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(54) **EB-PVD-LIKE PLASMA-SPRAYED COATINGS**

(57) With a conventional LPPS spraying apparatus and given parameters of the vacuum and used powder particle sizes, a columnar structure can be reached.

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## Description

**[0001]** The invention relates to a plasma-sprayed ceramic coating with a columnar structure similar to EB-PVD coatings.

**[0002]** Thermal Barrier Coatings (TBCs) are typical used in Gas Turbines to protect the combustor and turbine components along the hot gas path. TBC's are sprayed with conventional thermal spray technology such as Atmospheric Plasma Spray (APS) and they consist of droplets that deposit on each other to create successive layers that end up building the coating. The morphology of the powder particles as well as the stacking of the droplets and semi-molten particles during spraying influences the overall porosity of the TBC. High porosity homogeneous coatings are desired in order to achieve increased capacity for thermal strain tolerance as well as lower thermal conductivity. However, over a certain porosity level, the coatings cohesion will start degrading severely, reducing adversely its erosion resistance.

**[0003]** Coatings of high porosity demonstrate increased thermal strain tolerance compared to denser coatings of lower porosity. However, they cannot achieve the exceptional thermal strain tolerance of the Electron Beam Physical Vapor Deposition (EB-PVD) coatings, which present a columnar feathery microstructure. The orientation of the grain structure allows increased tolerances to thermal shocks and thermomechanical stress.

**[0004]** However, the drawbacks of the PVD processes are the high investment costs and low deposition rates, which makes it therefore attractive for application on small mostly components such as blades and vanes for aircraft engines, where durability is of outmost importance. For this reason, the coating in the field of industrial gas turbines no longer finds common usage today.

**[0005]** Coatings were developed, under an effort to reproduce the advantages of EB-PVD process with another manufacturing process. Certain TBCs which are sprayed with APS demonstrate the columnar microstructure, which resembles the columnar microstructure of the EB-PVD process. These coatings sprayed with the APS method are known as Segmented TBC's, whereas the Segmented and the EB-PVD coatings are characterized of similar microstructure the EB-PVD coatings present two significant benefits:

- a) They demonstrate increased thermal strain tolerance as a result of the more refined columnar microstructure that extends in the entirety of the coatings;
- b) Lower thermal conductivity. Regarding the latter, the segmented TBCs show very low porosity which inadvertently impacts their thermal conductivity, which can be a 20% - 50% increase compared to a typical porous TBC.

**[0006]** It is therefore the aim of the invention to overcome the problem mentioned above.

**[0007]** The problem is solved by a method according to claim 1.

**[0008]** In the dependent claims further measurements are listed which can be combined arbitrarily which each other to yield further advantages.

**[0009]** The innovative aspect of the present invention is to use a conventional vacuum thermal spray equipment to produce EB-PVD-like coatings. The important element to imitate the feathery EB-PVD microstructure is not just to melt, but to evaporate the ceramic powder and then let it deposit and resolidify on the substrate. That can be achieved through the combination of a high power plasma torch and a low pressure chamber, used for Low Pressure Plasma Spraying (LPPS). The typical pressure achieved at the LPPS booth is between 1mbar - 20mbar (100Pa to 2000Pa), which is much higher compared to the pressure achieved during a PVD process ( $10^{-4}$  mbar =  $10^{-2}$  Pa). However, that can be compensated with the usage of a high power torch that delivers an elongated flame, that can extent to more than 1 meter, under the low pressure environment at the LPPS booth.

**[0010]** Preferably the particle size distribution of ceramic coating, typically of 8YSZ chemistry, should be fine, such as  $-45\mu\text{m}$  or finer, in order to achieve fast and complete evaporation during the flight time of the particles in the flame.

**[0011]** Additionally, it is important that the apparatus has a vertical direction, in which the torch is placed vertically above the substrate and sprays downwards, to ensure that the evaporated material lands on the substrate.

**[0012]** Finally, the roughness of the bond coat should be low, ideally under  $R_a:4\mu\text{m}$  in order to allow a homogeneous growth of the vertical columns. That comes in contrast to the high bond coat roughness needed for the typical thermal sprayed TBC's in order to achieve a good mechanical interlocking.

**[0013]** The novelty of the present invention lies on

1) An industrial LPPS booth can be used to deposit EB-PVD-like ceramic coatings using conventional spray torches.

2) The combination of high power torch and low pressure results to a long and wide flame that achieves higher deposition rates compared to EB-PVD, thus reducing the cost to coat a part and making the process attractive to coat even Large Gas Turbines (LGTs) parts.

3) The possibility to coat LGT parts with feathery like microstructure can increase significantly the duration of the coatings in the engine, reduce the need for service and even allow the application of higher Turbine Inlet Temperatures, which can increase the efficiency of the Gas Turbine.

**Claims**

1. Method  
to produce a ceramic columnar structured coating  
on a substrate 5  
in a Low Pressure Plasma Spraying (LPPS) spray  
equipment, wherein a pressure between 100Pa to  
2000Pa is used, and wherein a maximum grain size  
of 45 $\mu$ m or finer for the sprayed powder is used. 10
2. Method according to claim 1,  
wherein the roughness of the substrate is below  
 $R_a=4\mu$ m.
3. Method according to claim 1 or 2, 15  
wherein a nickel-based substrate with a metallic  
bond coat, especially a NiCoCrAlY bond coat,  
is coated with the ceramic coating.
4. Method according to any of the claims 1, 2 or 3, 20  
wherein  
the torch of the LPPS is placed vertically above the  
substrate and sprays downwards,  
to ensure that the evaporated material lands on the  
substrate. 25
5. Method according to any of the claims 1, 2, 3 or 4,  
wherein Zirconia is used as ceramic coating,  
especially a partially stabilized Zirconia. 30

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EUROPEAN SEARCH REPORT

Application Number  
EP 18 19 9594

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Place of search The Hague		Date of completion of the search 26 November 2018	Examiner Chalaftris, Georgios	
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