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EXPLOSIVE COATING OF METALLIC SUBSTRATES WITH POWDER

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1 Claim

ABSTRACT OF THE DISCLOSURE

A method for coating a surface of a material such as iron, aluminum, copper, titanium, or an alloy thereof by using the explosion energy of a detonating explosive, said method comprising disposing a layer consisting of one or more kinds of powdery, granular or flaky substance such as a metal, alloy, metal oxide, metal carbide, metal boride, metal silicide, metal silicate or metal nitride, directly on the surface of the material to be coated, providing a layer of a detonating explosive upon the said layer via a buffering layer, and detonating the explosive layer.

This application is a continuation-in-part of applicant's copending application, Ser. No. 358,418, filed on April 8, 1964 and now abandoned.

This invention relates to a method for coating the surface of a metal or other material base, which is hereafter referred to as "base material," with a powdery, granular or flaky substance having thermal resistance, abrasion resistance, corrosion resistance property or like properties, utilizing the explosion energy of an explosive.

A method, wherein powdery substances are surrounded by a high explosive and tightly compressed by detonation thereof, is known and the method is hereafter referred to as the "explosive compression method." According to that method, a container having enough strength to support the powdery substance is necessary when the explosive compression is carried out, the explosion energy being transmitted through the container, the powdery substances being compressed inside the container. However, the conventional explosive compression method only provides a method, wherein the powdery substances are compressed into a columnar or hollow cylindrical shape.

Further, there is a method wherein a metallic cylinder of low melting point charged with an explosive is coaxially inserted into an outer metallic cylinder, leaving a gap between the outer metallic cylinder and the cylinder of low melting point metal, and the said metal of low melting point is scattered and firmly attached to the inner surface of the outer cylinder by detonation of the explosive, but this method is restricted only to use with cylindrical shape and also to metals of low melting point.

Recently, especially with advances in space technology, there have been proposals for coating the surface of a material with a ceramic, a cermet, an alloy or a metal, that is, in an attempt to obtain excellent thermal resistance, abrasion resistance or corrosion resistance properties.

Usually, such substances are produced in the form of powders, granules or flakes, and it is most desirable to use them as they are.

The coating methods of the above-mentioned substances now in use fall into two classes, namely (I) a glazing method wherein a mill additive and a frit are

pulverized and blended to form a glaze which is then applied to the material by a glazing technique, and (II) a flame spray coating method wherein the substance is blazed with a flame spray gun, plasma-jet and the like. In method (I), the coating has poor thermal or mechanical shock resistance as compared with that of method (II). Thus, the latter has gradually come into use. However, even the flame spray coating method has the following disadvantages.

(1) Adherence of the substance to the surface of the base material is not always good and the substance tends to be peeled off when subjected to thermal or mechanical shock.

(2) The coating of the substance on the surface is so porous that its corrosion resistance is inadequate.

(3) Since the sprayed particles of the substance tend to be scattered widely of the material and to bounce off the surface of the material, the loss thereof becomes great. The amount of the substance which actually forms the coating may be only about 60% by weight of the total substance sprayed.

(4) High melting point substances such as silicon carbide, tungsten and the like are too hard to use.

The object of the present invention is to eliminate the disadvantages in the conventional methods, and to provide a method for applying a coating onto the surface of a base material, easily and economically, for imparting to the base material the properties of excellent heat resistance, abrasion resistance, corrosion resistance or the like.

According to the present invention, a method for coating the surface of a base material comprises placing at least one kind of powdery, granular or flaky substance directly on the surface of the base material, the substance being deposited in an amount to form a layer, the depth of which is not more than four times the resultant thickness of the coating on the surface, placing a layer of a detonating explosive having an explosion velocity of more than 1500 m./sec. upon the first said layer via a buffering layer which is virtually unable to retain its original form upon explosion of the explosive, and detonating the detonating explosive layer to form a coating of the substance having a thickness of 0.005 mm. to 10.0 mm. on the base material.

The layer which comprises the powdery, granular or flaky substance is hereinafter referred to as "the coating layer."

The mechanism by which the coating layer becomes attached to the surface of the base material in the method of the present invention is not yet fully understood, but it appears that the powdery or granular substance, when subjected to the explosion pressure, becomes semi-molten by the heat generated by friction or collision between particles of the substance, and firmly adheres to the base material. At the same time, it appears that the particles coalesce by compression due to the explosion pressure. This explosion pressure is transmitted through the buffering layer, which protects the substance from being directly exposed to the blow of explosion gases and scattered. As a result of experiments, it has been found out that the explosion pressure is proportional to the explosion energy and that the explosion energy necessary for carrying out the coating is represented almost entirely by the quantity and the explosion velocity of the explosive employed. In carrying out the method enough explosion energy is required to obtain (A) adhesion between the base material and the said substance and (B) coalescence of the particles of the substance.

The explosion energy necessary for carrying out the coating of the surface of a base material with a powdery, granular or flaky substance depends upon the coating thickness. But since the relationship between the explo-

sion energy and the coating thickness varies according to the kind of the substance and base material, it is fixed as the case may be.

For example, in the case of a coating with zirconium oxide powder being sieved to pass through a No. 100 mesh screen (hereinafter the mesh numbers are of ASTM) in an 0.5 mm. coating thickness applied to a mild steel plate, a plastic explosive consisting mainly of PETN (pentaerythritol tetranitrate) and paraffin of 5000 to 7000 m./sec. explosion velocity may be used in an amount of 1 g./cm.². Similarly, in the case of a coating with zinc being sieved to pass through a No. 170 mesh screen in an 0.1 mm. coating thickness applied to a mild steel plate, the explosive may consist mainly of a mixture of ammonium nitrate and fuel oil of about 1600 m./sec. explosion velocity in an amount of 1.0 g./cm.².

Generally, the present invention can be carried out by using an explosive having an explosion velocity of more than about 1500 m./sec. in an amount of 0.1 to 10 g./cm.².

When the explosion velocity is not more than about 1500 m./sec., it becomes difficult to carry out coating effectively.

In carrying out the present method, the particle size and the shape of the substance is not so significant, though the maximum diameter of the particle is ordinarily less than about 5 mm.

The resultant thickness of the coating varies according to the kind of powdery, granular or flaky substance and ordinarily, is about 7/8 to 1/4 of the depth of the powdery or granular layer. That is, the substance is deposited in an amount such as will form a layer, the depth of which is not more than four times the resultant thickness of the coating. The present method is most effective when the resultant thickness of the coating is about 10 mm. to 0.05 mm.

In carrying out the present invention, the powdery, granular or flaky substance may include metals, alloys, metal oxides, carbides, borides, silicides, silicates, and nitrides, such as:

(1) Metals: iron, chromium, nickel, aluminum, lead, copper, zirconium, manganese, tungsten, molybdenum, titanium, tin, zinc, silver, platinum, gold.

(2) Alloys: steel Monel, Hastelloy, Stellite (both manufactured by Union Carbide Co.), Inconel, brass, bronze, Duralumine.

(3) Metal oxides: chromium oxide, aluminum oxide, titanium oxide, zirconium oxide, silicon oxide.

(4) Metal carbides: titanium carbide, tungsten carbide, niobium carbide, tantalum carbide, silicon carbide.

(5) Metal borides: chromium boride.

(6) Metal silicides: molybdenum silicide.

(7) Metal silicates: aluminum silicate, zirconium silicate, magnesium silicate.

(8) Metal nitrides: boron nitride.

The said powdery, granular or flaky substance is not the only substance that can be used for the coating in the present invention, but other substances such as powders of non-metals, for example, powder of carbon, boron or silicic acid may be used as well.

Further, those materials which undergo no destructive deformation by explosion are all involved as the base material to be coated in the material.

For example,

(1) Ferrous material: mild steel, hard steel, cast iron, stainless steel.

(2) Non-ferrous metal: aluminum, copper, titanium, or an alloy of any of said metals.

The surface of the base material is not always restricted to a plain one, but may involve such shapes as semi-spherical, conical, angular conical and other.

In carrying out the coating, it is very effective to dispose a buffering layer which virtually uses its original form by explosion of the explosive layer, between the said powdery layer and the explosive layer to prevent the sub-

stance from being scattered away. For the buffering layer, materials such as paper, plastic film or sheet, saw dust molded under pressure together with resin, paraffin, tar, pitch, or agar-agar gel and the like molded into a sheet form, can be used.

The residues of these substances hardly remain on the coating after explosion of the explosive or if they do remain, they can be manually removed in such a manner as brushing or washing.

If desired, powdery or granular substances which have been mixed with a sticky substance and molded temporarily into sheet form, may be disposed between the base material to be coated and the buffering layer. Further, the powdery or granular substance may be temporarily attached to the surface of the buffering layer, and disposed on the surface of the material to be coated.

Further, the present invention may be carried out not only in the atmosphere, but also under a vacuum. The present invention may be also carried out in a medium such as sand, saw dust, water or the like to effectively utilize the explosion energy.

Adherence between the coating layer and the surface of the base material, when applied by the method according to the present invention, is very excellent, and the number of pores in the coating layer is small. Further, almost 100% of the powdery or the like substance employed is formed into the coating.

EXAMPLE 1

A zirconium oxide powder layer being sieved to pass through a No. 200 mesh screen and to hold on a No. 300 mesh screen, and having 1 mm. thickness was disposed directly on the surface of a 10 mm. thick steel plate (ASTM A8-54), and three sheets of 0.5 mm. thick cardboard were placed one upon another on the zirconium oxide layer. On the cardboard, a layer of a plastic explosive of the following composition was provided in an amount of 1 g./cm.², which had an explosion velocity of 500 m./sec. By detonating the said explosive layer, a good coating of zirconium oxide was formed on the steel plate in about 0.5 mm. thickness.

	Percent
PETN -----	30
ZnO -----	40
Paraffin wax -----	9
Ester gum (rosin derivatives) -----	6
Petrolatum grease -----	15

EXAMPLE 2

An aluminum oxide powder layer being sieved to pass through a No. 200 mesh screen and to hold on a No. 300 mesh screen, and having 1 mm. thickness was disposed directly on the surface of a 10 mm. thick steel plate (ASTM A8-54), and four sheets of 0.5 mm. thick cardboard were placed one upon another on the aluminum oxide layer. On the said cardboard, a layer of plastic explosive of the following composition was placed in an amount of 1.5 g./cm.², which had an explosion velocity of 7000 m./sec. By detonating the said explosive layer, a good coating of aluminum oxide was formed on the steel plate in about 0.5 mm. thickness.

	Percent
PETN -----	40
ZnO -----	30
Paraffin -----	9
Ester gum (rosin derivatives) -----	6
Petrolatum grease -----	15

The properties of the plates with zirconium oxide and aluminum oxide as in Examples 1 and 2 were compared with those of articles available on the market as listed in the following table. The articles available on the market had been coated by oxyacetylene flame spray coating.

	Zirconium oxide		Aluminum Oxide	
	Example 1	Article available in market	Example 2	Article available in market
Ratio of number of pores (article available in market taken as 1, see Note 1 below)-----	0.17	1	0.16	1
Adherence (kg./cm. ² see Note 2 below)-----	84	52	77	48
Thermal shock resistance (Number of repetition, see Note 3 below)---	19	12	15	8
Percentage in the layer of powdery substance employed in the coating operation (See Note 4 below)-----	99	(About 60)	99	(About 60)

NOTE 1.—On the surface of the coating layer was dropped 0.5 cc. of ink, and the areas over which the ink spread were compared.

NOTE 2.—A steel piece was adhered on the coating layer using "Araldite resin" (manufactured by Ciba Ltd.) so that the adhesion area was 1 cm.² and then tension test was carried out to measure the strength required for the coating layer to be peeled off the surface of the material.

NOTE 3.—The coated body was heated at a temperature of 900° C. in an electric furnace and quenched by dropping it into water at normal temperature. This operation was repeated until the coating layer was visually seen to be peeled off, and the number of repetitions was counted.

NOTE 4.—For the article available in the market the figure is an estimate corresponding to the average normally achieved using flame spray techniques.

EXAMPLE 3

A titanium powder layer being sieved to pass through a No. 100 mesh screen and having 1.5 mm. thickness was disposed on the surface of a 5 mm. thick stainless steel plate (ASTM 304), and three sheets of 0.5 mm. thick cardboard were placed one upon another on the titanium powder layer. In contact with the cardboard, a plastic explosive layer similar to that used in Example 1 was applied in an amount of 1 g./cm.². By detonating the explosive layer, a good coating of titanium was obtained in about 0.7 mm. thickness.

EXAMPLE 4

A Hastelloy (manufactured by Union Carbide Co.) powder (through No. 170 mesh) layer of 2.0 mm. thickness was disposed on the surface of a 3 mm. thick stainless steel plate (ASTM 316), and a sheet of 1.5 mm. thick polyvinyl chloride sheet on the Hastelloy powder layer. In contact with the polyvinyl chloride sheet, a plastic explosive layer similar to that used in Example 2 was placed in an amount of 1.5 g./cm.². By detonating the explosive layer, a good coating of Hastelloy was obtained in about 1 mm. thickness.

EXAMPLE 5

A chromium boride powder layer being sieved to pass through a No. 200 mesh screen and to hold on a No. 300 mesh screen, having 0.5 mm. thickness was disposed directly on the surface of a 3 mm. thick duralumina plate, and a sheet of 0.8 mm. thick Celluloid were placed one upon another on the chromium boride layer. Then a 5 mm. thick sheet of agar-agar gel was placed thereupon. In contact with the agar-agar gel sheet, a PETN layer was applied in an amount of 1.5 g./cm.², the explosion velocity being 8000 m./sec. By detonating the explosive layer, a good coating of chromium boride was formed in about 0.2 mm. thickness.

EXAMPLE 6

A boron nitride powder layer being sieved to pass through a No. 200 mesh screen and to hold on a No. 300 mesh screen, having a 0.2 mm. thickness was disposed directly on the surface of a 10 mm. thick aluminum plate, and five 0.8 mm. thick hardboards consisting of sawdust bonded with melamine-urea resin were placed one upon another on the boron nitride layer. In contact with the hard board, a "Shingiri dynamite" (manufactured by Asahi Chemical Industry Co., Ltd.) layer was applied in an amount of 5 g./m.². The explosion velocity was 7000 m./sec. By detonating the explosive layer, a good coating of boron nitride was formed on the aluminum plate in about 0.1 mm. thickness.

EXAMPLE 7

In the same way as in Example 1 except for the use of a 1 mm. thick silicon carbide powdery layer, a good coating of silicon carbide was obtained in about 0.5 mm. thickness.

EXAMPLE 8

In the same way as in Example 1 except for the use of a powdery mixture of chromium oxide, anhydrous silicic acid and nickel in a ratio by weight of 3:1:1, each having been sieved to pass through a No. 170 mesh screen and to hold on a No. 300 mesh screen, a good coating of the said mixture was obtained in about 0.5 mm. thickness.

EXAMPLE 9

In the same way as in Example 2 except for the use of a powdery mixture of aluminum oxide and cobalt in a ratio by weight of 7:3 (each through No. 200 mesh and held on No. 300 mesh), a good coating of the said mixture was obtained in about 0.4 mm. thickness.

EXAMPLE 10

In the same way as in Example 3 except for the use of granular zirconium, 1 to 2 mm. in particle sizes, a good coating of zirconium was obtained in about 0.8 mm. thickness.

EXAMPLE 11

In the same way as in Example 4 except for the use of a thick flaky aluminum, having 3 to 5 mm. in sizes and about 0.1 mm. in thickness, a good coating of aluminum was obtained in about 0.8 mm. thickness.

EXAMPLE 12

This was similar to Example 3 except that the coating was applied to a hemispherical concave surface of a steel die (AISI H11). On detonation a good coating of titanium oxide was formed on that surface in about 0.5 mm. thickness.

EXAMPLE 13

By carrying out the same method as in Example 1 in sand, but using chromium oxide powder (through No. 200 mesh), a good coating of chromium oxide was obtained in about 0.5 mm. thickness.

EXAMPLE 14

By carrying out in saw dust a method similar to that described in Example 1, a good coating of zirconium oxide was obtained.

EXAMPLE 15

By carrying out in water a method similar to that described in Example 2 except that the steel plate, the

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powdery layer and the explosive layer were all tightly sealed in polyethylene sheeting, a good coating of aluminum oxide was obtained.

EXAMPLE 16

In the same way as in Example 1 except for the use of powdery zirconium silicate (through No. 200 mesh), a good coating of zirconium silicate was obtained in about 0.5 mm. thickness.

What is claimed is:

1. A method for coating a surface of a base material constituted of iron, aluminum, copper, titanium or an alloy thereof which base material is not destructively deformed by detonation, said method comprising directly placing at least one kind of a powdery, granular or flaky substance selected from the group consisting of a metal, an alloy, a non-metallic element, a non-metallic inorganic compound, a metal oxide, a metal carbide, a metal boride, a metal silicide, a metal silicate and a metal nitride and having a maximum size of less than 5 mm. in diameter, on the surface of the base material, the substance being deposited in an amount to form a layer of substantial depth of not more than four times the resultant thickness of coating on the surface, placing a layer of a detonating explosive having an explosion velocity of more than 1500 m./sec. upon the first said layer via a buffering layer consisting of paper, plastic film, plastic sheet, saw dust molded under pressure together with resin, paraffin wax, tar, pitch or agar-agar gel molded into sheet form and

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being virtually unable to retain its original form at the explosion of the detonating explosive, and detonating the explosive layer to form a coating of the substance having a thickness of 0.005 mm. to 10.0 mm. on the base material.

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