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METHOD OF INCREASING THE CORROSION RESISTANCE OF ALUMINUM ALLOYS AND PRODUCTS RESULTING THEREFROM

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The present invention relates to a method of increasing the corrosion resistance of aluminum alloys and more particularly to a method of increasing the corrosion resistance of the surface of corrodible age hardening aluminum alloys of the Duralumin type while retaining the strength thereof.

Heretofore, it has been known to improve the resistance to corrosion of hard aluminum alloys, especially aluminum alloys containing copper, by providing a layer of pure aluminum or of a corrosion-resistant aluminum alloy on a base by plating and subsequently uniting this plating with the base by welding. For the purpose of obtaining sufficient protection generally layers having a thickness of about 5% to about 7% of the thickness of the object to be plated were employed. Since pure aluminum and the corrosion-resistant aluminum alloys were free from or were poor in copper, they possessed less strength or hardness than the very strong alloys constituting the base. The decrease in the hardness of the surface by means of such softer coatings was found to be especially disadvantageous, because this tended to decrease the resistance of the object to wear and because this tended to decrease the over-all strength of the plated object. It has been proposed, for example, in U. S. Patent No. 1,927,945, to obtain the desired hard surface by using such alloys for the plating which in addition to high resistance to corrosion also have the same strength and hardness as the alloys constituting the base. In practice, however, the favorable mechanical properties of the aluminum alloys were usually obtained by the presence of such percentages of copper that considerable reduction of the resistance to corrosion resulted. Various attempts have been made to overcome the difficulties but, as far as is known, none has been wholly satisfactory and successful, especially when conducted on an industrial scale for the production of commercial products.

It is an object of the present invention to increase the corrosion resistance of hardened and strengthened aluminum alloys in such manner as to eliminate the disadvantages referred to hereinabove.

A further object of the present invention is to provide a method of providing a corrosion resistant surface to corrodible articles constituted of age hardening aluminum alloys while retaining the over-all strength of such articles.

The invention also contemplates providing a new article of manufacture comprising a core of corrodible age hardening aluminum alloy having high strength and a skin having high corrosion resistance and integrally united to said core by heat treatment which causes copper to diffuse and progressively decrease from the inside of the core to underneath the skin and to be substantially absent from the surface of the skin.

Other objects and advantages of the invention will become apparent from the following description.

It has been discovered that the corrosion resistance may be considerably increased by providing the base with a layer of pure aluminum or of an aluminum alloy substantially free from copper which is so thin that it will completely disappear through diffusion during the subsequent heat treatment and will become an integral part of the base. Although this layer or coating ceases to exist in the form of an independent layer or coating, nevertheless, it is capable of increasing the chemical stability of the surface without detrimentally influencing the mechanical properties, strength or hardness of the surface.

Generally speaking, the present process is carried into practice, for example, in such manner that a coating of pure aluminum is welded with the alloy of the base by means of rolling in the conventional manner. The thickness of this coating is selected to be only about 1% of the thickness of the object to be protected. During the subsequent heat treatment in a salt bath at about 510° C., the thin coating is caused to practically completely diffuse into the surface of the object. This subsequent heat treatment is carried out in the conventional manner with respect to the temperature and time. Preferably the aluminum alloys of the Mg—Cu—Al type are treated for about 10 to 30 minutes longer than the usual annealing time, the increase in the time corresponding to the diameter or cross section of the material, which require more than this time before the heat reaches the inside of the object and the proper temperature is attained. The temperature of the heat treatment is about 500° C. to 510° C. Tests have demonstrated that there is no measurable change in the mechanical properties of the object thus treated in accordance with the principles of the present invention. In distinct contrast to the present invention, the conventional plating of 5% in thickness of aluminum alloys containing about 4% copper, about 0.5% magnesium and about 0.5% manganese reduced the strength by about 8% with respect to the full cross section.

By proceeding according to the present process, the aluminum practically completely diffuses

into the alloy constituting the base and the chemical resistance of the surface of the object or article is considerably increased compared to that of the unplated object or article. This will clearly appear from the following table. Two aluminum alloys containing about 4.2% copper, about 0.5% magnesium and about 0.6% manganese each after a heat treatment and in the form of sheets of about 1 mm. in thickness have been subjected for 30 days to the corrosion test of Mylius. Alloy I was unplated whereas Alloy II has been provided with 1% coating of pure aluminum and has been treated according to the present invention. After the present heat treatment, the plating of Alloy II practically completely disappeared and became an integral part of the object or article. The comparison of the experimental values clearly demostrates the new results obtained by the invention and the advantages thereof.

	Alloy I		Alloy II	
	Tensile strength	Elongation	Tensile strength	Elongation
	kg/mm²	*Percent*	*kg/mm²*	*Percent*
Initial condition	38.5	18.0	39.0	18.0
After 10 days corrosion	28.8	2.5	39.0	15.0
After 20 days corrosion	27.0	2.7	39.2	17.0
After 30 days corrosion	25.0	2.6	39.0	15.5

It is to be noted that the present invention provides a method of increasing the corrosion resistance of aluminum alloys by plating them with pure aluminum or aluminum alloys free from or poor in copper which comprises uniting a film, plate, clad, layer or coating of aluminum or such aluminum alloys to a base constituted of aluminum alloy of the age hardening type by means of welding without reducing strength and hardness, arranging the plating in the form of a coating of about 1% in thickness of that of the object and so thin that during the subsequent conventional heat treatment it will practically completely disappear by diffusion and will be found to cease existing in the form of an independent layer, and then subjecting the thus plated article to a heat treatment involving heating to a temperature of about 500° C. to about 520° C. for about 10 to 30 minutes longer than the annealing time usually employed for age hardening aluminum alloys.

It is also to be observed that the present invention provides a method of making aluminum alloys resistant to corrosion by plating with pure aluminum or with aluminum alloys free from copper characterized by the fact that the plating layer is provided in a thickness of about 1% of the thickness of the object to be protected and is completely alloyed with the metal of the base by means of diffusion during the subsequent heat treatment so that the plating practically ceases to exist in the form of an independent layer and becomes incorporated as an integral part of the object.

Furthermore, the present process possesses considerable advantages due to the fact that the diffusion does not provide a uniform copper content through the outer skin, but the copper content is diluted in a uniformly decreasing manner from the inside of the article to underneath the outer skin. In the outermost surface or skin, there is hardly any copper at all, but the copper content rapidly increases progressing toward the inside until it reaches the usual values in the interior of the article. The corrosion resistance of the outermost surface layer or skin remains very good, and of course, this fact determines the corrosion resistance of the entire object. At the same time, the rapidly increasing copper content of the outer layer or skin permits completely retaining the strength of the alloy constituting the inner or core.

Moreover, the present improved heat treated alloys are not to be confused with prior aluminum alloys such as Duralumin which has been plated only with pure aluminum. Due to its composition (about 4.5% of copper, about 0.5 to 1% of magnesium, about 0.5 to 1% of manganese, about 0.4 to 0.7% of silicon, and remainder aluminum). Duralumin possesses excellent mechanical strength of about 40 kg/mm², about the strength of steel, but its resistance to corrosion, however, is only very moderate. The layers of plating, on the other hand, have a high resistance to corrosion but have a rather low strength. Pure aluminum soft annealed, for example, has only a strength of about 8 kg/mm². The plating of Duralumin has been carried out in different ways. An example of a plating process of this character is disclosed in U. S. Patent No. 1,865,089. Although it was possible to make Duralumin resistant to corrosion, the plating layer was rather soft. Furthermore, the plating reduced the strength of the material to a certain extent because a plating having 5% of the cross section in thickness on each side of the object plated amounted to about 10% of the full cross section and of the total weight. This reduction in strength calculated on the weight of the object was particularly objectionable in the airplane industry which started to use aluminum alloys instead of pure aluminum. For the aforesaid platings, reference is made to U. S. Patents Nos. 1,805,448; 1,975,105, and 1,997,165. All of these prior alloys have both strength and hardness in the exterior layer but they are incapable of reaching the strength of Duralumin. The principal reason for this shortcoming is that there is no copper in these alloys. Copper is omitted on purpose due to the well-known fact that copper reduces the corrosion-resistance of aluminum alloys. On the other hand, it is copper, especially in connection with magnesium, which makes it possible to considerably increase the strength and hardness of the alloy by aging the alloy after heating and quenching. In consideration of this difficulty, it has been suggested in U. S. Patent No. 1,927,945 to plate with copper-containing alloys. This caused a small decrease in the corrosion-resistance of the covering layer, but, on the other hand, permitted considerably increasing the strength of the complete surface. Since the covering layer has to contain less copper than the alloy constituting the base (practically about 0.5 to 1%), it is possible to obtain higher resistance against corrosion than would be possible with an uncoated alloy. In any event, all of these prior methods have disadvantages and must not be confused with the present method which has been described in detail hereinbefore.

What is claimed is:—

1. The process for producing a high strength integral corrosion resistant aluminum article containing an appreciable amount of copper and having a surface hardness greater than and a corrosion resistance substantially equal to that of pure aluminum which comprises welding a very thin layer of pure aluminum to a core of aluminum-

copper alloy of the age-hardening type to form a composite article having (1) a high strength, corrodible core, (2) a low strength, corrosion resistant coating, and (3) a bond containing copper and uniting said core and said coating and having a thinness approximating that of a conventional bond; heat treating said composite article at an annealing temperature beyond the usual annealing time for a period up to 30 minutes to cause accentuated diffusion of said copper throughout said coating; stopping said heating just prior to the occurrence of the copper in the surface skin of said coating whereby the bond and coating substantially disappear and an integral article is formed having high strength and having copper diffused substantially throughout the same except in the surface skin which is practically devoid of copper and which has a hardness greater than that of pure aluminum and a corrosion resistance practically that of pure aluminum.

2. The process for producing a high strength integral corrosion resistant aluminum article containing an appreciable amount of copper and having a surface hardness greater than and a corrosion resistant substantially equal to that of pure aluminum which comprises welding a very thin layer of pure aluminum to a core of aluminum-copper alloy of the age-hardening type to form a composite article having (1) a high strength, corrodible core, (2) a low strength, corrosion resistant coating, and (3) a bond containing copper and uniting said core and said coating and having a thinness approximating that of a conventional bond; heating said composite article at a temperature within a range of about 500° C. to about 520° C. for a period of time sufficient to cause diffusion of copper throughout a zone having a thinness approximating that of a conventional bonding zone; continuing said heating for an extended period to cause accentuated diffusion of said copper throughout said coating; stopping said heating just prior to the occurrence of the copper in the surface skin of said coating whereby the bond and coating substantially disappear and an integral article is formed having high strength and having copper diffused substantially throughout the same except in the surface skin which is greater than that of pure aluminum and a corrosion resistance practically that of pure aluminum.

3. The process for producing a high strength integral corrosion resistant aluminum article containing an appreciable amount of copper and having a surface hardness greater than and a corrosion resistance substantially equal to that of pure aluminum which comprises uniting a core of aluminum-copper alloy of the age-hardening type to a layer of pure aluminum having a thickness of about 0.01th of that of said core to form a composite article having (1) a high tensile strength, corrodible core, (2) a low strength, corrosion resistant coating, and (3) a bond containing copper and uniting said core and said very thin coating and having a thinness approximating that of a conventional bond, heating said composite article at temperatures of about 500° C. to about 520° C. for a period of time sufficient to cause diffusion of copper throughout a zone having a thinness approximating that of a conventional bonding zone, continuing said heating for an extended period of time to cause accentuated diffusion of said copper throughout said coating, stopping said heating just prior to the occurrence of copper in the surface skin of said coating whereby the bond and coating disappear and an integral article is formed having high strength and having copper diffused substantially throughout the same, except in the surface skin which is practically devoid of copper and which has a hardness greater than that of pure aluminum and a corrosion resistance practically that of pure aluminum.

4. As a new article of manufacture, a high strength corrosion resistant integral aluminum article containing appreciable amounts of copper comprising a core and coating having copper diffused substantially throughout said article, and a surface skin consisting of pure aluminum on said article practically devoid of copper, and having a hardness greater than and a corrosion resistance substantially equal to that of pure aluminum, said article having no sharp line of demarcation from the interior thereof to said surface skin and having an over all tensile strength substantially equal to that of an age-hardening copper-containing aluminum alloy, the copper being diffused in decreasing amounts from the core up to the surface skin.

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