United States Patent Office

3,031,330

Patented Apr. 24, 1962

3,031,330

METHOD OF BONDING AN OUTER COATING OF ONE METAL TO A BASE SURFACE OF ALUMINUM OR THE LIKE

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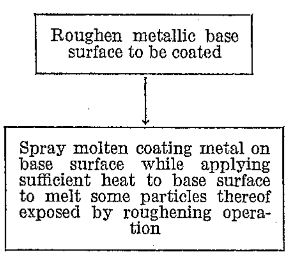
No Drawing. Filed Jan. 8, 1959, Ser. No. 824,447
18 Claims. (Cl. 117—46)

This invention relates to improved methods for applying a coating of one metal to a metallic base surface and this application is a continuation-in-part of our co-pending application Serial No.755,919, filed August 19, 1958.

Our prior application discloses methods for applying an outer coating of one metal to a base of another metal through use of a third metal which acts as a bonding agent between the base metal and the metal of the outer coating. Our present invention results from the discovery that a coating of one metal can be applied directly to a metallic base surface such as aluminum without the use of an intermediate coating of a metal which acts as a bonding agent. Naturally, considerable savings in time and material can be obtained through the use of the methods of the present invention, although the methods disclosed in our prior application are still thought to have commercial application.

The present method may be described graphically as follows:



The method of the present invention consists generally in applying a coating of one metal to a surface of an aluminum base metal by the steps of first roughening the base metal surface and then spraying the metal coating on the roughened surface with the coating metal in a molten condition and with the application of heat to the base surface sufficient to cause a combining of the molten coating metal and the metal of the roughened base surface. This combining of the two metals takes place through a melting and /or distortion of the particles of the base surface exposed by the roughening operation with the result that a positive bond is formed between the coating metal and the base surface.

The bond that is formed may be either a metallurgical one or a mechanical one or a combination of these two types. The nature and characteristics of this bond vary mainly in accordance with the specific metals involved in a particular application of our process as will be more fully explained in descriptions to be given herein of a few examples of the process.

The roughening operation employed prior to application of the coating metal is such as to impart a finish having harply defined depressions and projections which provide exposed particles of the base aluminum surface.

Application of the coating metal to this roughened base surface is preferably done by spraying with so-called metallizing equipment where a wire of the coating metal is fed through a gun which ejects the coating metal in molten condition. Heat from the metallizing gun and from the molten coating metal is ordinarily relied upon to produce the aforementioned combining of the coating metal with the metal of the roughened base surface.

Present conventional metallizing guns operate under a combination of oxygen, air and acetylene and the pressure at which each of these gases is supplied to the gun can be regulated. We have discovered that a markedly superior bond can be obtained between a coating metal and a base surface when the oxygen pressure to the metallizing gun is regulated so as to be in the order of twice that considered normal practice for a particular material being sprayed. When such excessive oxygen pressure is used, the bond obtained between the coating metal and the base surface is remarkably free of oxide and we have been able to obtain bonds where an alloying of the coating material and base surface has visibly taken place when examined by photomicrograph.

In some instances a step of pre-heating the base metal may be employed in order to reduce the amount of heat to be transferred from the metallizing equipment and the molten coating metal.

In other instances where a satisfactory bond is difficult to obtain, we have found that this condition can be corrected by the use of an additional step of pre-heating the base surface to spraying temperature, water quenching the base surface, and then applying a coating according to the present method.

At the present time there is great interest in finding a method by which a coating of ferrous or other high melting-point materials can be successfully and commercially applied to an aluminum base surface. Much of our work has been done with materials of this nature and several examples of the application of coatings of this type to an aluminum base surface will be described herein. As yet we have not had an opportunity to fully investigate applications of the invention to base surfaces other than aluminum.

EXAMPLE 1

Stainless Steel on Aluminum

A test bar of 2024–T4 aluminum having a diameter of 0.75 inch was formed with a roughened surface by placing the bar in a lathe and employing a sharp-pointed tool which was traversed over the surface of the bar at a depth of .015 inch and at a feed of 52 threads per inch. The tool was then traversed in the opposite direction at a feed of 32 threads per inch. This machining resulted in a rough fuzzy finish of a grade of approximately 450 microinches. Excessive fuzz was knocked off with a scraping tool.

The aluminum test bar was then mounted in a second lathe and rotated at approximately 18 revolutions per minute for application of the coating material. The coating material should be applied to an aluminum surface of this type within twelve hours after the surface has been roughened. Otherwise, excessive oxidation of the surface to be coated will take place and make the coating step either more difficult or impossible to successfully perform.

The test specimen was then pre-heated to a surface temperature of approximately 600° F.

A metallizing gun was positioned so that its nozzle was approximately 4½ inches from the surface of the test specimen and with the gun adjusted to operate at an air pressure of 60 p.s.i., acetylene pressure of 18 p.s.i. and oxygen pressure 30 p.s.i., No. 304 stainless steel wire was fed through the gun at a rate of approximately one foot per twenty-five seconds (Note: 15 p.s.i. would ordinarily be considered normal oxygen pressure for this material). A relatively light coating of stainless steel was applied to the aluminum surface, to a depth of approximately .010 inch. Then the gun was reset to a distance of approximately 5½ inches from the surface and the coating of stainless steel was built up to a depth of approximately one-thirty-second of an inch.

During the first stage of the coating process when the initial thin layer of stainless steel was being applied, a mingling of molten particles of aluminum could be observed in the molten stainless steel. The extent to which molten particles of aluminum are mingled, or drawn into the pores of the stainless steel coating, can be controlled as a function of the heat applied. This in turn is preferably controlled by varying the distance between the nozzle of the gun and the aluminum surface.

This test sample was subjected to conventional salt spray testing for a period of 500 hours. At the end of this time only small traces of corrosion were found. Naturally, higher corrosion resistance can be obtained by employing a more corrosion resistant stainless steel, such as type 316, for the coating material. The method for applying it is the same as that given.

EXAMPLE 2

Copper on Aluminum

A test bar of 2024–T4 aluminum was prepared and its surface roughened in the manner described under Example 1 above except that excessive aluminum fuzz left by the machining operation was not scraped off.

The test sample was placed in a lathe for the coating operation and pre-heated to a surface temperature of approximately 800° F. Then, with the nozzle of the metallizing gun about four inches from the work, and with fuel settings as in Example 1, an initial relatively thin (.015 in.) layer of copper was sprayed on the work. The gun was left at this setting and the depth of coating built up by successive passes of the gun along the rotating test specimen.

Other test specimens of copper on aluminum have been prepared by this method but with the excess fuzz removed from the aluminum surface before coating as is described under Example 1 above.

In cases where a heavy copper aluminum eutectic layer is not required or desired, the aluminum surface is roughened to a 350–450 microinch finish and pre-heated to approximately 300° F.

Some of these test specimens have, after machining and polishing of the copper coating, been given a conventional copper-nickel-chrome plating and then subjected to corrodkote tests. Such plated samples have withstood corrodkote test for periods in excess of 20 hours without the outer coating of sprayed copper and plating popping off or becoming discolored in any manner.

EXAMPLE 3

Nickel on Aluminum

A test specimen was prepared in the same manner described under Example 1 above and a coating of nickel was applied to the roughened aluminum surface by the same technique given in Example 1 above.

As in the case of the coating of stainless steel on aluminum, Example 1, an intermingling of molten aluminum in the molten nickel could be visibly observed during the application of the first layer of nickel.

EXAMPLE 4

2S Aluminum on Aluminum

The test specimen was prepared in the same manner described in Example 1 above.

After surface preparation of the specimen, it was mounted in the second lathe for the coating operation and its surface pre-heated to approximately 600° F. The nozzle of the metallizing gun was adjusted to a distance of approximately 5½ inches from the surface and a layer of coating material applied in a series of passes to a depth of approximately one-thirty-second of an inch.

In order to more completely describe the method of the present invention and its application to other materials, the following general description is given of the individual steps:

(1) *Surface Preparation.*—The purpose of the step of roughening the surface is to remove any oxides and to expose particles of the base material by forming a series of ridges and depressions. These exposed particles will, during the coating step, be melted and/or distorted by heat.

Surface roughness is specified herein in terms of the peak-to-valley dimension in microinches. In accordance with the American standard of surface roughness, when a single number is used to designate the degree of surface roughness the number shall be the maximum permissible for the part. When the surface roughness is designated by two numbers, the roughness of the surface must fall between these maximum and minimum values.

Where the base surface is aluminum, magnesium or similar relatively soft material, the surface can be roughened by machining as described in the above example, by abrading or by blasting. For abrading we have found that the use of an aluminum oxide open belt, 16–24 grit will give a very rapid surface roughening to a finish of 350 to 450 microinches.

A similar finish can also be obtained by blasting. For example, with 36 grit Blastite (Carborundum Company) or equivalent.

(2) *Pre-heating.*—Temperatures given in the examples are in excess of those actually required, especially in commercial applications of the process. In the examples, the test specimens were completely exposed and rotating during the coating process and due to the curved surface of these specimens the direct heat of coating only affected a limited surface area.

We have satisfactorily applied coatings similar to those described in the examples with the test specimen preheated only to 300° F. for an aluminum base surface.

In general, pre-heating merely serves to decrease the amount of heat required during application of the coating metal to cause the desired melting and/or distortion of the particles of the roughened base surface.

(3) *Spraying.*—In all our work to date, application of the coating metal has been made with the use of commercially available metallizing equipment which operates under a combination of three gases—oxygen, acetylene and air—to melt and spray a wire of metal. Pressures at which these gases are supplied to the metallizing gun are controllable and are normally specified by the manufacturer of the equipment.

These normal gas or fuel pressures are employed in our process with the exception of the oxygen pressure which is adjusted to an excessive value on the order of twice that considered normal. After the metallizing gun is fired, the oxygen pressure is then gradually increased to this excessive value.

When such a higher oxygen setting is used the coating metal sprays from the gun in a relatively fine fluid stream and only a small area of the base surface is acted upon at any time. Under higher oxygen setting, the heat delivered by the gun to the base surface is higher than normal for a given distance between the nozzle of the gun and the base surface. This heat supplied to the base surface is regulated by varying the distance between the gun nozzle and the surface as illustrated in the settings given in the foregoing examples.

We believe that the almost complete absence of the formation of oxides between the base surface and coating metal results in some way from the excessive oxygen setting used.

We have found by experiment that a bond comparable to any of those shown in the accompanying photomicrographs is not obtained if the metallizing equipment is operated with an oxygen pressure considered normal.

On aluminum, magnesium, and other base surfaces having a relatively low melting point, an actual melting of particles of the base surface exposed by the roughening operation can be obtained and physically observed. These molten particles of the base material can furthermore be drawn through the pores of the coating metal as the coating metal is applied. The extent of this drawing action can be regulated as a function of the heat applied to the base surface. Normally, actual melting and drawing of exposed surface particles into the coating metal is obtained only during the application of the first, or boundary layer of coating metal, but by maintaining sufficient heat, the drawing action can be continued through successive layers, and can be stopped by reducing the heat applied, as by setting the metallizing gun at a greater distance from the surface.

In some instances we have experienced difficulty in obtaining a permanent bond between the coating metal and the base surface. In such instances, the coating metal flakes off after spraying. This difficulty is usually corrected if the surface to be coated is first heated to spraying temperature, then quenched and reheated before spraying the coating metal.

We claim:

1. The method of applying a coating of one metal to a metallic surface comprising the steps of roughening said surface to expose metallic particles thereof in a series of ridges and depressions, and spraying a coating of said one metal in its molten state on said surface while applying heat to said surface sufficient to cause a melting of at least a portion of said exposed surface particles and a combining of the molten metal with said melted surface particles.

2. The method set forth in claim 1 wherein the combining of said coating metal and said surface particles is accompanied by a visible intermingling of said melted surface particles with the coating metal.

3. The method set forth in claim 1 wherein the step of roughening said surface imparts a finish thereto within the range of 300–450 microinches.

4. The method set forth in claim 1 further characterized by the added step of heating said surface to a temperature of at least 300° F. after roughening and prior to the spraying thereof.

5. The method set forth in claim 1 wherein said metallic surface is aluminum.

6. The method set forth in claim 1 wherein said spraying step is carried out with the use of metallizing equipment operating under an excessive supply of oxygen.

7. The method of applying a coating of one metal to a metallic surface comprising the steps of roughening said surface to expose metallic particles thereof in a series of ridges and depression, and spraying a coating of said one metal in its molten state on said surface while applying heat to said surface sufficient to cause a melting of at least a portion of said exposed surface particles and a flowing of said melted surface particles into the pores of the coating metal.

8. The method set forth in claim 7 wherein said spraying step is employed to apply a layer of said one metal to said surface, and further characterized by the added steps of reducing said heat until such flowing action ceases, and spraying such further layers of said one metal as may be necessary to build up the coating thereof to the thickness desired.

9. The method of applying a coating of one metal to a surface of aluminum comprising the steps of roughening said aluminum surface to a finish of 300 to 450 microinches, heating said roughened surface to at least 300° F., and spraying said coating metal in its molten state on said roughened surface under heat sufficient to cause a melting of at least particles of said surface exposed by said roughening operation.

10. The method set forth in claim 9 wherein said metallic surface is aluminum, said coating metal is copper, and further characterized by the additional step of treating said copper coating with a copper-nickel-chrome plating.

11. The method set forth in claim 9 wherein said coating metal is a metal having a melting point at least equal to that of said aluminum surface.

12. The method of applying a coating of one metal to a surface of aluminum comprising the steps of roughening said aluminum surface to a finish of 300 to 450 microinches, heating said roughened surface to at least 300° F., placing a wire of said one metal in a suitable metallizing gun, adjusting said gun to melt and spray said wire with an oxygen pressure on the order of twice that considered normal for the material of which said wire is formed, adjusting the distance between the nozzle of said gun and said surface so that said one metal is sprayed thereon under heat sufficient to cause a melting of at least particles of said surface exposed by said roughening operation and a combining of said one metal with said melted surface particles.

13. The method set forth in claim 12 wherein said one metal has a melting point at least equal to that of aluminum.

14. The method of applying a coating of copper to a surface of aluminum comprising the steps of roughening said aluminum surface to impart a heavy fuzzy finish thereto of a roughness of at least 400 microinches, preheating said copper surface to a temperature of approximately 800° F., spraying a layer of copper on said roughened surface under heat sufficient to cause a melting of at least particles of said surface exposed by said roughening operation and an alloying of said melted particles with said coating of copper.

15. The method set forth in claim 14 further characterized by spraying such additional layers of copper on said initial layer to build up the copper coating to the depth desired, such additional layers being sprayed without materially changing the heat supplied during such spraying operation.

16. The method of applying a coating of stainless steel to a surface of aluminum comprising the steps of roughening said aluminum surface to a finish of 300 to 450 microinches, heating said roughened surface to at least 300° F., spraying said stainless steel on said roughened surface from a metallizing gun operated under an oxygen pressure excessive for stainless steel, said metallizing gun being placed close enough to said surface so that the heat supplied thereto during application of at least the initial layer of stainless steel is sufficient to cause a melting of at least particles of said surface exposed by said roughening operation and a combining of the stainless steel with said melted aluminum particles.

17. The method of applying a coating of nickel to a surface of aluminum comprising the steps of roughening said aluminum surface to a finish of 300 to 450 microinches, heating said roughened surface to at least 300° F., spraying said nickel on said roughened surface from a metallizing gun operated under an oxygen pressure excessive for nickel, said metallizing gun being placed close enough to said surface so that the heat supplied thereto during application of at least the initial layer of nickel is sufficient to cause a melting of at least particles of said surface exposed by said roughening operation and a combining of the nickel with said melted aluminum particles.

18. The method of applying a coating of aluminum to an aluminum surface comprising the steps of roughening said surface to a finish of 300 to 450 microinches, heating said roughened surface to at least 300° F., and spraying said aluminum on said roughened surface under heat sufficient to cause a melting of at least particles of said surface exposed by said roughening operation and a combining of said aluminum coating therewith.

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