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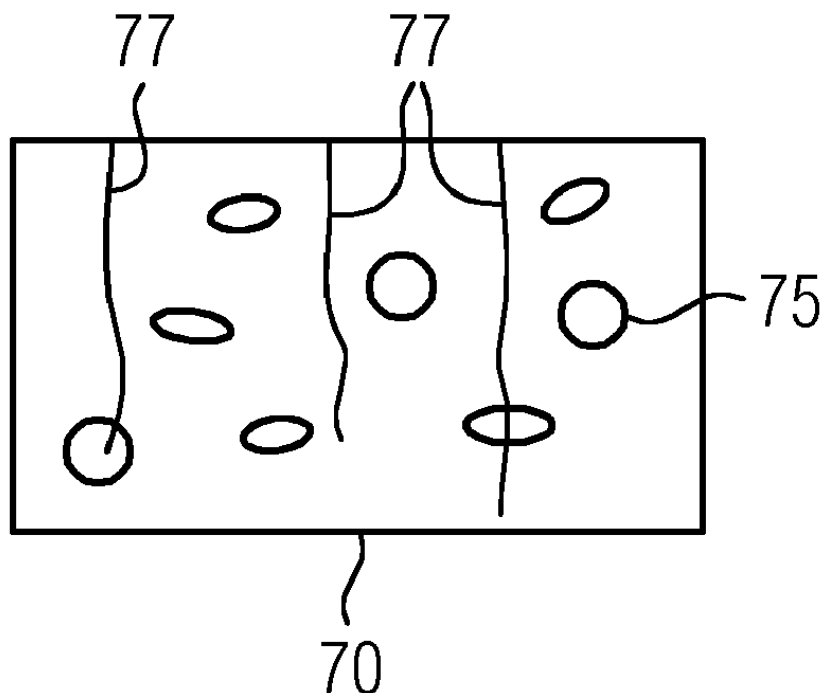
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(54) **METHOD AND DEVICE TO PRODUCE A SEGMENTED POROUS CERAMIC COATING, AND A COMPONENT THEREOF**

(57) By a subsequent heat treatment of a porous ceramic coating a segmented porous coating can be yield.

FIG 3



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Description

[0001] The invention relates to a heat treatment of a porous ceramic coating to yield a segmentation and a device.

[0002] The most severe failure mode for thermal barrier coatings (TBC) is delamination followed by spallation. The driving forces are thermal strains caused by steep temperature gradients in thickness direction and mismatch of thermal expansion between coating and underlying bond coat/substrate.

[0003] On newly developed engines the stationary temperature gradient can be higher than 1000 K/mm. Under transient conditions (heating up, shut down) with temperature rates $>> 100$ K/s the local temperature gradient can be much higher resulting in strains, which exceed the coating strain tolerance and lead to crack formation. The focus for the development of TBC's with enhanced life is to increase and maintain the strain tolerance under high temperature exposure by keeping the thermal conductivity as low as possible.

[0004] The possible solutions to address the temperature induced stresses in thermally sprayed coatings follow two different pathways:

The first has pushed thermal spray coatings porosity upwards in order to decrease the elastic modulus which directly decreases the thermally induced stresses. Additionally, higher porosity reduces the thermal conductivity, rendering the coating a better thermal insulator.

However, that has caused the shrinkage of the sprayability window that allows coatings to combine high porosity and good cohesion. As a result of the dwindling coating cohesion, erosion has started manifesting itself as a major issue for coatings in specific parts and engines. The problem is relatively new and no solution has been implemented till now. Additionally as the firing temperature of turbines increases, sintering of the coatings occurs rather fast which leads to an increase in coating stiffness and elastic modulus. Thus the same thermal strains cause higher stresses under progressive sintering which reduce the TBC life.

[0005] The second pathway to reduce thermal stresses in the coatings is to try to adopt the columnar structure of the EB-PVD coatings, which has shown evidently its long life due to its unique architecture. This, in thermal spraying, is succeeded with producing a Dense Vertical Cracked (or Segmented) microstructure. The vertical cracks produced in the coating allow it to "balance" different strain rates along its thickness. The disadvantage of this pathway is the higher effective thermal conductivity in thickness direction which has to be compensated by thicker coating.

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

[0007] The problem is solved by a method according

to claim 1 and a device according to claim 4 and a component according to claim 6.

[0008] In the subclaims further advantageous features are listed which can be arbitrarily combined with each other to yield further advantages.

[0009] The idea of the present invention is to introduce vertical cracks in a porous coating after spraying.

[0010] The process is preferably based on a 8YSZ coating typically thermally sprayed on samples or components.

The coated component is subjected to a steady sintering stage under a controlled thermal gradient wherein the heat flow is directed from the surface of the coating to the substrate. The heat sources can be lasers, high power lamps, hot gas burners, plasma guns or special designed ovens.

[0011] The surface temperature has to be monitored and used to control the heating power. The surface temperature has to be high enough to initiate the sinter process of the coating within reasonable times (>1523 K). To avoid phase transitions and melting an upper temperature limit has to be established as well.

[0012] To ensure a steep thermal gradient and to protect the metallic part from oxidation, the metallic substructures have to be cooled actively and in a controlled manner. Complex hot gas path components have internal cooling structures already included which need to be used. Under this uneven steady temperature gradient two processes take place:

- i) sintering which increases the stiffness of the coating and leads to shrinkage
- ii) creep, which leads to a complete relaxation of the mostly compressive stress within the hot coating surface region. The sintering driven shrinkage of the coating material can already form a network of vertical cracks. But the major driving force for segmentation are the high tensile stresses applied during cooling down and boosted due to stress reversion of the relaxed compressive stresses.

[0013] The spacing of the vertical crack pattern is mainly determined by the coating stiffness, which depends on the exposure time and temperature level as well as on the cooling rate. By adjusting the time at temperature-gradient-exposure and cooling rate a well-defined vertical crack pattern or segmentation network with tuned spacing can be formed.

[0014] This method presents the following advantages, regarding design and manufacturability:

- 1) The initial coating can be a typical ceramic coating, which means that the overall porosity is lower than the currently used dense vertical cracked (DVC) TBCs. Thus, the resulting coatings of this type can be thinner by offering the same thermal insulation.

- 2) The manufacturability of this process is easier of

the ones followed to manufacture a segmented TBC on a gas turbine part. Typically the segmented TBCs need a tight control of the substrate temperature and can be expensive depending on the hardware consumed during spraying.

[0015] The most significant benefit though is related to performance:

During testing of the same coating before and after a sintering treatment a significant difference in the performance of the coating has been detected. Specifically, during thermal cycling on a High Heat Flux Test rig where the difference between coating surface and substrate temperature was more than 973K, the sintered coating has shown more than 100 times life increase. While the porous 8YSZ coating lasted only 6 cycles, the thermally pre-segmented coating lasted more than 800 cycles.

Figure 1 shows an inventive device,
figure 2 a component and
figure 3 a enlarged view of a ceramic coating.

[0016] The figure 1 shows an inventive device 1.

[0017] The device 1 comprises at least an oven 10 in which several hollow components 7', 7", ..., 100 can be mounted on adapters 11', 11", ... which provide a cooling medium.

[0018] The cooling medium is especially provided by one or several tubes 4 which is especially air or any gas especially from outside the oven 10.

[0019] This cooling medium must not be at ambient temperature but can be heated too.

[0020] The heating on an outer side of the ceramic coating 70 (fig. 2) can especially performed by laser beams.

[0021] A control unit 13 is used for regulating the cooling, the heating of the coating 70 and the temperature of the oven.

[0022] Figure 2 shows a component 100 which is an example for component 7', 7".

[0023] The component 100 has especially a metallic substrate 40 which is especially a nickel or cobalt based super alloy.

[0024] On this substrate 40 several coatings like metallic bond coats (not shown, e. g. NiCoCrAlY) are present and at least an outer ceramic coating 70.

[0025] The ceramic coating 70 is especially made of zirconia, especially 8YSZ, 48YSZ or a pyrochlore structure.

[0026] The ceramic coating 70 has a porosity of at least 3%, especially of at least 5% and maximum 15%, especially maximum 10%, very especially maximum 8%.

[0027] Before the heat treatment the ceramic coating 70 has no long, vertical cracks, wherein "vertical" means almost perpendicular to the outermost surface towards substrate 40 and "long" means at least 10% to 90% es-

pecially 20% to 80% of the thickness of the ceramic coating 70.

[0028] In figure 3 an enlarged view of the microstructure of the coating 70 is shown. The ceramic coating 70 comprises some pores 75, wherein due to the thermal treatment in the oven 10 vertical cracks 77 were firstly developed, which start from the outermost surface of the coating 70.

[0029] The coating 70 was produced by a spraying method (APS, VPS, LPPS, HVOF, cold spray, ...) using powder grains. By the heat treatment the powder grains sinter together.

Claims

1. Method

to produce a segmented porous ceramic coating (70), wherein firstly a grained ceramic coating on a hollow component (100, 7', 7", ...) is provided or a grained ceramic coating is applied on a hollow substrate (40) of a component (100, 7', 7", ...), wherein almost no long, vertical cracks are present in the ceramic coating (70), applying a heat treatment to the component (7', 7", ...) with the coating,

to sinter the grains of the ceramic coating (70), wherein the hollow component (100, 7', 7", ...) is simultaneously cooled inside during the heat treatment to yield a thermal gradient between the cooled area and the ceramic coating (70) to yield the long vertical cracks.

2. Method according to claim 1,

wherein the ceramic coating (70) comprises zirconia, especially 8YSZ, or a pyrochlore structure.

3. Method according to claim 1 or 2,

wherein the temperature of the heat treatment is at least 1523K.

4. Method according to claim 1, 2 or 3,

wherein the duration of the heat treatment enables sintering of the grains of the ceramic coating (70).

5. Device,

especially to perform a method according to claim 1, 2, 3 or 4, which at least comprises:

an oven (10),

at least one adapter (11', 11", ...) for components (7', 7", ...) at least one in the oven,

wherein the adapter (11', 11", ...) supplies a cooling medium into the component (7', 7", ...), heating elements and

a control unit (13).

6. Device according to claim 5,
where the heating elements are laser beams.
7. Component (100, 7', 7'', ...),
which comprises 5
an hollow substrate (40),
which can be cooled inside and
at least an outer ceramic coating (70),
wherein the ceramic coating (70) comprises zirconia,
which has a porosity of at least 3%, 10
especially of at least 5%, and
vertical cracks (77),
wherein the ceramic coating (70) was produced by
spraying grains of powder and 15
wherein the sprayed grains are sintered together af-
ter spraying.
8. Component according to claim 7,
wherein the ceramic coating 70 has a porosity of at
least 3%, especially of at least 5% and 20
maximum 15%, especially maximum 10%, very es-
pecially maximum 8%.

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FIG 1

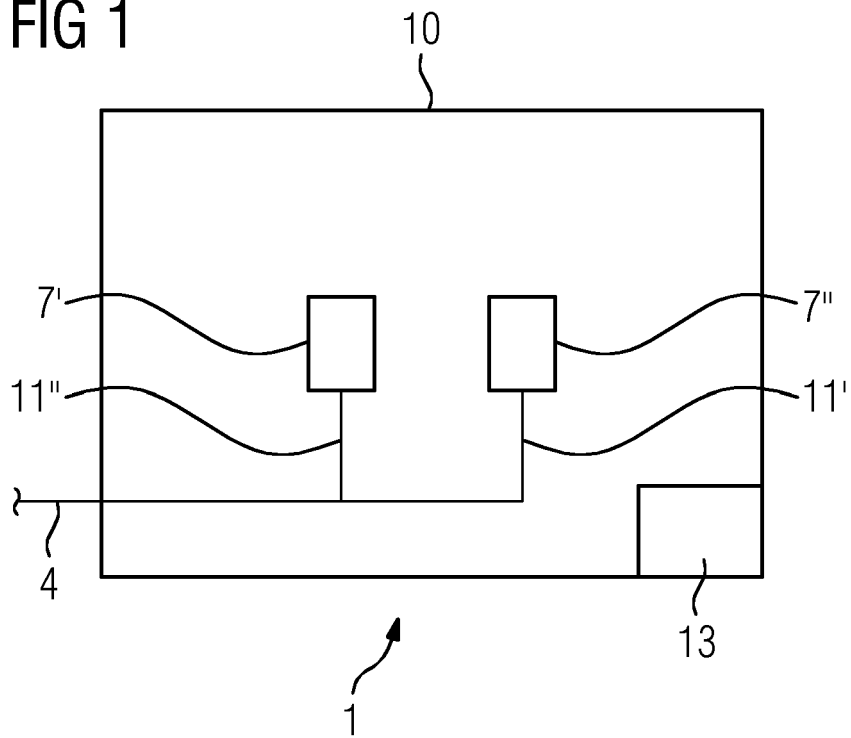


FIG 2

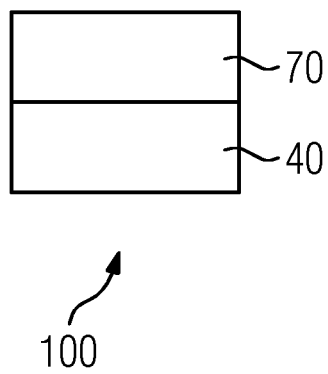
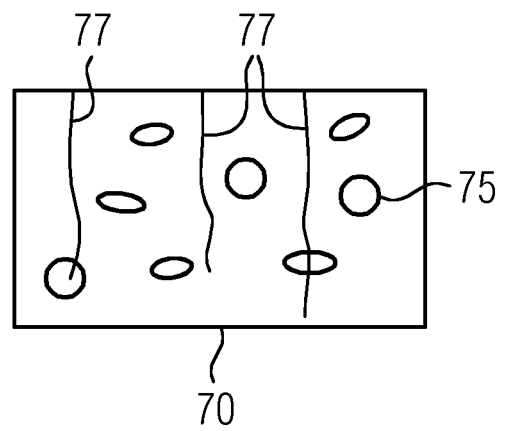


FIG 3





EUROPEAN SEARCH REPORT

 Application Number
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 20 February 2017	Examiner Tsipouridis, P
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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