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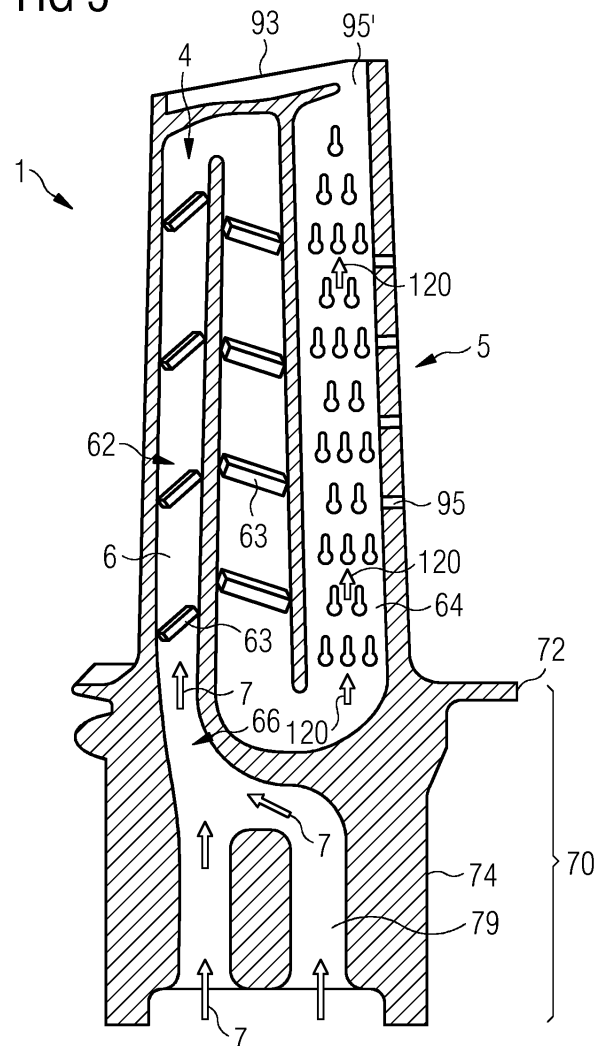
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(54) **A TURBOMACHINE COMPONENT AND METHOD OF MANUFACTURING A TURBOMACHINE COMPONENT**

(57) The invention is directed to a turbomachine component (1), particularly an aerofoil (5), more particularly an aerofoil (5) of a blade (38) or a vane (40) for a gas turbine engine (10), the turbomachine component (1) comprising a first cavity wall (2) and a second cavity wall (3) bordering a cavity (4), and at least one cooling channel (6) extending inside the cavity (4), wherein the cooling channel (6) is adapted to guide a cooling fluid (7) through the cooling channel (6). Furthermore it comprises at least one vortex generating element (8) positioned in the cooling channel (6), wherein the vortex generating element (8) is adapted to generate a swirl in a flow of the cooling fluid (7) and is shaped, in main flow direction (120) of the cooling fluid (7), as a substantially cylindrical component (100) protruding from the first and/or the second cavity wall followed downstream by a substantially straight wall section (105) protruding from the first cavity and/or the second wall, wherein a diameter (103) of the cylindrical component is greater than a width (108) of the straight wall section (105). The invention is also directed to a method of manufacturing such a component.

**FIG 5**



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## Description

**[0001]** The present invention relates to a vortex generating element, particularly for use in blades or vanes of gas turbines or other components that require cooling.

**[0002]** Cooling of turbomachine components, such as a gas turbine blade or vane is a major challenge and an area of interest in turbine technology. A common technique for cooling a turbine blade/vane, i.e. blade and/or vane, is to have one or more internal passages, referred to as cooling channels or cooling passages, within the blade/vane, via which a cooling fluid guided during operation of the turbine, such as cooling air through the cooling channel. Surfaces of such cooling channel or channels are often lined with turbulators to enhance the heat transfer into the cooling air from the blade/vane internal surfaces forming surfaces of the cooling channel. Often a series of rib turbulators or pin-fin turbulators are arranged along the flow path of the cooling fluid within the cooling channel. The turbulators induce turbulence in the cooling fluid and thereby increase the efficiency of the heat transfer.

**[0003]** The flowing cooling fluid passes over, about and/or around sequentially arranged rows or members of the turbulators and a heat transfer by the cooling fluid is increased as the cooling fluid passes over or around the turbulators which may be positioned in a staggered way.

**[0004]** The object of the present disclosure is to provide a solution for a turbomachine component having a cooling channel, to improve a cooling effect of a cooling fluid passing through the cooling channel, thus for enhancing an efficiency of cooling in the turbomachine component.

**[0005]** The above objects are achieved by a turbomachine component and a method of manufacturing of such a turbomachine component according to the independent claims. Advantageous embodiments of the present technique are provided in dependent claims.

**[0006]** According to the invention a turbomachine component, which may be preferably a gas turbine component, particularly an aerofoil, more particularly an aerofoil of a blade or a vane for a gas turbine engine, comprises a first cavity wall and a second cavity wall bordering a cavity, and at least one cooling channel extending inside at least a part of the cavity, wherein the cooling channel is adapted to guide a cooling fluid through the cooling channel. In case of an aerofoil, the first cavity wall may be a suction side wall of the aerofoil and the second cavity wall may be the pressure side wall of the aerofoil. At least one vortex generating element - particularly a plurality of these - is positioned in the cooling channel, wherein the vortex generating element is adapted to generate a swirl in a flow of the cooling fluid. The vortex generating element is shaped, in main flow direction of the cooling fluid during operation, as a substantially cylindrical component protruding from the first cavity wall and/or the second cavity wall followed downstream by a substantially straight wall section protruding from the first cavity wall

and/or the second cavity wall, wherein a diameter of the cylindrical component is greater than a width of the straight wall section.

**[0007]** These diameter and width dimensions are taken substantially perpendicular to the main flow direction of the cooling fluid, i.e. the vortex generating element reduces a flow area of the main flow direction.

**[0008]** In this patent application, when the term "flow direction" is mentioned, if not specified differently, the flow direction of the cooling fluid within the cooling channel is meant. The flow may be generated by the machine in which the turbomachine component is installed. For example the cooling fluid flow is generated by a compressor of a gas turbine engine, and a part of the compressed fluid is guided into the cooling channel of the to be cooled turbomachine component.

**[0009]** The present technique is preferably directed to a turbomachine component which has an aerofoil. An example of such turbomachine component is a blade or a vane for a turbomachine or a gas turbine engine. Alternatively the solution may be used in a combustor liner or for cooling passages included in a burner of a gas turbine engine.

**[0010]** Focusing, on an implementation of an aerofoil, the cavity of the turbomachine component is particularly the aerofoil cavity of the hollow aerofoil. The first cavity wall may be a suction side wall of the aerofoil and the second cavity wall may be the pressure side wall of the aerofoil. The cooling channel that is formed within the hollow aerofoil may be a single passage that meanders through the aerofoil. Alternatively several individual channels are present within the aerofoil, so that at least one of these channels is equipped with the cooling features according to the invention.

**[0011]** The cooling channel usually has an inlet that receives the cooling fluid which then flows through the cooling channel. In case of a turbine blade, the cooling channel may be provided with the cooling fluid via an inlet which is provided as a passage through the blade root. In case of a turbine guide vane, the inlet may be an opening of a platform of the guide vane, and the aerofoil cavity is provided via this opening with the cooling fluid. The aerofoil of the guide vane may be provided with cooling fluid from either one, or both, of both platforms of the guide vane.

**[0012]** The cooling channel may also have a series of traditional turbulators positioned inside the cooling channel, besides the vortex generating element(s) according to the invention. The cooling fluid flows over and about the turbulators.

**[0013]** The effect of the turbulators and of the vortex generating element(s) is to induce swirl or turbulence, including to generate a vortex and/or disturbing a cooling fluid stream. As a result the cooling effect is improved.

**[0014]** The specifically shaped vortex generating element is particularly advantageous as wakes shed from the cylindrical component then impinge or scour over the straight wall section. Hence not only does the cooling

flow pass over an increased hot surface area, but the swirling nature of the flow causes a greater impingement effect, enhancing the heat transfer on the straight wall section of the vortex generating element. Hence the overall heat transfer for the vortex generating element is increased by both of these mechanisms.

**[0015]** Additionally the vortex generating element does not increase a pressure loss compared to mere pin-fin design. As usually the majority of the pressure loss is from a flow around the cylindrical component, the increase in pressure loss of the vortex generating element is only slightly greater than that of wholly cylindrical pedestals, hence a heat transfer performance of the pedestal would increase.

**[0016]** According to the vortex generating element has substantially a shape of a key-hole. Therefore in here also the term key-hole pedestal is used for the vortex generating element.

**[0017]** In an embodiment, the substantially cylindrical component of the vortex generating element may be shaped either circular cylindrical or tapered circular cylindrical, i.e. conical. One variant would also be a conical frustum shape.

**[0018]** Furthermore, the straight wall section may be oriented in substantially a same direction as the main flow direction present during operation upstream of the cylindrical component.

**[0019]** The vortex generating element is connected to one or both of the cavity walls. Preferably at least one of the cylindrical component and the straight wall section may be oriented substantially perpendicular to the first cavity wall and/or the second cavity wall. In other words, a central axis of the cylindrical component may be oriented substantially perpendicular to the first cavity wall and/or the second cavity wall.

**[0020]** In an embodiment the cylindrical component may be connected gaplessly to the straight wall section. So both form a common component. So no flow of cooling fluid is possible between the cylindrical component and the straight wall section.

**[0021]** Preferably the straight wall section may not be a perfect cuboid. It may have a semi-cylindrically shaped downstream end, i.e. at the end of the straight wall section that is opposite to the cylindrical component.

**[0022]** So far a single vortex generating element was discussed. In an embodiment a plurality of the at least one vortex generating element may be present in the cooling channel are may be arranged in an array or grid. The plurality of vortex generating elements may be staggered.

**[0023]** Particularly individual ones of the plurality of the at least one vortex generating elements may be placed distant to another in main flow direction and distant to another lateral to the main flow direction. That means that a gap is present upstream of the first cavity wall. Preferably also a gap is present downstream of the straight wall section.

**[0024]** Alternatively, individual ones of the plurality of

the at least one vortex generating elements may be placed distant to another in lateral direction but in main flow direction at least two consecutive vortex generating elements may be connected to another. Preferably exactly two or three consecutive vortex generating elements may be connected to another. That means a first vortex generating element and a second vortex generating element of the at least one vortex generating element may be present, the first vortex generating element may comprise a first cylindrical component and a first straight wall section and the second vortex generating element may comprise a second cylindrical component and a second straight wall section and the two vortex generating elements may be connected gaplessly to another such that the first straight wall section of the first vortex generating element may be attached to the downstream following second cylindrical component of the second vortex generating element.

**[0025]** In an embodiment, the vortex generating element may be a protrusion integrally formed with the first cavity wall and/or the second cavity wall, at a location at which the vortex generating element is positioned. Preferably the vortex generating element may provide a cross-connection between the first cavity wall and the second cavity wall. Thus, the first cavity wall the second cavity wall and the vortex generating element may be a single component, preferably manufactured by casting or additive manufacturing.

**[0026]** Alternatively, the first cavity wall and the second cavity wall and the vortex generating element may be individually manufactured elements that are attached to another in a later manufacturing step. That means the vortex generating element may be a fixture attached to the first cavity wall and/or the second cavity wall at which the vortex generating element is positioned.

**[0027]** The vortex generating element, or each one of the element in case of a plurality of vortex generating elements, may have dimensions relative to the cooling channel, for example a height of the vortex generating element is between 10 percent and 50 percent of a height of the cooling channel at a location of the vortex generating element. Alternatively, the height of the vortex generating element may be 100% of the height of the cooling channel.

**[0028]** As previously indicated, in case of the turbomachine component comprising an aerofoil, the vortex generating element may be positioned within an aerofoil cooling cavity within a hollow core of the aerofoil. The first cavity wall and the second cavity wall may be walls that will have surfaces facing to the cooling channel and additionally having further walls that will have surfaces facing away from the cooling channel and therefore facing a main fluid path of the turbomachine for combusted fluids.

**[0029]** As said, the vortex generating element may be positioned within an aerofoil cooling cavity within a hollow core of the aerofoil. The cooling cavity may be a cavity that meanders through the interior of the aerofoil. The

meandering or serpentine cavity may have a main expanse in longitudinal direction of the aerofoil. The cavity may be particularly a single-pass passage or multi-pass cooling passages on portions of the pressure and suction sides of the aerofoil. Preferably the cavity is bordered directly by the pressure and suction sides of the aerofoil. So this design may particularly be directed to aerofoils without impingement cooling inserts.

**[0030]** As said, the invention is also directed to manufacturing of the turbomachine component as previously defined, with the manufacturing step of generating at least one vortex generating element onto the first cavity wall or the second cavity wall via additive manufacturing, particularly selective laser melting. Alternatively, the turbomachine component may be a cast element.

**[0031]** Preferably the cast or additively generated turbomachine component may result in a solid single component, in which the first cavity wall and/or the second cavity wall and at least one or all vortex generating element(s) is/are integrally formed with the first cavity wall and/or the second cavity wall.

**[0032]** As stated before, the invention is explained mainly in reference to a hollow aerofoil of a gas turbine engine. Alternatively other components of a gas turbine engine can be equipped with the inventive vortex generating element(s). Besides, also other turbomachine, like steam turbines or compressors, can use the inventive vortex generating element(s). Nevertheless, the invention is particularly advantageous for components that experience heat of several hundreds of centigrade. The used material for the turbomachine component is therefore preferably a metal or an alloy to withstand these temperatures.

**[0033]** The above mentioned attributes and other features and advantages of the present technique and the manner of attaining them will become more apparent and the present technique itself will be better understood by reference to the following description of embodiments of the present technique taken in conjunction with the accompanying drawings, wherein:

FIG 1 shows part of a turbine engine in a sectional view and in which an aerofoil of the present technique can be incorporated;

FIG 2 schematically illustrates a perspective view of an exemplary embodiment of a turbomachine component with an aerofoil;

FIG 3 schematically illustrates a cross-section of an exemplary embodiment of the aerofoil normal to a longitudinal axis of the aerofoil;

FIG 4 schematically illustrates a vertical section of the turbomachine component depicting an hollow core of an exemplary prior art aerofoil;

FIG 5 schematically illustrates a vertical section of

the turbomachine component depicting an exemplary embodiment with vortex generating elements according to the present technique;

5 FIG 6 schematically illustrates an exemplary embodiment of a single vortex generating element according to the present technique;

10 FIG 7 schematically illustrates an exemplary embodiment of two consecutive vortex generating elements according to the present technique;

15 FIG 8 schematically illustrates an alternative exemplary embodiment of two consecutive vortex generating elements according to the present technique;

20 FIG 9 schematically illustrates a flow behaviour of a cylindrical pedestal according to the prior art;

FIG 10 schematically illustrates a flow behaviour of a cylindrical pedestal according to the prior art;

25 FIG 11 schematically illustrates a segment of a vertical section of the turbomachine component depicting an exemplary embodiment with vortex generating elements according to the present technique.

30 **[0034]** Hereinafter, above-mentioned and other features of the present technique are described in details. Various embodiments are described with reference to the drawing, wherein like reference numerals are used to refer to like elements throughout the different figures. In the following description, for the purpose of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more embodiments. It may be noted that the illustrated embodiments are intended to explain, and not to limit the invention. It may be evident that such embodiments may be practiced without these specific details.

35 **[0035]** The basic idea of the present disclosure is to introduce a turbulence or swirl in the cooling fluid as the cooling fluid is guided through the cooling channel. The introduction of the swirl in the cooling fluid is achieved, according to the present technique, by positioning one or several vortex generating elements in the cooling channel. The vortex generating element generates a swirl in the cooling fluid by having a shape that induces swirling of the fluid or generation of vortices in the cooling fluid flow. The turbulence or swirl is initiated by highly unsteady flow features that are created by the vortex generating device in the cooling fluid. These features include vortex shedding, fluid shear layers within the passage containing flow recirculations and flow separations and unstable shear layers that do not have a stable location.

40 **[0036]** FIG. 1 shows an example of a gas turbine en-

gine 10 in a sectional view. The sectional view is taken in a plane spanned by a rotational axis 20 and a radial direction to this axis 20. The gas turbine engine 10 comprises, in flow series of a main working fluid, an inlet 12, a compressor or compressor section 14, a combustor section 16 and a turbine section 18 which are generally arranged in flow series and generally about and in the direction of a longitudinal or rotational axis 20. The gas turbine engine 10 further comprises a shaft 22 which is rotatable about the rotational axis 20 and which extends longitudinally through the gas turbine engine 10. The shaft 22 drivingly connects the turbine section 18 to the compressor section 14.

**[0037]** In operation of the gas turbine engine 10, air 24, which is taken in through the air inlet 12 is compressed by the compressor section 14 and delivered to the combustion section or burner section 16. The burner section 16 comprises - in case of a can-annular design - itself a longitudinal axis 35 of the burner, a burner plenum 26, one or more combustion chambers 28 and at least one burner 30 fixed to each combustion chamber 28. The combustion chambers 28 and the burners 30 are located inside the burner plenum 26.

**[0038]** The compressed air passing through the compressor 14 enters a diffuser 32 and is discharged from the diffuser 32 into the burner plenum 26 from where a portion of the air enters the burner 30 and is mixed with a gaseous or liquid fuel. The air/fuel mixture is then burned and the combustion gas 34 or working gas from the combustion is channeled through the combustion chamber 28 to the turbine section 18 via a transition duct 17.

**[0039]** This exemplary gas turbine engine 10 has a can-annular - or cannular - combustor section arrangement 16, which is constituted by an annular array of combustor cans 19 each having the burner 30 and the combustion chamber 28, the transition duct 17 has a generally circular inlet that interfaces with the combustor chamber 28 and an outlet in the form of an annular segment. An annular array of transition duct outlets form an annulus for channeling the combustion gases to the turbine 18.

**[0040]** The turbine section 18 comprises a number of blade carrying discs 36 attached to the shaft 22. In the present example, two discs 36 each carry an annular array of turbine blades 38. However, the number of blade carrying discs could be different, i.e. only one disc or more than two discs. In addition, guide vanes 40, which are fixed to a stator 42 of the gas turbine engine 10, are disposed between the stages of annular arrays of turbine blades 38. Between the exit of the combustion chamber 28 and the leading turbine blades 38 turbine inlet guide vanes 44 are provided and turn the flow of working gas onto the turbine blades 38.

**[0041]** The combustion gas from the combustion chamber 28 enters the turbine section 18 and drives the turbine blades 38 which in turn rotates the shaft 22. The guide vanes 40, 44 serve to optimise the angle of attack of the combustion or working gas onto the turbine blades

38.

**[0042]** The rotating shaft driven by the turbine section 18 drives the rotating components of the compressor section 14. The compressor section 14 comprises an axial series of vane stages 46 and rotor blade stages 48. The rotor blade stages 48 comprise a rotor disc supporting an annular array of blades. The compressor section 14 also comprises a casing 50 that surrounds the rotor stages and supports the vane stages 48. The guide vane stages 46 include an annular array of radially extending vanes that are mounted to the casing 50. The vanes are provided to present gas flow at an optimal angle for the compressor blades at a given engine operational point. Some of the guide vane stages 48 of the compressor section 14 have variable vanes, where the angle of the vanes, about their own longitudinal axis, can be adjusted for angle according to air flow characteristics that can occur at different engine operational conditions.

**[0043]** The casing 50 defines a radially outer surface 52 of the passage 56 of the compressor 14. A radially inner surface 54 of the passage 56 is at least partly defined by a rotor drum 53 of the rotor which is partly defined by the annular array of blades 48.

**[0044]** The present technique is described with reference to the above exemplary turbine engine having a single shaft or spool connecting a single, multi-stage compressor and a single, one or more stage turbine. However, it should be appreciated that the present technique is equally applicable to two or three shaft engines and which can be used for industrial, aero or marine applications.

**[0045]** The terms upstream and downstream refer to the flow direction of a fluid flow. The terms forward and rearward refer to the general flow of gas through the engine. The terms axial, radial and circumferential are made with reference to the rotational axis 20 of the engine.

**[0046]** It may be noted that the present technique will be explained in the following in details with respect to an embodiment of a turbine blade, however, it must be appreciated that the present technique is equally applicable and implemented similarly with respect to a turbine vane or any other turbomachine component having an hollow aerofoil being cooled by a cooling channel.

**[0047]** FIG 2 schematically illustrates a blade 1 as a turbomachine component having an aerofoil 5, for example the turbine blade 38 (or alternatively the vane 40) of FIG 1. FIG 3 illustrates a cross section of the aerofoil 5 of the blade 1. For the blade 1, the aerofoil 5 extends from a platform 72 in a radial direction 97, and more particularly from a side 71, hereinafter referred to as the aerofoil side 71, of the platform 72. The platform 72 extends circumferentially i.e. along curved axis 98. From another side 73, hereinafter referred to as the root side 73, of the platform 72 arises a root 74 or a fixing part 74. The root 74 may be used to attach the blade 1 to the turbine disc 38 (shown in FIG 1). The root 74 and the platform 72 together form a base 70 in the blade 1. It may be noted that in some other embodiments like a vane,

the root 74 may not be present and the base 70 is then formed only of the platform 72.

**[0048]** The aerofoil 5 includes a suction side wall 2 as the inventive first cavity wall, also called suction side 2, and a pressure side wall 3 as the inventive second cavity wall, also called pressure side 3. The side walls 2 and 3 meet at a trailing edge 92 on one end and a leading edge 91 on another end. The aerofoil 5 has a tip end 93. The aerofoil 5 may also be connected to a shroud (not shown) at the tip end 93 of the aerofoil 5. The side walls 2 and 3 of the aerofoil 5 act as boundary for an aerofoil cavity 4 (see FIG 3).

**[0049]** Referring to FIG 4, an exemplary embodiment of a prior art blade 1 is shown, which later on will, in reference to FIG. 5, be modified to show the inventive concept.

**[0050]** The blade 1 has at least one cooling channel 6 that extends inside at least a part of the aerofoil cavity 4. A cooling fluid, such as cooling air, has been represented by arrows marked with reference numeral 7. The cooling fluid 7 flows through the cooling channel 6. The cooling channel 6 has an inlet 66 that receives the cooling fluid 7 which then flows through the cooling channel 6. The cooling channel 6 usually has a serpentine path though the aerofoil cavity 4. The cooling channel 6 also has a series of turbulators 62 positioned in a sequential manner with respect to the flow of the cooling fluid 7 inside the cooling channel 6. The turbulators 62 inside the cooling channel 6 may be rib shaped 63 or pin fin (pedestal) shaped 64. The cooling fluid 7 flows over and about the turbulators 62. The cooling fluid 7, after flowing through the cooling channel 6 and the turbulators 62, exits the cooling channel 6 for example by holes 95 or by a tip exhaust hole 95' that fluidly connect the cooling channel 6 to an outside of the aerofoil 5. The holes 95 may be present at any region of the aerofoil 5, but preferably for example at the trailing edge 92.

**[0051]** It may be noted that for FIG 4, the base 70 may have a base cavity 79, for example a root cavity (now shown) and/or a platform cavity (not shown), and the cooling channel 6 may be supplied with the cooling air 7 from the base cavity 79 and thus the inlet 66 of the cooling channel 6 may be present in the base 70, fluidly connected with the base cavity 79. Eventually, the cooling channel 6 may lead to a bank of vortex generating elements 64. In case of FIG. 4, these vortex generating elements 64 are merely shaped as cylindrical pins or pin-fins.

**[0052]** Now turning to FIG 5, an inventive concept is shown, in which the configuration of FIG 4 is modified such that the bank of vortex generating elements 64 is now configured by using vortex generating elements 8 which are each shaped in main flow direction 120 of the cooling fluid 7 during operation, as a substantially cylindrical component 100 (for details of a single vortex generating element 8 see FIG 6) protruding from the suction side wall 2 and/or the pressure side wall 3 followed downstream by a substantially straight wall section 105 protruding as well from the suction side wall 2 and/or the

pressure side wall 3. As shown in FIG 5 but in more detail in FIG 6, a diameter 103 of the cylindrical component 100 is greater than a width 108 of the straight wall section 105. By this shape, the vortex generating element 8 is adapted to generate a swirl in a flow of the cooling fluid 7. This will lead to an improved heat transfer within the bank of vortex generating elements 64 compared to the configuration of FIG 4.

**[0053]** In FIG 5, the bank of vortex generating elements 64 is configured such that a plurality of vortex generating elements 8 is configured in lines and rows in a staggered way. These elements may be positioned differently based on the actual temperature requirements. Also different sizes of vortex generating elements 64 can be provided in the bank.

**[0054]** FIG 6 shows a preferred configuration of a single vortex generating element 8. Also fluid flow around the single vortex generating element 8 is schematically indicated. The straight wall section 105 is trailing - in flow direction - the cylindrical component 100. The diameter 103 of the cylindrical component 100 is at least 20% larger than the width 108 of the straight wall section 105. In an example, the diameter 103 of the cylindrical component 100 is between double and ten times the size of the width 108 of the straight wall section 105.

**[0055]** A length 110 of the straight wall section 105 in flow direction may be particularly at least the size of the diameter 103 of the cylindrical component 100. Even more preferably, the length 110 of the straight wall section 105 in flow direction may be between 100% and 500% of the size of the diameter 103 of the cylindrical component 100.

**[0056]** In FIG 6 and also the following figures, a separating point 121 is shown at which a cooling fluid flow separates from a surface of the cylindrical component 100. It has to be noted that the separating point 121 may move upstream and downstream in a repetitive manner, with the consequence of oscillations of the fluid downstream of the cylindrical component 100.

**[0057]** Furthermore, FIG 6 shows that a downstream end of the straight wall section 105 may be curved. Particularly it may be formed as a semi-cylinder and is thus called in this document as semi-cylindrically shaped downstream end 109 of the straight wall section 105.

**[0058]** The configuration of FIG 6 and also the ones of the following figures provide a re-circulating flow downstream of the cylindrical component 100, which has an impingement cooling effect on the trailing straight wall section 105.

**[0059]** FIG 7 shows a schematic view of two consecutive vortex generating elements 8, particularly a first vortex generating element 8A and a second vortex generating element 8B. Again the fluid flow is also indicated in a schematic way. The first vortex generating element 8A comprises a first cylindrical component 101 and a first straight wall section 106. The second vortex generating element 8B comprises a second cylindrical component 102 and a second straight wall section 107.

**[0060]** A gap 110 between the two second vortex generating elements 8A and 8B may be preferably at least the size of the length 110 of the straight wall section 105. In one embodiment the length of the gap 110 is between 50% and 300% of the length of the length 110 of the straight wall section 105.

**[0061]** In FIG 8 an alternative to FIG 7 is shown. In this configuration the first vortex generating element 8A and the second vortex generating element 8B are immediately connected to another, without an intermediate gap (like gap 110 in FIG 7). This forms a gapless connection of two vortex generating elements that are located behind another in downstream orientation.

**[0062]** Preferably the diameters 103 of the first cylindrical component 101 and the second cylindrical component 102 are substantially identical. In an alternative, the diameter 103 trailing second cylindrical component 102 may be 70% to 150% of the diameter 103 of the leading first cylindrical component 101.

**[0063]** The length of the first straight wall section 106 and the second straight wall section 107 may be identical (not shown). Alternatively, the first straight wall section 106 may have a length 110 of 50% to 500% of the length 110 of the second straight wall section 107. In the depicted example, the first straight wall section 106 may have a length 110 between 300% and 400% of the length 110 of the second straight wall section 107.

**[0064]** It may be particularly be advantageous, if only two successive vortex generating elements are connected to another and that a gap is present after the trailing second vortex generating element 8B.

**[0065]** Again, re-circulating flow is provided downstream of each of the cylindrical components 100, which has an impingement cooling effect on the respective trailing straight wall sections 105.

**[0066]** FIG 9 illustrates in more details some turbulating effect of a vortex generating element 8 in the theoretical flow analysis.

**[0067]** FIG 10 shows abstractly, how a cylinder in a flow path could generate vortices, depending on the flow conditions. Thus positioning a straight wall section 105 as indicated via a dashed line could make advantage of the effect that some vortices would then hit the straight wall section 105.

**[0068]** It has to be noted that the vortices may not stay at a fixed position but will move downstream. Thus, a straight wall section of a sufficient length provides a sufficient barrier even if the vortex moves downwards.

**[0069]** FIG 11 shows schematically an illustration of a segment of a vertical section of the blade 1. The segment may be a trailing edge bank of vortex generating elements 64.

**[0070]** While in the previous example of FIG 5 the bank of vortex generating elements 64 were oriented in radial direction so that all vortex generating elements 8 were arranged into a cooling fluid flow leading to the tip of the aerofoil, in FIG 11 the bank of vortex generating elements 64 is oriented into direction of the trailing edge 92.

**[0071]** In FIG 11 the cooling channel 6 is provided with rib turbulators 63. The cooling channel 6 is originally oriented in radial direction, provides a bend so that the cooling channel 6 then is directed in a second section to the trailing edge 92. In this second section of the cooling channel 6 a plurality of vortex generating elements 8 are positioned in a staggered layout. Each of the vortex generating elements 8 is again provided with a cylindrical component and a consecutive straight wall section. Eventually a fluid flow along the cooling channel 6 and through the bank of vortex generating elements 8 is exhausted via exhaust slots 122 at the trailing edge 92 of the blade 1.

**[0072]** For all the inventive embodiments, the cooling fluid 7 flows over turbulators and about the vortex generating elements 8. At least a part of the cooling fluid 7 flows such that it will contact the vortex generating elements 8. The external shape of the vortex generating elements 8 is such that turbulence or swirl is introduced in the flowing cooling fluid 7 as a result of contacting or flowing around the vortex generating elements 8. The shape and dimensions of the vortex generating elements 8 are such that turbulence is generated and that a fraction of the turbulated flow hits the straight wall sections 105 of the vortex generating elements 8.

**[0073]** Different shapes for the vortex generating elements 8 can be provided. The cylindrical component 100 of the vortex generating elements 8 may be circular cylindrical or elliptical cylindrical. Alternatively it may be of conical frustum shape. The straight wall section 105 is preferably in shape of a cuboid with substantially parallel side walls. Possibly, the side walls may be narrowing into trailing direction. The side walls may be even without protrusions or depressions. Alternatively, the side walls may be curved.

**[0074]** Preferably the vortex generating elements 8 may be connected to both walls 2 and 3 of the aerofoil. Alternatively they may only be fixed to one of the walls 2 or 3.

**[0075]** Generally, the invention provides an alternative solution for cooling of a narrow channel - for example the trailing edge region of a turbine blade -, which is often enhanced by use of circular pin-fins or pedestals across the passage. According to the invention, the use of key-hole shaped pedestals - as described throughout this document - will increase the flow of heat from the hot wall to the cool cooling fluid - particularly air -, so improving the cooling efficiency of the cooling system.

**[0076]** The common shape of a pin-fin or pedestal is circular, which has been set largely by traditional casting criteria. The invention benefits from methods of manufacturing, like Selective Laser melting or 'MIKRO' casting methods, allowing other shapes of pedestals to be manufactured.

**[0077]** The given invention provides an improvement to a usual bank of fully circular pin-fins. The flow through a bank of circular pin-fins has been well documented. The flow is similar to that of a flow round a circular cylin-

der, in that wakes are shed alternately from the downstream edge of the cylinder, so forming a series of vortices that interact with each other, which is also called "Karman Vortex street". The invention benefits from "Karman Vortices" that fluid will periodically change the turbulence.

**[0078]** The shape of the inventive pedestal - i.e. the vortex generating elements 8 - is such that wakes shed from the cylindrical portion then impinge or scour over the straight portion of the pedestal. Hence not only does the cooling flow pass over an increased hot surface area as the vortex generating element 8 is connected with the hot cavity walls 2 and 3, but the swirling nature of the flow causes a greater impingement effect, enhancing the heat transfer on the straight portion of the pedestal. Hence the overall heat transfer for the key-hole pedestal shape is increased. As the majority of the pressure loss is from the flow around the circular portion, the increase in pressure loss of the key-hole pedestal is predicted to be only slightly greater than that of wholly circular pedestals, hence the heat transfer performance of the pedestal would increase.

**[0079]** The proposed pedestals may be arranged in a cooling array. These cooling configurations with present straight wall sections 105 also have the advantage of directing the flow along the passage between the pedestals, Hence flow perpendicular to the direction of the pedestal array (from say pressure differentials or effects of rotation) is suppressed.

**[0080]** While the present technique has been described in detail with reference to certain embodiments, it should be appreciated that the present technique is not limited to those precise embodiments. Rather, in view of the present disclosure which describes exemplary modes for practicing the invention, many modifications and variations would present themselves, to those skilled in the art without departing from the scope and spirit of this invention. The scope of the invention is, therefore, indicated by the following claims rather than by the foregoing description. All changes, modifications, and variations coming within the meaning and range of equivalency of the claims are to be considered within their scope.

## Claims

1. A turbomachine component (1), particularly an aerofoil (5), more particularly an aerofoil (5) of a blade (38) or a vane (40) for a gas turbine engine (10), the turbomachine component (1) comprising:
  - a first cavity wall (2) and a second cavity wall (3) bordering a cavity (4), and
  - at least one cooling channel (6) extending inside at least a part of the cavity (4), wherein the cooling channel (6) is adapted to guide a cooling fluid (7) through the cooling channel (6), and
  - at least one vortex generating element (8) po-

sitioned in the cooling channel (6), wherein the vortex generating element (8) is adapted to generate a swirl in a flow of the cooling fluid (7),

5 wherein the vortex generating element (8) is shaped, in main flow direction (120) of the cooling fluid (7) during operation, as a substantially cylindrical component (100) protruding from the first cavity wall (2) and/or the second cavity wall (3) followed downstream by a substantially straight wall section (105) protruding from the first cavity wall (2) and/or the second cavity wall (3), wherein a diameter (103) of the cylindrical component (100) is greater than a width (108) of the straight wall section (105).

2. The turbomachine component (1) according to claim 1, **characterised in that** the substantially cylindrical component (100) is shaped either circular cylindrical or tapered circular cylindrical.
3. The turbomachine component (1) according to any one of the preceding claims, **characterised in that** the straight wall section (105) is oriented in substantially a same direction as the main flow direction (120) present during operation upstream of the cylindrical component (100).
4. The turbomachine component (1) according to any one of the preceding claims, **characterised in that** at least one of the cylindrical component (100) and the straight wall section (105) is oriented substantially perpendicular to the first cavity wall (2) and/or the second cavity wall (3).
5. The turbomachine component (1) according to any one of the preceding claims, **characterised in that** the cylindrical component (100) is connected gaplessly to the straight wall section (105).
6. The turbomachine component (1) according to any one of the preceding claims, **characterised in that** the straight wall section (105) has a semi-cylindrical shaped downstream end (109).
7. The turbomachine component (1) according to any one of the preceding claims, **characterised in that** a plurality of the at least one vortex generating element (8) is arranged in an array or grid.
8. The turbomachine component (1) according to any one of the preceding claims,

**characterised in that**

a plurality of the at least one vortex generating element (8) are placed distant to another in main flow direction (120) and distant to another lateral to the main flow direction (120).

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9. The turbomachine component (1) according to any one of the preceding claims,

**characterised in that**

a first vortex generating element (8A) and a second vortex generating element (8B) of the at least one vortex generating element (8), the first vortex generating element (8A) comprising a first cylindrical component (101) and a first straight wall section (106) and the second vortex generating element (8B) comprising a second cylindrical component (102) and a second straight wall section (107), are connected gaplessly to another such that the first straight wall section (106) of the first vortex generating element (8A) is attached to the downstream following second cylindrical component (102) of the second vortex generating element (8B).

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10. The turbomachine component (1) according to any one of the preceding claims,

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**characterised in that**

the vortex generating element (8) is a protrusion integrally formed with the first cavity wall (2) and/or the second cavity wall (3) at which the vortex generating element (8) is positioned.

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11. The turbomachine component (1) according to any of claims 1 to 10,

**characterised in that**

the vortex generating element (8) is a fixture attached to the first cavity wall (2) and/or the second cavity wall (3) at which the vortex generating element (8) is positioned.

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12. The turbomachine component (1) according to any one of the preceding claims,

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**characterised in that**

in case of the turbomachine component (1) comprising an aerofoil (5), the vortex generating element (8) is positioned within an aerofoil cooling cavity (4) within a hollow core of the aerofoil (5).

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13. Method of manufacturing of a turbomachine component (1) as defined according to any one of the preceding claims, with the steps of:

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generating at least one vortex generating element (8) onto the first cavity wall (2) or the second cavity wall (3) via additive manufacturing, particularly selective laser melting.

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14. Method of manufacturing according to claim 13, comprising the further step of:

generating the first cavity wall (2) and/or the second cavity wall (3) via additive manufacturing, particularly selective laser melting, such that the at least one vortex generating element (8) is integrally formed with the first cavity wall (2) and/or the second cavity wall (3).

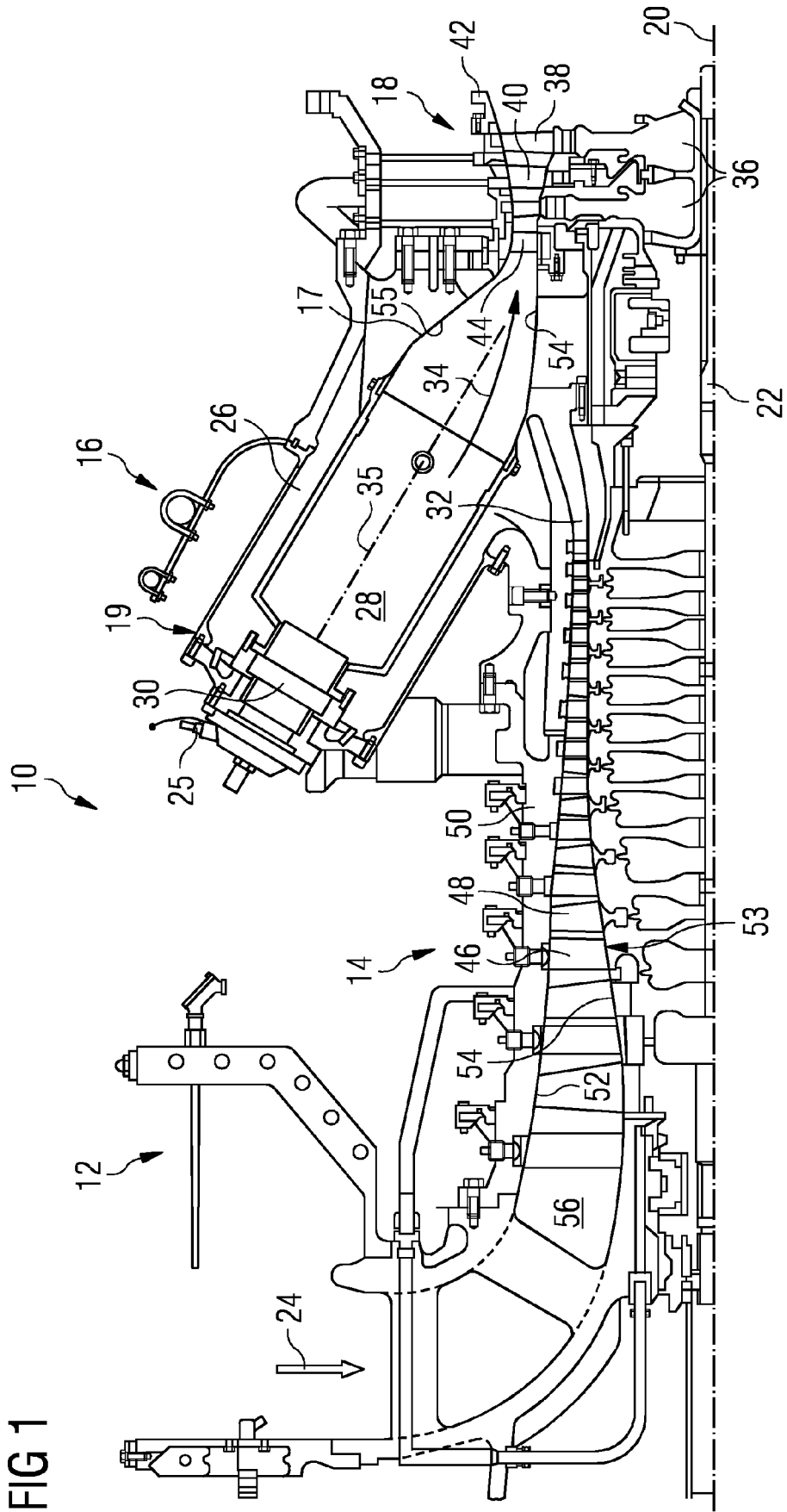




FIG 4

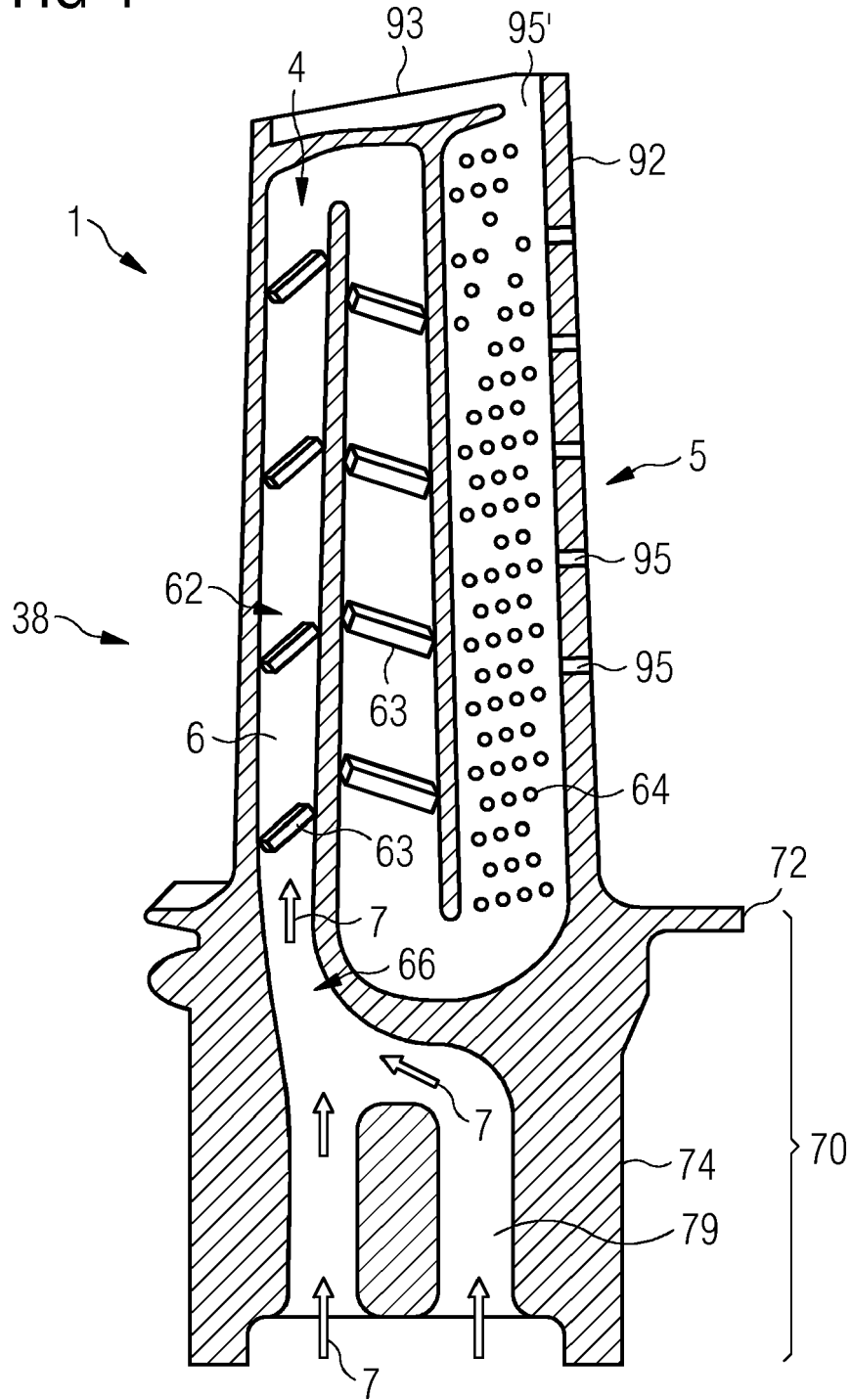


FIG 5

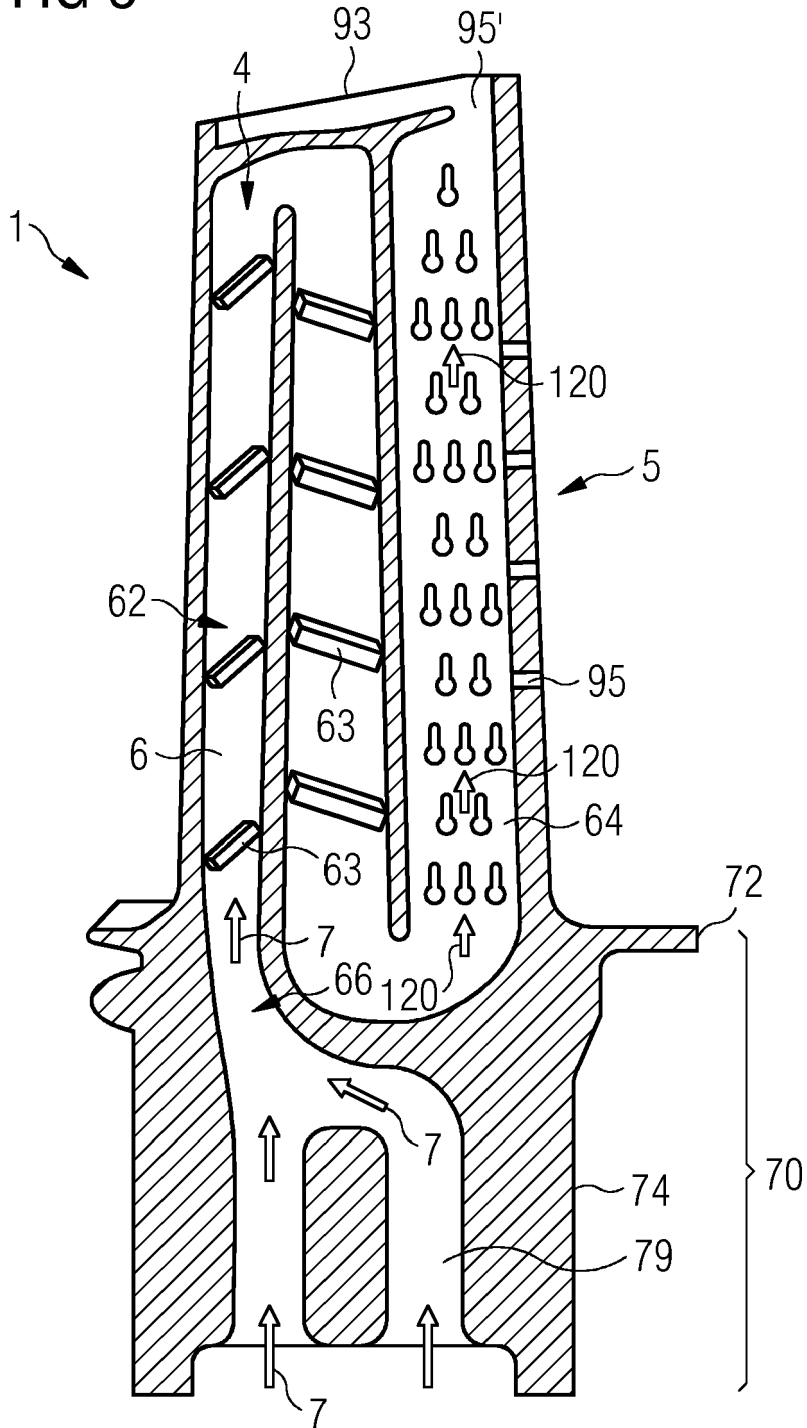


FIG 6

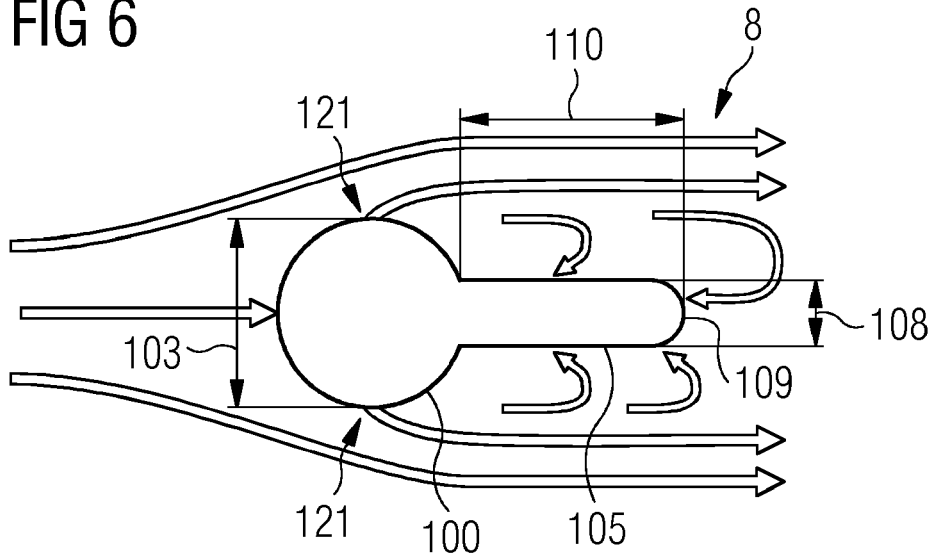


FIG 7

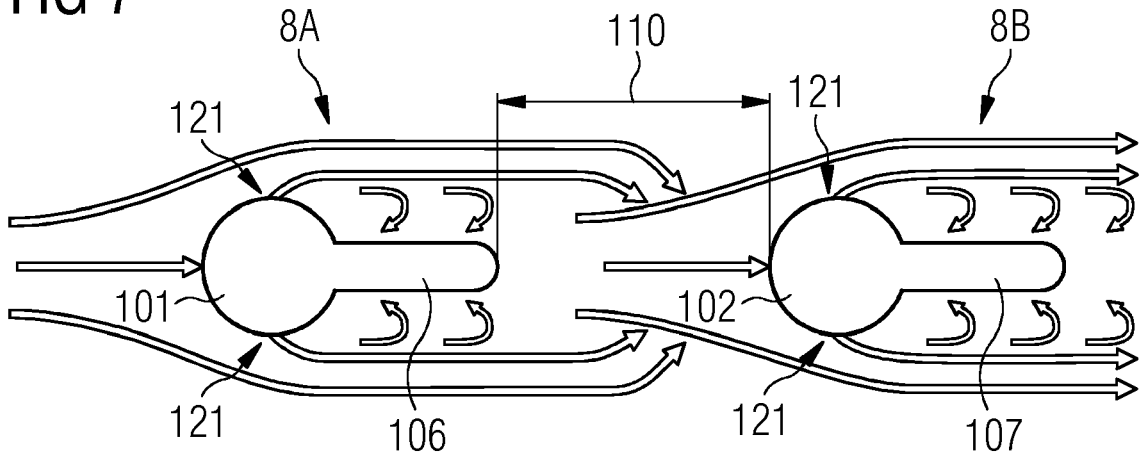


FIG 8

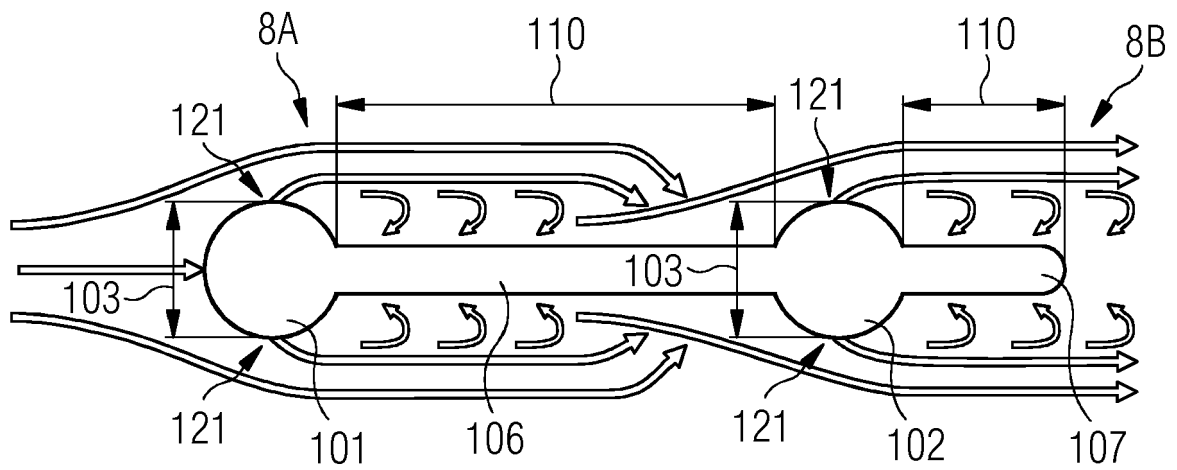


FIG 9

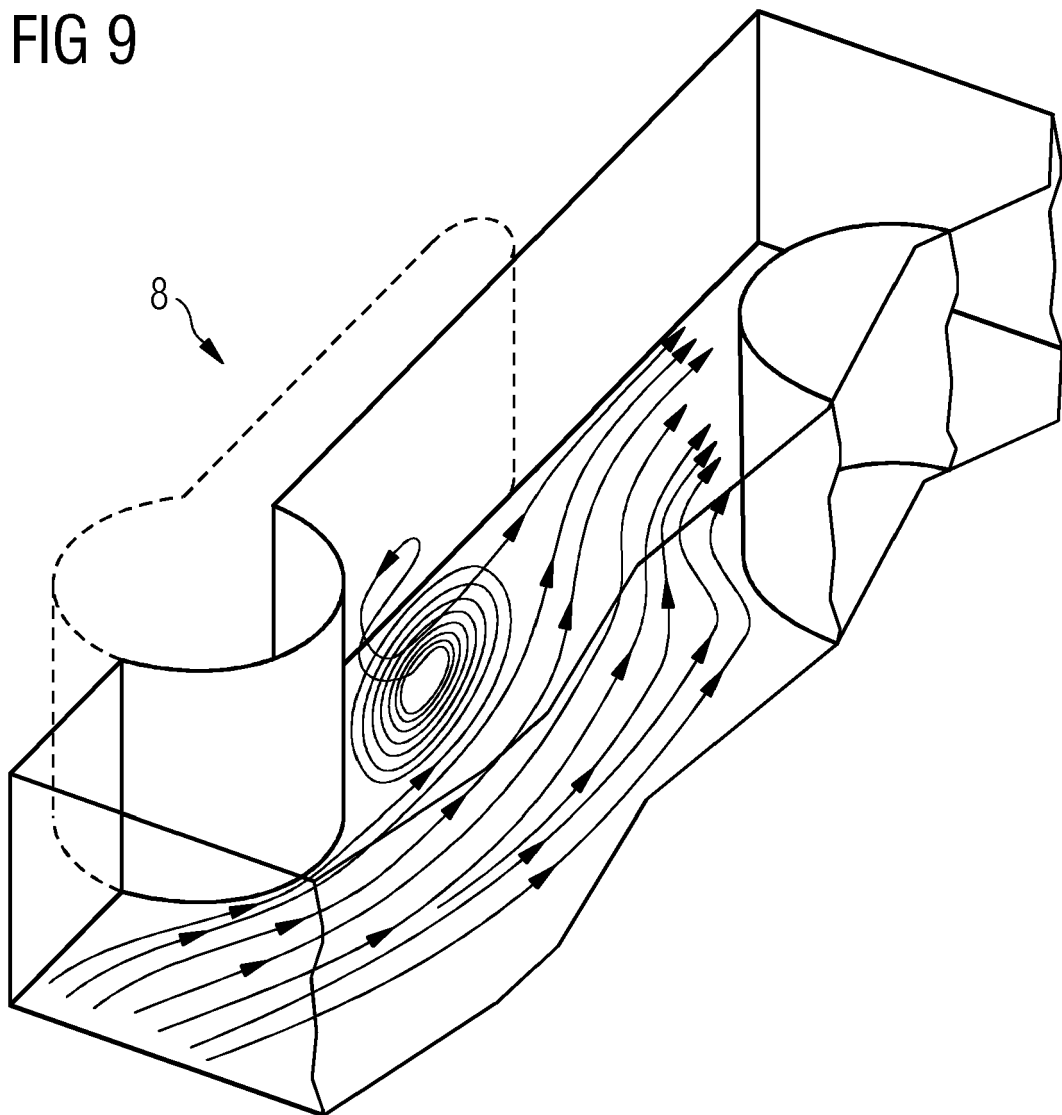


FIG 10

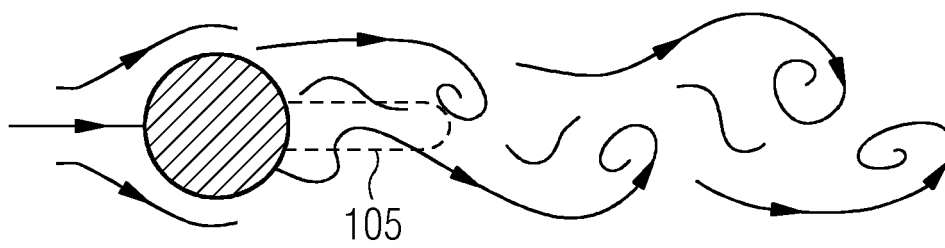
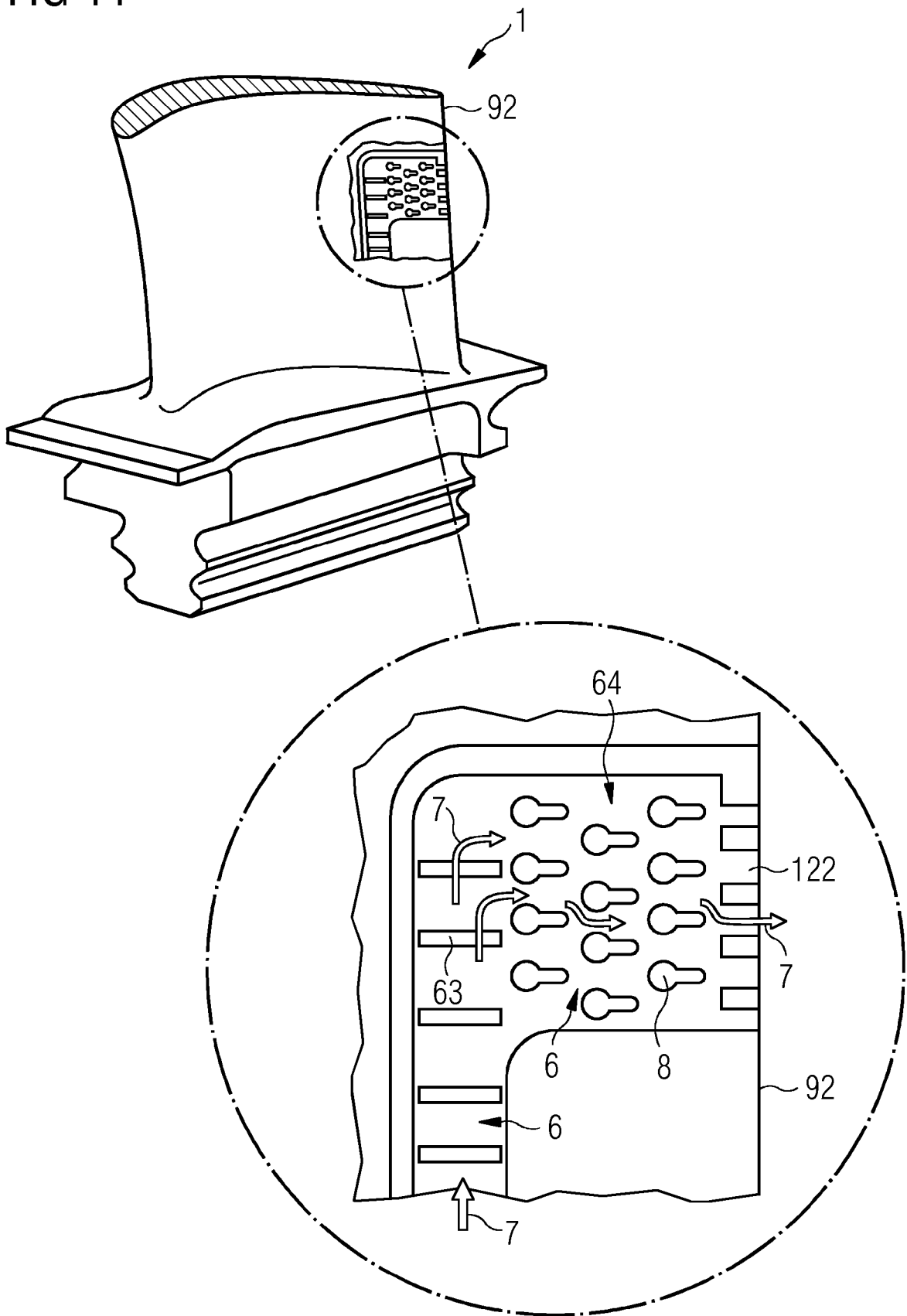


FIG 11





EUROPEAN SEARCH REPORT

Application Number  
EP 17 17 8391

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The present search report has been drawn up for all claims			
Place of search <b>Munich</b>		Date of completion of the search <b>29 November 2017</b>	Examiner <b>Lutoschkin, Eugen</b>
<b>CATEGORY OF CITED DOCUMENTS</b> 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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ON EUROPEAN PATENT APPLICATION NO.

EP 17 17 8391

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The members are as contained in the European Patent Office EDP file on  
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