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Wolf

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[54] **METHOD OF CONFORMING A FLEXIBLE SELF-SUPPORTING MEANS TO THE SURFACE CONTOUR OF A SUBSTRATE**

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[51] **Int. Cl.^{2}** **B23K 31/02**

[58] **Field of Search** 29/472.9, 472.5, 473.1, 29/475, 478, 481, 482

[56] **References Cited**

UNITED STATES PATENTS

3,677,853	7/1972	Anzelone	29/472.9 X
3,778,586	12/1973	Breton	29/472.9 X

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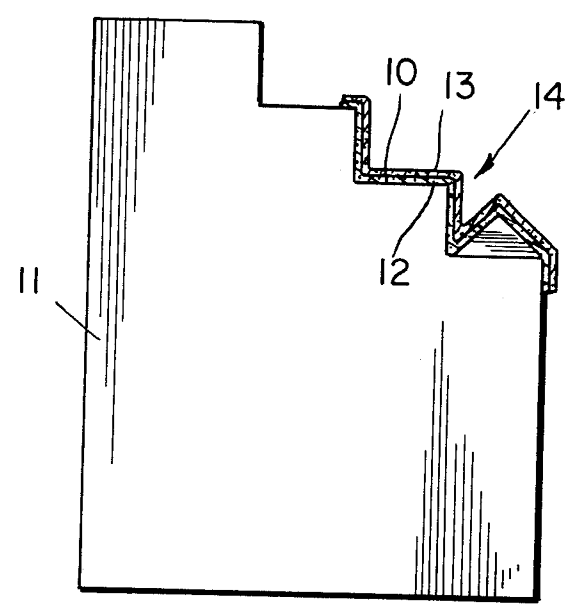
[57] **ABSTRACT**

A method of conforming a flexible self-supporting means to the surface contour of a substrate and articles made by the method. In the method of coating a wear resistant material over an intricate surface contour of a substrate, it is important that the wear resistant material be substantially uniformly distributed over the surface contour thereof, and that the coating be metallurgically joined to the surface contour. The method includes the steps of providing a flexible self-supporting means including wear resistant powder and a powdered material to serve as a matrix material with a heat decomposable organic binder, then overlaying the surface contour of the substrate with the means, causing the means to substantially conform to the intricate surface contour of the substrate, and heating the means to a temperature below the decomposition temperature of the organic binder to relieve stresses in the means created by conforming it to the surface contour of the substrate. Alternatively, the means may be heated prior to conforming it to the surface contour, or simultaniously with conforming it to the surface contour to relieve the aforementioned stresses. Preferably, the step of causing the means to conform to the intricate surface contour of the substrate includes the application of pressure to the means.

9 Claims, 2 Drawing Figures



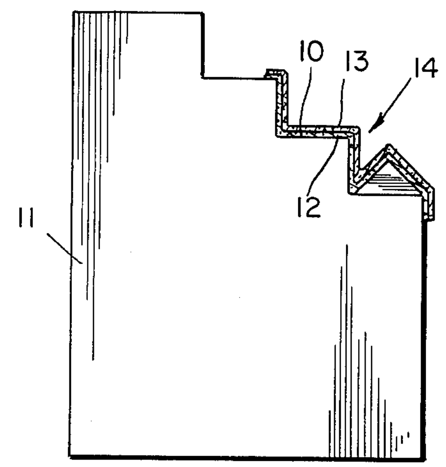


FIG. 1

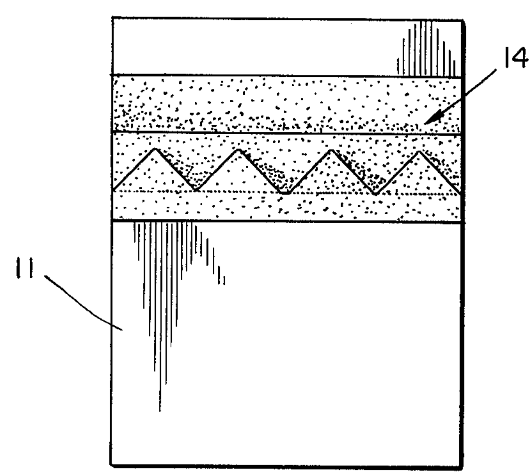


FIG. 2

METHOD OF CONFORMING A FLEXIBLE SELF-SUPPORTING MEANS TO THE SURFACE CONTOUR OF A SUBSTRATE

The present invention relates to a method and to an article produced by that method wherein a flexible self-supporting means is conformed to an intricate surface contour of a substrate to be coated with a wear resistant material. The flexible self-supporting means is caused to conform to the intricate contour of the surface of the substrate, and then heated to a temperature below the decomposition temperature of a heat decomposable organic binder incorporated in the self-supporting means to relieve stresses in the means created by conforming it to the contour of the substrate. Alternatively, the means may be heated prior to conforming it to the surface contour, or simultaneously with conforming it to the surface contour to relieve the aforementioned stresses. Preferably, the step of causing the flexible self-supporting means to conform to the intricate includes the application of pressure to the self-supporting means.

u.S. Pat. No. 3,743,556 granted to E. J. Breton et al. discloses a method of coating a substrate with a wear resistant coating including wear resistant powder dispersed in a metal matrix. In an example given in the patent, a flexible sheet containing a mixture of polytetrafluoroethylene and powdered tungsten carbide is made by ball milling and then pressing the ball milled mixture between pressure rolls to provide a flexible sheet having a thickness of about 30 mils. Another flexible sheet containing a mixture of polytetrafluoroethylene and a powdered nickel based material is made by ball milling and then pressing the ball milled mixture between pressure rolls to provide a flexible sheet having a thickness of about 20 mils. A surface of a substrate to be coated with wear resistant material is overlayed with the sheet containing the powdered tungsten carbide and then that sheet is overlayed with the sheet containing powder nickel based material to form a laminate of sheets. The laminate of sheets is heated to a temperature in a neutral or reducing atmosphere which causes decomposition and volatilization of the polytetrafluoroethylene of both sheets and flowing of the nickel base material to metallurgically wet the powdered tungsten carbide and metallurgically wet the surface of the substrate to provide a substrate with a wear resistant metallurgically bonded coating including tungsten carbide in a nickel based matrix.

Using the techniques disclosed in U.S. Pat. No. 3,743,556, it is difficult to coat a surface of a substrate having an intricate contour such as acute and/or obtuse angle joints. In the event there is little close contact between the surface of the substrate to be coated and the liminate of sheet material, discontinuities in the resultant coating of wear resistant material tend to result which may have a harmful effect on the wear resistant characteristics desired of the coating. One suggestion is to cut sections of sheet into the desired configuration and adhere such sections of sheet to the intricate surface contour in an attempt to conform sheet material to the surface contour. Production difficulties manifest themselves when one attempts to handle a multiplicity of small pieces of cut sheet to be used in coating a surface of a substrate.

It was found that the above problems could be minimized by conforming the self-supporting means to the

contour of the surface to be coated and heating the means, either prior to, simultaneous with, or subsequent to conforming to the surface to be coated, to a temperature below the decomposition temperature of the organic binder to permit the means to relieve stresses caused by conforming the means to the surface contour of the substrate. The means is then subjected to a temperature sufficient to remove the organic binder and cause the powdered material to metallurgically wet the wear resistant powder and function as a matrix material, and to metallurgically wet the surface of the substrate. Preferably, pressure is used to conform the means to the surface contour of the substrate.

Accordingly, it is a feature of the present invention to provide a method of conforming a self-supporting means containing powdered metal containing material with an organic binder to the surface of a substrate prior to treating the self-supporting means to remove the organic binder. Another feature of the present invention is to provide a method of causing a self-supporting means including metal containing material with an organic binder to conform to an intricate surface contour of a substrate by the application of pressure, and heating the means to a temperature below the decomposition temperature of the organic binder to relieve stresses in the means created by conforming the means to the surface contour of the substrate. Other features will be apparent from the following detailed description and claims.

In the drawing:

FIG. 1 is a side view of a substrate having an intricate surface contour overlayed with the flexible self-supporting means; and

FIG. 2 is a front view of the substrate illustrated in FIG. 1 overlayed with the flexible self-supporting means.

Generally speaking, the method of the present invention relates to coating a surface of a substrate with wear resistant powder in a metal matrix that wets the wear resistant powder and metallurgically bonds to the surface of the substrate. The matrix material has a melting point temperature lower than the melting point temperature of the powdered wear resistant material and the substrate. The method includes the steps of providing a flexible self-supporting means including the powdered wear resistant and powdered material to serve as a matrix material with a heat decomposable organic binder. The substrate is overlayed with the flexible self-supporting means, caused to conform to the surface contour of the substrate, and heated to a temperature of the organic binder to help relieve stresses created in the means by conforming it to the surface contour of the substrate. Preferably, pressure is applied to conform the self-supporting means to the contour of the surface of the substrate.

U.S. Pat. No. 3,743,556 teaches a method for making the self-supporting means including decomposable organic binder, wear resistant powder and a powdered metal which is intended to serve as a matrix material. The teachings of the patent relating to a method of making the self-supporting means are incorporated herein by reference.

Powdered wear resistant material and powdered material to serve as a matrix material are mixed with powdered polytetrafluoroethylene. The mixture is mechanically worked to cause the polytetrafluoroethylene to fibriliate to entrap and retain particles of both powdered materials. The resultant self-supporting means has good handleability and drapeability characteristics.

The fibrillable polytetrafluoroethylene used in the method is commercially available in a molecular weight range of about 10 to 20 million. Preparation of polytetrafluoroethylene useful in the present invention is described in U.S. Pat. No. 2,510,112, U.S. Pat. No. 2,587,357 and U.S. Pat. No. 2,685,707. The average particle size of such polytetrafluoroethylene is up to about 500 microns or more. However, polytetrafluoroethylene having a larger average particle size or a smaller average particle size of down to 50 microns or less is useful in making the flexible self-supporting means. Polytetrafluoroethylene used in the fibril containing self-supporting means is sold by E. I. duPont de Nemours & Company of Wilmington, Del. as Teflon 6, 6C, 6H and 3264.

The powdered material contained in the self-supporting sheet material that may serve as a matrix material includes ceramics, metals, metal containing compounds, plastics and the like. The matrix substance appears in the self-supporting sheet material in powdered form. The average particle size of the powdered matrix material can vary widely. The average particle size of the powdered matrix material may be as small as a few microns up to 100 microns or larger. The powdered material, in order to function as a matrix material, must have a melting point temperature less than the melting point temperature of the powdered wear resistant material, and must be capable of metallurgically wetting both the surface of the substrate to be coated and then powdered wear-resistant material. Preferably, the powdered material which is to function as the matrix material of the coating is selected from metal alloys including iron based alloys, nickel based alloys or cobalt based alloys, and most preferably the powdered material is a nickel based alloy. Typical nickel based alloys useful are self-brazing alloys selected from the group of ASTM BNI–1 thru ASTM–BNi–7.

The powdered wear resistant material useful in providing wear resistant coatings includes wear resistant alloys, diamond, tungsten carbide, tantalum carbide, chromium carbide, titanium carbide, silicon carbide, tungsten boride, chromium boride, titanium boride, silicon boride, tungsten silicide, tantalum silicide, chromium silicide, titanium silicide and the like. The average particle size of the wear resistant material may be as small as 10 microns or up to 50 microns or larger. The powdered wear resistant material, in order to function as a wear resistant material, must be highly wear resistant and must be metallurgically wetted by the matrix material of the coating. Preferably, the wear resistant material of the coating is either tungsten carbide or chromium carbide. Generally, tungsten carbide is employed in use situations where good wear resistant characteristics are required. Chromium carbide is employed in use situations requiring high temperature resistance and in conventional grinding situations.

The amount of pressure required to conform the flexible self-supporting means to the intricate surface contour of the substrate to be coated varies in proportion to the amount of heat needed to relieve the stresses created in the self-supporting means. Generally speaking, the greater the pressure used to conform the means to the surface contour the less temperature required to relieve stresses in the means. For example, if about 30 to 70 pounds per square inch are exerted against the means to conform it to the contour of the surface to be coated, the temperature of the means should be raised to about 90°C to about 325°C to relieve stresses created in the means by conforming it to the surface contour of the substrate. The preferred temperature range for relieving stresses in the conformed self-supporting means is about 175°C to about 200°C. Note that the temperature range is below the decomposition temperature of polytetrafluoroethylene.

Preferably, pressure to conform the self-supporting means to the surface contour of the substrate to be coated is applied through a surface complimentary with the surface of the substrate to be coated. Such a complimentary surface may be provided in a number of ways. One presently preferred complimentary surface is provided by a thick, flexible sheet of polyurethane attached to a rigid backing means.

The following example illustrates a specific embodiment of the method of the invention.

EXAMPLE

A self-supporting sheet with tungsten carbide is made in the following manner: 95 volumes of 10 micron tungsten carbide powder is ball milled with 5 volumes of polytetrafluoroethylene (DuPont 6C Teflon) for 30 minutes. The ball milled mixture is pressed between pressure rolls to provide a sheet. The rolled mixture is rotated 90° and rerolled. The rotation of the sheet 90° and re-rolling is repeated until a self-supporting sheet of about 20 mils to 50 mils in thickness is provided.

A self-supporting sheet with a nickel based alloy of ASTM BNi–1 is made in the following manner: 95 volumes of 10 micron ASTM BNi–1 is ball milled with 5 volumes of polytetrafluoroethylene (DuPont 6C Teflon) for 30 minutes. The ball mixture is pressed between pressure rolls to provide a sheet. The rolled mixture is rotated 90° and rerolled. The rotation of the sheet 90° and rerolling is repeated until a self-supporting sheet of about 20 mils to 50 mils in thickness is provided.

A surface **10** of a substrate **11** is heated to a temperature of about 175°C. A self-supporting sheet **12** with tungsten carbide and fibrillated polytetrafluoroethylene is placed contiguous to the surface **10** of the substrate **11** to be coated with a wear resistant coating (not shown). The sheet **12** may be coated with a suitable adhesive such as shellac and the like. Substrate **11** is a plain carbon steel. The self-supporting sheet **13** with ASTM BN–1 and fibrillated polytetrafluoroethylene is overlayed the self-supporting sheet **12.** The laminate of sheets **12** and **13** provides a flexible self-supporting means **14.** A complimentary surface (not shown) is brought in contact with the self-supporting means **14** to apply sufficient pressure to cause the means **14** to conform to the surface contour **10** of the substrate **11.** The complimentary surface is withdrawn leaving behind self-supporting means **14** conformed to the intricate surface contours of substrate **11.** The heated surface **10** of the substrate **11** relieves stresses created in the means **14** by conforming it to the contour of the surface of the substrate.

The substrate **11** with the conformed, self-supporting means **14** is heated in a hydrogen atmosphere or vacuum to a temperature of about 975°C to about 1150°C for a sufficient length of time to decompose and volitilize the polytetrafluoroethylene binder, and to flow the ASTM BNi–1 material so as to metallurgically wet the tungsten carbide and the surface of the substrate. The substrate **11** and the coating (not shown) are cooled in a reducing atmosphere. The resultant coating of tungsten carbide particles in a nickel based alloy matrix is continuous, substantially uniform in thickness and metallurgically bonded to the surface of the plain carbon steel substrate.

A bond between a coating including tungsten carbide and a nickel based alloy may have a shear strength up to 38,000 psi or greater.

The wear resistant material content in the coating may be varied from 0 to about 70 wt.%. The wear resistant material is substantially uniformly distributed in the matrix material. Both the particle size of the wear resistant and the material to be used as a matrix as well as the wt.% of each can be varied to provide coatings with controlled variations in hardness, wear resistance and toughness. The coatings applied to substrate **11** may be applied in thicknesses of from about 0.005 to about 0.06 inch with a porosity less than about 5%.

Coatings of wear resistant material can be applied to substrates of plain carbon steel, alloy steel, stainless steel, tool steel, aerospace alloys, nickel based alloys, high density powder compacts and the like.

This invention has numerous practical applications. These include, but are not limited to, rolls including printing rolls, cutting tools, collets, gripper jaws, threads, scribes, gears and the like.

As disclosed hereinbefore, the stresses created in the flexible self-supporting means by conforming it to the irregular surface contour of the substrate are relieved by heating the self-supporting means either subsequent to, simultaneous with or prior to said conforming step. It is presently preferred to heat the flexible self-supporting means during conforming it to the substrate.

The foregoing detailed description has been given for clarity of understanding only and no unnecessary limitations are to be understood therefrom. The invention is not limited to the specific embodiments shown and described for obvious modifications will occur to those skilled in the art.

I claim:

1. In a method of coating a substrate with a wear resistant material including wear resistant powder and a matrix material, the matrix material being the product of a flowing powdered material having a melting point temperature lower than the melting point temperature of the wear resistant powder, the method including the steps of providing a flexible self-supporting means including the wear resistant powder and the powdered material to serve as a matrix material in a heat decomposable fibrillated organic binder, overlaying the substrate with the flexible self-supporting means, causing the flexible self-supporting means to substantially conform to the contour of the substrate, and heating the flexible self-supporting means to a temperature below the decomposition temperature of the fibrillated organic binder to relieve stresses in the flexible self-supporting means caused by conforming the flexible self-supporting means to the contour of the substrate.

2. In the method of claim **1**, the further step of, after conforming the flexible self-supporting means the surface contour of the substrate, treating the fibrillated organic binder to remove the binder and causing the powdered material to flow into intersticies between and wet the surface contour of the substrate and solidifying the flowable material to provide a wear resistant coating including powdered wear-resistant material and a matrix material.

3. In the method of claim **2**, wherein the wear resistant powder is selected from the group consisting wear resistant alloys, diamond, tungsten carbide, tantalum carbide, chromium carbide, titanium carbide, silicon carbide, tungsten boride, tungsten silicide, tantalum silicide, chromium silicide or titanium silicide, preferably tungsten carbide or chromium carbide, and wherein the matrix material is selected from the group consisting of iron based alloys, nickel based alloys or cobalt based alloys, preferably a nickel based alloy.

4. In a method of claim **2**, including the further step of, prior to treating the fibrillated organic binder to remove it, treating the flexible self-supporting means to cause it to adhere to the surface of the substrate.

5. In the method of claim **4**, wherein the step of treating the flexible self-supporting means includes providing the means with an adhesive between it and the substrate.

6. In the method of claim **1**, wherein the step of causing the flexible self-supporting means to substantially conform to the substrate further includes applying pressure to the flexible self-supporting means.

7. In the method of claim **6**, wherein the fibrillated organic binder is fibrillated polytetrafluoroethylene which entraps the particulate filler and matrix substance, the organic binder being about 0.5 to about 10 volume % of the flexible self-supporting means.

8. An article of manufacture having a wear resistant surface made according to the method of claim **2**.

9. In the method of claim **1** wherein the step of heating the flexible self-supporting means to relieve stresses is done either prior to or simultaneous with the step of causing the flexible self-supporting means to conform to the contour of the substrate.

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