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(54) Turbomachine with reduced tip leakage flow

(57) The invention refers to a turbomachine, such as a turbine or a compressor, with a reduced tip leakage flow.

It is an object of the invention to provide a constructionally simple and effective solution for reducing the amount of over-tip leakage flow between the stationary and the rotating components in the turbomachine, by applying measures forincreasing the flow losses within the clearance gap between said components, e.g. the shroud of a rotating blade and the opposite flow duct delimiting segment, which will ultimately lead to an increased efficiency of the turbomachine.

The invention is based on the idea to provide a number of dimples (10), impressed at least in part into the surfaces (7) of the flow-delimiting contours within the clearance gap (4) between the stationary and rotating components.

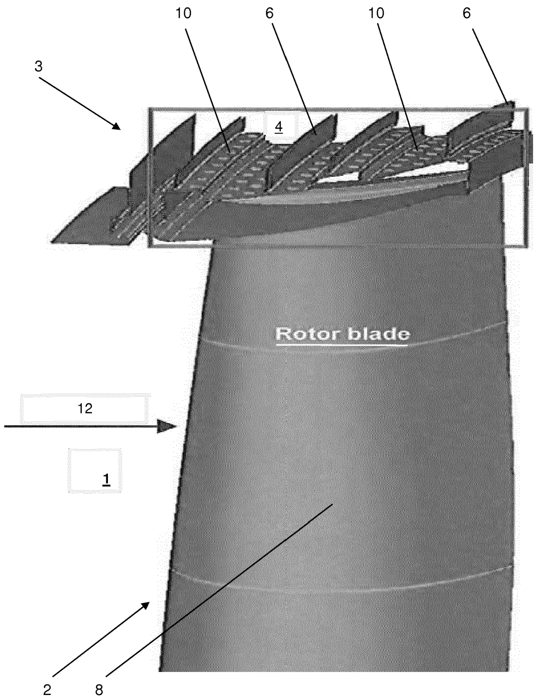

Fig. 2

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Description

TECHNICAL FIELD

[0001] The present invention relates to the field of turbomachines. It refers to surface features of the flow-delimiting contours within the clearance gap between the tip of a blade or vane row and an opposite wall segment for reducing the leakage flow of the working medium through this gap.

BACKGROUND OF THE INVENTION

[0002] The performance and efficiency of a turbomachine, such as a turbine or a compressor, are, amongst others, critically affected by the tip clearances between its rotating and stationary components within the flow duct for the working medium. The clearance gaps between the tip of a rotating blade and the radially opposite stationary vane carrier provide a narrow flow passage between the high pressure side and the low pressure side of a blade row, resulting in a detrimental leakage mass flow. Particularly, even though not exclusively, under efficiency aspects it is desirable to reduce the clearance mass flow to a minimum. Increasing clearance gaps decrease the efficiency, but decreasing clearance gaps increase the risk of blade rubbing and consequential machine damages. Accordingly, the designer aims to maintain the clearance gaps at an inevitable minimum without affecting the structural integrity of the involved components.

[0003] Shrouded blades can be employed to reduce leakage around the blade tip. By using a shrouded blade a seal can be produced between the blade shroud and the radially opposite casing wall. Typically one or more radially aligned fins extend into the gap between the stationary and the moving components to hinder leakage flow. The fins of each blade shroud or casing segment abut the fins of the adjacent blade shrouds to provide one or more complete circumferential fins around the circumference of an assembled blade row. Additional steps in axial direction between the fins may be provided to improve seal effectiveness.

[0004] From heat transfer technology it is known to equip a heat transfer surface with a plurality of more or less spherical concavities, so-called dimples. These dimples, arranged in an arbitrary pattern, create local turbulences in the boundary layer between the surface and a fluid flow and thus increasing the heat transfer between the surface and the fluid.

[0005] In addition, it is known that the friction of a gas flow could be reduced by means of dimples, located on the surface of the flow channel, whereby the heat transfer between the surface and the flowing gas is increased.

[0006] The document WO 2004083651 discloses a surface structure for optimized flow properties in view of friction resistance and heat transfer. Accordingly, that document proposes a surface, comprising a number of dimples of a defined geometry with rounded edges, forming a central dimple area and a curvature area for each dimple, which continuously connects the dimple with the surrounding surface. Such a geometry improves the flow properties with respect to friction resistance and additionally with respect to heat transfer. The dimples have essentially the form of a segment of a sphere or an ellipsoid. The underlying principle are secondary vortices, originating in the dimples and leading to an organized transportation of gas flow from the surface to the main flow. Due to the reduced pressure inside the vortex flows the boundary layer is sucked in, so that the thickness of the boundary layer does not increase.

[0007] In addition this document discloses the teaching that dimples having relatively low depth in relation to the diameter additionally reduce the friction resistance.

SUMMARY OF THE INVENTION

[0008] It is an object of the invention to provide a constructionally simple and effective solution for reducing the amount of over-tip leakage flow between the stationary and the rotating components in a turbomachine, such as a turbine or a compressor, by applying measures for increasing the flow losses within the clearance gap between said components, e.g. the shroud of a rotating blade and the opposite flow duct delimiting segment, which will ultimately lead to an increased efficiency of the turbomachine.

[0009] The object is achieved by the sum total of the features of claim 1.

[0010] The invention is based on the idea to provide a number of dimples, impressed at least in part into the surfaces of the flow-delimiting contours within the clearance gap between the stationary and rotating components.

[0011] According to a preferred embodiment the radially outer surface of the blade shroud and/or the opposite casing wall are provided with a dimple array.

[0012] The key advantage of the invention is especially to be seen in the fact that the leakage flow of the working medium through the gap along the surface portions, structured in such a way, initiates the formation of three-dimensional energy dissipating vortices in the flow structure. This significant development of turbulence increases the amount of pressure loss in the gap and - as a consequence of these losses - the amount of over-tip leakage flow is reduced to a respective degree.

[0013] According to one embodiment the impressed dimples have a circular rim, the rim being the interface between the dimple and the surface, and are shaped as a spherical segment.

[0014] The maximum depth of a dimple, designed in this way, is to be limited to less than half its diameter.

[0015] However, according to the requirements of the individual case, alternative dimple designs for promoting losses in the clearance gap are possible, such as dimples of elliptical or rectangular shapes (in top view) and with curved or straight wall and bottom sections.

[0016] It is an advantage of the present invention that this solution may be applied to new machines, but already existing machines can also be retrofitted at little cost. There is no requirement of additional changes to their sealing system, e.g. a re-design of the existing sealing system is not necessary.

[0017] Another advantage of this solution is its flexibility and broad applicability. It is not bound to a certain sealing system, e.g. a sealing system as described below in an exemplary embodiment, but can be coupled with other known sealing systems too.

[0018] Another embodiment of the invention is distinguished by the fact that the flow delimiting contours in the clearance gap, at least in part, are equipped with periodic arrays of dimples, consisting of rows of dimples arranged in a staggered manner in the flow direction.

BRIEF EXPLANATION OF THE FIGURES

[0019] The invention shall subsequently be explained in more detail based on exemplary embodiments in conjunction with the drawing. In the drawing

Fig. 1 schematically shows in a perspective view a clearance gap between a blade row and the casing wall according to the state of the art,

Fig. 2 shows a shrouded blade according to the invention,

Fig. 3 shows a detail from Fig. 2,

Fig. 4a shows in a cross-sectional view a surface portion of a shroud or wall segment having a dimple impressed therein,

Fig. 4b shows a top view of a dimple in the surface of a shroud or wall segment.

WAYS OF IMPLEMENTING THE INVENTION

[0020] The invention in its preferred embodiments is illustrated for its use in a gas turbine. A gas turbine comprises an annular hot gas channel 1 with a rotor at its central axis. At least one row of turbine blades 2 extends from the periphery of the rotor into the hot gas channel 1. An airfoil 8 of blade 2 extends outwardly through the hot gas channel 1, where the working medium 9 executes a motive force on it. At its outer tip portion the blade 2 is equipped with a shroud 3 defining a clearance gap 4 to the outer delimiting wall 5 of the hot gas channel 1. The shrouds 3 of adjacent blades 2 of a blade row contact one another to form a closed circumferential ring. In flow direction of the working medium 9 the outer surface 7 of the shroud 3 is designed with a stepped contour. From the outer wall 5 flow restricting sealing fins 6 extend radially inwards towards the outer surface 7 of the shroud 3.

[0021] The performance and efficiency of the turbine is, amongst others, critically affected by the over-tip leakage flow of working medium through the clearance gap 4, as illustrated in Fig. 1, because this leakage flow does not exert motive forces onto the blade airfoil 8. A reduced leakage flow increases the turbine efficiency. Therefore it is a permanent aim to minimize the leakage flow through said gap 4 under operation conditions.

[0022] This invention discloses a way to further minimize the leakage flow by increasing the flow resistance within the leakage gap 4, i.e. between the outwards facing surface 7 of the shroud 3 of a blade row and the inwards facing surface of the opposite outer wall 5.

[0023] Figures 2 and 3 show the essential elements of the leakage gap 4, applying the measures which are proposed according to the invention. For affecting the aerodynamic characteristics within the gap a plurality of dimples 10 is impressed onto an extensive area of the surfaces facing the gap 4. At least a portion of the outwardly facing surface 7 of the shroud 3 is equipped with arrays of dimples 10. The dimples 10 may have the same shape and size. The latter, however, is not compulsory. If the conditions of the specific application should require, the dimensioning of the individual dimples 10 or dimple arrays can be altered continuously or in steps corresponding to the requirements, such as the flow parameters in selected operation modes of the machine.

[0024] The leakage flow 13 of the working medium 9 through the gap 4 along the structured surface portions 7 and/or 14 of the flow delimiting contours 3, 5 initiates the formation of three-dimensional energy dissipating vortices in the flow. This significant development of turbulence within the individual cavities between the sealing fins 6, sequently located in the gap 4, increases the amount of pressure loss in the gap 4. As a consequence of these losses the amount of over-tip leakage flow is reduced.

[0025] The dimples 10 can form different patterns on the surface 7. In principle, they can be arranged periodically or in random order. In the interests of foreseeable fluidic effects and continuity in the mechanical properties of the involved elements 5, 7 in the gap 4 preference is to be given, however, to a periodic pattern, as is reproduced, for example, in Fig. 3 in the form of rows of dimples 10 of equal dimension which are arranged in a staggered manner.

[0026] Fig. 4a schematically shows a sectional view through a shroud (3) or a wall (5) segment with a number of dimples 10, impressed into the surface 7, 14 of said segment (only one dimple is shown). Arrow 12, 13 symbolizes the tip leakage flow of the working medium and its direction through the gap 4. Two alternative designs of the dimple 10 are touched in this sketch. Preferably circular dimples 10, i.e. dimples 10 with a (in top view) circular rim 11, whereby the rim 11 is defined as being the interface between the dimple 10 and the surface 7, 14, may be formed as a spherical segment, symbolized by curve 15 in Fig. 4a.

[0027] Naturally, shapes which deviate from such a cup shape are also possible. According to an alternative design, particularly applicable to non-circular dimples 10, e.g. with elliptical, rectangular or even irregular forms (in top view), the dimple 10 may have a polygon-like design with straight wall and bottom sections, symbolized by the dashed line 16 in Fig. 4a.

[0028] Fig. 4b shows a top view on a non-circular dimple 10, impressed into the surface 7, 14 of the flow delimiting contour 3, 5 within the gap 4. The non-circular dimple 10 comprises a length (L), defined as being the maximum extension of the rim 11 in a first direction, e.g. in the flow direction 12, and a width (W), defined as being the maximum extension in a second direction, perpendicularly to said first direction. The most preferred embodiment of this category of forms are elliptical dimples 10, whereby Fig. 4b shows a configuration with the longitudinal axis of the ellipse parallel to the direction 12 of the leakage flow 13. However, this alignment is not obligatory. The longitudinal axis of the dimple 10 may be arranged with an angle between 0 ° and 90 ° to the flow direction 12.

[0029] The dimples 10 which are impressed into the flow delimiting contour 7, 14 have a diameter (D) and a depth (S) with the proviso that $S_{max} \leq D/2$ (circular dimples) or $S_{max} \leq L/2$ (non-circular dimples). As a rule, the flow-delimiting contours (3, 5) are equipped with arrays of dimples 10, the maximum depth of which is $S_{max} \leq D/4$ (circular dimples) or $S_{max} \leq L/4$ (non-circular dimples). The distances (a) between adjacent dimples 10 inside an array are not to exceed five-times their diameter (D) or length (L), that is to say are to follow the inequation $0 \leq a \leq 5$ D or $0 \leq a \leq 5$ L.

[0030] The preferred order of magnitude of the distance (a) lies with the range of $1 D \leq a \leq 3D$ or $1L \leq a \leq 3L$.

LIST OF DESIGNATIONS

[0031]

1 flow duct

2 blade

3 shroud

4 gap

5 outer wall of the flow duct

6 sealing fins

7 outer surface of the shroud

8 airfoil of the blade

9 working medium

10 dimple

11 rim of the dimple

12 flow direction

13 leakage flow

14 inner surface of the outer wall

15 spherical contour of a dimple

16 straight bottom section of a dimple

Claims

1. Turbomachine with a reduced tip leakage flow (13), at least comprising an annular flow duct (1) for a gaseous medium, a radially outer casing providing an outer flow duct delimiting wall (5), a rotor with at least one row of blades (2), extending radially outwards into the annular flow duct (1), the blades (2) comprising a root portion, an airfoil (8) and a tip portion, the tip portion being equipped with a shroud (3) defining a clearance gap (4) to the opposite flow delimiting wall (5), one or more circumferentially aligned sealing fins (6) are disposed in the clearance gap (4) to reduce a leakage flow (13) through the clearance gap (4), **characterized in that** a number of dimples (10) is impressed, at least in part, into the surfaces (7, 14) of the flow-delimiting contours (3, 5) within the clearance gap (4).

2. Turbomachine as claimed in claim 1, **characterized in that** the radially outer surface (7) of the shroud (3) and/or the inwards facing surface (14) of the opposite flow duct delimiting wall (5) are provided with a dimple (10) array.

3. Turbomachine as claimed in claim 1, **characterized in that** at least one dimple (10) has a circular rim (11), the rim (11) being the interface between the dimple (10) and the surface (7, 14).

4. Turbomachine as claimed in claim 3, **characterized in that** the at least one dimple (10) is designed as a segment of a sphere (15).

5. Turbomachine as claimed in claim 3, **characterized in that** the at least one dimple (10) is of a polygon-like design and has a straight bottom section (16).

6. Turbomachine as claimed in claim 1, **characterized in that** at least one dimple (10) has a non-circular rim (11), the rim (11) being the interface between the dimple (10) and the surface (7, 14).

7. Turbomachine as claimed in claim 6, **characterized in that** the rim (11) has a length (L) and a width (W), wherein the length (L) and the width (W) are either equal or unequal.

8. Turbomachine as claimed in claim 7, **characterized in that** the dimples (10) have an elliptical rim (11).

9. Turbomachine as claimed in one of the claims 3 to 5, **characterized in that** the dimples (10) have an at least approximately circular rim (11) with a diameter (D) and have a depth (S), wherein a maximum depth $S_{max} \leq D/2$ applies.

10. Turbomachine as claimed in claim 9, **characterized in that** it applies: $S_{max} \leq D/4$.

11. Turbomachine as claimed in one of the claims 5 to 8, **characterized in that** the dimples (10) have a length (L), a width (W) and a depth (S), wherein a maximum depth $S_{max} \leq L/2$, preferably $S_{max} < L/4$, applies.

12. Turbomachine as claimed in claim 1, **characterized in that** at least one of the flow-delimiting contours (7, 14) within the clearance gap (4) comprises an area with a dimple (10) array.

13. Turbomachine as claimed in claim 12, **characterized in that** the dimples (10) form a periodic array on the surfaces (7, 14) of the flow-delimiting contours (7, 14).

14. Turbomachine as claimed in claim 1, **characterized in that** the surfaces (7, 14) of the flow-delimiting contours (3, 5) have a pattern consisting of rows of dimples (10) which are arranged in a mutually staggered manner in the flow direction (12).

15. Turbomachine as claimed in claim 1, **characterized in that** the majority of the dimples (10) is basically equally dimensioned.

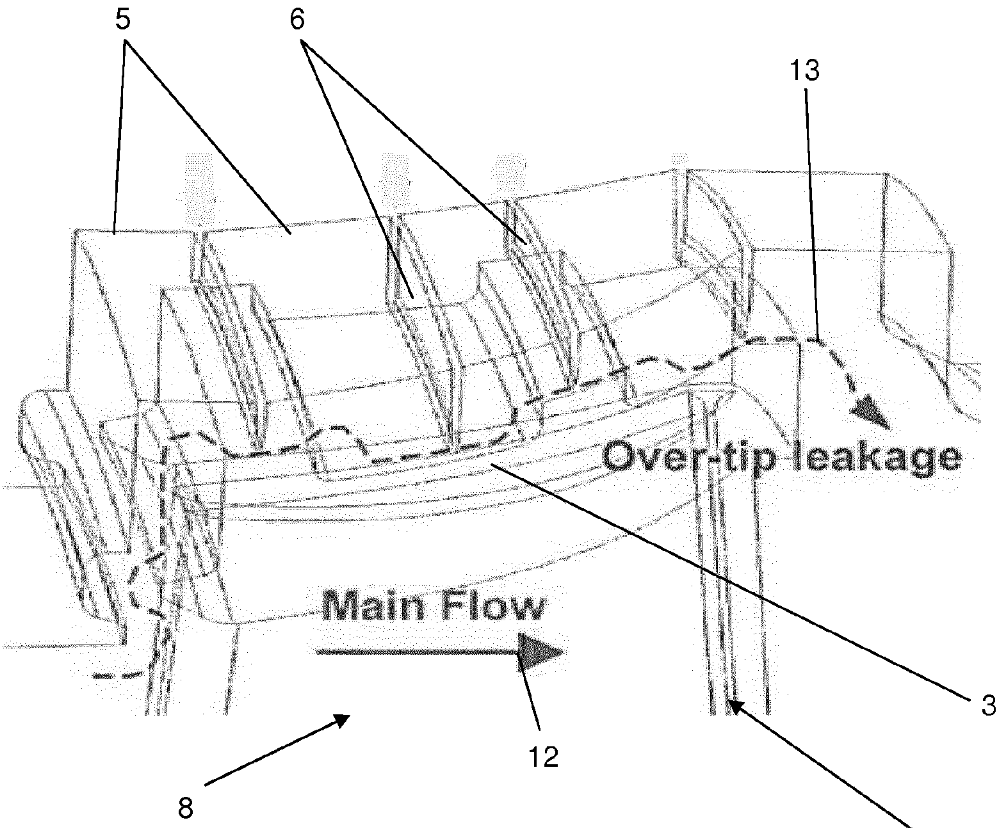

Fig. 1

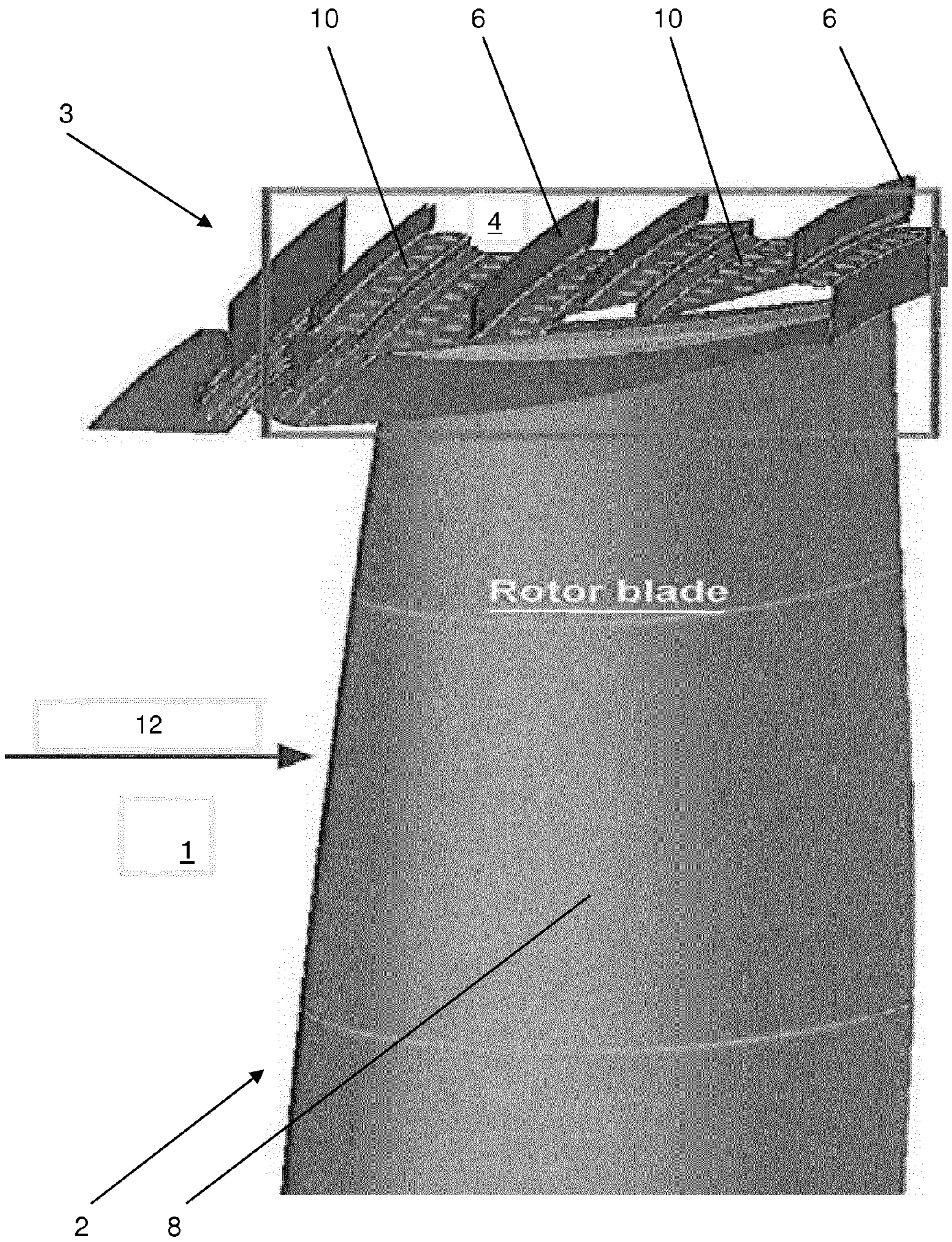

Fig. 2

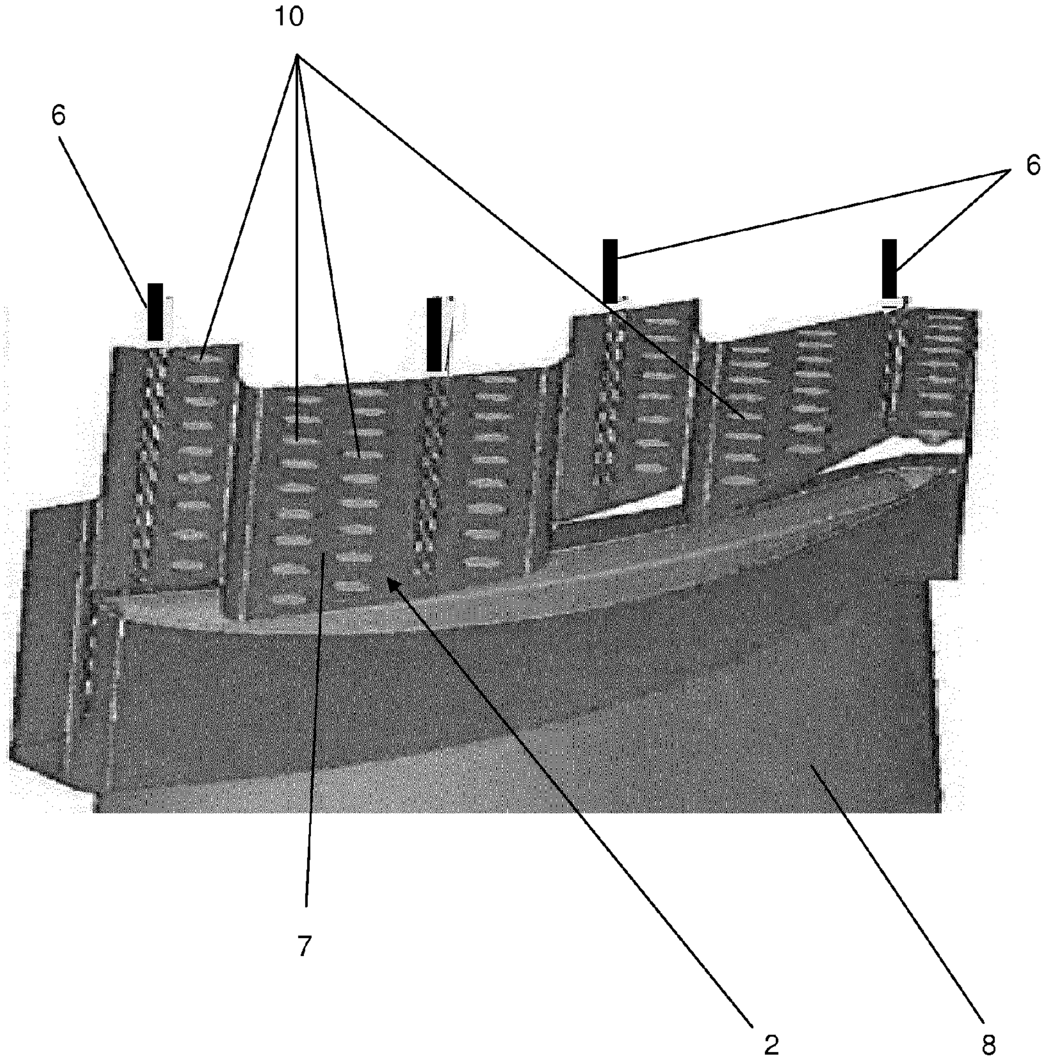

Fig. 3

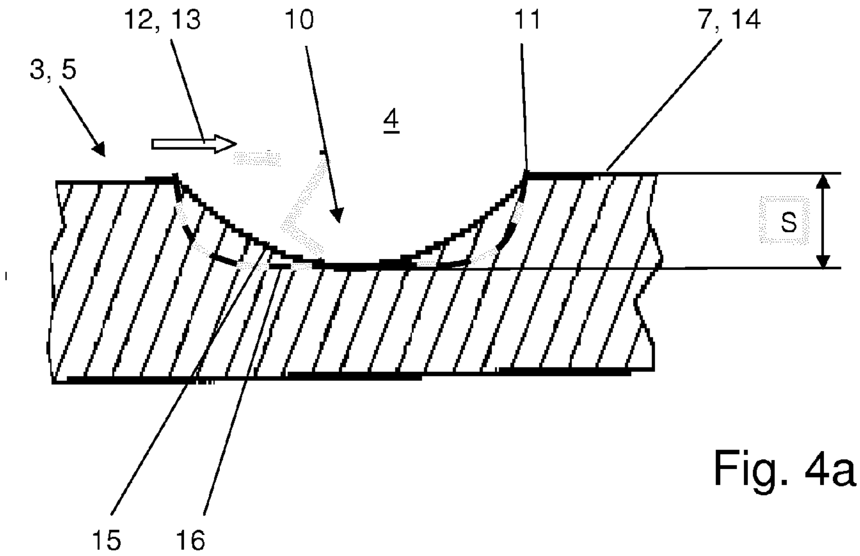

Fig. 4a

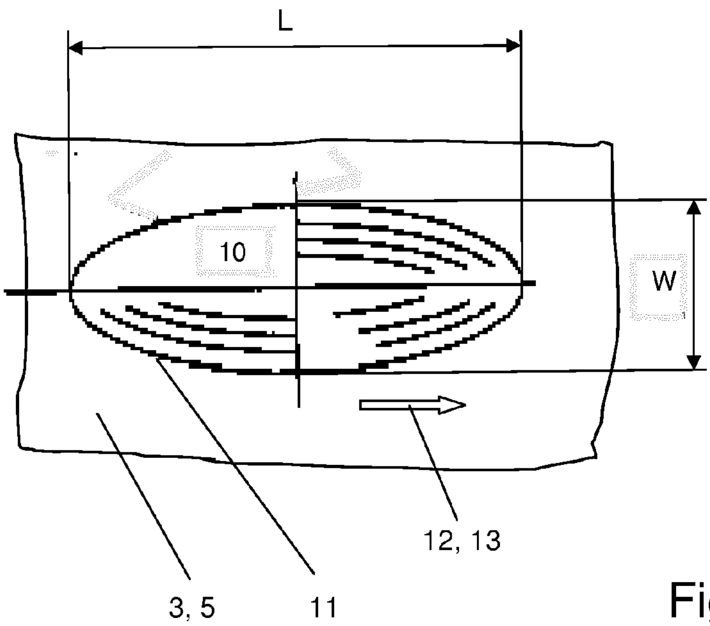

Fig. 4b

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EUROPEAN SEARCH REPORT

Application Number
EP 13 17 7237

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2007 046252 A1 (GEN ELECTRIC [US]) 3 April 2008 (2008-04-03) * paragraph [0021] - paragraph [0027] * * paragraph [0030] - paragraph [0033] * * paragraph [0035] - paragraph [0042]; claims 1,2,5 6; figures 1-11 *	1-15	INV. F01D11/02 F01D11/08 F01D11/10
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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	29 October 2013	Balice, Marco

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CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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