. It is also to be understood that other variations in the invention may be made within the scope of the appended claims.

This application is a continuation-in-part of our application Serial No. 757,920, filed June 28, 1948, and now abandoned.

We claim:

1. In the process of bonding a coating of aluminum to

a plain carbon steel base by dipping said plain carbon steel base into a bath of molten aluminum to form a coating of aluminum thereon and a ferro-aluminum bonding alloy at the interface between said plain carbon steel base and said aluminum coating, the improvement comprising initially alloying in said plain carbon steel base about 1 per cent of a metal selected from the group consisting of molybdenum and tungsten, immersing the resulting alloyed body into a bath of molten aluminum maintained at a temperature not above about 1350° F. for a period to form the desired thickness of said coating, said bonding alloy being simultaneously formed and automatically controlled to a thickness not in excess of 0.6 mil, irrespective of the time of immersion in said molten bath.

2. In the process of bonding a coating of aluminum to a low alloy steel base containing about 1 per cent of a metal selected from the group consisting of molybdenum or tungsten by dipping said low alloy steel base into a bath of molten aluminum to form a coating of aluminum thereon and a ferro-aluminum bonding alloy at the interface between said coating and said base, the improvement comprising immersing said low alloy steel base into a bath of molten aluminum maintained at a temperature not above about 1350° F. for a period to form the desired thickness of said coating, said bonding alloy being simultaneously formed and automatically controlled to a thickness not greater than about 0.4 to 0.6 mil, irrespective of the time of immersion in said bath.

3. In the process of bonding a coating of aluminum to a ferrous metal article by dipping said article into a bath of molten aluminum to form a coating of aluminum



thereon and a ferro-aluminum bonding alloy at the interface between said ferrous metal article and said coating, the improvement comprising initially alloying in said ferrous metal article about 1 per cent of a metal selected from the group consisting of molybdenum and tungsten, immersing the resulting alloyed body into a bath of molten aluminum maintained at a temperature above the fusion temperature of said aluminum but below 1350° F., for a period to form the desired thickness of said coating, said bonding alloy being thereby simultaneously formed and automatically controlled to a thickness not in excess of 0.6 mil.

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