

UNITED STATES PATENT OFFICE

2,565,768

ALUMINUM COATING OF FERROUS METAL
AND RESULTING PRODUCT

Daniel O. Gittings, Pittsburgh, Pa., assignor to
United States Steel Company, a corporation of
New Jersey

No Drawing. Application April 2, 1948,
Serial No. 18,727

8 Claims. (Cl. 29—196.2)

1 This invention relates to hot-dip coating ferrous base metal with aluminum.

The utility of coated products depends to a large extent on their ability to withstand severe forming operations. This involves adherence of the coating to the base metal, i. e. resistance to flaking or peeling, and ductility of the coating as conventionally determined by 180° flat bend tests. The latter characteristic is necessary to avoid cracking at the formed areas since cracking of the coating may seriously affect the corrosion resistance of the product and detract from its appearance. In addition to the foregoing characteristics, it is necessary for the coating to have a good appearance to meet the demands of the trade.

It has heretofore been proposed to hot-dip coat ferrous base metal with aluminum. While such coatings have a satisfactory appearance, they are not sufficiently adherent and ductile to withstand severe forming operations. Various ways of overcoming these poor characteristics have been proposed but they do not result in coatings having the foregoing characteristics in a high degree. One of the chief factors in obtaining an adherent, ductile hot-dip coating is the control of the formation and growth of the alloy layer which forms almost immediately upon immersion in the molten coating metal. This layer tends to be hard and brittle and consists of an intermetallic compound, or compounds of the coating and base metal. Since physical properties of this layer in combination with its thickness largely control the adherence and ductility, it is desired to obtain a thin relatively soft alloy layer. The alloy layer formed from unalloyed aluminum baths tends to "grow" rapidly at high temperatures so that it is desirable to coat at the lowest possible temperatures.

It is accordingly an object of this invention to provide hot-dipped aluminum coatings which combine good adherence, ductility and appearance.

It is a further object to improve the adherence and ductility of aluminum coatings without detracting from the appearance thereof.

It is another object of this invention to provide a method of producing a relatively soft interfacial alloy layer on hot-dipped aluminum coated ferrous base metals, and at the same time maintain said layer at a minimum thickness.

2 It is a still further object of the present invention to provide a method of hot-dip coating ferrous metal with aluminum which can be carried out at relatively low temperatures.

I have discovered that the foregoing and further objects can be obtained by the addition of small but effective amounts of beryllium to the molten aluminum coating bath. Such addition does not detract from the coating appearance and at the same time improves adherence and ductility to a very marked degree.

The effect on the thickness of the interfacial alloy layer of the aluminum or aluminum alloy coating will be evident from the following Table I which sets forth the reduced thickness of the alloy layer for various beryllium additions as compared to the thickness of the layer obtained when high purity aluminum (contains up to .08% silicon and .06% iron as impurities) bath metal is used. All of the coatings were obtained by dipping for 20 seconds in a bath maintained at 1250° F. With such time and temperature, an alloy layer of .00140" thickness with the pure aluminum was obtained.

Table I

Amount of Beryllium added to Aluminum Bath Metal	Thickness Reduction of Alloy Layer (per cent of .00140" thickness obtained with pure Aluminum)
Per cent by weight	
.05	35
.1	50
.3	75
.4	82
.5	80
.6	79
.7	83
.8	80
.9	82
1.0	76
1.4	78
1.7	80
2.0	82

This table shows that an average reduction in thickness of the alloy layer of 80.64% is obtained for .3 to 2% beryllium additions and that as little as .05% beryllium results in substantial reductions.

At the same time, a very substantial decrease in the hardness of the interfacial alloy layer is obtained. The results of Tukon microhardness tests on the interfacial alloy layer of an aluminum coating, and on that of an aluminum-beryllium coating are shown in the following Table II:

Table II

Coating	Knoop Hardness Number 25 Gram Load	Converted Hardness (Brinell)
Al.....	889	725
Al with .5% Beryllium.....	326	310

The high quality adherence and ductility, associated with the decrease in thickness and hardness of the alloy layer, were reflected in the results of flat bend tests (180° bend over zero thickness) of coated 20 gauge material. These tests showed that the aluminum-beryllium alloy coatings of this invention, within the range of .1% to 2% beryllium contents, have good adherence and, therefore, do not flake or peel. In addition, the coatings containing over .1 and up to .6% beryllium have good ductility and are free of cracks. Pure aluminum coatings subjected to flat bends showed poor adherence and ductility. In addition to showing a slight tendency to crack, coatings containing more than .6% beryllium tended to have pimples, ridges, etc. on the surface. Likewise, although the appearance and adherence of coatings containing less than .1% beryllium is good, ductility as indicated by the flat bend test was not quite as good as those containing over .1% beryllium since the coatings with less than .1% beryllium exhibit a tendency to crack. For optimum results, a bath containing .3 to .5% beryllium is preferred.

An additional important feature of the aluminum-beryllium coatings of my invention is the relatively low bath temperatures which they permit. A coating bath containing up to 2% beryllium additions is sufficiently fluid to coat at temperatures below 1300° so that it is not necessary to exceed this maximum practical temperature. With the exception of the eutectic composition, temperatures above 1200° F. are necessary to have the bath sufficiently fluid, so that 1250° F. is a practical temperature throughout most of the range of beryllium additions. If desired, higher temperatures up to 1625° F. may be used but above 1300° F. the process becomes less economical, the growth of alloy layer and the formation of aluminum oxide on the bath surface are accelerated. Likewise, the structure of the base metal may be undesirably affected for some purposes. Use of too low temperatures which cause the bath to be "mushy" or not sufficiently fluid should, however, be avoided.

To further illustrate the teachings of my invention, the following example is given:

A suitable ferrous metal base, such as low-metalloid steel sheet or strip preferably containing less than .10% carbon and .40% manganese, is fluxed by immersion in a solution of the chloride salts of zinc and ammonia or by heating at about 1250° F. in a suitable reducing atmosphere. The surfaces thus prepared are protected against oxidation and immersed immediately in the molten aluminum coating bath which contains beryllium, preferably in the amount of .3 to .5%. The bath may be prepared in a number of ways but a convenient manner is to add beryllium in

the form of a beryllium rich aluminum-beryllium alloy to commercially pure molten aluminum, additions of the alloy being made from time to time to keep the beryllium content within the desired range. Aluminum may be added in bar form to keep the quantity or level of the bath at the level desired. A suitable bath temperature is 1250° and the time of immersion will of course vary depending on the thickness of the base metal and its temperature as it enters the bath. It is desirable to keep the base metal in the bath the shortest practical time since additional time promotes the growth of the alloy layer. For ordinary gauges to be coated, an immersion time of 20 seconds or less is satisfactory. The thickness of the coating may be controlled by pressure rolls at the exit side of the bath or by other available conventional means. It is desirable for the coated product to cool sufficiently for the coating to solidify before contacting rolls or conveying mechanism beyond the finishing rolls. If desired, forced cooling may be used.

While I have shown and described several specific embodiments of my invention, it will be understood that these embodiments are merely for the purpose of illustration and description and that various other forms may be devised within the scope of my invention, as defined in the appended claims.

I claim:

1. In the method of hot-dip coating ferrous base metal with aluminum, the step of adding at least .05% beryllium to the aluminum coating bath to substantially reduce the thickness and hardness of the alloy layer.

2. In the method of hot-dip coating ferrous base metal with aluminum, the step of adding between .1 and .6% beryllium to the hot-dip coating bath to materially reduce the thickness and hardness of the alloy layer.

3. In the method of hot-dip coating ferrous base metal with aluminum, the step of adding between .3 and .5% beryllium to the hot-dip coating bath to reduce the thickness and hardness of the alloy layer and obtain a coating having sufficient adherence and ductility to withstand flat bend tests without flaking or cracking.

4. The method of hot-dip coating ferrous base metal with aluminum comprising adding beryllium in effective amounts from about .1% up to 2% to the molten coating bath, maintaining the molten bath at a temperature below 1300° F. and dipping ferrous base metal having cleaned surfaces therein.

5. A hot-dipped coated product comprising a ferrous metal base and an outer layer of aluminum containing beryllium having a thin relatively soft beryllium-containing iron aluminum alloy layer therebetween and resulting from the process of claim 1.

6. A hot-dipped coated product comprising a ferrous metal base and an outer layer of beryllium-containing aluminum having a thin relatively soft beryllium-containing iron aluminum alloy layer therebetween and resulting from the process of claim 2.

7. A hot-dipped coated product comprising a ferrous metal base and an outer layer of beryllium-containing aluminum having a thin relatively soft beryllium-containing iron aluminum alloy layer therebetween and resulting from the process of claim 3.

8. A hot-dipped coated product comprising a ferrous metal base and an outer layer of beryllium-containing aluminum having a thin rela-

2,565,768

5

tively soft beryllium-containing iron aluminum alloy layer therebetween and resulting from the process of claim 4.

DANIEL O. GITTINGS.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,126,484	Kirby	Jan. 26, 1915
1,254,987	Cooper	Jan. 29, 1918

Number
1,515,082
1,706,130
1,716,943
1,764,132
2,135,652
2,394,546

5

Name	Date
Veazey	Nov. 11, 1924
Ruder	Mar. 19, 1929
Archer	June 11, 1929
Wehr	June 17, 1930
Whitfield	Nov. 8, 1938
Harrington	Feb. 12, 1946

6

OTHER REFERENCES

10 Bass-Beryllium as an alloying component (reprinted from April 1946 issue of Industrial Plastics), 4 pages.