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METHOD OF COATING FERROUS METALS WITH MAGNESIUM AND MAGNESIUM-BASE ALLOYS

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1

The invention relates to a method of coating iron and steel with magnesium and magnesium-base alloys. It more particularly concerns an improved method of applying a coating of magnesium or magnesium-base alloy from a molten bath of such metal to the surface of an article of iron or steel.

The principal object of the invention is to provide articles of iron and steel with an adherent coating of magnesium or an alloy thereof in which magnesium is the predominant constituent. Other objects and advantages will appear as the description of the invention proceeds.

Briefly, the method contemplated by the invention comprises first fluxing the clean article to be coated and then introducing the fluxed article into a pool of a molten coating metal of magnesium or a magnesium-base alloy. The article becomes wetted by the coating metal which readily displaces the flux from the surface. The liquid metal wetted article is then withdrawn from the pool of coating metal and cooled so as to solidify the coating.

In carrying out the method, the surface of the iron or steel article to be coated, if not already substantially free from foreign matter, is cleaned in any suitable manner as by pickling, wire brushing, or sand blasting. Pickling is a preferred way and may be accomplished by immersion in a 15 per cent aqueous solution of hydrochloric acid, although other ways known in the art may be used.

In order to render the cleaned surface of the iron or steel wettable by molten magnesium and its alloys, we have compounded certain saline fluxes that can be used as fluxing agents. As compounded, they have the property of both protecting the molten pool of coating metal from oxidation and rendering the iron or steel wettable by the coating metal. Among the suitable fluxes are those which comprise mixtures of alkali chlorides, preferably sodium and potassium chloride, to which is added between about 1 and 20 per cent of magnesium fluoride (MgF_2), although preferred proportions are between about 3 and 6 per cent. If more than about 6 per cent of magnesium fluoride is used, it separates from the balance of the flux as 6 per cent is about the limit of its solubility. Barium fluoride may be used similarly. Various proportions of sodium and potassium chloride may be used, such as those in the range of 20 parts of sodium chloride and 80 parts of potassium chloride to 80 parts of sodium chloride and 20 parts of potassium chloride, although approximately equal amounts

2

of each such chloride are to be preferred. The presence of other alkali metal chlorides in the flux may be tolerated, as for example lithium chloride, in minor amount but its use is usually uneconomic.

The coating metal may be melted in any suitable melting vessel, such as an iron or steel crucible, under the protection of a quantity of the flux of the aforesaid composition. The flux is lighter than the molten metal and largely floats upon its upper surface. Usually enough flux is used to make a layer about an inch deep over the pool of molten coating metal in the crucible, although other amounts of flux may be used.

The coating metal pool and flux bath is maintained at a temperature in the range of about 725° to 925° C. depending upon the melting point of the coating metal. Temperatures slightly above the melting point of the coating metal are preferred. In most instances, a temperature in the range of 750° to 850° C. is satisfactory.

The iron or steel article to be coated is introduced into the flux layer so as to flux the coated article before contact with the liquid coating metal. Contact with the coating metal results in displacement of the flux from the surface of the article and the coating thereof with liquid coating metal. The article may be left in the metal pool a few minutes before being removed. After being so coated, the article is withdrawn from the coating metal pool through the flux into the atmosphere and subsequently cooled below the temperature at which magnesium and its alloys rapidly oxidize. Above the flux layer, we provide an ambient amosphere of argon, helium, nitrogen, or other non-reactive gas, if desired, to protect the article from direct contact with the air until cool enough to solidify the coating. Thereafter, the article may be quickly cooled and washed freed from adhering flux as by quenching in water.

Continued use of a given bath of flux causes contamination with magnesium chloride which gradually is formed due to the action of the magnesium in the coating metal pool on the flux. As the flux becomes excessively contaminated with magnesium chloride its effectiveness to bring about wetting of iron or steel by molten magnesium and its alloys is destroyed. We have found that the maximum amount of magnesium chloride that can be tolerated in the flux composition in about 5 per cent by weight. Best results are had when the flux contains about 1 to 2 per cent of magnesium chloride as this salt

tends to reduce the oxidation of the coated article as it is withdrawn from the flux layer.

Example

The following example is illustrative of the invention:

Test pieces of mild steel 1'' x 2'' x ⅛'' which were cleaned of foreign material by pickling in a 25 per cent HCl at 150° F. for 15 minutes followed by a further pickling for 15 minutes in a non-aqueous solution comprising ethyl alcohol saturated with HCl gas, the solution thus saturated containing 0.4 gram of HCl per gram of ethyl alcohol, were coated in accordance with the invention. The clean test pieces were introduced into a molten salt flux bath overlaying a pool of molten magnesium. The flux was composed of 53 per cent of KCl, 42 per cent of NaCl, and 5 per cent of MgF_2, the temperature of the flux and metal was between about 750° and 800° C. The test pieces thus fluxed were passed from the flux directly into the molten metal. The test pieces were thus first wetted by the molten flux and then by the molten magnesium which displaced the flux from the surface of the test pieces thereby coating them with magnesium. The magnesium coated test pieces were left in the pool of molten magnesium for about 3 minutes. An atmosphere of argon was provided over the flux bath and the coated test pieces withdrawn from the bath into the argon atmosphere where they were allowed to cool below about 500° C. The so-called test pieces were then quickly transferred to a water bath which quenched the test pieces to room temperature and washed off adhering flux. Examination showed that each piece was uniformly coated with a continuous adherent layer of magnesium in crystalline form having a thickness of about 0.001 inch.

Similar operations with magnesium-base alloys such as those containing aluminum, zinc or both with or without manganese, as in the usual commercial magnesium-base alloys, produced similar coatings on iron and steel articles, the crystals of the coating metal being finer in the case of magnesium-base alloys than those obtained with unalloyed magnesium.

The effectiveness of the coatings to protect steel from atmospheric corrosion has been ascertained by providing steel test panels with a coating as described 0.001 inch thick of a magnesium-base alloy having a nominal composition of 6.0 per cent of aluminum, 0.2 per cent of manganese, 3.0 per cent of zinc, the balance being magnesium, and subjecting the so-coated panels to atmospheric exposure. For comparison, similar test panels were coated with zinc 0.001 inch thick and subjected to the same atmospheric exposure conditions. After about two months of such continuous atmospheric exposure the zinc coated steel panels were largely denuded of the zinc coating and the denuded area covered with rust while the coating of the magnesium-base alloy coated steel panels was still intact and the panels substantially free from rust.

Among the advantages of the invention are that thin uniform adherent coating of magnesium and its alloys may be provided upon iron or steel articles. The coatings serve to protect iron or steel from atmospheric corrosion. The coating makes possible bonding magnesium or alloy thereof to an iron or steel article as by casting magnesium or a magnesium alloy in direct contact therewith when provided with the coating as described. The coating in such applications acts to promote good adhesion of the article to the cast metal. Attempts to pull apart an iron or steel article and a magnesium or magnesium alloy article cast against the iron or steel article coated according to the method described requires the application of a tensile stress almost equal to the ultimate strength of the metals involved.

We claim:

1. The method of producing an adherent coating of a coating metal of the group consisting of magnesium and magnesium alloys upon articles of ferrous metal which comprises introducing the article to be coated into a molten body of the coating metal through a flux layer floating upon said molten body of coating metal, the flux consisting of a mixture of 20 to 80 parts of sodium chloride and 80 to 20 parts of potassium chloride to which is added per 100 parts of said mixture, from about 1 to 20 parts of magnesium fluoride, said flux containing not more than about 5 per cent of magnesium chloride, whereby the surface of the article is first fluxed and then brought into contact with the coating metal, holding the article in the molten coating metal so as to permit the same to displace the flux from and wet the surface of the article, and then withdrawing the wetted article from the molten body of coating metal through the flux layer, and cooling the withdrawn article in an inert atmosphere.

2. The method according to claim 1 in which the inert atmosphere is argon.

3. The method according to claim 1 in which the inert atmosphere is helium.

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