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ALUMINUM COATING PROCESS

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1 Claim. (Cl. 22—204)

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This invention relates to an aluminum coating process and has particular reference to the coating of copper articles with aluminum and its alloys.

We have found that although the temperature of molten aluminum (about 1218° F.) is lower than the melting point of copper (about 1929° F.), copper is readily soluble in molten aluminum applied to the unmolten copper surface, and that this solution results in the formation of an extremely uneven and very heavy copper-aluminum alloy at the interface, which is very brittle and impairs the strength of the copper. Also, the brittleness of the alloy precludes working of the aluminum-coated article, because the alloy is not ductile and readily ruptures, thus causing separation of the aluminum from the copper. The affinity between the copper and the aluminum is so avid that the solution is difficult to control on a time basis and also by rapid cooling such as quenching. Nevertheless, an alloy bond between the copper and the aluminum is necessary when the aluminum is applied directly to the copper, in order to obtain the desired adhesion between the dissimilar copper and aluminum metals, and therefore the aforementioned objections cannot be avoided in present practice, thus greatly proscribing the field of use of composite aluminum and copper articles made in that manner. The same condition obtains between aluminum and a high copper alloy, between a high aluminum alloy and copper, and between a high aluminum alloy and a high copper alloy, but usually to a lesser degree, depending upon the nature of the alloy in each case.

It is frequently desirable to coat articles having a copper base with an aluminum or its alloys, which are subjected to rigorous treatment in use or in fabrication, so that a firm bond between them is not only necessary to preclude subsequent separation, but the bond must not materially impair the physical, thermal, or electrical properties of the copper or the aluminum, or both. Examples of such articles are aluminum alloy-lined copper base journal bearing shells, heat-radiating or exchanging articles, such as high power vacuum tubes, engine and pump cylinders, steam tubing, and the like, aluminum-coated copper wire, bus bars and the like, which must be bent, drawn, or otherwise worked before finishing or in use, and the like, or which are subjected to wide temperature fluctuations tending to separate the metals due to differing expansion coefficients, but the invention is not limited to such articles.

After much experimentation and research, we

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have discovered that the physical properties of the copper-containing metal base and the aluminum-containing metal coating are retained without solution of the copper in the aluminum, but nevertheless with a good bond between them, when the copper surface to be aluminum-coated is first covered with a thin skin or layer of a metal of the class consisting of nickel, iron, cobalt, manganese and chromium, or alloys of two or more of these metals. Unlike intermediate coatings of zinc, tin and the like, the metals of the aforementioned class are not very active in contact with the copper or aluminum but constitute a barrier precluding the very undesirable solution of the copper in the aluminum. These barrier metals also have sufficiently higher melting points than the aluminum or aluminum-based alloys, so that they are not appreciably dissolved therein.

The barrier layer on the copper article need be only between about three and about seven mils in thickness, excellent results having been obtained with an electro-plated layer of about five mils in thickness. The barrier layer may be applied otherwise than by electro-plating, as long as it is continuous, and substantially uniform in thickness. In some cases, barrier metal-coated copper articles may be subjected to a thermal diffusion treatment at about 1400° F. to improve their adhesion, probably due to a certain amount of solution and, in some instances, alloying between the barrier metal and the copper, this treatment being conducted in non-oxidizing or reducing atmosphere to prevent oxidation of barrier metal while so heated.

After the thin barrier layer has been applied in the manner described, the article is dipped in molten aluminum or its alloy, at a temperature somewhat above the melting point of the metal constituting the bath, usually not more than 100° F. above the maximum temperature of about 1300° F. having been found sufficient for an aluminum bath, thus precluding appreciable solution of the barrier metal. The article is held in the bath until the barrier layer is heated to approximately the temperature of the bath, or the surface to be aluminum-coated is preheated to approximately that temperature in a neutral or reducing atmosphere before application of the molten aluminum, whereupon a thin film of aluminum becomes bonded to the barrier layer, which must be clean before dipping or other application of the aluminum thereto. In the case of dipping, the range of immersion time in the molten aluminum-containing metal bath is from about a fraction of a second to five or more min-

utes, depending upon the time required to heat the surface to be coated to the temperature of the bath, which in turn depends on the volume of the article. In the case of preheating the surface to the temperature of the molten aluminum-containing metal, the time of heating depends upon the method of heating, e. g., high frequency electric heating for a few seconds, whereas, heating as by oven, depends upon mass and conductivity of the article. An example of a method of high frequency electric heating is disclosed in application Serial No. 524,395, filed February 29, 1944, by applicant Whitfield.

When a heavy layer of aluminum is desired, molten aluminum or aluminum base alloy is cast or frozen upon the thin aluminum film on the article while this aluminum film is still wet, to thereby obtain a continuous and homogeneous aluminum-containing layer of the desired thickness on the copper article when said layer has congealed. The casting may be effected in any known way, such as by inserting the aluminum-filmed article in a mold of the desired dimensions and then casting aluminum between the wet aluminum film on the article and the mold. A method of freezing the thick aluminum layer directly on the article without an intermediate aluminum dipping step is disclosed in said Whitfield application. In some cases where a relatively thin aluminum coating or film of a few thousandths of an inch is sufficient, the article may be withdrawn from the molten aluminum bath and cooled without employing the casting step. Congealing of the final aluminum layer may be hastened by cooling, as by quenching in oil, by air blast, or other means. This quenching procedure will also improve the physical properties of the article at the alloy interface.

Aluminum and aluminum alloys and copper and copper alloys contemplated herein are predominantly aluminum and predominantly copper, generally considered as aluminum and copper base metals, respectively.

It has been found that the thin barrier layer does not materially impair the ductility of the copper or the aluminum, and billets or bars of copper which have been coated with aluminum over the barrier layer in accordance with this invention may be drawn or rolled without separation of the aluminum from the copper.

Similarly, copper bus bars, anodes, and the like, aluminum-clad according to the invention, whether or not subsequently drawn, bent or otherwise deformed, produce superior electrical conductors not subject to the oxidation of the copper in an acid atmosphere, such as adjacent to storage cells and the like. Also copper or high-copper alloy shell journal bearings desired for light weight engine crankcases, because their

high coefficient of thermal expansion minimize the possibility of loosening of the shell, are rendered feasible when lined with aluminum-alloy-bearing metal according to this invention.

Similarly, copper engine and pump cylinders, copper anodes of high power, vacuum tubes, copper heat-exchanger tubes, and the like, requiring high thermal conductivity under widely fluctuating thermal conditions, are rendered more efficient thermally when aluminum-clad according to this invention, minimizing liability of separation of the aluminum from the barrier layer or the latter from the copper, due to the differing coefficients of thermal expansion.

Although the process of this invention has been described in connection with various copper articles and uses, the invention is not limited thereby but is susceptible of many other uses and applications, as well as changes within the scope of the appended claim.

We claim:

The method of coating a copper-base article with aluminum-base metal, which consists in applying to the surface of the copper-base article to be coated a thin barrier layer of at least one of the metals of the class consisting of nickel, iron, cobalt, manganese and chromium, heating said article under non-oxidizing conditions to about 1400° F. to cause the barrier layer metal to at least partially diffuse into the underlying surface of said article, applying an aluminum-base metal in the molten state to said barrier layer while the latter is heated to at least the melting point of the aluminum base metal to form a film of said aluminum-base metal on said barrier layer, and then casting an additional coating of aluminum-base metal in the molten state upon said aluminum base film while the latter is molten, whereby the aluminum-base metal forms a continuous bonded coating of the desired thickness on said article when the former has congealed.

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