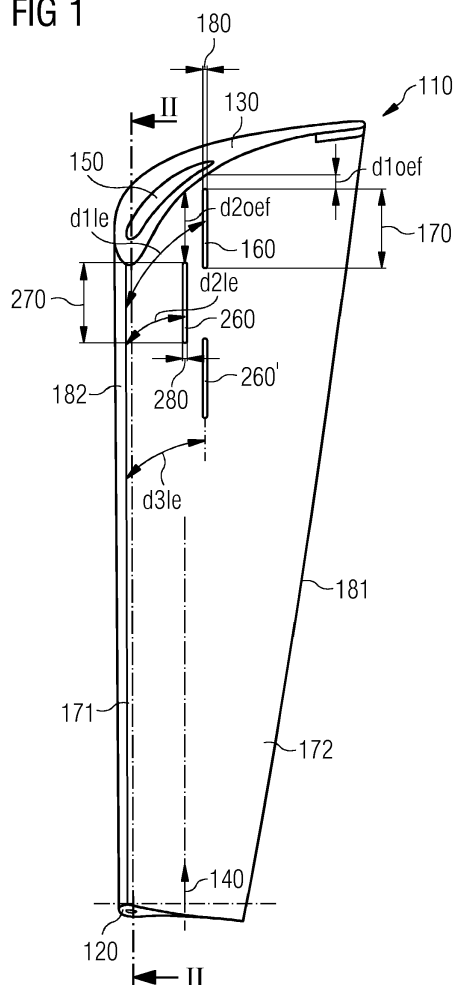


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Description

Field of invention

[0001] The present invention relates to a blade device for a turbine, in particular to a steam turbine. Additionally, the invention relates to a method for manufacturing such a blade device.

Art Background

[0002] Steam turbines are machines which are used to convert thermal energy of steam into mechanical work on an output shaft. As the name steam turbine already implicates, steam turbines are run with steam. As steam is heated water, the steam may have certain wetness. In the steam turbines which are used today the steam may condensate on the blades or on the housing of the chamber walls surrounding the blades. The water which is "produced" by condensation rests in the turbine and lowers the efficiency of the turbines and increase an erosion of the rotor blades. To avoid these effects, the condensation water must then be drained off from the turbine flow channel. This is done through holes in the carrier.

[0003] Today, the blades and the ring (which may also be denoted as carrier) are built together in one piece. For this reason the holes are created into the inside of the blades. The creation of the holes requires special manufacturing methods on the inner ring and outer ring. Additionally, the holes required for draining condensation water from the turbine have to be big enough and on the right place. The "right place" is not easy to define as the condensation water is in different places during operation of the turbine with different rotation speeds.

Summary of the Invention

[0004] It may be an object of the present invention to simplify a drainage of a condensation water out of a fluid flow section of a steam turbine.

[0005] This object may be solved by a blade device for turbines and by a method of manufacturing such a blade device for turbines according to the independent claims.

[0006] According to a first aspect of the present invention, a blade device for a turbine, in particular a steam turbine, is disclosed. The blade device comprises a blade body comprising a radially inner end face and a radially outer end face which is formed opposed to the inner end face with respect to a radial direction of the turbine. The blade body comprises a channel extending between the inner end face and the outer end face. The blade body further comprises a first groove which connects the channel and an environment of the blade body such that a fluid connection between the environment and the channel is given. The first groove has a first groove length and a first groove width which is smaller than the first groove length. The first groove width is smaller than 2 mm.

[0007] The blade body may be an aerodynamic flow

profile which generates lift if a working fluid of the turbine, such as steam, passes the blade body. The blade body may be a flow optimized profile like a NACA profile which is optimized for a certain flow velocity. As the blade body is usually used in a steam turbine a flow optimized profile may be preferred.

[0008] The radial direction may be a radial direction with respect to an axial direction which is defined by a rotary axis of a rotary shaft of the steam turbine. The blade device may be coupled to the rotary shaft such that the blade device rotates together with the rotary shaft around the rotary axis. The radial direction of a turbine is defined as the direction which is perpendicular to a longitudinal direction (i.e. axial direction) of the rotary axis of the turbine. The radial direction crosses the rotary axis. A circumferential direction is perpendicular to the radial direction and the axial direction and runs along a circumferential direction.

[0009] The radially inner end face may be the end face which is closer to the rotary axis than the radially outer end face. The outer end face is formed opposed to the inner end face along the radial direction. The distance between the inner end face and the outer end face may define the length of the blade body. The blade body may be formed as a one piece body. Furthermore, the blade body may also be built of several pieces which together form the blade body between the inner end face and the outer end face.

[0010] The channel may extend from the inner end face to the outer end face. The channel may be the shortest possible connection between the inner end face and the outer end face. Furthermore, the channel may be formed in any possible shape, like for example in a S-shape, a zig-zag-shape, meander-like shape, a half-arch-shape, a staircase-shape or in a rectangular shape. The preferred embodiment may be a straight line channel which at the same time is the shortest connection between the inner end face and the outer end face. For example, the opening may be star-shaped, circular, rectangular, squared, elliptic, oval or squared with rounded corners. Furthermore, the channel may have different diameters over its length. For example the channel may have a smaller diameter near the inner end face and a bigger diameter near the outer end face, due to more condensation water being pushed to the outer end face by centrifugal force.

[0011] The environment of the blade body may be any space around the blade body, which may be filled by the working fluid of the turbine, such as steam. If the blade body is used in a turbine the environment is usually the space inside the casing, in particular the space where the working fluid flows, further in particular the space between the different blade bodies and the respective inner and outer rings as described further below.

[0012] The fluid connection is provided by an opening (i.e. the groove) which is formed between the environment and the channel in the blade body. The size of the groove may be formed large enough to enable a fluid,

like for example water, to pass through the groove from the environment to the channel and vice versa. Additionally, it may be possible for water, steam and/or air to pass simultaneously through the groove.

[0013] The first groove may be an opening which leads from the environment to the channel and which may provide the fluid connection between the environment of the blade and the channel inside the blade body. Furthermore, the first groove may extend along the radial direction. Alternatively, the first groove may have at least one groove section which has a directional component which is non-parallel to the radial direction. Hence, the first groove may also extend in a direction forming an angle of 1 degree to 179 degree with respect to the radial direction.

[0014] The first groove length may be for example the length of the first groove having e.g. a rectangular shape which defines the longer side of the groove. The first groove width may be for example the width of the first groove which defines the shorter side of the groove with respect to the first groove length. In other words, the first groove width may be smaller as the first groove length.

[0015] By the approach of the present invention, the first groove width is smaller than 2 mm. The first groove width being smaller than 2 mm may ensure that water which condensates at a blade body surface passes the groove, wherein the first groove is small enough such that no or only small disturbances and thus small turbulences in the fluid flow of the working fluid flowing through environment of the blade body are generated. In an exemplary embodiment of the present invention, the first groove length is approximately 50 mm to 55 mm, in particular approximately 52 mm, and the first groove width is approximately 0,5 mm to approximately 1,0 mm, in particular 0,7 mm. This leads to a ratio of the first groove length to the first groove width of approximately 70 to 80. Hence, the first groove length may be for example 74 times the first groove width.

[0016] Hence, by the blade body comprising the first groove and the channel a condensation water from the blade body may be drained off without generating turbulences which affect the turbine efficiency negatively.

[0017] Additionally, the blade body comprising the channel and at least the first groove may be manufactured in a cost efficient way. As the blade body usually may be assembled with an inner ring, an outer ring and a blade carrier, but being a separate part, the holes used for drainage may be provided separately in each part. This has the effect, that all of the parts of the turbine may be manufactured separately and independently from each other, so as to provide a modular construction system in which every part may be replaced individually. Thus, the blade system is cost efficient.

[0018] According to a further exemplary embodiment of the present invention, the first groove has an extension direction extending along the first groove length. Furthermore, at least one component of the extension direction is parallel to the radial direction. The extensional direction

may be defined as the direction of a straight line connecting the starting point of the first groove being positioned at an end of the first groove, which is nearer to the radially inner end face, and the ending point of the first groove positioned at a further end of the first groove, which is nearer to the radially outer end face. Thus, also a first groove having an S-shape may have an extension direction. When the first groove is a straight groove, the extension direction may coincide with the first groove length. As the extension direction may be a direction on one surface of the blade body, the extension direction may be defined by two components. The two components defining the extension direction are the radial direction and the direction being perpendicular to the radial direction. Thus, at least one component of the extension direction is parallel to the radial direction. In other words, one component of the extension direction being parallel to the radial direction may be equal to zero. Alternatively, the extension direction of the first groove may also be perpendicular to the radial direction.

[0019] According to a further exemplary embodiment, the first groove length is longer than 15 mm. With a first groove width being smaller than 2 mm and a first groove length being longer than 15 mm, the first groove may have a dimension with a ratio first groove length/first groove width of at least 7,5. Advantages arising from this shape may be a fluid flow adjacent to the blade body with small decollation and less turbulences.

[0020] Furthermore, according to a further exemplary embodiment, the first groove width is smaller than 1 mm and the first groove length is longer than 50 mm. Thus, the first groove may have a bar-shape with a ratio first groove length/first groove width of at least 50. Furthermore, as described above, in a preferred embodiment the first groove width may be approximately 0,7 mm and the first groove length may be approximately 52 mm.

[0021] According to a further exemplary embodiment, the blade body comprises a leading edge connecting the inner end face and the outer end face and a trailing edge connecting the inner end face and the outer end face. Additionally, the blade body comprises a suction side connecting the inner end face, the outer end face, the leading edge and the trailing edge, and a pressure side connecting the inner end face, the outer end face, the leading edge and the trailing edge. Further the pressure side is formed opposed to the suction side.

[0022] The leading edge may be positioned at the upstream end of the blade body which is the side where the edge of the blade body which is first exposed to the working fluid flow of the turbine. Additionally, the leading edge comprises the stagnation point which is developed when the turbine is in operation. The trailing edge may be positioned at the downstream end of the blade body which is the side where the fluid flow may stop following the blade body contour. Both the leading edge and the trailing edge may connect the inner end face and the outer end face at their particular position. The suction side may be the surface which is delimited by the leading edge, the

outer end face, the trailing edge and the inner end face (listed clockwise). When the turbine is in use, the suction side may be exposed to suction forces. The pressure side may be the surface which is delimited by the leading edge, the outer end face, the trailing edge and the inner end face (listed clockwise) and the pressure side is positioned opposed to the suction side. When the turbine is in operation, the pressure side may be exposed to pressure forces. The vector of the pressure force on the pressure side and the vector of the suction force on the suction side result in a movement of the blade body and thus in a movement of the turbine stage and the rotary shaft, when the blade body is used in a rotor stage, and in a force component acting on the fluid flow, when the blade body is used in a stator stage.

[0023] The inner end face, the outer end face, the suction side and the pressure side together may form the outer contour of the blade body. Additionally, the trailing edge and the leading edge are extending in radial direction and having the same length. However, the inner end face and the outer end face may also have different shapes and may not be congruent, but may have a certain offset between them, and additionally the trailing edge and the leading edge may extend in a direction which forms an angle with the radial direction of the turbine and the leading edge and the trailing edge may be of different length. Thus, using the characteristics mentioned above, the shape of the blade body may be optimized according to the operating conditions present or expected in the used turbine.

[0024] According to a further exemplary embodiment, the first groove is formed within the suction side. Furthermore, the first groove may be formed within the pressure side. Depending on within which side the groove is formed there may be an influence on the amount of fluid, in particular condensation water, which enters the blade body. The first groove being formed on the pressure side may have the advantage that the component of the pressure force, during the use of the turbine, which acts perpendicular on the pressure side at the first groove, "presses" the fluid inside the first groove.

[0025] In another exemplary embodiment of the present invention the blade body further comprises a second groove which connects the channel and the environment of the blade body such that a second fluid connection between the environment and the channel is given. The second groove has a second groove length and a second groove width which is smaller than the second groove length. Further the second groove width is smaller than 2 mm and the second groove is formed spaced apart from the first groove.

[0026] The second groove may be of the same shape as and may have the same dimensions as the first groove described above. The second groove is a further opening through which a condensation water may flow from the environment to the channel and which may provide the second fluid connection between the environment of the blade and the channel inside the blade body. The second

groove may, for example, be formed being rectangular, squared, circular, oval, elliptic, star-shaped, S-shaped, staircase-shaped, or may have a corner of any angle in its shape. Furthermore, the second groove may extend in the radial direction, but the second groove may also extend in any other direction forming an angle of 1 degree to 179 degree between the second groove and the radial direction of the blade body.

[0027] In an exemplary embodiment, the first groove and the second groove are formed parallel with respect to each other.

[0028] The second groove may also provide a second fluid connection between the environment of the blade body and a further channel being formed inside the blade body. The further channel may be formed spaced apart from the channel. The channel and the further channel may have the same shape. All the conclusions made above for the channel may also be valid for the further channel. Additionally, all the conclusions made above for the first groove may be valid for the second groove as well.

[0029] Additionally, there is the possibility of a third groove or more which may be formed spaced apart to the first groove and e.g. the second groove. Thus, any quantity of grooves (n grooves) may be present within the blade body. The n grooves may have the same dimension as the first groove, i.e. the n grooves may have a respective groove width less than 2mm.

[0030] In an exemplary embodiment, three grooves with each having the groove length of 52 mm and the groove width of 0.7 mm are present within the blade body. The extension direction of each of the three grooves is in the radial direction and the three grooves are parallel to each other.

[0031] Additionally, the first groove may have a first distance to the leading edge d_{1le} and being parallel to the leading edge. The second groove may be of the same shape and may have the same groove length and groove width as the first groove, but may have a second distance to the leading edge d_{2le} . The third groove may have a third distance to the leading edge d_{3le} . Also, the end of the first groove being nearest to the outer end face may have a first distance to the outer end face d_{1oef} , the end of the second groove being nearest to the outer end face may have a second distance to the outer end face d_{2oef} and the same is valid for the end of the other grooves which may be present within the blade body.

[0032] In an exemplary embodiment the second distance to the leading edge d_{2le} is smaller than the first distance to the leading edge d_{1le} and the third distance to the leading edge d_{3le} may be the same as the first distance to the leading edge d_{1le} . Additionally, the third distance to the outer end face d_{3oef} is larger than the first distance to the outer end face d_{1oef} . The third distance to the outer end face d_{3oef} is larger than two times the first groove length. Thus, the first groove and the third groove may be aligned in the radial direction and may be spaced apart by nearly once the first groove length. The

second distance to the leading edge d_{2le} may be smaller than the first distance to the leading edge d_{1le} and may be designed as being sufficiently high to ensure the stability of the blade body having three grooves within. Accessorily, the distance between the radially outer end of the second groove and the outer end face d_{2oef} may be calculated by the following equation

$$d_{2oef} = (d_{1oef} + d_{3oef}) / 2$$

[0033] According to a further exemplary embodiment, a blade device comprises a further blade body which comprises a further radially inner end face and a further radially outer end face which is formed opposed to the further inner end face with respect to the radial direction of the turbine. The further blade body is arranged space apart from the blade body along the circumferential direction.

[0034] In a further exemplary embodiment, the further blade body comprises a further channel extending between the further inner end face and the further outer end face. Furthermore, the further blade body comprises a further first groove which connects the further channel and the environment of the further blade body such that a further fluid connection between the environment and the further channel is given. The further first groove has a further first groove length and a further first groove width which is smaller than the further first groove length. The further first groove width is smaller than 2 mm.

[0035] The further blade body may also be free of further grooves for draining off condensation water from the environment.

[0036] The further blade body may be a flow profile. The further blade body may be a flow optimized profile like a NACA profile which is optimized for a certain flow velocity. As the further blade body is also usually used in a steam turbine a flow optimized profile may be preferred.

[0037] The further blade body, the further channel and the further first groove(s) may have the same dimensions, shapes and features as described above for the blade body, the channel and the first groove.

[0038] Hence, a plurality of blade bodies is arranged one after another along the circumferential direction.

[0039] In another exemplary embodiment of the present invention, the further blade body is free of any grooves and channels. The further blade body being free of any grooves and channels may be a solid blade body. The solid geometry may be defined by the inner end face, suction side, outer end face and pressure side.

[0040] In another exemplary embodiment of the present invention, the blade device further comprises an inner ring having a first surface and a second surface opposed to the first surface, along the radial direction. The inner ring comprises between the first surface and the second surface a first through hole and a second

through hole. The first surface is connected to the radially inner end face of the blade body such that the channel is connected to the first hole. The second through hole is formed spaced apart from the first through hole such that the second through hole is connected to the environment surrounding the blade body.

[0041] The first surface may be the surface adjoining the inner end face of the blade body and the second surface may form together with the first surface and a lateral area connecting the first surface and the second surface the inner ring. In this case, the first surface may be circular and may have a diameter which is larger than the diameter of the circular second surface.

[0042] The first through hole and the second through hole may be bore holes which can be formed in the inner ring by cutting, chipping or eroding. For example, the through hole may be star-shaped, circular, rectangular, squared, elliptic, oval or squared with rounded corners.

[0043] The first through hole may have an effective diameter which is large enough to drain the condensation water out of the blade body into the inner ring. For example, the first through hole may have the same effective diameter than an outlet section of the channel at the inner end face. The inner ring itself may be connected to an external drainage system.

[0044] The second through hole may be formed a certain distance away from the first through hole. The certain distance may be the distance which is long enough to ensure that the second through hole is connected to the environment of the blade body. The second through hole may ensure the pressure equalization such that the pressure inside the inner ring and the pressure in the environment of the blade body may be in a ratio which may ensure a proper functionality of the drainage system.

[0045] According to a further exemplary embodiment, the blade device further comprises an outer ring which is connected to the radially outer end face. The outer ring has a further first surface and a further second surface opposed to the further first surface along the radial direction. Furthermore, the outer ring comprises between the further first surface and the further second surface a further first through hole and a further second through hole. The further first surface is connected to the outer end face of the blade body such that the channel is connected to the further first through hole. The further second through hole is formed spaced apart from the further first through hole such that the further second through hole is connected to the environment surrounding the blade body.

[0046] The further first surface may be adjoining the outer end face of the blade body.

[0047] The further first through hole and the further second through hole may be formed in the outer ring by cutting, chipping, eroding, or any other suitable metal processing method. For example, the further first through hole and/or the further second through hole may be star-shaped, circular, rectangular, squared, elliptic, oval or squared with rounded corners. The further first through

hole may have an effective diameter which is large enough to drain the condensation water out of the blade body through the outer ring and outside the turbine. For example, the further first through hole may have the same effective diameter than an outlet section of the channel at the outer end face. The outer ring itself may be connected to an external drainage system.

[0048] The further second through hole may be formed at a certain distance away from the further first through hole. This certain distance may be the distance which is long enough to ensure that the further second through hole is connected to the environment of the blade body. The further second through hole may ensure the pressure equalization such that the pressure outside the outer ring and the pressure in the environment of the blade body may be in a ratio which may ensure a proper functionality of the drainage system.

[0049] The outer ring and the inner ring may be made of any material usable under high temperature conditions in turbines, like, for example, super alloys. The outer end face may be connected with the outer ring and/or the inner end face may be connected with the inner ring by screws, by welding, a dovetail connection or a fir tree connection or may be formed in one piece.

[0050] In another exemplary embodiment of the present invention, the blade device further comprises a blade carrier which is connected to the outer ring. The outer ring is coupleable by the blade carrier to a housing of the turbine.

[0051] According to a further exemplary embodiment, the blade carrier is divided in two halves. The two halves are connected together, in particular by a screw connection.

[0052] The blade carrier may be the connection part between the outer ring and the housing of the turbine. The housing of a steam turbine may be of any size which is suitable for the size of the outer ring. The blade carrier may be provided with bore holes which are adjacent to the further first through hole and the further second through hole in the outer ring as to ensure the existence of a connection from the outer ring to a drainage system outside the blade carrier.

[0053] The two halves of the blade carrier which are connected together by screws may enable an easy replacement of the blade carrier and also may enable an easy access to the outer ring and the blade bodies, respectively.

[0054] According to a further exemplary embodiment of the present invention, a method for manufacturing a blade device for a turbine, in particular a steam turbine is described. The method comprises forming a blade body comprising a radially inner end face and a radially outer end face which is formed opposed to the inner end face with respect to a radial direction of the turbine. Furthermore, the method comprises forming a channel within the blade body. The channel extends between the inner end face and the outer end face. Furthermore, the method comprises forming a first groove within the blade body.

The first groove connects the channel and an environment of the blade body such that a fluid connection between the environment and the channel is given. Further the first groove has a first groove length and a first groove width which is smaller than the first groove length. The first groove is smaller than 2 mm.

[0055] The blade body may be formed by any metal forming process as, for example, casting, forging or cutting. The blade body may also be formed from more than one piece of metal. When the blade body is formed from more than one piece, the different pieces have to be fixed together, for example by means of temporary joining or permanent joining.

[0056] The groove and the channel may be formed within the blade body by means of for example drilling, eroding, cutting or other methods for removing material.

[0057] In another exemplary embodiment of the present invention, the blade body and/or the further blade body with special drainage system are welded to the inner ring and the outer ring of the guide ring (which may also be denoted as blade carrier). This guide ring is divided in two halves (a lower and an upper half). The two halves (the lower and the upper half of the blade carrier and guide ring assembly) are connected together by screws in the horizontal splitting plane. The blade body and/or the further blade body are produced by eroding methods.

[0058] According to a further exemplary embodiment of the present invention, the blade body and/or the further blade body are welded to the inner ring and outer ring of the guide ring by fillet welds. The blade body and/or the further blade body contain three grooves with a length about 52 mm. The wetness may enter into the blade body and/or the further blade body, so that the blade body and/or the further blade body have some channels having a diameter of about 6 mm. The condensation water is leaving through the channel out of the blade body and/or the further blade body. Within the blade carrier there are bore holes for the drainage of the condensation water from the blade carrier.

[0059] According to a further exemplary embodiment of the present invention, the advantages of the present invention are for example that the different lifetimes of different components of the turbine are considered by using multiple different parts to form the turbine and the ease of assemblage of the different parts of the turbine.

[0060] It has to be noted that embodiments of the invention have been described with reference to different subject matters. In particular, some embodiments have been described with reference to apparatus type claims whereas other embodiments have been described with reference to method type claims. However, a person skilled in the art will gather from the above and the following description that, unless other notified, in addition to any combination of features belonging to one type of subject matter also any combination between features relating to different subject matters, in particular between features of the apparatus type claims and features of the method type claims is considered as to be disclosed with

this application.

Brief Description of the Drawings

[0061] The aspects defined above and further aspects of the present invention are apparent from the examples of embodiment to be described hereinafter and are explained with reference to the examples of embodiment. The invention will be described in more detail hereinafter with reference to examples of embodiment but to which the invention is not limited.

Fig.1 shows a perspective front view of a blade body according to an exemplary embodiment of the present invention;

Fig.2 shows a partially sectional view of the blade body according to an exemplary embodiment of the present invention;

Fig.3 shows a front view of the blade carrier assembled with a plurality of blade bodies according to an exemplary embodiment of the present invention;

Fig.4A shows a perspective cutout of the outer ring according to an exemplary embodiment of the present invention;

Fig.4B shows a plan view cutout of the outer ring according to an exemplary embodiment of the present invention;

Fig.5 shows a sectional view of the blade device according to an exemplary embodiment of the present invention;

Fig.6 illustrates a method for manufacturing a blade device for a turbine according to an exemplary embodiment of the present invention.

Detailed Description

[0062] The illustrations in the drawings are schematic. It is noted that in different figures similar or identical elements are provided with the same reference signs.

[0063] Fig.1 shows a blade body 110 of a blade device 300 (shown in Fig. 3), the blade body 110 comprising a radially inner end face 120 and a radially outer end face 130 which is formed opposed to the inner end face 120 with respect to a radial direction 140 of a turbine, in particular a steam turbine. The blade body 110 comprises a channel 150 extending between the inner end face 120 and the outer end face 130. The blade body 110 comprises a first groove 160 which connects the channel 150 and an environment of the blade body 110 such that a fluid connection between the environment and the channel 150 is given. The first groove 160 has a first groove length 170 and a first groove width 180 which is smaller

than the first groove length 170. Furthermore, the first groove width 180 is smaller than 2 mm.

[0064] The blade body 110 has a flow profile which may be optimized for a certain flow velocity of a working fluid passing the blade body 110.

[0065] The radial direction 140 is a radial direction with respect to an axial direction which is defined by a rotary axis of a rotary shaft of the turbine. The blade device 300 may be coupled to the rotary shaft such that the blade device 300 rotates together with the rotary shaft around the rotary axis. The radial direction 140 of the turbine is defined as the direction which is perpendicular to a longitudinal direction (i.e. axial direction) of the rotary axis of the turbine. The radial direction 140 crosses the rotary axis. A circumferential direction is perpendicular to the radial direction and the axial direction and runs along a circumferential direction.

[0066] The radially inner end face 120 is the end face which is closer to the rotary axis than the radially outer end face. The outer end face 130 is formed opposed to the inner end face along the radial direction. Opposed to the inner end face means that the inner end face 120 and the outer end face 130 may be spaced apart by a distance which corresponds to the length of the blade body 110 and is delimited by the diameter of the blade carrier 550 (shown in Fig.5).

[0067] The channel 150 extends from the inner end face 120 to the outer end face 130. In Fig.1 the channel 150 is a straight channel which, at the same time, is the shortest connection between the inner end face 120 and the outer end face 130. In Fig.1, the opening of the channel 150 is oval at the outer end face 130 and circular at the inner end face 120. Furthermore, the channel 150 has different diameters over its length. The channel 150 has a smaller diameter near the inner end face 120 and a larger opening near the outer end face 130 due to more condensation water being pushed to the outer end face 130 by centrifugal force.

[0068] The environment of the blade body 110 may be the space around the blade body 110, which may be filled by a working fluid of the turbine. When the blade body 110 is used in a turbine, the environment is usually the space inside the casing, in particular the space where the fluid flows, further in particular the space between the different blade bodies 110 and the respective inner and outer rings 315, 325 as described further below in Fig. 3.

[0069] The first groove 160 is formed between the environment and the channel 150 in the blade body 110. The size of the groove may be formed large enough to enable a fluid, for example water, to pass through the groove 160 from the environment to the channel 150 and vice versa. Additionally it may be possible for water, steam and/or air to pass simultaneously through the groove 150.

[0070] The first groove 160 is an opening which leads from the environment to the channel 150 and which provides the fluid connection between the environment of

the blade body 110 and the channel 150 inside the blade body 110. In Fig.1 the first groove 160 has a slit-like, rectangular shape. Furthermore, the first groove 160 extends along the radial direction 140. The first groove length 170 is the length of the first groove 160 which defines the longer side of the first groove 160. The first groove width 180 is the width of the first groove 160 which defines the shorter side of the first groove 160. Furthermore, the first groove width 180 may be about 74 times smaller as the first groove length 170. The first groove width 180 being smaller than 2 mm may ensure that water which condensates at a blade body surface passes the first groove 160, wherein the first groove 160 is small enough such that no or only small disturbances and thus small turbulences in the fluid flow of the working fluid flowing through the environment of the blade body 110 are generated.

[0071] The blade body 110 further comprises a second groove 260 which connects the channel 150 and the environment of the blade body 110 such that a second fluid connection between the environment and the channel 150 is given. The second groove 260 has a second groove length 270 and a second groove width 280 which is smaller than the second groove length 270. Furthermore, the second groove width 280 is smaller than 2 mm and the second groove 260 is formed spaced apart from the first groove 160.

[0072] The second groove 260 is of the same shape as the first groove 160. Furthermore, the second groove 260 extends in the radial direction 140 and is in particular parallel to the radial direction 140. Additionally, all the conclusions made above for the first groove 160 may be valid for the second groove 260 as well.

[0073] There is a third groove 260' formed adjacent to the first groove 160. Furthermore, the first groove 160, the second groove 260 and the third groove 260' are formed parallel with respect to each other.

[0074] In Fig.1 three grooves 160, 260, 260' with the identical groove length 170, 270, 270' of 52 mm and the identical groove width 180, 280, 280' of 0.7 mm are present within the blade body 110. The extension direction of each of the three grooves 160, 260, 260' is in the radial direction 140 and the three grooves 160, 260, 260' are parallel to each other.

[0075] The blade body 110 comprises a leading edge 171 and a trailing edge 181. The leading edge 171 may be positioned at the upstream end of the blade body 110. Additionally, the leading edge 171 comprises a stagnation point which is developed when the turbine is in operation. The trailing edge 181 may be positioned at the downstream end of the blade body 110 which is the side where the fluid flow may stop following the blade body contour. Both the leading edge 171 and the trailing edge 181 may connect the inner end face 120 and the outer end face 130 at their particular position.

[0076] A suction side 182 is the surface which is delimited by the leading edge 171, the outer end face 130, the trailing edge 181 and the inner end face 120 (listed

clockwise). When the turbine is in operation, the suction side 182 is exposed to suction forces. A pressure side 172 may be the surface which is delimited by the leading edge 171, the outer end face 130, the trailing edge 181 and the inner end face 120 (listed clockwise) and the pressure side 172 is positioned opposed to the suction side 182. When the turbine is in operation, the pressure side 172 is exposed to pressure forces.

[0077] The first groove 160 has a first distance d_{1le} to the leading edge 171. The first groove 160 is parallel to the leading edge 171. The second groove 260 is of the same shape and has the same groove length 270 and groove width 280 as the first groove 160, but has a second distance d_{2le} to the leading edge 171. The third groove 260' has a third distance d_{3le} to the leading edge 171. Also, a radially outer end of the first groove 160 being nearest to the outer end face 130 has a first distance d_{1oef} to the outer end face 130, a radially outer end of the second groove 260 being nearest to the outer end face 130 has a second distance d_{2oef} to the outer end face 130 and the same is valid for a radially outer end of the third groove 260' which is present within the blade body 110.

[0078] In Fig.1 the second distance d_{2le} to the leading edge 171 is smaller than the first distance d_{1le} to the leading edge 171 and the third distance d_{3le} to the leading edge 171 is the same as the first distance d_{1le} to the leading edge 171. Additionally, the third distance d_{3oef} to the outer end face 130 is larger than the first distance d_{1oef} to the outer end face 130. The third distance of the third groove 260' to the outer end face 130 is larger than two times the first groove length 170, for example. Thus, the first groove 160 and the third groove 260' are aligned in the radial direction 140 and are spaced apart by nearly once the first groove length 170. The second distance d_{2le} to the leading edge 171 is smaller than the first distance d_{1le} to the leading edge 171 and is designed as being sufficiently high to ensure the stability and robustness of the blade body 110 having three grooves 160, 260, 260' within. Additionally, the distance d_{2oef} between the radially outer end of the second groove 260 and the outer end face 130 is calculated for example by the following equation

$$d_{2oef} = (d_{1oef} + d_{3oef}) / 2.$$

[0079] The inner end face 120, the outer end face 130, the suction side 182 and the pressure side 172 together form the outer contour of the blade body 110. Additionally, the trailing edge 181 and the leading edge 171 are extending in the radial direction 140 and having the same length.

[0080] Fig.2 shows the blade body 110 from Fig.1 in a partially sectional view II-II. In particular, in Fig.2 the channel 150 is illustrated in partially sectional view. As may be seen from Fig.2, the channel 150 has two different

sizes along the radial direction 140. The part of the channel 150 adjacent to the inner end face 120 is smaller and circular with a certain diameter and the part of the channel 150 adjacent to the outer end face 130 has a further diameter which is larger than the diameter adjacent to the inner end face 120. Also illustrated in Fig.2, the transition from one diameter to the other may be not continuously but abrupt.

[0081] Fig.3 illustrates the blade device 300 comprising a plurality of blade bodies 110, 110' and also a plurality of blade bodies 310, 310' being free of any grooves and e.g. channels. The blade device 300 further comprises the inner ring 315 with a first surface 316, 316' and a second surface 317, 317', and an outer ring 325, 325' with a further first surface 321, 321' and a further second surface 322, 322'. The first surface 316, 316' has a circular shape along the circumferential direction and is connected to the radially inner end face 120, 120' of the respective blade bodies 110, 110' and of the further inner end face 320, 320' of the respective blade bodies 310, 310'. The further first surface 321, 321' has also a circular shape along the circumferential direction and is connected to the radially outer end face 130, 130' of a respective blade body 110, 110' and the further outer end face 330, 330' of the respective blade bodies 310, 310'.

[0082] Furthermore, an outer ring and an inner ring are shown in two halves 351, 352, 315, 325.

[0083] Fig.4A shows a perspective sectional view of the outer ring 325 according to an exemplary embodiment of the present invention. In Fig.4A the first surface 321, the second surface 322, a further first through hole 423 and a further second through hole 424 are shown.

[0084] The further second through holes 424 are circular bore holes which are formed in the outer ring 325 e.g. by cutting, drilling or eroding. The further first through holes 423 may be oval shaped bore holes which are formed in the outer ring 325 by cutting, drilling, milling or eroding, or any other suitable metal processing method.

[0085] The effective diameter of the further first through hole 423 is designed large enough to enable the drainage of condensation water out of the channel 160 within the blade body 110 through the outer ring 325 and outside the turbine. The outer ring 325 itself may be connected to an external drainage system (not shown) such that the fluid passing the further first through hole 423 may be guided out of the turbine.

[0086] The further second through hole 424 is formed at a certain distance away from the further first through hole 423 to ensure that the further second through hole 424 is connected to the environment of the blade body 110 and not covered by the blade body 110. The further second through holes 424 ensure the pressure equalization such that the pressure outside the outer ring 325 and the pressure in the environment of the blade body 110 may be in a ratio which may ensure a proper functionality of the drainage system.

[0087] Fig.4B shows a plan view cutaway view of the outer ring 325 according to an exemplary embodiment

of the present invention. Fig.4B illustrates the further first through hole 423 and the further second through hole 424. What may be seen in Fig.4B is that the further first through holes 423 and the further second through holes 424 are arranged spaced apart along the circumferential direction.

[0088] Fig.5 illustrates a sectional view of the blade device 300. The blade carrier 550, the outer ring 325, the blade body 110 and the inner ring 315 may be seen in Fig.5.

[0089] The first surface 316 of the inner ring 315 is connected to the radially inner end face 120 and comprises the first through hole 518 and the second through hole 519. The first through hole 518 and the second through hole 519 are bore holes which are formed in the inner ring 315 by cutting, chipping or eroding. Additionally, the first through hole 518 and the second through hole 519 are circular.

[0090] The first through hole 518 has a diameter which is large enough to drain the condensation water out of the blade body 110 into the inner ring 315. The diameter of the first through hole 518 is the same as the diameter of the second through hole 519. The inner ring 315 itself may be connected to an external drainage system.

[0091] The second through hole 519 is formed spaced apart to the first through hole 518, such that the second through hole 519 is connected to the environment of the blade body 110 and not covered by the blade body 110. The second through hole 519 ensures the pressure equalization such that the pressure inside the inner ring 315 and the pressure in the environment around the blade body 110 may be in a ratio which may ensure a proper functionality of the drainage system.

[0092] Fig.5 shows the further first through hole 423 in the upper half of the blade device 300. As may be seen from Fig.5 condensation water which have entered the blade body 110 is drained through the channel (not shown in Fig.5) and through the further first through hole 423 into a cavity which is formed between the further second surface 322 and the blade carrier 550. The condensation water can leave the turbine by drainage holes 551, 551' being provided in the blade carrier 550.

[0093] Fig.6 illustrates a method for manufacturing a blade device 300 for a turbine, in particular a steam turbine. First, the method comprises forming 601 a blade body 110. The blade body 110 comprises a radially inner end face 120 and a radially outer end face 130 which is formed opposed to the inner end face 120 with respect to a radial direction 140 of the turbine. The second step of the method comprises forming 602 a channel 150 within the blade body 110. The channel 150 extends between the inner end face 120 and the outer end face 130. The last step of the method comprises forming 603 a first groove 160 within the blade body 110. The first groove 160 connects the channel 150 and an environment of the blade body 110 such that a fluid connection between the environment and the channel 150 is given. The first groove 160 has a first groove length 170 and a first groove

width 180 which is smaller than the first groove length 170. Furthermore, the first groove width 180 is smaller than 2 mm.

[0094] 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.

Claims

1. Blade device (300) for a turbine, in particular a steam turbine, the blade device (300) comprising

a blade body (110) comprising a radially inner end face (120) and a radially outer end face (130) which is formed opposed to the inner end face (120) with respect to a radial direction (140) of the turbine,

wherein the blade body (110) comprises a channel (150) extending between the inner end face (120) and the outer end face (130),

wherein the blade body (110) comprises a first groove (160) which connects the channel (150) and an environment of the blade body (110) such that a fluid connection between the environment and the channel (150) is given,

wherein the groove has a first groove length (170) and a first groove width (180) which is smaller than the first groove length (170), and
wherein the first groove width (180) is smaller than 2 mm.

2. Blade device (300) according to claim 1, wherein the first groove (160) has an extension direction extending along the first groove length (170), wherein at least one component of the extension direction is parallel to the radial direction (140).

3. Blade device (300) according to claim 1 or 2, wherein the first groove length (170) is longer than 15 mm.

4. Blade device (300) according to one of the claims 1 to 3, wherein the first groove width (180) is smaller than 1 mm and the first groove length (170) is longer than 50 mm.

5. Blade device (300) according to one of the claims 1 to 4, wherein the blade body (110) further comprises a leading edge (171) connecting the inner end face (120) and the outer end face (130) and a trailing edge

(181) connecting the inner end face (120) and the outer end face (130),

wherein the blade body (110) further comprises

a suction side (182) connecting the inner end face (120), the outer end face (130), the leading edge (171) and the trailing edge (181), and
a pressure side (172) connecting the inner end face (120), the outer end face (130), the leading edge (171) and the trailing edge (181),

wherein the pressure side (172) is formed opposed to the suction side (182).

6. Blade device (300) according to claim 5, wherein the first groove (160) is formed within the suction side (182).

7. Blade device (300) according to claim 5 or 6, wherein the first groove (160) is formed within the pressure side (172).

8. Blade device (300) according to one of the claims 1 to 7, wherein the blade body (110) further comprises a second groove (260) which connects the channel (150) and the environment of the blade body (110) such that a second fluid connection between the environment and the channel (150) is given, wherein the second groove (260) has a second groove length (270) and a second groove width (280) which is smaller than the second groove length (270), wherein the second groove width (280) is smaller than 2 mm, and
wherein the second groove (260) is formed spaced apart from the first groove (160).

9. Blade device (300) according to claim 8, wherein the first groove (160) and the second groove (260) are formed parallel with respect to each other.

10. Blade device (300) according to one of the claims 1 to 9, further comprising

a further blade body (310) comprising a further radially inner end face (320) and a further radially outer end face (330) which is formed opposed to the further inner end face (320) with respect to the radial direction (140) of the turbine,

wherein the further blade body (310) is arranged spaced apart from the blade body (110) along a circumferential direction.

11. Blade device (300) according to claim 10, wherein the further blade body (310) comprises a further channel extending between the further inner

end face (320) and the further outer end face (330), wherein the further blade body (310) comprises a further first groove which connects the further channel and the environment of the further blade body (310) such that a further fluid connection between the environment and the further channel is given, wherein the further groove has a further first groove length and a further first groove width which is smaller than the further first groove length, and wherein the further first groove width is smaller than 2 mm, and wherein the further blade body (310) is arranged spaced apart from the blade body (110).

12. Blade device (300) according to one of the claims 1 to 11, further comprising

an inner ring (515) having a first surface (516) and a second surface (517) opposed to the first surface (516), along the radial direction (140),

wherein the inner ring (515) comprises between the first surface (516) and the second surface (517) a first through hole (518) and a second through hole (519),

wherein the first surface (516) is connected to the radially inner end face (120) of the blade body (110) such that the channel (150) is connected to the first through hole (518), wherein the second through hole (519) is formed spaced apart from the first through hole (518) such that the second through hole (519) is connected to the environment surrounding the blade body (110).

13. Blade device (300) according to claim 1 or 12, further comprising

an outer ring (325) which is connected to the radially outer end face (130),

wherein the outer ring (325) has a further first surface (321) and a further second surface (322) opposed to the further first surface (321), along the radial direction (140), wherein the outer ring (325) comprises between the further first surface (321) and the further second surface (322) a further first through hole (323) and a further second through hole (324), wherein the further first surface (321) is connected to the outer end face (130) of the blade body (110) such that the channel (150) is connected to the further first through hole (323), wherein the further second through hole (324) is formed spaced apart from the further first through hole (323) such that the further second through hole (324) is connected to the environment surrounding the blade body (110).

14. Blade device (300) according to claim 13, further

comprising

a blade carrier (550) which is connected to the outer ring (325),

wherein the outer ring (325) is coupleable by the blade carrier (550) to a housing of the turbine.

15. Blade device (300) according to claim 14, wherein the blade carrier (550) is divided in two halves (351, 352), wherein the two halves (351, 352) are connected together in particular by a screw connection.

16. Method for manufacturing a blade device (300) for a turbine, in particular a steam turbine, the method comprising

forming a blade body (110) comprising a radially inner end face (120) and a radially outer end face (130) which is formed opposed to the inner end face (120) with respect to a radial direction (140) of the turbine, forming a channel (150) within the blade body (110),

wherein the channel (150) extends between the inner end face (120) and the outer end face (130),

forming a first groove (160) within the blade body (110),

wherein the first groove (160) connects the channel (150) and an environment of the blade body (110) such that a fluid connection between the environment and the channel (150) is given, wherein the first groove (160) has a first groove length (170) and a first groove width (180) which is smaller than the first groove length (170), and wherein the first groove width (180) is smaller than 2 mm.

Amended claims in accordance with Rule 137(2) EPC.

1. Blade device (300) for a turbine, in particular a steam turbine, the blade device (300) comprising

a blade body (110) comprising a radially inner end face (120) and a radially outer end face (130) which is formed opposed to the inner end face (120) with respect to a radial direction (140) of the turbine, and

an inner ring (315) having a first surface (316) and a second surface (317) opposed to the first surface (316) along the radial direction (140),

- wherein the blade body (110) comprises a channel (150) extending between the inner end face (120) and the outer end face (130),
 wherein the blade body (110) comprises a first groove (160) which connects the channel (150) and an environment of the blade body (110) such that a fluid connection between the environment and the channel (150) is given,
 wherein the first groove (160) has a first groove length (170) and a first groove width (180) which is smaller than the first groove length (170), and
 wherein the first groove width (180) is smaller than 2 mm, wherein the inner ring (315) comprises between the first surface (316) and the second surface (317) a first through hole (518) and a second through hole (519),
 wherein the first surface (316) is connected to the radially inner end face (120) of the blade body (110) such that the channel (150) is connected to the first through hole (518), wherein the second through hole (519) is formed spaced apart from the first through hole (518) such that the second through hole (519) is connected to the environment surrounding the blade body (110).
2. Blade device (300) according to claim 1,
 wherein the first groove (160) has an extension direction extending along the first groove length (170),
 wherein at least one component of the extension direction is parallel to the radial direction (140).
 3. Blade device (300) according to claim 1 or 2,
 wherein the first groove length (170) is longer than 15 mm.
 4. Blade device (300) according to one of the claims 1 to 3,
 wherein the first groove width (180) is smaller than 1 mm and the first groove length (170) is longer than 50 mm.
 5. Blade device (300) according to one of the claims 1 to 4,
 wherein the blade body (110) further comprises a leading edge (171) connecting the inner end face (120) and the outer end face (130) and a trailing edge (181) connecting the inner end face (120) and the outer end face (130),
 wherein the blade body (110) further comprises a suction side (182) connecting the inner end face (120), the outer end face (130), the leading edge (171) and the trailing edge (181), and
 a pressure side (172) connecting the inner end face (120), the outer end face (130), the leading edge (171) and the trailing edge (181),
 wherein the pressure side (172) is formed opposed to the suction side (182).
 6. Blade device (300) according to claim 5,
 wherein the first groove (160) is formed within the suction side (182).
 7. Blade device (300) according to claim 5 or 6,
 wherein the first groove (160) is formed within the pressure side (172).
 8. Blade device (300) according to one of the claims 1 to 7, wherein the blade body (110) further comprises a second groove (260) which connects the channel (150) and the environment of the blade body (110) such that a second fluid connection between the environment and the channel (150) is given,
 wherein the second groove (260) has a second groove length (270) and a second groove width (280) which is smaller than the second groove length (270),
 wherein the second groove width (280) is smaller than 2 mm, and
 wherein the second groove (260) is formed spaced apart from the first groove (160).
 9. Blade device (300) according to claim 8,
 wherein the first groove (160) and the second groove (260) are formed parallel with respect to each other.
 10. Blade device (300) according to one of the claims 1 to 9, further comprising
 a further blade body (310) comprising a further radially inner end face (320) and a further radially outer end face (330) which is formed opposed to the further inner end face (320) with respect to the radial direction (140) of the turbine,
 wherein the further blade body (310) is arranged spaced apart from the blade body (110) along a circumferential direction.
 11. Blade device (300) according to claim 10,
 wherein the further blade body (310) comprises a further channel extending between the further inner end face (320) and the further outer end face (330),
 wherein the further blade body (310) comprises a further first groove which connects the further channel and the environment of the further blade body (310) such that a further fluid connection between the environment and the further channel is given,
 wherein the further first groove has a further first groove length and a further first groove width which is smaller than the further first groove length, and
 wherein the further first groove width is smaller than 2 mm, and
 wherein the further blade body (310) is arranged spaced apart from the blade body (110).
 12. Blade device (300) according to claim 1 or 11, further comprising
 an outer ring (325) which is connected to the radially

outer end face (130),
 wherein the outer ring (325) has a further first surface (321) and a further second surface (322) opposed to the further first surface (321), along the radial direction (140),
 wherein the outer ring (325) comprises between the further first surface (321) and the further second surface (322) a further first through hole (323) and a further second through hole (324),
 wherein the further first surface (321) is connected to the outer end face (130) of the blade body (110) such that the channel (150) is connected to the further first through hole (323),
 wherein the further second through hole (324) is formed spaced apart from the further first through hole (323) such that the further second through hole (324) is connected to the environment surrounding the blade body (110).

13. Blade device (300) according to claim 12, further comprising
 a blade carrier (550) which is connected to the outer ring (325),
 wherein the outer ring (325) is coupleable by the blade carrier (550) to a housing of the turbine.

14. Blade device (300) according to claim 13,
 wherein the blade carrier (550) is divided in two halves (351, 352),
 wherein the two halves (351, 352) are connected together in particular by a screw connection.

15. Method for manufacturing a blade device (300) for a turbine, in particular a steam turbine, the method comprising
 forming a blade body (110) comprising a radially inner end face (120) and a radially outer end face (130) which is formed opposed to the inner end face (120) with respect to a radial direction (140) of the turbine, forming a channel (150) within the blade body (110),
 wherein the channel (150) extends between the inner end face (120) and the outer end face (130), forming a first groove (160) within the blade body (110),
 wherein the first groove (160) connects the channel (150) and an environment of the blade body (110) such that a fluid connection between the environment and the channel (150) is given,
 wherein the first groove (160) has a first groove length (170) and a first groove width (180) which is smaller than the first groove length (170), and wherein the first groove width (180) is smaller than 2 mm
 forming an inner ring (315) having a first surface (316) and a second surface (317) opposed to the first surface (316), along the radial direction (140), forming a first through hole (518) between the first surface (316) and the second surface (317),

forming a second through hole (519) between the first surface (316) and the second surface (317), wherein the first surface (316) is connected to the radially inner end face (120) of the blade body (110) such that the channel (150) is connected to the first through hole (518), and wherein the second through hole (519) is formed spaced apart from the first through hole (518) such that the second through hole (519) is connected to the environment surrounding the blade body (110).

FIG 1

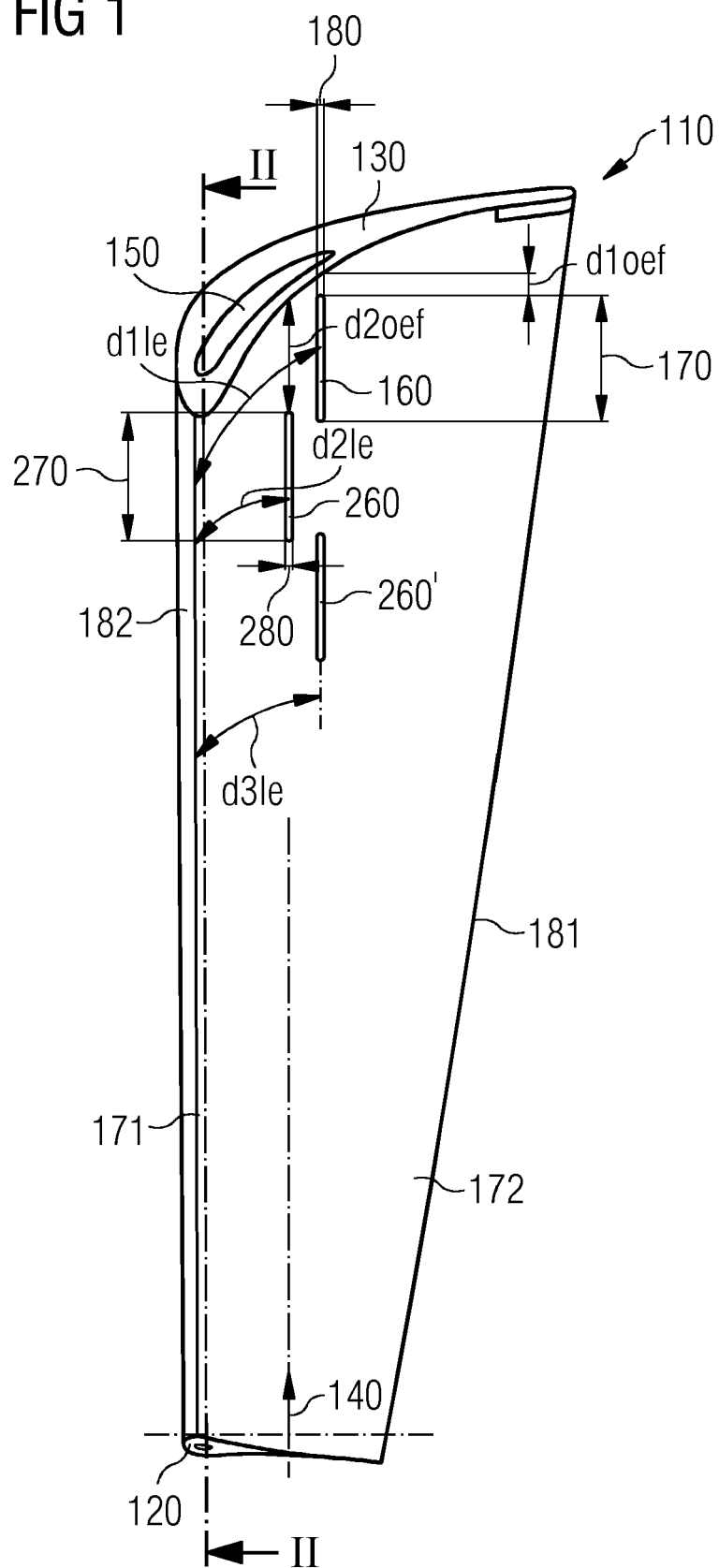


FIG 2 II-II

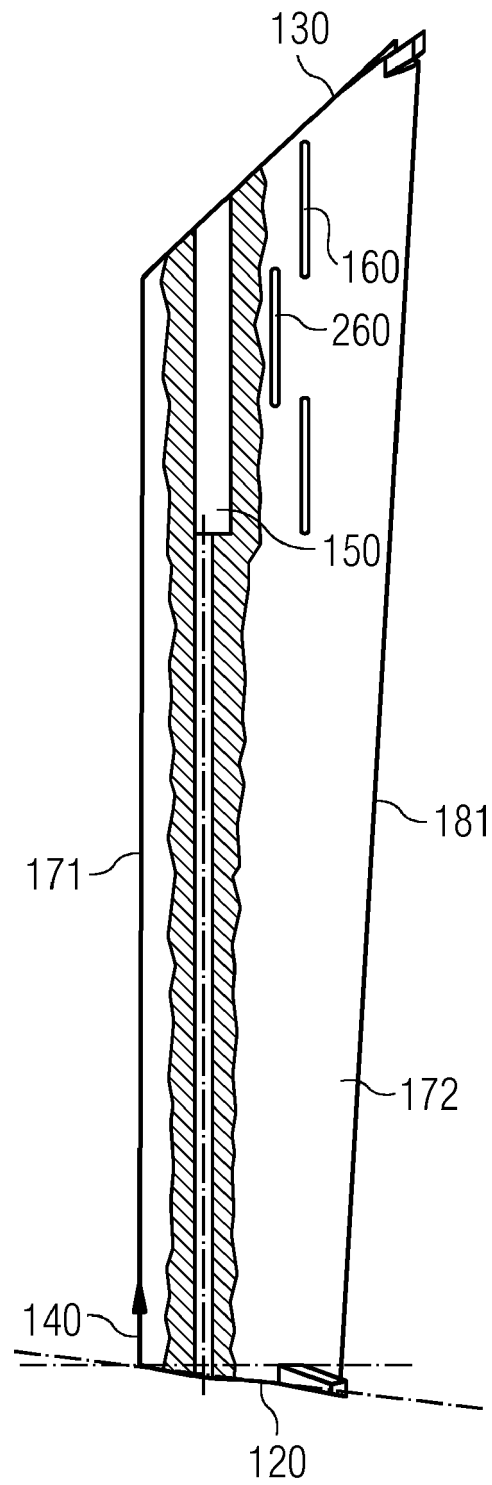


FIG 3

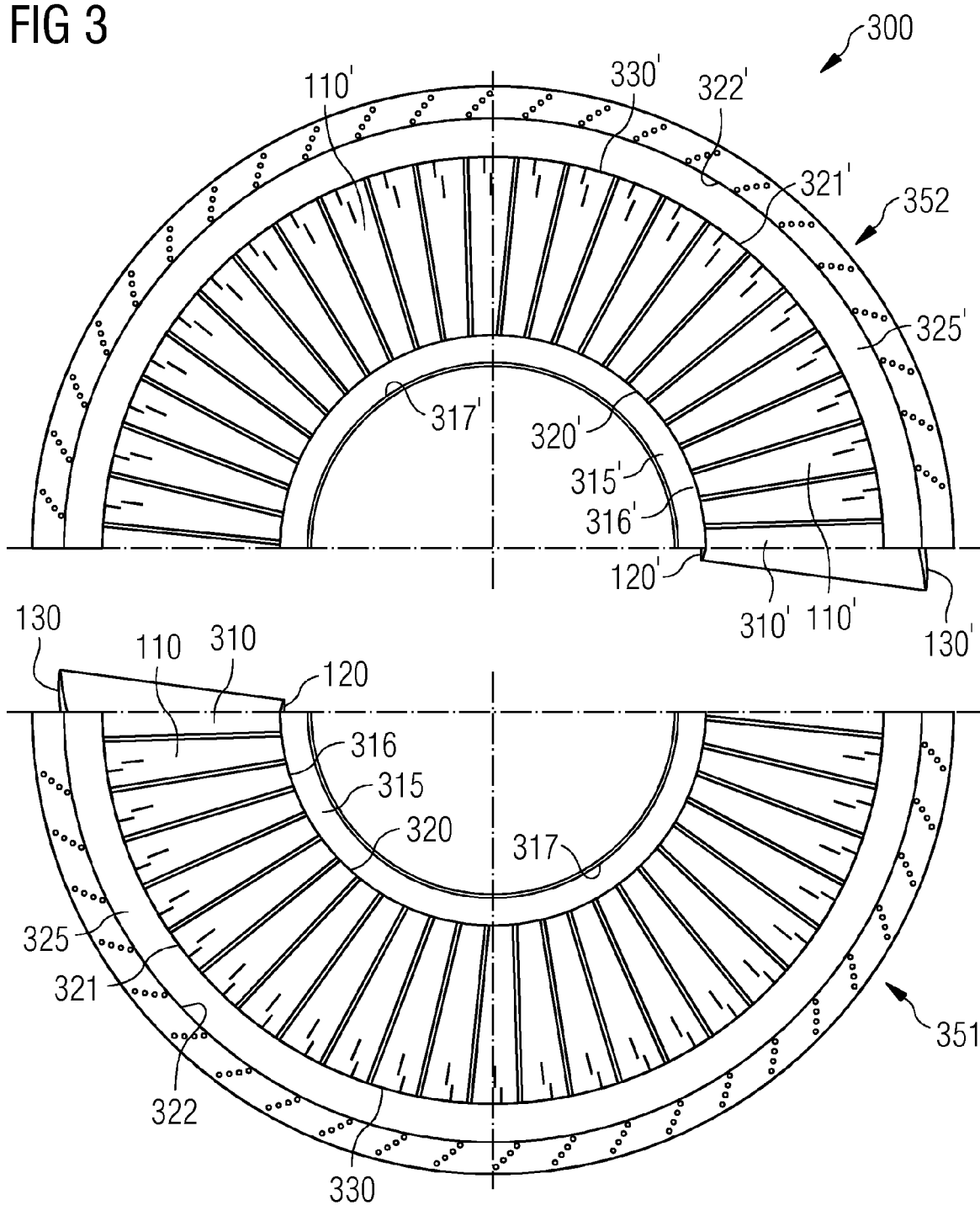


FIG 4A

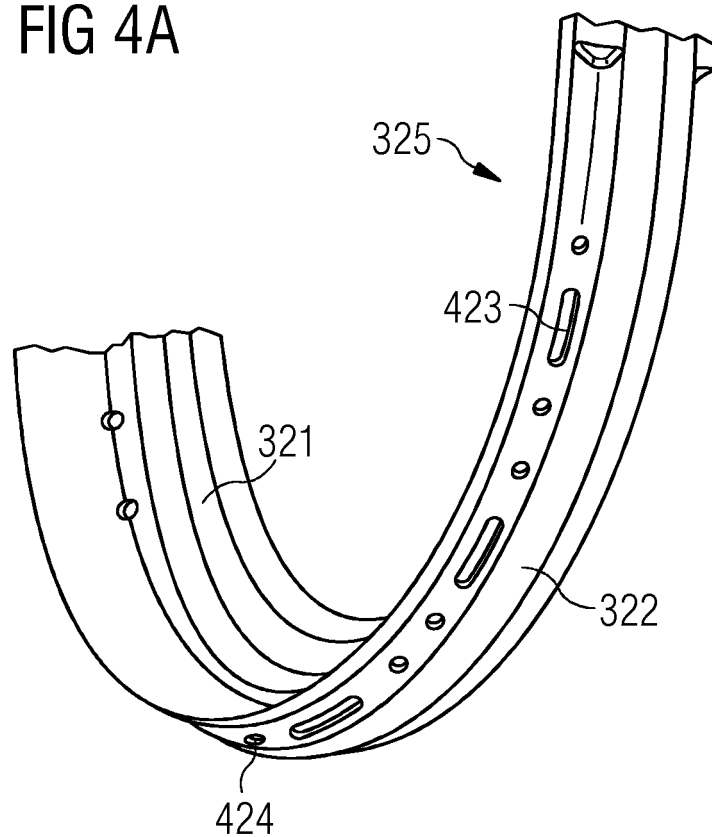


FIG 4B

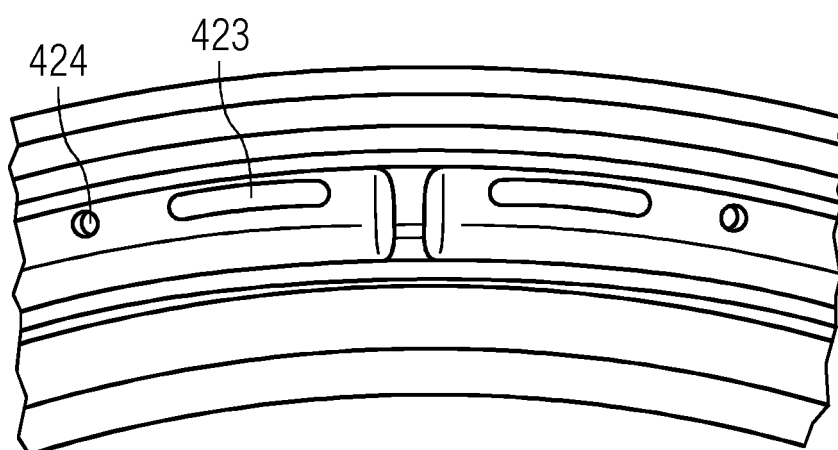


FIG 5

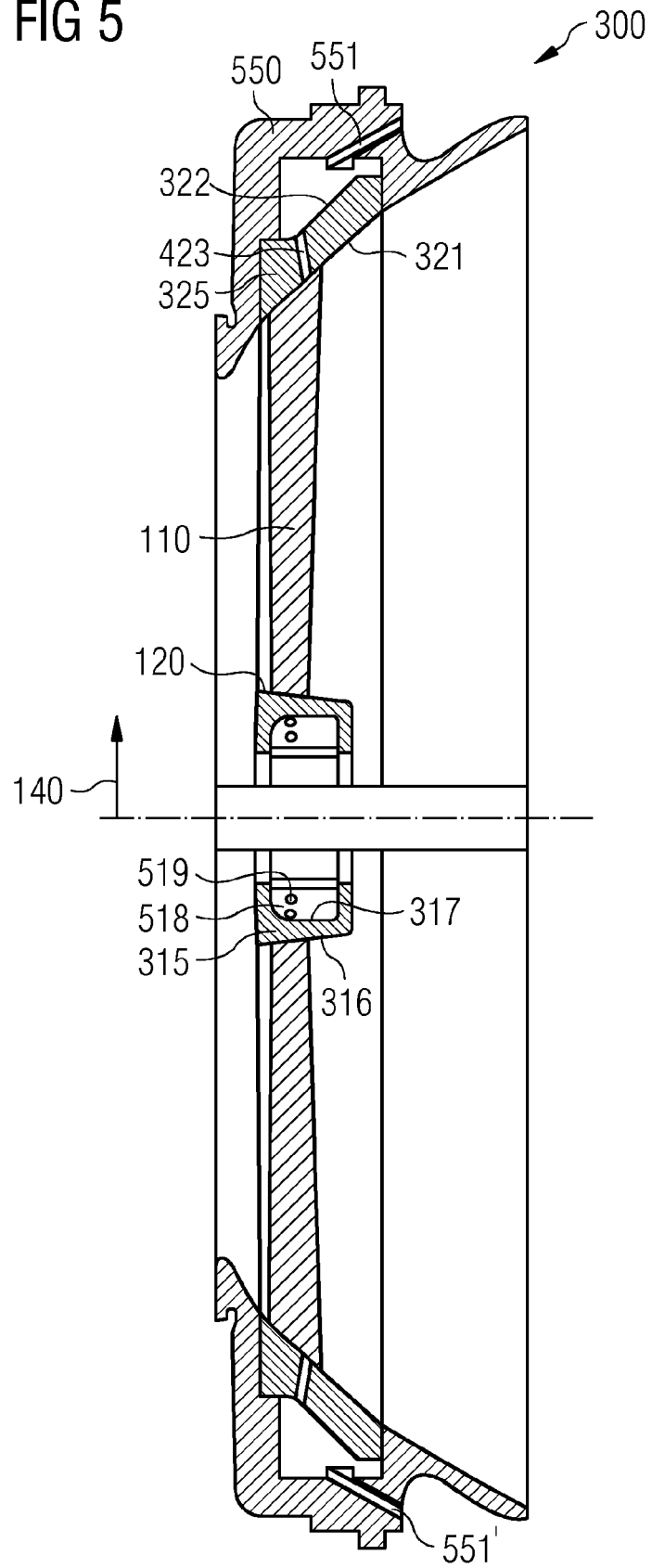
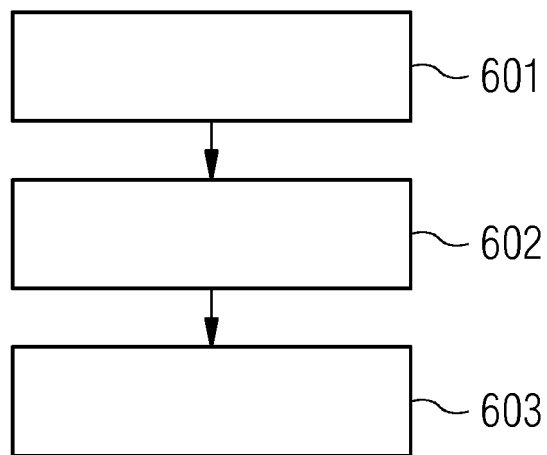


FIG 6



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			TECHNICAL FIELDS SEARCHED (IPC)
			F01D
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
Munich	12 January 2015	Raspo, Fabrice	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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

EP 14 18 0680

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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			KR 20140035811 A 24-03-2014
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JP 2012241607	A	10-12-2012	NONE

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