

[54] **MIXED METAL AND HIGH-TEMPERATURE PLASTIC FLAME SPRAY POWDER AND METHOD OF FLAME SPRAYING SAME**

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[56]

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UNITED STATES PATENTS

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[57]

ABSTRACT

The flame spraying of high temperature plastic powder as for example polyimides, polyamide-polyimides, polyester imides, or aromatic polyester high temperature plastics in admixture with a flame spray metal powder as for example aluminum alloy, nickel, copper, bronze, babbitt or stainless steel flame spray powder.

14 Claims, No Drawings

MIXED METAL AND HIGH-TEMPERATURE PLASTIC FLAME SPRAY POWDER AND METHOD OF FLAME SPRAYING SAME

This application is a continuation-in-part of copending application Ser. No. 16,247 filed Mar. 3, 1970 now abandoned.

This invention relates to the flame spraying of high temperature plastics.

Various plastic materials which remain stable at elevated temperatures are known. These plastics are generally known and referred to as high temperature plastics and remain stable at temperatures above 500°F and often will not melt even at temperatures as high as 1,000°F. These high temperature plastics may often be formed and worked in accordance with metal working technology as, for example, formed into shaped articles by hot sintering of the powder.

It has also been proposed to form coatings with the high temperature plastics utilizing the well known flame spraying techniques that are conventionally utilized for applying metal coatings. Due to the thermal stability of a high temperature plastic, however, it is often necessary to effect the spraying with a higher temperature plasma flame. While the sprayed coatings thus formed by the flame spraying of these high temperature plastics have many desirable characteristics, particularly with respect to their temperature stability, dielectric strength and the like, their usefulness and desirability could be greatly enhanced if their strength, hardness and erosion resistance could be increased. Furthermore, a reduction in the coefficient of friction of the sprayed surfaces would greatly increase their desirability as bearing surfaces, particularly of the self-lubricating type.

Another problem with flame sprayed coatings of the high temperature plastic is a tendency to fail upon thermal cycling to high temperature, and it would be desirable to improve on this thermal shock resistance. Thus in spite of the basic ability to remain chemically stable at high temperature, the high temperature plastics have mechanical shortcomings in thermal environments.

It is an object of this invention to enhance the characteristics of flame sprayed coatings formed of high temperature plastics in the above indicated manners. This and still further objects will become apparent from the following description:

In accordance with the invention a high temperature plastic powder is flame sprayed in admixture with about 5 - 99 weight percent, and preferably about 40 - 80 weight percent, of a flame spray metal powder by heating the mixture to a temperature sufficient to substantially melt the metal powder and surface heat-soften the high temperature plastic, and propelling the thus heated particles onto a surface, forming a coating.

The high temperature plastic powder which may be flame sprayed in accordance with the invention may be any of the known or conventional high temperature plastic powders which remain thermally stable at temperatures up to 500°F and preferably do not melt even at higher temperatures as for example temperatures up to 1,00°F.

Examples of these high temperature plastics include the well known polyimide plastics, polyamide-polyimide plastics, the polyester imide plastics and the aromatic polyester plastics.

High temperature plastics of the above mentioned types are, for example, described in U.S. Pat. No. 3,238,181; U.S. Pat. No. 3,426,098, U.S. Pat. No. 3,382,203 and British Pat. No. 570,858.

Particularly suitable are high temperature aromatic polyester plastics of the type formed from phenyl acetate as for example the poly(para-oxybenzoly) ester or poly(para-oxybenzoylmethyl) ester.

The starting high temperature plastics should be in powder form having a particle size between about -100 mesh and 3 microns, and preferably between -140 and 5 microns.

As is conventional in flame spray techniques the particle size distribution range should be as narrow as possible, as for example one desirable size distribution is -170 - + 325 mesh, and another desirable size distribution is -325 - +5 microns.

The high temperature plastic powder is admixed with about 5 - 99 weight percent, preferably 40 - 80 weight percent of a conventional flame spray metal powder having a melting point below about 3,000°F and preferably below 2,000°F.

Typical metal powders for mixing with the plastic are aluminum alloys, nickel alloys, copper, bronze, babbitt and stainless steels.

Since the density of a metal is many times greater than the density of a plastic, the percentages by weight as given herein actually reflect lower volume percentages.

When simply admixed or blended with the high temperature plastic powder the metal powder should have a size and form that is conventionally used in flame spraying as for example a particle size between about -100 mesh, U.S. standard screen size, and 3 microns, and preferably between 140 mesh and 5 microns. The particle size distribution should also be as is conventional in flame spray powder.

It is preferable to use a finer size metal powder than the plastic powder, for example -170 +325 mesh plastic and -325 mesh +10 micron metal powders. Generally the higher the melting point of the metal the finer the powder should be in relation to the size of the plastic.

In addition to simple blends or mixtures of the high temperature plastic powder and flame spray metal powder, composite particles containing the metal and the high temperature plastic may be used. Thus for example, plastic particles of the above mentioned type, but coated with finer particles of the metal, may be used. For this purpose, the metal may be in the form of a very fine powder or dust as for example having a particle size between about 25 and 0.5, and preferably between 10 and 1 microns, which is bonded to the surface of a plastic as for example with a binding agent such as a phenolic resin binding agent or any other organic binding agent or is simply thermally bonded or bonded in any other manner to the plastic.

Alternately, the individual particles may be metal particles of size suitable for flame spraying, but coated with finer particles of the plastic. In this case the plastic is in the form of a very fine powder or dust such as between about 25 and 0.5 and preferably between 10 and 1 microns. Similar binding means as described above may be used.

The powder may also comprise individual composite grains containing sub-particles of both the metal and plastic. Both the metal and plastic sub-particles may be in the form of a very fine powder or dust as for example having a particle size between 25 and 0.5 and preferably between 10 and 1 microns. The aggregate particles may be formed or briquetted or tableted from the finer particles by conventional powder metallurgy techniques with or without a bonder, or by spray drying, as for example described in co-pending application Ser. No. 671,880 filed Sept. 29, 1967 now U.S. Pat. No. 3,617,358.

The spraying of the powder mixture in accordance with the invention is effected in the conventional well-known manner for flame spraying, utilizing conventional flame spray equipment, i.e. conventional flame spray guns. The spraying must be effected under conditions, however, which will cause the metal powder to substantially completely melt while at the same time surface heat softening the high temperature plastic. Factors of flame temperature and residence time determine the temperature to which the particles are actually heated. In this connection it must be noted that due to the greater thermal conductivity of the metal particles the same will be much more rapidly heated and thus may reach their melting temperature of for example between 2,000° and 3,000°F in the same environment and under the same conditions that the high temperature plastic powder particles are only surface heat softened.

The term "surface heat softened" as used herein is intended to describe a thermal conditioning of the plastic particles in which their surface is heated to a temperature at which the same will deform and flow under pressure or impact without complete melting of the particles and without heating the entire particle to a detrimental or degrading temperature. Such surface heat softening may include a superficial chemical or physical modification of the plastic surface of each particle.

The spraying may be effected, for example, using a conventional powder type plasma flame spray gun as for example a Metco Type 3MB plasma flame spray gun using a GP nozzle, No. 2 powder port, argon plasma forming gas at 100 psi and 200 standard cubic feet per hour (SCFH) with hydrogen added at 50 psi and 5 SCFH, 70 to 80 volts and 500 amperes. Powder is fed to the gun with a Metco Type 3 MP powder feeder using the S powder conveying wheel at a speed adjusted to feed the powder at about 3 pounds per hour into 10 SCFH argon carrier gas.

Spraying may be effected on any surface or substrate such as carbon steel, stainless steel, aluminum, copper or copper alloys, nickel alloys, cobalt alloys and titanium. Although metals are generally used for substrates, other substrate materials may include oxide ceramics, plastics, fiberglass-plastic composites, or even cloth or wood. The surface must be cleaned and roughened to achieve bonding of the plastic mixture. To roughen the surface, grit blasting is used such as with SAE G25-40 steel grit or -16 +20 mesh aluminum oxide propelled by high pressure air.

A substrate surface roughness of at least 75 microinches RMS should be achieved for this coating, and preferably about 200 RMS. However, instead of or

in addition to roughening, a suitable bonding coating material, and preferably a self-bonding material may be flame sprayed onto a surface which has merely been cleaned such as by machining, etching or by light grit blasting. Self-bonding coating materials are well known in the flame spray art and, for example, include molybdenum or composite nickel-aluminum powders or wires for plasma or combustion flame spraying such as described in U.S. Pats. Nos. 3,222,515 and 3,436,248. These self-bond to most metal substrates. Suitable known coating materials for bonding to other substrates may be used, such as copper or glass to ceramic substrates, or zinc to low melting substrates including plastics. In each case the bond coat is applied in the known manner to a thickness of approximately 0.005 inches. The plastic metal powder is sprayed directly onto the bond coating. The mixture is sprayed to any thickness from about 0.001 inches to ¼ inch or more depending on the application. The coatings may be used in their as-sprayed condition, or may be easily machined to suitable dimension or to provide a smooth surface.

Coatings sprayed with the plastic powder mixture are excellent for use in seal areas such as on engine or pump shafts, or as low friction bearing surfaces especially where no further lubrication is used, or as abrasible coatings as in gas compressor or pump housings.

Very surprisingly, the coatings formed in accordance with the invention show marked increase in hardness and strength as compared with coatings of pure plastic. Furthermore in many instances there is a dramatic drop in the coefficient of friction, as for example with coatings formed from poly(paraoxybenzoyl) esters and aluminum-silicon alloys containing for example 5 to 30 and preferably about 12 percent silicon by weight of the aluminum alloy. With for example 60 percent by weight of the 12 percent silicon-aluminum alloy, the coefficient of friction drops manyfold, while at the same time the hardness and strength shows a manyfold increase over that of the pure plastic. Another surprising result is a major improvement in resistance to cracking and spalling from thermal cycling between about 600°F and room temperature. Whereas sprayed coatings of pure plastic failed, the coatings combining plastic and aluminum alloy performed well.

The following examples are given by way of illustration and not limitation.

EXAMPLE 1

A blend of 60 percent by weight (73 percent by volume) of a high temperature aromatic polyester plastic, poly(paraoxybenzoyl) ester, sold under the trade name of EKONOL by the Carborundum Company, having a size of -170, +325 mesh, U.S. standard screen size, is blended with 40 percent by weight (27 percent by volume) of a silicon - aluminum alloy containing 12 percent silicon and of a size of -325, +10 microns.

This blend is sprayed with a Metco 3 MB plasma flame spray gun and 3 MP powder feeder. Additional heavy air vibrator is mounted on the meter block and operated at 15 lbs. of air pressure to produce a more uniform flow of powder. An "S" powder feed wheel at 28 RPM and an argon carrier gas flow of about 10

SCFH results in a feed rate of approximately 3 ½ lbs. per hour. Parameters are GP nozzle; No. 2 feed port; Argon gas 100 psi and 200 SCFH; secondary gas Hydrogen 50 psi and 5 SCFH; 500 amperes and 70 volts. A standard Metco Type PSA air cooler is also used at 75 lbs. air pressure and the cooling air streams are parallel to the flame. Nozzle to work distance is 3 ½ inches. The substrate is 1 inch × 3 inch × ¼ inch mild steel. Steel grit G 25-40 with suction feed at 90 psi air in a ¾ inch diameter nozzle is the method of blast separation. Coating thickness is 0.100 inch.

EXAMPLE 1-A

Example 1 is repeated exactly, except with a blend of 40 percent by weight (55 percent by volume) of the high temperature plastic powder and 60 percent by weight (45 percent by volume) of the silicon aluminum alloy powder.

EXAMPLE 1-B

Example 1 is repeated exactly, except using pure high temperature plastic powder.

Samples of the sprayed coatings of Examples 1, 1-A, and 1-B are measured for hardness, elastic limit, rupture strength, modulus of elasticity, coefficient of friction, density and blast erosion resistance, and the results are set forth in Table I.

TABLE I

Example	Hardness	Elastic limit, p.s.i.	Rupture strength, p.s.i.	Mod. of elasticity, p.s.i.	Coeff. of friction	Density (gm./cc.)	Blast erosion volume loss*, gm./min.
1-A.....	R 15 W 33	4,400	47,000	36,500	0.28-0.45	1.65	0.076
1.....	R 15 W 4	4,200	33,000	31,500	0.25-0.32	1.35	0.079
1-B.....	R 15 W -51	2,200	19,000	13,000	0.37-0.40	1.1	0.256

*Aluminum oxide, -270 mesh +15 microns under 50 p.s.i. air pressure in a 3/16" nozzle.

EXAMPLE 2

The following mixtures of the aromatic polyester plastic powder described in Example 1 with aluminum powders are prepared and sprayed: Blends comprising 10 and 50 weight percent pure aluminum powder in the size range -170 +325 mesh; blends comprising 20, 30, 40, 50 and 60 weight percent of an aluminum alloy powder containing 24 percent silicon (based on the alloy). Coatings similar to those described in Examples 1 and 1-A are obtained. These coatings are for lightweight abrasible sealing surfaces for aircraft engines. The different proportions of aluminum provide different degrees of abrasibility and erosion resistance for different applications for abrasible coatings. The coatings with 60 percent aluminum are also useful for low friction bearing type of applications.

EXAMPLE 3

Aluminum flake powder of substantially -5 micron size is used to clad the same plastic powder of Example 1 using a phenolic resin binding agent. The plastic powder is clad with 20 wt-percent aluminum powder whose average particle size was 3.5-4.5 microns. Cladding procedure is as follows: 80 gms of plastic, es-

entially -170 +325, is mixed with 12 gms of phenolic binder (15 wt-percent of the plastic). To 20 gms of the -5 micron aluminum powder, is added enough phenolic thinner (5 gms) to dampen the aluminum flake. This combination is then introduced to the plastic mixture and blended in an electric mixer until completely dry. Halfway through the mixing period of 20 - 30 minutes, heat is applied to the mixing container to speed up the drying process. Final product is screened through a 100 mesh screen and the material retained on the screen discarded.

Other powders are made using 5 and 10 wt-percent of the aluminum flake. Coatings similar to those of Examples 1 and 2 are obtained by plasma flame spraying these composite powders.

EXAMPLE 4

The plastic powder of Example 1 is blended with an aluminum-bronz alloy powder, i.e., a copper alloy containing about 9 percent aluminum, of size -270 mesh +10 microns. Different mixtures contain 20, 30, 40, 60 and 95 wt-percent bronze. The 95 wt-percent bronze corresponds to about 80 volume percent metal and 20 percent plastic. Coatings of this type offer a hard but permanently lubricated surface for sliding contacts such as in bridge plates and airplane flaps.

EXAMPLE 5

Mixtures of 20 and 50 wt-percent pure copper powder -325 mesh are prepared with the same plastic

of Example 1. Another blend is prepared containing 42 wt-percent -170 +325 mesh of copper. Other powders are prepared by cladding 20 and 35 wt-percent -5 micron copper flake onto the same type of plastic particles using a phenolic binding agent. 20 wt-percent copper flake corresponds to four percent by volume of the composite powder. All these powders are plasma flame sprayed in the same manner as Example 1, producing bearing surfaces of good thermal conductivity, low friction and self-lubrication.

EXAMPLE 6

A mixture of 35 percent -325 mesh pure nickel powder is blended with the same plastic of Example 1. Another powder is prepared with 97 wt-percent +200 -325 mesh nickel. A composite powder is prepared using 20 wt-percent -5 micron nickel flake coated on the plastic articles using a phenolic binding agent. Excellent flame sprayed coatings are produced.

EXAMPLE 7

Similar blends of powder are prepared with SAE type 316 stainless steel +270 mesh +10 microns size. Powders with 20, 40 and 60 wt-percent stainless steel

powder are made. Plasma flame sprayed coatings are produced which were hard and corrosion resistant bearing surfaces.

EXAMPLE 8

Poly(paraoxybenzoyl) ester powder of size -325 mesh was blended with -325 mesh aluminum - 24 percent silicon alloy and plasma flame sprayed to produce a fine textured coating.

While the invention has been described in detail with reference to certain specific embodiments, various changes and modifications will become apparent to the skilled artisan. The invention is therefore only intended to be limited by the appended claims or their equivalents, wherein we have endeavored to claim all inherent novelty.

What is claimed is:

1. A process for flame spraying high temperature plastic powder which comprises heating a mixture of the plastic powder and at least about 5 - 99 percent by weight of a flame spray metal powder to a temperature sufficient to substantially melt the metal powder and surface heat soften the high temperature plastic, said plastic powder having a particle size between about -170 and +325 mesh and said metal powder having a particle size between about -325 mesh and +10 microns, the particle sizes of said plastic and metal powders being selected relative to each other such that the metal is melted but the plastic is only surface softened and propelling the thus heated particles onto a surface, forming a coating.

2. Process according to claim 1, in which the particles are heated in a plasma flame.

3. Process according to claim 1, in which said high temperature plastic is an aromatic polyester.

4. Process according to claim 3, in which said high

temperature plastic is a poly (paraoxybenzoyl) ester.

5. Process according to claim 4, in which said metal powder is an aluminum powder.

6. Process according to claim 5, in which said aluminum powder is an aluminum silicon alloy containing about 5 to 30 percent silicon.

7. Process according to claim 1, in which said metal powder is present in an amount of about 40 to 80 percent by weight.

8. Process according to claim 7, in which said metal powder is present in an amount of about 60 percent by weight.

9. Process according to claim 1, in which said mixture is formed of individual composite particles containing both said plastic and metal.

10. A flame spray powder for use in the process according to Claim 1, comprising a mixture of a high temperature poly (paraoxybenzoyl) ester plastic having a particle size between about 100 mesh and 0.5 microns and 5 to 99 percent by weight of a flame spray metal powder having a melting point below about 3,000°F and a particle size between 100 mesh and 0.5 microns.

11. A flame spray powder according to claim 10, in which said mixture is a simple blend of said plastic having a particle size between about 100 mesh and 5 microns and said metal having a particle size between about 100 mesh and 5 microns.

12. A flame spray powder according to claim 11, in which said metal powder is an aluminum powder.

13. A flame spray powder according to claim 12, in which said aluminum powder is an aluminum silicon alloy powder containing 5 to 30 percent silicon.

14. A flame spray powder according to claim 10, in which said mixture is formed of individual composite particles containing both said plastic and metal.

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