

PLASMA APPLICATION OF THERMAL BARRIER COATINGS WITH REDUCED
THERMAL CONDUCTIVITY ON COMBUSTOR HARDWARE

STATEMENT OF GOVERNMENT INTEREST

[0001] The Government of the United States of America may have rights in the present invention as a result of Contract No. N00019-02-C-3003 awarded by the Department of the Air Force.

BACKGROUND

[0002] The present disclosure is directed to thermal barrier coatings with reduced thermal conductivity on combustor hardware, which coatings are applied using a plasma.

[0003] Ceramic thermal barrier coatings (TBCs) have been used for many years to extend the life of combustors and high turbine stationary and rotating parts in gas turbine engines. TBCs typically consist of a metallic bond coat and a ceramic top coat applied to a nickel or cobalt based alloy substrate which forms the part being coated. The coatings are typically applied to thicknesses between 5 and 40 mils and can provide up to 300 degrees F temperature reduction to the substrate metal. This temperature reduction translates into improved part durability, higher turbine operating temperatures, and improved turbine efficiency. Typically, the ceramic layer is a 7 wt% yttria stabilized zirconia applied by air plasma spray (APS). New low thermal conductivity coatings have been developed which can provide improved part performance.

[0004] One coating which has been used in the past for TBCs is gadolinia stabilized zirconia based thermal barrier coatings.

SUMMARY OF THE INVENTION

[0005] It is desirable to form a thermal barrier coating which has a relatively low thermal conductivity.

[0006] As described herein, there is provided a process for forming a thermal barrier coating comprises the steps of providing a substrate, providing a gadolinia stabilized zirconia powder, and forming a thermal barrier coating having at least one of a porosity in a range of from 5 to 20% and a dense segmented structure on said substrate by supplying the gadolinia stabilized powder to a spray gun and using an air plasma spray technique.

[0007] Other details of the thermal barrier coatings applied using an air plasma spray technique, as well as advantages attendant thereto, are set forth in the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Figs. 1 and 2 are photomicrographs showing a low conductivity cracked coating formed using a F4 Plasma Spray Gun, which coating includes a ceramic layer consisting of 30 wt% Gd_2O_3 and 70 wt% ZrO_2 with a air plasma sprayed MCrAlY bond coat);

Fig. 3 is a photomicrograph showing a coating system which includes a metallic bond coat, a ceramic bond coat, and a ceramic top coat formed by a low conductivity coating in which the metallic bond coat is an air plasma-sprayed MCrAlY bond coat, the ceramic bond coat is a 7 YSZ interlayer, and the ceramic top coat is a 30 wt% Gd₂O₃ - 70 wt% ZrO₂ top layer.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0009] As described herein, a plasma spray technique is utilized to apply a gadolinia stabilized zirconia based thermal barrier coatings on combustor hardware such as panels, chambers, heat shields, transition ducts, augmenters, etc. The plasma spray technique may be an air plasma spray technique in which a desirable coating microstructure is produced.

[0010] In air plasma spray, the coating material is propelled toward the surface of the substrate to be coated. The coating material is in the form of a spray. The powder or powders forming the coating material are fed along with carrier gases into a high temperature plasma gas stream. In the plasma gas stream, the powder particles are melted and accelerated toward the surface of the substrate to be coated. The powder particles are fed to a spray gun at a desired feed rate. A carrier gas flow such as an argon gas flow is used to maintain the powder under pressure and facilitate powder feed. The carrier gas flow rate is described in standard cubic feet per hour. Standard conditions may be defined as about room temperature and about one atmosphere of pressure.

[0011] The gases that make up the plasma gas stream comprise a primary gas (such as an argon gas or nitrogen gas) and a secondary gas (such as a hydrogen gas). Helium gas may be used as the secondary gas if desired.

[0012] The process includes the step of translating a spray gun so that the nozzle is positioned at a desired distance from the surface to be coated. The substrate to be coated may be passed through the spray of powder particles emanating from the spray gun.

[0013] The spray gun to be used to form the coatings disclosed herein may include both internal feed and external feed spray guns. Suitable spray guns include the Plasmadyne SG-100, Sulzer Metco 3MB, 7 MB, or 9 MB, and the Plasma Technic F-4. The desired coating may also be applied with the high deposition rate Sulzer Metco Triplex gun and/or the Progressive HE100 gun.

[0014] Zirconia based powder with the additions of rare earth stabilizers, such as gadolinia, have been found to yield coatings having lower thermal conductivities than many current thermal barrier coatings. A useful zirconia based powder is one which consists of optionally 3.0 to 14 wt% of at least one of yttria and titania, 15 to 70 wt% gadolinia, and the balance zirconia. The yttria and/or titania, and the gadolinia, improve the thermal barrier coating's ceramic mechanical properties, while still achieving a reduced thermal conductivity ceramic coating. Coatings formed using these powders are shown in Figs. 1 and 2.

[0015] If desired, one could apply to a substrate, a coating which has a metallic bond coat, such as a MCrAlY type coating where M is Ni or Co, a ceramic interlayer, such as a 7 YSZ coating, deposited on the metallic bond coat and a ceramic top coat comprising from 15 to 70 wt% gadolinia and the balance zirconia. Such a coating system is illustrated in Fig. 3.

[0016] The air plasma spray parameters may be adjusted to produce a coating with a desired level of porosity or a coating with a dense segmented structure. For porous coatings, the coating may have a thermal conductivity which ranges from 3.0 to 10 BTU in/hr ft² F. For segmented coatings, the coating may have a thermal conductivity which ranges from 5.0 to 12.5 BTU in/hr ft² F.

[0017] A useful coating has a porosity in the range of 5.0 to 20%. The desired porosity for the coating may be obtained by altering the gun power settings, the standoff distance, the powder particle size, and the powder feed rate.

[0018] Segmented coatings provide the coating with strain tolerance during operation which leads to increased spallation life. For combustor panel applications, a coating system having a segmented microstructure topcoat layer with a ceramic interlayer provides a useful coating system.

[0019] If desired, one can obtain a coating with a dense segmented structure by increasing the power settings and shorten the standoff distance. One can do this by using

the settings set forth in columns 6 - 8 of U.S. patent no. 5,879,753, which patent is incorporated by reference herein.

[0020] For example, a useful coating may be applied using the Plasmadyne SG-100 spray gun using an amperage range of 350 to 825 amps, a voltage of 35 to 50 volts applied to a cathode and anode within the plasma-gun body, an argon primary gas flow of 75 - 105 SCFH, a hydrogen secondary gas flow of 1.0 to 10 SCFH or a helium gas flow of 45 - 75 SCFH, a powder gas flow exiting the gun of 4.0 to 20 SCFH, a powder feed rate to the gun of 10 to 40 grams/min., and a gun distance from the surface being coated of from 3.0 to 5.0 inches. Alternatively, the coatings may be applied with the Plasma Technic F-4 spray gun using an amperage range of from 500 to 700 amps, a voltage of 55 to 65 volts, an argon primary gas flow of 65 to 90 SCFH, a hydrogen secondary gas flow of 8 - 22 SCFH, a powder gas flow from the spray gun of 6 to 12 SCFH, a powder feed rate to the spray gun of 35 - 55 grams/min. and a gun distance from the surface being coated of from 4.0 to 7.0 inches.

[0021] One of the benefits of the process of the present invention is the application of a thermal barrier coating having lower thermal conductivity than many current coatings resulting in longer coating life, performance improvements, and cost savings.

[0022] Burner rig testing of a low conductivity coating formed in accordance with the present disclosure with a ceramic interlayer was found to be 1.6 to 1.9 times better in spallation resistance than without the interlayer. In

addition, low conductivity coatings with an interlayer are 1.3 to 1.5 times better in spallation than current coatings.

[0023] In accordance with the foregoing disclosure, there has been provided a plasma application of thermal barrier coatings with reduced thermal conductivity on combustor hardware. While the plasma application of thermal barrier coatings has been described in the context of specific embodiments thereof, other unforeseeable alternatives, modifications, and variations may become apparent to those skilled in the art having read the foregoing description. Accordingly, it is intended to embrace those alternatives, modifications, and variations as fall within the broad scope of the appended claims.

WHAT IS CLAIMED IS:

1. A process for forming a thermal barrier coating comprising the steps of:

providing a substrate;

providing a gadolinia stabilized zirconia powder; and

forming a thermal barrier coating having at least one of a porosity in a range of from 5 to 20% and a dense segmented structure on said substrate by supplying the gadolinia stabilized powder to a spray gun and using an air plasma spray technique.

2. The process according to claim 1, wherein said substrate providing step comprises providing a combustor component.

3. The process according to claim 1, wherein said substrate providing step comprises providing one of a combustor panel, a combustor chamber, a combustor heat shield, a combustor transition duct, and a combustor augmentor.

4. The process according to claim 1, wherein said powder providing step comprises providing a powder consisting of optionally from 3.0 to 14 wt% of at least one of yttria and titania, from 15 to 70 wt% gadolinia, and the balance zirconia.

5. The process according to claim 1, wherein said powder providing step comprises providing a powder consisting of from 3.0 to 14 wt% of at least one of yttria and titanium, from 15 to 70 wt% gadolinia, and the balance zirconia.

6. The process according to claim 1, wherein said thermal barrier coating forming step comprises using an amperage range of 350 to 825 amps, a voltage of 35 to 50 volts, an argon primary gas flow of 75 to 105 SCFH, at least one of a hydrogen secondary gas flow of 1.0 to 10 SCFH and a helium secondary gas flow of 45 to 75 SCFH, a powder gas flow exiting a spray gun of 4.0 to 20 SCFH, a powder feed rate to the spray gun of 10 to 40 grams/min., and a gun distance from a surface of the substrate being coated of from 3.0 to 5.0 inches.

7. The process according to claim 1, wherein said thermal barrier coating forming step comprises using an amperage range of from 500 to 700 amps, a voltage of 55 to 65 volts, an argon primary gas flow of 65 to 90 SCFH, a hydrogen secondary gas flow of 8 to 22 SCFH, a powder gas flow from a spray gun of 6 to 12 SCFH, a powder feed rate to the spray gun of 35 to 55 grams/min. and a gun distance from a surface of a substrate being coated of from 4.0 to 7.0 inches.

8. The process according to claim 1, further comprising depositing a ceramic interlayer on said substrate prior to said thermal barrier coating step.

9. The process according to claim 8, wherein said ceramic interlayer depositing step comprises depositing a layer of 7.0 wt% yttria stabilized zirconia.

10. The process according to claim 8, further comprising depositing a bondcoat layer on said substrate prior to said ceramic interlayer depositing step.

11. The process according to claim 10, wherein said bondcoat layer depositing step comprises depositing a metallic bondcoat layer.

12. The process according to claim 1, wherein said thermal barrier coating forming step comprises forming a segmented coating having a thermal conductivity in the range of from 5.0 to 12.5 BTU in/hr ft² F.

13. The process according to claim 1, wherein said thermal barrier coating forming step comprises forming a porous coating having a thermal conductivity in the range of from 3.0 to 10 BTU in/hr ft² F.