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A COMPOSITE METAL BODY OF A FERROUS BASE AND ALUMINUM BASE ALLOY COAT

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This invention relates to composite metal articles having a ferrous metal base portion coated with a particular aluminum base alloy, the process for producing such composite articles and the aluminum base coating alloys. More particularly, the invention relates to aluminum alloys particularly adapted for the hot dip coating of a ferrous metal base, the hot dip process and the resulting composite metal article.

Coatings of aluminum on iron and steel products are highly desirable, since the composites resulting in effect embody the superior properties resident in each metal. To the strength and other desirable characteristics of the iron or steel core, the aluminum coating adds the more salient properties of resistance to corrosion and oxidation at both atmospheric and elevated temperatures, enhanced electrical conductivity, improvement in the facility of brazing and soldering of aluminum to steel, and a more attractive appearance.

In the fabrication of aluminum coated ferrous base metal products, it is often necessary that the composite article exhibit the ability to withstand high degrees of deformation upon subsequent working or forming. The coating upon the ferrous base in such cases must possess satisfactory adherence so that upon bending or drawing or other deformation the coating will not break away, that is peel or flake off the base metal. In addition, the composite of the ferrous base and aluminum coating, as well as the coating itself must exhibit satisfactory ductility so that cracking of the coating and exposure of the base metal to corrosion will not occur. In addition, such coatings to be commercially acceptable must exhibit a satisfactory appearance in regard to coverage on the ferrous base, for example wire or strip, continuity and smoothness of the coating, and the luster or attractiveness of the coating.

Of the several processes for the production of aluminum coated ferrous base composite articles, the hot dip method is the most desirable from an economic standpoint and from the standpoint of range of applicability. However, the production of "aluminized" (aluminum-coated) ferrous base metal articles has presented many problems even in the advantageous hot dip method to which the present invention is particularly directed.

In hot dip coating ferrous metal articles with high purity or commercially pure aluminum, the principal difficulties encountered have been the lack of satisfactory adherence of the coating to the base metal, lack of ductility of the composite and coating, and relatively poor appearance because of the tendency to produce large grains which are noticeable to the naked eye. These deficiencies have seriously interfered with the utility of such hot dip aluminum coated articles, since the formability of the composite in regard to subsequent working is unsatisfactory due to cracking, peeling or flaking of the coating upon deformation of the composite. In addition, cracking of the coating leads to unsatisfactory "in service" performance in regard to the intended purpose of the coating to enhance the appearance and corrosion resistance of the ferrous base. Accordingly, for the most part only the color characteristic of the high purity or commercially pure aluminum coating on the ferrous base has proved to be satisfactory.

Attempts have been made to counteract the rather poor adherence and ductility characteristics of aluminum coated ferrous metal composite articles wherein high purity or commercially pure aluminum has been employed as the coating metal or alloy. It has been determined that the ductility of the coating and composite is primarily adversely affected by the thickness and hardness of the intermetallic brittle Fe-Al phase layer formed between the core and the superimposed or outer layer of the aluminum-rich coating metal upon immersion of the base metal into the molten bath of coating metal. With commercially pure or high purity aluminum as the coating metal, the intermetallic or interfacial Fe-Al layer grows relatively rapidly, by diffusion, at normal hot dip coating temperatures so that the composites exhibit an undesirably low ductility and adherence.

It has heretofore been recognized that the addition of silicon in various amounts to a hot dip aluminum coating bath advantageously effects a control on the formation and growth of the intermetallic Fe-Al alloy layer so that although the layer forms in the proper thickness to provide the requisite adherence or bonding between the coating and the ferrous base, its thickness is greatly reduced in comparison to that when utilizing high purity or commercially pure aluminum. Also, the structure of the layer is altered from a hard finger-like formation to a soft banded-type formation. The combination of a thinner intermediate zone of intermetallic compound and the modified structure provides greater ductility than that obtained with high purity or commercial aluminum. Large reductions in intermetallic layer thickness (above 50%) usually require the addition of over two percent silicon based on the weight of the aluminum-silicon alloy utilized as the coating alloy. Amounts of silicon as low as about one percent will produce a decrease in intermetallic alloy layer thickness, but the increase in ductility and adherence is much less marked than where the silicon is employed in the larger amounts. Thus, satisfactory adherence and ductility may be obtained when utilizing aluminum-silicon alloys in the hot dip coating process. Unfortunately, however, the addition of silicon, particularly in the amounts required to produce significantly high properties of ductility causes an undesirable appearance of the coating in regard to both luster, smoothness and color. The coatings darken in service upon weathering. Also, the continuity of the coating tends to decrease with the larger amounts of silicon since the molten coating bath becomes increasingly sensitive to minor variations in the cleanliness of the ferrous base. The silicon-containing aluminum alloys provide a characteristically grey, nonlustrous appearance, which becomes markedly roughened in surface characteristics where the silicon is used in the most favorable amounts in regard to the ductility and adherence characteristics of the composite articles.

It is accordingly a primary purpose and object of this invention to provide hot dip aluminum alloy coated ferrous base metal articles which combine the several properties of good adherence, ductility and excellent appearance in regard to coverage, smoothness, continuity and luster of the coating, and other factors affecting appearance.

It is a further object of the invention to provide aluminum base alloys particularly adapted for the hot dip coating of ferrous base metals characterized by their ability to form coatings and composite articles exhibiting good properties of formability due to high ductility and adherence, and desirable appearance of the coatings in regard to brightness, smoothness and continuity and absence of undesirable visible surface grains.

It is a more specific object of the present invention to provide aluminum alloys for coating ferrous metal wherein the advantages of good adherence and ductility characterized by silicon-containing coating alloys are ob-

tained while at the same time the disadvantages in regard to coating appearance characterizing aluminum-silicon binary coating alloys are substantially eliminated.

It is a further object of the invention to provide a method of hot dip coating ferrous metal with particular aluminum base alloys to produce coatings on composite articles having the desirable combination of properties above mentioned while operating at advantageous temperatures in regard to minimizing the thickness of the intermetallic alloy layer.

These and other objects and advantages of the invention will be apparent from the following detailed description thereof.

It has been discovered according to the invention that hot dip aluminum coatings on ferrous base metal and the composite articles resulting therefrom having outstanding ductility and adherence properties similar to those of aluminum-silicon binary alloys and an appearance at least equal to and in most cases better than that obtained with high purity or commercially pure aluminum may be obtained by the utilization of certain ternary and more complex aluminum base alloys.

In general the aluminum base alloys of the invention contain from about one to six percent silicon and small but effective amounts of at least one of the elements chromium, molybdenum and tungsten, employed either singly or collectively, to produce the above mentioned desired results. It was found that the presence of chromium, molybdenum and tungsten, notably the latter two, improved the continuity and coverage of the coating on the ferrous base in comparison with the coverage obtained with the aluminum-silicon binaries under the conditions generally employed in the hot dip process. These alloying elements increased the ability of the aluminum to wet the ferrous base metal providing faster coating and improved appearance. In addition, these elements, notably molybdenum, or a combination of chromium and molybdenum, further improved the surface appearance of the coatings by at least partially eliminating the characteristic rough surface inherent with the use of silicon in amounts effective to produce significant increases in ductility. Also, chromium and molybdenum, and to a somewhat lesser extent tungsten, were found to be effective in improving the color and brightness or luster of the coatings by offsetting the characteristic dull grey appearance of the aluminum-silicon binary alloy coatings having relatively high silicon content. A further notable effect particularly characterized by the presence of molybdenum or chromium or the two elements collectively was their ability to decrease the amount of surface tarnish on the coating during cooling, particularly with silicon containing aluminum base alloys and regardless of whether the coating was air-cooled or water-quenched. In respect of all of these improvements, these addition elements did not exhibit any unduly adverse effect upon the ductility of the coating and composite primarily imparted by the silicon, and in certain instances wherein the amount of silicon was within the lower range, i.e. one to about two percent, the chromium and molybdenum actually exerted a beneficial influence on ductility.

The elements chromium, molybdenum and tungsten generally may be present in amounts of from about 0.1% to 0.40% each when used singly, or up to a total of about 0.5% when collectively used. The preferred range when these elements are added singly is from about 0.15% to 0.35%, while this range is also the preferred total when two such elements are added. In this connection, it is recommended that optimum results are obtained by single additions of these elements or by additions of both chromium and molybdenum. On the other hand, however, it has been found less preferable to utilize all three of these elements in a single coating alloy and although included within the scope of the invention, the results are not as desirable when all three elements are present, or when chromium and tungsten, or molybdenum and tungsten are both present.

It has also been found according to the invention that very limited or small amounts of beryllium have a desirable effect on the appearance of the coatings. This element exhibits the ability to reduce the amount of surface oxide on the molten aluminum alloy coating bath. The use of beryllium is particularly advantageous when coating with aluminum alloys containing silicon or sodium. Brown oxides are formed on the bath surface when these elements are incorporated in the molten coating alloy and cause staining of the coating. Amounts of from about 0.001 to 0.015% of beryllium are very effective in preventing the formation of this stain due to the brown oxide, and at the same time do not have any adverse effect on the ductility of the coating. A preferred lower amount of about 0.002% beryllium is recommended.

The use of beryllium in these amounts is to be distinguished from the use of beryllium in larger amounts where it functions similarly to silicon in having a pronounced intermetallic layer thickness reducing effect. In any event, beryllium as an optional element in the coating alloys of the present invention for improvement in the appearance of the composite is limited to amounts below 0.02%, and amounts substantially in excess of this value are required to provide a decrease in the thickness of inter-metallic layer and resulting improvement in ductility.

Where beryllium is added to the molten aluminum coating alloy bath, additions are made periodically to replace that lost through oxidation and due to chlorine fluxing, when the latter method is employed. These additions are made preferably by adding aluminum-5% beryllium hardener to maintain the composition at the desired beryllium content in the alloy.

It was also found according to the invention that the addition of the element zinc to the aluminum-silicon alloys, above-described, imparted to the coatings characteristics common to those imparted by chromium, molybdenum and tungsten, and in particular the element molybdenum. Zinc additions in proper amounts were found to at least partially eliminate the surface roughening effect and steel grey appearance imparted to the coatings by the presence of silicon, particularly in the upper range of amounts. Thus, the zinc increased the surface brightness or luster and enhanced the surface appearance of the coatings by also producing a smoothing effect. In general, additions of zinc in amounts of from about 0.5% to about 2% by weight of the total alloy composition were found to be effective in this regard. The most desirable results were obtained using the preferred amount of zinc of from about 0.6% to about 1%, since coatings containing as high as 2% zinc in some instances resulted in a decreased fluidity of the bath and showed a tendency towards a spangling effect on the surface of the coating.

It is to be noted that additions of the elements molybdenum and zinc collectively is particularly desirable in its effect upon the appearance of the aluminum-silicon binaries. In other words, it was found that the effects of these two addition elements were additive in regard to offsetting the surface roughening effect and the steel grey appearance imparted by the silicon content in the higher ranges, for example, above about 3%.

The addition of zinc therefore improved the appearance and continuity of the coatings produced by the alloys of the invention and without any deleterious effects on the ductility of the composite. Furthermore, zinc as a constituent of the coating alloys provides cathodic protection to any portion of the basis metal of iron or steel which might become exposed should the coating develop any cracks.

The invention also contemplates the addition of small but effective amounts of at least one of the following elements: boron, titanium, vanadium and zirconium. It was found that these elements used singly, or collectively,

exerted a pronounced beneficial effect on the coating by improving surface texture and producing a very smooth and uniform lustrous metallic appearance and light color. It is to be noted, however, that single additions of these elements are to be preferred to the use of these elements collectively. Also the advantages derived from these elements as alloying additions are exhibited particularly with the alloys of the invention which contain molybdenum and/or chromium with or without zinc. It was also noted that the tendency towards a spangling effect on the surface of a coating containing zinc in amounts as high as 2% was substantially offset by the presence of boron, titanium, vanadium and/or zirconium.

The element boron as one of the above group produces the advantages above noted, and, in addition, may be advantageously used in very small amounts to reduce bumpiness sometimes occurring in wire coatings and to effect a general smoothing action on the coating.

Although the addition of these elements did not produce a marked increase in the ductility of the composite ferrous metal aluminum alloy coated article as compared with additions of silicon, particularly in the higher amounts of the range of the latter element, their contribution toward increased ductility is considered very significant in many of the coating alloys, particularly those of low total alloy content and of low silicon content, for example, where silicon is present in amount from about 1% to about 2.5%. Also, the addition of boron, titanium, vanadium, and/or zirconium contributed along with zinc in increasing the smoothness, continuity and appearance of the alloy coating.

Additions of boron and titanium may be used in amounts of from about 0.02% to about 0.20% by weight of the alloy. The most desirable results were obtained using these constituents in the preferred amounts of from about 0.02% to 0.05% boron, and from about 0.02% to 0.10% titanium. The other two elements, namely vanadium and zirconium are recommended in amount from about 0.1% to about 0.25%. Where used collectively, and as a rule not more than two such elements are generally used, the total should not exceed about 0.5%. In the case of boron and titanium used together, the total preferably does not exceed about 0.06%.

It is to be emphasized in regard to the coating alloys of the present invention that the selection of a given alloy for aluminizing by hot dip methods should be governed by the application for which the composite is intended. Accordingly, several of the specific alloys included in the present invention are classified in the following tables on the basis of those characteristics which are the most important for the purpose for which the alloy is intended.

TABLE I

Alloys best suited for general purpose applications (combining properties of good ductility, good appearance, and good operational characteristics of the molten bath)

Nominal composition in percentage of alloying constituents based on weight of total alloy:

(1) 5% silicon–0.25% chromium
(2) 5% silicon–0.36% molybdenum
(3) 4% silicon–0.20% chromium–0.20% molybdenum
(4) 4% silicon–0.35% molybdenum–0.07% titanium
(5) 4% silicon–0.03% boron–1% zinc–0.20% molybdenum

Reference alloys with which comparison of the alloys above set forth were made included 99.9% aluminum, 2S alloy (commercially pure aluminum), and aluminum–5% silicon binary alloy.

The improved results with respect to ductility, obtained by the alloys of the invention are more fully illustrated with reference to the following chart showing comparison ratings on ductility of ferrous strip stock coated with the aluminum alloys set forth above in Table I and with reference alloys such as 99.9% aluminum, 2S (commercially pure aluminum), and 5% silicon binary aluminum alloy.

Nominal composition in percentage of alloying constituents based on weight of alloy (In as-coated condition)	Ductility Point Ratings [1]	
	180° Bend Test	Spiral Wrap Test
5% silicon—0.25% chromium	1	2
5% silicon—0.36% molybdenum	1.5	3
4% silicon—0.20% chromium—0.20% molybdenum	1.5	2
4% silicon—0.35% molybdenum—0.07% titanium	1	2-2.5
4% silicon—0.03% boron—1% zinc—0.20% molybdenum	2	2-3
Reference Alloys:		
99.9% aluminum	4	4
2S (commercially pure aluminum)	4.5	5
5% silicon binary aluminum alloy	1.5	2

[1] In each of the above tests the ferrous stock specimens were mild steel strip 12 inches in length, 0.25 inch wide and 0.032 inch thick. In the 180° bend test the radius of bend was 0.10 inch and in the spiral wrap test the radius of bend was 0.070 inch. The point ratings are relative to the test behavior of 99.9% aluminum in the as-coated condition which is arbitrarily assigned the value of 4 for each bend test. The rating is such that the lower the point rating, the more desirable is the coating alloy and the meanings attached to the various point ratings are as follows:

1=Nil to very slight wrinkling on the inner or compression side of the coated strip with no cracking.
2=Slight wrinkling on the inner or compression side of the coated strip with no cracking.
3=Moderate wrinkling on the inner or compression side of the coated strip with no cracking.
4=Marked wrinkling on the inner or compression side of the coated strip with slight cracking and spalling on the outer or tension side of the coated strip.

It is readily seen from the above rating chart that the aluminum alloys of the invention in the as-coated condition are superior in ductility to the more pure aluminum coating alloys such as 2S alloy or 99.9% aluminum alloy. It is also to be noted that the aluminum alloys of the invention in the as-coated condition were found to have a ductility rating substantially equivalent to that of the ductile 5% silicon binary aluminum alloy in the as-coated condition.

TABLE II

Alloys having outstanding appearance in the as-coated condition (ductility of composites not considered)

(1) 1.5% silicon-0.32% molybdenum-0.06% titanium
(2) 2% silicon-1% zinc-0.20% molybdenum-0.07% titanium
(3) 4% silicon-1% zinc-0.20% molybdenum-0.07% titanium
(4) 2.5% silicon-0.28% molybdenum-0.05% titanium

The reference alloys with which comparison of the above mentioned alloys was made were 99.9% aluminum, 2S alloy (commercially pure aluminum), and aluminum-5% silicon binary alloy.

The surfaces of the specimen coated with 99.9% aluminum were mottled in appearance due to the visible large grain structure of the coating and the coverage of the coating at the edges of the strip tended to be incomplete, or where continuous it was rough.

The coating of commercially pure aluminum (2S alloy) was also characterized by a visible large grain, which, however was somewhat obscured by a more or less opaque oxide film which presented a relatively dull appearance compared to a metallic luster. The coating on the edges of the strip was rough and continuity was slightly lacking.

The 5% silicon-aluminum alloy coating had a dull greyish color seriously lacking in luster, and was characterized by a markedly rough surface texture over substantially the whole strip, although the coating was continuous on the strip edges.

The alloy examples of the invention as set forth above in Table II, however, when used as coating materials for ferrous base metals produce composites of improved appearance and continuity as evidenced by the excellent

coverage, smooth grainless texture and luster of the coatings compared to conventional high purity and commercially pure aluminum coatings, and vastly improved appearance as contrasted with the aluminum silicon alloys. From appearance standpoint, the preferred silicon range is about 2 to 3%.

The aluminum alloys of the invention embrace those coating materials which may be designated as the ternary and more complex alloys set forth above wherein the balance of the alloy is substantially all aluminum and impurities in normal amounts. The term "impurities in normal amounts" as used herein and in the appended claims includes the iron which may be progressively picked up by the molten aluminum alloy bath from the ferrous base during continued operation, as discussed herein below. Other elements in the form of residuals or impurities such as copper may be present in normal impurity amount without unduly adversely affecting the beneficial results obtained by the combination of silicon and the other alloying constituents of the invention with the aluminum coating metal.

In utilizing the alloys of the present invention in the hot dip process various procedural modifications may be employed. Thus, the process may be conducted on either a batch or continuous basis, depending primarily on the nature of the article to be coated. For example, with wire, strip or sheet, the continuous method is usually employed, whereas with individual work pieces such as castings and the like, the batch process may be preferable. In either case, the coating alloys and molten baths prepared therefrom produce aluminum alloy coated ferrous metal articles superior to similar articles coated with high purity aluminum (99.9%), commercially pure aluminum (2S) and even aluminum containing 5% or more silicon.

The various addition elements of the above indicated chromium group and titanium group may be added to the molten aluminum base in the form of aluminum hardeners to adjust or maintain the alloy composition. The hardeners consist of comparatively high percentages of the addition element in aluminum pig. Adding the elements to the bath in this way facilitates dissolution of the element in the melt.

Cleanliness of the aluminum alloy bath is maintained by periodic fluxing with dry chlorine gas to remove insoluble oxides. This eliminates entrapped impurities which may reduce the corrosion resistance and impair the appearance of the coating.

The ferrous articles to be coated are first thoroughly cleaned by any suitable method, such as acid pickling to remove oxide film or scale. They may then be rinsed and dried, and immersed in the coating bath with or without the use of a conventional flux. For large sections the use of flux may be desired for preheating and further cleaning before immersion in the alloy bath. On the other hand, the articles with or without pickling depending upon the nature of the surface may be pretreated by bright annealing in suitable apparatus in an inert or reducing atmosphere and then directly immersed in the molten coating bath without exposure to the atmosphere.

The bath temperature is maintained sufficiently high so that the alloys employed are completely molten. Of course, the particular bath temperature depends upon the coating alloy composition and the composition and nature of the ferrous article; and in regard to the alloys herein disclosed temperatures of from about 1280 to about 1375° F. are recommended.

Since thickness of the Fe-Al interfacial layer increases with bath temperature, it is recommended that the lowest operating temperature consistent with good coating results be used. It is an advantage of the invention, however, that the rate of increase in thickness of the Fe-Al layer with temperature is lower with the alloys herein disclosed than with pure aluminum.

The time of immersion depends principally upon the composition of the molten bath, the composition and nature of the ferrous article, and the temperature of the molten bath. The immersion time and also the bath temperature may be regulated to produce a composite suitable for the intended application. Extending the time of immersion tends to increase the thickness of the Fe-Al layer and accordingly the shortest immersion times consistent with satisfactory coverage are usually recommended.

EXAMPLE

As an example of one specific procedure in utilizing the coating materials of the invention to produce composites by the hot dip method, the following is set forth as illustrative without constituting a limitation on the scope of the disclosure and claims appended hereto:

A specimen of mild steel strip containing 0.2% manganese and less than 0.1% carbon, 12 inches in length, 0.25 inch wide and 0.032 inch thick was used. The specimen was degreased with carbon tetrachloride and wiped dry with cloth, then pickled in a 40% HCl solution for from 15 to 25 seconds at a temperature of 140–160° F. This was followed by a water rinse and the cleaned specimen was dried with gauze.

The specimen was then dipped in a molten bath of aluminum base alloy containing 4% silicon, 0.20% chromium, and 0.20% molybdenum, the balance aluminum and less than 1% normal impurities. No fluxes were employed, and the specimen was immersed for from 15 to 30 seconds with the bath temperature maintained at about 1300° F. The coated specimen was then withdrawn and tapped lightly while in a vertical position to facilitate removal of the excess coating.

It is to be noted that during the course of operation, either batch or continuous, the molten aluminum alloy bath gradually increases in iron content due to pickup by dissolution of iron from the basis metal. Small amounts of iron in the coating alloy up to about 2.5% may be tolerated without any significant adverse effect on the character of the coating and composite. However, when the iron exceeds this amount, for example, approaches saturation on the order of about 3% at the usual coating temperatures of the bath above referred to, various procedures may be adopted for reducing the iron content. Among such procedures may be mentioned discontinuance of operation of the bath while permitting the heavy iron component to settle out of the molten aluminum alloy, or addition of fresh amounts of pure aluminum alloy to effectively reduce the concentration of iron in the total molten bath.

As a result of the present invention, coating alloys have been developed for aluminum hot dip coating of ferrous metal articles whereby composites of ductilities and adherence equal to that of aluminum silicon binaries are produced, while at the same time the aluminum alloy coatings on the composites exhibit appearances which are at least equal to and in many instances better than that of high purity aluminum coatings.

All percentages in the claims are by weight of the total alloy.

This application is a continuation-in-part of my copending application 264,661 filed January 2, 1952, now abandoned.

What is claimed is:

1. A composite article comprising a base portion of ferrous metal hot dip coated with an aluminum base alloy of improved wettability of the ferrous base consisting essentially of from about 1 to about 6% silicon and at least one element selected from the group consisting of chromium, molybdenum and tungsten in amount from about 0.1 to about 0.4%, the total amount not exceeding about 0.5%, balance substantially all aluminum and impurities in normal amounts, said composite article having a ductility comparable to that of an aluminum-silicon binary alloy coated ferrous base and a surface appearance in the as-coated condition superior to said

ductile aluminum-silicon binary alloy coated composites and non-ductile high purity and commercial purity aluminum coated composites.

2. A composite article according to claim 1 in which the aluminum base alloy also contains zinc in amount from about 0.5 to about 2%.

3. A composite article according to claim 1 in which the aluminum base alloy also contains beryllium in amount from about 0.001 to below 0.02%.

4. A composite article according to claim 1 in which the aluminum base alloy also contains at least one element selected from the group consisting of boron, titanium, vanadium and zirconium in amount from about 0.02 to about 0.20% boron and titanium, and from about 0.1 to about 0.25% vanadium and zirconium, the total of these elements not exceeding about 0.5%.

5. A composite article according to claim 2 in which the aluminum base alloy also contains beryllium in amount from about 0.001 to about 0.015%.

6. A composite article according to claim 2 in which the aluminum base alloy also contains at least one element selected from the group consisting of boron, titanium, vanadium and zirconium in amount from about 0.02 to about 0.20% boron and titanium, and from about 0.1 to about 0.25% vanadium and zirconium, the total of these elements not exceeding about 0.5%.

7. A composite article according to claim 3 in which the aluminum base alloy also contains at least one element selected from the group consisting of boron, titanium, vanadium and zirconium in amount from about 0.02 to about 0.20% boron and titanium, and from about 0.1 to about 0.25% vanadium and zirconium, the total of these elements not exceeding about 0.5%.

8. A composite article according to claim 5 in which the aluminum base alloy also contains at least one element selected from the group consisting of boron, titanium, vanadium and zirconium in amount from about 0.02 to about 0.20% boron and titanium, and from about 0.1 to about 0.25% vanadium and zirconium, the total of these elements not exceeding about 0.5%.

9. A hot dip aluminum alloy coated composite article comprising a base portion of ferrous metal having a coating thereon of an aluminum base alloy of improved wettability to the ferrous base consisting essentially of

silicon in amounts from about 2 to about 3%, a single element selected from the group consisting of chromium, molybdenum and tungsten in amount from about 0.15 to 0.35%, the balance all aluminum and impurities in normal amounts.

10. A composite article according to claim 9 in which the aluminum base alloy coating also contains zinc in amount from about 0.6 to 1%.

11. A composite article according to claim 9 in which the aluminum base alloy coating also contains beryllium in amount from about 0.002 to about 0.015%.

12. A composite article according to claim 9 in which the aluminum base alloy coating also contains a single element selected from the group consisting of boron, titanium, vanadium, and zirconium in amount from about 0.02 to 0.05% boron, 0.02 to 0.10% titanium, and about 0.1 to about 0.25% vanadium and zirconium.

13. A composite article according to claim 10 in which the aluminum base alloy coating also contains beryllium in amount from about 0.002 to about 0.015%.

14. A composite article according to claim 12 in which the aluminum base alloy coating also contains zinc in amount from about 0.6 to about 1%.

15. A composite article according to claim 12 in which the aluminum base alloy coating also contains beryllium in amount from about 0.002 to about 0.015%.

16. A composite article according to claim 14 in which the aluminum base alloy coating also contains beryllium in amount from about 0.002 to about 0.015%.

References Cited in the file of this patent

UNITED STATES PATENTS

1,663,150	Archer	Mar. 20, 1928
1,850,355	Russell	Mar. 22, 1932
2,043,855	Keller	June 9, 1936
2,091,419	Schroeder	Aug. 31, 1937
2,280,174	Stroup	Apr. 21, 1942
2,526,227	Grundstrom	Oct. 17, 1950
2,565,768	Gittings	Aug. 28, 1951
2,664,874	Graham	Jan. 5, 1954

OTHER REFERENCES

Effect of Bath Composition on Steel, Gittings et al., Reprint Pub. October 1950, A.S.M., 19 pages.