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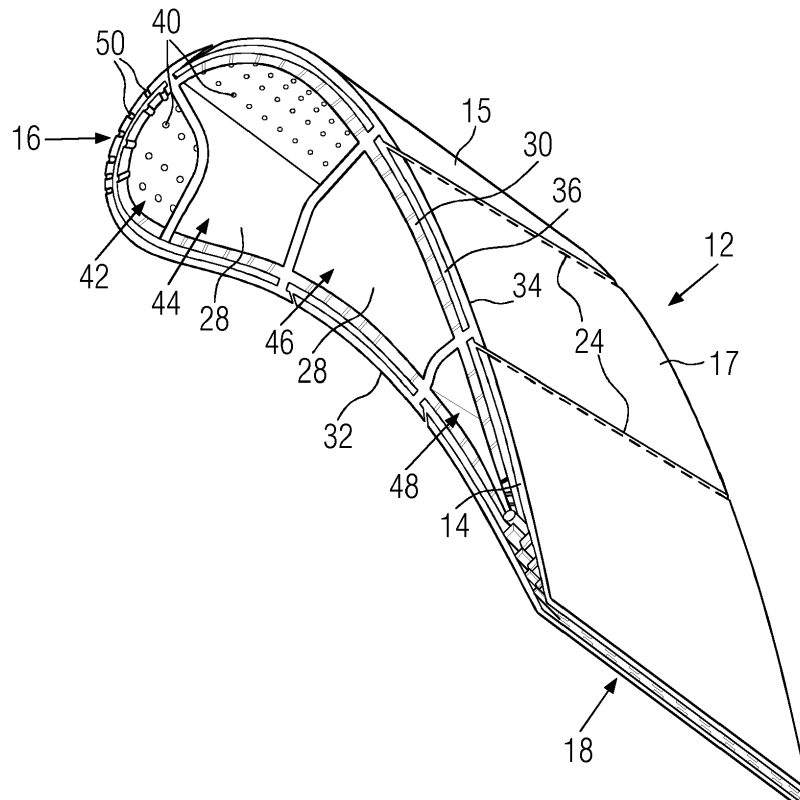
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(54) **Vane for a turbomachine**

(57) A vane for a turbomachine is presented. The vane (10) includes at least one inner cavity (28) defined by an inner wall (30) having a plurality of impingement holes (40), and an outer wall (14) surrounding the inner wall (30) forming a passageway (36) therebetween for a cooling fluid to pass through the impingement holes (40)

from the inner cavity (28) towards the passageway (36), wherein the outer wall (14) comprises a plurality of openings (24) for exit of the cooling fluid, characterized in that, the outer wall (14) is divided into a plurality of portions (15,17) disconnected from each other by openings (24) allowing independent thermal expansion of said portions (15, 17).

FIG 2



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Description

[0001] The present invention relates to an airfoil for a turbomachine and more particularly to a vane for 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 "vane", but the specifications can be transferred to a blade. The high temperatures during operation of the turbomachine may damage the vane component, hence cooling of the vane 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 vane component.

[0003] Components of the turbomachine such as the blade or the vane are subjected to changes in temperature and also mechanical strain resulting in damage to the component. This process of fatigue damage is generally referred to as Thermo-mechanical fatigue (TMF).

[0004] An airfoil such as a vane has a leading edge and a trailing edge. Currently, the leading edge of the airfoil portion of the vane is cooled by impingement cooling or by film cooling and the trailing edge by matrix arrangement of ribs, pin-fins and so forth. However, such an arrangement is unable to prevent failure of the component due to thermo-mechanical fatigue.

[0005] It is therefore an object of the present invention to provide a vane for a turbomachine which reduces the damage due to thermo-mechanical fatigue.

[0006] The object is achieved by providing a vane for turbomachine according to claim 1 and a method according to claim 14.

[0007] According to the invention the vane for a turbomachine includes at least one inner cavity defined by an inner wall having a plurality of impingement holes, and an outer wall surrounding the inner wall forming a passageway therebetween for a cooling fluid to pass through the impingement holes from the inner cavity towards the passageway, wherein the outer wall comprises a plurality of openings for exit of the cooling fluid such that the outer wall is divided into a plurality of portions disconnected from each other by openings allowing independent thermal expansion of said portions. By having a plurality of impingement holes in the inner wall, cooling due to impingement is achieved. In addition, the passageway improves cooling of the vane at both the inner wall and outer wall. Furthermore, the opening in the outer wall provides the exit of the cooling fluid which results in film cooling at the outer wall thereby reducing the temperature. Additionally, by having the openings formed in the outer wall as a result of plurality of portions of the outer wall which are disconnected with each other ensures sufficient amount of thermal expansion without causing stress over the other portion of the outer wall. This arrangement obviates the strain caused due to thermo-mechanical fa-

tigue in the vane.

[0008] In one embodiment, the openings extend in a direction radial to an axis of rotation of a rotor of the turbomachine.

5 **[0009]** In another embodiment, the openings form channels by a first front face of the first portion of the outer wall and a second front face of the second portion of the outer wall for cooling fluid, wherein at least one of the front faces is provided with protrusions extending into
10 said channel's width, wherein said protrusions are provided with contact surfaces and are designed such that said contact surfaces contact said respective opposite front face under full temperature conditions due to the thermal expansion of said outer wall portions. Due to the
15 presence of such an arrangement, exit of the cooling fluid is achieved even when the portions of the outer wall are in contact with each other, thus allowing cooling of the outer wall of the vane.

20 **[0010]** In one embodiment, the inner wall defines the structure of the vane including the inner cavities and the matrix arrangement of ribs at the trailing edge.

[0011] In another embodiment, the vane includes a trailing section and the leading section, the cooling fluid is directed to the trailing edge through the passageway
25 in the trailing section. Such an arrangement ensures cooling fluid to move to the trailing edge and provide a cooling therein.

[0012] In one embodiment, the opening for exit of cooling fluid is a slot. Slot ensures that only a limited amount
30 cooling fluid passes through thereby ensuring film cooling. Additionally during thermal expansion, slots allow the cooling fluid to exit the outer wall of the vane thereby aiding in film cooling.

35 **[0013]** In one embodiment, the openings are configured to partially exit the cooling fluid. This ensures cooling fluid to cool internal structures and some of the fluid to be directed to other parts of the vane including the trailing edge.

40 **[0014]** In another embodiment, the openings extend through the outer wall inclined to a surface normal to the outer wall so as to prevent the entire cooling fluid to exit through the openings.

[0015] In one embodiment, the outer wall is connected to the inner wall at a plurality of locations to ensure a strong attachment between the outer wall and the inner wall.
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[0016] In another embodiment, the outer wall and the inner wall are formed using laser sintering technique. This ensures forming a desired three dimensional shape
50 with an outer wall and inner wall and passageway with channels to ensure cooling effectiveness.

[0017] In one embodiment, the outer wall and the inner wall are formed of same material so that the thermal expansion is similar throughout the component and also the cooling rate is same at all the portions of the component.
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[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 vane of a turbomachine,

FIG. 2 is a diagram depicting an isometric view of an airfoil of the vane of FIG. 1,

FIG. 3 is a cross sectional view of the vane along the lines III-III of FIG. 1,

FIG. 4 is a blown up view of an outer wall of the vane, with opening, and

FIG. 5 is a flow diagram depicting a method for cooling the exemplary vane, in accordance with aspects of the present technique.

[0019] Embodiments of the present invention relate to an airfoil in a turbomachine, more particularly to an airfoil of a vane component for the turbomachine. However, the details of the embodiments described in the following can be transferred to a blade component without modifications, that is the terms "vane" or "blade" 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] FIG. 1 is a schematic diagram depicting an exemplary vane 10 of a turbomachine, such as a gas turbine, in accordance with aspects of the present technique. The vane 10 includes an airfoil portion 12 formed from an outer wall 14 and having a leading edge 16 and a trailing edge 18 enclosed between a first end wall 20 and a second end wall 22 opposite each other as depicted in FIG. 1.

[0021] The exemplary vane 10 includes one or more inner cavities 28 for a supply of cooling fluid, which may include cooling air for cooling the vane 10 during operation. Reference numeral 26 is indicative of a flow of cooling fluid inside the vane of the turbomachine.

[0022] The outer wall 14 includes one or more openings 24 extending from the first end wall 20 to the second end wall 22 for exiting the cooling fluid from the vane 10 thereby providing film cooling at the outer wall 14 of the vane 10. The openings 24 extend in a radial direction to an axis of rotation of a rotor (not shown) of the turbomachine which is enclosed by a stator securing the vanes, such as the vane 10.

[0023] It may be noted that the airfoil portion 12 of the vane 10 may be cast as a single component or may alternatively be assembled from multiple components. The multiple component vane may include a leading edge component, a trailing edge component and core region components. The components may be cast separately

and thereafter joined together by bonding or brazing for example.

[0024] In accordance with aspects of the present technique, the vane 10 may be formed by a technique, such as but not limited to laser sintering, which enables forming multiple layers in the vane 10.

[0025] In an alternate embodiment, the vane 10 may be formed by using an investment casting technique.

[0026] Referring now to FIG. 2 an isometric view of the airfoil portion 12 of the vane 10 is depicted. An inner wall 30 defines the internal structure of the vane. The vane includes one or more inner cavities 28 for supply of cooling fluid or cooling air. The inner cavities 28 are defined by the inner wall 30 which extends from a pressure side 32 to a suction side 34 present on opposing sides of the airfoil 12.

[0027] The inner wall 30 includes one or more impingement holes 40 extending from the leading edge 16 to the trailing edge 18 of the airfoil 12. The cooling fluid entering the one or more inner cavities 28 exits through the impingement holes 40, resulting in impingement cooling of the inner wall 30. As previously noted, the airfoil 12 of the vane 10 includes the outer wall 14 which surrounds the inner wall 30 forming a passageway 36 therebetween for circulating the cooling air in the one or more sections 42, 44, 46, 48 of the vane 10.

[0028] As previously noted the internal structure of vane 10 is defined by the inner wall 30. The inner wall 30 extends from the leading edge 16 to the trailing edge 18 and further extends from the pressure side 32 to the suction side 34 forming one or more inner cavities 28 therein.

[0029] The airfoil 12 includes the outer wall 14 surrounding the inner wall 30, which also extends from the leading edge 16 to the trailing edge 18.

[0030] In accordance with aspects of the present technique, the outer wall 14 and the inner wall 30 are attached to each other at one or more locations over the extent of the airfoil 12. The inner wall 30 and the outer wall 12 may be attached with each other by using laser sintering technique.

[0031] In the presently contemplated configuration, the outer wall 14 and the inner wall 30 are formed by use of laser sintering technique. The laser sintering technique uses high power laser to fuse small particles of metals for example to form a desired three dimensional shape.

[0032] As previously noted, the outer wall 14 is formed from a plurality of portions, such as a first portion 15 and a second portion 17 such that an opening 24 is formed between the portions. The outer wall 14 also includes a plurality of film cooling holes 50 at a portion forming the leading edge 16, as depicted in FIG. 2.

[0033] In accordance with aspects of the present technique, the openings 24 in the outer wall 14 extend from the first end wall 20 to a second end wall 22 (see FIG. 1). A cooling fluid such as, but not limited to cooling air enters the inner cavities 28 in the airfoil 12 of the vane 10, thereafter the cooling fluid is directed to the passage-

way 36 between the inner wall 30 and the outer wall 14 through impingement holes 40 present in the inner wall 30. The cooling fluid cools the outer wall portions and exits through the openings 24. In one embodiment, the cooling fluid may also include a coolant, oil or steam for example.

[0034] In the presently contemplated configuration, openings 24 extend through the outer wall 14 inclined to a surface normal to the outer wall 14. It may be noted that the angle of inclination may be greater than 0 degree and less than 90 degrees. The openings 24 in the outer wall 14 allow a portion of the cooling fluid to exit the outer wall 14 thereby providing film cooling at the surface of the vane 10.

[0035] During the operation of the turbomachine, the vane 10 gets heated resulting in thermal expansion. As previously noted, the openings 24 in the outer wall 14 are disconnected with each other. The openings 24 in the outer wall 14 thus obviate the stress caused due to thermal expansion. The inner wall 30 and the outer wall 14 may be formed from a same material. More particularly, the inner wall 30 and the outer wall 14 may be formed of metal or metal alloy capable of withstanding high temperatures, which may sometimes reach about 800 degree centigrade. Such high temperatures result in thermal expansion which may damage the vane component. The openings 24 in the outer wall 14 allow for thermal expansion and thus reduce stress on the vane 10.

[0036] In one embodiment, the opening 24 in the outer wall 14 may include a plurality of slots to allow a portion of cooling air to exit even when the opening is closed due to the expansion of the first portion 15 and the second portion 17 of the outer wall 14, for example. Such an arrangement provides escape of cooling fluid and hence aids in film cooling. The rest of the air cools the internal structure of the vane 10. It may be noted that the inner wall 30 and the outer wall 14 are cooled resulting in an increase in the temperature of cooling fluid. The hot air is then convectively circulated in the passageway 36 between the inner wall 30 and the outer wall 14 and directed out of the vane through the opening 24 thus dissipating the heat from the vane 10.

[0037] FIG. 3 is a cross sectional view of vane 10 of FIG. 1. The vane 10 is divided into a plurality of sections formed by the inner wall 30. The first section 42 or the leading section at the leading edge 16, two middle sections 44, 46 present in a core region of the vane 10 and a trailing section 48 at the trailing edge 18 of the vane 10. The leading section 42, the middle sections 44, 46 and the trailing section 48 each have an inner cavity 28 for receiving a cooling fluid, such as cooling air.

[0038] The vane 10 includes the outer wall 14 surrounding the inner wall 30 as depicted in FIG. 3. The outer wall 14 is attached to the inner wall 30 at one or more locations 52, 54 and forms a passageway 36 for cooling fluid for each section 42, 44, 46, 48. Specifically, atleast a portion of the outer wall 14 is attached to the inner wall 30 at the one or more locations 52, 54.

[0039] In accordance with aspects of the present technique, the inner wall 30 and outer wall 14 may be connected to each other by connecting-pins or connecting-ribs such that the connecting-ribs or connecting-pins allow thermal expansion of the portions in circumferential direction of a profile of the vane.

[0040] As previously noted the inner wall 30 of the vane 10 includes a plurality of holes 40 to allow the cooling air to pass through. The cooling fluid from each of the section 42, 44, 46, 48 passes through the holes 40 into the passageway 36 between the outer wall 14 and the inner wall 30. The outer wall 14 includes openings 24 to allow the cooling fluid to exit.

[0041] At the trailing section 48 the cooling fluid is directed to the passageway 36 through the holes 40 in the inner wall 30. A portion of the cooling air is supplied to a matrix arrangement of ribs 60 and pins or fins (not shown) to cool the trailing section 48 and directed out of the vane 10 through the trailing edge 18. The remaining portion of the cooling fluid is exited outside the vane 10 through the opening 24 in the outer wall 14, thereby providing film cooling.

[0042] It may be noted that the flow of the cooling fluid in the passageway 36 is opposite to the flow of hot gas in the airfoil 12 of the vane 10. In other words, cooling fluid flows in counterflow to the hot gas in the airfoil 12.

[0043] In the presently contemplated configuration, the outer wall 14 portion at the leading section 42 includes a plurality of holes 50 to allow for film cooling. Furthermore, the leading section 42 also includes opening 24 in the outer wall 14 which is inclined with respect to a surface normal to the outer wall 14, which improves the cooling at the leading section 42 of the vane 10.

[0044] FIG. 4 is a blown up view 62 of the vane 10, depicting the outer wall 14 in accordance with aspects of the present technique. As previously noted the outer wall 14 includes a plurality of portions, such as the first portion 15 and the second portion 17 forming opening 24 which is formed due to a gap between the portions of the outer wall 14. The first portion 15 of the outer wall 14 includes a plurality of protrusions 25 spaced apart forming a plurality of slots 27 in between as depicted in FIG. 4.

[0045] More particularly, the plurality of slots 27 are in the form of channels formed by a first front face of the first portion 15 and a second front face of the second portion of the outer wall for the cooling fluid to pass through the slots 27.

[0046] During the operation of the turbomachine, the vane 10 is exposed to high operating temperatures, which results in thermal expansion of outer wall 14, since the wall 14 is formed of the first portion 15 and the second portion 17, therefore the first portion 15 and the second portion 17 expand thereby getting in contact with each other. More particularly, the protrusions 25 on the first portion 15 get in contact with the second portion 17 of the outer wall 14. The slots 27 allow the cooling fluid to exit the outer wall of the vane.

[0047] It may further be noted that the protrusions 25

may be present on the front faces of the first portion 15 or the second portion 17, the protrusions 25 are provided with contact surfaces 29 which get in contact with the opposite front face under full operating temperature condition due to the thermal expansion of the portions of the outer wall 14.

[0048] Referring now to **FIG. 5**, a flow diagram depicting a method 70 for cooling the vane 10 of a turbomachine is presented. The method 70 includes providing a plurality of impingement holes 40 in the inner wall 30 of the vane 10. The impingement holes 40 may be formed during casting process, alternatively, the impingement holes 40 may be formed in the inner wall 30 by selective laser sintering technique. The inner wall 30 is designed such that it forms one or more inner cavities 28 therein as at step 72.

[0049] At step 74, the inner wall 30 is surrounded by an outer wall 14 by attaching at one or more locations 52, 54, such that a passageway 36 is formed between the inner wall 30 and the outer wall 14.

[0050] At step 76, a cooling fluid entering the inner cavities 28 is directed towards the passageway 36 through the impingement holes 40 in the inner wall 30.

[0051] Subsequently, at step 78 the cooling fluid is exited from the vane 10 through one or more openings 24 in the outer wall 14. The openings 24 are formed by assembling the outer wall 14 as a plurality of portions, such as the first portion 15 and the second portion 17 (see FIG. 2 and FIG. 4).

[0052] In the presently contemplated configuration the openings 24 are formed as slots 27 in the outer wall 14 for the exit of cooling fluid from the vane 10. The exiting cooling fluid forms a film of cooling air over the outer wall 14 thereby dissipating the heat from the vane 10.

[0053] 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 vane (10) for a turbomachine, comprising:

- at least one inner cavity (28) defined by an inner wall (30) having a plurality of impingement holes (40), and
- an outer wall (14) surrounding the inner wall (30) forming a passageway (36) therebetween for a cooling fluid to pass through the impingement holes (40) from the inner cavity (28) towards the passageway (36), wherein the outer wall (14) comprises a plurality of openings (24)

for exit of the cooling fluid,

characterized in that,

the outer wall (14) is divided into a plurality of portions (15,17) disconnected from each other by openings (24) allowing independent thermal expansion of said portions (15, 17).

2. The vane (10) according to claim 1, wherein the openings (24) extend in a direction radial to an axis of rotation of a rotor of the turbomachine.

3. The vane (10) according to claims 1 and 2, wherein the openings (24) form channels by a first front face of the first portion (15) of the outer wall (14) and a second front face of the second portion (17) of the outer wall (14) for cooling fluid, wherein at least one of the front faces is provided with protrusions (25) extending into said channel's width, wherein said protrusions (25) are provided with contact surfaces (29) and are designed such that said contact surfaces (29) contact said respective opposite front face under full temperature conditions due to the thermal expansion of said outer wall portions (15, 17).

4. The vane (10) according to claim 1, further comprising a leading section (42) and a trailing section (48), wherein the cooling fluid at the trailing section (48) is directed via the passageway (36) to a trailing edge (18) of the vane (10).

5. The vane (10) according to any of the claims 1 to 4, wherein the openings (24) comprise a plurality of slots (27).

6. The vane (10) according to any of the claims 1 to 5, wherein the openings (24) extend through the outer wall (14) inclined to a surface normal to the outer wall (14).

7. The vane (10) according to any of the claims 1 to 6, wherein the openings (24) are configured to at least partially exit the cooling fluid.

8. The vane (10) according to any of the claims 1 to 7, wherein the outer wall (14) is attached to the inner wall (30).

9. The vane (10) according to claim 8, wherein the outer wall (14) is attached at a plurality of locations (52, 54) to the inner wall (30).

10. The vane (10) according to claims 8 and 9, wherein the outer wall (14) is attached to the inner wall (30) by laser sintering technique.

11. The vane (10) according to any of the claims 1 to 10, wherein the inner wall (30) and outer wall (14) are connected to each other by connecting-pins or con-

necting-ribs wherein, the connecting-ribs or connecting-pins allow thermal expansion of said portions in circumferential direction of a profile of the vane.

12. The vane (10) according to any of the claims 1 to 11, further comprising a matrix arrangement of ribs (60) for cooling the trailing edge (18). 5
13. The vane (10) according to any of the claims 1 to 12, wherein the cooling fluid flows in a direction opposite to a flow of hot gas in the airfoil (12) of the vane. 10
14. A turbomachine comprising the vane (10) according to any of the preceding claims 1 to 13. 15
15. A method (70) of cooling a vane (10) for a turbomachine, comprising:
- providing (72) a plurality of impingement holes in an inner wall of the vane, the inner wall forming at least one inner cavity in the vane, 20
 - surrounding (74) the inner wall by an outer wall by attaching the outer wall to the inner wall to form a passageway therebetween,
 - directing (76) a cooling fluid from the inner cavity towards the passageway via the impingement holes, and 25
 - exiting (78) the cooling fluid from the vane through one or more openings in the outer wall. 30
16. The method (70) according to claim 14, further comprising forming the outer wall from a plurality of portions disconnected from each other to form the openings therebetween. 35

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FIG 1

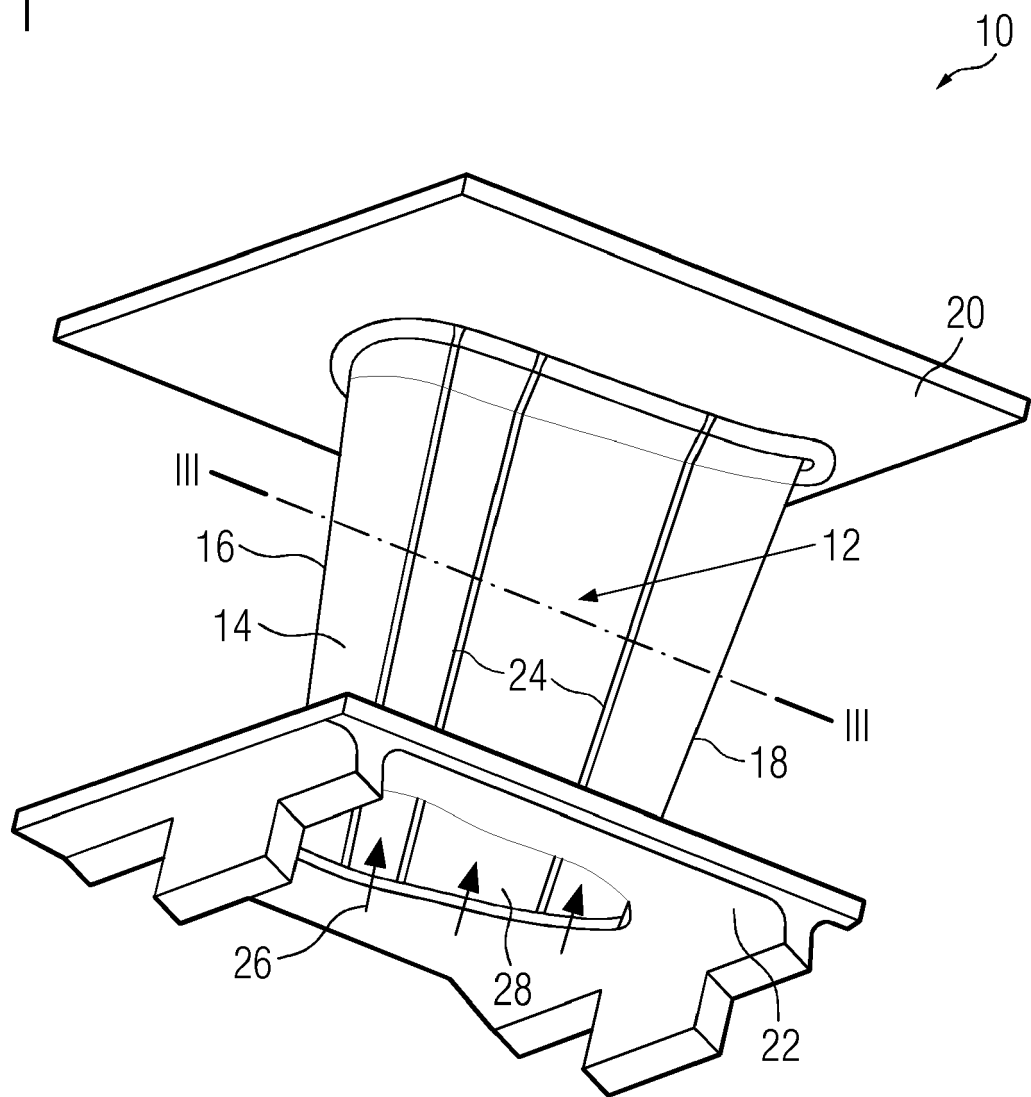
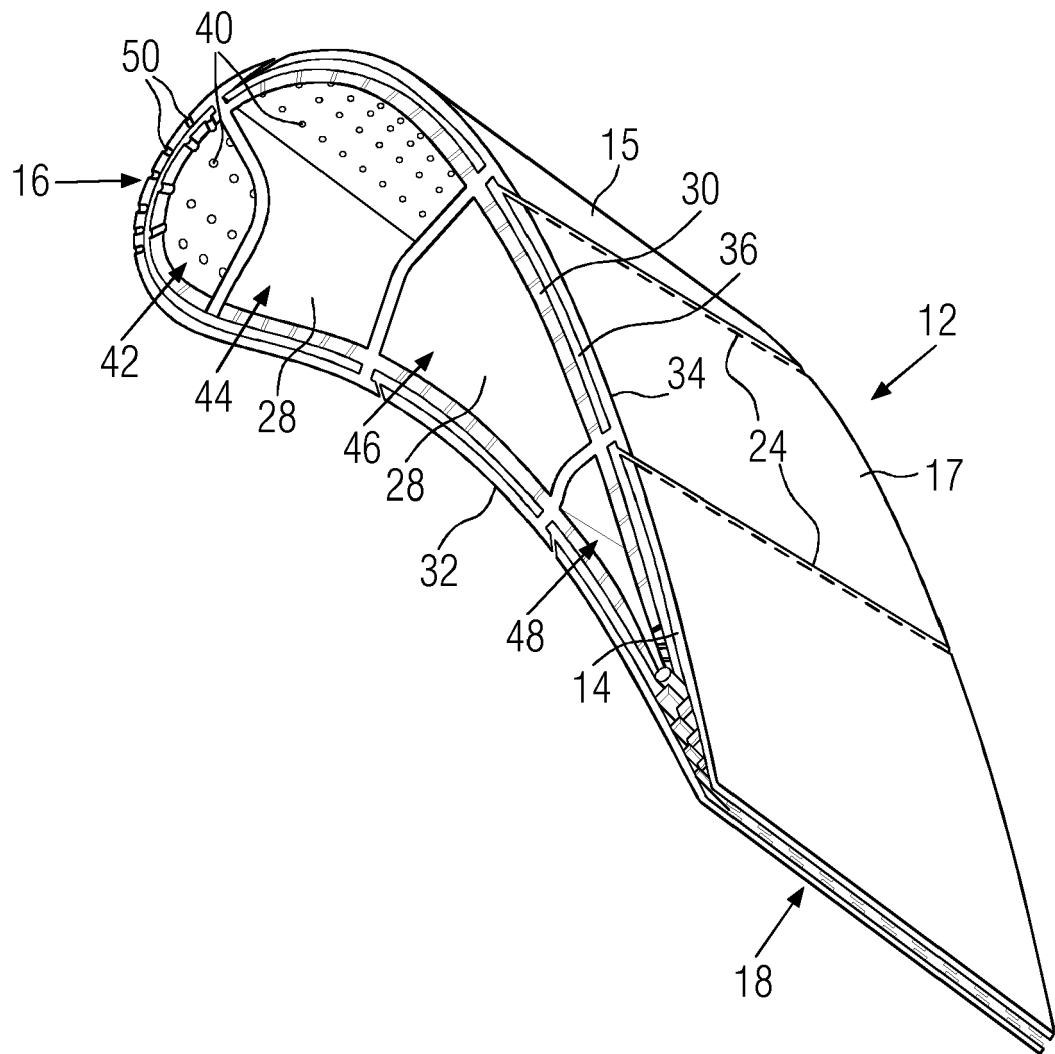


FIG 2



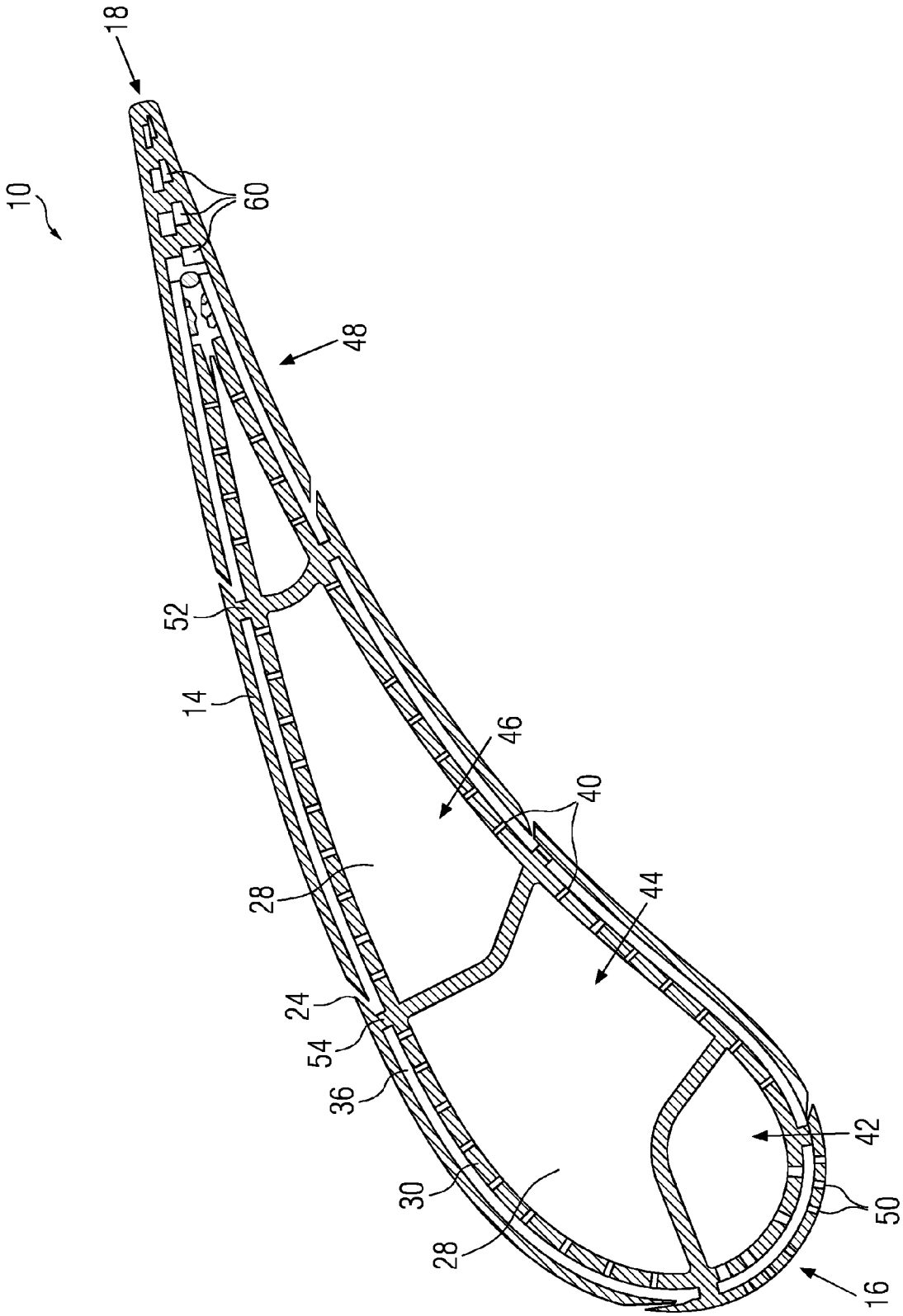


FIG 3

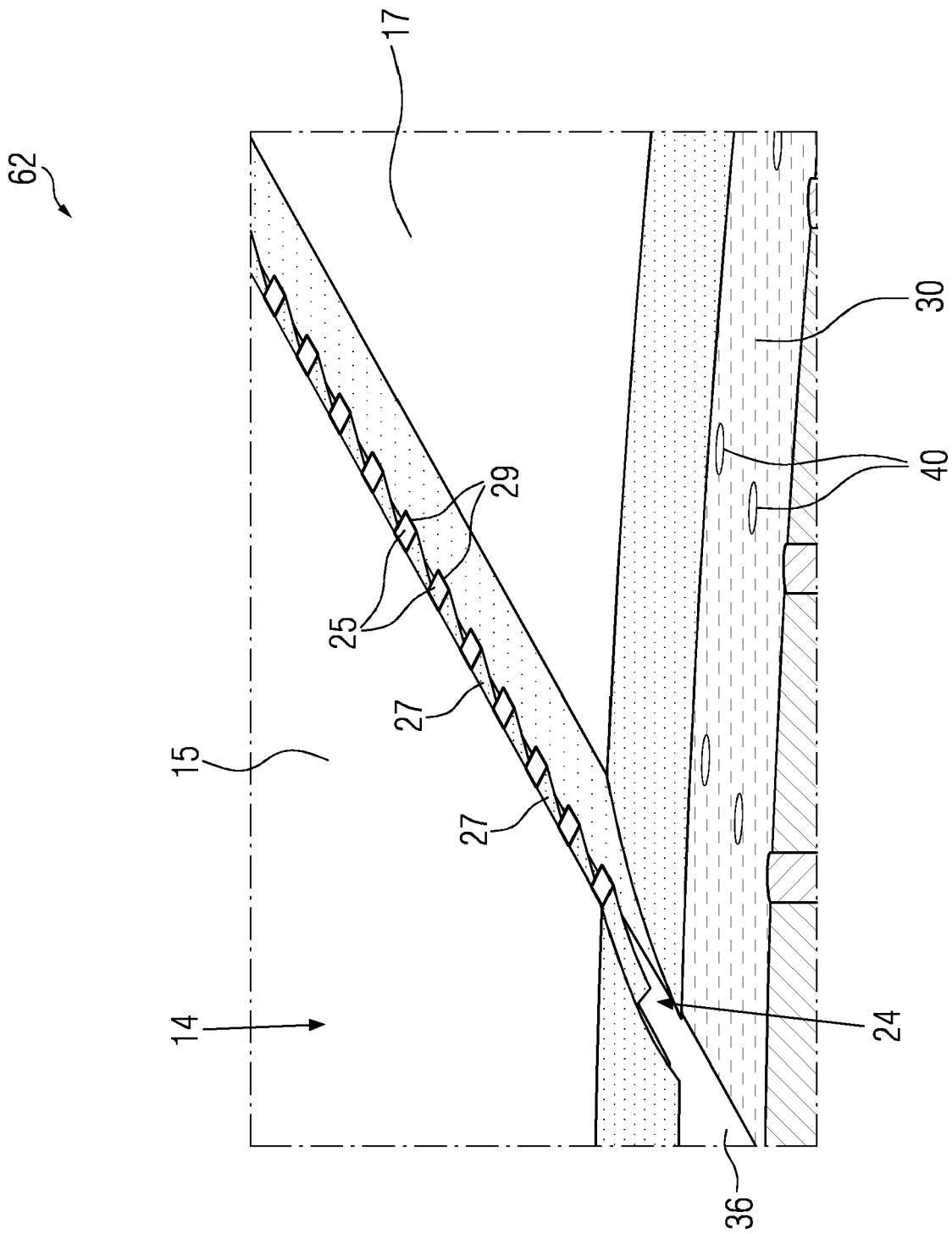
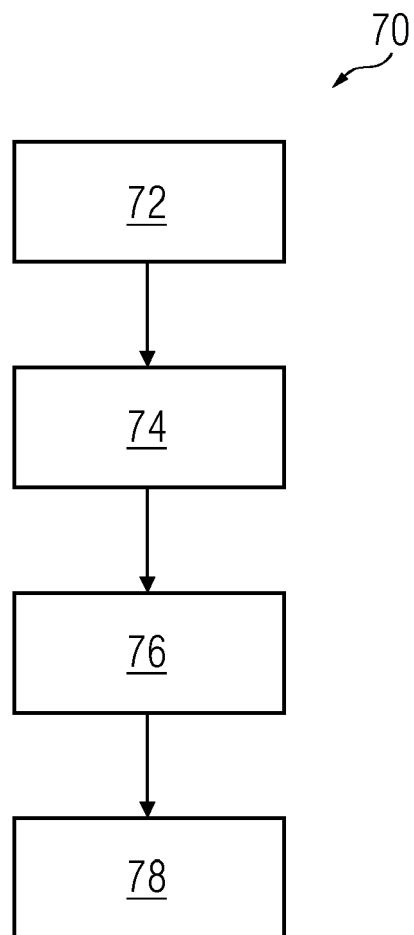


FIG 5





EUROPEAN SEARCH REPORT

Application Number
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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