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(54) **ROTOR BLADE AND CORRESPONDING GAS TURBINE**

(57) A rotor blade includes an airfoil 106 having a blade tip 120 and a tip cavity 134 formed at the blade tip. The blade tip defines a radially outer surface of the airfoil. The tip cavity includes a tip cap 136 that is recessed radially inwardly from the tip and surrounded by pressure 114 and suction 116 side walls of the airfoil. The tip cap is in fluid communication with an internal cavity defined

within the airfoil. A portion of the suction and/or the pressure side wall that define the tip cavity extends obliquely outwardly from the tip cavity. A plurality of slots 148 is defined in the suction and/or the pressure side wall along the radially outer surface proximate to the trailing edge of the airfoil.

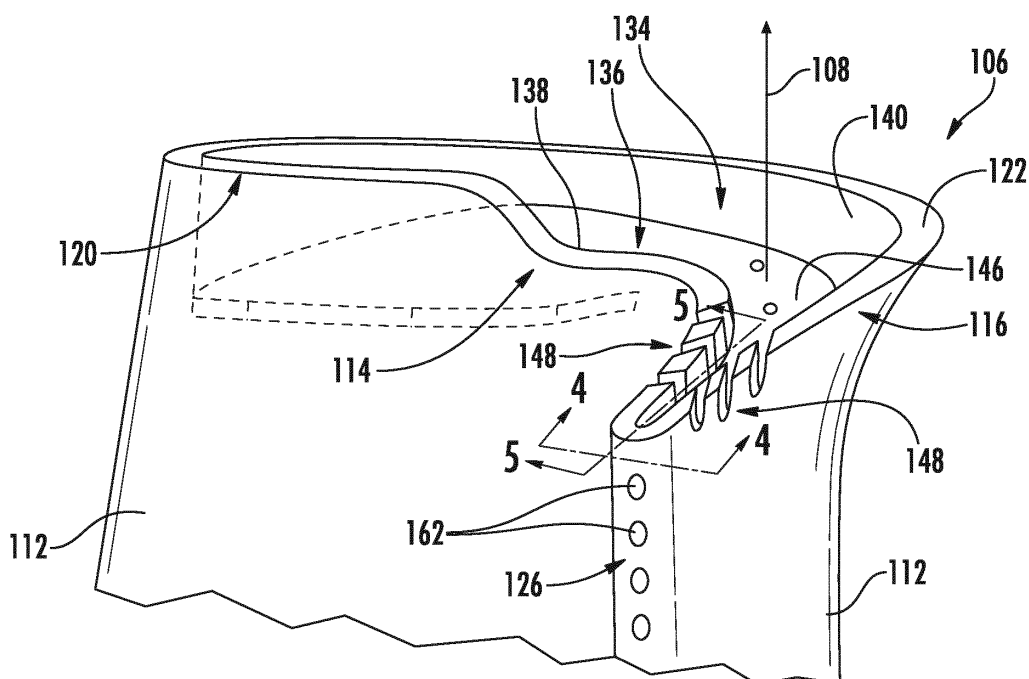


FIG. 3

Description

FIELD OF THE INVENTION

[0001] The present invention generally relates to a rotor blade for a turbine. More particularly, this invention involves a rotor blade having a flared tip configured for cooling a trailing edge portion of the rotor blade.

BACKGROUND OF THE INVENTION

[0002] In an air-ingesting turbo machine (e.g., a gas turbine), air is pressurized by a compressor and then mixed with fuel and ignited within an annular array of combustors to generate combustion gases. The hot gases are routed through a liner and into a hot gas path defined within a turbine section of the turbo machine. Kinetic energy is extracted from the combustion gases via one or more rows of turbine rotor blades that are connected to a rotor shaft. The extracted kinetic energy causes the rotor shaft to rotate, thus producing work.

[0003] The turbine rotor blades or blades generally operate in extremely high temperature environments. In order to achieve adequate service life, the blades typically include various internal cooling passages or cavities. During operation of the gas turbine, a cooling medium such as compressed air is routed through the internal cooling passages. A portion of the cooling medium may be routed out of the internal cooling passages through various cooling holes defined along the blade surface, thereby reducing high surface temperatures. An area that is generally challenging to cool effectively via the cooling medium is a blade tip portion of the turbine rotor blade, more particularly a trailing edge region of the blade tip.

[0004] The blade tip is generally defined at a radial extremity of the turbine rotor blade and is positioned radially inward from a turbine shroud that circumscribes the row of blades. The turbine shroud defines a radially outward boundary of the hot gas path. The proximity of the blade tip to the turbine shroud makes the blade tip difficult to cool. The contiguity of the shroud and the blade tip minimizes the leakage of hot operating fluid past the tip which correspondingly improves turbine efficiency.

[0005] In particular blade designs, a tip cavity formed by a recessed tip cap and a pressure side wall and a suction side wall provides a means for achieving minimal tip clearance while at the same time assuring adequate blade tip cooling. The pressure side wall and the suction side wall extend radially outwardly from the tip cap. At least a portion of at least one of the suction side wall and the pressure side wall is flared or inclined outward with respect to a radial centerline of the blade. The pressure side wall intersects with the suction side wall at a leading edge portion of the blade. However, the pressure side wall does not intersect with the suction side wall at the trailing edge, thus forming an opening therebetween. This configuration is generally due to the lack of an appropriate wall thickness of the blade along the trailing

edge.

[0006] In operation, the cooling medium is exhausted from the internal passages through holes in the tip cap into the tip cavity, thus effectively cooling the pressure and suction side walls as well as the tip cap surface. However, it may also be desirable to effectively cool the leading and trailing edges of the airfoil. Therefore there is a need for a blade tip design having improved blade tip trailing edge cooling.

BRIEF DESCRIPTION OF THE INVENTION

[0007] Aspects and advantages of the invention are set forth below in the following description, or may be obvious from the description, or may be learned through practice of the invention.

[0008] One embodiment of the present invention is a rotor blade. The rotor blade includes an airfoil having a pressure side wall and a suction side wall that are connected at leading and trailing edges of the airfoil. A blade tip defines a radially outer surface of the airfoil. The rotor blade also includes an internal cavity for receiving a cooling medium. A tip cavity that is in fluid communication with the internal cavity is at least partially defined by a tip cap. The tip cavity is recessed radially inwardly from the radially outer surface and surrounded by the pressure and suction side walls. A portion of at least one of the suction side wall or the pressure side wall that defines the tip cavity extends obliquely outwardly from the tip cavity. A plurality of slots is defined in at least one of the suction side wall or the pressure side wall along the radially outer surface proximate to the trailing edge of the airfoil.

[0009] Another embodiment of the present invention is a gas turbine. The gas turbine includes, in serial flow order, a compressor section, a combustion section and a turbine section. The turbine section includes a rotor shaft and a plurality of rotor blades that are coupled to the rotor blade. Each rotor blade includes an airfoil having a pressure side wall and a suction side wall that are connected at leading and trailing edges of the airfoil. A blade tip defines a radially outer surface of the airfoil. The rotor blade also includes an internal cavity for receiving a cooling medium. A tip cavity that is in fluid communication with the internal cavity is at least partially defined by a tip cap. The tip cavity is recessed radially inwardly from the radially outer surface and surrounded by the pressure and suction side walls. A portion of at least one of the suction side wall or the pressure side wall that defines the tip cavity extends obliquely outwardly from the tip cavity. A plurality of slots is defined in at least one of the suction side wall or the pressure side wall along the radially outer surface proximate to the trailing edge of the airfoil.

[0010] Those of ordinary skill in the art will better appreciate the features and aspects of such embodiments, and others, upon review of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] A full and enabling disclosure of the present invention, is set forth more particularly in the remainder of the specification, including reference to the accompanying figures, in which:

FIG. 1 illustrates a functional diagram of an exemplary gas turbine as may incorporate at least one embodiment of the present invention;

FIG. 2 is a perspective view of an exemplary rotor blade as may be incorporated in the gas turbine shown in FIG. 1 and as may incorporate various embodiments of the present disclosure;

FIG. 3 is a perspective view of a portion of an exemplary airfoil according to at least one embodiment of the present invention;

FIG. 4 is a cross sectioned top view of a portion of the airfoil taken along section line A-A as shown in FIG. 3, according to at least one embodiment of the present invention;

FIG. 5 is a cross sectioned side view of a portion of the airfoil taken along section line B-B as shown in FIG. 3, according to at least one embodiment of the present invention;

FIG. 6 is a perspective view of a portion of an exemplary airfoil according to at least one embodiment of the present invention; and

FIG. 7 is a cross sectioned side view of a portion of the airfoil taken along section line C-C as shown in FIG. 6, according to at least one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0012] Reference will now be made in detail to present embodiments of the invention, one or more examples of which are illustrated in the accompanying drawings. The detailed description uses numerical and letter designations to refer to features in the drawings. Like or similar designations in the drawings and description have been used to refer to like or similar parts of the invention. As used herein, the terms "first", "second", and "third" may be used interchangeably to distinguish one component from another and are not intended to signify location or importance of the individual components. The terms "upstream" and "downstream" refer to the relative direction with respect to fluid flow in a fluid pathway. For example, "upstream" refers to the direction from which the fluid flows, and "downstream" refers to the direction to which the fluid flows. The term "radially" refers to the relative direction that is substantially perpendicular to an axial

centerline of a particular component and/or substantially perpendicular to an axial centerline of the turbomachine, and the term "axially" refers to the relative direction that is substantially parallel and/or coaxially aligned to an axial centerline of a particular component and/or to an axial centerline of the turbomachine.

[0013] Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that modifications and variations can be made in the present invention without departing from the scope or spirit thereof. For instance, features illustrated or described as part of one embodiment may be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents. Although an industrial or land based gas turbine is shown and described herein, the present invention as shown and described herein is not limited to a land based and/or industrial gas turbine unless otherwise specified in the claims. For example, the invention as described herein may be used in any type of turbine including but not limited to a steam turbine or marine gas turbine.

[0014] Referring now to the drawings, FIG. 1 illustrates a schematic diagram of one embodiment of a gas turbine 10. The gas turbine 10 generally includes an inlet section 12, a compressor section 14 disposed downstream of the inlet section 12, a plurality of combustors (not shown) within a combustor section 16 disposed downstream of the compressor section 14, a turbine section 18 disposed downstream of the combustor section 16 and an exhaust section 20 disposed downstream of the turbine section 18. Additionally, the gas turbine 10 may include one or more shafts 22 coupled between the compressor section 14 and the turbine section 18.

[0015] The turbine section 18 may generally include a rotor shaft 24 having a plurality of rotor disks 26 (one of which is shown) and a plurality of rotor blades 28 extending radially outwardly from and being interconnected to the rotor disk 26. Each rotor disk 26 in turn, may be coupled to a portion of the rotor shaft 24 that extends through the turbine section 18. The turbine section 18 further includes an outer casing 30 that circumferentially surrounds the rotor shaft 24 and the rotor blades 28, thereby at least partially defining a hot gas path 32 through the turbine section 18.

[0016] During operation, a working fluid such as air flows through the inlet section 12 and into the compressor section 14 where the air is progressively compressed, thus providing pressurized air to the combustors of the combustion section 16. The pressurized air is mixed with fuel and burned within each combustor to produce combustion gases 34. The combustion gases 34 flow through the hot gas path 32 from the combustor section 16 into the turbine section 18, wherein energy (kinetic and/or thermal) is transferred from the combustion gases 34 to the rotor blades 28, thus causing the rotor shaft 24 to

rotate. The mechanical rotational energy may then be used to power the compressor section 14 and/or to generate electricity. The combustion gases 34 exiting the turbine section 18 may then be exhausted from the gas turbine 10 via the exhaust section 20.

[0017] FIG. 2 is a perspective view of an exemplary rotor blade 100 as may incorporate one or more embodiments of the present invention and as may be incorporated into the turbine section 18 of the gas turbine 10 in place of rotor blade 28 as shown in FIG. 1. As shown in FIG. 2, the rotor blade 100 generally includes a mounting or shank portion 102 having a mounting body 104, and an airfoil 106 that extends in span outwardly in a radial direction 108 from a platform portion 110 of the rotor blade 100. The platform 110 generally serves as a radially inward flow boundary for the combustion gases 34 flowing through the hot gas path 32 of the turbine section 18 (FIG. 1). As shown in FIG. 2, the mounting body 104 of the mounting or shank portion 102 may extend radially inwardly from the platform 110 and may include a root structure, such as a dovetail, configured to interconnect or secure the rotor blade 100 to the rotor disk 26 (FIG. 1).

[0018] The airfoil 106 includes an outer surface 112 that surrounds the airfoil 106. The outer surface 112 is at least partially defined by a pressure side wall 114 and an opposing suction side wall 116. The pressure side wall 114 and the suction side wall 116 extend substantially radially outwardly from the platform 110 in span from a root 118 of the airfoil 106 to a blade tip or tip 120 of the airfoil 106. The root 118 of the airfoil 106 may be defined at an intersection between the airfoil 106 and the platform 110. The blade tip 120 is disposed radially opposite the root 118. As such, a radially outer surface 122 of the blade the tip 120 may generally define the radially outermost portion of the rotor blade 100.

[0019] The pressure side wall 114 and the suction side wall 116 are joined together or interconnected at a leading edge 124 of the airfoil 106 which is oriented into the flow of combustion gases 34. The pressure side wall 114 and the suction side wall 116 are also joined together or interconnected at a trailing edge 126 of the airfoil 106 which is spaced downstream from the leading edge 124. The pressure side wall 114 and the suction side wall 116 are continuous about the trailing edge 126. The pressure side wall 114 is generally concave and the suction side wall 116 is generally convex. The chord of the airfoil 106 is the length of a straight line connecting the leading edge 114 and the trailing edge 116 and the direction from the leading edge 114 to the trailing edge 116 is typically described as the chordwise direction. A chordwise line bisecting the pressure side wall 114 and the suction side wall 116 is typically referred to as the mean-line or camber-line 128 of the airfoil 106.

[0020] Internal cooling of turbine rotor blades is well known and typically utilizes a cooling medium, as indicated by solid and dashed arrows 130, such as a relatively cool compressed air bled from the compressor section 14 (FIG. 1) of the gas turbine engine 10 which is

suitably channeled through the mounting or shank portion 102 of the rotor blade 100 and into an internal cavity or passage 132 that is at least partially defined within the airfoil 106 between the pressure side wall 114 and the suction side wall 116.

[0021] The internal cavity 132 may take any conventional form and is typically in the form of a serpentine passage. The cooling medium 130 enters the internal cavity 132 from the mounting or shank portion 102 and passes through the internal cavity 132 for suitably cooling the airfoil 106 from the heating effect of the combustion gases 34 flowing over the outer surface 112 thereof. Film cooling holes (not shown) may be disposed on the pressure side wall 114 and/or the suction side wall 116 for conventionally film cooling the outer surface 112 of the airfoil 106.

[0022] In various embodiments, a tip cavity or plenum 134 is formed at or within the blade tip 120. The tip cavity 134 is at least partially formed by a tip cap 136. As shown in FIG. 2, the tip cap 136 is recessed radially inwardly from the blade tip 120 and/or the outer surface 122 of the blade tip 120 and forms a floor portion of the tip cavity 134. The tip cap 136 is surrounded continuously by the pressure side wall 114 and the suction side wall 116.

[0023] The tip cap 136 is connected to and/or forms a seal against an inner surface or side 138 of the pressure side wall 114 and an inner surface or side 140 of the suction side wall 116 along a periphery 142 of the tip cap 136 between the leading and trailing edges 124, 126 of the airfoil 106. The tip cap 136 further includes a plurality of holes or apertures 144 that extend through a top surface or side 146 of the tip cap 136 and that provide for fluid communication between the internal cavity 132 and the tip cavity 134.

[0024] FIG. 3 provides a perspective view of a portion the airfoil 106 which includes the blade tip 120 according to at least one embodiment of the present invention. FIG. 4 provides a cross sectioned top view of a portion of the airfoil 106 taken along section lines 4-4 as shown in FIG. 3, according to at least one embodiment of the present invention. FIG. 5 provides a cross sectioned side view of a portion of the airfoil 106 taken along section lines 5-5 as shown in FIG. 3, according to at least one embodiment of the present invention.

[0025] In particular embodiments, as shown in FIG. 3, a portion of at least one of the suction side wall 116 or the pressure side wall 114 that defines the tip cavity 134 extends obliquely outwardly from the tip cavity 134 and/or the top surface 146 of the tip cap 136 with respect to radial direction 108 and/or with respect to the outer surface 112 of the airfoil 106. Radial direction 108 may be substantially perpendicular to the top surface 146 of the tip cap 136.

[0026] In particular embodiment, as shown in FIG. 3, a portion of the suction side wall 116 that defines the tip cavity 134 and a portion of the pressure side wall 114 that defines the tip cavity 134 extends obliquely outwardly from the tip cavity 134 with respect to radial direction 108

and/or with respect to the outer surface 112 of the airfoil 106. In particular embodiments, a portion of the suction side wall 116 that defines the tip cavity 134 extends obliquely outwardly from the tip cavity 134 with respect to radial direction 108 and/or with respect to the outer surface 112 of the airfoil 106. In particular embodiments, a portion of the pressure side wall 114 that defines the tip cavity 134 extends obliquely outwardly from the tip cavity 134 with respect to radial direction 108 and/or with respect to the outer surface 112 of the airfoil 106.

[0027] A portion of the inner surface or side 140 of the suction side wall 116 that defines the tip cavity 134 may extend obliquely outwardly from the tip cavity 134 with respect to radial direction 108, thus increasing an overall volume of the tip cavity 134. In addition or in the alternative, as shown in FIG. 3, a portion of the inner surface or side 138 of the pressure side wall 114 that defines the tip cavity 134 may extend obliquely outwardly from the tip cavity 134 with respect to radial direction 108, thus increasing an overall volume of the tip cavity 134.

[0028] In various embodiments, as shown collectively in FIGS. 3-5, the airfoil 106 includes a plurality of slots 148 defined by or within at least one of the suction side wall 116 or the pressure side wall 114 along the radially outer surface 122 and positioned proximate to the trailing edge 126 of the airfoil 106. As shown in FIGS. 3 and 4, the pressure side wall 114 and the suction side wall 116 maintain continuity across the trailing edge 126. Although the plurality of slots 148 are shown in FIGS. 3 and 4, as occurring on both the pressure and suction side walls 114, 116, it is intended that the plurality of slots 148 may occur only along the suction side wall 116 or occur only along the pressure side wall 114 or may occur along both the pressure side and the suction side walls 114, 116 as shown.

[0029] For example, in one embodiment, the plurality of slots 148 occurs only along the suction side wall 116. In another embodiment, the plurality of slots 148 occurs only along the pressure side wall 114. In one embodiment, as shown in FIG. 4, the plurality of slots 148 includes a first slot 150 defined in the pressure side wall 114 and a second slot 152 defined within the suction side wall along the radially outer surface proximate to the trailing edge 126 of the airfoil 106. In particular embodiments, the plurality of slots 148 is equally or non-equally distributed on both the pressure and suction side walls 114, 116.

[0030] In various embodiments, as shown in FIGS. 3 and 5, one or more slots 148 of the plurality of slots 148 extend through the radially outer surface 122 of the airfoil 106 towards the top surface 146 of the tip cap 136. In particular embodiments, as shown in FIG. 4, one or more of the slots 148 may be angled towards the trailing edge 126 as it extends through the inner surface 138 of the pressure side wall 114 or the inner surface 140 of the suction side wall 116 and the outer surface 112 of the airfoil 106. In particular embodiments, as shown in FIG. 5, at least one slot 148 of the plurality of slots 148 extends

radially into and/or at least partially through the top surface 146 of the tip cap 136.

[0031] FIG. 6 provides a perspective view of a portion the airfoil 106 which includes the blade tip 120 according to at least one embodiment of the present invention. FIG. 7 provides a cross sectioned side view of a portion of the airfoil 106 taken along section lines 7-7 as shown in FIG. 6, according to at least one embodiment of the present invention. In one embodiment, as shown in FIGS. 6 and 7, a portion 154 of the top surface 146 of the tip cap 136 that is proximate to the trailing edge 126 is stepped radially inwardly. Stepped portion 154 may be inclined along the camber line 128 (FIG. 2) or otherwise contoured to facilitate or enhance cooling effectiveness.

[0032] In various embodiments, one or more of the slots 148 of the plurality of slots 148 may be tapered and/or non-linear to enable flow of the cooling medium from the tip cavity 134 adjacent to the trailing edge 126. For example, as shown in FIG. 7, at least one slot 148 of the plurality of slots 148 may taper inwardly from the outer radial surface 122 of the blade tip 120 towards the top surface 146 of the tip cap 136. In addition or in the alternative, as shown in FIG. 4, at least one slot 148 of the plurality of slots 148 may include a curved or widened inlet 156 along inner surfaces 138, 140. As shown in FIG. 6, at least one slot 148 may also include a widened or diffusing outlet 158 along the outer surface 112. As shown in FIG. 4, at least one slot may include a narrowing region 160 defined between the inlet 156 and outlet 158.

[0033] As shown in FIGS. 4-7, at least one aperture 144 of the plurality of apertures 144 is positioned proximate to the trailing edge 126. In one embodiment, as shown in FIG. 5, at least one aperture 148 of the plurality of apertures 144 is angled aft towards the trailing edge 126 of the airfoil 106 with respect to radial direction 108. In particular embodiments, as shown in FIGS. 4 and 7, at least one aperture 144 of the plurality of apertures 144 is defined between adjacent slots 148 of the plurality of slots 148. In one embodiment, at least one aperture 144 may be disposed upstream of at least one slot 148.

[0034] In particular embodiments, as shown in FIGS. 3 and 5, one or more holes 162 are defined along the trailing edge 126 of the airfoil 106 radially below the tip cap 136. The one or more holes 162 may be in fluid communication with the internal cavity 132, thus providing additional cooling along the trailing edge 126 of the airfoil 106.

[0035] This written description uses examples to disclose the invention, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other and examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences

from the literal language of the claims.

[0036] Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A rotor blade, comprising:

an airfoil having a pressure side wall and a suction side wall connected at leading and trailing edges of the airfoil, a blade tip defining a radially outer surface of the airfoil, and an internal cavity for receiving a cooling medium; and

a tip cavity in fluid communication with the internal cavity and at least partially defined by a tip cap recessed radially inwardly from the radially outer surface and surrounded by the pressure and suction side walls, wherein a portion of at least one of the suction side wall or the pressure side wall that defines the tip cavity extends obliquely outwardly from the tip cavity, wherein a plurality of slots is defined in at least one of the suction side wall or the pressure side wall along the radially outer surface proximate to the trailing edge of the airfoil.

2. The rotor blade as in clause 1, wherein at least one slot of the plurality of slots extends radially into a top surface of the tip cap.

3. The rotor blade as in any preceding clause, wherein at least one slot of the plurality of slots includes at least one of a widened inlet defined along an inner surface of the pressure or suction side walls, a widened outlet defined along an outer surface of the pressure or suction side walls or a narrowing region defined between the inlet and outlet.

4. The rotor blade as in any preceding clause, wherein the plurality of slots includes a first slot defined in the pressure side wall and a second slot defined within the suction side wall along the radially outer surface proximate to the trailing edge of the airfoil.

5. The rotor blade as in any preceding clause, wherein a top surface of the tip cap is stepped radially inwardly proximate to the trailing edge.

6. The rotor blade as in any preceding clause, further comprising a plurality of apertures that extend through the tip cap, wherein the plurality of apertures provide for fluid communication between the internal cavity and the tip cavity, wherein at least one aperture of the plurality of apertures is defined upstream from at least one slot of the plurality of slots.

7. The rotor blade as in any preceding clause, wherein one or more slots of the plurality of slots is angled

towards the trailing edge with respect to a chamber line of the airfoil.

8. The rotor blade as in any preceding clause, further comprising a hole defined along the trailing edge of the airfoil and positioned radially below the tip cap, wherein the hole is in fluid communication with the internal cavity.

9. The rotor blade as in any preceding clause, wherein a portion of the suction side wall that defines the tip cavity extends obliquely outwardly from the tip cavity with respect to a radial direction.

10. The rotor blade as in any preceding clause, wherein a portion of the pressure side wall that defines the tip cavity extends obliquely outwardly from the tip cavity with respect to a radial direction.

11. A gas turbine, comprising:

a compressor section;

a combustion section; and

a turbine section, the turbine section having a rotor shaft and a plurality of rotor blades coupled to the rotor blade, each rotor blade comprising:

an airfoil having a pressure side wall and a suction side wall connected at leading and trailing edges of the airfoil, a blade tip defining a radially outer surface of the airfoil, and an internal cavity for receiving a cooling medium; and

a tip cavity in fluid communication with the internal cavity and at least partially defined by a tip cap recessed radially inwardly from the radially outer surface and surrounded by the pressure and suction side walls, wherein a portion of at least one of the suction side wall or the pressure side wall that defines the tip cavity extends obliquely outwardly from the tip cavity, wherein a plurality of slots is defined in at least one of the suction side wall or the pressure side wall along the radially outer surface proximate to the trailing edge of the airfoil.

12. The gas turbine as in any preceding clause, wherein at least one slot of the plurality of slots extends into a top surface of the tip cap.

13. The gas turbine as in any preceding clause, wherein at least one slot of the plurality of slots includes at least one of a widened inlet defined along an inner surface of the pressure or suction side walls, a widened outlet defined along an outer surface of

the pressure or suction side walls or a narrowing region defined between the inlet and outlet.

14. The gas turbine as in any preceding clause, wherein the plurality of slots includes a first slot defined in the pressure side wall and a second slot defined within the suction side wall along the radially outer surface proximate to the trailing edge of the airfoil.

15. The gas turbine as in any preceding clause, wherein a top surface of the tip cap is stepped radially inwardly proximate to the trailing edge.

16. The gas turbine as in any preceding clause, further comprising a plurality of apertures that extend through the tip cap, wherein the plurality of apertures provide for fluid communication between the internal cavity and the tip cavity, wherein at least one aperture of the plurality of apertures is defined along a chamber line of the airfoil between adjacent slots of the plurality of slots.

17. The gas turbine as in any preceding clause, wherein one or more slots of the plurality of slots is angled towards the trailing edge with respect to a chamber line of the airfoil.

18. The gas turbine as in any preceding clause, further comprising a hole defined along the trailing edge of the airfoil and positioned radially below the tip cap, wherein the hole is in fluid communication with the internal cavity.

19. The gas turbine as in any preceding clause, wherein a portion of the suction side wall that defines the tip cavity extends obliquely outwardly from the tip cavity with respect to a radial direction.

20. The gas turbine as in any preceding clause, wherein a portion of the pressure side wall that defines the tip cavity extends obliquely outwardly from the tip cavity with respect to a radial direction.

Claims

1. A rotor blade, comprising:

an airfoil having a pressure side wall and a suction side wall connected at leading and trailing edges of the airfoil, a blade tip defining a radially outer surface of the airfoil, and an internal cavity for receiving a cooling medium; and a tip cavity in fluid communication with the internal cavity and at least partially defined by a tip cap recessed radially inwardly from the radially outer surface and surrounded by the pressure

and suction side walls, wherein a portion of at least one of the suction side wall or the pressure side wall that defines the tip cavity extends obliquely outwardly from the tip cavity, wherein a plurality of slots is defined in at least one of the suction side wall or the pressure side wall along the radially outer surface proximate to the trailing edge of the airfoil.

2. The rotor blade as in claim 1, wherein at least one slot of the plurality of slots extends radially into a top surface of the tip cap.

3. The rotor blade as in claim 1 or 2, wherein at least one slot of the plurality of slots includes at least one of a widened inlet defined along an inner surface of the pressure or suction side walls, a widened outlet defined along an outer surface of the pressure or suction side walls or a narrowing region defined between the inlet and outlet.

4. The rotor blade as in claim 1, 2 or 3, wherein the plurality of slots includes a first slot defined in the pressure side wall and a second slot defined within the suction side wall along the radially outer surface proximate to the trailing edge of the airfoil.

5. The rotor blade as in any of claims 1 to 4, wherein a top surface of the tip cap is stepped radially inwardly proximate to the trailing edge.

6. The rotor blade as in any preceding claim, further comprising a plurality of apertures that extend through the tip cap, wherein the plurality of apertures provide for fluid communication between the internal cavity and the tip cavity, wherein at least one aperture of the plurality of apertures is defined upstream from at least one slot of the plurality of slots.

7. The rotor blade as in any preceding claim, wherein one or more slots of the plurality of slots is angled towards the trailing edge with respect to a chamber line of the airfoil.

8. The rotor blade as in any preceding claim, further comprising a hole defined along the trailing edge of the airfoil and positioned radially below the tip cap, wherein the hole is in fluid communication with the internal cavity.

9. The rotor blade as in any preceding claim, wherein a portion of the suction side wall that defines the tip cavity extends obliquely outwardly from the tip cavity with respect to a radial direction.

10. The rotor blade as in any preceding claim, wherein a portion of the pressure side wall that defines the tip cavity extends obliquely outwardly from the tip

cavity with respect to a radial direction.

11. A gas turbine, comprising:

a compressor section; 5
 a combustion section; and
 a turbine section, the turbine section having a
 rotor shaft and a plurality of rotor blades coupled
 to the rotor blade, each rotor blade comprising: 10
 an airfoil having a pressure side wall and a
 suction side wall connected at leading and
 trailing edges of the airfoil, a blade tip de-
 fining a radially outer surface of the airfoil,
 and an internal cavity for receiving a cooling 15
 medium; and
 a tip cavity in fluid communication with the
 internal cavity and at least partially defined
 by a tip cap recessed radially inwardly from
 the radially outer surface and surrounded 20
 by the pressure and suction side walls,
 wherein a portion of at least one of the suc-
 tion side wall or the pressure side wall that
 defines the tip cavity extends obliquely out-
 wardly from the tip cavity, wherein a plurality 25
 of slots is defined in at least one of the suc-
 tion side wall or the pressure side wall along
 the radially outer surface proximate to the
 trailing edge of the airfoil. 30

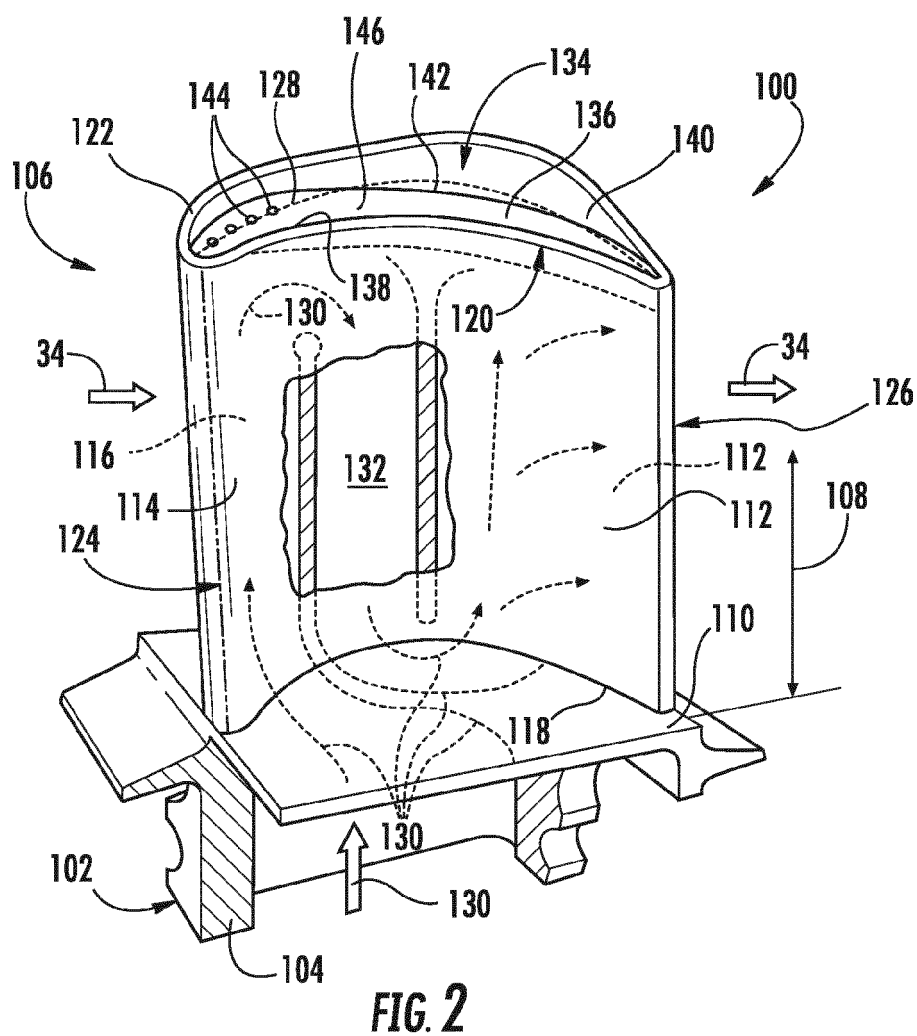
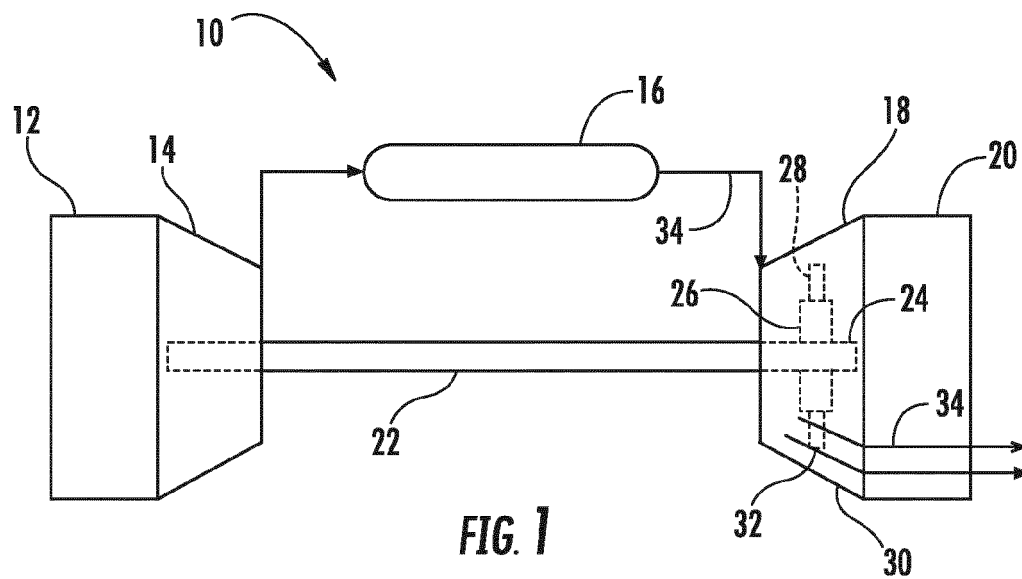
12. The gas turbine as in claim 11, wherein at least one
 slot of the plurality of slots extends into a top surface
 of the tip cap.

13. The gas turbine as in claim 11 or 12, wherein at least 35
 one slot of the plurality of slots includes at least one
 of a widened inlet defined along an inner surface of
 the pressure or suction side walls, a widened outlet
 defined along an outer surface of the pressure or
 suction side walls or a narrowing region defined be- 40
 tween the inlet and outlet.

14. The gas turbine as in claim 11, 12 or 13, wherein the
 plurality of slots includes a first slot defined in the
 pressure side wall and a second slot defined within 45
 the suction side wall along the radially outer surface
 proximate to the trailing edge of the airfoil.

15. The gas turbine as in claim 11, 12, 13 or 14, wherein
 a top surface of the tip cap is stepped radially inward- 50
 ly proximate to the trailing edge.

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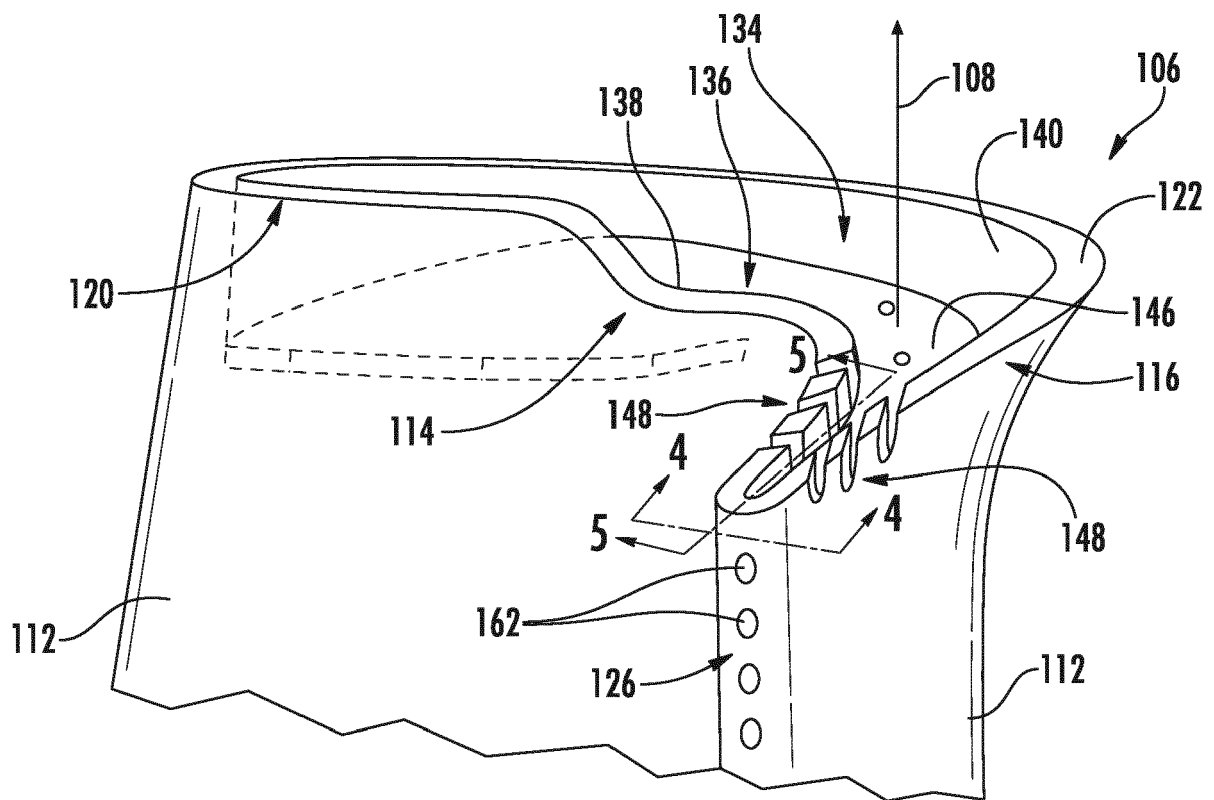
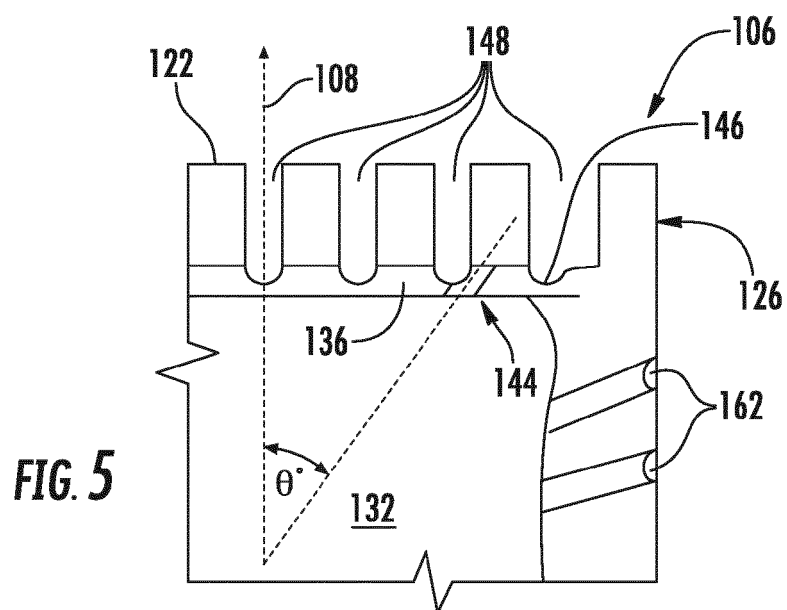
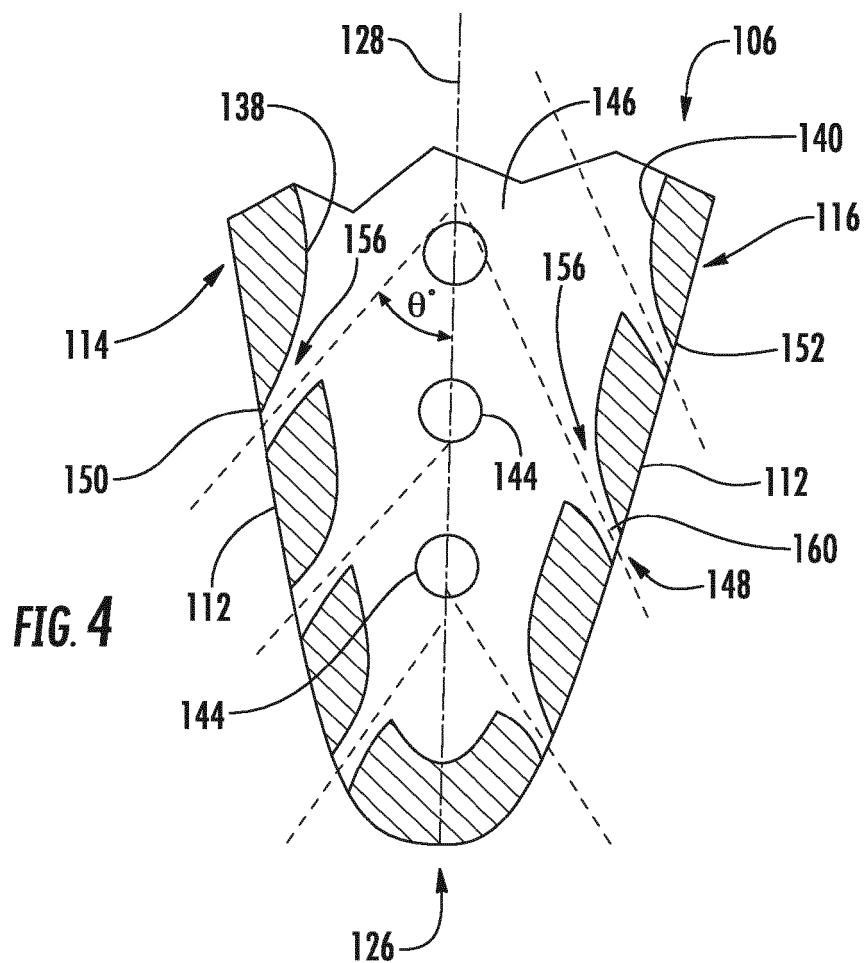
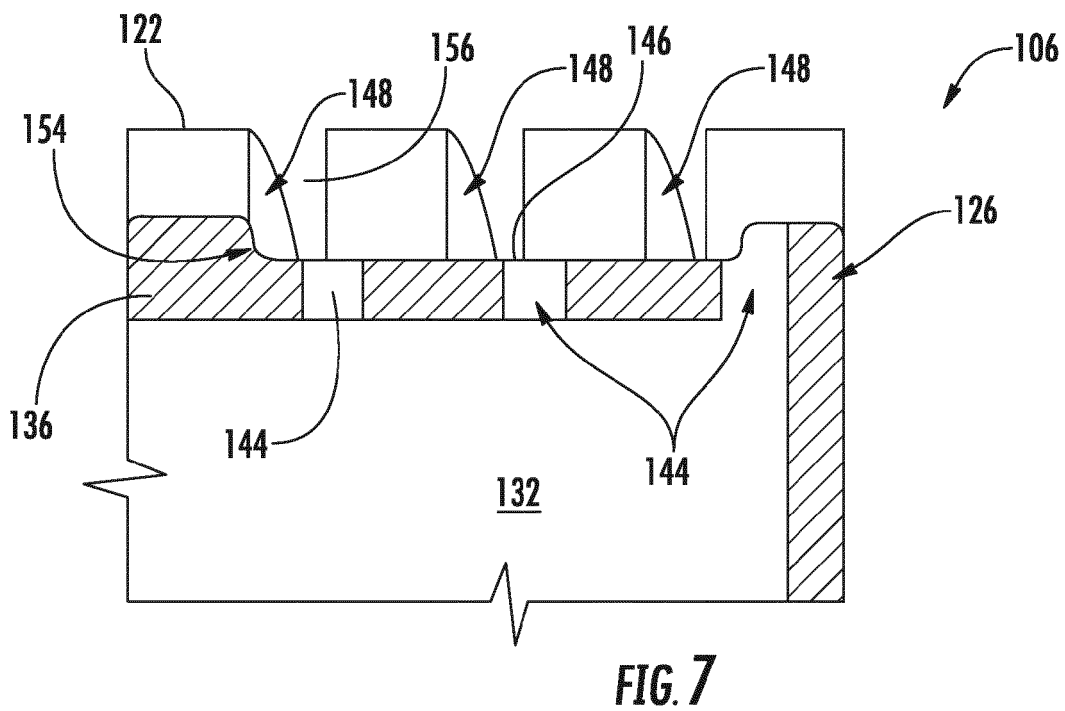
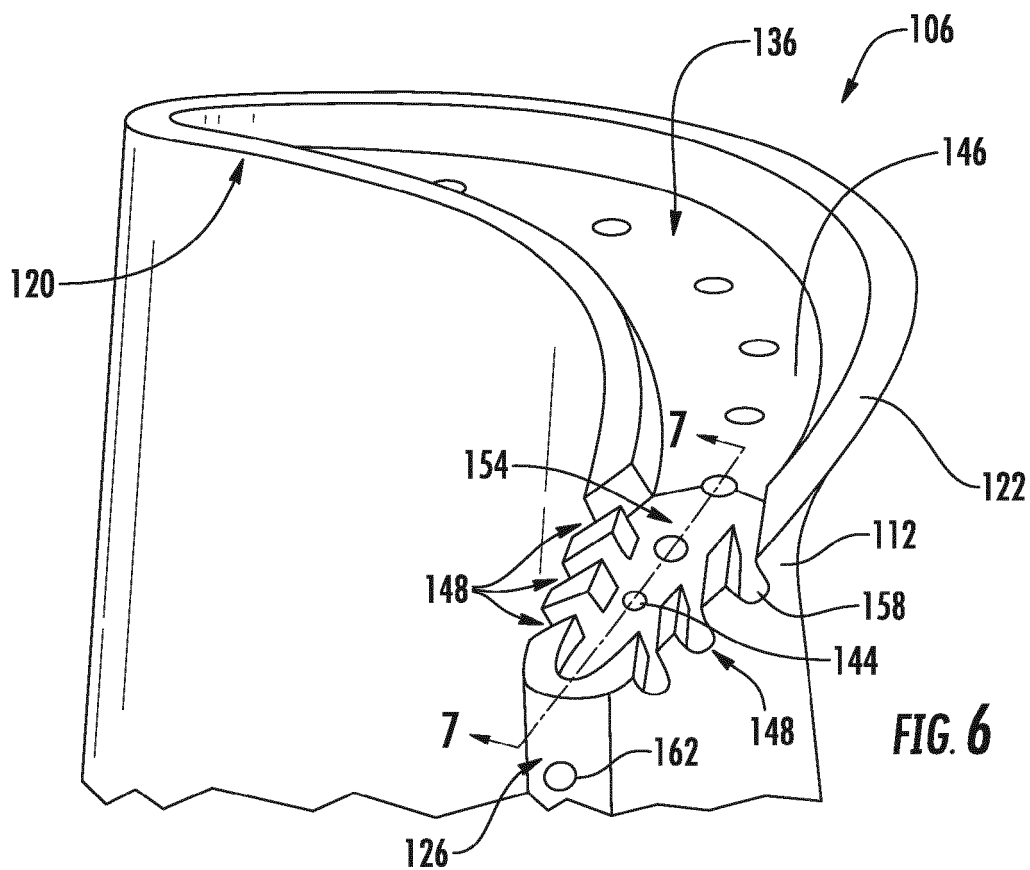


FIG. 3







EUROPEAN SEARCH REPORT

 Application Number
 EP 16 16 6812

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2002/182074 A1 (BUNKER RONALD SCOTT [US]) 5 December 2002 (2002-12-05) * paragraphs [0020] - [0021], [0027]; figures 3,9,10 *	1,3,5,6,10,11,13,15	INV. F01D5/20
X	US 2004/179940 A1 (LIANG GEORGE [US]) 16 September 2004 (2004-09-16) * paragraphs [0025], [0034], [0035]; figures 4,1 *	1,3-6,9-11,13-15	
X	US 2014/047842 A1 (CHLUS WIESLAW A [US] ET AL) 20 February 2014 (2014-02-20) * paragraphs [0032] - [0036]; figures 3-5 *	1-3,5-9,11-13,15	
X	US 8 801 377 B1 (LIANG GEORGE [US]) 12 August 2014 (2014-08-12) * column 3, line 52 - line 67; figures 2,7 *	1,3-6,8,10,11,13-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F01D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 28 July 2016	Examiner Ketelheun, Anja
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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 EPO FORM 1503 03.82 (P04C01)

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

EP 16 16 6812

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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28-07-2016

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2002182074 A1	05-12-2002	NONE	
US 2004179940 A1	16-09-2004	US 2004179940 A1	16-09-2004
		US 2006029497 A1	09-02-2006
US 2014047842 A1	20-02-2014	EP 2885504 A2	24-06-2015
		US 2014047842 A1	20-02-2014
		WO 2014058493 A2	17-04-2014
US 8801377 B1	12-08-2014	NONE	