(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 873 806 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**20.05.2015 Bulletin 2015/21**

(21) Application number: **13192899.6**

(22) Date of filing: **14.11.2013**

(51) Int Cl.:
***F01D 5/28*** *(2006.01)* ***F01D 5/18*** *(2006.01)*
***F01D 5/00*** *(2006.01)* ***C23C 28/00*** *(2006.01)*
***C23C 28/04*** *(2006.01)*

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**

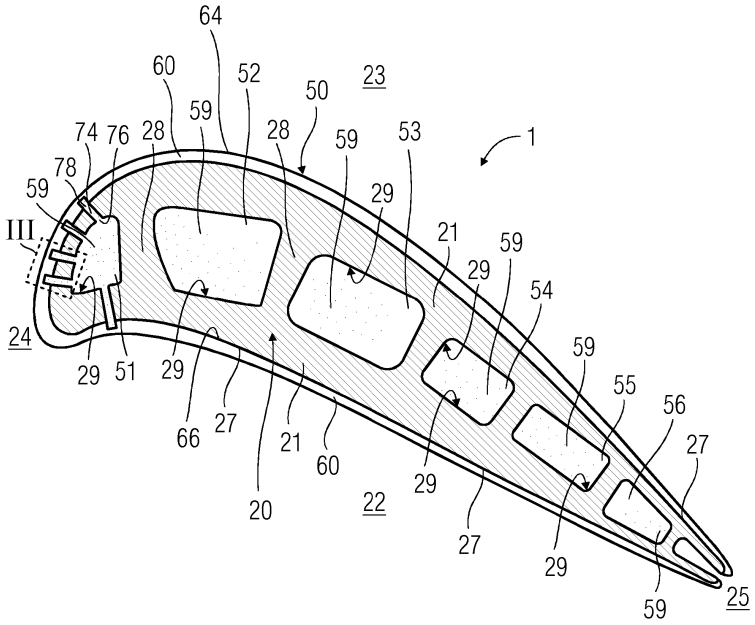
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(54) **A thermal barrier coating enhanced cooling arrangement for a turbomachine component**

(57) A turbomachine component including a base component and a thermal barrier coating (TBC) is provided. The base component includes an outer wall having an external and an internal surface. The outer wall surrounds a volume adjoining the internal surface. The cooling arrangement, a section of which is located in the volume, includes a cooling channel for guiding a cooling fluid. The TBC covers a part of the external surface and has an outer surface, an inner surface. The TBC includes first regions with a first coating thickness and second regions at defined locations with a second coating thickness that is less than the first coating thickness. Each second region is surrounded by at least one of the first regions. The inner surface of the TBC is fluidly connected to the cooling arrangement at the locations of the second regions.

FIG 3




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## Description

**[0001]** The present invention relates to a blade or a vane for a turbomachine and more particularly to an arrangement for achieving continuous cooling of the blade or the vane in case of a damage of a thermal barrier coating of the blade or the vane.

**[0002]** In the present application, for the sake of brevity only the term "blade" has been used, but the specifications and features can be transferred to a vane of a turbomachine without further modifications. It might be mentioned that the basic idea of the invention is also applicable for a platform of a blade or a platform of a vane.

**[0003]** In modern day turbomachines various components of the turbomachine operate at very high temperatures. Especially, turbine blades of the first stages of the turbomachines are thermally high loaded due to hot gas temperatures and high heat transfer coefficients caused by flow stagnation at the leading edges as well as high hot gas velocities.

**[0004]** The high temperatures during operation of the turbomachine may damage the blades. Therefore, the blades are coated with a ceramic thermal barrier coating (TBC) to reduce heat flux from the hot gas to the blade's base material which is typically a metal. This results in lower metal temperatures than without the TBC.

**[0005]** Furthermore, various methods of cooling of the blades are applied to achieve moderate temperatures during operation of the turbomachine.

**[0006]** For example, internal cooling is generally achieved by passing a cooling fluid through a core passage way cast into the blade component and into the airfoil of the blade, respectively. The airfoil portion of the blade is cooled by directing the cooling fluid to flow through multiple flow paths of the core passage way that are designed to maintain all aspects of the turbine blade at a relatively uniform temperature. Therewith, the cooling fluid is directed over the internal surfaces of the airfoils to achieve a cooling effect.

**[0007]** In addition to the internal cooling, film cooling holes are available through which the cooling fluid can exit the blade to create a separation in the form of a film of the cooling fluid between the blade surface and the hot gas flowing in vicinity of the blade surface. This results in external cooling of the blade. The film cooling holes are especially located at thermally high loaded areas of the blade and the airfoil such as the leading edge. The cooling fluid can be fed to the film cooling holes by the core passage way. The core passage ways and/or the cooling holes form a cooling arrangement of the blade.

**[0008]** However, with the need for increasing gas turbine efficiency, not only the temperatures of the hot gases are increased, but also the cooling fluid mass flow is decreased. This necessitates thicker TBC layers to ensure that the base metal temperatures during operation remain at levels which can still guarantee the structural integrity of the base material of the blade. Yet, a strong reliance on the TBC could lead to fatal failures of the blade in case the TBC cracks and gets lost so that the underlying base metal surface would be exposed. In that scenario and under the precondition of less cooling fluid mass flow, local temperatures higher than the melting point of the base metal can be reached. Such temperatures would compromise the mechanical integrity of the blade and lead to fatal failures within a time span which can be shorter than a typical inspection interval.

**[0009]** It is an object of the present technique to achieve a longer life time of a damaged turbomachine component. It has to be achieved that the functionality of the damaged component can be maintained until the next inspection.

**[0010]** The object is achieved by providing a component for a turbomachine according to claim 1 and a method for manufacturing a component for a turbomachine according to claim 14.

**[0011]** The approach of the present technique is to address the issue of local overheating, and resulting extremely high temperatures, by introducing regions of reduced thickness of the TBC, for example by implementing recesses in the TBC, at predefined areas of the TBC covering certain regions of the component. The regions of reduced thickness of the TBC are in fluid communication with the cooling holes that connect to the cooling arrangement for guiding a cooling fluid within the component. For example, the regions of reduced thickness can be located in the TBC covering a leading edge of an airfoil wall of a blade of the turbomachine and can be in fluid communication with the cooling channels inside the airfoil through cooling holes emanating from the cooling channels and running through the airfoil wall of the blade.

**[0012]** The regions of reduced thickness of the TBC are realized as predetermined breaking points of the TBC because of the reduced thickness of the TBC in these regions compared to a thickness of the TBC in other regions of the TBC. In case of loss of TBC caused by TBC spallations and/or foreign object damage, the regions of reduced thickness of the TBC will break faster than the other regions of the TBC owing to a thicker TBC in the other regions compared to the regions of reduced thickness of the TBC. This will open up the cooling holes which were earlier covered by the regions of reduced thickness of the TBC and thus the cooling fluid from the underlying core passage way or the cooling arrangements can exit the airfoil at regions affected by TBC loss, resulting in a film cooling effect. This cooling will protect the blade at least temporarily and guarantee a proper functioning until the next inspection. This helps in preventing a damaged component from complete failure at least until the next inspection of the component. In other words, the opened holes resulting from the breaking or loss of the TBC at the regions of reduced thickness will act as a cooling opening, without affecting the structural integrity of the blade.

**[0013]** According to a first aspect of the present technique, a component for a turbomachine is provided. The component includes a base component and a thermal

barrier coating (hereinafter referred to as, TBC). The base component includes an outer wall surrounding a volume and a cooling arrangement. The outer wall has an external surface and an internal surface. The internal surface adjoins at least a part of the volume and at least a section of the cooling arrangement is located in the volume, e.g. one of a plurality of cooling channels of the cooling arrangement which are used for guiding a cooling fluid. The TBC covers at least a part of the external surface of the outer wall. The TBC has an outer surface, an inner surface facing the external surface of the outer wall, and a plurality of thicknesses. The TBC includes first regions with at least one first coating thickness and second regions at defined locations of the TBC with at least one second coating thickness. The second coating thickness is less than the first coating thickness. Each second region is surrounded by at least one of the first regions. Therein, the term "surrounded" includes an arrangement in which the second region is arranged in between two first regions, i.e. those first regions are arranged on either side of the particular second region. For example, this scenario might occur in case the second region comprises a lengthy slot, as will be described later, and the two first regions are located on both sides of the lengthy slot. The inner surface of the TBC is fluidly connected to the cooling arrangement at least at the locations of the second regions.

**[0014]** Thus, in case of loss of TBC, resulting from foreign object damage and/or spallation of TBC and/or melting of the TBC and/or by other TBC damaging phenomenon, the TBC will break first at the second region generating a break or space or crack in the TBC which will be in fluid communication with the cooling arrangement of the base component and thus initiating a flow of the cooling fluid from the cooling arrangement through the break in TBC and into a region in and around the TBC damage. Thus as a result of the break in the TBC in the second regions, the cooling fluid is enabled to stream through the break in the TBC to achieve a film cooling effect in the regions of the TBC surrounding the break. This film cooling effect protects the component and the TBC surrounding the break against further melting such that a longer life time is achieved despite the loss of TBC.

**[0015]** In one embodiment of the component, the cooling arrangement further comprises at least one cooling hole fluidly connecting the inner surface of the TBC to the cooling channel. The cooling hole has an inlet located at the internal surface of the outer wall and an outlet located at the external surface of the outer wall. Thus the second regions can be located such that when the TBC at the second region gets damaged the cooling holes of the base component are opened up. This helps in selecting the defined locations of the second regions with ease.

**[0016]** In another embodiment of the component, at least one of the second regions comprises a recess with a three dimensional shape. At least a part of the recess is located on the inner surface of the TBC such that the inner surface is fluidly connected to the cooling arrangement via the recess. Such a recess can be manufactured easily and it results in the reduced wall thickness in the second regions of the TBC.

**[0017]** Therein, the three dimensional shape of the recess is such that a diameter of the recess increases with a decreasing thickness of the TBC which might occur due to TBC spallation and/or erosion of the TBC and/or TBC melting. Thus, when the TBC breaks open, a hole is generated that continues to increase in diameter with reduction in thickness of the TBC, allowing a stronger flow of the cooling fluid through the hole with increase in the TBC damage. This measure achieves in an increased cooling effect with gradually increasing damage of the TBC.

**[0018]** In one embodiment, the recess has a star-shaped cross section in a direction of viewing perpendicular to the TBC. This increases the wetted surface in the recess and the hole, respectively, so that a stronger heat transfer can be achieved.

**[0019]** In another embodiment, the three dimensional shape is a lengthy slot with an extension in a first direction along the TBC being significantly larger than the extensions in the other directions. Therein, the term "significantly" refers to dimensions of the extension in the first direction which are larger than the other two dimensions by a factor of 3 or more. The extension in the first direction might be such that the one or more of the lengthy slots forms a closed loop around the circumference of the component. With this approach, large parts of the component span or chord can be covered and the probability that TBC is lost in an area without a second region is reduced significantly.

**[0020]** In a further embodiment, the three dimensional shape is a conic shape, a pyramidal shape, or a half dome shape. Therein, the corresponding recesses are arranged such that the axis of symmetry of these shapes is perpendicular to the TBC. Such shapes can be manufactured easily and they achieve that the diameter of the recess increases with a decreasing thickness of the outer wall, resulting in an increased cooling effect with decreasing TBC thickness.

**[0021]** Therein, the three dimensional shape is a truncated shape with a first flat surface A at a base of the shape and a second flat surface B at a top of the shape, wherein an area of the second surface B at the top of the shape is lesser than an area of the first surface A at the base of the shape. Again, such shapes can be manufactured easily and they achieve that the diameter of the recess increases with a decreasing thickness of the TBC, resulting in an increased cooling effect with decreasing TBC thickness.

**[0022]** In another embodiment, the three dimensional shape is cylinder or a box with at least two parallel surfaces A, B, wherein the three dimensional shape comprises a first flat surface A at a base of the shape and a second flat surface B at a top of the shape. The corresponding recess would again be arranged such that the axis of symmetry of the cylinder is perpendicular to the

TBC at the location of the recess.

**[0023]** The recess is oriented such that the first surface A of the shape is facing to the inner surface of the TBC and the second surface B is facing to the outer surface of the TBC. The first surface A and the second surface B are essentially parallel to the TBC. With the above explained features of the surfaces A, B, an improved cooling effect is achieved with decreasing wall thickness.

**[0024]** During operation of the turbomachine, the base component typically comprises zones with different thermal loads, i.e. at least a zone with highest thermal load, a zone with medium thermal load, and a zone with lowest thermal load. The second regions are located in the zone with highest thermal load. In that zone, the probability of damages is highest, so that the arrangement of the second regions in that zone guarantees the best protection with least efforts.

**[0025]** In another embodiment of the component of the turbomachine, the base component comprises a leading edge zone and a trailing edge zone, and the second regions are located in the leading edge zone.

**[0026]** In another embodiment of the component of the turbomachine, the base component is an airfoil of a blade or a vane.

**[0027]** According to a second aspect of the present technique, a method for manufacturing a component for a turbomachine is presented. The method includes a step of providing an insert in a cooling hole of a base component. The insert at least comprises a protrusion projecting outside the cooling hole and beyond an external surface of the base component. The protrusion corresponds to a recess with a three dimensional shape to be generated on an inner surface of a TBC. The method further includes a step of applying the TBC on the external surface of the base component with the insert, such that the protrusion of the insert is completely embedded in the TBC. Finally, the method includes a step of removing the insert from the cooling hole of the base component such that the recess with the three dimensional shape is formed in the TBC.

**[0028]** In an embodiment of the method, the step of applying the TBC includes a step of applying a bond coat after providing the insert in the cooling hole of the base component and a step of applying a top coat after applying the bond coat.

**[0029]** The above-mentioned and other features of the present technique will now be addressed with reference to the accompanying drawings. The illustrated embodiments are intended to illustrate, but not limit the invention. The drawings contain the following figures, in which like numbers refer to like parts, throughout the description and drawings.

FIG 1 schematically represents a perspective view of a blade of a turbomachine;

FIG 2 schematically represents a cross-sectional view of an airfoil of the blade without TBC;

FIG 3 schematically represents a cross-sectional view of the airfoil of the blade with TBC;

FIG 4 depicts an enlarged view of the section III of FIG 3 with an intact TBC;

FIG 5 depicts an enlarged view of the section III with a damaged TBC;

FIG 6 depicts the shape of a cylindrical recess;

FIG 7 depicts the shape of a conic recess;

FIG 8 depicts the shape of a pyramidal recess;

FIG 9 depicts the shape of a cubic recess;

FIG 10 depicts the shape of a recess in the form of a lengthy slot;

FIG 11 depicts the shape of a half-dome recess;

FIG 12 depicts a star-like cross section of a recess;

FIG 13 schematically represents a hexagonal distribution of recesses;

FIG 14 schematically represents a triangular distribution of recesses;

FIG 15 schematically represents a quadratic distribution of recesses;

FIG 16 is a flow chart depicting a method for manufacturing a component for a turbomachine;

FIG 17 schematically represents an insert in a cooling hole of a base component;

FIG 18 schematically represents the insert embedded in the TBC applied to the base component; and

FIG 19 schematically represents a recess formed in the TBC after removing the insert depicted in FIGs 17 and 18, in accordance with aspects of the present technique.

**[0030]** Embodiments of the present invention described below relate to a blade component in a turbomachine. However, the details of the embodiments described in the following can be transferred to a vane component without modifications, that is the terms "blade" or "vane" can be used in conjunction, since they both have the shape of an airfoil with an integrated cooling arrangement in the form of a core passage way comprising one or multiple flow paths through which a cooling fluid is directed. The turbomachine may include a gas turbine,

a steam turbine, a turbofan and the like.

**[0031]** The present invention relates to a component of a turbomachine, especially to a blade. The blade is connected to a rotor of said turbomachine, wherein the rotor with the blade is rotatable around an axis of rotation. Herein, any term describing a direction like "radial" or "axial" is with reference to the axis of rotation of the rotor, i.e. a radial direction means a direction perpendicular to the axis of rotation of the rotor and an axial direction is in parallel to the axis of rotation.

**[0032]** FIG 1 shows a schematic diagram of an exemplary blade 1 of a rotor (not shown) of a turbomachine (not shown), such as a gas turbine. The blade 1 includes an airfoil portion 20, a root portion 30, and a platform portion 40. The airfoil portion 20 projects from the root portion 30 in a radial direction and the platform portion 40 is located between the airfoil portion 20 and the root portion 30. Thus, the airfoil portion 20 extends radially along a longitudinal direction of the blade 1.

**[0033]** The blade 1 is attached to a body of the rotor (not shown), in such a way that the root portion 30 is attached to the body of the rotor whereas the airfoil portion 20 is located at a radially outermost position. The platform portion 40 is attached to the radial outer surface of the rotor. Platform portions of neighbouring blades form an essentially cylindrical surface.

**[0034]** Moreover, the blade 1 and the airfoil portion 20 comprises a cooling arrangement 50 (not visible in FIG 1), typically with a plurality of cooling paths and cooling cavities. During operation of the turbomachine, a cooling fluid 59 (not visible in FIG 1) is directed through the cooling arrangement 50 to maintain a suitable temperature of the blade 1 and the airfoil 20, respectively.

**[0035]** FIG 2 shows a cross-sectional view of the airfoil 20 without a thermal barrier coating in a radial direction, including a simplified version of the cooling arrangement 50 with a plurality of cooling channels 51-56.

**[0036]** The airfoil portion 20 has a pressure side 22 and a suction side 23. The pressure side 22 and the suction side 23 are joined together along a leading edge 24 and a trailing edge 25. The leading edge 24 and the trailing edge 25 extend along the radial direction.

**[0037]** The airfoil 20 comprises an outer wall 21 with at least one internal surface 29 and an external surface 27. The outer wall 21 surrounds a volume in which the cooling arrangement 50 is arranged. The internal surface 29 adjoins at least a part of the volume. Moreover, the volume contains ribs 28, which are arranged to divide the cooling channels 51-56 inside the airfoil 20, wherein the ribs 28 are usually only slightly thicker than the outer wall 21. The channels 51-56 of the cooling arrangement 50 might be interconnected in a serpentine manner or they are connected to a separating cavity via which the cooling fluid 59 would be provided. For the sake of brevity, the cooling arrangement 50 is not described herein in more detail since its design is not an essential part of the present technique. It is sufficient to mention that the cooling arrangement 50 has a cooling path along which the cooling fluid 59 is directed. The cooling path extends along the channels 51-56.

**[0038]** The cooling path and the channels 51, respectively, is fluidly connected with the internal surface 29 of the outer wall 21 of the airfoil 20, such that during operation of the turbomachine, when the cooling fluid 59 is streaming through the cooling arrangement 50 and through the channels 51 along the cooling path, the cooling fluid 59 is in connection with the internal surface 29 of the outer wall 21, so that a heat transfer from the internal surface 29 to the cooling fluid 59 is achieved. Furthermore, the cooling arrangement 50 may include at least one cooling hole 74 emanating from and fluidly connected to the cooling channel 51. The cooling hole 74 has an inlet 76 located at the internal surface 29 of the outer wall 21 and an outlet 78 located at the external surface 27 of the outer wall 21. Thus when the cooling fluid 59 is streaming through the cooling channel 51 of the cooling arrangement 50, the cooling fluid 59 also streams through the cooling hole 74.

**[0039]** It might only be mentioned, that in cases in which the cooling arrangement 50 is more complicated than the arrangement shown in FIG 2, one or more cooling channels might be arranged such that they are not fluidly connected to the internal surface 29 of the outer wall 21. However, in the embodiment shown in FIG 2 all channels 51-56 of the cooling arrangement 50 are fluidly connected to a section of the internal surface 29 of the outer wall 21.

**[0040]** In accordance with aspects of the present technique, the airfoil 20 may be a base component 20 that is at least partially covered by a thermal barrier coating (TBC) 60, as schematically depicted in FIG 3.

**[0041]** Referring to FIG 3, in combination with FIG 4 that depicts a rotated and enlarged view on section III marked in FIG 3, in accordance with aspects of the present technique, a component 1, i.e. the blade 1, for the turbomachine is provided. The component 1 includes the base component 20, i.e. the airfoil 20, and the TBC 60. The TBC 60 covers at least a part of the external surface 27 of the outer wall 21. The TBC 60 has an outer surface 64, an inner surface 66 facing the external surface 27 of the outer wall 21, and a plurality of thicknesses d1, d2 (visible in FIG 4). The TBC 60 includes first regions 71 in which the TBC 60 has a first coating thickness d1. Furthermore, the TBC 60 includes second regions 72 in which the TBC 60 has a second coating thickness d2 at defined locations of the TBC 60. The thickness d2 of the coating in the second regions 72 of the TBC 60 is less than the thickness d1 of the coating in the first regions 71 of the TBC 60, i.e. $d2<d1$. Thus, the TBC 60 has an inconsistent or nonuniform or heterogeneous thicknesses d1, d2 at different regions of the TBC 60. The coating thicknesses d1, d2 as used herein are measures for the extension of the TBC 60 from the external surface 27 of the outer wall 21 and in a direction perpendicular to the outer wall 21. Any gap or separation or space between the TBC 60 and the outer wall 21 are not included in the

coating thicknesses d1, d2.

**[0042]** For example, the TBC 60 may comprise recesses 73 of a certain three dimensional (3D) shape in the second regions 72. At the location of a recess 73, the thickness d2 of the TBC 60 is less than the thickness d1 in regions surrounding the recess 73, i.e. the first regions 71.

**[0043]** At least at the locations of the second regions 72, the inner surface 66 of the TBC 60 is fluidly connected with the cooling arrangement 50 and the cooling channels 51-56, respectively. Thus, in case the cooling fluid 59 is directed through the cooling channels 51-56 of the cooling arrangement 50, the cooling fluid 59 gets in contact with the second regions 72 at the inner surface 66 of the TBC 60. In embodiments including the recess 73, at least a part of the recess 73 is located on the inner surface 66 of the TBC 60 and thus the inner surface 66 is fluidly connected to the cooling arrangement 50 via the recess 73.

**[0044]** Preferably, as shown in the example of FIG 3, the second regions 72 with the recesses 73 are located in a zone of the airfoil 20, i.e. the base component 20, which has the highest thermal load during operation of the turbomachine. Such a zone would be located at the leading edge 24. Thus, the second regions 72 with reduced thickness d2 of the TBC 60 are preferably located at least at the external surface 27 of the outer wall 21 around the outlet 78 of the cooling hole 74 emanating from the particular cooling channel 51 which is located at the leading edge 24.

**[0045]** The TBC 60, as depicted in FIG 4, may optionally include separate layers or coats, for example a bond coat 61 and a top coat 62. Typically in the TBC 60, the bond coat 61 is arranged between external surface 27 of the outer wall 21 and the other layers of the TBC 60 such as the top coat 62. The top coat 62 may be formed of a ceramic material for example yttria-stabilized zirconia (YSZ) and the bond coat may be formed of a metallic bond material such as mercury based alloy.

**[0046]** In accordance with aspects of the present technique, the material of the outer wall 21 may comprise one or more metals or alloys and on the metal surface of the outer wall 21 the TBC 60 is applied. The applied TBC 60 at the second regions 72 covers the cooling holes 74, and only in an event when the TBC 60 at the second regions 72 is damaged or develops a break by loss due to foreign object damage and/or spallations of the TBC 60 and/or melting of the TBC 60, the cooling holes 74 open up and become active i.e. conduct a flow of the cooling fluid 59 from the cooling channel 51 onto the damaged TBC region.

**[0047]** The section III of FIG 3 is represented in FIGs 4 and 5. The section III depicts the outer wall 21, the TBC 60, hot gas 80, first and second regions 71, 72, recesses 73, and the particular cooling channel 51. FIG 4, as explained earlier, depicts an enlarged view of the section III of FIG 3 with an intact TBC 60, whereas FIG 5 depicts an enlarged view of the section III of with a damaged TBC 60.

**[0048]** FIG 5 depicts an exemplary situation in which the TBC 60 is damaged and a part of the TBC 60 has been lost. Therewith, one of the cooling holes 74 i.e. the cooling hole 74-1 opens up and becomes active.

**[0049]** In accordance with aspects of the present technique, under the influence of damaging causes such as TBC spalling and/or damages caused by foreign objects, the TBC 60 at the second regions 72 will be damaged before the TBC 60 at the first regions 71 breaks because the coating thickness d2 in the second region 72 at the location of the recess 73 is less that the coating thickness d1 in the first region 71, i.e. in the region surrounding the recess 73. Thus, the TBC 60 in the second region 72 will break before the TBC 60 in the surrounding first region 71.

**[0050]** This results in a break 79 in the TBC 60 at the second region 72, as depicted in FIG 5. The break 79 fluidly connects to the recess 73 which in turn is fluidly connected to the cooling hole 74 which subsequently is connected to the cooling channel 51 of the cooling arrangement 50. Thus, as a result of breaking of the TBC 60 in the second region 72, a fluid connection is established between the cooling channel 51 and the broken region of the TBC 60. As a result, the cooling fluid 59 streaming through the cooling arrangement 50 will pass through the break 79 and portions of the cooling fluid 59 will leave the blade 1 through the break 79. This results in a protective film 75 of the cooling fluid 59 and a film cooling effect at the location of the damage or the break 79 of the TBC 60 so that further damage of the TBC 60 in and around the break 79 and subsequent damages to the base component 20 by total loss of the TBC 60 are avoided.

**[0051]** The break 79 would be detected with the next inspection interval and the blade would be repaired. However, it can be assured that the blade can be used for normal operation in spite of the local damage.

**[0052]** As mentioned earlier, the airfoil 20 i.e. the base component 20, typically comprises zones with different thermal loads during operation of the turbomachine. The thermal load will be highest in a zone around the leading edge 24 and lowest in a zone around the trailing edge 25. In an intermediate zone between the leading edge 24 and the trailing edge 25, thermal load will be medium. Preferably, the second regions 72 are located only in the zone with highest thermal load, i.e. in the zone around the leading edge 24. Additionally, second regions 72 might be located in the intermediate zone.

**[0053]** For example, in areas prone to loss of the TBC 60, a distance between neighboring second regions 72 should be less than 10mm in all directions along the outer wall 21. This is especially applicable in the leading edge zone.

**[0054]** As mentioned above and as illustrated in FIG 6, the recesses 73 have a certain three dimensional (3D) shape. For example, the recess 73 can be cylindrical, wherein the recess 73 would be arranged such that the

axis of symmetry of the cylinder is perpendicular to the outer wall 21 at the location of the recess 73.

**[0055]** Alternatively, the recess 73 can be conical. Preferably, the conical shape is only a section of a full cone, i.e. a truncated cone or a conic section, as shown FIG 7. The shape has a first flat surface A at the base and a second flat surface B at the top. The cross-sections of those surfaces A, B can be round or oval. The area of the surface B at the top is less than the area of the surface A at the base of the conic section.

**[0056]** In another alternative, the recess 73 has a pyramidal shape. Preferably, the pyramidal shape is only a section of a full pyramid, i.e. a truncated pyramid or a pyramidal section, as shown FIG 8. The shape has a first flat surface A at the base and a second flat surface B at the top. The cross-sections of the surfaces A, B can be rectangular, especially square. The area of the surface B at the top is less than the area of the surface A at the base of the pyramidal section.

**[0057]** In another alternative, the recess 73 is box shaped. Therein, the box might be cubic, cuboid, or rectangular cuboid, as shown FIG 9.

**[0058]** In a special embodiment, the extension of the boxed shaped recess 73 in one particular direction parallel to the TBC 60, i.e. to the inner surface 66 or the outer surface 64 of the TBC 60, is substantially larger than the extensions in the other two directions, as shown in FIG 10. Thus, the recess 73 has the shape of a lengthy slot. The extension in the particular direction might be such that one or more of the lengthy slot form a closed loop around the circumference of the airfoil 20 i.e. the base component 20. With this approach, large parts of the airfoil span or chord can be covered and the probability that TBC 60 is lost in an area without a second region 72 is reduced significantly.

**[0059]** In another alternative, the recess 73 has the shape of a half dome. Preferably, the domed shape is only a section of a full half dome, i.e. a truncated half dome, as shown FIG 11. The shape has a first flat surface A at the base and a second flat surface B at the top. The cross-sections of those surfaces A, B can be round or oval. The area of the surface B at the top is less than the area of the surface A at the base of the conic section.

**[0060]** In case of the conic shape, the pyramidal shape, and the half dome shape, the recess 73 is oriented such that the larger base surface A of the shape is facing the inner surface 66 of the TBC 60 and the smaller top surface B is facing the outer surface 64 of the TBC 60. Both the top surface B and the base surface A are essentially parallel to the TBC 60 surfaces 64, 66. In general, the shape of the recess 73 increases in diameter with a decreasing thickness of the TBC 60 due to foreign object damage and/or spallations of the TBC 60 and/or melting to increase cooling flow and thereby increase cooling.

**[0061]** For example, the equivalent diameter of the cross-section area of the recess 73 can be between 0.0 and 0.7mm at the top and between 0.2 and 1.5mm at the base.

**[0062]** As an additional measure to increase heat transfer of an opened up break 79, the whole cross-section of the recess 73 in a direction of viewing perpendicular to the TBC 60 at the location of the recess 73 can be shaped like a star instead of a circle or a rectangle etc., as shown in FIG 12 in a direction of viewing perpendicular to the TBC 60. This measure increases the so called wetted surface, i.e. the surface of the film 75 on the surface of the TBC 60 at the location of the break 79 and its surroundings, and, therewith, the heat transfer to the cooling fluid 59.

**[0063]** It may be noted that the recess 73 may be filled up with a metal or a polymer insert (not shown), wherein the metal or the polymer insert is such that the metal or the polymer insert vaporizes or melts when exposed to the hot gas 80. Thus, as soon as the break 79 is introduced in the second regions 72 of the TBC 60 and the metal or the polymer insert is exposed to the hot gas 80 it melts or vaporizes establishing the fluid connection between the break 79 and the cooling channel 51. A part of the insert may also be present in the cooling hole 74 (as shown in FIG 4 and 5) and this part also vaporizes on exposure to the hot gas 80.

**[0064]** In one embodiment, the first regions 71 are interconnected with each other, i.e. practically the first regions 71 form an uniform, extended surface and the second regions 72 with the recesses 73 are depressions in the uniform, extended surface 71. Thus, the recesses 73 and the second regions 72, respectively, are not interconnected i.e. not connected to the other recesses 73 and the other second regions 72. The second regions 72 can be distributed in the extended surface 71 according to a certain pattern. For example, the pattern can be a hexagonal pattern with the second regions 72 and the recesses 73 located on the corners of the hexagons of the pattern, as shown in FIG 13. Alternatively, the pattern might be a triangular (FIG 14) or a quadratic pattern (FIG 15) consisting of a plurality of regular triangles or squares, respectively, with the second regions 72 located at the corners of the triangles or squares. In FIGs 12, 13, and 14, only few of the second regions 72 have been marked with reference signs.

**[0065]** In accordance with aspects of the present technique, a method 1000 for manufacturing a component 1 for a turbomachine is presented, as depicted by flow chart of FIG 16, in combination with FIGs 17, 18 and 19. The method 1000 includes a step 500 of providing an insert 90 in a cooling hole 74 of a base component 1. The objective of the method 1000 is to manufacture the component 1 as described in accordance with the first aspect of the present technique and explained with respect to FIGs 1 to 15. FIG 17 schematically represents the insert 90 in the cooling hole 74 of the base component 20. The insert 90 at least includes a protrusion 92 projecting outside the cooling hole 74 and beyond an external surface 27 of the base component 20. The protrusion 92 corresponds to a recess 73 with a three dimensional shape to be generated on an inner surface 66 of a TBC 60. The

base component 20, the cooling arrangement 60 with the cooling channel 51 and the cooling hole 74, the TBC 60 and the recess 73 are similar to as explained in reference to FIGs 1 to 15 while describing the component 1.

**[0066]** The insert 90 may be formed of a polymer or a metallic material. The insert 90 may be completely formed before being provided or inserted into the cooling hole 74 or may be applied as a viscous fluid which solidifies inside the cooling hole 74 and thus gets formed.

**[0067]** The method 1000 further includes a step 550 of applying the TBC 60 on the external surface 27 of the base component 20 with the insert 90, such that the protrusion 92 of the insert 90 is completely embedded in the TBC 60. FIG 18 schematically represents the protrusion 92 of the insert 90 embedded in the TBC 60 applied to the base component 20.

**[0068]** In an embodiment of the method 1000, the step 550 of applying the TBC 60 includes a step 520 of applying a bond coat 61 after providing 500 the insert 90 in the cooling hole 74 of the base component 20 and a step 540 of applying a top coat 61 after applying 520 the bond coat 61.

**[0069]** Finally, the method 1000 includes a step 600 of removing the insert 90 from the cooling hole 74 of the base component 20 such that the recess 73 with the three dimensional shape is formed in the TBC 60. FIG 19 schematically represents the recess 73 formed in the TBC 60 after removing the insert 90 as was depicted in FIGs 17 and 18. In one embodiment of the method 1000, the insert 90 is removed either by directly physically removing the insert 90 in the same form as it was when it was provided into the cooling hole 74 in the step 500. This can be achieved by pulling out the insert 90 from the cooling hole 74. In another embodiment, the insert 90 may be removed by melting or vaporising of the insert 90 after the step 550 is performed.

**[0070]** Although the invention has been described with reference to specific embodiments, this description is not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternate embodiments of the invention, will become apparent to persons skilled in the art upon reference to the description of the invention. It is therefore contemplated that such modifications can be made without departing from the embodiments of the present invention as defined.

## Claims

**1.** A component (1) of a turbomachine, comprising:

- a base component (20) comprising
  - an outer wall (21) surrounding a volume, the outer wall (21) having an external surface (27) and an internal surface (29), wherein the internal surface (29) is adjoining at least a part of the volume,
  - a cooling arrangement (50) with at least one cooling channel (51-56) adapted to guide a cooling fluid (59) in the base component (20) and wherein at least a section (51) of the cooling arrangement (50) is located in the volume, and
- a thermal barrier coating (60) covering at least a part of the external surface (27) of the outer wall (21), the thermal barrier coating (60) having an outer surface (64), an inner surface (66) facing the external surface (27) of the outer wall (21) of the base component (20), and a plurality of thicknesses (d1, d2) of the thermal barrier coating (60),

wherein thermal barrier coating (60) comprises

- first regions (71) with at least one first coating thickness (d1),
- second regions (72) at defined locations of the thermal barrier coating (60) with at least one second coating thickness (d2), wherein each second region (72) is surrounded by at least one of the first regions (71) and wherein the second coating thickness (d2) is less than the first coating thickness (d1),

and wherein

- the inner surface (66) of the thermal barrier coating (60) is fluidly connected to the cooling arrangement (50) at least at the locations of the second regions (72).

**2.** The component (1) according to claim 1, wherein the cooling arrangement (50) further comprises at least one cooling hole (74) fluidly connecting the inner surface (66) of the thermal barrier coating (60) to the cooling channel (51-56), the cooling hole (74) having an inlet (76) located at the internal surface (29) of the outer wall (21) and an outlet (78) located at the external surface (27) of the outer wall (21).

**3.** The component (1) according to claim 1 or 2, wherein at least one of the second regions (72) comprises a recess (73) with a three dimensional shape, wherein at least a part of the recess (73) is located on the inner surface (66) of the thermal barrier coating (60) such that the inner surface (66) of the thermal barrier coating (60) is fluidly connected to the cooling arrangement (50) via the recess (73).

**4.** The component (1) according to claim 3, wherein the three dimensional shape of the recess (73) is such that a diameter of the recess (73) increases with a decreasing thickness (d2) of the thermal barrier coating (60).

5. The component (1) according to claim 3 or 4, wherein the recess (73) has a star-shaped cross section in a direction of viewing perpendicular to the thermal barrier coating (60).

6. The component (1) according to claim 3 or 4, wherein the three dimensional shape is a lengthy slot with an extension in a first direction along the thermal barrier coating (60) being significantly larger than the extensions in the other directions.

7. The component (1) according to claim 3 or 4, wherein the three dimensional shape is a conic shape, a pyramidal shape, or a half dome shape.

8. The component (1) according to claim 7, wherein the three dimensional shape is a truncated shape with a first flat surface (A) at a base of the shape and a second flat surface (B) at a top of the shape, wherein an area of the second surface (B) at the top of the shape is lesser than an area of the first surface (A) at the base of the shape.

9. The component (1) according to claim 3 or 4, wherein the three dimensional shape is cylinder or a box with at least two parallel surfaces (A, B), wherein the three dimensional shape comprises a first flat surface (A) at a base of the shape and a second flat surface (B) at a top of the shape.

10. The component (1) according to claim 8 or 9, wherein the recess (73) is oriented such that the first surface (A) of the shape is facing the inner surface (66) of the thermal barrier coating (60) and the second surface (B) is facing the outer surface (64) of the thermal barrier coating (60), wherein both the first surface (A) and the second surface (B) are essentially parallel to the thermal barrier coating (60).

11. The component (1) according to any of claims 1 to 10, wherein the base component (20) comprises zones with different thermal loads during operation of the turbomachine, wherein the second regions (72) are located in the zone with highest thermal load.

12. The component (1) according to any of claims 1 to 11, wherein the base component (20) comprises a leading edge (24) zone and a trailing edge (25) zone, wherein the second regions (72) are located in the leading edge (24) zone.

13. The component (1) according to any of claims 1 to 12, wherein the base component (20) is an airfoil of a blade or a vane.

14. A method (1000) for manufacturing a component (1) for a turbomachine, the method (1000) comprising:

- a step (500) of providing an insert (90) in a cooling hole (74) of a base component (20), wherein the insert (90) at least comprises a protrusion (92) projecting outside the cooling hole (74) and beyond an external surface (27) of the base component (20), the protrusion (92) corresponding to a recess (73) with a three dimensional shape to be generated on an inner surface (66) of a thermal barrier coating (60), wherein the recess (73) is according to any of claims 3 to 10,
- a step (550) of applying the thermal barrier coating (60) on the external surface (27) of the base component (20) with the insert (90), such that the protrusion (92) of the insert (90) is completely embedded in the thermal barrier coating (60), and
- a step (600) of removing the insert (90) from the cooling hole (74) of the base component (20) such that the recess (73) with the three dimensional shape is formed in the thermal barrier coating (60).

15. The method (1000) according to claim 14, wherein the step (550) of applying the thermal barrier coating (60) comprises a step (520) of applying a bond coat (61) after providing (500) the insert (90) in the cooling hole (74) of the base component (20) and a step (540) of applying a top coat (62) after applying (520) the bond coat (61).

FIG 1

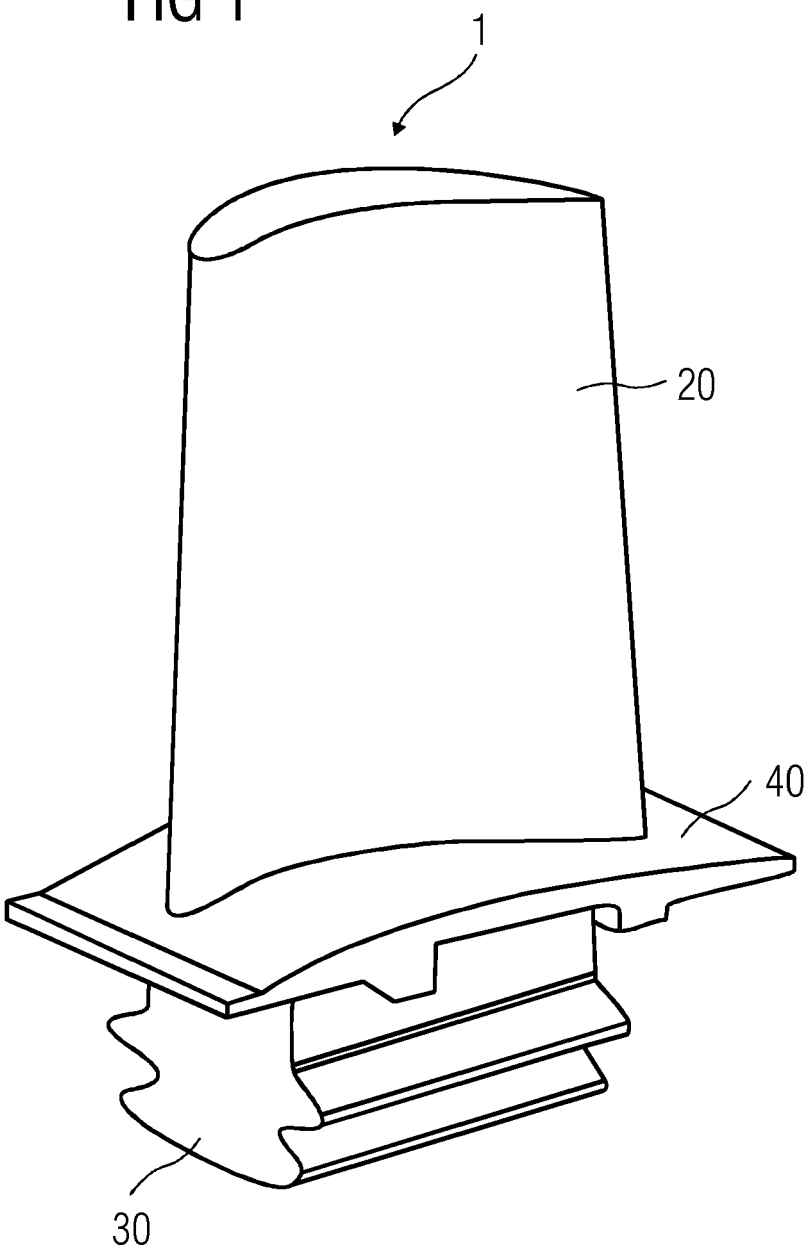


FIG 2

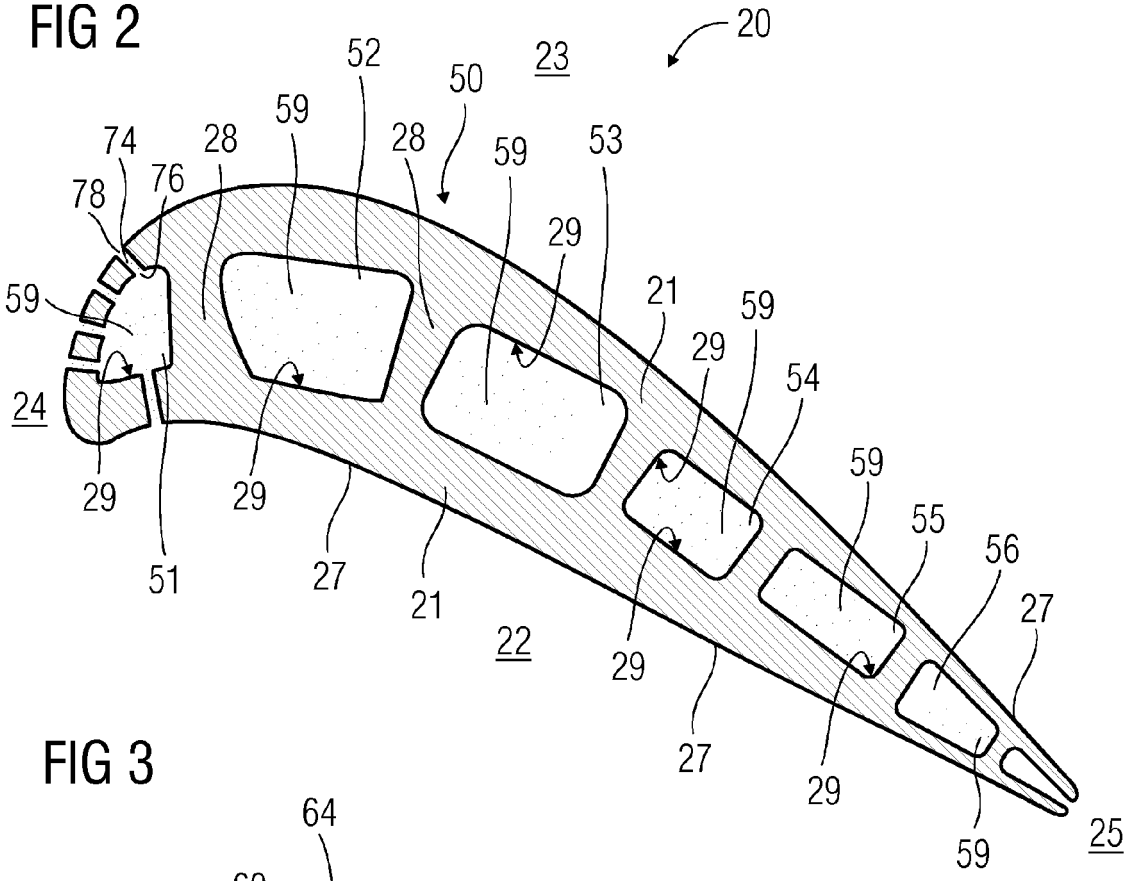

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FIG 3

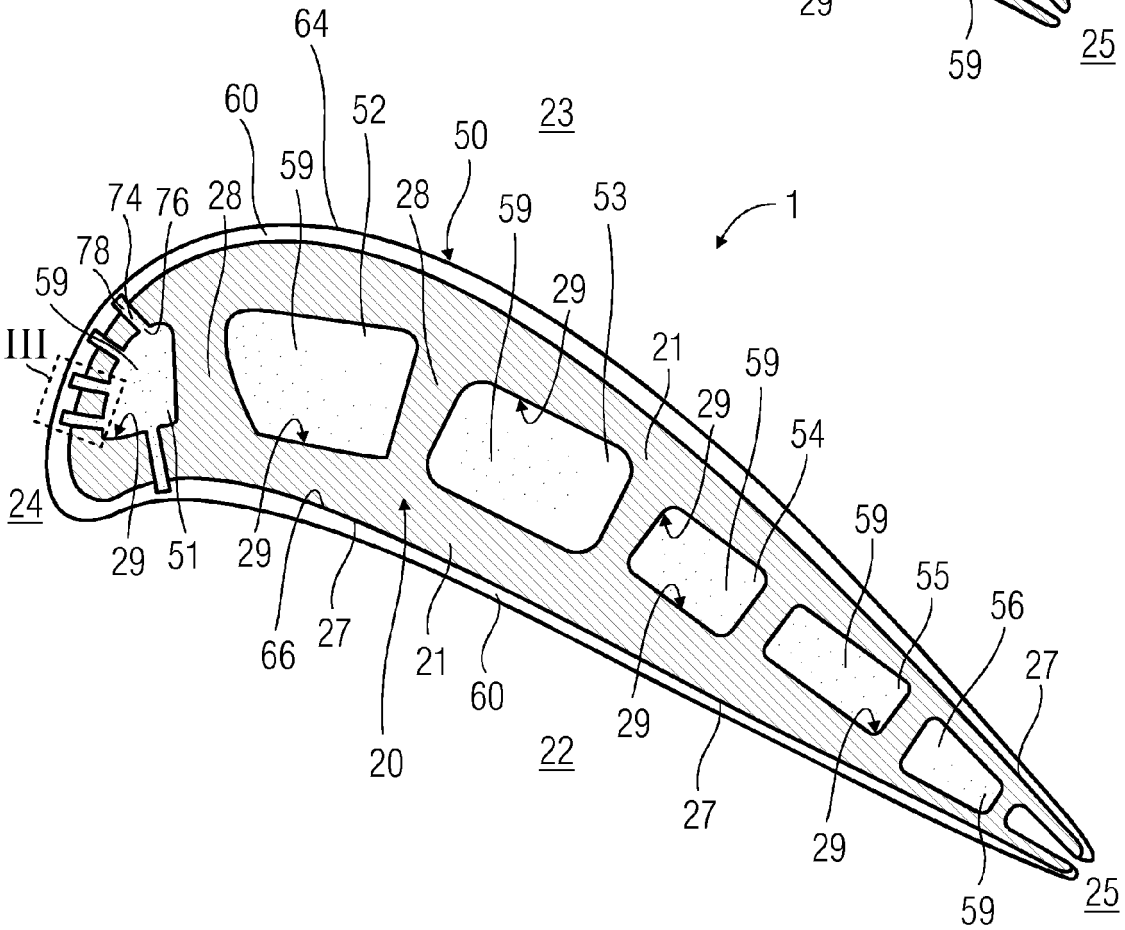

64
60
52
23
50
59
74
76
28
28
59
53
1
78
59
29
III
21
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29
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24
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66
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59
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FIG 4

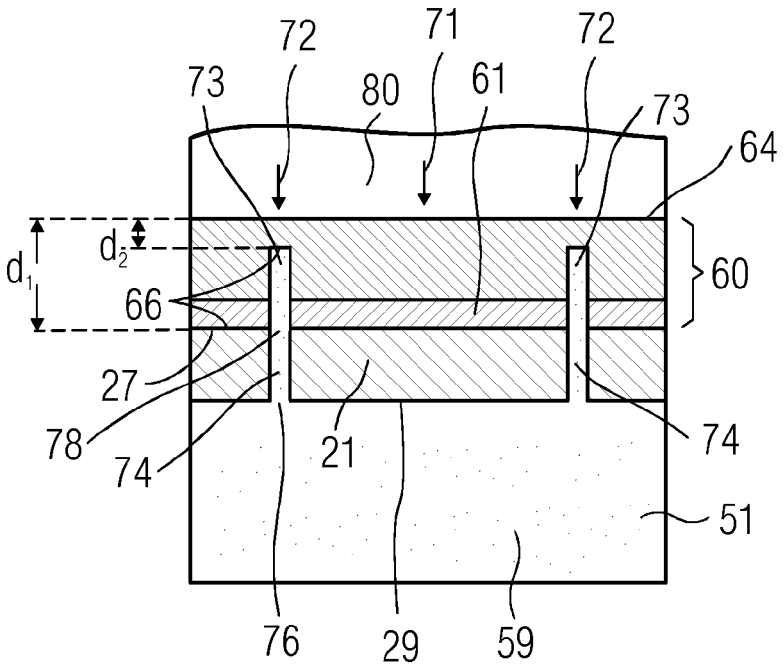

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71
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73
80
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d2
d1
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66
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21
74
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76
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FIG 5

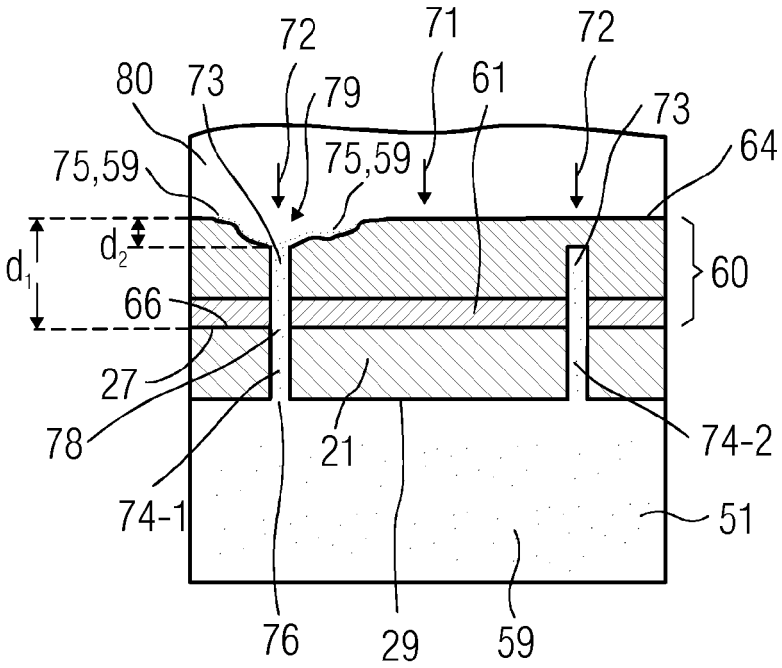

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80
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64
75,59
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d2
d1
60
66
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78
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74-2
74-1
51
76
29
59

FIG 6

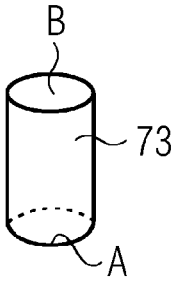



FIG 7

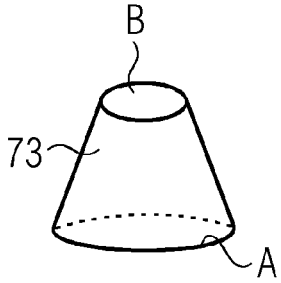



FIG 8

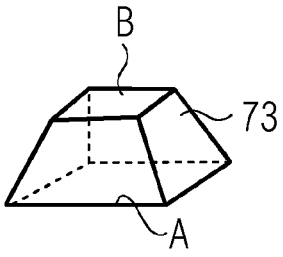



FIG 9

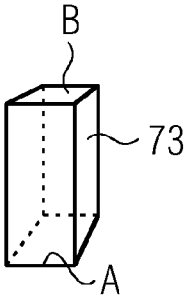



FIG 10

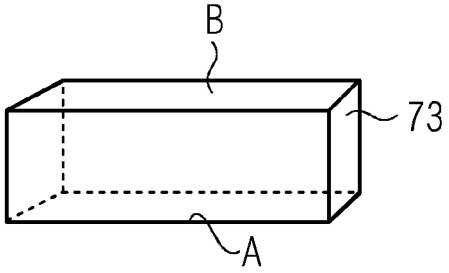



FIG 11

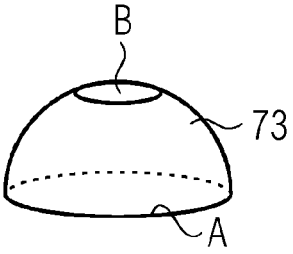



FIG 12

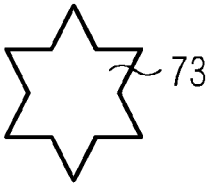


FIG 13

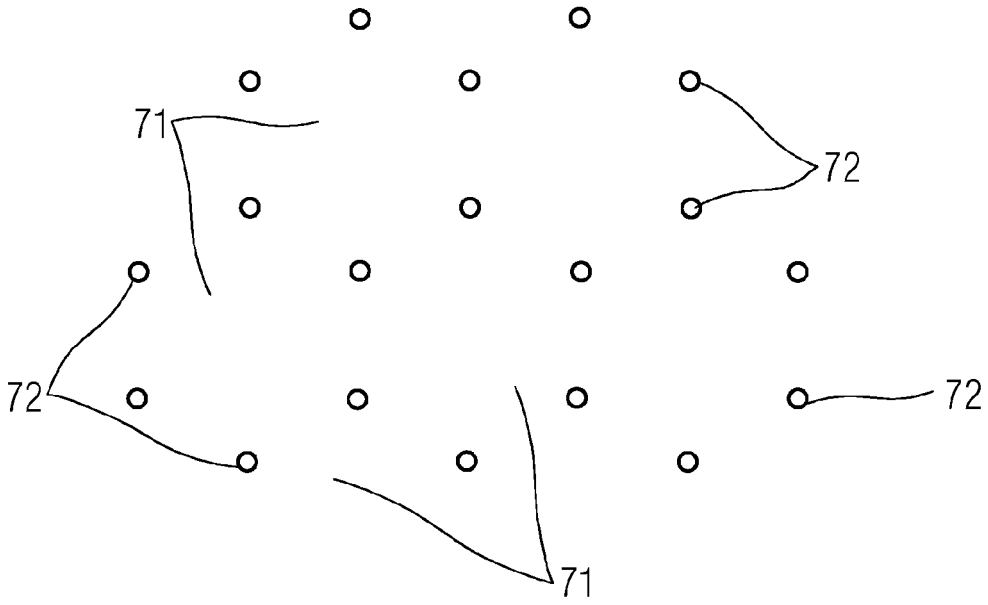



FIG 14

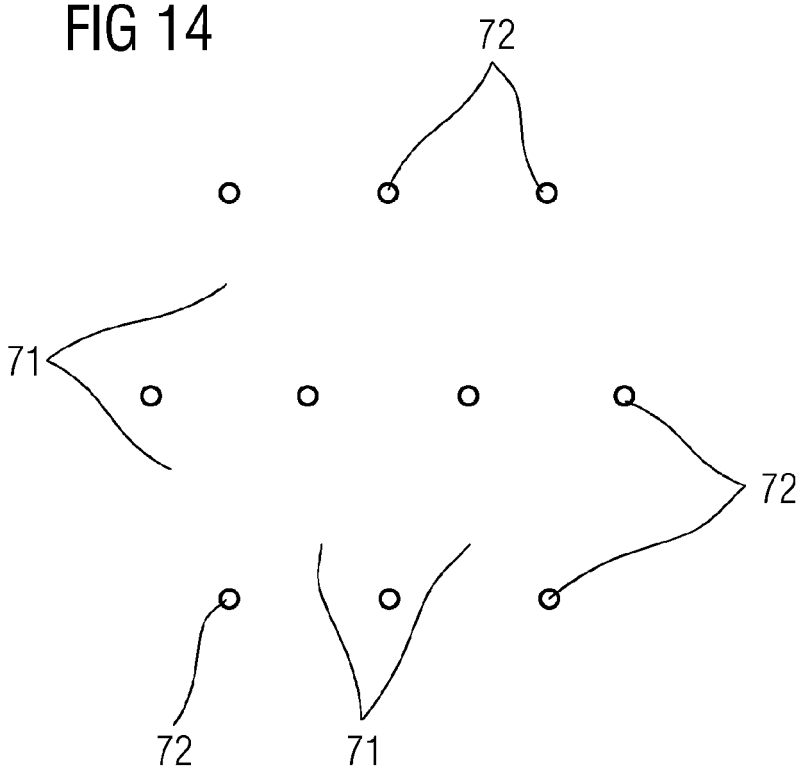


FIG 15

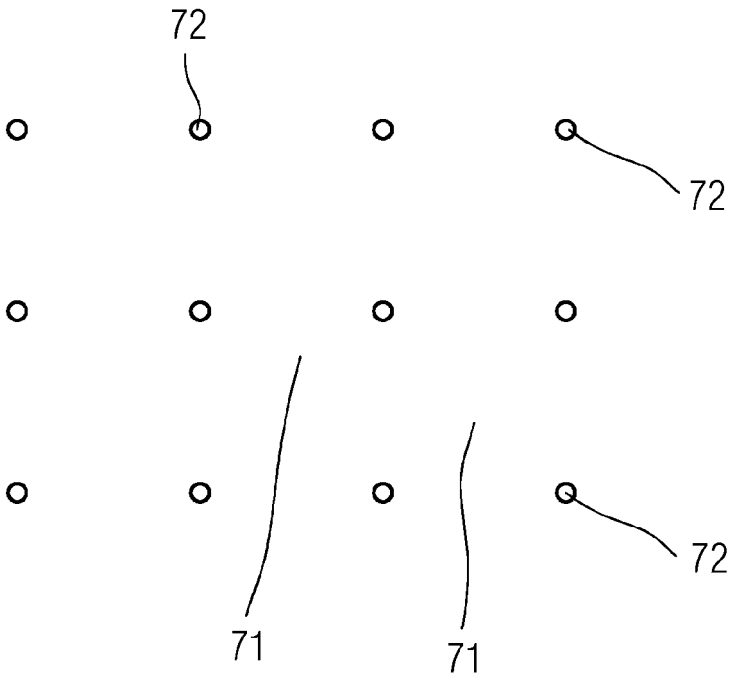



FIG 16

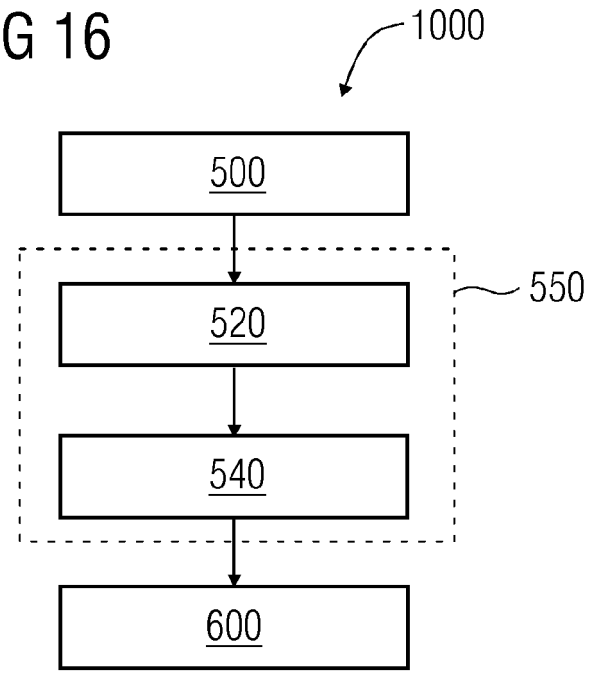


FIG 17

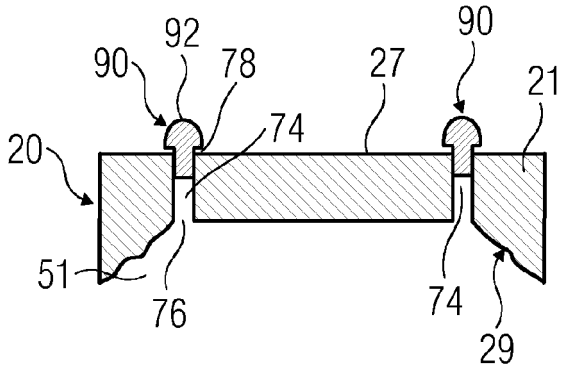



FIG 18

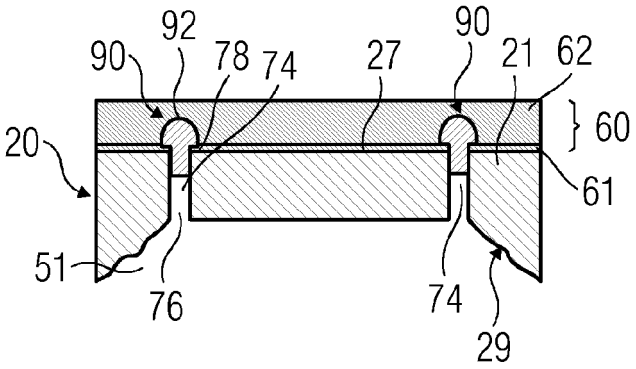
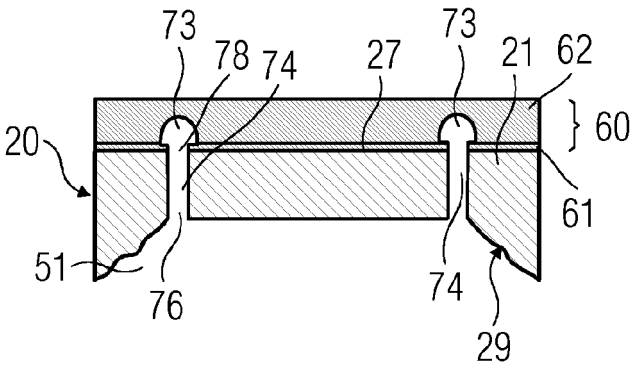



FIG 19



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# EUROPEAN SEARCH REPORT

Application Number
EP 13 19 2899

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 23 January 2014 | Klados, Iason |

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