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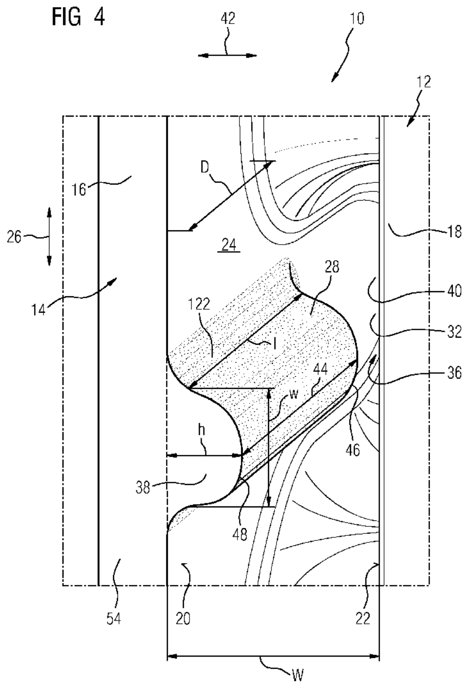
(54) Title: TURBINE ASSEMBLY

FIG 4



(57) Abstract: The present invention relates to a turbine assembly (10) comprising at least one basically hollow aerofoil (12) with at least one trailing edge (14) comprising at least two wall segments (16, 18) that each comprises an inner surface (20, 22), wherein the inner surfaces (20, 22) face each other, and wherein the inner surfaces (20, 22) enclose at least one exit aperture (24) extending basically in span wise direction (26) of the at least one basically hollow aerofoil (12), wherein at least one of the inner surfaces (20, 22) of the at least two wall segments (16, 18) of the trailing edge (14) comprises at least one surface increasing structure (28, 28') extending partially into the at least one exit aperture (24) from one inner surface (20, 22) to the other inner surface (20, 22), wherein the turbine assembly further comprises at least one cooling passage (32, 32') for a cooling medium (34) discharging in the at least one exit aperture (24) and wherein the at least one cooling passage (32, 32') has an exit opening (40) and wherein the at least one exit aperture (24) has a depth (D) in a direction (42) basically perpendicular to a span wise direction (26) of the basically hollow aerofoil (12) and wherein the at least one surface increasing structure (28, 28') has a longitudinal extension (44) with a forward end (46) and a rear end (48) and wherein the at least one surface increasing structure (28, 28') extends from its forward end (46) to its rear end (48) along the depth (D) of the at least one exit aperture (24) and wherein the forward end (46) of the at least one surface increasing structure (28, 28') is arranged in the exit opening (40) of the at least one cooling passage (32, 32 ') · This provides a sufficient heat transfer and thus cooling of the turbine assembly (10).

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DESCRIPTION

TURBINE ASSEMBLY

Field of the Invention

The present invention relates to a turbine assembly like an aerofoil-shaped turbine assembly such as turbine rotor blades and stator vanes. The present invention further relates to a matrix component and method for manufacturing said turbine assembly.

Background to the Invention

Modern turbines often operate at extremely high temperatures. The effect of temperature on the turbine blades, stator vanes and surrounding components can be detrimental to the efficient operation of the turbine and can, in extreme circumstances, lead to distortion and possible failure of such components. In order to overcome this risk, high temperature turbines may include hollow blades or vanes comprising cooling passages for a cooling medium to cool the blades and vanes during operation of the turbine assembly.

Such blades or vanes with e.g. an inner serpentine geometry for the cooling passages are typically made by an investment casting process which uses a ceramic core to define the various internal passages and further structures. After casting, the ceramic core is removed from the aerofoil by a leaching process.

The cooling passages terminate into a vertical slot positioned at a trailing edge of the aerofoil. Due to different flow dynamics inside the hollow aerofoil local heat distribution along the slot may vary. Hence, selected regions may overheat and be subjected to detrimental heat effects which, in turn, can lead to failure of the aerofoil and thus the turbine engine.

It is a first objective of the present invention to provide an aerofoil-shaped turbine assembly such as a turbine rotor blade and a stator vane with which the above-mentioned short-comings can be mitigated, and especially that an effective cooling concept can be realised which provides sufficient cooling and ensures effective heat transfer.

It is a second objective of the invention to provide an advantageous matrix component which reliably forms the shape of the turbine assembly during the casting process. A third objective of the invention is to provide a method for manufacturing a turbine assembly that is reliable and time-efficient.

These objectives may be solved by a turbine assembly, a matrix component and a method according to the subject-matter of the independent claims.

Summary of the Invention

Accordingly, the present invention provides a turbine assembly comprising at least one basically hollow aerofoil with at least one trailing edge comprising at least two wall segments that each comprises an inner surface, wherein the inner surfaces face each other, and wherein the inner surfaces enclose at least one exit aperture extending basically in span wise direction of the at least one basically hollow aerofoil, wherein that at least one of the inner surfaces of the at least two wall segments of the trailing edge comprises at least one surface increasing structure extending partially into the at least one exit aperture from one inner surface to the other inner surface, wherein the turbine assembly further comprises at least one cooling passage for a cooling medium discharging in the at least one exit aperture and wherein the at least one cooling passage has an exit opening and wherein the at least one exit aperture has a depth in a direction basically perpendicular to a span wise direction of the basically hollow aerofoil and wherein the at least one surface increasing structure has a longitudinal extension with a forward end and a rear end and wherein the at least one surface increasing structure extends from its forward end to its rear end along the depth of the at least one exit aperture and wherein the forward end of the at least one surface increasing structure is arranged in the exit opening of the at least one cooling passage.

Due to the inventive matter an effective cooling can be provided. Furthermore, a heat transfer of the aerofoil and especially the trailing edge can be increased in comparison to state of the art systems. Thus, overheating and detrimental effects can be prevented resulting in a reliable turbine assembly and hence a secure turbine engine operation.

Even if a term like aerofoil, edge, wall segment, inner surface, exit aperture, surface increasing structure, cooling passage, medium, area, exit opening, end, rim, material, matric component or cavity is used in the singular or in a specific numeral form in the claims and the specification the scope of the patent (application) should not be restricted to the singular or the specific numeral form. It should also lie in the scope of the invention to have more than one or a plurality of the above mentioned structure(s).

A turbine assembly is intended to mean an assembly provided for a turbine engine, like a gas turbine, wherein the assembly possesses at least one aerofoil. The turbine assembly may be a part of a turbine wheel or a turbine cascade with circumferential arranged aerofoils. The turbine assembly may comprise in addition to the aerofoil further structures, like a root portion and/or an outer and/or an inner platform. The latter two would be arranged at opposed ends of the aerofoil(s) and/or the inner platform would be arranged between the aerofoil and the root portion.

In this context a “basically hollow aerofoil” means an aerofoil with a casing, wherein the casing encases at least one cavity and/or an e.g. meandering cooling passage. A structure, like a rib, which divides different cavities/passages in the aerofoil from one another and for example extends in a span wise direction of the aerofoil, does not hinder the definition of "a basically hollow aerofoil". In particular, the basically hollow aerofoil, referred to as aerofoil in the following description, has two cooling regions, a channelled cooling region at a leading edge of the aerofoil and pin-fin/pedestal cooling region at the trailing edge. These regions could be separated from one another through a rib.

The wall segment is preferably a part of either a suction side or a pressure side of the aerofoil. Generally the surface increasing structure may also be positioned or arranged at or formed in a partitioning wall dividing the exit aperture in the direction from the pressure to the suction side.

In this context a "surface increasing structure" is intended to mean any structure, like a knoll, rib, hoop or the like, which increases the surface of the wall to which the structure is attached or where it is positioned or in which it is formed that is feasible for a person skilled in the art. The attachment may be facilitated by any connection feasible for a person skilled in the art, like screwing, welding, gluing, etc. Moreover, an effective surface area comprises all surfaces that interact with the cooling medium bypassing the surface increasing structure. In the case of an embodiment of the surface increasing structure as basically a knoll like rib the effective surface comprises the surfaces extending along a width and along a length of the surface increasing structure as well as both sloping flanges of the surface increasing structure extending to the wall segment having the surface increasing structure. For example, when the surface increasing structure has a width of 0.4 mm, a height of 0.3 mm and a length of 1.4 mm the effective surface is 1.587 mm^2.

Preferably, the at least one surface increasing structure and the wall segment of the at least two wall segments that is embodied with the at least one surface increasing structure are embodied integrally with each other. Hence, a secure attachment can be provided. Further, the surface increasing structure can be cast during the casing process of the turbine assembly and thus advantageously economising the manufacturing process. Moreover, smooth junctions between the surface increasing structure and the wall segment can be provided. In this context "formed integrally" is intended to mean that the surface increasing structure and the wall segment are built from the same piece, that they are a one-piece part or that they cannot be separated from each other without damaging at least one of the structures or that there is a loss of function for at least one of the structures.

An "exit aperture" is intended to mean an opening or hole which primary function is to provide an exit for a selected structure or means, like a fluid, a gas, a liquid or the like. Generally, another function may be also possible, like a fastening function etc. The selected structure may be any structure feasible for a person skilled in the art and is preferably a cooling medium traveling at least one cooling passage inside of the aerofoil for example with a flow path or direction leading basically from the leading edge to the trailing edge. Additionally, the exit aperture may have any shape or cross section feasible for a person skilled in the art, like circular, triangular, rectangular or oval etc. Preferably, the exit aperture is a slot. The exit aperture or the slot, respectively, may extend over a part of the trailing edge viewed in span wise direction or basically all along a span wise extension of the trailing edge.

Moreover, there may be a plurality of exit apertures or slots, respectively, arranged in span wise direction one after the other. A span wise direction of the aerofoil is defined as a direction extending basically perpendicular, preferably perpendicular, to a direction from a leading edge to a trailing edge of the aerofoil or the direction from a root portion to a tip of the aerofoil or the direction from one platform to the opposed platform in case of the embodiment of the aerofoil as a vane.

The phrase "extending partially into" should be understood that the surface increasing structure originates at one wall segment and extends in direction to the opposed wall segment or its inner surface, respectively, thereby crossing a part of the exit aperture. Specifically, the surface increasing structure does not physically connect the two wall segments with each other. Thus, there is always a gap between the top of the surface increasing structure and the opposed arranged wall segment.

The dimensions of the exit aperture and of the surface increasing structure depend on the dimensions of the turbine assembly or its aerofoil, respectively. These dimensions may be specified as relative values or as absolute values.

Preferably, the at least one exit aperture has a width extending from one inner surface to the other inner surface and wherein the at least one surface increasing structure has a height that is maximally 50% of the width if the at least one exit aperture. Thus, a balance between a sufficient area used for heat transfer and thus cooling purposes and an unobscured flow path of the flow medium, like cooling air, exiting at the exit aperture can be provided. In the scope of maximally 50% should lie a divergence from 50% of about 5% to 10%. Moreover, the at least two wall segments are spaced apart a distance from each other and wherein the at least one surface increasing structure extends maximally along 50% of the distance between the at least two wall segments. For example in a turbine assembly with an aerofoil span of about 70 millimetres (mm) the exit aperture may have a width of about 0.5 mm to 0.9 mm, thus the height of the surface increasing structure would maximally be about 0.25 mm to 0.45 mm.

Furthermore, it is provided that the at least one aerofoil has a span in span wise direction and wherein a width of the at least one surface increasing structure is greater than 0.4% of the span of the at least one aerofoil or preferably of about 0.4% to 1% of the span and most preferably of about 0.5% of the span. Specifically, in case of a turbine assembly with an aerofoil having a span of 70 mm the width of the at least one surface increasing structure is greater than 0.4 mm. Moreover, a height of the at least one surface increasing structure is greater than 0.3% of the span of the at least one aerofoil or preferably of about 0.3% to 1% and most preferably of about 0.4% of the span. Specifically, in case of a turbine assembly with an aerofoil having a span of 70 mm the height of the at least one surface increasing structure is greater than 0.3 mm. Further, a length of the at least one surface increasing structure is greater than 1% of the span of the at least one aerofoil or preferably of about 1% to 3% and most preferably of about 2% of the span. Specifically, in case of a turbine assembly with an aerofoil having a span of 70 mm the length of the at least one surface increasing structure is greater than 1.4 mm. These dimensions and values have been shown to provide a sufficient area for effective heat transfer. Additionally, a turbine assembly with a thus dimensioned surface increasing structure can be manufactured or casted easily resulting in a turbine assembly without stability issues.

Generally, in case of more than one surface increasing structure and/or cooling passage it may be possible to dimension each surface increasing structure as well as an exit opening or cross section of each cooling passage individually.

As stated above the turbine assembly comprises at least one cooling passage for the cooling medium discharging in the at least one exit aperture, thus, providing a selected flow path for the cooling medium. Further, the at least one cooling passage has a cross sectional area and the at least one surface increasing structure has a cross sectional area. According to a preferred embodiment of the invention the cross sectional area of the at least one surface increasing structure is less than 60% of the cross sectional area of the at least one cooling passage and preferably about 40% to 60% and most preferably the cross sectional area of the at least one surface increasing structure is maximally 50% of the cross sectional area of the at least one cooling passage. Hence, the portion of the cross sectional area of the cooling passage where the flow of the cooling medium is unhindered by the surface increasing structure is large enough to allow a sufficient amount of cooling medium to be discharged from the cooling passage to bypass the surface increasing structure for heat transfer and thus cooling.

Preferably, the at least one surface increasing structure is positioned at the hottest point of the at least one aerofoil during operation of the turbine assembly. Thus, the surface increasing structure can take effect at the region of the aerofoil where cooling is needed the most and the risk for detriment is highest. This location can be determined beforehand of the casting of the aerofoil with specific software under consideration of characteristics of the turbine assembly as well as the used turbine engine, like used materials, position of the turbine assembly along the flow path of the cooling medium, temperatures at selected positions of the turbine engine, flow capacity and velocity, speed of the turbine engine etc.

As stated above the at least one cooling passage has an exit opening and the at least one exit aperture has a depth in a direction basically perpendicular to a span wise direction of the basically hollow aerofoil. In this context an "exit opening" is intended to mean the region where the cooling medium, like air, is discharged from the cooling passage and specifically into the exit aperture to be released from the turbine assembly into the surrounding environment. In case of more than one cooling passage the portions of the flow medium discharged from different cooling passages can be merged after passing the exit opening. The scope of a "basically perpendicular" arrangement should also lie an arrangement of the depth in respect to the span wise direction that deviates up to 10% from the strict span wise orientation.

As stated above the at least one surface increasing structure has a longitudinal extension with a forward end and a rear end and wherein the at least one surface increasing structure extends from its forward end to its rear end along the depth of the at least one exit aperture and wherein the forward end of the at least one surface increasing structure is arranged in the exit opening of the at least one cooling passage. Due to this arrangement the cooling of the discharged cooling medium can start to take effect directly after the cooling medium exits the cooling passage. The arrangement as "arranged in" should be understood as positioned at or starts/originates at/in the exit opening or directly adjacent to the exit opening. Thus, the exit opening and the forward end are basically at the same depth viewed in direction from the leading edge to the trailing edge. The surface increasing structure with its forward and rear ends is preferably embodied as a rib.

An especially effective heat transfer can be provided when the turbine assembly comprises a plurality of surface increasing structures. Furthermore, it is advantageous when the plurality of surface increasing structures extend basically in parallel towards each other, thus minimising the risk of flow perturbation along the flow path of the cooling medium after exiting the cooling passage(s). A homogeneous discharge can be provided when the surface increasing structures of the plurality of surface increasing structures are arranged equally spaced towards each other.

It is possible to arrange the surface increasing structures in span wise direction of the aerofoil all along the exit aperture. However, to allow a sufficient amount of the cooling medium/air to exit the aerofoil unhindered the positioning of the surface increasing structures (only) at selected areas might be more advantageous. Hence, the surface increasing structures can be arranged in one or more groups with a selected number of surface increasing structures. For example, it would be possible to arrange a group of six surface increasing structures at the region where the aerofoil will be hottest during operation of the turbine engine, like near the tip of the aerofoil.

In case of an embodiment with a plurality of surface increasing structures and a plurality of cooling passages it is advantageous when each of the cooling passages of the plurality of cooling passages comprises at least one surface increasing structure of the plurality of surface increasing structures. Hence, good heat transfer can be provided at each cooling passage. As stated above, it might be more advantageous to position a selected number of surface increasing structures at a selected number of cooling passages out of the plurality of cooling passages. Advantageous, each of these cooling passages would have at least one surface increasing structure. However, in case, for example, of a large turbine assembly the cooling passage(s) might have a dimension that would allow to arrange more than one surface increasing structure per cooling passage.

Further, the at least one cooling passage has a longitudinal extension and the at least one surface increasing structure has a longitudinal extension. According to a further realisation of the invention the longitudinal extension of the at least one surface increasing structure and the longitudinal extension of the at least one cooling passage are arranged aligned with each other. In other words, the longitudinal extension of the at least one surface increasing structure and the axial extension of the at least one cooling passage extend basically coaxial with each other or the direction of the flow path of the cooling medium is coaxial to the extension of the surface increasing structure. Hence, the risk of turbulences of the flow medium after exiting the cooling passage is minimised.

The turbine assembly has a suction side and a pressure side. Generally, the surface increasing structure can be arranged at either side or even at both sides. However, to gain the highest cooling effect it is advantageous when the wall segment of the at least two wall segments that is embodied with the at least one surface increasing structure is positioned at the pressure side of the at least one hollow aerofoil. In other words, the surface increasing structure is a part of or formed in the pressure side of the aerofoil or its inner surface, respectively.

As stated above, the at least one surface increasing structure has a rear end. Moreover, the trailing edge has a termination rim. The term “rim” should be also understood as edge or border. Beneficially, the rear end of the surface increasing structure terminates flush with the trailing edge termination rim. As a result, a homogeneously moulded or shaped trailing edge can be provided minimising manufacturing problems and inaccuracies in the finished turbine assembly. In this embodiment, the length of the surface increasing structure is basically equal to the depth of the exit aperture.

The cooling passage has a cross section and two cooling passages have a span wise distance towards each other. This span wise distance is basically the cross section of the cooling passage. Furthermore, two surface increasing structures have a span wise distance towards each other that is basically the cross section of the cooling passage. In other words, the spacing between two surface increasing structures is the same as or equal to the spacing between two cooling passages. Thus, a balanced construction can be provided resulting in a stable and robust turbine assembly.

In a further advantageous embodiment the aerofoil is a turbine blade or turbine vane, and especially a turbine blade.

It is a further object of the present invention to provide a matrix component for manufacturing by a casting method with at least one casting material the inventive turbine assembly.

It is provided that the matrix component comprises at least one cavity, wherein dimensions of the at least one cavity are embodied in such a way so that during the casting process with the at least one casting material at least one surface increasing structure of the turbine assembly is formed.

Due to this the surface increasing structure can be formed reliably and easily during the manufacturing or casting process, respectively, of the turbine assembly, what further advantageously economising the manufacturing process. Moreover, smooth junctions between the surface increasing structure and the wall segment can be provided.

In his context the term "matrix" should be understood as template or blueprint. The casting material may be any material feasible for a person skilled in the art to form the shape and structures of the turbine assembly, like a metal, a blended metal mixture or an alloy etc. The matrix component may be manufactured or built of any material feasible for a person skilled in the art that can be removed after the casting process and may for example be a ceramic material. Thus, the matric component may be named ceramic core.

The invention further provides a method for manufacturing the inventive turbine assembly by using the inventive matrix component.

It is proposed that the method comprises at least the steps of: Casting a casting material around the matrix component and removing the matrix component and thus obtaining the turbine assembly.

Due to this manufacturing process the surface increasing structure can be integrated in the turbine assembly effectively and reliably. Furthermore, an additional manufacturing step for integration of the surface increasing structure can be omitted saving time and costs.

The above-described characteristics, features and advantages of this invention and the manner in which they are achieved are clear and clearly understood in connection with the following description of exemplary embodiments which are explained in connection with the drawings.

Brief Description of the Drawings

The present invention will be described with reference to drawings in which:

FIG 1: shows a schematically and sectional view of a gas turbine engine comprising several inventive turbine assemblies,

FIG 2: shows a perspective view of one turbine assembly from FIG 1 with an aerofoil comprising a trailing edge with an exit aperture,

FIG 3: shows two wall segments and the exit aperture of the aerofoil from FIG 2 with surface increasing structures at one wall segment,

FIG 4: shows one surface increasing structure from FIG 3 in an enlarged view,

FIG 5: shows a matrix component for a casting process for the turbine assembly from FIG 2 with cavities corresponding to the surface increasing structures from FIG 4 and

FIG 6: shows a trailing edge region of the matrix component from FIG 5 with cavities in an enlarged view.

Detailed Description of the Illustrated Embodiments

The terms upstream and downstream refer to the flow direction of the airflow and/or working gas flow through the engine 68 unless otherwise stated. If used and not otherwise stated, the terms axial, radial and circumferential are made with reference to a rotational axis 78 of the engine 68.

FIG 1 shows an example of a gas turbine engine 68 in a sectional view. The gas turbine engine 68 comprises, in flow series, an inlet 70, a compressor section 72, a combustion section 74 and a turbine section 76, which are generally arranged in flow series and generally in the direction of a longitudinal or rotational axis 78. The gas turbine engine 68 further comprises a shaft 80 which is rotatable about the rotational axis 78 and which extends longitudinally through the gas turbine engine 68. The shaft 80 drivingly connects the turbine section 76 to the compressor section 72.

In operation of the gas turbine engine 68, air 82, which is taken in through the air inlet 70 is compressed by the compressor section 72 and delivered to the combustion section or burner section 74. The burner section 74 comprises a burner plenum 84, one or more combustion chambers 86 defined by a double wall can 88 (not shown in detail) and at least one burner 90 fixed to each combustion chamber 86. The combustion chamber(s) 86 and the burner(s) 90 are located inside the burner plenum 84. The compressed air passing through the compressor section 72 enters a diffuser 92 and is discharged from the diffuser 92 into the burner plenum 84 from where a portion of the air enters the burner 90 and is mixed with a gaseous or liquid fuel. The air/fuel mixture is then burned and the combustion gas 94 or working gas from the combustion is channelled via a transition duct 96 to the turbine section 74.

The turbine section 76 comprises a number of blade carrying production discs 98 or turbine wheels attached to the shaft 80. In the present example, the turbine section 76 comprises two discs 98 each carry an annular array of turbine assemblies 10 which each comprises a basically hollow aerofoil 12 (see FIG 2) embodied as a turbine blade. However, the number of blade carrying production discs 98 could be different, i.e. only one production disc 98 or more than two production discs 98. In addition, turbine assemblies 10 embodied as aerofoils 12 from turbine cascades 100 are disposed between the turbine blades. Each turbine cascade 100 carries an annular array of aerofoils 12 in the form of guiding vanes, which are fixed to a stator 102 of the gas turbine engine 68. Between the exit of the combustion chamber 86 and the leading turbine blades inlet guiding vanes or nozzle guide vanes 104 are provided.

The combustion gas 94 from the combustion chamber 86 enters the turbine section 76 and drives the turbine blades which in turn rotate the shaft 80. The guiding vanes 104 serve to optimise the angle of the combustion or working gas 94 on to the turbine blades. The compressor section 72 comprises an axial series of guide vane stages 106 and rotor blade stages 108 with turbine assemblies 10 or turbine blades or vanes, respectively.

FIG 2 shows in a perspective view a turbine assembly 10 or turbine blade of the gas turbine engine 68 with an aerofoil 12.

The turbine assembly 10 comprises a basically hollow aerofoil 12, with two cooling regions, specifically, a channelled cooling region and a fin-pin/pedestal cooling region (not shown in detail). The former is located at a leading edge 110 and comprises a meandering cooling channel 112 for a cooling medium 34 (see FIG 5) that extend in span wise direction 26 of the aerofoil 12 and different parts of the cooling channel 12 are separated by ribs 114. The latter is located at a trailing edge 14 of the aerofoil 12. The cooling channel 112 is spliced at the trailing edge 14 in several cooling passages 32, 32′ (see FIG 5) which were also separate by ribs 114. The cooling channel 112 and the cooling passages 32, 32′ may be in flow communication with each other or with other cooling features of the aerofoil 12, like film cooling holes, impingement devices or the like (not specified or shown).

The turbine assembly 10 further comprises a platform 116 and a root portion 118, wherein the platform 116 is arranged in span wise direction 26 between the aerofoil 12 and the root portion 118. Further, the aerofoil 12 may comprise, if embodied as guide vane, an outer platform, embodied as a shroud, at its tip, which is not shown in FIG 2.

The trailing edge 14 comprises two wall segments 16, 18, wherein the wall segment 16 is a part of a pressure side 52 and the wall segment 18 is a part of a suction side 120 of the aerofoil 12. Thus, the wall segments 16, 18 extend in a span wise direction 26 of the aerofoil 12. Moreover, the wall segments 16, 18 each comprise an inner surface 20, 22 (see FIG 3 and 4) that face each other and that enclose an exit aperture 24, wherein the cooling medium 34 is discharged from the cooling passages 32, 32′ into the exit aperture 24 and subsequently in the surrounding environment, like the gas path in the compressor section 72 or the turbine section 76. The exit aperture 24 extends in span wise direction 26 of the aerofoil 12 basically all along a span 30 of the aerofoil 12. Furthermore, the exit aperture 24 has a depth D in a direction 42 basically perpendicular to a span wise direction 26 or the direction 42 from the leading edge 110 to the trailing edge 52 of the aerofoil 12.

As can be seen in FIG 3 that shows an enlarged part III of FIG 2 the inner surface 20 of the wall segment 16 of the pressure side 52 of the aerofoil 12 comprises several, in this exemplary embodiment six, surface increasing structures 28, 28′. These surface increasing structures 28, 28′ extend partially into the exit aperture 24 and specifically they originate from the inner surface 20 of the pressure side 52 (wall segment 16) to the opposed inner surface 22 of the suction side 120 (wall segment 18).

Beforehand of specifying the characteristics of the surface increasing structures 28, 28′ further the manufacturing process will be described with reference to FIG 5 and 6, wherein FIG 5 shows a matrix component 62 for the manufacturing of the turbine assembly 10 and FIG 6 an enlarged part of a trailing edge region of the matrix component 62.

For the manufacturing by a casting method with a casting material 64 (the material out of which the turbine assembly is made, e.g. stainless steel, see FIG 2) the matrix component 62, like a core out of a ceramic material, is used as a template to form the innards of the aerofoil 12, like the cooling passages 32, 32′, the dividing ribs 114, the exit aperture 24 or the surface increasing structures 28, 28′ etc. Structures which are shown in FIG 5 and 6 in solid form are structures that will be holes, openings or empty apertures in the resulting aerofoil 12. Vacant spaces, in turn, will be solid structures in the resulting aerofoil 12 or turbine assembly 10, respectively. To mark the template structures in the matrix component 62 the reference numerals of the end structures (12, 16, 20, 24, 28, 28′, 32, 32′, 114) according to FIG 1 to 4 are used in FIG 5 and 6 even if they are not actually shown.

The method for manufacturing the turbine assembly by using the matrix component 62 comprises at least the steps of: Casting a casting material 64 around the matrix component 62 and removing the matrix component 62 by a leeching process and thus obtaining the turbine assembly 10 comprising the surface increasing structures 28, 28′ due to the integrated cavities 66, 66′ in the matrix component 62.

The matrix component 62 comprises cavities 66, 66′ (note that the cavities are also marked with the reference numerals for the corresponding surface increasing structures 28, 28′ in FIG 5 and 6) which dimensions are embodied in such a way so that during the casting process with the casting material 64 the surface increasing structures 28, 28′ of the turbine assembly 10 are formed.

Due to this manufacturing process the surface increasing structures 28, 28′ and the wall segment 16 are embodied integrally with each other.

The features of the surface increasing structures will be described in reference to FIG 3 to 6. Even if the surface increasing structures 28, 28′ as well as the cooling passages 32, 32′ and the exit aperture 24 are only indirectly shown through their corresponding structures in the matrix component 62 of FIG 5 and 6 some features will be described in reference to these FIG because these FIG depict the features more clearly than FIG 3 and 4.

The surface increasing structures 28, 28′ extend basically in parallel towards each other and are arranged equally spaced towards each other (see FIG 6).

As can be seen in FIG 3 and 6 each of the cooling passages 32, 32′ of the plurality of cooling passage 32, 32′ comprises one surface increasing structure 28, 28′ of the plurality of surface increasing structures 28, 28′. Further, each surface increasing structure 28, 28 has a longitudinal extension 44 and each cooling passage 32, 32′ has a longitudinal extension 50. The longitudinal extension 44 of each surface increasing structure 28, 28′ and the longitudinal extension 50 of each cooling passage 32, 32′ are arranged aligned with each other or are arranged coaxial towards each other.

Moreover, each cooling passage 32, 32′ has a cross section 56 and two cooling passages 32, 32′ have a span wise distance 58 towards each other. The span wise distance 58 between two cooling passages 32, 32′ is basically the cross section 56 of one cooling passage 32, 32′. Furthermore, two surface increasing structures 28, 28′ have a span wise distance 60 towards each other that is basically the cross section 56 and thus the span wise distance 58 of the (two) cooling passage(s) 32, 32′.

Further, the exit aperture 24 has a width W extending from inner surface 20 to inner surface 22. To allow sufficient cooling medium 34 to exit the cooling passages 32, 32′ and thus the aerofoil 12 the dimensions of each surface increasing structure 28, 28′ is balanced with the dimensions of the corresponding cooling passage 32, 32′ and with the exit aperture 24. Hence, each surface increasing structures 28, 28′ has a height h that is maximally 50% of the width W of the exit aperture 24. Furthermore, a cross sectional area 38 of each surface increasing structure 28, 28′ is maximally 50% of a cross sectional area 36 of each cooling passage 32, 32′ (see FIG 3 and 6).

As can be seen in FIG 4, which shows one surface increasing structure 28 in more detail, a width w of the surface increasing structure 28 is about 0.5% of the span 30 of the aerofoil 12. A height h of the surface increasing structure 28 is about 0.4% of the span 30 and a length l of the surface increasing structure 28 is about 2% of the span 30. Specifically, the width w is greater than 0.4 mm, the height h is greater than 0.3 mm and the length l is greater than 1.4 mm. In case of a turbine assembly 10 with an aerofoil 12 having a span of 70 millimetre (mm) the width w will be 0.4 mm, the height h will be 0.3 mm and the length l will be 1.4 mm. For this values an effective surface 122 of the surface increasing structure 28 is 1.587 mm^2 (see dotted area in FIG 4).

Each cooling passage 32, 32′ has an exit opening 40 to discharge the cooling medium 34 into the exit aperture 24 (see FIG 6). The longitudinal extension 44 of each surface increasing structure 28, 28′ has a forward end 46 (towards the leading edge 110) and a rear end 48 (towards the trailing edge 52). The surface increasing structure 28, 28′ extends from its forward end 46 to its rear end 48 along the depth D of the exit aperture 24. Moreover, the forward end 46 of each surface increasing structure 28, 28′ is arranged in the exit opening 40 of the corresponding cooling passage 32, 32′ (see also FIG 6).

Additionally, the rear end 48 of each surface increasing structure 28, 28′ terminates flush with a termination rim 54 of the trailing edge 14 (see FIG 6).

It should be noted that the term “comprising” does not exclude other elements or steps and “a” or “an” does not exclude a plurality. Also elements described in association with different embodiments may be combined. It should also be noted that reference signs in the claims should not be construed as limiting the scope of the claims.

Although the invention is illustrated and described in detail by the preferred embodiments, the invention is not limited by the examples disclosed, and other variations can be derived therefrom by a person skilled in the art without departing from the scope of the invention.

CLAIMS

1. Turbine assembly (10) comprising at least one basically hollow aerofoil (12) with at least one trailing edge (14) comprising at least two wall segments (16, 18) that each comprises an inner surface (20, 22), wherein the inner surfaces (20, 22) face each other, and wherein the inner surfaces (20, 22) enclose at least one exit aperture (24) extending basically in span wise direction (26) of the at least one basically hollow aerofoil (12),
wherein at least one of the inner surfaces (20, 22) of the at least two wall segments (16, 18) of the trailing edge (14) comprises at least one surface increasing structure (28, 28’) extending partially into the at least one exit aperture (24) from one inner surface (20, 22) to the other inner surface (20, 22),
wherein the turbine assembly further comprises at least one cooling passage (32, 32’) for a cooling medium (34) discharging in the at least one exit aperture (24) and wherein the at least one cooling passage (32, 32’) has an exit opening (40) and wherein the at least one exit aperture (24) has a depth (D) in a direction (42) basically perpendicular to a span wise direction (26) of the basically hollow aerofoil (12) and wherein the at least one surface increasing structure (28, 28’) has a longitudinal extension (44) with a forward end (46) and a rear end (48) and wherein the at least one surface increasing structure (28, 28’) extends from its forward end (46) to its rear end (48) along the depth (D) of the at least one exit aperture (24) and wherein the forward end (46) of the at least one surface increasing structure (28, 28’) is arranged in the exit opening (40) of the at least one cooling passage (32, 32’).

2. Turbine assembly according to claim 1, wherein the at least one exit aperture (24) has a width (W) extending from one inner surface (20, 22) to the other inner surface (20, 22) and wherein the at least one surface increasing structure (28, 28’) has a height (h) that is maximally 50% of the width (W) of the at least one exit aperture (24).

3. Turbine assembly according to claim 1 or 2, wherein the at least one aerofoil (12) has a span (30) in span wise direction (26) and wherein a width (w) of the at least one surface increasing structure (28, 28’) is about 0.5% of the span (30) of the at least one aerofoil (12) and/or wherein a height (h) of the at least one surface increasing structure (28, 28’) is about 0.4% of the span (30) of the at least one aerofoil (12) and/or wherein a length (l) of the at least one surface increasing structure (28, 28’) is about 2% of the span (30) of the at least one aerofoil (12) and specifically, the width (w) of the at least one surface increasing structure (28, 28’) is greater than 0.4 mm and/or the height (h) of the at least one surface increasing structure (28, 28’) is greater than 0.3 mm and/or the length (l) of the at least one surface increasing structure (28, 28’) is greater than 1.4 mm.

4. Turbine assembly according to any preceding claim, wherein the at least one cooling passage (32, 32’) has a cross sectional area (36) and wherein the at least one surface increasing structure (28, 28’) has a cross sectional area (38) and wherein the cross sectional area (38) of the at least one surface increasing structure (28, 28’) is maximally 50% of the cross sectional area (36) of the at least one cooling passage (32, 32’).

5. Turbine assembly according to any preceding claim, characterised by a plurality of surface increasing structures (28, 28’) and wherein the plurality of surface increasing structures (28, 28’) extend basically in parallel towards each other and/or are arranged equally spaced towards each other.

6. Turbine assembly according to any preceding claim, characterised by a plurality of surface increasing structures (28, 28’) and a plurality of cooling passages (32, 32’) for a cooling medium (34) discharging in the at least one exit aperture (24) and wherein each of the cooling passages (32, 32’) of the plurality of cooling passages (32, 32’) comprises

at least one surface increasing structure (28, 28’) of the plurality of surface increasing structures (28, 28’).

7. Turbine assembly according to any preceding claim, wherein at least one cooling passage (32, 32’) has a longitudinal extension (50) and the at least one surface increasing structure (28, 28’) has a longitudinal extension (44) and wherein the longitudinal extension (44) of the at least one surface increasing structure (28, 28’) and the longitudinal extension (50) of the at least one cooling passage (32, 32’) are arranged aligned with each other.

8. Turbine assembly according to any preceding claim, wherein the wall segment (16) of the at least two wall segments (16, 18) that is embodied with the at least one surface increasing structure (28, 28’) is positioned at a pressure side (52) of the at least one hollow aerofoil (12).

9. Turbine assembly according to any preceding claim, wherein the trailing edge (14) has a termination rim (54) and wherein the rear end (48) terminates flush with the termination rim (54) of the trailing edge (14).

10. Turbine assembly according to any preceding claim, wherein the at least one surface increasing structure (28, 28’) and the wall segment (16) of the at least two wall segments (16, 18) that is embodied with the at least one surface increasing structure (28, 28’) are embodied integrally with each other.

11. Turbine assembly according to any preceding claim, characterised by at least two cooling passages (32, 32’) for the cooling medium (34) discharging in the at least one exit aperture (24) and by at least two surface increasing structures (28, 28’), wherein each of the cooling passages (32, 32’) of the at least two cooling passages (32, 32’) has a cross section (56) and the at least two cooling passages (32, 32’) have a span wise distance (58) towards each other and wherein the span wise distance (58) between the at least two cooling

passages (32, 32’) is basically the cross section (56) of the cooling passage (32, 32’) and wherein the at least two surface increasing structures (28, 28’) have a span wise distance (60) towards each other that is basically the cross section (56) of the cooling passage (32, 32’).

12. Turbine assembly according to any preceding claim, wherein the at least one basically hollow aerofoil (12) is a turbine blade or vane.

13. Matrix component (62) for manufacturing by a casting method with at least one casting material (64) the turbine assembly (10) according to claims 1 to 12, characterised by at least one cavity (66, 66’), wherein dimensions of the at least one cavity (66, 66’) are embodied in such a way so that during the casting process with the at least one casting material (64) at least one surface increasing structure (28, 28’) of the turbine assembly (10) is formed.

14. A method for manufacturing a turbine assembly (10) according to claims 1 to 12 by using the matrix component (62) according to claim 13,
characterised at least in the steps of:
- Casting a casting material (64) around the matrix component (62) and
- Removing the matrix component (62) and thus obtaining the turbine assembly (10).

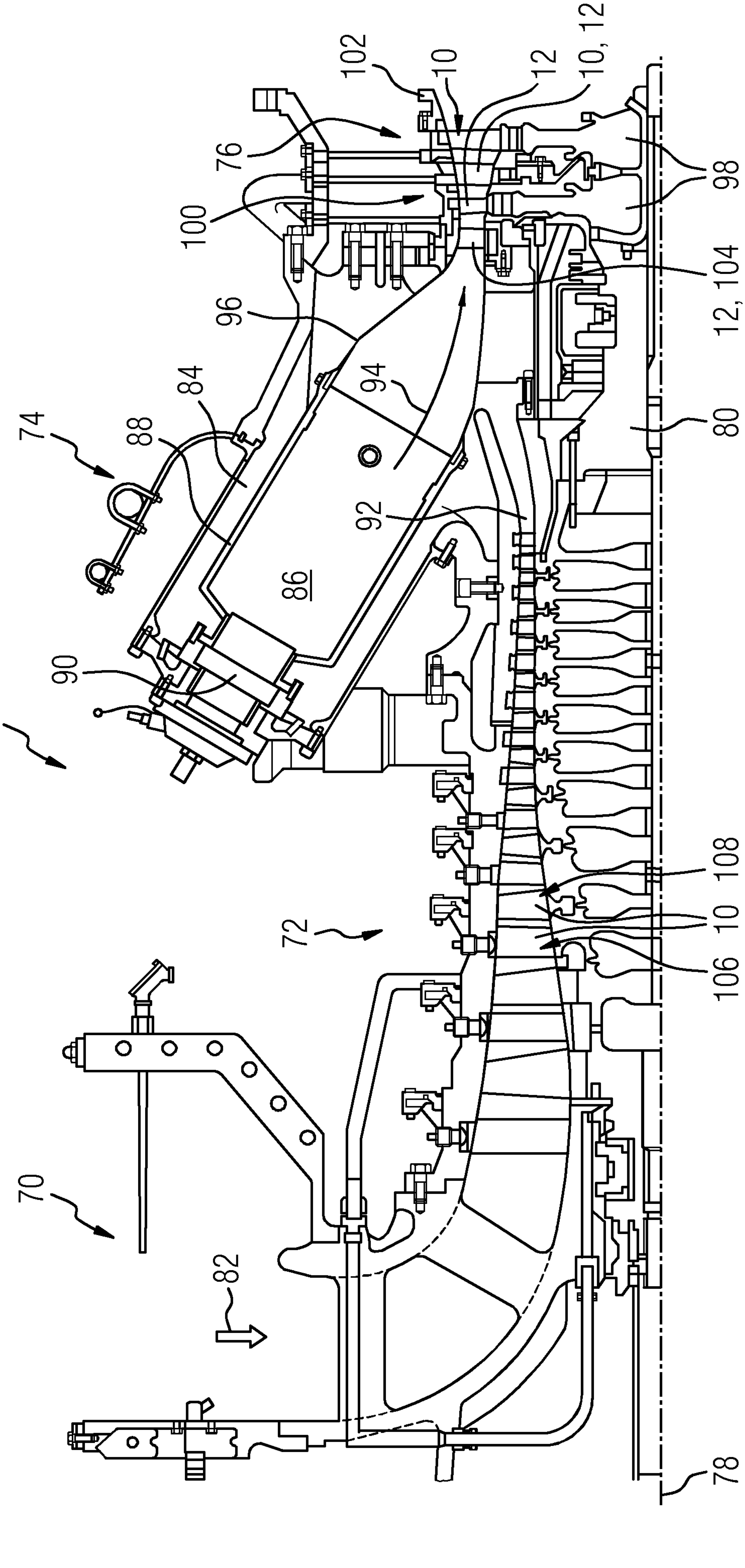
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FIG 1

FIG 2

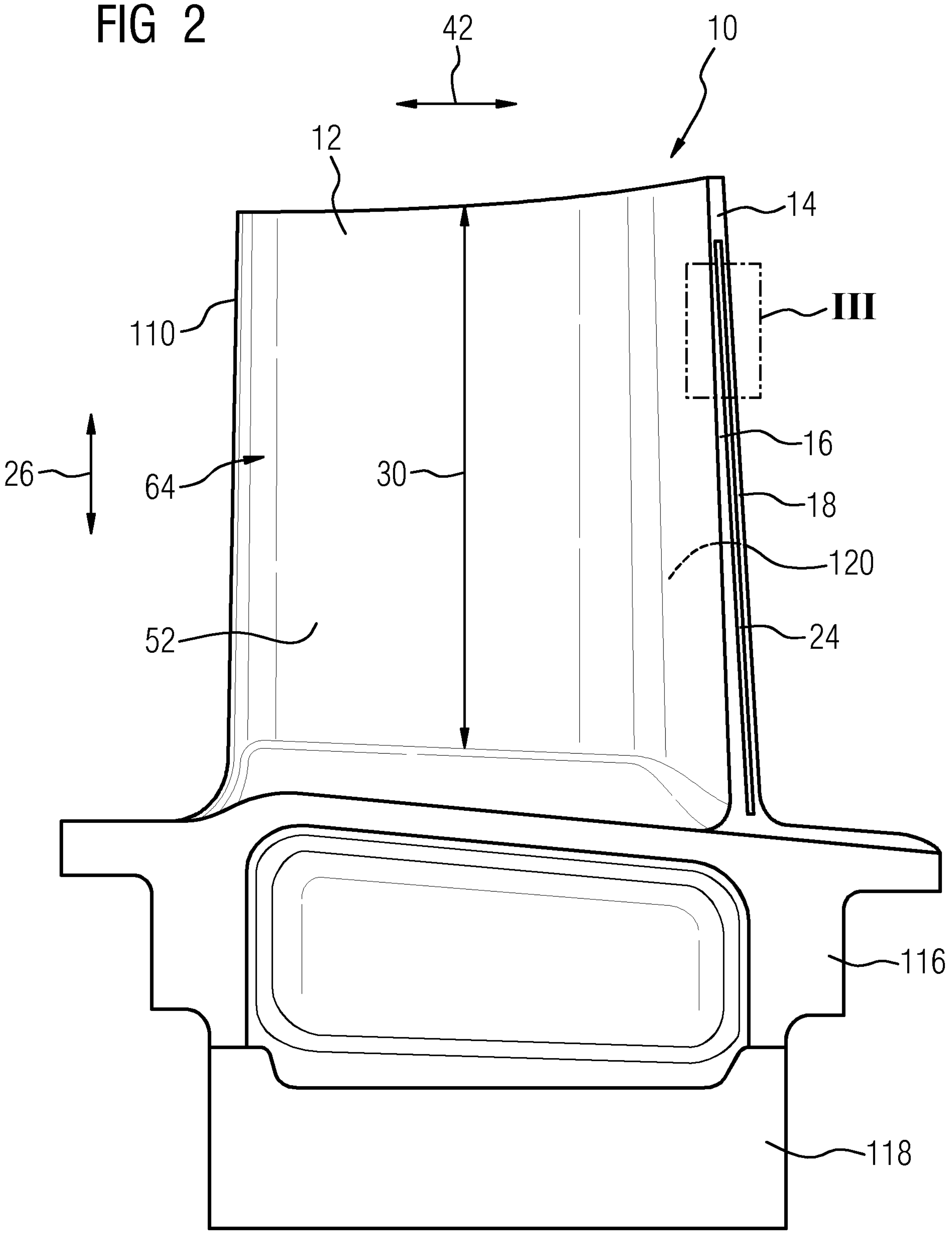


FIG 3

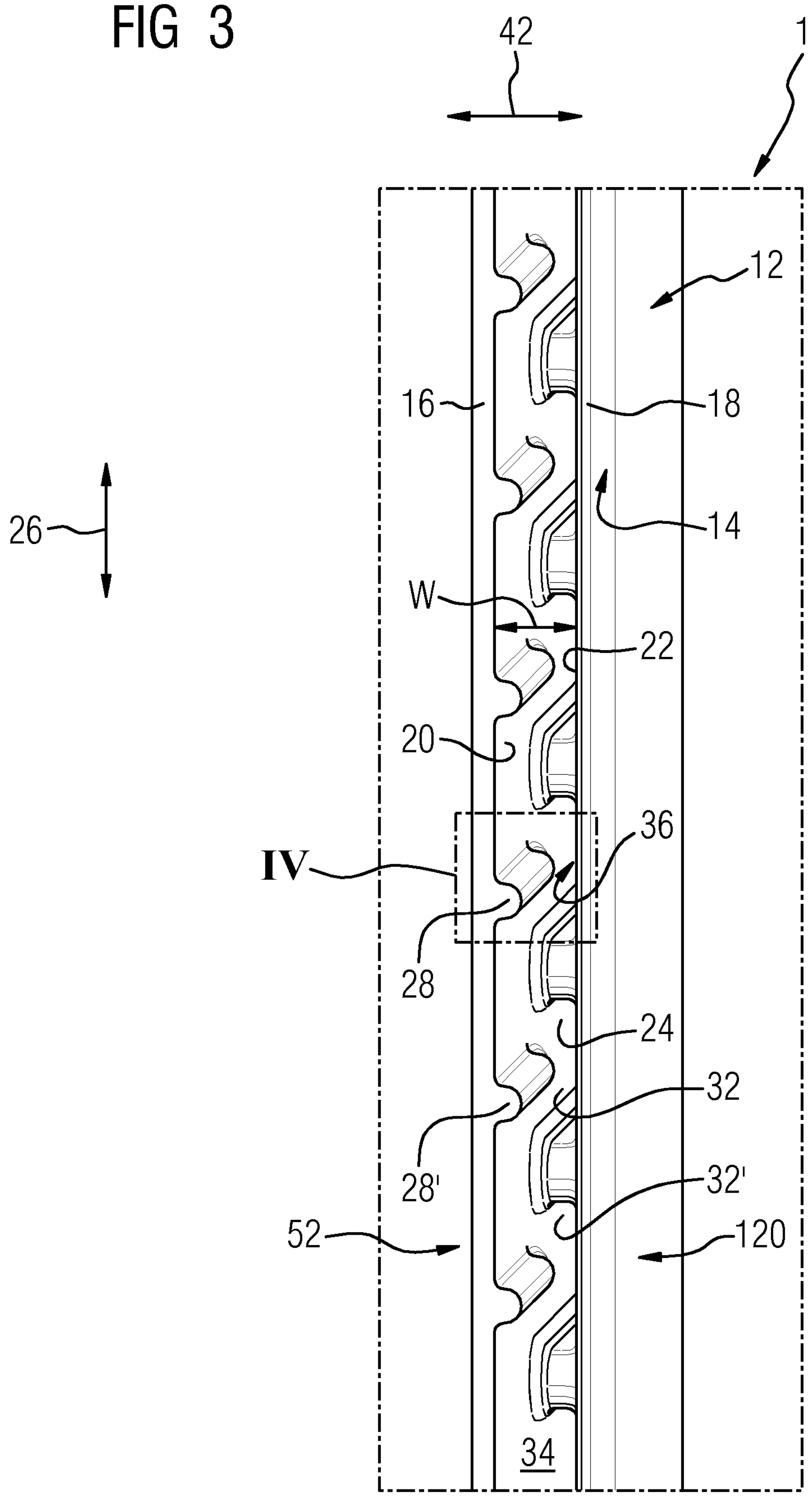


FIG 4

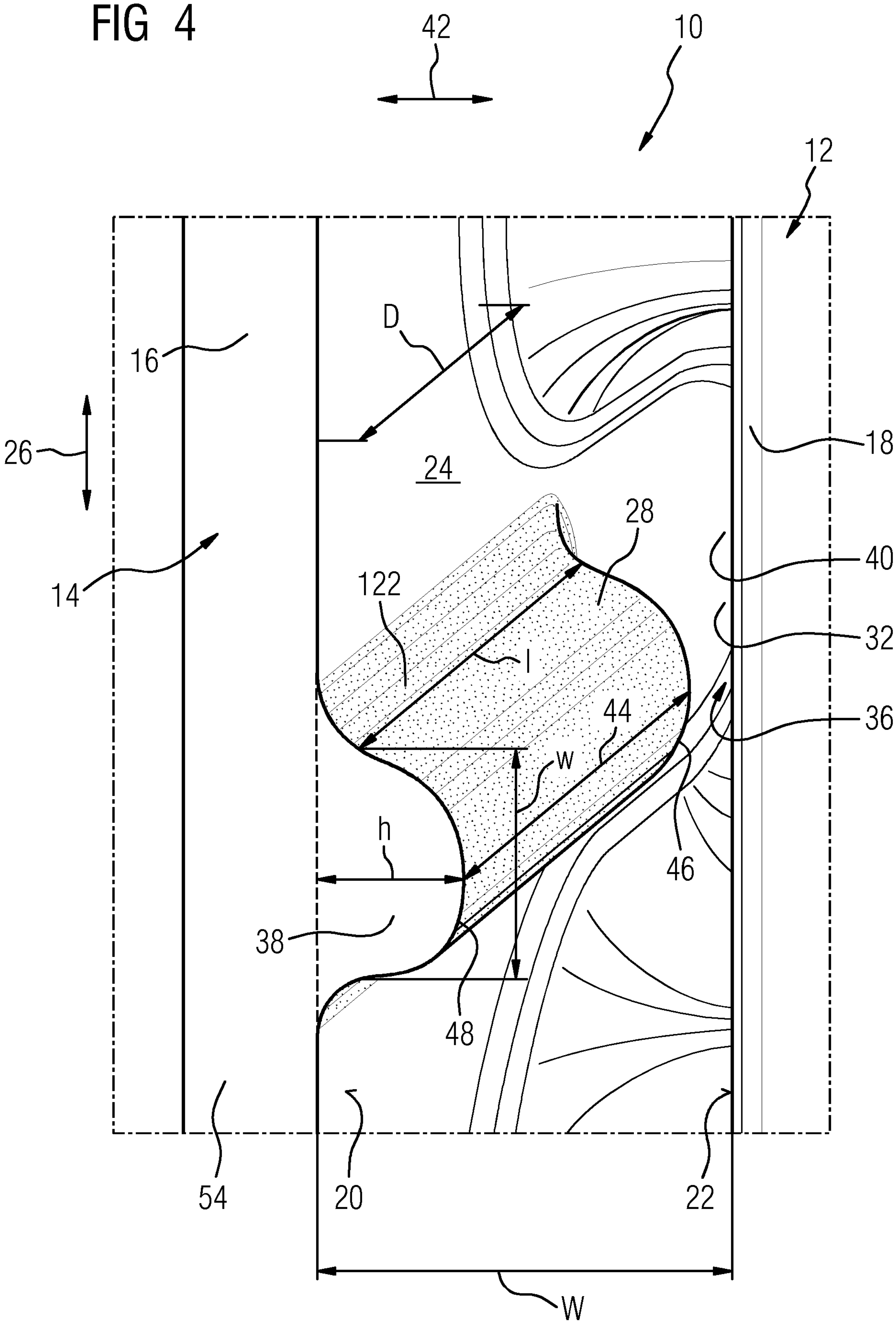
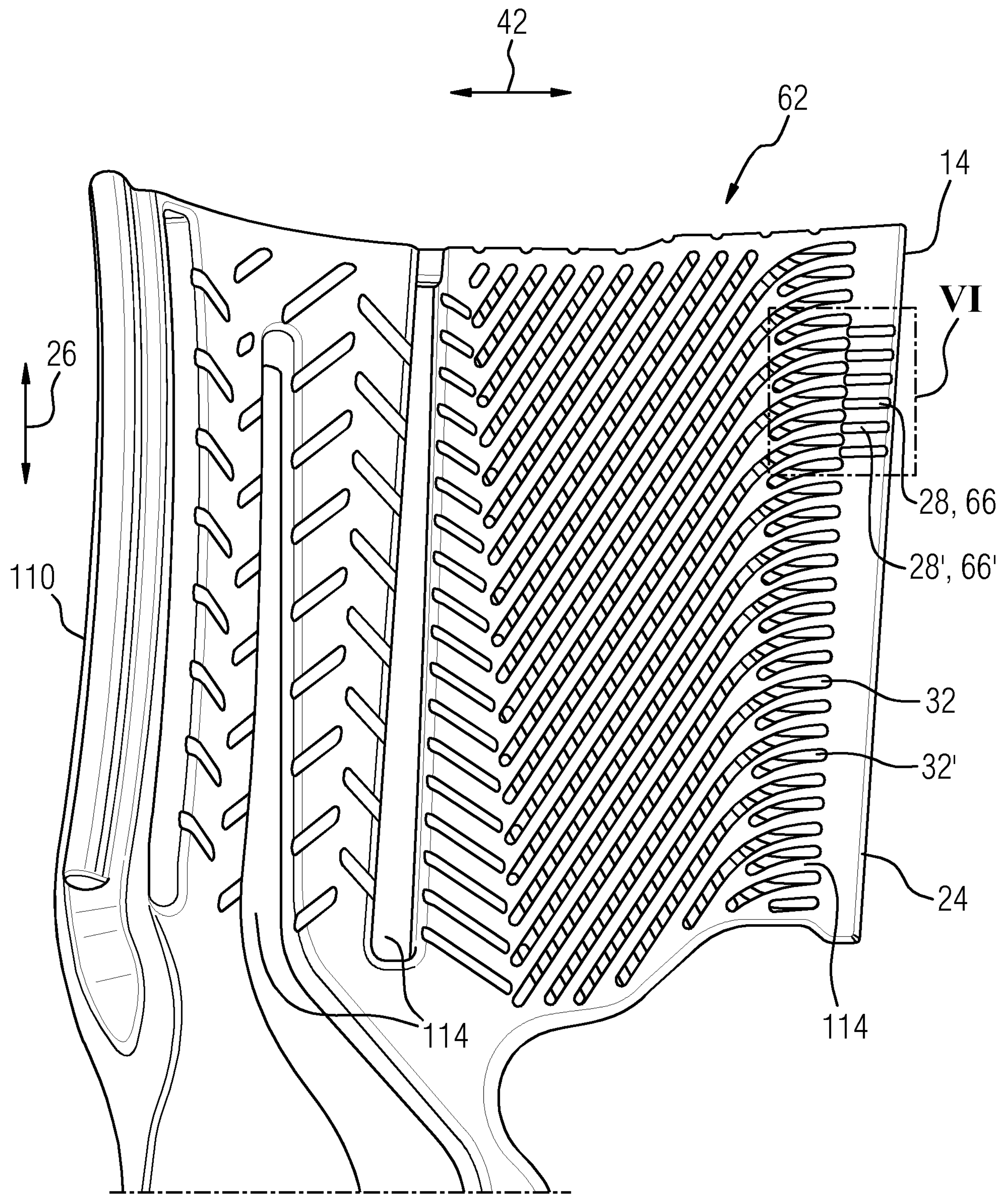


FIG 5



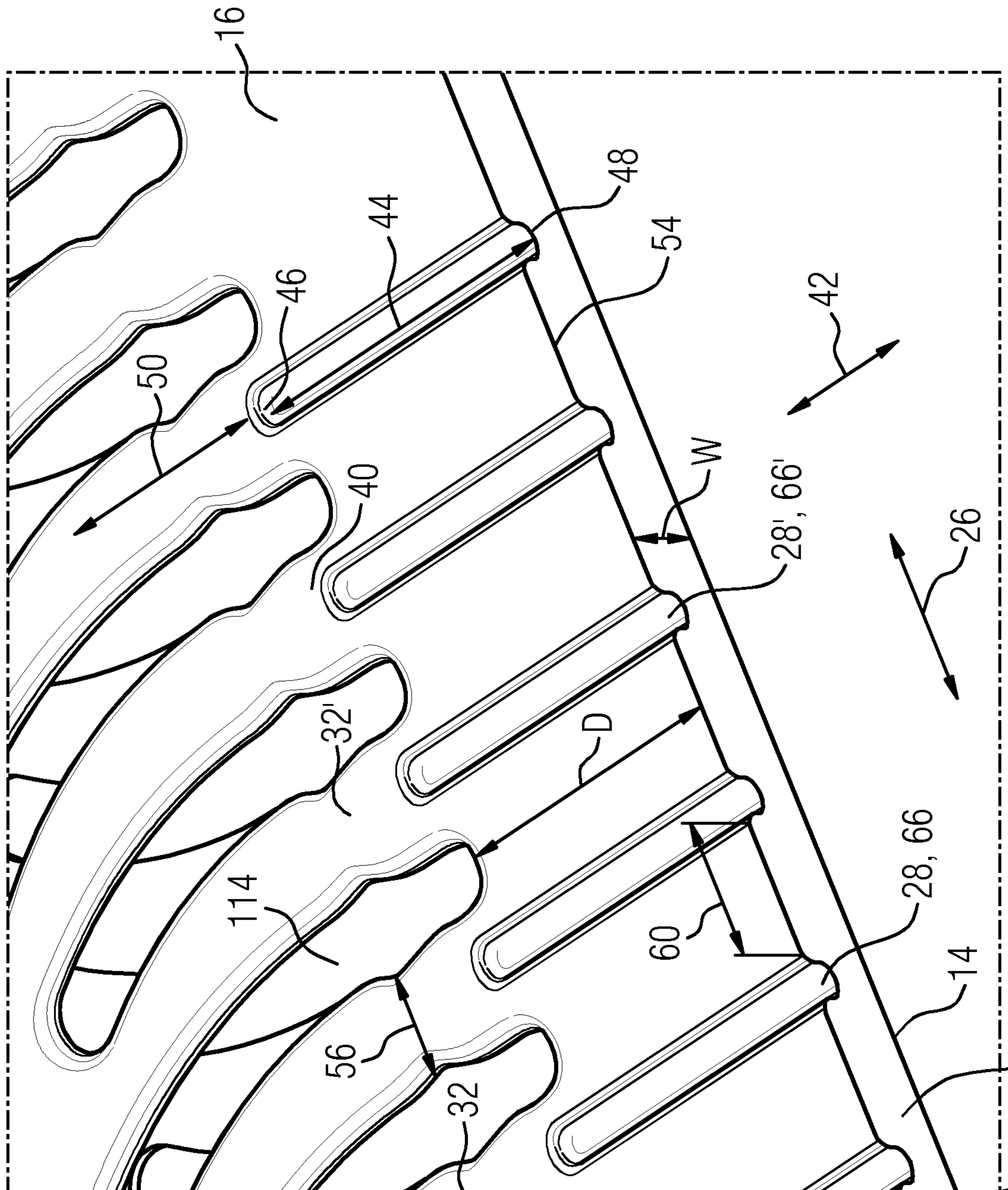


FIG 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/062581

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D5/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01D B22C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2013/302179 A1 (BERGHOLZ JR ROBERT FREDERICK [US] ET AL) 14 November 2013 (2013-11-14) page 1, paragraph 14 - page 4, paragraph 50; figures 2,5-10	1-7,9-12 13,14
X	US 2010/074763 A1 (LIANG GEORGE [US]) 25 March 2010 (2010-03-25) page 2, paragraph 20 - page 4, paragraph 33; figures 2-6	1,2,4, 9-12
X	EP 2 787 173 A1 (IHI CORP [JP]; OF JAPANESE AEROSPACE COMPANIES SOC [JP]) 8 October 2014 (2014-10-08) column 5, paragraph 24 - column 8, paragraph 38; figures 2-3	1,8

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 September 2016	29/09/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Rau, Guido

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 1 895 098 A2 (HONEYWELL INT INC [US]) 5 March 2008 (2008-03-05) the whole document -----	13,14

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2016/062581

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			CN	104285037	A	14-01-2015
			EP	2861828	A1	22-04-2015
			JP	2015516538	A	11-06-2015
			US	2013302179	A1	14-11-2013
			WO	2013169435	A1	14-11-2013
US 2010074763	A1	25-03-2010	NONE			
EP 2787173	A1	08-10-2014	EP	2787173	A1	08-10-2014
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EP 1895098	A2	05-03-2008	EP	1895098	A2	05-03-2008
			US	2008056908	A1	06-03-2008