

## UNITED STATES PATENT OFFICE

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METHOD FOR COATING METAL WITH  
ALUMINUM OR THE LIKE

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This invention relates to a method of coating metal with aluminum, aluminum alloys, and other similar metals, as magnesium for example, and more particularly it is concerned with the coating of ferrous metals with aluminum or the like, the term aluminum being used herein as generic to any suitable alloy thereof.

A practical method of coating ferrous metal with aluminum or the like has been proposed, said method including the steps of subjecting the ferrous base metal, after it has been suitably cleaned, to a reducing gas while the metal is raised to a temperature on the order of 1350° F., and then passing the base metal with little or no diminution of temperature into an aluminum bath, through a restricted opening disposed below the free surface of the bath, to establish a substantially complete alloy bond between the base and coating metals.

In accordance with the preferred practice of this method, the sheet, strip, wire, or other ferrous base to be coated, after being suitably cleaned, is passed at a proper speed and for a proper length of time through a chamber containing an atmosphere of reducing gas of a character that will not deposit foreign particles on the traveling base, hydrogen being preferred, while said base metal is heated to a temperature in excess of 1300° F., a temperature on the order of 1350° F. being preferred. This treatment results in the reduction of any oxide or oxygen entrained by the base metal, and also probably in an absorption by or prepacking to some extent of the base metal by the reducing gas, so that the treated metal is in a condition to establish the desired alloy bond without interference from oxides at the contacting surfaces of the base and coating metals. Following the foregoing treatment the base metal is passed, preferably without contact with the air, into the aluminum bath, preferably through a restricted orifice disposed below the surface of the aluminum, so that the base metal is not brought into contact with the oxide film usually existing at the surface of the bath, but rather the molten aluminum at its contact with the base metal has little free surface but is kept in vigorous circulation by the moving base, so that little opportunity exists for an oxide to form and interfere with the establishment of the desired alloy bond. Ferrous sheets, strips, bands, wires, etc., so treated have been found to have a closely adherent substantially continuous coating that cannot be stripped from the base metal, and by moving the base metal at a considerable speed through the molten

aluminum, the alloy bond has been kept fairly thin so that the composite metal is possessed of appreciable ductility, as well as other highly desirable characteristics.

We have discovered that the ductility in particular, and also some of the other desirable characteristics, of the coated metal may be materially improved, in the practice of the foregoing method, by proceeding as hereinafter described to control and limit the interpenetration of the contacting metals and, while causing the establishment of an alloy bond between the base and coating metals to render the same inseparable, keeping the thickness of said bond so thin as to be membranous in character. For example, aluminum coated iron or steel formed in conformity with the process as heretofore outlined is possessed of appreciable ductility, but experience has demonstrated that owing to the inherent brittleness of the ferrous aluminum alloy formed at the junction between the ferrous base and the aluminum coating, the limit is soon reached beyond which it is not safe to go in drawing or otherwise working the coated metal because, as shown in microscopic studies, the alloy bond, although it may be correctly denominated as relatively thin, exists as a layer of substantial thickness.

We have discovered that ferrous metal may be coated with aluminum or the like, and at the same time be made highly ductile, and also have increased brightness, improved electrical and corrosion resisting characteristics, etc., by establishing the alloy bond between the coating and base metals under conditions that narrowly limit and control the interpenetration of the two metals, so that although a substantially continuous and uniform alloy bond is produced, it has a thickness much less than that heretofore established between the contiguous surfaces of the two metals and exists as little more than a thin film of the bond interlocking the crystals of the base and coating layers.

It is therefore an object of this invention to provide an improved method of coating metal with aluminum or the like to produce a substantially uniform and continuous but membranous alloy bond between the contiguous surfaces of the two metals.

Another object of this invention is to provide an improved method of coating ferrous metals with aluminum or the like whereby the coated metal is rendered highly ductile so that it may be reduced in cross section, drawn, and otherwise

worked extensively and to amounts not heretofore found practical.

Another object of this invention is to provide an improved method of coating a ferrous metal with aluminum or the like whereby the thickness of the coating may be so controlled and predetermined as to materially improve the electrical characteristics of the resulting product.

Another object of this invention is to provide an improved method of providing a ferrous metal with a coating of aluminum or the like which has improved characteristics with respect to its resistance to corrosion.

Another object of this invention is to provide an improved method of producing aluminum coated ferrous metal which may be rolled, drawn, bent, shaped, and otherwise worked into a wide variety of fabricated articles without substantial injury to the coating or its adherence to the base metal.

Other objects of the invention will appear as the description of the invention proceeds.

The present invention may be practiced in connection with any suitable base metal, preferably iron or steel, in any suitable form, but inasmuch as the present invention is chiefly concerned with the production of continuous lengths of coated metal for use in the production of fabricated articles, the invention will be explained as embodied in the treatment of a strip of ferrous metal, it being expressly understood, however, that the term "strip" is used generically herein to embrace lengths of any suitable width and thickness including wire of any suitable cross section as well as sheet stock of any suitable width and thickness.

In conformity with the present invention a strip of suitable base metal, preferably iron or steel, is suitably cleaned to remove grease, scale and other foreign material, with or without the application of heat, coating with boric acid, etc., and the strip is then passed through a suitable chamber, having a suitable length so that for the rate of speed hereinafter referred to said strip will be subjected to the atmosphere of said chamber for a suitable length of time, and containing an atmosphere of hydrogen or other suitable reducing gas that is relatively stable so that it does not deposit foreign particles on the traveling strip, while said strip is raised to a temperature on the order of 1300 to 1350° F., to the end that the moving and heated strip shall be acted upon and, in accordance with the explanation above given, probably, becomes prepacked with the reducing gas.

In accordance with our discovery said moving strip should then be precooled, at least to a temperature on the order of or below that of the melting temperature of the coating metal, the optimum temperature being a temperature somewhat below 1000° F., after which it is introduced into the coating bath of molten metal, preferably through a restricted orifice disposed at a point below the free surface of the bath. The temperature of the coating bath is preferably maintained at or closely adjacent the melting point of coating metal, i. e., around 1220° F. for pure aluminum and the corresponding temperatures for suitable alloys thereof. From the coating bath the moving strip is immediately passed to a quenching apparatus of any suitable character. Air blasts have been used satisfactorily, but we prefer to employ jets of atomized liquid, such as water. The coated strip may then be withdrawn from the apparatus, or it may be passed

to any suitable cold working apparatus as hereinafter explained, depending upon the character of the strip and the use to which it is to be put.

We have discovered that by at least precooling the base strip to a temperature on the order of the melting temperature of the bath, and preferably somewhat below, and then at a suitable speed passing the chilled strip through a bath wherein the temperature is on the order of the melting point of the aluminum or other metal used, and thereafter immediately quenching the coated strip, the ductility of the coated metal is greatly increased. The coating is also found to be much brighter and have other improved characteristics as herein explained. Without necessarily confining ourselves to the following explanation thereof, microscopic and other studies of the coated metal seem to establish that the foregoing treatment results in the formation of a substantially continuous and substantially uniform alloy bond between the contacting faces of the base and coating metals which is membranous in its thinness, so that during subsequent drawing and other cold working operations, the continuity of the bond is more nearly preserved. The absence of deep interpenetration of the iron into the aluminum also appears in the lighter color of the aluminum coating.

The thickness desired for the alloy bond will of course vary with the character of the strip being treated and the use to which it is to be put, and we have found that by varying the degree of precooling of the strip, the temperature of the bath, the rate of traverse of the strip through the bath, and the promptness and rapidity with which the quenching is effected, the thickness of the bond may be varied so as to give the desired characteristics to the particular strip being treated. Inasmuch as the temperature on the order of 1300 to 1350° F. to which the strip is subjected in the atmosphere of reducing gas appears to be rather critical, the subsequent treatment involves the variable factors of extent of prechilling, temperature of the bath, rate of traverse of the strip through the bath, and promptness and rate of quenching. Any one or more of these may be varied to predetermine the characteristics of the resulting bond. The strip must not be precooled to such an extent that it will chill the bath unduly, and therefore a certain dependency of relationship exists between the temperature of the bath and the extent of precooling. The preferred procedure is to maintain the bath at or near the melting temperature of the aluminum or other bath metal being used while retaining the bath metal properly liquid, i. e., at a temperature on the order of 1220° F. for pure aluminum for example, and then quench the strip immediately that it leaves the bath by means, such as liquid jet sprays, that will effect a rapid quenching. Under such conditions, a chilling of the strip to a temperature on the order of 1000° F. and passing the strip at a speed of from 8 to 15 feet per minute through the bath have been found to produce aluminum coated iron and steel strips, whose coating is intimately attached to the base metal by a relatively thin alloy bond that is substantially continuous and uniform, while the coated metal is possessed of high ductility so that it may be subjected to sharp bending, relatively large reductions in cross section, drawing, rolling and other mechanical cold working treatments, etc., without disrupting the intimate adherence of the coating metal to the base metal or breaking through the coating metal,

whereby the coated metal may be fabricated into a wide variety of articles for which aluminum coated iron has heretofore been considered unavailable.

5 The foregoing treatment also enables the control of the thickness of the aluminum coating on the strip. This is of importance under many conditions; for example, the electrical characteristics of a ferrous wire may be materially im-  
10 proved if the core may be provided with a coating of aluminum on the order of from 8 to 10 thousandths of an inch in thickness. Experience has demonstrated that such a relatively thick coating without deep penetration of the alumi-  
15 num into the core may be obtained by the practice of the invention as heretofore described.

We have also found that improved corrosion resistance characteristics can be obtained by cold rolling the strip after it is coated. This not  
20 only improves the smoothness of the surface, and gives it a brighter color, but the cold rolling apparently compacts the aluminum, making it more resistant to penetration by outside agents. Ow-  
25 ing to the character of the bond produced in conformity with the present invention, the coated strip may be cold worked without danger that the alloy bond will be brought to or through the surface of the coated metal to cause electrolytic  
30 action. Hence, cold rolling of the metal as it comes from the quenching apparatus may be used to materially improve the coated metal in its capacity to resist corrosion and also improve the same in other respects.

While the foregoing illustration of the practice  
35 of the present invention has been described with considerable detail, it is to be expressly understood that the invention may be variously embodied, as will now be apparent to those skilled in the art. While a ferrous base has been selected  
40 for illustration and as the preferred metal, the invention is not restricted thereto, as other suitable base metals may be employed. Also, while aluminum has been particularly emphasized as the coating metal, the invention is not restricted  
45 thereto as the invention may be employed in conjunction with other coating metals, as magnesium for example, which presents similar difficulties in producing a suitably continuous and uninterrupted alloy bond of controlled thickness,  
50 while any suitable alloy of aluminum may be employed in place of pure aluminum and is to be understood as included in the generic term aluminum. While the invention has been particu-  
55 larly described with respect to the use of continuous strips, it is apparent that the same sequence of operations may be carried out in connection with sheets, tubes, rods, and fabricated shapes, etc., and therefore while the preferred embodi-  
60 ment involves the coating of continuous lengths, the invention in its broader aspects is not necessarily restricted thereto. Also, as heretofore explained, changes may be made in the rates of speed, temperatures, etc., to vary the thickness  
65 ing from the present invention provided the underlying principles thereof are employed. Except that the suitable treatment of the base metal with a suitable gas and at a suitable temperature is apparently necessary for preparing the base  
70 metal so as to enable a substantially continuous and uniform alloy bond to be formed between the coating and base metals, preliminary to the treatment with which the present invention is more immediately concerned, it is also to be expressly  
75 understood that the manner and form in which

the base metal is subjected to heat in the presence of a reducing gas may be varied without departing from the present invention. Reference is therefore to be had to the appended claims for a definition of said invention.

What is claimed is:

1. The method of making a ductile and malleable laminated metal having a ferrous base and a coating of aluminum or the like which includes the steps of subjecting the uncoated ferrous base  
10 metal to a temperature on the order of 1300°-1350° F. in the presence of a reducing gas, then forming on said base metal a coating of alumi-  
15 num or the like which is connected to said base metal by a substantially uniform bond composed of an alloy of said base and coating metals but  
20 which alloy bond is kept relatively thin by first reducing the temperature of the base metal, before subjecting the same to the bath of molten coating metal, to a temperature in the range  
25 between the melting temperature of the coating metal and a temperature on the order of 1000° F., then passing the base metal at its reduced tem-  
30 perature into direct contact with the molten coating metal maintained at a temperature above but relatively close to the melting tem-  
35 perature of said coating metal, and then quickly discontinuing the interpenetration of the base and coating metals and the growth of the alloy layer by applying a quenching medium to the  
40 coated metal to rapidly chill the same.

2. The method of making a ductile and malleable laminated metal having a ferrous base and a coating of aluminum or the like which in-  
35 cludes the steps of subjecting the uncoated ferrous base metal to a temperature on the order of 1300-1350° F. in the presence of a reducing gas, then forming on said base metal a coating  
40 of aluminum or the like which is connected to said base metal by a substantially uniform bond composed of an alloy of said base and coating metals but which alloy bond is kept relatively  
45 thin by first reducing the temperature of the base metal, before subjecting the same to the bath of molten coating metal, to a temperature on the order of 1000° F., then passing the base  
50 metal at its reduced temperature into direct contact with the molten coating metal maintained at a temperature above but relatively close to the melting temperature of said coating metal,  
55 and then quickly discontinuing the interpenetration of the base and coating metals and the growth of the alloy layer by applying a quenching medium to the coated metal to rapidly chill the same.

3. The method of making a ductile and malleable laminated metal having a ferrous base and a coating of aluminum or the like which in-  
60 cludes the steps of subjecting the uncoated ferrous base metal to a temperature on the order of 1300°-1350° F. in the presence of a reducing gas, then forming on said base metal a coating of  
65 aluminum or the like which is connected to said base metal by a substantially uniform bond composed of an alloy of said base and coating metals but which alloy bond is kept relatively thin by  
70 first reducing the temperature of the base metal, before subjecting the same to the bath of molten coating metal, to a temperature in the range between the melting temperature of the coating  
75 metal and a temperature on the order of 1000° F., then passing the base metal at its reduced temperature into direct contact with the molten coating metal maintained at a temperature above but relatively close to the melting temperature

of said coating metal, controlling the rate of movement of said base metal to predetermine the thickness of the coating, and then quickly discontinuing the interpenetration of the base and coating metals and the growth of the alloy layer by applying a quenching medium to the coated metal to rapidly chill the same.

4. The method of making a ductile and malleable laminated metal having a ferrous base and a coating of aluminum or the like which includes the steps of subjecting the uncoated ferrous base metal to a temperature on the order of 1300°-1350° F. in the presence of a reducing gas, then forming on said base metal a coating of aluminum or the like which is connected to said base metal by a substantially uniform bond composed of an alloy of said base and coating metals but which alloy bond is kept relatively thin by first reducing the temperature of the

base metal, before subjecting the same to the bath of molten coating metal, to a temperature in the range between the melting temperature of the coating metal and a temperature on the order of 1000° F., then passing the base metal at its reduced temperature into direct contact with the molten coating metal maintained at a temperature above but relatively close to the melting temperature of said coating metal, then quickly discontinuing the interpenetration of the base and coating metals and the growth of the alloy layer by applying a quenching medium to the coated metal to rapidly chill the same, and thereafter increasing the corrosion resistance of the coated metal by compacting the coating thereof.

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