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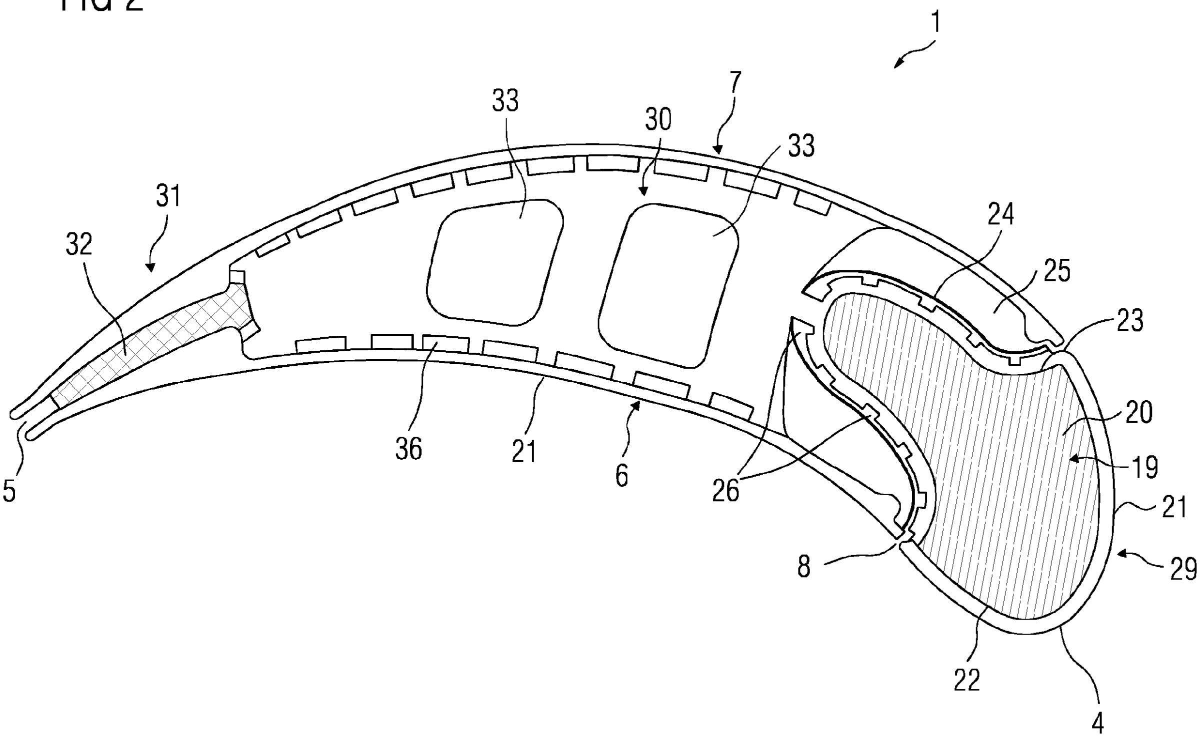
(54) Liquid metal cooled blade

(57) A blade (1) for a turbomachine is presented. The blade includes a leading edge (4) and a trailing edge (5), and a cavity (20) located at the leading edge (4) characterized in that the cavity (20) is at least partly filled by a material (19) which is liquid at operating temperature of the turbomachine.

FIG 2



EP 2 540 970 A1

Description

[0001] The invention relates to a blade for a turbomachine and more particularly to an airfoil portion of the blade.

[0002] In modern day turbomachines various components of the turbomachine operate at very high temperatures. These components include the blade or vane component, which are in shape of an airfoil. In the present application, only "blade", but the specifications can be transferred to a vane. The high temperatures during operation of the turbomachine may damage the blade component, hence cooling of the blade component is important. Cooling of these components is generally achieved by passing a cooling fluid that may include air from a compressor of the turbomachine through a core passage way cast into the blade component.

[0003] An airfoil such as a blade has a leading edge and a trailing edge. Cooling of the leading edge is very important since the largest thermal load occurs at the leading edge and the cooling flow affects the aerodynamics and heat transfer of the entire airfoil. Currently, the leading edge of the airfoil portion of the blade is cooled by impingement cooling or by film cooling and the trailing edge by matrix arrangement of ribs, pin-fins and so forth.

[0004] One such way of cooling is mentioned in US patent no. 6,241,469 which describes a turbine blade with a metal blade body and a protective coating constructed of a porous intermetallic felt. In the blade body cooling air channels are constructed that end at the intermetallic felt in order to supply it with cooling air. The intermetallic felt is formed from an iron or nickel aluminide alloy.

[0005] US patent no. 5,348,446 describes an airfoil for a gas turbine engine which is constructed from a core body formed of a conventional nickel-based super alloy and leading and trailing edge components and squealer tip formed of a nickel aluminide alloy. The nickel aluminide components exhibit a high degree of thermal conductivity and transfer heat from the leading edge and the trailing edge into the core body by direct conduction.

[0006] It may be noted that the turbomachines as mentioned in these patents operate at high temperatures which may cause the material inside the blade to melt resulting in loss of stability.

[0007] It is therefore an object of the present invention to provide an approach for improved cooling of a turbomachine blade.

[0008] The object is achieved by a blade for a turbomachine according to claim 1.

[0009] The invention is based on the idea to use both conduction and convection effects for cooling of the leading edge of the blade by including a material with special properties inside the blade.

[0010] According to the invention the blade of the turbomachine includes a cavity at the leading edge. The cavity is at least partly filled by a material which is liquid near the operating temperatures of the turbomachine. By having a material which is liquid near the operating temperatures of the turbomachine, allows the heat transfer from the leading edge to the other portions of the blade through conduction and convection. The liquid material transfers the heat through convection to the core region, from where the heat is easily dissipated through a wall which is cooled via cooling medium. In addition, the rotation of the blade during operation of the turbomachine also generates centrifugal force which aids in cooling by convection in the cavity at the leading edge because colder liquid material is forced in a radial direction towards the outer portions of the cavity which is hot.

[0011] In one embodiment, the blade of the turbomachine has a root portion and an airfoil portion, wherein the airfoil portion has the leading edge and the trailing edge.

[0012] In one embodiment, the material is zinc. Zinc has a high degree of thermal conductivity of about 116 Watt/meter*Kelvin and is in liquid state near the operating temperatures of the turbomachine which aids in both the heat transfer through conduction and convection.

[0013] In another embodiment, the material is aluminium. Aluminium has a high thermal conductivity of about 240 Watt/meter*Kelvin. Furthermore, aluminium is liquid at operating temperatures of the turbomachine.

[0014] In one embodiment, the cavity is defined by a wall inside the blade having one or more cooling means. The one or more cooling means allow efficient cooling of the wall and thus dissipate the heat to the surroundings.

[0015] In one embodiment, the cooling means include cooling channels, pins, and/or fins to allow efficient transfer of heat and cooling of the blade.

[0016] The cooling channels include a cooling medium such as a coolant or air to cool the inner portions of the blade.

[0017] The wall defines the cavity which extends into the core region from the leading edge of the blade. Heat is transferred via the material in the cavity to the wall from the leading edge to the core region of the blade, which prevents the leading edge from being over heated.

[0018] The surface area of the cavity proximal to the core region of the blade is greater than the surface area of the cavity at the leading edge. Greater surface area proximal to the core region enables higher cooling and dissipation of heat.

[0019] In one embodiment, at least one of the leading edge, trailing edge, the core region and the wall defining the cavity are formed from a super alloy. Super alloys have excellent mechanical strength and creep resistance at high temperatures. In addition, the super alloys have good surface stability and are corrosion resistant.

[0020] The above-mentioned and other features of the invention will now be addressed with reference to the accompanying drawings of the present invention. 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 is a schematic diagram of a blade of a turbomachine; and

FIG. 2 shows a radial sectional view through the exemplary blade of the turbomachine along the lines II-II of FIG. 1.

[0021] 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. The turbomachine may include a gas turbine, a steam turbine, a turbofan and the like.

[0022] **FIG. 1** is a schematic diagram of an exemplary blade 1 of a rotor (not shown) of a turbomachine, such as a gas turbine. The blade 1 includes an airfoil portion 2 and a root portion 3. The airfoil portion 2 projects from the root portion 3 in a radial direction as depicted, wherein the radial direction means a direction perpendicular to the rotation axis of the rotor. Thus, the airfoil portion 2 extends radially along a longitudinal direction of the blade 1. The blade 1 is attached to a body of the rotor (not shown), in such a way that the root portion 3 is attached to the body of the rotor whereas the airfoil portion 2 is located at a radially outermost position. The airfoil portion 2 has an outer wall including a pressure side 6, also called pressure surface, and a suction side 7, also called suction surface. The pressure side 6 and the suction side 7 are joined together along an upstream leading edge 4 and a downstream trailing edge 5, wherein the leading edge 4 and the trailing edge 5 are spaced axially from each other as depicted in FIG. 1.

[0023] In accordance with the aspects of the present technique, one or more cooling holes 8 are present on the pressure side 6 and the suction side 7 of the blade as depicted in FIG. 1. The cooling holes 8 aid in film cooling of the blade 1 as will be described in more detail with reference to FIG. 2.

[0024] Furthermore, it may be noted that the blade 1 may be cast as a single component or may alternatively be assembled from multiple components. The multiple component blade may include a leading edge component, a trailing edge component and a core region component. The components may be cast separately and thereafter joined together by bonding or brazing for example.

[0025] Referring now to **FIG. 2,** a radial sectional view of the blade 1 of the gas turbine at the airfoil portion 2 along the lines II-II in FIG.1 is depicted. The blade 1 includes an outer wall 21 extending from the leading edge 4 to the trailing edge 5. Additionally, the blade 1 includes an inner wall 22 adjacent the outer wall 21 extending from the leading edge 4 to the trailing edge 5 of the blade.

[0026] Typically, the blade 1 may have three regions, namely the leading region 29, the trailing region 31 and the core region 30 between the leading region 29 and the trailing region 31. Additionally, the blade 1 may also include a cavity 20 or webs which are structures cast inside the blade 1 extending from the pressure side 6 to the suction side 7 of the blade 1. These structures such as ribs, fins or pins may be casted or machined inside the components such as at the core region 30 or the trailing region 31 of the blade 1.

[0027] In the presently contemplated configuration, the blade 1 comprises the cavity 20 at the leading edge 4 which is defined by a wall 23. As illustrated in FIG. 2, the wall 23 separates the leading region and the core region of the blade 1. In accordance with aspects of the present technique, the extent or boundary of the cavity 20 is defined by the wall 23.

[0028] The cavity 20 is at least partly filled with a material 19 which is liquid at the operating temperature of the turbomachine. The material 19 is a metal with high thermal conductivity such as, but not limited to zinc or aluminium. The material 19 may also include any other material with similar characteristics or properties such as turning into liquid state at the operating temperatures of the turbomachine.

[0029] In accordance with aspects of the present technique, a cooling passage 25 is located adjacent the wall 23. The cooling passage 25 allows air from the surrounding to be directed inside the blade, the cool air dissipates the heat from the wall 23 and directs the air outside the blade via one or more cooling holes 8 located on both the pressure side and the suction side of the blade for film cooling. More particularly, the cooling holes 8 are present on the outer wall of the blade.

[0030] During the operation of the gas turbine, temperature at the leading edge 4 may exceed 900 degree centigrade and the temperature at the interior of the blade may be in the range of about 750 degree centigrade. Metals such as aluminium and zinc have a low melting point and therefore melt at the operating temperatures. For example, zinc has a melting point of about 420 degree centigrade and aluminium has a melting point of about 660 degree centigrade. At operating temperatures these materials are in a liquid state and hence also transfer heat due to convection besides transferring the heat through conduction. More particularly, the heated material at the leading edge moves due to convection to the cooler portion that is near the wall 23, the heat from the material 19 is transferred to the wall 23, which is thereafter dissipated to the surroundings via the air passing through the cooling channels 26. Additionally, the centrifugal force created due to rotation of blade 1 during operation ameliorates the transfer of heat from the leading edge 4 to the wall 23 and subsequently to the cooling passage 25 of the blade 1.

[0031] As will be appreciated, aluminium has a high thermal conductivity of about 240 Watt/meter*Kelvin and zinc has thermal conductivity of about 116 Watt/meter*Kelvin. Thereby, transfer of heat from the leading edge to other parts of the blade is achieved in a short duration.

[0032] In the presently contemplated configuration, the cavity 20 is completely filled with the material 19. However, in one embodiment the cavity 20 is only partially filled with the material 19. The material 19 while changing state from solid to liquid may expand; hence, partially filling the cavity 20 with the material 19 prevents stress on the wall 23 and the leading edge 4 to increase due to expansion of the material 19.

[0033] During operation of the gas turbine, heat from the leading edge 4 is transferred to the wall 23. More particularly, heat from the leading edge 4 is transferred to the wall 23 through conduction as well as convection. The wall 23 includes one or more cooling means such as cooling channels 26, which allow a cooling medium, such as but not limited to air to pass through. In one embodiment, the cooling medium may also include a coolant, oil or steam for example. The cooling medium passes through the cooling channels 26 and thereby dissipates heat from the wall 23 via the cooling holes 8. Thus, the temperature of the blade 1 is reduced.

[0034] Additionally, the cooling passage 25 dissipates the heat from the wall 23 through the cool air passing through the cooling passage 25; the air is thereafter discharged from the blade through the cooling holes 8 (see also FIG. 1).

[0035] The blade 1 may also include an insert 24 located adjacent the wall 23 as depicted in FIG. 2. The insert 24 is formed of a material such as, but not limited to steel. The insert 24 aids in cooling of the wall 23 by causing impingement of cool air flowing through the cooling passage 25 along the surface of the wall 23.

[0036] It may be noted that the shape of the cavity 20 and of the wall 23, respectively, proximal to the core region 30 is such that the wall 23 has a greater surface area than at the leading edge 4, as illustrated in FIG. 2.

[0037] Furthermore, the wall 23 may also include structures such as ribs, pin-fins and so forth, resulting in an enlarged surface area of the wall 23 to aid in cooling of the blade 1. In the presently contemplated configuration, the wall 23 includes cooling channels 26 for cooling of the blade 1. The cooling medium such as air after dissipating the heat from the wall 23 is exited to the surroundings through the cooling holes 8 as depicted.

[0038] As previously noted, the middle portion of the blade 1 which is also known as the core region 30 is defined by the inner wall 22 which extends throughout the extent of the blade 1. The core region 30 of the blade 1 may include structures 36 such as fins, ribs for cooling. It may be noted that for a vane configuration, an insert may also be present in the core region defining core cooling passages. The insert present in the vane configuration aids in impingement cooling of the core region of the vane. It may be noted that the insert may be formed of a material such as but not limited to steel.

[0039] In accordance with aspects of the present technique, the core cooling passages 33 allows air from the surrounding inside the core region 30 to cool the core region.

[0040] With continuing reference to FIG. 2, a matrix arrangement 32 of ribs is present at the trailing region 31 of the blade for allowing air to efficiently cool the trailing region 31.

[0041] It may be noted that the blade 1 may be formed of a superalloy such as but not limited to a nickel based superalloy. Typically, the outer wall 21, the inner wall 22 and the wall 23 may be formed of a superalloy. In addition, the leading edge 4, the trailing edge 5, the core region may be formed of a superalloy. Super alloys have excellent mechanical strength and creep resistance at high temperatures. In addition, the super alloys have good surface stability and are corrosion resistant.

[0042] 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 blade (1) for a turbomachine, comprising:

- a leading edge (4) and a trailing edge (5), and
- a cavity (20) located at the leading edge (4) **characterized in that** the cavity (20) is at least partly filled by a material (19) which is liquid near operating temperature of the turbomachine.

2. The blade (1) according to claim 1, further comprising a root portion (3) and an airfoil portion (2) wherein the leading edge (4) and the trailing edge (5) are located at the airfoil portion (2).

3. The blade (1) according to claims 1 and 2, wherein the material (19) is a metal.

4. The blade (1) according to claims 1 to 3, wherein the material (19) is zinc.

5. The blade (1) according to claims 1 to 3, wherein the material (19) is aluminium.

6. The blade (1) according to any of the claim 1 to 5, wherein the cavity (20) at the leading edge (4) is defined by a wall (23) of the blade having one or more cooling means formed thereon.

7. The blade (1) according to claim 6, wherein the cooling means comprise at least one of cooling channels, pins, fins, ribs.

8. The blade (1) according to claim 7, wherein the cooling channels (26) comprise a cooling medium.

9. The blade (1) according to any of the claim 1 to 8, wherein the cavity (20) is defined by the wall (23), the cavity (20) extending from the leading edge (4) to a core region (3) of the blade (1).

10. The blade (1) according to any of the claims 1 to 9, wherein a surface area of the cavity (20) proximal to the core region (30) is greater than a surface area of the cavity (20) proximal to the leading edge (4).

11. The blade (1) according to any of the claims 1 to 10, further comprising an insert (24) separating the wall (23) defining the cavity from the core region.

12. The blade (1) according to any of the claims 1 to 11, further comprising a cooling passage (25) adjacent the insert (24).

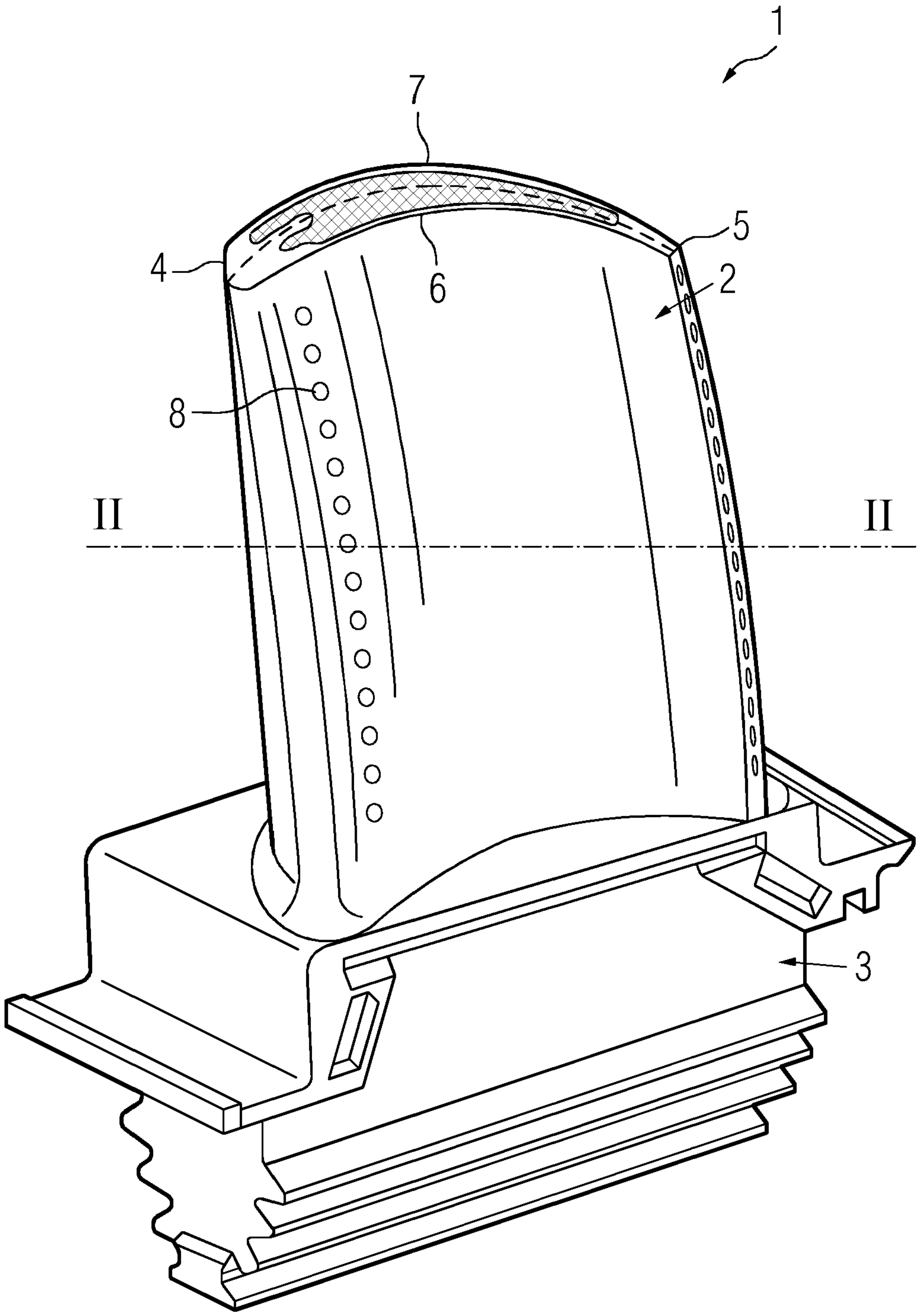
13. The blade (1) according to any of the claims 1 to 12, further comprising one or more cooling holes (8) located at a pressure side (6) and a suction side (7) of the blade (1).

14. The blade (1) according to any of the claim 1 to 13, wherein at least one of the leading edge (4), the trailing edge (5), the core region (30) and the wall (23) defining the cavity (20) is formed from a super alloy.

15. A turbomachine comprising a blade (1) according to any of the preceding claims 1 to 14.

16. The turbomachine according to claim 15, wherein turbomachine is a gas turbine.

FIG 1



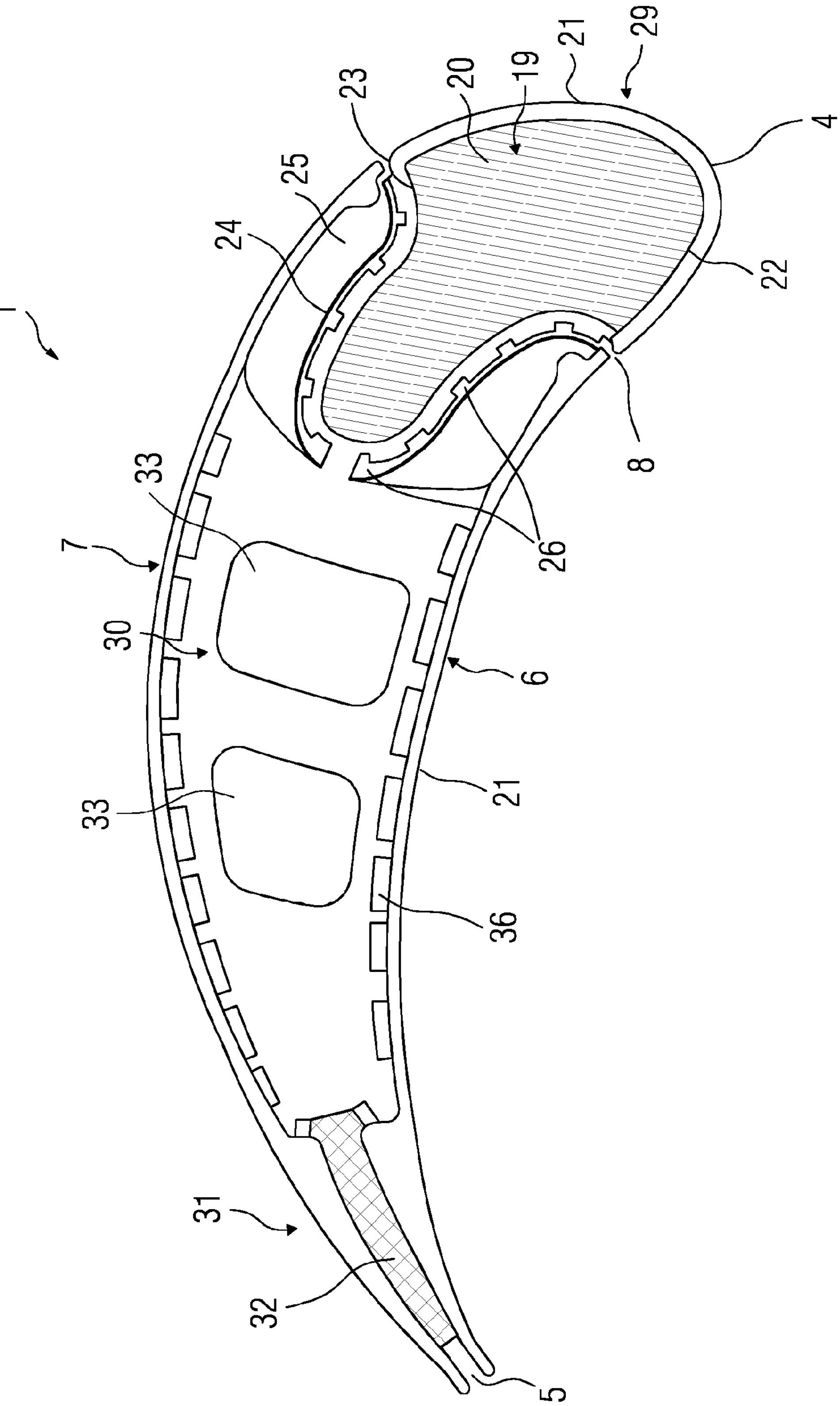


FIG 2

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EUROPEAN SEARCH REPORT

Application Number
EP 11 17 2402

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	GB 610 737 A (POWER JETS RES & DEV LTD; JOHN FORSTER ALCOCK) 20 October 1948 (1948-10-20) * sentences 53-59; figures 4,5 * * page 3, lines 7-12 * * page 3, line 103 - page 4, line 5 *	1-3,5, 15,16	INV. F01D5/18
X	US 3 314 650 A (MCCORMICK SIGNE M) 18 April 1967 (1967-04-18) * figures 3,4 *	1-3,6,7, 9-12,15, 16	
X	FR 1 102 424 A (PARSONS & MARINE ENG TURBINE) 20 October 1955 (1955-10-20) * page 2, lines 56-68; figure 1 *	1-5,15, 16	
X	FR 1 374 906 A (GEN ELECTRIC) 9 October 1964 (1964-10-09) * page 2, line 15 - page 2, line 60; figure 2 * * page 3, line 53 - page 3, line 98 *	1-3, 6-10,12, 15,16	TECHNICAL FIELDS SEARCHED (IPC)
X	GB 2 087 980 A (ROLLS ROYCE) 3 June 1982 (1982-06-03) * page 1, lines 52-93; figure 1 *	1,2, 6-10,12, 13,15,16	F01D
X	GB 2 245 660 A (ROLLS ROYCE [GB]) 8 January 1992 (1992-01-08) * figure 3 *	1,2, 6-11,15, 16	
X	GB 2 051 964 A (ROLLS ROYCE) 21 January 1981 (1981-01-21) * page 1, line 129 - page 2, line 24; claim 4; figure 2 *	1-3,6-8, 13,15,16	
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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	1 March 2012	Teusch, Reinhold

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EUROPEAN SEARCH REPORT

Application Number
EP 11 17 2402

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	DE 23 50 010 A1 (BERGMANN BORSIG VEB) 25 July 1974 (1974-07-25) * page 4; figures 2,3 * * page 5, lines 9-12 * -----	1-3,15, 16	

TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	1 March 2012	Teusch, Reinhold

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01-03-2012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 610737 A	20-10-1948	NONE	
US 3314650 A	18-04-1967	GB 1078098 A	02-08-1967
		US 3314650 A	18-04-1967
FR 1102424 A	20-10-1955	NONE	
FR 1374906 A	09-10-1964	NONE	
GB 2087980 A	03-06-1982	NONE	
GB 2245660 A	08-01-1992	NONE	
GB 2051964 A	21-01-1981	DE 3023022 A1	08-01-1981
		FR 2460387 A1	23-01-1981
		GB 2051964 A	21-01-1981
		JP 1363562 C	09-02-1987
		JP 56012002 A	05-02-1981
		JP 61023362 B	05-06-1986
		US 4529357 A	16-07-1985
DE 2350010 A1	25-07-1974	CS 163396 B1	15-09-1975
		DD 105287 A1	12-04-1974
		DE 2350010 A1	25-07-1974

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6241469 B **[0004]**
- US 5348446 A **[0005]**