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METHOD OF CHEMICALLY BONDING ALUMINUM OR ALUMINUM ALLOYS TO FERROUS ALLOYS

Mamoru Imabayashi, Ibaragi-ken, Japan, and Shichiro Ohshima, 1198, 1-chome, Honcho, Funabachi-shi, Chiba-ken, Japan; said Imabayashi assignor to said Ohshima

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ABSTRACT OF THE DISCLOSURE

A method of bonding aluminum or aluminum alloys to ferrous alloys including the step of dipping the ferrous alloy in a bath of molten zinc alloy containing 0.001 to 0.01% beryllium, 0.2 to 2% aluminum, less than 7% copper and less than 3% manganese. After the zinc-base alloy solidifies, molten aluminum is brought into association therewith and set to form the aluminum layer on the ferrous alloy.

This invention relates to the technique of bonding aluminum or aluminum alloys to ferrous alloys and has for its object to provide a novel method of chemically bonding aluminum or aluminum alloys to ferrous alloys in a solid state.

Various methods have previously been proposed to bond aluminum or aluminum alloys to ferrous alloys. In one proposed method, a film layer of aluminum or aluminum alloy is formed on the surface of ferrous material by hot dipping and through the medium of the layer a mass of aluminum or aluminum alloy is bonded to the ferrous material. In such method, however, the presence of a firm oxide film on the layer has much precluded chemical combination between the ferrous and aluminum alloys. Because of this, in cases where the aluminum alloy is to be poured after solidification of the dip-coated layer, it has been difficult to chemically bond the two metal alloys unless some pretreatment is used to remove the oxide film on the layer before the melt of aluminum alloy is placed in contact therewith. Besides, even if some chemical bond be attained, the bonding strength would be limited because of the extreme brittleness of the Fe-Al intermetallic compound intermediating such chemical bond and separation or cracking might possibly occur therein.

According to the method of the present invention, ferrous alloys in a solid state are first dipped in a bath of molten zinc-base alloy of the following composition to form a film layer of the same composition on the surface of the ferous alloy.

COMPOSITION OF BATH

	Percent
Beryllium	0.001 to 0.01
Aluminum	0.2 to 2
Copper	<7
Manganese	<3
Zinc	Remainder

Subsequently, before the ferrous alloy cools down, any excess of the molten zinc alloy adhering to its surface is removed by mechanical vibration or blasting of compressed air preliminary to the pouring of a melt of aluminum or aluminum alloy into contact with the coated ferrous material.

The constituent elements of the above composition have respective marked significances as described below.

Beryllium is markedly effective to preclude oxidation of the other elements included in the zinc alloy. Thus, it not only prevents any buildup of oxides on the surface of the bath of molten zinc alloy, but also prevents the zinc alloy film formed on the ferrous material from being oxidized as its cools down, ensuring a neat and clean appearance to the film. This is a first factor in the present invention of facilitating formation of the chemical bond between the ferrous alloy and the aluminum or aluminum alloy poured therein. The percentage content of beryllium in the zinc alloy should be in the range of from 0.001% to 0.01%. Any excess of beryllium would result in formation of a firm film of beryllium oxide, adversely affecting the chemical bond subsequently formed between the ferrous alloy and the aluminum alloy poured therein.

Zinc inherently exhibits a high diffusion characteristic to aluminum and the fact that such zinc metal element forms a major constituent of the melt bath is a second factor in the present invention of facilitating formation of the chemical bond between the ferrous and aluminum alloys. This second factor in combination with the first one enables the zinc content in the zinc alloy film formed on the ferrous material to diffuse into the poured mass of aluminum alloy in an extremely short period of time to form a perfect chemical bond between the ferrous and aluminum alloys.

Aluminum in the zinc alloy has the same influence thereupon as beryllium and facilitates formation of a film of the zinc alloy on the ferrous material. The thickness of the zinc alloy film formed can be controlled by varying the percentage content of aluminum in the zinc alloy within the range of from 0.2 to 2% according to the type of ferrous material. Aluminum also is effective to increase the strength of the chemical bond between ferrous and aluminum alloys. To this end, the aluminum content in the bath composition is limited within the range of from 0.5 to 1%. It has been found that any excess amount of aluminum has an adverse effect upon the formation of a chemical bond between ferrous and aluminum alloys as with the case of beryllium.

Copper and manganese are added to prevent occurrence of casting defects in amounts not exceeding 7% and 3%, respectively, according to the type and shape ferrous material, the type of aluminum alloy and the conditions under which the bonded product is to be used. For certain types of product, satisfactory results can even be obtained without addition of any amounts of copper and manganese. The copper and manganese contents in the zinc alloy bath act to reduce the amount in which the zinc in the film of zinc layer formed on the ferrous material is allowed to diffuse into the aluminum alloy later cast in contact therewith, and expedite the solidification of the layer of zinc alloy thereby to prevent occurrence of casting defects in the vicinity of the chemical bond.

The temperature of the bath of molten zinc alloy is properly selected within the range of from 550° C. to an appropriate high temperature not exceeding the boiling point of zinc according to the type and shape of the ferrous material used. The length of dipping time is also properly selected according to the type and shape of this material. For example, carbon steel should be dipped in a bath held at a relatively low temperature within the above range and for a relatively short period of time. Cast iron is to be dipped at a relatively high temperature and for a longer period of time.

In comparison with conventional methods, the method of the present invention has various advantageous features. One advantage of the inventive method is that a satisfactory bond can be formed between the ferrous material coated with a layer of zinc alloy and the aluminum alloy even when the latter is cast in after a long period of storage of the film-coated ferrous material.

Another feature of the present invention is that a perfect bond can be formed without the need of subjecting the film-coated ferrous material to some pretreatment such as preheating, fluxing or polishing. In the inventive method, aluminum alloys are poured as a rule when the ferrous material is at the room temperature, and even under such condition satisfactory results are obtainable.

A further advantage of the present invention is that a satisfactorily high bonding strength can be obtained which eliminates the danger of separation or cracking taking place in the bond even under severe conditions of use. This is due to the fact that that the Fe-Zn intermetallic compound has a strength substantially higher than that of the Fe-Al intermetallic compound. For example, in the case where a bath of molten zinc alloy comprising 0.003% of beryllium, 0.7% of aluminum, 1.5% of copper, 0.5% of manganese and the rest of zinc was used, the bond formed between a cast iron and aluminum alloy JIS AC2B was measured to have a shear strength of 12 kg./mm.^{2}. Aluminum alloy JIS AC2B has the following composition:

Cu—2.0–4.0%
Si—5.0–7.0%
Mg—not more than 0.5%
Zn—not more than 1.0%
Fe—not more than 1.0%
Mn—not more than 0.5%
Ni—not more than 0.3%
Ti—not more than 0.2%
Al—remaining

The present invention has an additional advantage that it simplifies the bonding process, increasing productivity.

It will be appreciated from the foregoing that the method of the present invention is highly valuable in various industrial applications, making it easily possible to form a firm and perfect chemical bond between ferrous alloys, on one hand, and aluminum or aluminum alloys, on the other hand.

It will be understood that the inventive method can be applied not only to the ordinary casting procedure but also to the diecasting process, giving satisfactory results in casting cylinder heads, cylinder blocks, brake drums, gear casings and other mechanical components.

What is claimed is:

1. A method of chemically bonding aluminum or aluminum alloys to ferrous alloys comprising the steps of dipping the ferrous alloy in a bath of molten zinc alloy containing from about 0.001% to about 0.01% of beryllium, from about 0.2% to about 2% of aluminum, and the rest consisting essentially of zinc to form on the surface of the ferous alloy a zinc-base alloy film of the same composition, and bringing a mass of a liquid material from the group consisting of aluminum, and aluminum alloy into contact with the zinc-base alloy film coated ferrous alloy after the latter has cooled down to the vicinity of room temperature whereby the ferrous alloy and aluminum are chemically bonded to each other through the intermediary of the zinc-base alloy film.

2. A method of chemically bonding aluminum or aluminum alloys to ferrous alloys as in claim **1** comprising the step of including copper and manganese in the molten zinc alloy, the copper being present from 1.5 to 7% and the manganese being present from 0.5% to 3% by weight in the alloy.

3. A method of chemically bonding aluminum or aluminum alloys to ferrous alloys as in claim **2** comprising the step of forming the molten zinc alloy from about .003% beryllium, about 0.7% aluminum, about 1.5% copper, about 0.5% manganese and the remainder consisting essentially of zinc.

4. A method of chemically bonding aluminum or aluminum alloys to ferrous alloys as in claim **1** comprising the steps of heating the molten zinc alloy to a temperature of at least about 550° C., and removing any excess molten zinc alloy from the ferrous alloy prior to solidification of such molten zinc alloy.

5. A method of chemically bonding aluminum or aluminum alloys to ferrous materials as in claim **1** comprising the step of pouring a material from the group consisting of molten aluminum and molten aluminum alloy into contact with at least a part of the zinc base alloy coated ferrous alloy.

6. A method of chemically bonding aluminum or aluminum alloys to an article made from a ferrous material comprising the steps of dipping the ferrous material article in a bath of molten zinc alloy containing from 0.001% to 0.01% of beryllium, from 0.2% to 2% of aluminum, and the rest consisting essentially of zinc to form on the surface of the ferrous material article a zinc alloy film, cooling the article to solidify the zinc alloy thereon, and pouring a mass of molten aluminum containing material onto the film coated ferrous material article whereby the ferrous article and aluminum material are chemically bonded to each other through the intermediary of the zinc base alloy film.

References Cited

UNITED STATES PATENTS

2,123,181	7/1938	Deputy	164—75
2,265,243	12/1941	McCullough et al.	164—75
2,328,788	9/1943	Deputy	164—75
2,544,670	3/1951	Grange et al.	164—75 X
2,634,469	4/1953	Pershing et al.	164—75 X
2,849,790	9/1958	Zwicker	164—100 X

OTHER REFERENCES

Sebisty, J. J. et. al.: The influence of combined additions of tin, cadmium, antimony and copper on the structure and properties of galvanized coatings, in edited proceedings 6th International Conference on Hot Dip Galvanizing, Interlaken, edited by Zinc Development Association, London, June 1961, p. 215.

Sebisty, J. J.: Hot dip galvanizing with less common bath additions, in edited proceedings 7th International Conference on Hot Dip Galvanizing, Paris, 1964, edited by Zinc Development Association, London, pp. 235, 236, 238.

ALFRED L. LEAVITT, Primary Examiner

J. R. BATTEN, JR., Assistant Examiner

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