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Lauterbach

[11] **3,900,639**

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[54] **METHOD FOR COATING SURFACES OF A WORKPIECE BY SPRAYING ON A COATING SUBSTANCE**

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[30] **Foreign Application Priority Data**

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[51] **Int. Cl.**............................ **B05b 7/16;** B05b 7/20

[58] **Field of Search**....... 117/93.1 PF, 105.1, 105.2; 118/49.1, 49.5, 302; 219/76; 134/19, 37

[56] **References Cited**

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Primary Examiner—Michael Sofocleous
Attorney, Agent, or Firm—Hill, Gross, Simpson, Van Santen, Steadman, Chiara & Simpson

[57] **ABSTRACT**

A method and apparatus for applying a homogeneous coating of material on a surface of a workpiece characterized by projecting a jet of heated particles of material at the surface to be coated and applying a transverse flow of gases to deflect decomposition products from the jet to the jet contacting the surface being coated. Preferably, the deflected decomposition products are caught by a collecting wall or plate and the method and apparatus can include a nozzle directing a cooling flow of gases onto the workpiece to prevent overheating of the coating and the workpiece.

2 Claims, 4 Drawing Figures

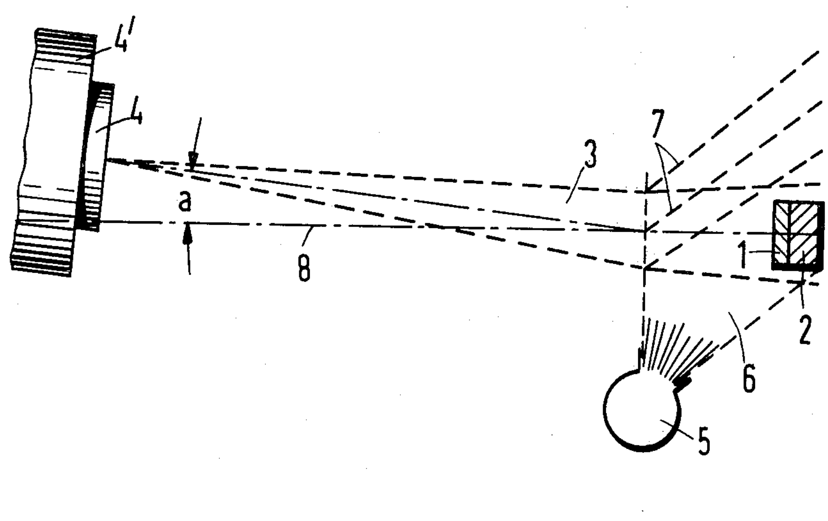


Fig. 1

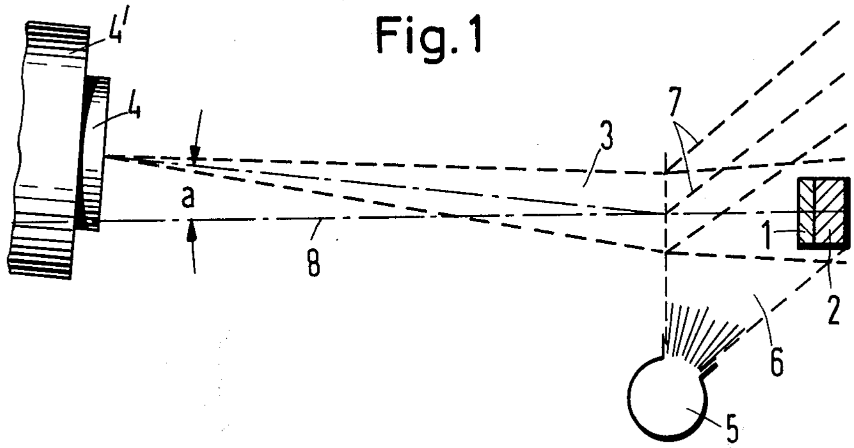


Fig. 2

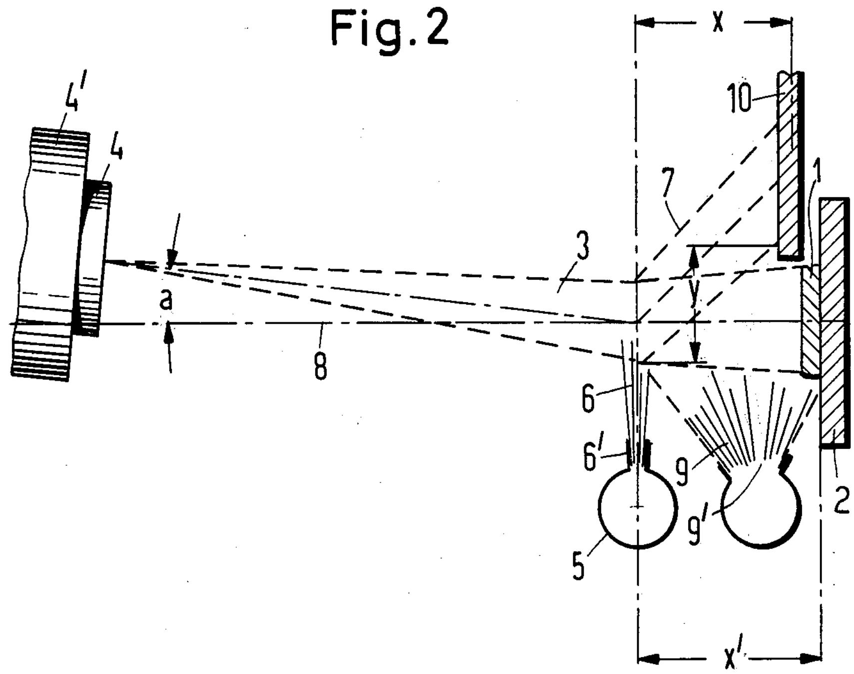


Fig. 3

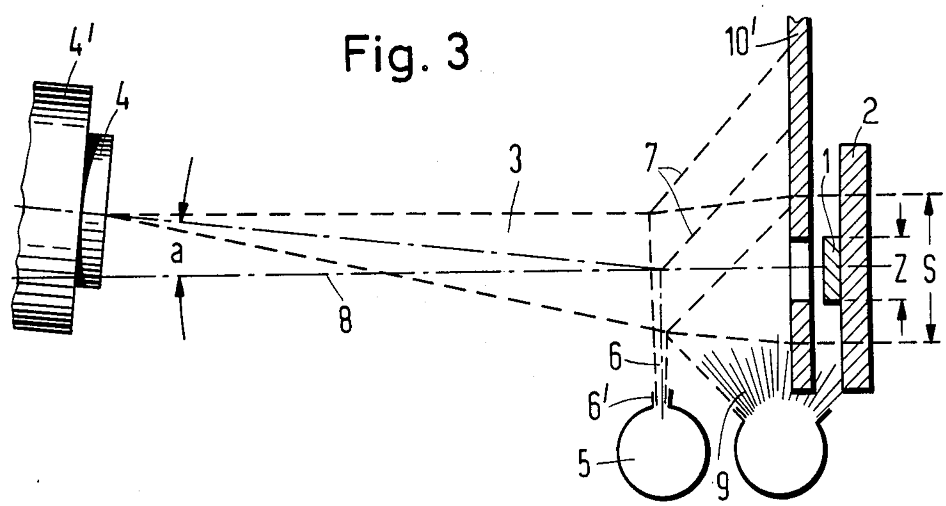
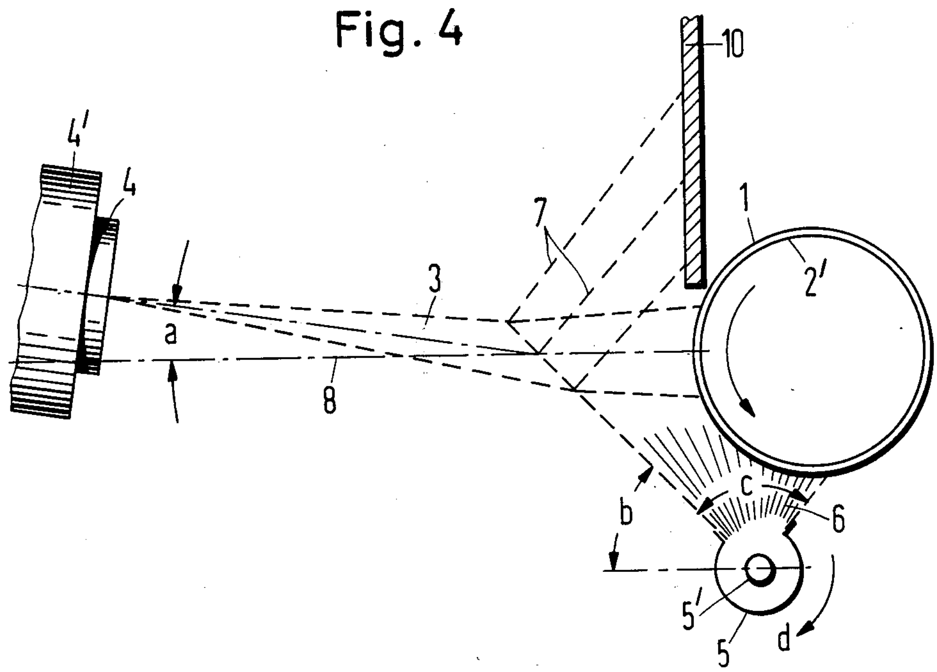


Fig. 4



METHOD FOR COATING SURFACES OF A WORKPIECE BY SPRAYING ON A COATING SUBSTANCE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method and apparatus for applying a homogeneous coating of material on the surface of a workpiece which utilizes a jet of particles heated to an elevated temperature and a transverse gas flow to deflect and remove decomposition products from the jet of particles prior to striking the surface being coated.

2. Prior Art

Numerous embodiments of devices for coating surfaces of a workpiece by spraying a jet of particles which have been heated to an elevated temperature are known. These devices include autogenous wire spraying (the Schoop method), autogenous powder spraying, arc spraying, detonation spraying and also plasma spraying.

A known device for coating a surface by means of arc spraying is disclosed in the U.S. Pat. No. 3,179,783 and this patent discloses a device in which the coating material is fed into an arc chamber and is melted. This material forms a jet of material which emerges from the nozzle of the spray device at a high temperature. In this arrangement, the nozzle is surrounded by a casing and a shielding gas flow is directed transversely to the material jet and is fed into the space surrounded by the casing. The casing terminates close to the workpiece to be coated so that the gas fed into the casing space is discharged between the workpiece and the end edge of the casing. Even those parts of the workpiece which are not currently undergoing coating are thus also cooled. This arrangement counteracts direct oxidation of the material contained in the jet of particles. However, the coating of a large area of a workpiece which is arranged at a greater distance from the nozzle of the spray device is difficult. Consequently, in order to protect the material from both oxidation and transformation and in order to achieve as clean as possible deposit on the workpiece, the usual practice is using a chamber filled with inert gases.

The exposure time, which is the time required for the coating of the workpiece, is generally very short and amounts to approximately 1.5 seconds.

In plasma spraying, the spray particle while in close vicinity to the spray nozzle and during their flight to the workpiece are melted in a period of time of approximately 200 μ seconds and are accelerated to supersonic speed. Within the individual spray particles there is thus a temperature drop with a negative temperature gradient extending from the surface of the particle to the core. To enable the particle to form a homogeneous layer when it hits or strikes the workpiece, it is necessary that the spray particles should at least be softened and thus the temperature of the core of the individual spray particles should therefore correspond approximately to the melting temperature of the material. Taking into account the relatively short time available for heating the particles, the surface of the particles are heated to well above the melting point. Consequently, part of the spray material will vaporize. Since the spray particles are generally different sizes, the smaller particles are heated more rapidly due to the surface being reduced in accordance with the square of the size and the volume reduced in accordance with the third power of the size. Thus smaller particles will vaporize to a greater degree and thus become even smaller. Independent on the type of spray process which is employed in the operating data, the overheated surface of the spray particles is also exposed to varying degrees of chemical attack. At the high spraying temperatures, many of the thus formed chemical compounds are volatile and will vaporize from the spray particles. Under the effect of the temperature many spray materials decomposite entirely or in part into various size components. In the spraying of mixtures composed of different materials, the material having the lower boiling point vaporizes to a greater degree than those with higher melting points and the material possessing the lower boiling point in a mixture is generally overheated and becomes exposed to a greater chemical attack. Therefore, the usual practice is for the material mixtures to contain a particularly endangered component in a quantity which takes into account the expected loss of the component. All of the split or vaporized components are smaller and lighter than the remaining particles of the jet or spray and are often clearly visible as socalled "smoke". It must be assumed that this "smoke" consists for the main part of decomposition products or other chemical compounds. These components which are referred to as "decomposition products" are carried along with the jet and reach the surface of the workpiece. The area of the workpiece which is to be coated thus becomes polluted with these decomposition products and a micrograph of the workpiece coated in this way will show inclusions which lead to a porous layer construction which disadvantageously affects the stability of the deposited layer. As stated above, in order to avoid or to restrict this disadvantage, it is known to use an argon chamber for plasma spraying. However, the overheated and decomposition products will still reach the surface of the workpiece. Also, the air locking of the workpiece into and out of the argon chamber requires a great deal of time and effort.

SUMMARY OF THE INVENTION

The present invention is directed to a method and apparatus to eliminate the above-mentioned disadvantages and to improve the spraying, in particular plasma spraying, in such a manner that a satisfactory coating which is clean and a homogeneous layer of material is achieved on the workpiece. The process and apparatus of the present invention accomplishes this task by carrying out the spraying in a normal atmosphere and by removing the decomposition products from the jet prior to the jet contacting the surface to be coated. To cause removal of the decomposition products from the jet, the apparatus arranges a nozzle adjacent the workpiece which nozzle directs a flow of gas in a direction extending transversely to the path of the jet to blow or deflect the decomposition particles from the jet. An embodiment of the process and apparatus includes providing collecting means such as a collector plate adjacent to the workpiece which plate collects all of the particles deflected out of the jet.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic presentation of an apparatus for performing the method of the present invention;

FIG. 2 is a schematic presentation of an embodiment of the apparatus for performing the present invention;

FIG. 3 is a schematic presentation of another embodiment for performing the method of the present invention; and

FIG. 4 is a schematic presentation of a further embodiment for performing the method of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The principles of the present invention are particularly useful in a method and apparatus for providing a homogeneous coating of a material on a workpiece by directing a jet of heated particles of material at the workpiece and applying a transverse flow of gas to the jet to deflect and remove the decomposition particles therefrom. Since the particle size and weight of the oxides, vapors, and other decomposition products are less than the heavier spray particles, the principles of the present invention utilize a transverse gas flow to deflect the decomposition products from the path of the jet which contains the spraying particles and which spraying particles are only slightly deflected by the transverse gas flow before striking the workpiece.

In FIG. 1, the workpiece 2 which is to be coated with a layer 1 of material is directly hit by a jet or spray 3 which contains the heated particles of material. The spray particles of the jet 3 of spray particles is created in a spray gun 4, which may include a plasma spraying arrangement 4, and is ejected at a high speed which is in the supersonic range and directed toward the workpiece 2. As illustrated, the axis of the jet 3 is at an angle a relative to a horizontal line 8 which is also perpendicular to the plane of the surface being coated on the workpiece 2. Outside of the region of the jet spray 3 and between the workpiece 2 and the spray gun 4 is arranged a nozzle 5 which directs a transverse flow 6 of gas at the jet 3. The transverse gas flow intersects the jet 3 and causes the lighter particles to be blown out of the path of the jet as illustrated by broken lines 7 and these lighter particles are conveyed outside of the range or area of the surface of the workpiece 2 which is to be coated. As illustrated, even the spray particles, which are sufficient size, are also slightly deflected. Since the spray or jet 3 is directed at an angle a in relation to the horizontal line 8, the flight path of the spray particles after the collision with the transverse flow of gas 6 is virtually horizontal so that the spray particles hit the workpiece at right angles.

The distance of the workpiece 2 from the spray gun 4 is for example 15 cm and the speed of the material flow or particles in the jet 3 is in the order of 450 m/s. The speed of the transverse gas flow is selected to be in a range of 200 to 450 m/s and is selected in dependence upon the nature of the material being utilized for the coating.

In the embodiment of FIG. 2, the spray or jet 3 is intersected by a transverse flow 6 of gas which is flowing at high speed, and the jet 3 is deflected. The smaller volume particles such as the decomposition products are deflected out of the jet 3 as indicated by the dash lines 7 and are collected by a diaphragm, wall or collection plate 10 which is arranged in front of the workpiece 2 and offset from the surface being coated. The plate or wall 10 prevents the decomposition products and also possibly oxides from contacting the workpiece 2 and from forming a layer thereon. In addition, the embodiment of FIG. 2 includes a flow 9 of cooling gases which is projected from a nozzle 9′ onto the workpiece to protect the workpiece 2 and the layer 1 from too great a heating.

The criterion for a clean separation of the material products from the decomposition products is provided by the difference of the deflection value Y. This value must be greater than the width or spread of the jet 3 in the close vicinity of the workpiece 2. An increase speed of the transverse flow 6 of gas will result in an increase angle of deflection and a higher deflection value Y. The flow speed of the transverse flow can be in the subsonic range and be controlled by the gas pressure applied on the nozzle 5. If the nozzle 5 has a Lavel nozzle indicated at 6′, the flow speed of the transverse flow 6 can be in the supersonic range. If the horizontal distance X from the center of the Lavel nozzle 6′ is increased, the deflection value Y also increases. This value then increases more rapidly than the width or spread of the particles in a jet 3. However, the distance X cannot be increased in an arbitrary fashion. When the spray particles pass through the remainder of the flight path X′, the spray particles will become cooled and there is also the danger of reoxidation. There are various possibilities of controlling deflection of the decomposition product from the material flow of the jet 3 by means of the transverse flow 6 of gas and by the diaphragm or plate 10. Both the gas speed of the transverse flow 6 of gas, its angle of incident to the line 8 and also the stray width or spread of the jet 3 can be adjusted.

In FIG. 3, another embodiment, which is similar to that of FIG. 2, is schematically illustrated. In this embodiment, the workpiece 2 is covered or preceeded by a diaphragm or collection plate 10′. This diaphragm or plate serves simultaneously to collect the decomposition products deflected out of the spray jet 3 by the transverse flow 6 of gas and provides a particularly suitable arrangement for spraying predetermined contours on the workpiece 2. Nevertheless, it is essential that the width Z of the sprayed layer or coating should be less than the spray width or spread S of the material in the jet 3. It is also necessary that the distribution of spray particles in the jet should be sufficiently uniform across the width of the jet 3. If the spray gun 4 is moved to and fro with the workpiece being held stationary or if the workpiece 2 is oscillated as the gun is held stationary, the deposition is carried out in a linear fashion. The diaphragm 10′ can also be placed on the workpiece, and in such an arrangement, the contour of the coating 1 corresponds to the shape of the opening in the diaphragm 10′. In order to coat the contours on larger areas, it is desirable to place a contour template (not illustrated) between the diaphragm 10′ and the workpiece 2. It is also possible for the template to be connected to the workpiece 2 and for the diaphragm 10′ to be connected to the nozzle 5. If the diaphragm or collector plate oscillates, the deposition is carried out in strips. This type of process may be recommended for coating larger areas.

FIG. 4 illustrates an arrangement of an embodiment for coating round workpieces. The round workpiece, for example, is a cylinder 2′ which is to be coated with a layer of material 1. In this case, it is desirable to direct the transverse gas flow towards the spray jet 3 at a smaller angle of incidence *b*. The small angle of incidence means that at lower gas speeds for the transverse flow 6 of gas can be utilized to obtain a relatively greater deflection of the decomposition products, from the jet **3**, as indicated by the lines **7**. Here, the transverse flow of gas also serves as a cooling gas for the workpiece **2'**. The rapidity of cooling of the deposited spray layer **1** can be varied by means of varying the width *c* of the transverse flow **6** of gas. If intensive cooling of the sprayed layer **1** is desired, this can be effected by rotating the nozzle **5** in the direction of the arrow *d* and possibly increasing the gas pressure in the nozzle line **5'**.

As mentioned hereinabove, the optimum angle at which the transverse flow **6** of gas meets the spray or jet **3** is dependent upon the speed of the spraying particles in the jet **3** and upon the nature of the material. This angle can be easily determined empirically. It is useful and advantageous to use the same gas or gas mixture for the transverse flow of gas as for the plasma gas. Not only may one use noble gases such as argon but also nitrogen with or without the addition of hydrogen. When spraying the workpiece with a metal oxide layer and the process permits an oxidizing atmosphere, it is also possible to use air.

When compared with spraying in an argon chamber in which the noble gas to a very large extent supresses the formation and embedding of oxides in the material flow or jet, the present process and apparatus has special advantages. For example, the material flow or jet is kept clean by having the oxides as well as the light deocmposition products being blown out or removed by the transverse flow of gas. Also the process of the present invention is less expensive and particularly well suited for mass production. Another advantage of the process and apparatus of the present invention is that unlike previous processes, it avoids the embedding of the vapors and oxides or combustion products into the layer which is to be constructed or deposited on the workpiece.

As mentioned above, the transverse flow of gas is produced by a nozzle which is connected to an independent supply of gas or air and is arranged in close vicinity to the workpiece and yet is of sufficient distance therefrom to prevent the particles blown out or deflected from the jet **3** from contacting the workpiece. As mentioned above, it is often desirable to place a diaphragm, collecting wall or collecting plate between the transverse flow and the workpiece to collect the particles deflected from the jet **3**.

A good control and setting of the transverse flow of gas is possible by means of varying the parameters of the flow. For example, its speed, its angle of incidence with the jet **3** and the angle of spread for the flow **6**. In addition, both the distance of the workpiece and the position of the collector plate or collecting means from the transverse flow of gas along with the structure of the collector plate may be arranged or selected within wide limits to meet the requirements of the particular material being applied by the jet. Even with only slight differences in the volume of the material mixture, it is still possible to achieve an exact separation if one limits the width of the jet and thus accepts a reduction in the degree of deposition.

Although various minor modifications might be suggested by those versed in the art, I wish to employ within the scope of the patent granted hereon all such modifications as reasonably and properly come within the scope of my contribution to the art.

I claim:

1. A method of applying a homogeneous coating of material on a surface of a workpiece comprising creating a jet of heated particles of material, directing the jet of particles along a path at the surface to be coated, removing decomposition products from the jet of particles prior to contacting the surface of the workpiece by directing a flow of gas transversely to the path of the jet to deflect the decomposition products from the path of the jet of particles prior to the particles of the jet striking the surface of the workpiece, and collecting the decomposition products deflected from the path of the jet of particles.

2. A method according to claim **1**, which further includes the step of providing a cooling flow on the surface of the workpiece to prevent overheating thereof.

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Notice of Adverse Decision in Interference

In Interference No. 99,514, involving Patent No. 3,900,639, R. Lauterbach, METHOD FOR COATING SURFACES OF A WORKPIECE BY SPRAYING ON A COATING SUBSTANCE, final judgment adverse to the patentee was rendered Nov. 1, 1977, as to claims 1 and 2.

[*Official Gazette February 14, 1978.*]

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