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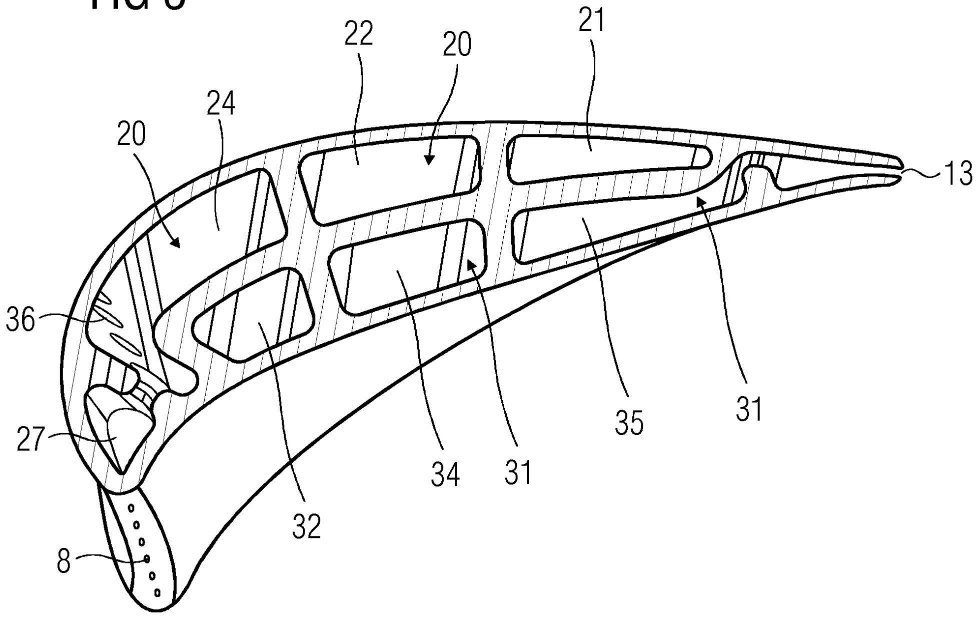
## (54) Blade for a turbomachine

(57) A blade (1) of a turbomachine is presented. The blade (1) includes an airfoil portion (2) and a root portion (3), the airfoil portion (2) comprising a pressure side (6) and a suction side (7) extending between a leading edge (4) and a trailing edge (5) of the airfoil portion (2), characterized in that the airfoil portion (2) comprises a cooling arrangement having an inlet system (28) for introducing cooling fluid (26) into the airfoil (2) for cooling the airfoil (2), at least one first cooling passage (20, 40, 68) for conducting cooling fluid in a direction from the trailing edge (5) to the leading edge (4) on the suction side (7), wherein the first cooling passage (20, 40, 68) is fluidly connected to the inlet system (28), at least one second cooling passage (31, 50, 69) for conducting cooling fluid in a direction from the leading edge (4) to the trailing edge (5) on the pressure side (6), wherein the second cooling passage (31, 50, 69) is fluidly connected to the inlet system (28).

FIG 3

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## Description

**[0001]** The present invention relates to a blade for a turbomachine and more particularly to a cooling arrangement for an airfoil of a blade of a turbomachine.

**[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]** The blade typically includes an airfoil portion and a root portion separated by a platform. The airfoil portion of the blade is cooled by directing a cooling fluid to flow through radial passages formed in the airfoil portion of the blades. Typically, a number of small axial passages are formed inside the blade airfoils that connect with one or more of the radial passages so that cooling air is directed over the surfaces of the airfoils, such as the leading and trailing edges or the suction and pressure surfaces. After the cooling air exits the blade it enters and mixes with the hot gas flowing through the turbine section.

**[0004]** Typically, cooling of the blade is achieved by supplying the cooling fluid from the compressor to the cooling channels in the blades. The cooling channels often include multiple flow paths that are designed to maintain all aspects of the turbine blade at a relatively uniform temperature.

**[0005]** Several different cooling arrangements based on a combination of convective, impingement, and external film-based cooling have been proposed in the state of the art.

**[0006]** It is an object of the present invention to provide an improved and efficient cooling arrangement for the blade of a turbomachine.

**[0007]** The object is achieved by providing a blade for a turbomachine according to claim 1.

**[0008]** According to the invention, a blade for a turbomachine is provided. The blade of a turbomachine includes an airfoil portion and a root portion, the airfoil portion including a pressure side and a suction side extending between a leading edge and a trailing edge of the airfoil portion, **characterized in that** the airfoil portion comprises a cooling arrangement, having an inlet system for introducing cooling fluid into the airfoil portion for cooling the airfoil portion, at least one first cooling passage for conducting cooling fluid in a direction from the trailing edge to the leading edge on the suction side, wherein the first cooling passage is fluidly connected to the inlet system and at least one second cooling passage for conducting cooling fluid in a direction from the leading edge to the trailing edge on the pressure side, wherein the second cooling passage is fluidly connected to the inlet system. By having the first cooling passage for conducting the cooling fluid in a direction from the leading edge to the trailing edge on the pressure side and the second cooling passage conducting the cooling fluid from the trailing edge to the leading edge on the suction side, the cooling efficiency is increased since the pressure side and the suction side surfaces of the airfoil are respectively and independently cooled by the cooling fluid flowing in different and opposite directions.

**[0009]** In one embodiment, the airfoil portion extends in a direction radial to an axis of rotation of a rotor of the turbomachine. In one embodiment, a separating cavity between the inlet system and the first cooling passage and the second cooling passage enables directing portions of the cooling fluid to the passages respectively, thereby enabling cooling of both the suction side and the pressure side surfaces of the airfoil.

**[0010]** Additionally, design of the separating cavity may also enable directing a first portion of the fluid in the first cooling passage and a second portion of the fluid in the second cooling passage depending on the amount of cooling required for the suction side and the pressure side.

**[0011]** In another embodiment, the inlet system includes a first inlet and a second inlet fluidly connected to the first cooling passage and the second cooling passage respectively. Such an arrangement enables a fixed and desired amount of cooling fluid into the airfoil based on the cooling required at the pressure side and the suction side.

**[0012]** In one embodiment, a plurality of impingement holes is present in the airfoil for cooling the leading edge portion of the blade. Cooling fluid flowing along the first cooling passage is directed towards the leading edge, which is exposed to high temperatures, hence impingement holes provide impingement cooling at the leading edge portion, prior to the cooling fluid exiting the blade from an outlet at the leading edge.

**[0013]** In one embodiment, the cooling passages include a plurality of cavities and/or cooling channels. Presence of cavities and channels enables directing the cooling fluid to all regions/portions of the airfoil.

**[0014]** In another embodiment, the cavities at the suction side are smaller than the cavities at the pressure side. Such an arrangement enables higher velocity of fluid flowing in the cavities at the suction side resulting in improved cooling. In one embodiment, the blade includes a platform separating the airfoil portion and the root portion, and the inlet system is present at the platform. Cooling fluid from the root portion is directed into the airfoil portion via the inlet system located at the platform.

**[0015]** In one embodiment, the cooling fluid flowing in the first cooling passage is directed out of the airfoil portion through a plurality of film cooling holes present at the leading edge. The film cooling holes enable cooling of the external surface of the blade providing a thin, cool, insulating blanket of cooling fluid thereby lowering the temperature.

**[0016]** In another embodiment, the cooling fluid flowing in the second cooling passage is discharged out of the airfoil portion through an opening at the trailing edge.

**[0017]** In one embodiment, the second cooling passage includes a cooling channel that has a first portion on the suction side extending in a direction from the trailing edge to the leading edge and a second portion downstream the first portion, the second portion extending from the leading edge to the trailing edge. Such an arrangement allows the inlet to be present at the core region of the blade between the trailing edge region and the leading edge region, but still allows the fluid to traverse along the extent of the blade such that the first portion provides cooling on the suction side and thereafter the second portion of the channel allows cooling on the pressure side.

**[0018]** 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,

FIG. 2 is a cross sectional view depicting a platform of the blade of FIG. 1 with an inlet system,

FIG. 3 is an isometric view of the blade of FIG. 1,

FIG. 4 is a cross sectional view depicting another embodiment of the blade of FIG. 1,

FIG. 5 is a cross sectional view depicting yet another embodiment of the blade of FIG. 1, in accordance with the aspects of the present technique.

**[0019]** 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.

**[0020]** Referring to **FIG. 1** alongwith **FIG. 2**, wherein FIG. 1 is a schematic diagram of an exemplary blade 1 of a rotor (not shown) of a turbomachine, such as a gas turbine and FIG. 2 is a cross sectional view of the blade depicting a platform of the blade with an inlet system. 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 10 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.

**[0021]** The outer wall portion on the pressure side may be referred to as the pressure-side wall 11 and the outer wall portion on the suction side may be referred to as the suction-side wall 12. The suction-side and the pressure-side walls 11, 12 collectively delimit an internal region of the airfoil, which is thus, demarcated from an external region located outside the airfoil 2. The respective surfaces of the walls 11, 12 facing the internal region are referred to as inner surfaces. Similarly, the respective surfaces of the walls 11, 12 facing the external region are referred to as outer surfaces.

**[0022]** 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.

**[0023]** A platform 9 is formed at an upper portion of the root portion 3. The airfoil portion 2 is connected to the platform 9 and extends in the radial direction outward from the platform 9.

**[0024]** In accordance with aspects of the present technique, the airfoil portion 2 of the blade 1 includes a cooling arrangement, which includes an intricate maze of internal structures such as cooling passages having cavities, channels and other structures such as ribs and pin fins for enabling enhanced cooling.

**[0025]** The cooling arrangement includes an inlet system 28 located at the platform between the root portion 3 and the airfoil portion 2 for introducing the cooling fluid 26 which may be cool air or a coolant into the airfoil portion 2, for cooling the airfoil portion 2.

**[0026]** The inlet system 28 includes one or more inlets, such as a first inlet 29 and a second inlet 30 for directing the cooling fluid into the airfoil portion 2 of the blade 1.

**[0027]** 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.

**[0028]** In accordance with aspects of the present technique, the blade is manufactured using precision casting technique.

**[0029]** With continuing reference to FIG. 1 and FIG. 2, the cooling fluid 26 is directed to various portions of the airfoil 2 through an intricate maze of passages.

**[0030]** In the presently contemplated configuration, at least one first cooling passage is fluidly connected to the inlet system 28 for conducting the cooling fluid in a direction from the trailing edge 5 to the leading edge 4 on the suction side 7.

**[0031]** Additionally, at least one second cooling passage is fluidly connected to the inlet system 28 for conducting the cooling fluid in a direction from the leading edge 4 to the trailing edge 5 on the pressure side 6.

**[0032]** It may be noted that the cooling fluid 26 is discharged from the blade at the leading edge 4 through the plurality of film cooling holes 8 present on the leading edge 4, whereas the cooling fluid 26 is discharged from the blade airfoil 2 at the trailing edge 5 through single or multiple opening 13 present at the trailing edge 5.

**[0033]** Referring now to **FIG. 3**, an isometric view of the airfoil portion 2 of the blade 1 of FIG. 1 is depicted. The airfoil 2 includes a plurality of cooling passages, wherein the cooling passages include a plurality of cavities and channels for conducting the cooling fluid 26 therein.

**[0034]** It may be noted that the cooling fluid may be present in a cooling-fluid source which may be located external to the blade 1. Alternatively, the cooling-fluid source may be internal to the blade 1 wherein the cooling fluid is stored in the root portion 3 of the blade 1.

**[0035]** As previously noted, the inlet system 28 such as the inlet system 28 of FIG. 2 located at the platform 9 directs the cooling fluid 26 inside the airfoil 2 through one or more cooling passages.

**[0036]** In one embodiment, the inlet system 28 includes one or more inlets 29, 30 for supplying the cooling fluid 26 to the airfoil 2.

**[0037]** In the embodiment described with reference to FIG. 3, the cooling fluid 26 is directed into a first cooling passage 20, at the suction side 7. The first cooling passage 20 includes a first trailing cavity 21, a core cavity 22 and a first cavity 24 in fluid communication through one or more cooling channels.

**[0038]** Typically, the blade 1 may have three regions, namely a leading region, a trailing region and a core region between the leading region and the trailing region. Hence, the cavities present at the leading region, core region and the trailing region are referred to as the leading cavity, core cavity and the trailing cavity respectively.

**[0039]** It may be noted that the airfoil portion 2 of the blade has a first end 15 and a second end 17 extending in a direction radial to the root portion 3, wherein the second end 17 is at the platform 9, adjacent to the root portion 3 and the first end 15 is distal from the platform 9 and the root portion 3. The first end 15 is also referred to as the tip of the blade 1.

**[0040]** With continuing reference to FIG. 3, the first trailing cavity 21 is connected to the core cavity 22 and the core cavity 22 is connected to the first cavity 24 through channels located at the first end 15 and the second end 17 of the blade.

**[0041]** The cooling fluid 26 enters the first trailing cavity 21 via the inlet system 28 located at the platform 9 of the blade 1 through the root portion 3. Thereafter, the fluid 26 is directed to the core cavity 22 and subsequently to the first cavity 24.

**[0042]** The fluid 26 after getting directed to the first cavity 24 impinges on a leading edge cavity 27 through a plurality of impingement holes 36. The fluid 26 is subsequently discharged from the blade through the film cooling holes 8 present at the leading edge 4 of the blade.

**[0043]** At the pressure side 6, the cooling fluid 26 is directed into a second cooling passage 31 which includes a second cavity 32, a second core cavity 34 and a second trailing cavity 35.

**[0044]** More particularly, the fluid 26 is directed into the second cavity 32 located on the pressure side 6, thereafter into the second core cavity 34 present at the core region of the blade through a channel present at a radially first end 15 opposite the root portion 3.

**[0045]** Thereafter, the cooling fluid 26 enters the second trailing cavity 35 through a second channel located at the second end 17 of the blade, and subsequently discharged through the opening 13 at the trailing edge 5.

**[0046]** Referring now to **FIG. 4**, a cross-sectional view depicting another embodiment of the blade 1 of FIG. 1 is presented. In the present embodiment, the inlet system 28 includes two inlets, a first inlet 29 supplies the cooling fluid 26 to a first cooling passage 40 and a second inlet 30 is fluidly connected to a second cooling passage 50 for supplying the cooling fluid. The first cooling passage 40 includes a cavity 42 located adjacent the suction side 7, a channel 46 directing the fluid 26 from the cavity 42 into the leading edge cavity 44.

**[0047]** The second cooling passage 50 includes a core cavity 48, located at the core region wherein the core cavity 48 is fluidly connected to the second inlet 30. A cooling channel 51 for conducting the cooling fluid 26 from the core cavity 48 to the second core cavity 56 located downstream the core cavity 48. The cooling channel 51 includes a first portion 52 and a second portion 54. The first portion 52 is on the suction side 7 extending in a direction from the trailing edge 5 to the leading edge 4 and the second portion 54 which is downstream the first portion 52, the second portion 54 extending in a direction from the leading edge 4 to the trailing edge 5.

**[0048]** The second core cavity 56 distributes the cooling into a trailing edge cavity 58 from where the cooling fluid 26 is discharged through the opening 13 at the trailing edge 5 into the hot gas path.

**[0049]** **FIG. 5** is a cross sectional view depicting yet another embodiment of the blade of FIG. 1. Cooling fluid 26 is supplied into airfoil portion 2 through the inlet system 28, which in the present embodiment includes one inlet (not shown in FIG. 5) from the root portion 3, wherein the inlet is located at the platform 9 of the blade. The cooling fluid 26 enters the core cavity 62 and turns at the tip 15 of the airfoil 2 to enter a second cavity 64. The second cavity 64 is fluidly connected to a separating cavity 66 at the second end 17 of the blade located proximal to the platform 9.

**[0050]** The separating cavity 66 directs a first portion of the cooling fluid 26 into a first cooling passage 68 which includes the channel 70 located at the suction side 7 and the leading edge cavity 72 and directs a second portion of the cooling fluid 26 into the second cooling passage 69 which includes the trailing edge cavities 73, 74 and thereafter discharges the fluid 26 through the opening 13 at the trailing edge 5.

**[0051]** It may be noted that in the presently contemplated configuration the cavities and/or channels at the suction side 7 are smaller than the cavities at the pressure side 6.

**[0052]** 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) of a turbomachine, comprising an airfoil portion (2) and a root portion (3), the airfoil portion (2) comprising:

- a pressure side (6) and a suction side (7) extending between a leading edge (4) and a trailing edge (5) of the airfoil portion (2),

**Characterized in that** the airfoil portion (2) comprises

- a cooling arrangement, having:

  - an inlet system (28) for introducing a cooling fluid (26) into the airfoil (2) for cooling the airfoil (2),
  - at least one first cooling passage (20, 40, 68) for conducting the cooling fluid (26) in a direction from the trailing edge (5) to the leading edge (4) on the suction side (7), wherein the first cooling passage (20, 40, 68) is fluidly connected to the inlet system (28),
  - at least one second cooling passage (31, 50, 69) for conducting cooling fluid in a direction from the leading edge (4) to the trailing edge (5) on the pressure side (6), wherein the second cooling passage (31, 50, 69) is fluidly connected to the inlet system (28).

**2.** The blade (1) for a turbomachine according to claim 1, wherein the airfoil portion (2) extends in a direction radial to an axis of rotation of a rotor of the turbomachine.

**3.** The blade (1) for a turbomachine according to claim 1 and 2, wherein the inlet system (28) comprises one inlet for the cooling fluid, wherein the cooling arrangement comprises a separating cavity (66) between the inlet and the first and second cooling passages (68, 69), wherein the separating cavity (66) directs a first portion of the cooling fluid into the first cooling passage (68) and second portion of the cooling fluid into the second cooling passage (69).

**4.** The blade (1) for a turbomachine according to claims 1 and 2, wherein the inlet system (28) comprising a first inlet (29) and a second inlet (30) for the cooling fluid (26), wherein the first inlet (29) is fluidly connected to the first cooling passage (40) and the second inlet (30) is fluidly connected to the second cooling passage (50).

**5.** The blade (1) for a turbomachine according to any of the claims 1 to 4, wherein the airfoil portion (2) further comprises a plurality of impingement holes (36) for cooling the leading edge (4).

**6.** The blade (1) for a turbomachine according to any of the claims 1 to 5, wherein the first cooling passage (20, 40, 68) and the second cooling passage (31, 50, 69) comprise a plurality of cavity and/or cooling channels.

**7.** The blade (1) for a turbomachine according to claim 6, wherein the cavities at the suction side (7) are smaller than the cavities at the pressure side (6).

**8.** The blade (1) for a turbomachine according to any of the claims 1 to 7, further comprising a platform (9) connecting the root portion (3) and the airfoil portion (2), such that the airfoil portion (2) extends in the radial direction from the platform (9).

**9.** The blade (1) for a turbomachine according to claim 8, wherein the inlet system (28) is located at the platform (9).

**10.** The blade (1) for a turbomachine according to any of the claims 1 to 9, wherein the cooling fluid (26) flowing in the first cooling passage (20, 40, 68) is directed out of the airfoil portion (2) through a plurality of film cooling holes (8) at the leading edge (4).

**11.** The blade (1) for a turbomachine according to any of the claims 1 to 9, wherein the cooling fluid (26) flowing in the second cooling passage (31, 50, 69) is directed out of the airfoil portion through an opening (13) at the trailing edge (5).

**12.** The blade (1) for a turbomachine according to any of the claims 1 to 11, wherein second cooling passage (50) comprises a cooling channel (51) having a first portion (52) on the suction side (7) extending in a direction from the trailing edge (5) to the leading edge (4) and a second portion (54) downstream the first portion (52), the second portion (54) extending in a direction from the leading edge (4) to the trailing edge (5).

**13.** The blade (1) for a turbomachine according to any of the claims 1 to 12 wherein the cooling fluid (26) is directed from the root portion (3) into the airfoil portion (2) through the inlet system (28).

**14.** The blade (1) for a turbomachine according to any of the claims 1 to 13, wherein the blade (1) is manufactured using precision casting technique.

FIG 1

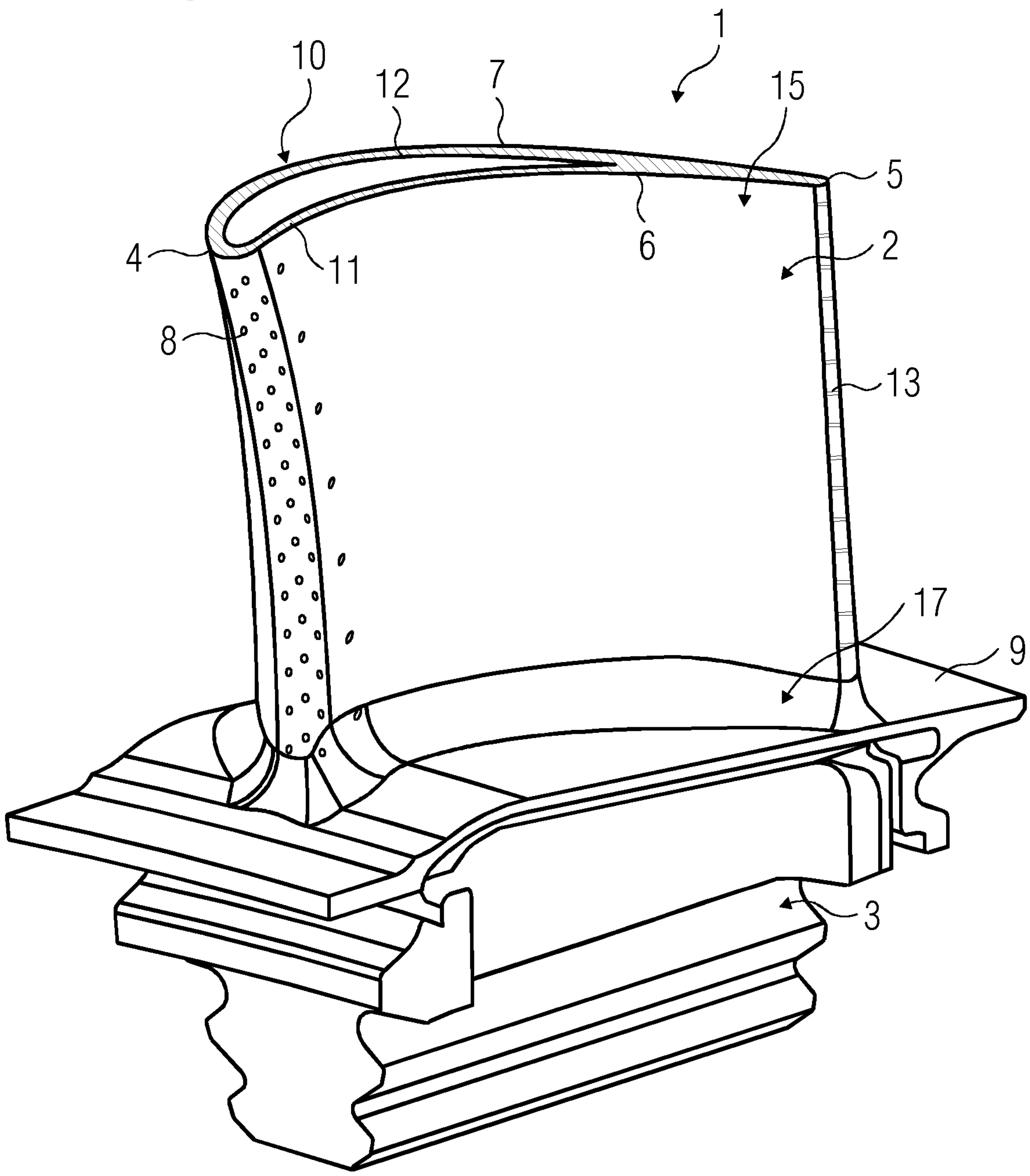


FIG 2

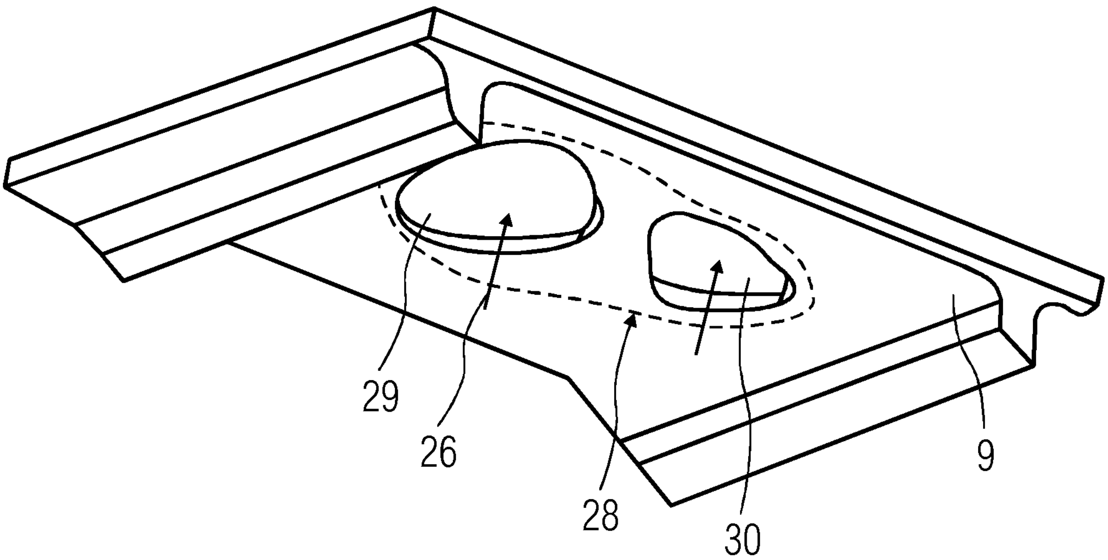


FIG 3

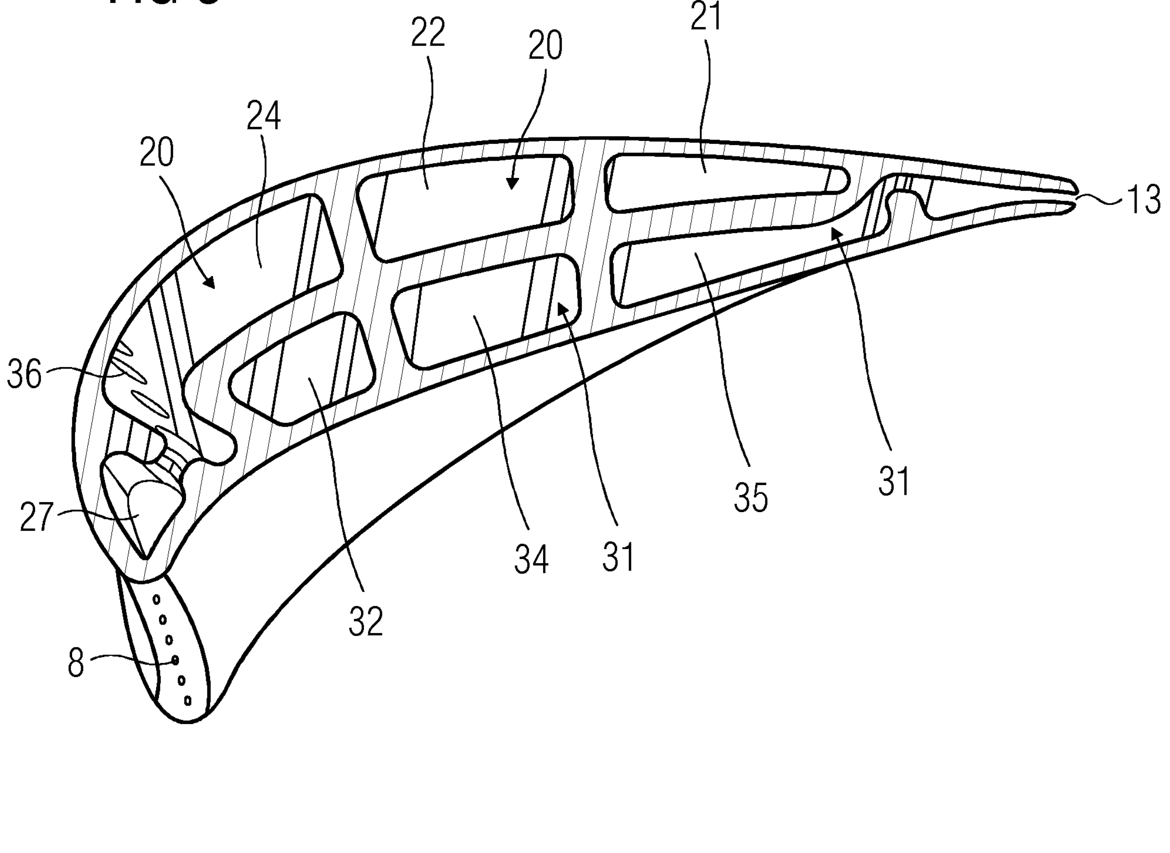


FIG 4

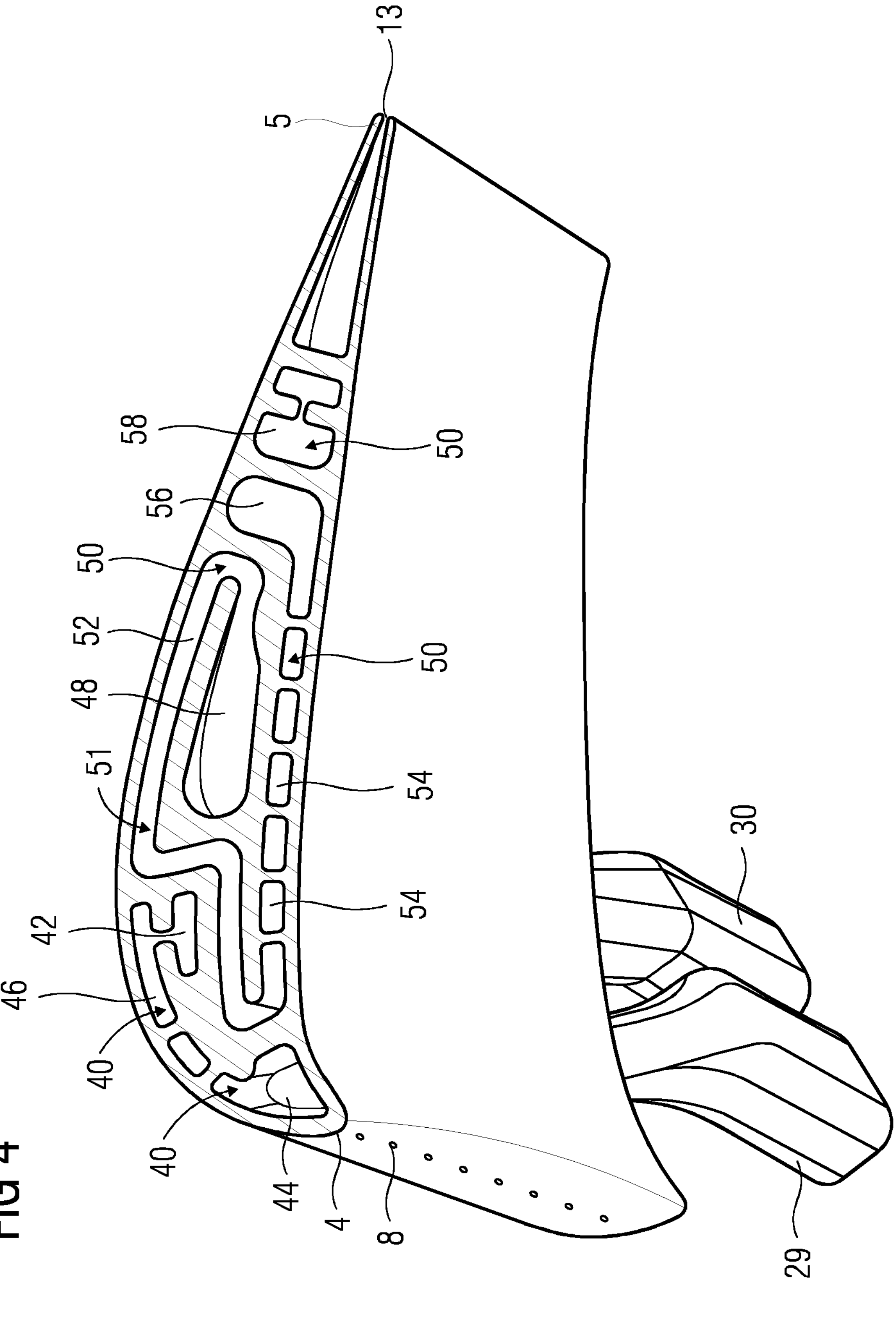
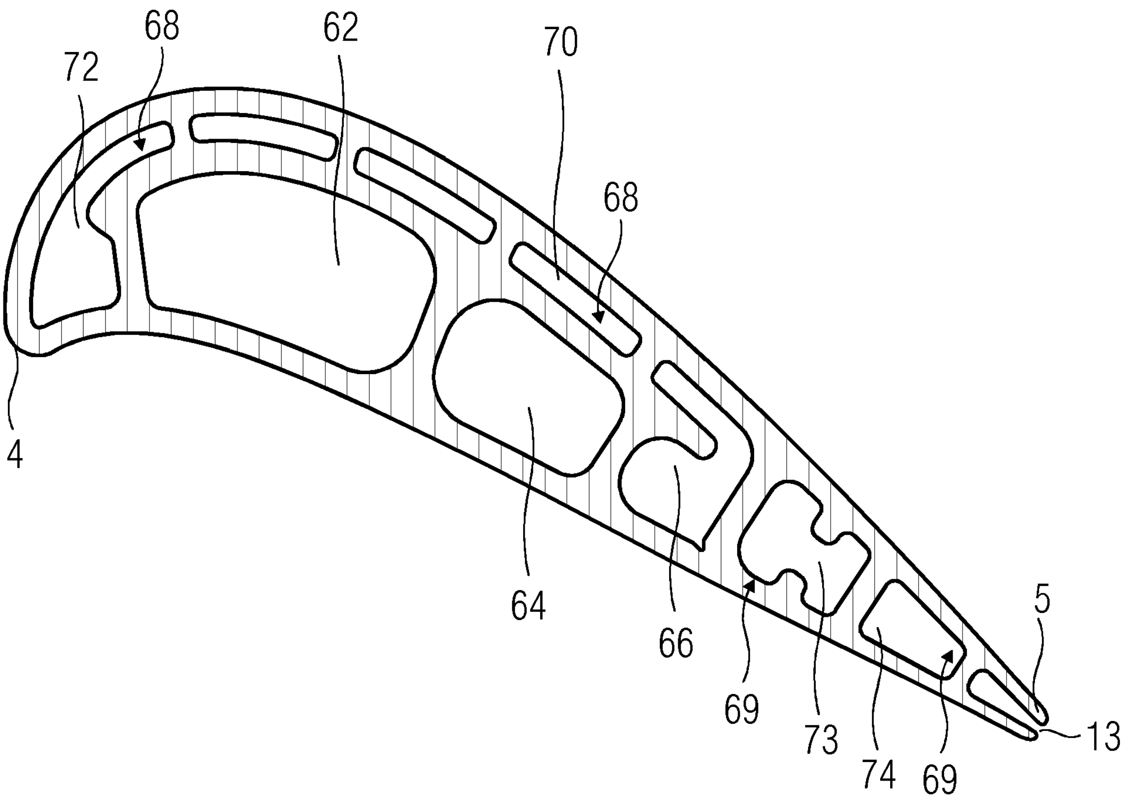


FIG 5



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# EUROPEAN SEARCH REPORT

Application Number
EP 13 15 0152

## 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<br>Y | EP 1 881 157 A1 (UNITED TECHNOLOGIES CORP [US]) 23 January 2008 (2008-01-23)<br>* paragraph [0010] - paragraph [0015]; claims 1-8, 11-14; figures 1-7 * | 1-13<br>14 | INV.<br>F01D5/18 |
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| X<br>Y | US 5 813 835 A (CORSMEIER ROBERT J [US] ET AL) 29 September 1998 (1998-09-29)<br>* column 3, line 48 - column 5, line 60; claims 1-4; figures 4-10 * | 1-13<br>14 | |

TECHNICAL FIELDS SEARCHED (IPC)

F01D

The present search report has been drawn up for all claims

1

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 15 May 2013 | Balice, Marco |

CATEGORY OF CITED DOCUMENTS

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## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 13 15 0152

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15-05-2013

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