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PROCESS FOR FORMING COMPOSITE ALUMINUM ALLOY

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This application is a continuation of now abandoned application Ser. No. 288,870 filed on June 19, 1963.

The present invention relates to a new and improved process for forming a composite aluminum alloy and to the resultant composite. More particularly, the present invention resides in a novel, convenient and expedient process for forming a composite aluminum alloy which combines high strength with good bright anodizing characteristics.

It is highly desirable to provide aluminum alloys which combine good bright anodizing characteristics and high strength. The term "bright anodizing" is used herein in the conventional sense, that is, a finishing process consisting of, for example, optional buffing and polishing of the work piece, chemical brightening by, for example, a nitric acid type solution, anodizing in an electrolyte, such as sulfuric acid and sealing in hot water containing the conventional additives, if desired.

The commercially available aluminum alloys that are capable of providing high quality, high specular finish upon bright anodizing are generally relatively low strength alloys. The base-purity of such alloys is relatively high and the total alloying content relatively small. The following table shows typical commercial alloys amenable to bright anodizing. In the following table, and throughout the present specification, the alloy designations are those assigned by the Aluminum Association.

TABLE 1

Alloy	Composition, percent				
	Si (max.)	Fe (max.)	Cu (max.)	Mn	Mg
5357	0.12	0.17	0.07	0.15–0.45	0.8–1.2
5457	0.08	0.10	0.20	0.15–0.45	0.8–1.2
5557	0.10	0.12	0.15	0.10–0.40	0.4–0.8
5257	0.08	0.10	0.10	0.03–max.	0.20–0.60

Typical yield strength for the foregoing group of alloys in the fully annealed condition ranges from about 5000 p.s.i. for alloy 5257, the last alloyed material, to about 7000 p.s.i. for alloy 5357, the strongest of the group. At the present time, the bright anodized finish obtainable with alloy 5457 is a standard generally accepted by the aluminum finishing industry.

Heretofore, it has been found possible to increase the magnesium content of the aluminum base alloy to about 2.5 percent, thereby effectively increasing the strength and yet maintaining bright anodizing characteristics comparable with those of alloy 5457. A yield strength of about 12,000 p.s.i. in the fully annealed condition is obtained in such an alloy. However, when the magnesium content is increased beyond 2.5 percent in order to further strengthen the material, it is found that the brightness, clarity and specularity of the bright anodizing finish are depreciated significantly, unless the impurity content is significantly lowered.

In order to overcome these limitations and, in fact, optimally to achieve even higher strength properties, it has been suggested to clad a high strength core material with a good bright anodizing coating material; however, when a high strength aluminum base alloy containing from 2 to 10 percent magnesium is heated, there is formed

on the surface a harmful layer of surface oxide that is enriched in magnesium oxide. This layer makes the forge welding of the cladding layer to the core or backing extremely difficult or erratic. One method which has been suggested to overcome this difficulty is to include varying amounts of an additional alloying ingredient, such as beryllium in an amount up to about 0.5 percent, in the core material. While this effectively overcomes the difficulty, it is subject to the disadvantages of requiring additional and often undesirable alloying ingredients.

Other methods for overcoming these limitations include (1) the use of a controlled atmosphere for heating of the cladding and core materials prior to the forge welding operation, and also (2) compounds, such as sodium fluoborate may be added to the furnace atmosphere to reduce the oxide formation. These methods are expensive and may require special equipment.

Accordingly, it is an object of the present invention to provide a novel and convenient process for achieving a composite aluminum alloy combining high strength with good bright anodizing characteristics.

It is a further object of the present invention to provide a process as aforesaid for cladding a high strength aluminum alloy core material with a good bright anodizing aluminum coating.

It is a still further object of the present invention to provide a process as aforesaid which is simple, convenient and readily amenable to commercial practices.

It is an additional object of the present invention to provide a process as aforesaid which enables the formation of new and improved high strength, good bright anodizing aluminum alloy composites without the necessity of utilizing undesirable or expensive or inconvenient alloying materials.

Further objects and advantages of the present invention will appear hereinafter.

In accordance with the present invention it has now been found that the foregoing objects and advantages can be readily and conveniently accomplished and there is obtained a novel clad product, i.e., a composite alloy, and a method for cladding a core material. The composite alloy comprises an aluminum base alloy containing from 2 to 10 percent magnesium with a coating consisting essentially of aluminum, and the method comprises forming an assembly by superimposing said coating on said core, venting the air at the interface and integrating said core and said coating.

The process of the present invention results in a high strength, good bright anodizing aluminum composite which achieves numerous heretofore unobtainable and often surprising advantages. These advantages will be discussed and elaborated upon throughout the present specification and examples. Surprisingly, the characteristics of the composite in the fully annealed condition are: a minimum yield strength of 14,000 p.s.i., a minimum tensile strength of 35,000 p.s.i. and a minimum elongation of 15 percent in two inches. In addition, surprisingly, the bright anodizing characteristics of the resultant composite are at least as good as, and generally superior to, those of the cladding alloy in single form.

The alloy obtained in accordance with the process of the present invention is especially useful in the preparation of formed articles since it has the characteristics necessary for use therein, such as good formability and fine grain size control.

It has been further found, surprisingly and unexpectedly, that the present invention renders it readily possible to produce sound, high strength bonds by hot rolling a high strength aluminum-magnesium core and good bright anodizing aluminum-magnesium surface cladding. This is quite surprising in view of the simple process employed in the present invention and in view of the common belief

heretofore that the magnesium oxide formed during the heating of the two aluminum-magnesium alloy components render it extremely difficult, if not impossible, to obtain a high strength pressure weld by hot rolling methods.

In accordance with the present invention, the core material comprises a high strength aluminum base alloy containing from 2 to 10 percent magnesium. Typical of such alloys are the following:

TABLE 2

Alloy	Content, percent		
	Mg	Mn	Cr
5086	4.0	0.45	0.15
5083	4.5	0.65	0.15
5456	5.1	0.75	0.15
Undesignated	7.0		

The typical yield strength in the fully annealed condition of the above alloys ranges from 17,000 p.s.i. for alloy 5086 to 21,000 p.s.i. for alloy 5083 and to 23,000 p.s.i. for alloy 5456. The corresponding tensile strengths of these alloys are typically 38,000 p.s.i. for alloy 5086, 42,000 p.s.i. for alloy 5083 and 45,000 p.s.i. for alloy 5456.

The core material may, of course, be any conventional high strength aluminum base alloy containing from 2 to 10 percent magnesium and preferably at least 85 percent aluminum. Additional alloying ingredients may, of course, be added to the core material if desired in order to obtain particular characteristics, as, for example, manganese and chromium may be added to obtain additional strength and provide better grain size control. The use of undesirable alloying ingredients is not necessary in accordance with the present invention in order to obtain a good bond between the core material and the coating material. Typical and conventional alloying elements often used and compatible in accordance with the present invention include the following with representative ranges thereof: manganese, from 0.15 to 1.0 percent, and chromium from .05 to .30 percent.

The cladding material which may be employed consists essentially of aluminum, i.e. a good bright anodizing material, such as an aluminum alloy containing up to 2.5 percent magnesium, and preferably from 0.01 to 2.5 percent, or alternatively, high purity or super purity aluminum. Where an aluminum base alloy is employed the aluminum content is preferably at least 95 percent. Conventional additives or other alloying materials may, of course, be included in the cladding material, provided that the good bright anodizing characteristics are not impaired, for example, any of the following or mixtures thereof: copper, up to 0.3 percent; manganese, up to 0.45 percent; iron, up to 0.17 percent; silicon, up to 0.12 percent; i.e., from about 0.001 up to the upper figure given. Typical coating alloys are those listed in Table 1 above.

The optimum cladding thickness is dependent upon the final buffing requirements. Generally speaking, it is not desirable to employ coatings above 20 percent since the thicker the coating the less the effect of the high strength core material is felt, and preferably from 5 to 20 percent.

In the preferred operation, the mating surfaces are cleaned in the conventional manner, such as chemical cleaning and wire brushing. The core material does not need to be hot worked prior to assembly with the cladding material for the hot rolling operation. The cladding is superimposed on the core to form an assembly, and the assembly is peripherally integrated leaving an unintegrated peripheral portion in the posterior section of said assembly, e.g., the core material is fusion welded to the coating material around its entire periphery leaving an unwelded area in one portion thereof. This unwelded area or exit vent serves to permit the escape of entrapped air or magnesium oxide. Once this is done the composite or assembly may be hot rolled by commercial rolling equipment with entrapped air escaping through the exit vent. The cladding material is generally hot rolled to the required gauge that will give the necessary percentage of the thickness of the final composite. Heating of the assembly for rolling may be done in a natural air atmosphere.

Alternatively, but less desirable, the initial fusion welding may be omitted and the core and coating material superimposed to form a composite, followed by an "ironing pass" at slow speed, i.e., less than about 10 feet per minute in the absence of rolling lubricant and with a reduction on the order of about less than 10 percent. This "ironing pass" serves to exhaust entrapped air by pressure, brings the cladding and core materials into intimate contact, i.e., a partial mechanical bond, and effectively precludes the contamination of the interface by rolling lubricant during the subsequent reduction to achieve a sound pressure weld. Subsequent passes may then fully weld the components.

In the preferred operation a minimum hot rolling reduction of about 30 percent is preferred prior to further hot rolling to final gauge.

In accordance with the present invention good bonds were obtained at hot rolling temperatures ranging from 450 to 950° F.

The resultant pressure welded interface of the composite alloy is characterized by no bond blistering developing during the thermal treatments of the composite alloy including high temperature annealing and no separation at the interface during extreme bending or drawing and cupping tests in which the pressure weld was held. In addition, the tensile properties of the composite alloy at 0.040 to 0.050 inch gauge were virtually equal to those of the core alloys in single alloy form despite a surface cladding of 8.5 percent of the much softer bright anodizing alloy. This characteristic is quite surprising and unexpected and means, in effect, for all practical purposes, the mechanical properties of the core alloys may be used to approximate the strength and formability. This is a particular and useful advantage of the present invention. Therefore, the composite alloy is characterized by the apparent strength of the core material and the bright anodizing characteristics of the cladding material.

Still further, the bright anodizing characteristics of the cladding alloy, including brightness, clarity, specularity and freedom from textural and structural streaking were noticeably improved as compared with the same alloy in single form produced by normal production methods. This improvement prevailed throughout the entire temperature range of hot rolling.

Other and significant advantages of the present invention include the attainment of good bright anodizing characteristics in the conventional bright anodizing alloy with a wide latitude of control in the fabricating operations. These cladding alloys were not as sensitive to the effects of thermal treatment as they normally are in the single form. In addition, fine grain size control was readily achieved in the composite.

The present invention and improvements resulting therefrom will be more readily apparent from a consideration of the following illustrative examples.

Example 1.—Core alloy 5086—cladding alloy 5457

The above core and cladding alloys were used in samples 9 inches long, 6 inches wide and 1.125 inches thick for alloy 5086 and 0.125 inch thick for alloy 5457. The mating surfaces of the alloys were cleaned and were brushed. The cladding alloy was superimposed on the core alloy to form an assembly and then sandwich welded along the entire lead end, sides and tail, except for a small vent in the tail end. The composite was then hot rolled by a light pass at 30 feet per minute followed by heavy passes at 100 feet per minute. The temperatures ranged from 850° F. to 500° F. The final gauge of half of the samples was 0.250 inch, and half 0.150 inch. The samples were then cold rolled and annealed. The bright anodizing characteristics of the resultant composite were

visually observed to be superior to those of the cladding alloy in single form in respect to specularity, clarity and uniformity.

The resultant composites had the following characteristics:

Yield strength	p.s.i.	17,000–20,000
Tensile strength	p.s.i.	36,000–38,000
Elongation in two inches	percent	21–27

Additional characteristics of the composite were: the high ductility of the composite, as evidenced by the large volume of elongation in the tensile test, in combination with the high strength levels imparted by the core material, enabled severe forming operations to be accommodated; the grain size of the cladding in the composite was observed to be generally finer than the same material in single alloy form; the integrity and soundness of the bonding between the core alloy and the cladding was proved by the fact that no separation occurred during severe forming, such as by Erichson bulge testing, by cupping, by pulling in tension to rupture, and by bending with the cladding either in tension or compression; and no bond blistering during thermal treatments of the composite, as, for example, high temperature annealing subsequent to cold rolling.

Further, the cladding and core materials were found to be compatible galvanically. The cladding provided cathodic protection for the core material.

Example 2.—Core alloy 5086—cladding alloy 5557

In a manner after Example 1 a composite was prepared from the above core and cladding alloys. The resultant composite had characteristics similar to that of Example 1, with the following specific values found:

Yield strength	p.s.i.	17,000–20,000
Tensile strength	p.s.i.	36,000–38,000
Elongation in two inches	percent	21–27

Example 3.—Core alloy 5083—cladding alloy 5457

In a manner after Example 1 a composite was prepared from the above core and cladding alloys. The resultant composite had characteristics similar to that of Example 1, with the following specific values found:

Yield strength	p.s.i.	21,000
Tensile strength	p.s.i.	42,000
Elongation in two inches	percent	22

Example 4.—Core alloy 5083—cladding alloy 5557

In a manner after Example 1 a composite was prepared from the above core and cladding alloys. The resultant had characteristics similar to that of Example 1, with the following specific values found:

Yield strength	p.s.i.	21,000
Tensile strength	p.s.i.	42,000
Elongation in two inches	percent	22

Example 5.—Comparative

Example 1 was repeated, with the exception that prior to hot rolling the composite was welded along the entire

lead end, sides and tail, with no vent being provided in the tail end. Separation of the cladding and core materials occurred upon the materials exiting from the rolls.

This invention may be embodied in other forms or carried out in other ways without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

What is claimed is:

1. The method of forming a composite which comprises:
   - providing a core material containing from 2 to 10% magnesium, balance essentially aluminum;
   - cleaning said core, forming an assembly by superimposing thereon a dissimilar cleaned cladding containing up to 2.5% magnesium, balance essentially aluminum;
   - peripherally integrating said assembly by fusion welding, leaving an unintegrating peripheral portion in the posterior portion of said assembly;
   - hot rolling said assembly at a temperature of from 450 to 950° F., thereby venting the air at the interface; and
   - integrating said core and cladding to form a composite wherein the cladding is from 5 to 20% of the thickness of the composite.

2. A method according to claim 1 wherein said cladding contains from 0.01 to 2.5% magnesium, up to 0.3% copper, up to 0.45% manganese, up to 0.17% iron, and up to 0.12% silicon.

3. A method according to claim 1 wherein said core material contains from 0.15 to 1.0% manganese, and from 0.05 to 0.30% chromium.

4. A method according to claim 1 wherein said core alloy is alloy 5086 and said cladding is alloy 5457.

5. A method according to claim 1 wherein said core alloy is alloy 5086 and said cladding is alloy 5557.

6. A method according to claim 1 wherein said core alloy is alloy 5083 and said cladding is alloy 5457.

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