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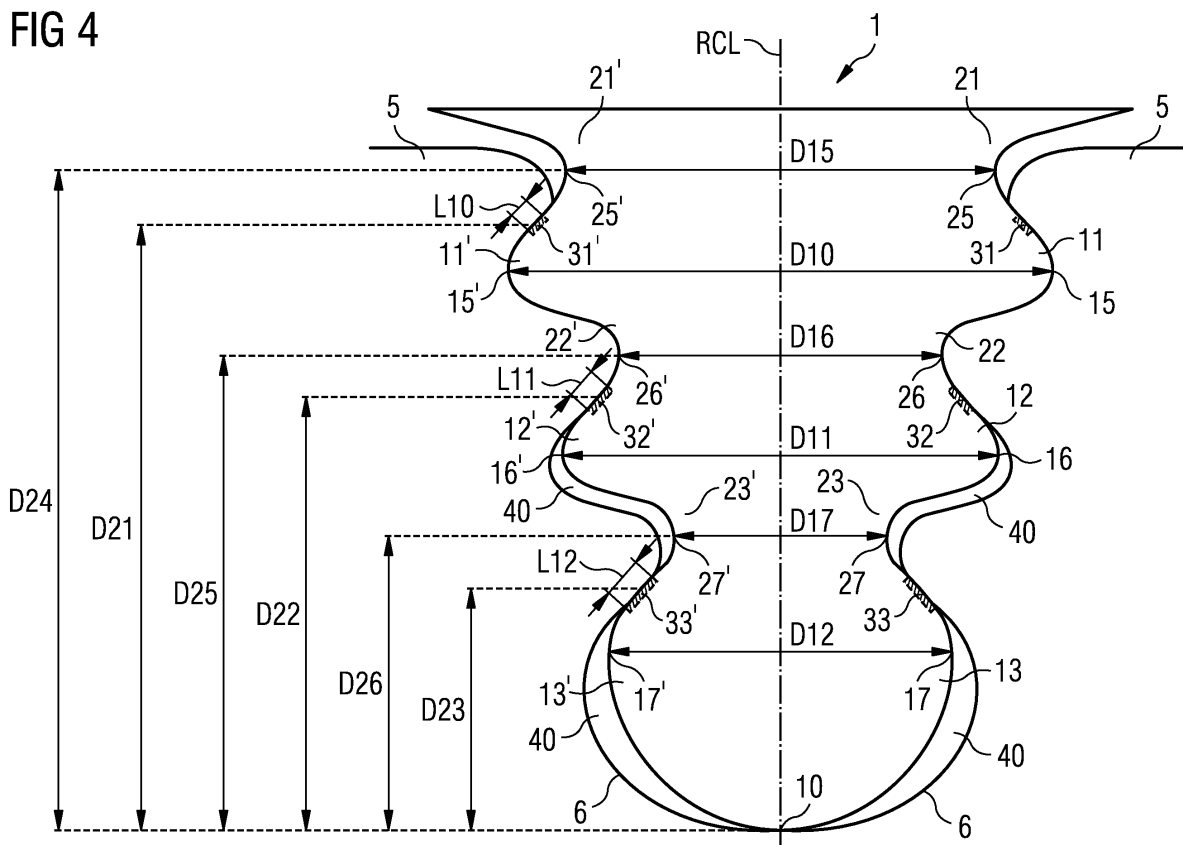
(54) **Blade root, particularly of a turbine blade, a blade, and a turbomachine assembly**

(57) A blade root (1) comprises a bottom (10) of the blade root (1), a plurality of opposite pairs of lobes (11,11', 12,12',13,13'), and a plurality of opposite pairs of fillets (21,21',22,22',23,23').

The root comprises a plurality of substantially planar flanks (31,31',32,32',33,33'), the lobes and fillets arranged in an alternating order and each of the flanks arranged between one of the lobes and one of the fillets,

wherein a first flank (31) of the plurality of flanks is arranged at a distant first position in regards to the bottom (10) of the blade root and having a first planar expansion (A10), and a second flank (32) of the plurality of flanks is arranged at a closer second position in regards to the bottom (10) of the blade root compared to the first position of the first flank (31) and having a second planar expansion (A11), the second planar expansion (A11) being greater than the first planar expansion (A10).

FIG 4



Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to a turbomachinery blade design and, more specifically, to an optimized blade root attachment profile.

BACKGROUND OF THE INVENTION

[0002] A turbine section of a gas turbine typically has a plurality of rows of stationary vanes and rotary blades. The blades of one row are usually identical to each other and include an aerofoil portion, a platform portion, and a root portion. Some blade rows may additionally include a shroud portion preventing the hot gases escaping over the blade tip. The root portion is the most radial inward section of the blade and is used to mount the blade in a mounting groove provided in a rotor disc. Typically for each rotor blade a corresponding mounting groove is provided. The blades are particularly assembled by axially sliding each root portion into the corresponding groove.

[0003] It is known for turbine blades to be fitted to turbine discs by means of cooperating firtree profiles. Such fixing methods provide accurate location of the blade with respect to the disc. Firtree profiles are sufficiently strong to withstand the radially outward forces imposed on the blade during rotation of the disc and its attached blades in operation of the turbine engine in which it is installed. In operation, flanks of the firtree profiles of the blades which face away - in a slanted manner - from an engine axis and which are in contact with opposite firtree profiles of the grooves, support the blades against radially outward movement, and can be regarded as loaded flanks. The oppositely facing flanks of the profiles can be regarded as unloaded flanks, since they do not support any significant radial forces in operation.

[0004] Conventional shape of a turbine blade firtree root is defined using straight lines and circular arcs only, when looked a sectional view of the blade root, the sectional view defined by a plane perpendicular to the rotor axis of the turbine. Such a shape is optimized against a number of geometric and mechanical constraints.

[0005] The flanks of the profiles are interconnected by transition regions which are alternately convex surfaces, which are usually but not always arcuate and are referred to as fillets or necks, and concave surfaces, which are usually but not always arcuate and are known as corners or lobes or teeth or lugs. The fillets are regions of high stress concentration.

[0006] Conventionally, firtree profiles on turbine blade roots may be formed in a grinding process.

[0007] The basic firtree root configuration contains multiple potential load paths, with the magnitude of the resulting stresses therein dependent upon the precision of the initial fit between the blade root and the corresponding groove in the disc. These stresses occur during operation caused by centrifugal forces affecting the blades

- the centrifugal load being dependent on the mass of the whole blade - and are of particular concern for such potential failure as fatigue or stress corrosion cracking. The life or the number of operation cycles of the blade may be limited.

[0008] A root may be substantially mirror-symmetrical. The root comprise a pair of symmetrical uppermost necks or fillets which extends downwardly from a lower surface of a platform, a pair of uppermost lugs or lobes which extend downwardly from the uppermost necks. A plurality of symmetrical pairs of necks and lobes may follow downwardly in alternating order. The root portion will end via a pair of symmetrical lowermost necks followed by a pair of symmetrical lowermost lobes. Surfaces of the pair of lowermost lobes will converge and will be joined at a most downward location via an arcuate or flat surface, the root bottom.

[0009] Patent publications US 3,079,681, US 5,147,180 A, US 5,176,500 A, EP 0 291 725 B1, DE 3236021 A1, among others, show different kinds of blade root profiles, substantially all focusing on stresses in different areas of the blade root, all directed to optimise the blade root for different types machines, for different sizes of blades, and/or for different operating speeds. Still, it is a goal to reduce high level of stresses in contact points between the blade and a corresponding disc at which the blade is mounted.

SUMMARY OF THE INVENTION

[0010] This objective is achieved by the independent claims. The dependent claims describe advantageous developments and modifications of the invention.

[0011] In accordance with the invention there is provided a blade root, particularly of a turbine blade and particularly provided for attaching the blade to a rotor in a slot of the rotor, comprising a bottom of the blade root, a plurality of opposite pairs of lobes, a plurality of opposite pairs of fillets, and a plurality of substantially planar flanks, the lobes and fillets arranged in an alternating order and each of the flanks arranged between one of the lobes and one of the fillets. Each of the pair of lobes are arranged substantially mirror-symmetrical and comprising most distal surface sections defining a widest distance between opposite surfaces of the pair of lobes, the most distal surface sections being arranged such that a first width between a first pair of most distal surface sections of a first opposite pair of lobes is higher than a second width between a second pair of most distal surface sections of a second opposite pair of lobes, the second pair of lobes being closer to a bottom of the blade root than the first pair of lobes. The lobes may be mirror-symmetrical to a central plane through the blade root, and the most distal surface section may be particularly the most distant line on a surface of the lobe to this central plane. The width is particularly the distance between two opposite most distal surface sections. Each of the pair of fillets are arranged substantially mirror-symmetri-

land comprising minimum distant surface sections defining a narrowest distance between opposite surfaces of the pair of fillets. A minimum distant surface section may be a base line on a surface of the fillet which defines the shortest distance of the base line to the central plane. The lobes and fillets arranged in an alternating order. The blade root further comprises a plurality of substantially planar flanks and each of the flanks arranged between one of the lobes and one of the fillets. The flank may be an angled surface, the surface facing substantially away from the bottom of the blade root and may define a bearing or contact surface area at which an opposite surface of a turbine disc is in close contact during operation of rotating machine in which the blade is equipped. A first flank of the plurality of flanks is arranged at a distant first position in regards to the bottom of the blade root and has a first planar expansion, and a second flank of the plurality of flanks is arranged at a closer second position in regards to the bottom of the blade root compared to the first position of the first flank and has a second planar expansion. According to the invention the second planar expansion is greater than the first planar expansion.

[0012] Therefore, the bearing surfaces increase for flanks that are closer to the bottom of the root. This is beneficial as load is distributed which may reduce the level of stress during operation in the area of contact between the blade root and the disc in which the blade is equipped. The lifetime of the blade root will increase, particularly the low cycle fatigue life.

[0013] With "opposite" pair of lobes two lobes are meant that are mirror symmetrical to each other and define surfaces which face in diametric directions. The same applies to opposite pair of fillets, flanks, ... accordingly.

[0014] In a preferred embodiment, the minimum distant surface sections may be arranged such that a third width between a first pair of minimum distant surface sections of a first opposite pair of fillets is higher than a fourth width between a second pair of minimum distant surface sections of a second opposite pair of fillets, the second pair of fillets being closer to a bottom of the blade root than the first pair of fillets. Thus, the first narrows in width from a platform region to the bottom.

[0015] As previously said, the plurality of planar flanks each may be a surface section substantially facing away from the bottom of the blade root. The flanks may be a radially outer flank of the tooth with respect to an axis of rotation if the blade root is inserted in a rotor disc which is rotatable about the axis.

[0016] The invention may be directed to an arrangement with three pair of lobes, three pairs of fillets and three pairs of flanks in between. If the second flank is considered to the intermediate flank and a third flank to be the closest to the bottom, than the planar expansion of the second flank and the third flank may be identical. Alternatively, a third planar expansion of the third flank may be greater than the second planar expansion of the

second flank.

[0017] Particularly, the second planar expansion may be 25%-50% greater than the first planar expansion. In a very preferred embodiment, the second planar expansion may be substantially 33% greater than the first planar expansion.

[0018] The surfaces of the fillets may be sections of cylinders, possibly even elliptic cylinders. A radius of the cylinder may be called fillet radius. One fillet may be defined by a section of one cylinder. Alternatively more complex surface structures are possible in which several parts of surfaces can be defined, for which each part of the surface is defined by a fillet radius. According to a preferred embodiment of the invention, a first fillet radius of a first fillet of the plurality of fillets may be arranged at a most distant position in regards to the bottom of the blade root, a second fillet radius of a second fillet of the plurality of fillets may be arranged at a closer - e.g. intermediate or bottom - position in regards to the bottom of the blade root, and the first fillet radius may be substantially equal to the second fillet radius. Preferably all fillet radii of the fillets may be identical as this may reduce points of stress.

[0019] Besides, the invention is also directed to a blade which may be provided for a rotating machine, like a turbomachine, e.g. particularly a turbine blade for a gas or a steam turbine. The blade comprises an aerofoil, a platform from which the aerofoil extends upwardly and a blade root extends downwardly, and a blade root for attaching the blade to a rotor in a groove or slot of the rotor, e.g. a rotor disc. The blade root is configured according to any of the embodiments as previously discussed above.

[0020] Furthermore the invention is also directed to a turbomachine assembly, particularly for a turbine, comprising a disk with a plurality of slots and a plurality of blades with a blade root as defined previously, each inserted into the plurality of slots. The slots and the blades are arranged such that during operation areas of contact - bearing surfaces - between a surface of the slots and a surface of the blades is limited to the plurality of substantially planar flanks of the blade roots.

[0021] As previously said, this invention is directed to mount parts intended to be rotated about an axis to a part that carries the mounted part. This applies for examples for rotor blades in steam turbines or gas turbines. The invention may in principle also be used in other rotating machines, like motors or compressors. Besides, the inventive blade root can also be used for mounting non-rotating stator vanes, even though the problem with centrifugal forces does not exist.

[0022] 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 fol-

lowing 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.

[0023] 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.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, of which:

- FIG. 1: shows schematically a part of a turbine section of a gas turbine in a cross sectional view;
- FIG. 2: illustrates rotor discs in a perspective view;
- FIG. 3: shows a firtree shaped root of a prior art blade in a cross-sectional view;
- FIG. 4: shows a firtree shaped root of an inventive blade in a cross-sectional view;
- FIG. 5: shows an inventive blade with a firtree shaped root in a perspective view;
- FIG. 6: illustrates locking plates attached to the rotor disc.

[0025] The illustration in the drawing is schematical. It is noted that for similar or identical elements in different figures, the same reference signs will be used.

[0026] Some of the features and especially the advantages will be explained for an assembled gas turbine, but obviously the features can be applied also to the single components of the gas turbine but may show the advantages only once assembled and during operation. But when explained by means of a gas turbine during operation none of the details should be limited to a gas turbine while in operation. In general the invention may be applied to other types of machines that provide a rotational movement about an axis of rotation and at which rotating parts need to be connected to a carrier element this executing a rotational movement about the axis, so that centrifugal forces effect the rotating parts. Particularly this technology may be applied to gas turbines engines or steam turbines engines. In regards of gas turbine engines, the invention may be applied to rotor blades within a turbine section and/or within a compressor section.

DETAILED DESCRIPTION OF THE INVENTION

[0027] Referring now to FIG. 1, a part of a turbine section of a gas turbine is depicted in a cross sectional view along an axis of rotation. Two stator vanes and two rotor blades are shown alternating. Rotor blade 2 comprises an aerofoil 4, a platform 2 and a blade root 1. The rotor

blade 2 is inserted via its blade root 1 into a slot of a rotor disc 5. The slot and the rotor disc 5 are formed such that the rotor blade 2 is held in position during rotation of the rotor disc 5 including an attached plurality of rotor blades. Particularly it is important that the rotor blade 2 is held in position when affected by centrifugal forces due to high rotational speeds of the rotor disc 5.

[0028] To withhold the rotor blade 2 in its position, the slots will typically be serrated, as it can be seen in FIG. 2.

[0029] Two rotor discs 5 are shown partially from a perspective view without its corresponding blades. A plurality of slots 6 are shown at a radially outer region of the discs 5. Each slot is designed such that they are shaped as a firtree to allow a blade with a firtree shaped root.

[0030] Features and terminology of a firtree shaped root of a prior art blade are explained in reference to FIG. 3, which shows a cross-sectional view of a known blade root. The cross section is given in a radial plane of the rotor disc, showing the firtree design of the blade root and not showing the corresponding rotor disc.

[0031] The two-dimensional shape of a blade root in a cross sectional view - or as seen from an axial direction for an axis of rotation of a rotor disc at which the blade can be attached -, as seen in FIG. 3, can be described using a set of straight lines and circular arcs. The full three-dimensional body may substantially be an axial projection of this two-dimensional shape.

[0032] A root 1 of a blade includes in descending order - as seen from an end of the root that is directed to a platform of the blade - an upper-most root neck or fillet 21, at least one intermediate neck or fillet 22, and a lower-most neck or fillet 23. Each fillet is formed symmetrically about a root centre line RCL by a pair of mirror-image curved surfaces having a unique shape which will be described in more detail below. Each minimal distant points of a pair of mirror symmetrical fillets are indicated as minimum distant surface sections 25, 26, 27 with its symmetrical minimum distant surface sections 25', 26', 27'. The distance between a pair of minimum distant surface sections 25-25', 26-26' and 27-27' has a width indicated by the horizontal lines D15, D16 and D17 for the upper-most fillet 21, intermediate fillet 22, and lower-most fillet 23, respectively.

[0033] The minimum distant surface section may also be called a bottom or trough. The distance will be measured perpendicular to the plane of symmetry.

[0034] An upper-most lug or lobe 11 is formed beneath the uppermost fillet 21 and is also symmetrically disposed about the root centre line RCL. An intermediate lug or lobe 12 is disposed beneath the intermediate fillet 22. A lower-most lug or lobe 13 is disposed beneath the lowermost fillet 23.

[0035] Each maximum distant points of a pair of mirror symmetrical lobes are indicated as most distal surface sections 15, 16, 17 with its symmetrical most distal surface sections 15', 16', 17'. The distance between a pair of most distal surface sections 15-15', 16-16' and 17-17' has a width indicated by the horizontal lines D10, D11

and D12 for the upper-most lobe 11, intermediate lobe 12, and lower-most lobe 13, respectively.

[0036] The most distal surface section may also be called a peak, cusp, or crest. The distance will be measured perpendicular to the plane of symmetry.

[0037] The upper-most fillet 21, on each side of the root centre line RCL, has a compound radius wherein a first radius R1 has a pivot centre R1C so as to define a surface which extends from the platform portion 3 to a point of transition 134. At point 134, a second radius R2 is used to complete the fillet surface by drawing a curve from a pivot centre R1C spaced inwardly of the pivot centre R1C.

[0038] The pivot centre R1C lies on a line TN which is tangent to the outer radial surfaces of the root lobes 11, 12 and 13. The point 134 of transition from the first radius to the second radius is selected by drawing a perpendicular line PL from the tangent TN and passing through a point PI of intersection on the root centre line RCL wherein planes PB which include the bearing surfaces of the uppermost lobe intersect each other and the root centre line RCL.

[0039] Each lobe has a flat, upper bearing surface, such that the lobe 11 has a bearing surface 28a, the lobe 12 has a bearing surface 30a and the lobe 13 has a bearing surface 32a. In the upper-most lobe 11, the bearing surfaces on opposite sides of the root centre line RCL intersect at the RCL and thus provide a reference point for the perpendicular line PL which provides the point of transition 134 between the first and second radii of the upper-most fillet 21.

[0040] According to FIG. 3, the bearing surfaces 28a will have a larger expansion than the bearing surface 30a. Additionally the bearing surfaces 30a will have a larger expansion than the bearing surface 32a.

[0041] For the remaining lobes and fillets, a single radius may be used at staggered pivot centres. For example, the outer radial extension of lobe 11 may be formed by two radius segments of radius R3 and R4. R3 and R4 may be equal to each other, but possibly the pivot centres R3C and R4C are staggered vertically so as to produce a flattened surface portion between the two radius portions formed by the two radii of equal length.

[0042] There may also be a flattened surface 28b that extends from the lobe 11 to the fillet 22. A further flattened surface 30b may be present between the lobe 12 and the fillet 23.

[0043] According to the drawing the lower-most lobe 13 has a flat bottom surface. The bottom is indicated by reference numeral 10.

[0044] Based on these introduced terms, an embodiment of the invention is described in the following in reference to FIG. 4.

[0045] A firtree shaped blade root 1 of an inventive blade is shown in a cross-sectional view including a firtree part section of the rotor disc 5, at which the blade is inserted. The cross section is given in a radial plane of the rotor disc 5 or as it could be seen when facing the rotor

disc 5 from an axial view, considering the rotor disc 5 will be rotating about an axis during operation.

[0046] As FIG. 4 shows a similar design as the blade root 1 shown in FIG. 3, same reference numerals are used. Already introduced elements may not be repeated again, as the previous said may be applied also to FIG. 4.

[0047] Before coming into detail, a main difference between FIG. 4 and FIG. 3 is that flanks representing the bearing surfaces between a part of the root 1 and a part of the surface of the disc 5 will increase from an upper end to a lower end of the root 1. By this, stress may be reduced and lifetime of the blade may be exceeded.

[0048] In this respect, "upper" or "upward" may indicate a position closer to the blade platform 3 or closer to the aerofoil 4.

[0049] "Lower", "downward", or "descending" means the opposite direction, away from the blade platform 3. The lowest part of the root 1 may be called bottom 10. Once assembled to the disc 5 which rotates about a rotational axis, the root centre line RCL of the blade root 1 is directed in radial direction. The bottom 10 is closer to the rotational axis than the other parts of the blade root 1. Thus, "radially outwards" corresponds to the "upward" direction, "radially inwards" defines the opposite direction.

[0050] The depicted blade root 1 is mirror symmetrical to a plane that is indicated by the root centre line RCL. Mirror symmetric elements are mentioned with the same reference numeral followed by an apostrophe (').

[0051] The blade root 1 comprises a bulb-like bottom 10, a plurality of opposite pairs of lobes, and a plurality of opposite pairs of fillets. Starting at an upward end of the root 1 near the platform and then proceeding downwards, the surface on one side of the root is formed by a first fillet 21, followed by a first lobe 11, further a second fillet 22 (intermediate fillet), continuing to a second lobe 12, followed by a third fillet 23 and a third lobe 13 (as part of a bottom bulb-like root end). Finally the surface is meeting the opposite surface at the bottom 10.

[0052] The opposite surface is identically formed, as it is symmetrical to the just defined surface. The same order applies to this opposite surface, i.e. a first fillet 21' near the platform, followed by a first lobe 11', a second fillet 22', a second lobe 12', a third fillet 23' and a third lobe 13'. Both surfaces will be closed at the bottom 10.

[0053] A distance can be taken between mirror symmetrical points on the opposite surfaces. A largest distance between surface areas of the pair of opposite first lobes 11, 11' is indicated as first width D10. The surface areas with the largest distance are indicated as most distal surface sections 15, 15'. Similarly, most distal surface sections 16, 16' define the largest surface distance - second width D11 - between the pair of opposite second lobes 12, 12'. Furthermore, a third width D12 is indicated between most distal surface sections 17, 17', which have the widest distance between the two surfaces in the area of the lobes 13, 13'.

[0054] As it can be seen in the figure regarding the

width between lobes, the first width D10 is wider than the second width D11. The smallest width is the third width D12.

[0055] Similar to the lobes also distances between the fillets can be defined. A shortest distance between surface areas of the pair of opposite first fillets 21, 21' is indicated as first width D15 (which corresponds to the "third width" according to the claims). The surface areas with the shortest distance are indicated as minimum distant surface sections 25, 25'. Similarly, minimum distant surface sections 26, 26' define the shortest surface distance - second width D16 (which corresponds to the "fourth width" according to the claims) - between the pair of opposite second fillets 22, 22'. Furthermore, a third width D17 is indicated between minimum distant surface sections 27, 27', which have the shortest distance between the two surfaces in the area of the minimum distant surface sections 23, 23'.

[0056] As it can be seen in the figure regarding the width between minimum distant surface sections, the first width D15 is wider than the second width D16. The smallest width is the third width D17.

[0057] All minimum distant surface sections 25, 26, 27 of one surface side may lie within a single planar plane. Also, all most distal surface sections 15, 16, 17 of one surface side may lie within a further single planar plane.

[0058] A tangent to one side of the root surfaces may be constructed on which all lobe surfaces of one root side may lie (see tangent TN in FIG. 3). Additionally also a tangent to one side of the root surfaces could be constructed on which all or at least two fillet surfaces of one root side may lie (see tangent TNN in FIG. 3).

[0059] The distances of the minimum distant surface sections to the bottom 10 are also indicated in the figure via reference signs D24, D25, D26. The minimum distant surface sections 25, 25' have a distance D24 to the bottom 10 which is greater than the distance D25 of the minimum distant surface sections 26, 26', which is again greater than the distance D26 of the minimum distant surface sections 27, 27'.

[0060] The distance D24 defines the "fourth position" of the first fillet 21 as defined in the claims. The distance D25 defines the "fifth position" of second fillet 22 as defined in the claims. The distance D26 defines the "sixth position" of third fillet 23 as defined in the claims.

[0061] As it can be seen, lobes and fillets are arranged in an alternating manner. There are transition areas in between. The transition areas of the blade root surface that face tilted in direction of the platform and face away from the bottom 10 of the root 1 and that will be in contact to an opposite surface of the slot 6 of the disc 5 is indicated as flank 31, 31', 32, 32', 33, 33'. The flanks are substantially planar and are bearing surfaces. In downward direction starting from the platform and focusing only on one surface, the first fillet 21 is followed by a first flank 31, which then merges to the first lobe 11. The second fillet 22 merges via a second flank 32 to the second lobe 12. Finally, the third flank 33 defines a transition area between the

third fillet 23 and the third lobe 13. The same applies to the symmetrical surface showing the flanks 31', 32', 33' opposite the flanks 31, 32, 33.

[0062] The first fillet 21 has a first planar expansion, which is indicated in FIG. 4 by a first surface length L10. The first planar expansion is substantially in form of a rectangular, with one side highlighted as the first surface length L10 and the other side being the axial length of the blade root.

[0063] The second fillet 22 has a second planar expansion, which is indicated in FIG. 4 by a second surface length L11. The third fillet 23 has a third planar expansion, which is indicated in FIG. 4 by a third surface length L12.

[0064] As can be seen, the first length L10 is less than the second length L11. Thus the first planar expansion is greater than the second planar expansion.

[0065] The second planar expansion may be equal to the second planar expansion. In another embodiment it may also be greater than the second planar expansion.

[0066] As the planar expansions indicate the bearing surfaces, it is understood that via the second flank 32 having a larger expansion than the first flank 31, less stress may occur in the root.

[0067] To properly define the positions of the flanks, the distances of the flanks to the bottom 10 are also indicated in the figure via reference signs D21, D22, D23. The flanks 31, 31' have a distance D21 to the bottom 10 which is greater than the distance D22 of the flanks 32, 32' to the bottom 10, which is again greater than the distance D23 of the flanks 33, 33' to the bottom 10.

[0068] The distance D21 defines the "first position" of first flank 31 as defined in the claims. The distance D22 defines the "second position" of second flank 32 as defined in the claims. The distance D23 defines the "third position" of third flank 33 as defined in the claims.

[0069] Centrifugal forces during operation are withheld via the flanks 31, 31', 32, 32', 33, 33'. Other surfaces may be in direct contact with the slot 6 of the disc 5 but may not be considered a bearing surface. Additionally in some parts there may even be a gap 40 between a surface of the slot 6 and a surface of the blade root 1.

[0070] The planar expansions also can be seen in FIG. 5 which shows an inventive turbine blade 2 in a perspective view. The first planar expansion A10 for the most upward flanks 31, 31' is highlighted and represents the area of contact to the opposite surface of the slot 6 of the disc 5, which is not shown in FIG. 5. The planar expansion A10 is a substantially flat and rectangular surface section.

[0071] Furthermore, the second planar expansion A11 is shown, which is greater than the first planar expansion A10. Particularly the second length L11 of the flank 32 is approximately 33% increased compared to the first length L10, e.g. the length L10 may be 1.4mm and the length L11 may be 1.9mm. As a consequence also the second planar expansion A11 is increased 33% compared to the first planar expansion A10.

[0072] Finally the third planar expansion A12 is also marked in FIG. 5, which is greater than the first planar

expansion A10 and may be equal to or greater than the second planar expansion A11. Again, the expansion of the third planar expansion A12 is defined by the second length L12 of the flank 33 and the axial length of the blade root 1.

[0073] The form of the surface between the lower lobes 13, 13' and the bottom 10 may be unmodified over the axial length. Alternatively, as shown in the figure, a middle section may have a recess, which may be used to form an inlet for cooling air which should be guided into the interior of the blade.

[0074] In FIG. 5 also fillet radii are indicated as R10, R11, and R12. It may be considered a simplification of the fillets only follow one section of circular cylinder or of an elliptic cylinder. The fillet may be composed of several sections which can be defined via fillet radii, as it is shown in FIG. 3. Nevertheless in a preferred embodiment, all fillet radii of all fillets are substantially identical.

[0075] An embodiment as introduced before may have a substantial benefit in regards of the lifetime of a blade. Particularly the low cycle fatigue life may be increased drastically. This is possible, as peak stresses can be avoided.

[0076] It has to be noted that that it may be advantageous if exactly three pairs of lobes and three pairs of fillets may be present on the blade root. Possibly other configurations may also be possible.

[0077] FIG. 6 illustrates locking plates 50 attached to the rotor disc 5 to seal gaps 40 from an axial end that are present between the disc 5 and the blade root 1 and radially inward surfaces of the blade platform. The locking plates 50 are clamped between a notch of the disc 5 and a rail of the radially inward side of the blade platform.

Claims

1. A blade root (1), particularly of a turbine blade (2), comprising:

- a bottom (10) of the blade root (1);
- a plurality of opposite pairs of lobes (11, 11', 12, 12', 13, 13'), each of the pair of lobes (11, 11', 12, 12', 13, 13') being arranged substantially mirror-symmetrical and comprising most distal surface sections (15, 15', 16, 16', 17, 17') defining a widest distance between opposite surfaces of the pair of lobes (11, 11', 12, 12', 13, 13'), the most distal surface sections (15, 15', 16, 16', 17, 17') being arranged such that a first width (D10) between a first pair of most distal surface sections (15, 15') of a first opposite pair of lobes (11, 11') is higher than a second width (D11) between a second pair of most distal surface sections (16, 16') of a second opposite pair of lobes (12, 12'), the second pair of lobes (12, 12') being closer to a bottom (10) of the blade root (1) than the first pair of lobes (11, 11');

- a plurality of opposite pairs of fillets (21, 21', 22, 22', 23, 23'), each of the pair of fillets (21, 21', 22, 22', 23, 23') being arranged substantially mirror-symmetrical and comprising minimum distant surface sections (25, 25', 26, 26', 27, 27') defining a narrowest distance between opposite surfaces of the pair of fillets (21, 21', 22, 22', 23, 23');

- a plurality of substantially planar flanks (31, 31', 32, 32', 33, 33'), the lobes (11, 11', 12, 12', 13, 13') and fillets (21, 21', 22, 22', 23, 23') arranged in an alternating order and each of the flanks (31, 31', 32, 32', 33, 33') arranged between one of the lobes (11, 11', 12, 12', 13, 13') and one of the fillets (21, 21', 22, 22', 23, 23'); wherein a first flank (31) of the plurality of flanks (31, 31', 32, 32', 33, 33') being arranged at a distant first position in regards to the bottom (10) of the blade root (1) and having a first planar expansion (A10), and a second flank (32) of the plurality of flanks (31, 31', 32, 32', 33, 33') being arranged at a closer second position in regards to the bottom (10) of the blade root (1) compared to the first position of the first flank (31) and having a second planar expansion (A11), the second planar expansion (A11) being greater than the first planar expansion (A10).

2. Method according to one of the preceding claims, **characterised in that**

the minimum distant surface sections (25, 25', 26, 26', 27, 27') being arranged such that a third width (D15) between a first pair of minimum distant surface sections (25, 25') of a first opposite pair of fillets (21, 21') is higher than a fourth width (D16) between a second pair of minimum distant surface sections (26, 26') of a second opposite pair of fillets (22, 22'), the second pair of fillets (22, 22') being closer to a bottom (10) of the blade root (1) than the first pair of fillets (21, 21').

3. Method according to one of the preceding claims, **characterised in that**

the plurality of planar flanks (31, 31', 32, 32', 33, 33') each being a surface section substantially facing away from the bottom (10) of the blade root (1).

4. Method according to one of the preceding claims, **characterised in that**

a third flank (33) of the plurality of flanks (31, 31', 32, 32', 33, 33') being arranged at a closer third position in regards to the bottom (10) of the blade root (1) compared to the second position of the second flank (32) and having a third planar expansion (A12), the third planar expansion (A12) being greater than the second planar expansion (A11) or the third planar expansion (A12) being equal to the second planar expansion (A11).

5. Method according to one of the preceding claims,
characterised in that
the second planar expansion (A11) being 25%-50%
greater than the first planar expansion (A10), partic- 5
ularly the second planar expansion (A11) being sub-
stantially 33% greater than the first planar expansion
(A10).
6. Method according to one of the preceding claims,
characterised in that 10
a first fillet radius (R10) of a first fillet (21) of the plu-
rality of fillets (21, 21', 22, 22', 23, 23') being arranged
at a distant fourth position in regards to the bottom
(10) of the blade root (1),
a second fillet radius (R11) of a second fillet (22) of 15
the plurality of fillets (21, 21', 22, 22', 23, 23') being
arranged at a closer fifth position in regards to the
bottom (10) of the blade root (1) compared to the
fourth position,
the first fillet radius (R10) being substantially equal 20
to the second fillet radius (R11).
7. Method according to one of the preceding claims,
characterised in that
a second fillet radius (R11) of a second fillet (22) of 25
the plurality of fillets (21, 21', 22, 22', 23, 23') being
arranged at a fifth position in regards to the bottom
(10) of the blade root (1),
a third fillet radius (R12) of a third fillet (23) of the 30
plurality of fillets (21, 21', 22, 22', 23, 23') being ar-
ranged at a closer sixth position in regards to the
bottom (10) of the blade root (1) compared to the
fifth position,
the second fillet radius (R11) being substantially 35
equal to the third fillet radius (R12).
8. A blade (2), particularly of a turbine, comprising:
- an aerofoil (4);
- a platform (3) from which the aerofoil (4) ex- 40
tends upwardly; and
- a blade root (1) configured according to any of
the claims 1 to 7, the blade root (1) extending
downwardly from the platform (3). 45
9. A turbomachine assembly, particularly for a turbine,
comprising:
- a disc (5) with a plurality of slots (6);
- a plurality of blades (2) as defined according 50
to claim 8, each inserted into the plurality of slots
(6);
wherein the slots (6) and the blades (2) are ar-
ranged such that during operation areas of con-
tact between a surface of the slots (6) and a 55
surface of the blades (2) is limited to the plurality
of substantially planar flanks (31, 31', 32, 32',
33, 33') of the blade roots (1).

FIG 1

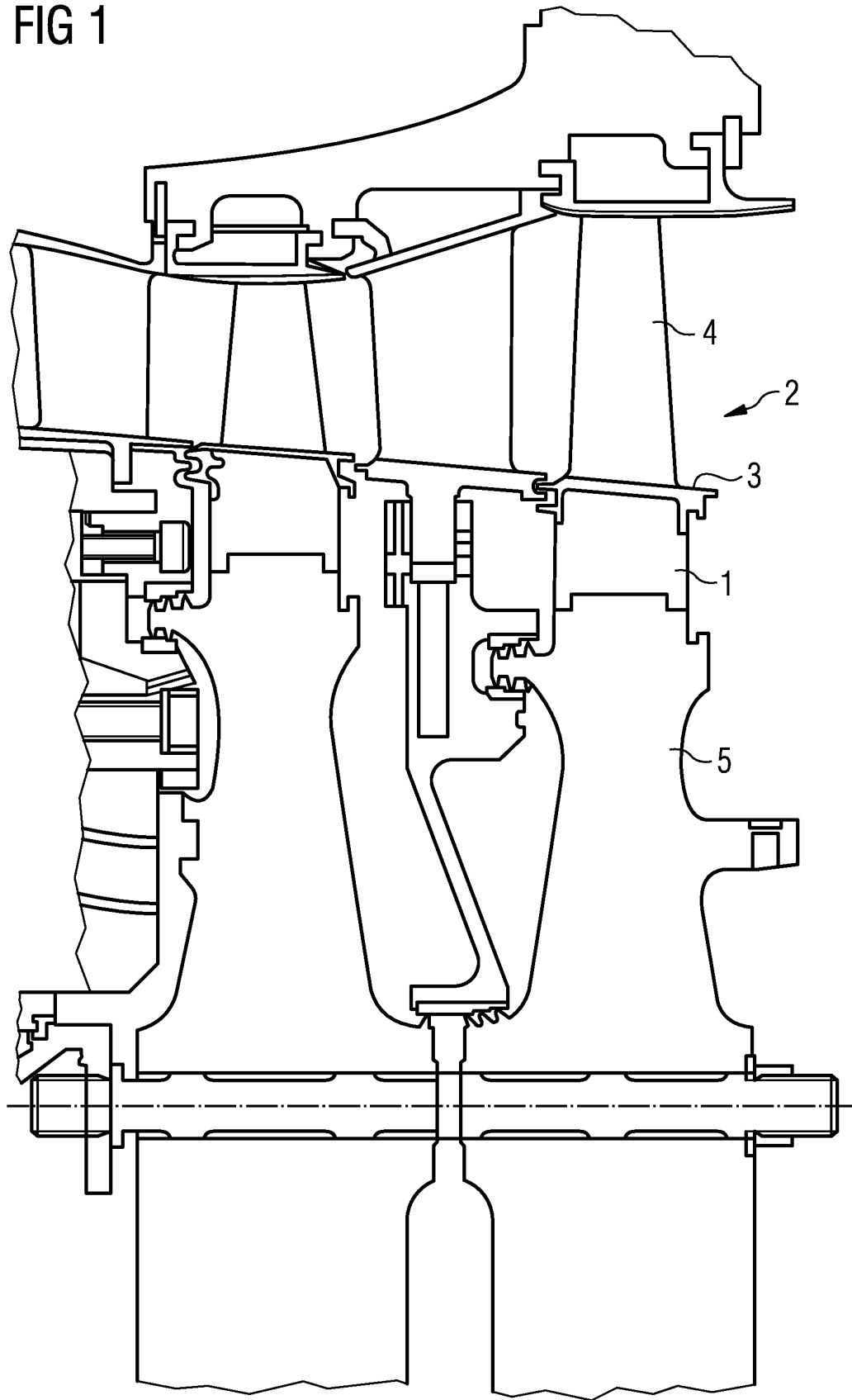


FIG 2

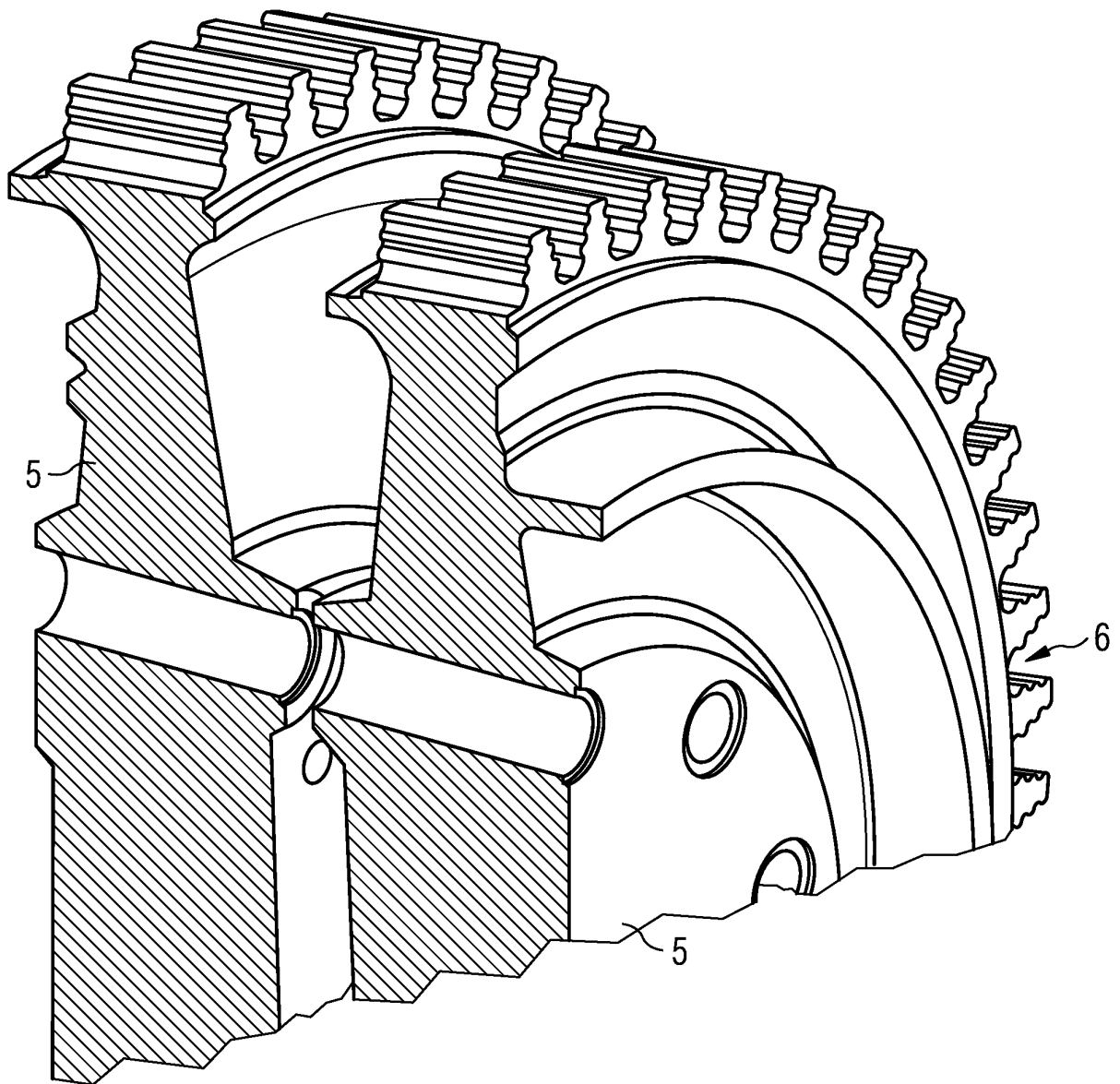
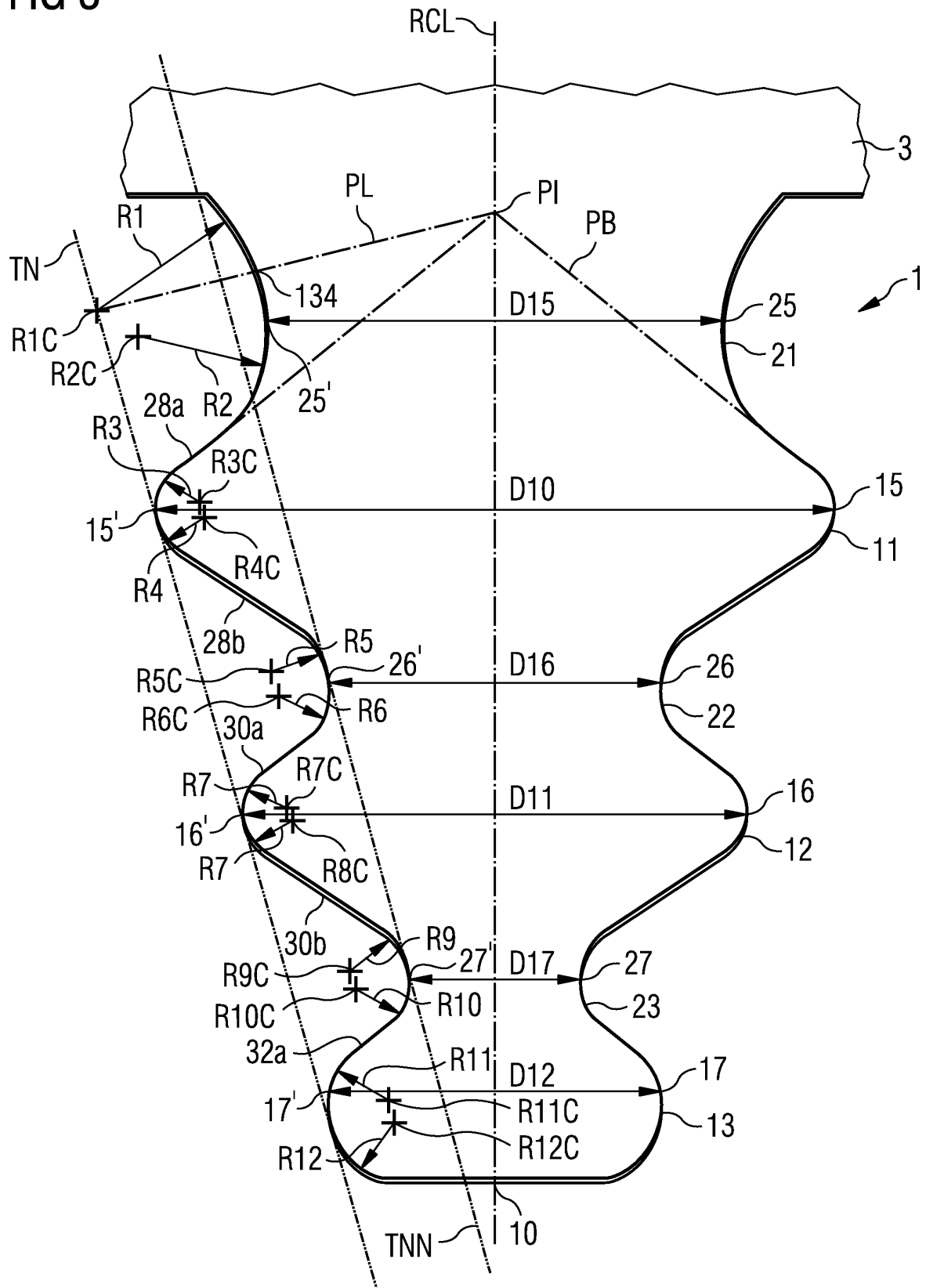


FIG 3



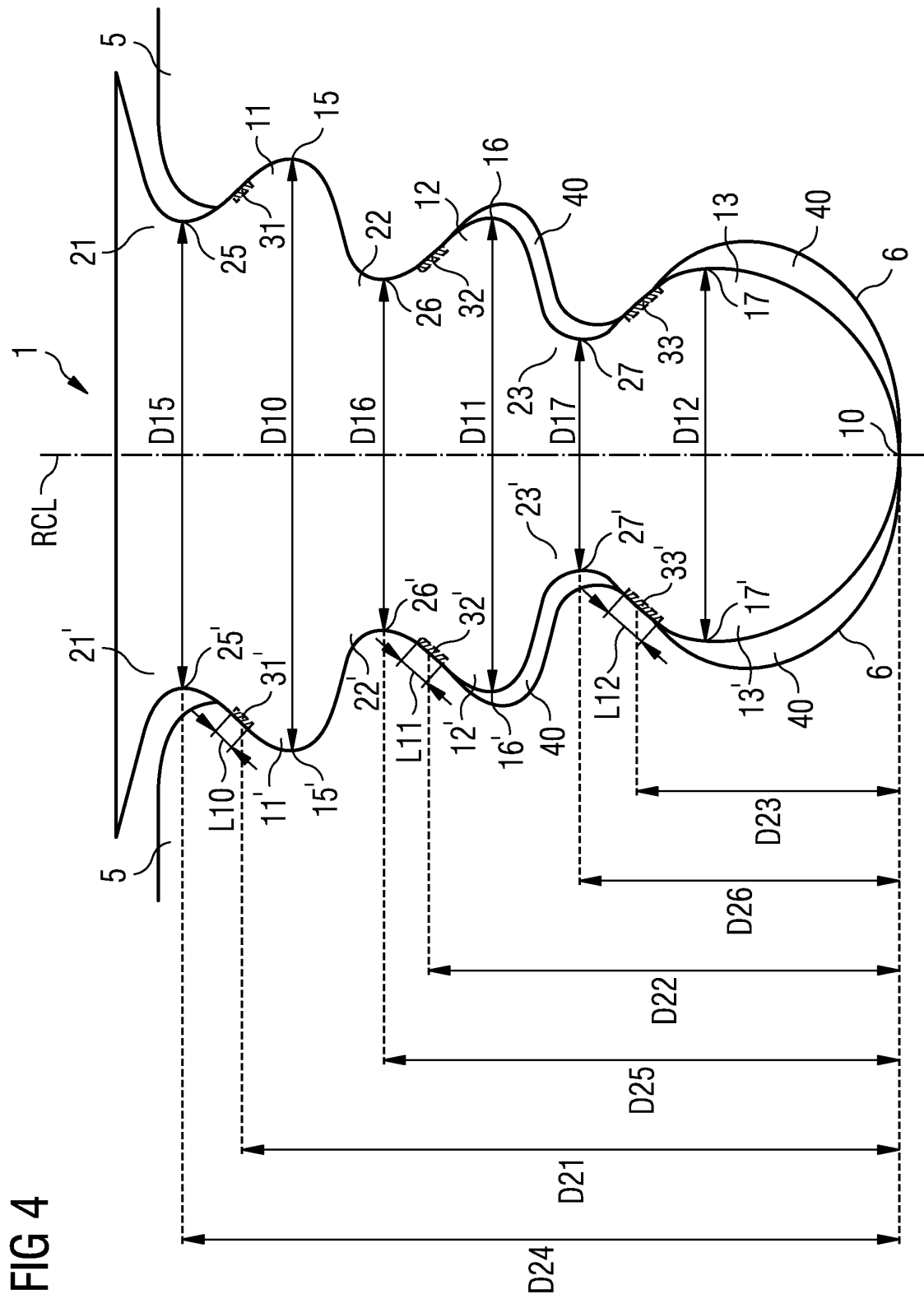


FIG 5

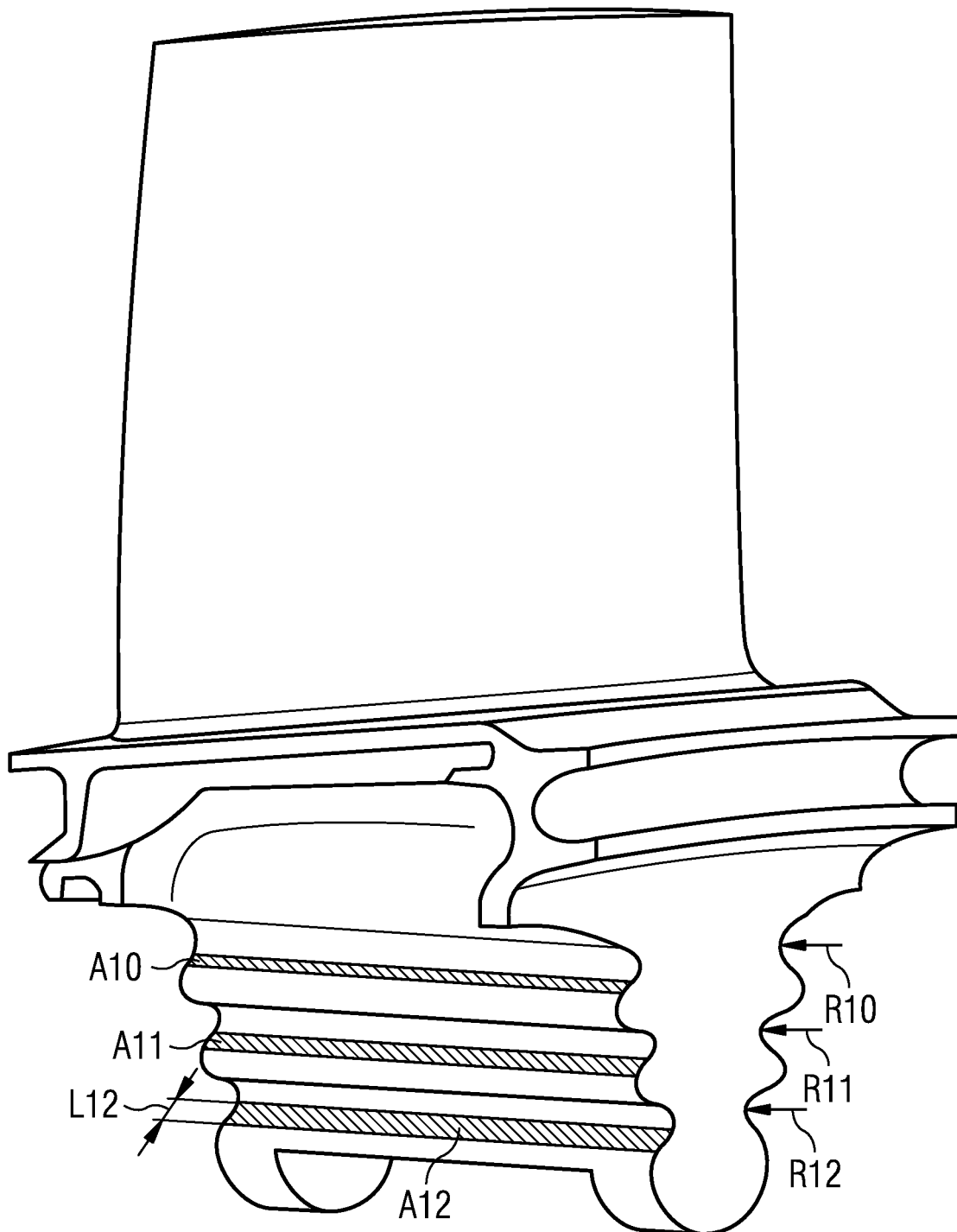
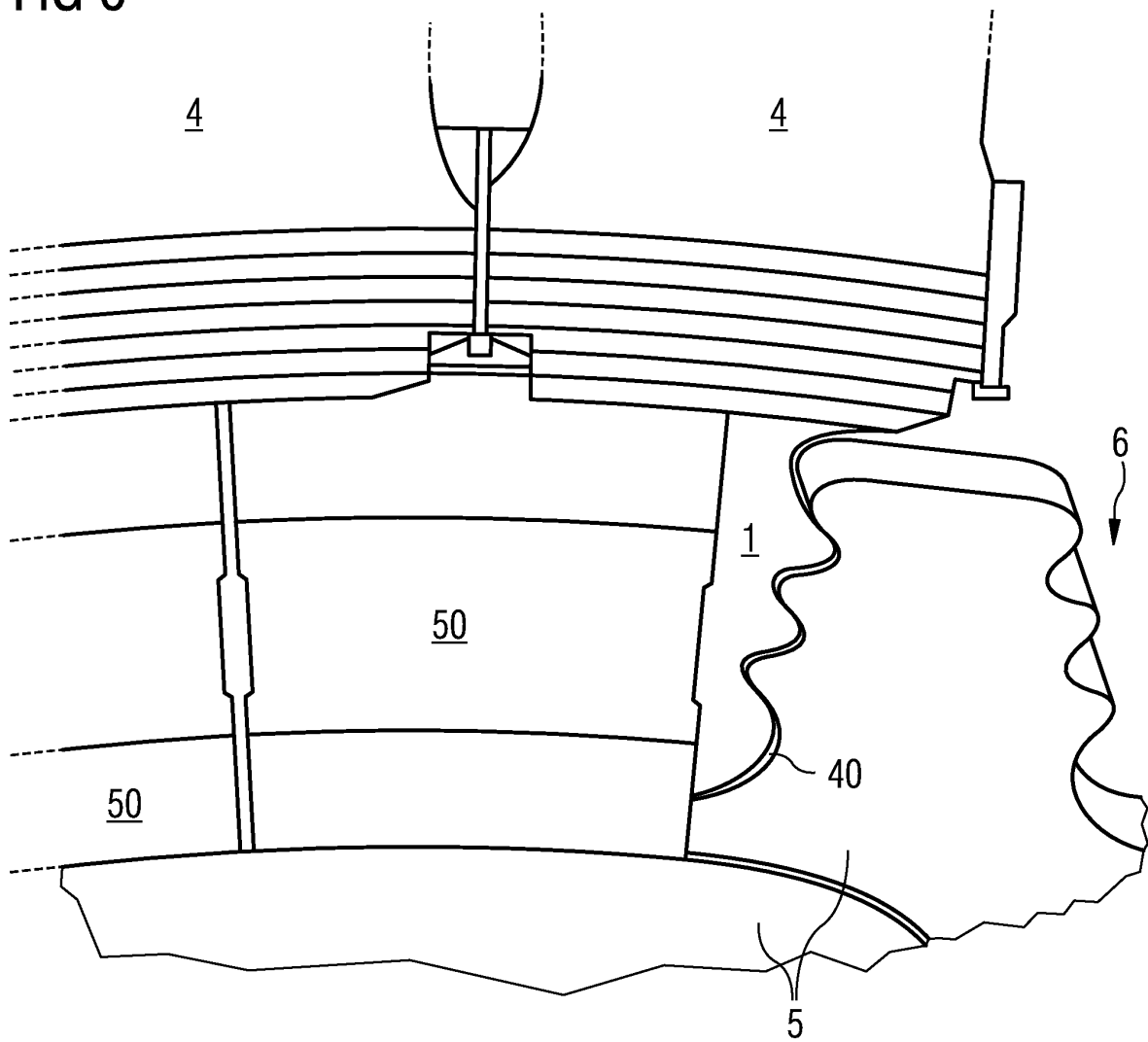


FIG 6





EUROPEAN SEARCH REPORT

Application Number
EP 10 18 2370

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			F01D
1	Place of search Munich	Date of completion of the search 16 December 2010	Examiner Raspo, Fabrice
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