

THERMAL SPRAY APPLICATION OF POLYMERIC MATERIAL

The present invention relates generally to the utilization of a thermal spray technique for application of polymeric materials, and particularly to a method that facilitates application of polyetheretherketone (PEEK) composite to a substrate.

Thermal spray techniques have been used for coating target materials or substrates with a desired material or composition of materials. Generally, thermal spray technology refers to a family of coating techniques based on the use of a high temperature heat source used to melt a material and propel it at a substrate, thereby forming a coating on the substrate. Powder, rod or wire can be used as raw materials that are melted by, for example, electric arcs, combustible gases or a combination of both. The heat melts the coating material which is then accelerated by a compressed gas towards the substrate to be coated. As the coating material melts, it forms platelets that are propelled towards the substrate where they adhere to the substrate and to each other. The platelets build up and cool into a lamellar structure forming the coating.

One such thermal spray technique is referred to as a high velocity oxy fuel (HVOF) process. This process utilizes continuous, sustained internal combustion of oxygen and fuel that produce high pressure in a combustion chamber. Powder particles of a desired coating material are exposed to the heat generated and then accelerated to supersonic speed for deposition on a desired substrate. A variety of HVOF systems are currently available on the market.

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The HVOF process and other thermal spray techniques have also been available for use with powdered polymeric materials. However, it has proved difficult to use certain polymeric materials with thermal spray techniques, such as the HVOF, that utilize relatively high heat. This is particularly true with certain polymers, such as PEEK.

PEEK, for example, has many applications as a coating material, but the utilization of an HVOF process in applying a coating of PEEK material to a substrate has proved difficult. PEEK can degrade in the presence of extreme heat or a high temperature flame. However, if the PEEK powder is not heated sufficiently, unmelted particles are propelled against the desired substrate resulting in poor adhesion and undesirably high porosity.

The utilization of polymeric materials having good thermal stability at high temperature, such as PEEK, can be accomplished by molding the PEEK material onto a desired substrate. The application of PEEK coating through molding, however, is limited with respect to the types of components that can be coated. Additionally, the molding technique tends to be more costly, particularly when the molded coating and/or coated component requires additional machining prior to use of the component. The application of materials such as PEEK through an HVOF process would alleviate these problems.

The present invention features a method for applying a PEEK composite material to a metallic substrate. The method includes the step of applying a metallic

bond layer on the metallic substrate. Further, the method includes depositing a layer of PEEK composite material over the metallic bond layer by an HVOF process.

According to another aspect of the invention, a method is provided for applying a polymeric material to a substrate to create a high load thrust bearing surface. The method includes preparing a metal substrate, and applying a metallic bond layer to the metal substrate. Additionally, a polymeric material, having a melting temperature above 300°C is deposited over the metallic bond layer by spraying heated particles of the polymeric material towards the metal substrate.

According to another aspect of the invention, a method is provided for applying a PEEK composite material to a component surface. The method includes preparing a surface of a component to receive a PEEK composite mixture. The PEEK composite mixture is sprayed via an HVOF process over the surface to form a PEEK composite layer. The PEEK composite layer is then annealed to create a durable coating.

The invention will hereafter be described, by way of example, with reference to the accompanying drawings, wherein like reference numerals denote like elements, and in which:

Figure 1 is a perspective view of a substrate that has received a molded PEEK coating according to the prior art.

Figure 2 is a cross-sectional view taken generally along line 2-2 of Figure 1;

Figure 3 is a flow chart representing the general steps of a process for applying PEEK through HVOF, according to a preferred embodiment of the present invention;

Figure 4 is a perspective view of a substrate having a coating of PEEK applied via the HVOF process, according to a preferred embodiment of the present invention; and

Figure 5 is a cross-sectional view taken generally along line 5-5 of Figure 4.

The present invention relates to the utilization of a thermal spray technique to apply a polymer material, having good thermal stability at high temperature, to a substrate. Specifically, the method disclosed according to a preferred embodiment of the present invention is particularly useful in the application of a polyetheretherketone (PEEK) composite by a high velocity oxy fuel (HVOF) process to a metal substrate. The process provides a durable PEEK composite coating having a low porosity, typically less than 1% porosity. This type of coating is amenable to use on components that act as bearing components.

For example, the following describes an exemplary application of this process in creating bearing surfaces by applying the PEEK composite coating to pads used in thrust bearings. Such thrust bearings are used in a variety of applications, including applications in various submergible components found in submergible pumping systems. Submergible pumping system components are used in relatively harsh wellbore environments under substantial load in pumping production fluids to the earth's surface. However, the inventive process is not limited to this particularly

amenable application.

The ability to utilize an HVOF process in applying PEEK composites to desired substrates provides great flexibility, efficiency and cost savings in coating various components. Traditionally, high-load thrust bearing pads have been coated with a PEEK composite through well known molding methods. A typical prior art thrust bearing pad coated with a molded PEEK composite layer is illustrated in Figures 1 and 2. The conventional molding process is a multi-step process that is less efficient and more costly than the present HVOF process for application of PEEK composite to a substrate.

In the prior art, a coated, thrust bearing pad 10 includes a metal substrate 12. Metal substrate 12 typically is made from a steel plate. A first bond layer 14, comprising copper, for example, is electroplated to metal substrate 12. A second bond layer 16, comprising bronze, for example, is applied to the first bond layer 14 and metal substrate 12 by a sintering process. This process creates a relatively porous bronze layer having voids into which molten PEEK material may flow. Thus, after application of first bond layer 14 and second bond layer 16, a layer of PEEK composite material 18 may be deposited by melting and pressing PEEK composite material onto the bronze second bond layer 16. Following application of PEEK composite coating 18, the coated steel plate is machined into coated thrust bearing pad 10.

The present invention provides a more efficient, less cost intensive approach

for coating a substrate with a durable polymeric material, such as a PEEK composite material. The present method may be readily understood with reference to the block diagram of Figure 3.

As illustrated, initially a substrate layer must be prepared for receipt of a polymer layer via a thermal spray process. In the preferred embodiment, the substrate is a metallic material, preferably stainless steel but other metallic materials may be appropriate depending on the specific application. The first step in the process is preparation of the substrate material as illustrated by block 20 of Figure 3. During this step, the substrate preferably is cleaned by removing dirt, moisture, oil and other contaminants from the surface to be coated. To facilitate adherence, it is also desirable to roughen the surface to be coated. If the substrate is stainless steel, it is preferred that the surface be roughened by grit blasting the substrate with aluminum oxide having a grit mesh size 28.

In another step of the inventive process, the polymeric material is prepared for use in coating the substrate, as illustrated in block 22 of Figure 3. For the applications of the present method, it is preferred that the polymeric material have a high melting temperature, i.e., above 300°C. In the most preferred embodiment, a PEEK material is used to prepare a composite material in powdered form. Although a variety of materials may be mixed with the PEEK material, it has been determined that a preferred composite comprises a mixture of PEEK with polytetrafluoroethylene (PTFE) and carbon. These materials enhance the low coefficient of friction and excellent wear properties of PEEK.

An exemplary ratio of materials is approximately 70% PEEK mixed with approximately 20% PTFE and approximately 10% carbon. Additionally, the selection of appropriate particle size can be critical to the HVOF process. It has been determined that optimal particle sizes for the various components of the PEEK composite are approximately 70 microns for the PEEK; approximately 53 microns for the PTFE; and approximately 6 microns for the carbon particles. Although specific mixture percentages and particle sizes have been provided, other mixture ratios, particle sizes, and mixture components may be amenable to the process of the present invention.

After cleaning and grit blasting of the substrate material, a bonding layer may be applied to the substrate, as illustrated in block 24 of Figure 3. The bonding layer preferably is a metallic material having sufficient surface asperities to facilitate the mechanical bonding of the PEEK composite layer to the substrate. Preferably, a single layer of metallic material, such as nickel aluminum alloy, is applied. This material has desired characteristics at high temperature and provides excellent bonding to a stainless steel substrate. Other bonding layer materials may work better with substrates formed of materials other than stainless steel.

In the preferred embodiment, the nickel aluminum alloy is arc sprayed against the substrate. Arc spraying, as is generally known to those of ordinary skill in the art, uses a high energy electric arc generated by bringing two electrically energized wires into contact with each other. The arc energy melts the wires, and compressed air atomizes the molten material and propels it onto the substrate, leaving a bonding

layer. Preferably, the bond layer has good thermal conductivity to help dissipate heat from the PEEK layer, particularly when the PEEK material is used as a bearing surface. It has been determined that an optimal thickness for the bond coat is in the range of approximately 0.014 to 0.018 inches.

Following preparation of the substrate, application of the bonding layer, and preparation of the PEEK composite material, the PEEK composite material is applied to the substrate over the bonding layer by a thermal spray, as illustrated by block 26 of Figure 3. In the preferred embodiment, an HVOF process is utilized to apply the PEEK composite mixture to the substrate and the bonding layer. An optimum window of spray parameters has been established to ensure low porosity and great bond strength to permit the PEEK composite layer to be used in load bearing environments.

Preferably, the HVOF process is carried out with the aid of a thermal spray gun, such as the Miller Thermal Spray Gun, Model HV2000, available from Miller Thermal, Inc. The Miller Thermal Spray Gun is equipped with an axial powder feed configuration and is controlled by the Miller Thermal Computerized Console, Model 4600. The Miller Thermal Spray Gun is equipped with a 12mm combustion chamber and the fuel gas, preferably hydrogen, to oxygen ratio is 3.33. Additionally, a carrier gas, preferably nitrogen, is flowed through the thermal spray gun at a flow rate of 30scfh to feed powder into the combustion chamber.

The powderized PEEK composite mixture is fed to the thermal spray gun via

an electronically controlled, pressurized hopper unit, as is well known to those of ordinary skill in the art. The PEEK composite material is then injected through the flame of the HVOF thermal spray gun and heated to at least the melting point of the PEEK composite material, e.g. approximately 340°C. The powder particles of the PEEK composite are partially or fully melted and propelled towards the substrate and bonding layer. This creates a stream of semi-molten or molten particles or platelets that hit the substrate to form a continuous coating typically having a lamellar structure. A mechanical interlocking process takes place between the particles and the rough substrate/bonding layer to securely bond the continuous coating to the substrate.

In the preferred embodiment, the PEEK composite powder is fed at a rate of 11 grams per minute and the thermal spray gun is moved at a traverse speed of 754 millimeters per second with a standoff of 7 inches. (The standoff refers to the distance between the substrate and the outlet tip of the thermal spray gun.) The PEEK composite coating is built up in multiple passes to a thickness between approximately 0.019 inches and 0.021 inches. Typically, there is one preheat cycle and 30 passes, following which, the coating is allowed to cool by a natural slow cool.

After application of the PEEK composite mixture to form a PEEK composite layer, it may be advantageous to adopt a post-deposition annealing process, as illustrated by block 28 of Figure 3. The post-deposition annealing process provides a more durable coating. It facilitates the removal of thermal history and residual stresses. It also increases the level of crystallinity of the PEEK composite coating.

A preferred post-deposition annealing process comprises heating the PEEK composite layer to approximately 400°C and holding it at that temperature for approximately 30 minutes. The PEEK composite layer, along with the substrate and bonding layer, then undergoes a controlled cooling to approximately 270°C at which temperature it is held for approximately 10 minutes. Thereafter, the PEEK composite layer, substrate and bonding layer undergo a controlled cooling to below 60°C.

The above-described method provides a PEEK composite coating that is easily applied and has low porosity, typically on the order of less than one percent porosity. The PEEK composite layer is particularly amenable to use as a bearing surface because of its low coefficient of friction, excellent wear properties and low porosity achieved with this process.

As a result, an exemplary product for which the inventive process is readily adapted includes thrust pads for use as thrust bearings, such as those described above with reference to Figures 1 and 2. A thrust pad 30 produced according to the method of the present invention is illustrated in Figures 4 and 5. In this particular utilization of the present inventive process, thrust pad 30 includes a substrate 32 that is formed as an investment casting of PH17-4 stainless steel. Substrate 32 initially is prepared as described above with reference to block 20 of Figure 3.

A single bonding layer 34, comprising a nickel aluminum alloy, is applied to substrate 32 by arc spraying, as described above with reference to block 24 of Figure 3. A PEEK composite material is prepared and sprayed against substrate 32 and bond

layer 34 as described above with reference to blocks 22 and 26 of Figure 3. As a result, a multiplicity of molten or partially molten platelets 36 bond to substrate 32, bonding layer 34 and each other to form a PEEK composite layer 38.

After formation of PEEK composite layer 38, the thrust pad 30, including PEEK composite layer 38, preferably is subjected to the post-deposition annealing described above with reference to block 28 of Figure 3. The formation of thrust pad 30 is efficient and inexpensive relative to the molding process of the prior art. It also provides a durable, PEEK composite bearing surface readily used in hostile environments, such as those encountered in a downhole, wellbore environment.

It will be understood that the foregoing description is of a preferred exemplary embodiment of this invention, and that the invention is not limited to the specific form shown. For example, the method may be applied to a wide variety of components; the precise mixture of constituents in the PEEK composite may be adjusted for desired applications or effects; the HVOF parameters may be adjusted according to the PEEK composite mixture, the particulate size, the type of HVOF thermal spray gun utilized and the environment in which the process is implemented; and the bonding layer material may be adjusted according the various other parameters, including the material used in formation of the substrate. These and other modifications may be made in the design and arrangement of the elements with departing from the scope of the invention as expressed in the appended claims.



CLAIMS

1. A method for applying a PEEK composite material to a metallic substrate (32), comprising:

applying a metallic bond layer (34) on a metallic substrate (32); and

depositing a layer (38) of PEEK composite material over the metallic bond layer (34) by an HVOF process.

2. A method as recited in claim 1, wherein the step of applying includes arc spraying a metallic material onto the metallic substrate (32).

3. A method as recited in claim 2, wherein the step of arc spraying includes arc spraying a nickel aluminum alloy material onto the metallic substrate (32).

4. A method as recited in any one of claims 1 to 3, wherein the step of depositing includes applying a PEEK composite material having a mixture of PEEK, PTFE and carbon.

5. A method as recited in any one of claims 1 to 4, further comprising preparing a roughened surface on the metallic substrate (32) prior to application of the metallic bond layer (34).



6. A method as recited in any one of claims 1 to 5, further comprising annealing the layer (38) of PEEK composite material after deposition over the metallic bond layer (34).
7. A method as recited in claim 6, wherein the step of annealing comprises heating the layer (38) of PEEK composite material to approximately 400°C for approximately 30 minutes, cooling the layer (38) to approximately 270°C for approximately 10 minutes, and then cooling the layer (38) to below 60°C.
8. A method for applying a polymeric material to a substrate to create a bearing surface, comprising:

preparing a metal substrate (32);

applying a metallic bond layer (34) to the metal substrate (32); and

depositing a polymeric material (36), having a melting temperature above 300°C, over the metallic bond layer (34) by spraying heated particles of the polymeric material (36) over the metallic bond layer (34).
9. A method as recited in claim 8, wherein the step of depositing is accomplished by a HVOF process.
10. A method as recited in claim 8 or claim 9, wherein the step of applying



includes arc spraying the metallic bond layer (34) onto the metal substrate (32).

11. A method as recited in claim 10, wherein the step of arc spraying includes arc spraying a nickel aluminum alloy material onto the metallic substrate (32).

12. A method as recited in any one of claims 8 to 11, wherein the step of depositing includes depositing a PEEK composite material (36).

13. A method as recited in claim 12, wherein the step of depositing a PEEK composite material (36) includes depositing a mixture of PEEK, PTFE and carbon.

14. A method as recited in any one of claims 8 to 13, further comprising annealing the polymeric material following deposition over the metallic bond layer (34).

15. A method as recited in any one of claims 8 to 14, further comprising preparing a roughened surface on the metal substrate (32) prior to application of the metallic bond layer (34).

16. A method for applying a PEEK composite material (36) to a component surface, comprising:

preparing a surface of a component to receive a PEEK composite mixture
(36);



-15-

spraying the PEEK composite mixture (36) over the surface by an HVOF process to form a PEEK composite layer (38); and

annealing the PEEK composite layer (38) to create a durable peek composite coating.

17. A method as recited in claim 16, wherein the step of preparing includes preparing the surface of a stainless steel component (32).

18. A method as recited in claim 16 or claim 17, wherein the step of spraying includes spraying a PEEK composite powder (36) having an average PEEK particle size of approximately 70 microns.

19. A method as recited in any one of claims 16 to 18, wherein the step of spraying includes attaining a PEEK composite layer (38) having a porosity less than one percent.

20. A method as recited in any one of claims 16 to 19, wherein the step of spraying includes spraying a PEEK composite powder having approximately 70 percent PEEK, approximately 20 percent PTFE and approximately 10 percent carbon.