

(19)



(11)

EP 2 770 165 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.08.2014 Bulletin 2014/35

(51) Int Cl.:
F01D 11/00 (2006.01) F01D 11/02 (2006.01)

(21) Application number: **13155933.8**

(22) Date of filing: **20.02.2013**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
 GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
 PL PT RO RS SE SI SK SM TR**
 Designated Extension States:
BA ME

(72) Inventor: **McKenna, Mike**
Newark NG24 1GL (GB)

(74) Representative: **Maier, Daniel Oliver et al**
Siemens AG
Postfach 22 16 34
80506 München (DE)

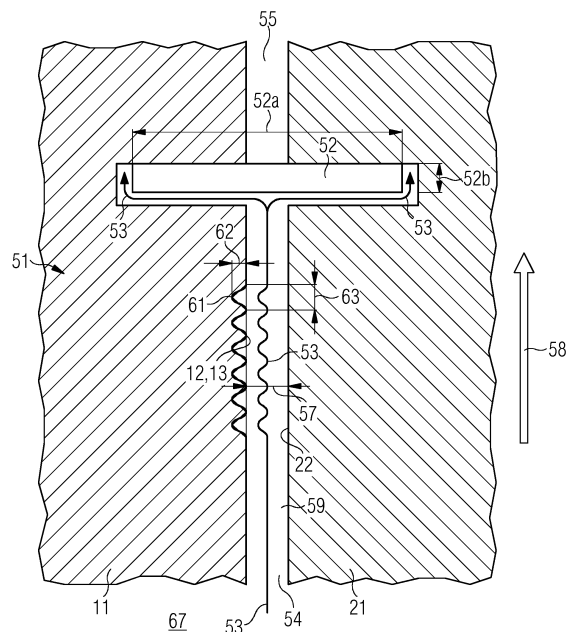
(71) Applicant: **Siemens Aktiengesellschaft**
80333 München (DE)

(54) **Riffléd seal, turbomachine with riffléd seal and method of manufacturing thereof**

(57) In accordance with the invention there is provided a seal (51) of a turbomachine for reducing a leakage flow (53) between a first component (11) of the turbomachine and a second component (12) of the turbomachine. The seal (51) comprises the first component (11) with a first surface (12) and the second component (21) with a second surface (22), wherein the first component (11) is stiff with regard to a first force exerted perpendicularly to the first surface (12) and the second component (21) is stiff with regard to a second force exerted perpendicularly to the second surface (22). The first surface (12) is opposite to the second

surface (22) and the first surface (12) comprises a first surface riffle (13). Furthermore, a turbomachine comprising a seal (51) as described above, wherein the turbomachine is a gas turbine engine is provided. A last aspect of the invention relates to a method of manufacturing a first component (11) of a turbomachine with a reduced leakage flow (53) between the first component (11) and a second component (12) of the turbomachine. The method comprises fabrication of a first surface riffle (13), in particular by grinding and/or by electrical discharge machining.

FIG 2



Description

FIELD OF INVENTION

[0001] The present invention relates to a seal between two components of a turbomachine. In other words, it relates to a reduction of a leakage flow between two components of a turbomachine. Furthermore, it relates to a turbomachine with such a seal and a method of manufacturing the seal.

BACKGROUND OF THE INVENTION

[0002] A gas path of a turbomachine is typically segmented in several sections. Between two adjacent sections, a gap usually exists. This is due to the fact that components of a turbomachine experience large temperature differences: In stand-by state, i.e. when the turbomachine stands still, temperature of the components of the turbomachine typically is around room temperature, while in operation, i.e. during rotation, the components bordering the gas path are in direct contact with a gas, which, e.g. in case of a gas turbine engine, easily can achieve a temperature of several hundred degree Celsius and can approach e.g. up to 1600 degree Celsius. A consequence of these temperature differences is an expansion of the components during operation compared to the stand-by state.

[0003] Therefore, components of the turbomachine that experience large temperature differences are typically arranged such that in stand-by state of the turbomachine a certain gap between adjacent components exist. This allows an expansion of these components during operation and high temperatures without damaging the assembled turbomachine.

[0004] However, an adverse consequence is a potential ingress of a gas, a fluid and/or particles from cavities surrounding the gas path via these gaps. Alternatively, also working gas, i.e. gas from the gas path, may escape into these cavities. This undesired ingress or escape of the gas, the fluid and/or particles is called a leakage flow.

[0005] Thus, methods have been investigated and applied in order to seal the gap between two adjacent components of the turbomachine. One way is the application of a thin strip of material, a so-called seal strip, which is captivated in a pair of slots in a pair of mating faces of two adjacent components. The seal strip creates a tortuous leak path that reduces the leakage flow.

[0006] However, there exist structures of a turbomachine where the application of a seal strip is not possible. Furthermore, there also exists the case where the application of a seal strip reduces the leakage flow to a certain extent, but a further reduction of the leakage flow is needed.

[0007] Therefore, there exists the need of an improved seal of a turbomachine for reducing the leakage flow between two adjacent components of the turbomachine further.

SUMMARY OF THE INVENTION

[0008] This objective is achieved by the independent claims. The dependent claims describe advantageous developments and modifications of the invention.

[0009] In accordance with the invention there is provided a seal of a turbomachine for reducing a leakage flow between a first component of the turbomachine and a second component of the turbomachine. The seal comprises the first component with a first surface and the second component with a second surface. The first component is stiff with regard to a first force exerted perpendicularly to the first surface and the second component is stiff with regard to a second force exerted perpendicularly to the second surface. Furthermore, the first surface is opposite to the second surface and the first surface comprises a first surface riffle.

[0010] The turbomachine as a whole may comprise a plurality of components. The first component and the second component may be adjacent to each other. Both components may partially or completely be in direct contact and/or indirect contact with each other. The contact between the first component and the second component may be permanent or temporary. There may for example be no direct contact between both components in stand-by state and low temperature, e.g. ambient temperature, but both components may get into contact at high temperatures, e.g. at temperatures of several hundred degree Celsius approaching 1600 degree Celsius.

[0011] The leakage flow comprises a gas, a liquid, particles and/or a combination thereof in a multi phase fluid.

[0012] The first component, the second component and any further component comprised by the turbomachine will in the following also denoted simply as a component. The first surface, the second surface and any further surface comprised by a component will in the following also denoted simply as a surface. The first surface riffle and any further surface ripples will in the following also denoted simply as a surface riffle.

[0013] The first surface, which is a part of the surface of the first component, is opposite to the second surface, which is a part of the surface of the second component. Both surfaces may be substantially parallel to each other.

[0014] The leakage flow that shall be reduced by the seal flows along the first surface and the second surface. In other words, it flows through a section confined by the first surface and the second surface. As the leakage flow shall be minimised, it is advantageous to minimise a distance between the first surface and the second surface, which is called a surface distance.

[0015] The surface distance may vary due to thermal expansion of the components, as already mentioned above. The surface distance furthermore depends on the size of the components and the materials they are made of - the latter one determining a coefficient of thermal expansion. However, in a preferred embodiment, the surface distance is below 2 mm (millimetre), in particular below 1 mm, during operation of the turbomachine; in

stand-by state the surface distance is below 5 mm, in particular below 3 mm.

[0016] The first component is stiff with regard to a first force exerted perpendicularly to the first surface. The first component may, however, be flexible with regard to another force exerted to another surface section of the first component. The first component does not comply substantially when the first force acts on the first surface. Analogously, the second component is stiff with regard to a second force exerted perpendicularly to the second surface.

[0017] Preferably the component is completely stiff with regard to any force exerted to any surface of the component. A "stiff component" in this patent application means that the component is rigid, unpliable and not deformable. The component does for example not comply with a seal strip, by comparison.

[0018] An important feature of the seal according to the invention is the first surface riffle, which is comprised by the first surface. The goal of a surface riffle is to further reduce the leakage flow passing by, i.e. passing along the surface riffle. This reduction in leakage is achieved by avoiding a straight through leak path, but replaces it by a more tortuous path. Thus a riffled surface discourages and reduces the leakage flow.

[0019] A riffle is preferably a surface with a certain surface structure comprising ridges and depressions.

[0020] The invention is directed to any seal of a turbomachine - particularly of a gas turbine engine - where a leakage flow between two adjacent components shall be reduced. Applications may in particular be in rotor blades, stator vanes, heat shield segments, combustion liners, tip seal segments and interstage seals.

[0021] In a first embodiment, the first surface riffle may comprise a plurality of notches.

[0022] A notch can also be labelled an indentation or a groove. A notch is characterised by a notch depth, a notch width and, in a three-dimensional view, a notch length. In a cross-sectional view, i.e. only considering the notch depth and the notch width, the notch may e.g. comprise a shape of a half circle or a half ellipse, i.e. a U-shape, a shape of a triangle, i.e. a V-shape, a shape of a rectangle or a shape a trapezium. Obviously, also other shapes which cannot be described by a simple geometrical term are possible.

[0023] To significantly influence the leakage path of the leakage flow a plurality of notches may be comprised by the first surface riffle. The notches may be adjacent to each other. Alternatively, there may also be a space between two neighbouring notches.

[0024] The plurality of notches may consist of notches, wherein each notch of the plurality of notches features a same or a similar shape. Alternatively, the plurality of notches may also consist of notches, wherein a first notch has a first shape, a second notch has a second shape and the first shape differs from the second shape.

[0025] The dimensions of a notch depend inter alia on the size of the component as well as on the surface dis-

tance. In a preferred embodiment, the notch depth may be in a range between 0.25 mm and 7 mm, in particular in a range between 0.75 mm and 4 mm. The notch width is advantageously in a range between 0.25 mm and 5 mm, in particular in a range between 0.75 mm and 3 mm. In a specific embodiment, the notch depth is in the range between 1 mm and 3 mm and the notch width is in the range of 1 mm and 2 mm.

[0026] Lateral extension and lateral shape of the notch also have an impact on the reduction of the leakage flow. The lateral extension is referred to as the notch length, while the lateral shape describes whether the notch is e.g. a straight line or whether it is curved. It may be beneficial to choose a notch length which is slightly smaller than the lateral extension of the surface where the surface riffle is applied to. A surface riffle which stops shortly before the end of the component has the advantage of preventing extra leak paths, e.g. an extra leak path of leakage flow that ingress on one side of the component, flows along a notch and escapes at the other side of the component.

[0027] The choice of the lateral shape of a notch depends on the shape of the component. If the component has e.g. a shape of a semicircle in a cross-sectional view along the notch length, a curved lateral shape is advantageous. The choice of the lateral shape also depends on effort of manufacture. Regarding this issue, a straight line may be advantageous compared to e.g. a wave shape.

[0028] A turbomachine may comprise a turbomachine rotor. The turbomachine rotor may comprise a plurality of blades, a rotor disc and a rotor axis. In this case, the axis of rotation of the turbomachine may coincide with the rotor axis. The first component and the second component may be located on the periphery of the rotor disc and circumferentially spaced one to each other. Then, the gap between both components where the leakage flow flows through may point in a direction which is radially extending from the axis of rotation.

[0029] Thus, when the first component and the second component are installed in the turbomachine, in a further embodiment the turbomachine may comprise an axis of rotation and the first surface and the second surface are radially extending from the axis of rotation.

[0030] Depending on the configuration of the turbomachine, a further surface riffle may be beneficial.

[0031] Thus, in another embodiment, the first component may comprise a third surface and the second component comprises a fourth surface. The third surface is opposite to the fourth surface. The second surface comprises a second surface riffle, the third surface comprises a third surface riffle and/or the fourth surface comprises a fourth surface riffle.

[0032] If the seal comprises two surface riffles (instead of three or four surface riffles), it may be beneficial from a manufacturing point of view that the two surface riffles are comprised by the same component. In other words, it may be beneficial if the first component comprises a

first surface riffle and a third surface riffle or if the second component comprises a second surface riffle and a fourth surface riffle.

[0033] As it has been mentioned already, a function of a surface riffle is to create a tortuous leakage path. Depending on a density, or in a non-physical terminology on intensity, of the leakage flow, it may be beneficial to apply a surface riffle on both surfaces opposite to each other. Furthermore, if e.g. the leak path is relatively long, it may be beneficial to have a further surface section with a riffled surface.

[0034] In a further embodiment, the second surface may be substantially parallel to the third surface and the fourth surface. The seal may for example reduce a leakage flow between two adjacent components that are joined with a mortise and tenon joint. A mortise and tenon joint comprises a mortise hole and a tenon. The tenon, formed on the end of a member generally referred to as a rail, may be inserted into e.g. a rectangular cuboid hole cut into a corresponding member, the mortise. Given this configuration, it may be beneficial to incorporate one riffled surface section, i.e. the first surface riffle and/or the second surface riffle, on one side of the tenon and incorporate, opposite and parallel on the other side of the tenon, another riffled surface section comprising the third surface riffle and/or the fourth surface riffle.

[0035] In a preferred embodiment, the leakage flow may be diverted by a diversion angle of greater than 135 degree between the first surface riffle and the third surface riffle and/or between the first surface riffle and the fourth surface riffle.

[0036] In particular, the diversion angle comprises substantially 180 degree. Given the example of a mortise and tenon joint described above, this would imply that the tenon has a shape of a rectangular cuboid.

[0037] A large diversion angle in general has the consequence that the leakage flow is redirected or deflected strongly, which may reduce the leakage flow itself significantly, compared to the case that the leakage flow runs straightly. Therefore, a large diversion angle of the leakage flow may be very beneficial for the seal.

[0038] In another preferred embodiment, the seal comprises a leakage flow access side, a leakage flow exit side and a seal strip with a horizontal seal strip extension and a vertical seal strip extension. A direction of a differential pressure between the leakage flow access side and the leakage flow exit side is substantially perpendicular to the horizontal seal strip extension.

[0039] The horizontal seal strip extension and the vertical seal strip extension may comprise an angle of substantially 90 degree.

[0040] Furthermore, the seal strip comprises a lateral seal strip extension.

[0041] A goal of the seal strip is to significantly further reduce the leakage flow of the seal.

[0042] A seal strip may have a flat shape, which means that the horizontal seal strip extension is at least one order of magnitude greater than the vertical seal strip

extension. In particular, a ratio between the horizontal seal strip extension and the vertical seal strip extension may be greater than 50, preferably greater than 100. Also the lateral seal strip extension is at least one order of magnitude greater than the vertical seal strip extension. In particular, a ratio between the lateral seal strip extension and the vertical seal strip extension may be greater than 50, preferably greater than 100.

[0043] A seal strip may be flexible, i.e. pliable, with regard to a force that is exerted perpendicularly to the horizontal seal strip extension. With regard to another force that is exerted perpendicularly to the vertical seal strip extension, the seal strip may be flexible or stiff.

[0044] It is beneficial that the seal strip is less stiff, i.e. more flexible, than the neighbouring components. In other words, it is beneficial if the seal strip complies when loaded by a stiffer structure, such as e.g. a thermally growing vane segment.

[0045] The seal strip may be partly in contact with the first component and/or the second component. The seal strip may be temporarily in contact with one or both of the components. Given a turbomachine with an axis of rotation, the horizontal seal strip extension may be perpendicularly to a line through the axis of rotation and the horizontal seal strip extension. In stand-by state, a direct contact may exist between parts of a lower horizontal surface of the seal strip, the lower horizontal surface being defined as a surface of the seal strip which is directed towards the axis of rotation of the turbomachine. During rotation of the turbomachine a centrifugal force applies on the seal strip pushing the seal strip away from the axis of rotation. Therefore, during rotation, a direct contact may exist between parts of an upper horizontal surface of the seal strip, the upper horizontal surface being defined as a surface of the seal strip which is directed opposite to the axis of rotation.

[0046] A seal strip may itself have a riffled surface section to reduce the leakage flow, e.g. during operation.

[0047] A side or section of the seal where the leakage flow ingresses, i.e. entries or accesses to or flows into, the surface distance is called the leakage flow access side. The leakage flow access side may be part of or adjacent to a cavity.

[0048] A side or section of the seal where the leakage flow escapes or exits the surface distance is called the leakage flow exit side. The leakage flow exit side may be part of or adjacent to a cavity, too.

[0049] The differential pressure between the leakage flow access side and the leakage flow exit side is defined as the difference between a first pressure at the leakage flow access side and a second pressure at the leakage flow exit side. If the first pressure is greater than the second pressure, the direction of the differential pressure points from the leakage flow access side to the leakage flow exit side. Analogously, if the first pressure is smaller than the second pressure, the direction of the differential pressure points from the leakage flow exit side to the leakage flow access side.

[0050] Exemplarily, in a turbomachine with a gas path - i.e. a main fluid path - section, a radially inner section and two components separated by a gap which has to be sealed, there may be, in a first operation mode of the turbomachine, a differential pressure from the gas path section to the radially inner section, i.e. the seal reduces ingress of gases from the gas path to the radially inner section. However, in a second operation mode of the turbomachine, there may be a differential pressure from the radially inner section to the gas path section, i.e. the seal minimises an escape of gases from the radially inner section to the gas path.

[0051] It is beneficial to place the seal strip, i.e. the horizontal seal strip extension, substantially perpendicularly to the direction of the differential pressure. "Substantially perpendicular" comprises a range from 80 degree to 100 degree, in particular a range from 85 degree to 95 degree. A first advantage of a substantially perpendicularly placed seal strip is the large diversion angle of the leakage flow. In this example, the leakage flow is first diverted by 90 degree, subsequently it is diverted by 180 degree and finally it is diverted again by 90 degree.

[0052] Another advantage of the seal strip is the possibility of defining only a relatively small gap between the surface of the component and the surface of the seal strip. Obviously, thermal expansion of the component and the seal strip during operation should be considered.

[0053] In a preferred embodiment, the first component and the second component are both part of a turbine blade or the first component and the second component are both part of a stator vane.

[0054] In a preferred embodiment, the first component may be a first part of a first turbine blade and the second component may be a second part of the first turbine blade. Alternatively, the second component may also be the second part of a second turbine blade.

[0055] Analogously, the first component may be a first part of a first stator vane and the second component may be a second part of the first stator vane. Alternatively, the second component may also be the second part of a second stator vane.

[0056] Furthermore, the invention is also directed towards a turbomachine comprising a seal as described above, wherein the turbomachine is a gas turbine engine.

[0057] A turbomachine is a machine that transfers energy between a rotor and a fluid. More specifically, it transfers energy between a rotational movement of a rotor and a lateral flow of a fluid. A first type of a turbomachine is a turbine, e.g. a turbine section of a gas turbine engine. A turbine transfers energy from a fluid to a rotor. A second type of a turbomachine is a compressor, e.g. a compressor section of a gas turbine engine. A compressor transfers energy from a rotor to a fluid.

[0058] A gas turbine engine can e.g. be used in aviation, passenger surface vehicles, ships, as mechanical drive and coupled with an electrical generator.

[0059] In a preferred embodiment, the seal is located in a gas turbine section of the turbomachine and/or in a

compressor section of the turbomachine.

[0060] A last aspect of the invention relates to a method of manufacturing a first component of a turbomachine with a reduced leakage flow between the first component and a second component of the turbomachine. The first component comprises a first surface and the second component comprises a second surface. The first surface is opposite to the second surface. The method comprises fabrication of a first surface riffle, in particular by grinding and/or by electrical discharge machining.

[0061] Grinding has to be understood as an abrasive machining process that uses e.g. a grinding wheel as a cutting tool.

[0062] Electric discharge machining (EDM), which is also referred to as spark machining, spark eroding, burning, die sinking or wire erosion, is a manufacturing process whereby a desired shape is obtained using electrical discharges, i.e. sparks.

[0063] 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

[0064] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, of which:

- FIG. 1: shows a riffled seal of a turbomachine and parts of the turbomachine in a cross-sectional view;
- FIG. 2: shows a riffled seal in a cross-sectional view;
- FIG. 3: shows a seal and parts of a nozzle segment in a cross-sectional view;
- FIG. 4: shows a mortise and tenon joint with a riffled seal in a cross-sectional view;
- FIG. 5: shows a circumferential surface riffle; and
- FIG. 6: shows a chordal surface riffle.

[0065] The illustration in the drawing is schematically. It is noted that for similar or identical elements in different figures, the same reference signs will be used.

DETAILED DESCRIPTION OF THE DRAWINGS

[0066] Referring to FIG. 1, a riffled seal of a turbomachine and parts of the turbomachine in a cross-sectional view in a plane perpendicularly to an axis of rotation 66 of the turbomachine are shown. Exemplarily, parts of rotor blades and parts of a rotor disc are illustrated. A first component 11 of the turbomachine comprises a fir-tree-shaped root and a platform. An aerofoil 56 is joined with the first component 11. Next to the first component 11, a second component 21 of the turbomachine is located. The second component 21 similarly comprises a fir-tree-shaped root and a platform. Also an aerofoil 56 is joined with the second component 21. The first component 11

and the second component 21 are separated by a gap. A part of the surface of the first component 11 is denoted by a first surface 12. The first surface 12 comprises a first surface riffle 13. Opposite to the first surface 12 a second surface 22 is located. Finally, the seal shown in FIG. 1 also comprises a seal strip 52, which is located in a pair of slots - each in one of the roots or platforms - perpendicularly to a direction of a differential pressure.

[0067] In FIG. 2 a riffled seal 51 according to the invention is exemplarily shown in a cross-sectional view in more detail. The seal 51 comprises again a first component 11 of a turbomachine with a first surface 12 and a second component 21 of a turbomachine with a second surface 22. The first surface 12 comprises a first surface riffle 13. The first surface riffle 13 comprises a plurality of notches. One of the plurality of notches - identified as notch 61 - is characterised by a notch depth 62 and a notch width 63. In FIG. 2, the plurality of notches comprises notches which feature a round, curved shape.

[0068] The first surface 12 and the second surface 22 are separated by a gap 59 which width is denoted by a surface distance 57. Furthermore, the seal 51 comprises a leakage flow access side 54 and a leakage flow exit side 55, defining thus a direction 58 of a differential pressure. As an example, in FIG. 2 a gas path of the turbomachine is conducted at the leakage flow exit side 55 in the upper part of the drawing, whereas in the lower part of the drawing, at the leakage flow access side 54, a radially inner section with a cavity 67 is situated. Therefore, the seal 51 reduces an undesired ingress of gases from the inner section into the gas path via the gap 59 between the first component 11 and the second component 21. More specifically, a leakage flow 53 is diverted, deflected and slowed down in a region of the first surface riffle 13. Thus a tortuous leakage flow 53 in that region results, leading to an overall reduction of the leakage flow 53.

[0069] FIG. 2 additionally shows another feature to reduce the leakage flow 53. A seal strip 52, comprising a horizontal seal strip extension 52a and a vertical seal strip extension 52b, is introduced into a leak path of the leakage flow 53. The leakage flow 53 is thus split into two fractions and guided along a number of edges.

[0070] FIG. 3 shows a seal 51 and parts of a nozzle segment in a cross-sectional view in a plane through an axis of rotation 66 of a turbomachine. A stator vane 68 with a mortise and tenon joint can be identified. The tenon refers to a first component 11 of the turbomachine, the mortise to a second component 21.

[0071] FIG. 4 shows a mortise and tenon joint with a riffled seal 51 in more detail. Again, the tenon refers to a first component 11 of a turbomachine, the mortise to a second component 21. In the drawing, a leakage flow access side 54 is on the left, a leakage flow exit side 55 on the right. Thus, a direction 58 of a differential pressure is pointing from left to right. The first component 11 comprises a first surface 12 with a first surface riffle 13. The second component 21 comprises a second surface 22 which is opposite to the first surface 12. Parallel to the

first surface 12 is located the third surface 31, which is also comprised by the first component 11. The third surface 31 comprises a third surface riffle 32, which is opposite to a fourth surface 41. The fourth surface 41 is comprised by the second component 21.

[0072] An effect of the tenon on the leakage flow 53 is that the tenon acts as a barrier to the leakage flow 53. An effect of the first surface riffle 13 and the second surface riffle 32 is that they force the leakage flow 53 into a tortuous path. By these measures, the leakage flow is thus reduced highly efficiently.

[0073] FIGS. 5 and 6 show embodiments of a surface riffle located on a surface in axial direction. In FIG. 5, a first surface riffle 13 on a first component 11 is shown. The first surface riffle 13 comprises four notches 61. Due to the curved shape of the notches 61, i.e. the curved shape of respective notch lengths, the first surface riffle 13 can be denoted as a circumferential surface riffle. Furthermore and in the shown example, it can be seen that the notches 61 stop shortly before a rim or edge of the first component 11. The reason for that is an avoidance of an extra leak path from a first side 64 of the first component 11 along a notch 61 to a second side 65 of the first component 11.

[0074] Finally, in FIG. 6, a first surface riffle 13 on a first component 11 is shown. The first surface riffle 13 comprises four notches 61. The notches 61 feature a shape of a straight line and can thus be denoted as a chordal surface riffle. An advantage of this shape is e.g. easing of manufacture.

Claims

1. Seal (51) of a turbomachine for reducing a leakage flow (53) between a first component (11) of the turbomachine and a second component (21) of the turbomachine, the seal (51) comprising the first component (11) with a first surface (12) and the second component (21) with a second surface (22), wherein
 - the first component (11) is stiff with regard to a first force exerted perpendicularly to the first surface (12);
 - the second component (21) is stiff with regard to a second force exerted perpendicularly to the second surface (22);
 - the first surface (12) is opposite to the second surface (22); and
 - the first surface (12) comprises a first surface riffle (13).
2. Seal (51) according to claim 2, **characterised in that** the first surface riffle (13) comprises a plurality of notches.
3. Seal (51) according to one of the preceding claims, **characterised in that**

- the turbomachine comprises an axis of rotation (66) and
 - the first surface (12) and the second surface (22) are radially extending from the axis of rotation (66).
4. Seal (51) according to one of the preceding claims, **characterised in that**
- the first component (11) comprises a third surface (31) and the second component (21) comprises a fourth surface (41);
 - the third surface (31) is opposite to the fourth surface (41); and
 - the second surface (22) comprises a second surface riffle, the third surface (31) comprises a third surface riffle (32) and/or the fourth surface (41) comprises a fourth surface riffle.
5. Seal (51) according to claim 4, **characterised in that** the second surface (22) is substantially parallel to the third surface (31) and the fourth surface (41).
6. Seal (51) according to one of the claims 4 or 5, **characterised in that** the seal (51) is configured such that the leakage flow (53) is diverted by a diversion angle of greater than 135 degree, in particular greater than substantially 180 degree,
- between the first surface riffle (13) and the third surface riffle (32) and/or
 - between the first surface riffle (13) and the fourth surface riffle.
7. Seal (51) according to one of the preceding claims, **characterised in that** the seal (51) comprises
- a leakage flow access side (54),
 - a leakage flow exit side (55) and
 - a seal strip (52) with a horizontal seal strip extension (52a) and a vertical seal strip extension (52b);
- wherein
- a direction (58) of a differential pressure between the leakage flow access side (54) and the leakage flow exit side (55) is substantially perpendicular to the horizontal seal strip extension (52a).
8. Seal (51) according to one of the preceding claims, **characterised in that** the first component (12) is a first part of a first turbine blade and the second component (14) is a second part of the first turbine blade or the second part of a second turbine blade.
9. Seal (51) according to one of the claims 1 to 7, **characterised in that** the first component (12) is a first
- part of a first stator vane and the second component (14) is a second part of the first stator vane or the second part of a second stator vane.
10. Turbomachine comprising a seal (51) according to one of the preceding claims, **characterised in that** the turbomachine is a gas turbine engine.
11. Turbomachine according to claim 10, **characterised in that** the seal (51) is located in a gas turbine section of the turbomachine and/or in a compressor section of the turbomachine.
12. Method of manufacturing a first component (11) of a turbomachine with a reduced leakage flow (53) between the first component (11) and a second component (21) of the turbomachine, the first component (11) comprising a first surface (12) and the second component (21) comprising a second surface (22), the first surface (12) being opposite to the second surface (22); the method comprising fabrication of a first surface riffle (13), in particular by grinding and/or by electrical discharge machining.

FIG 1

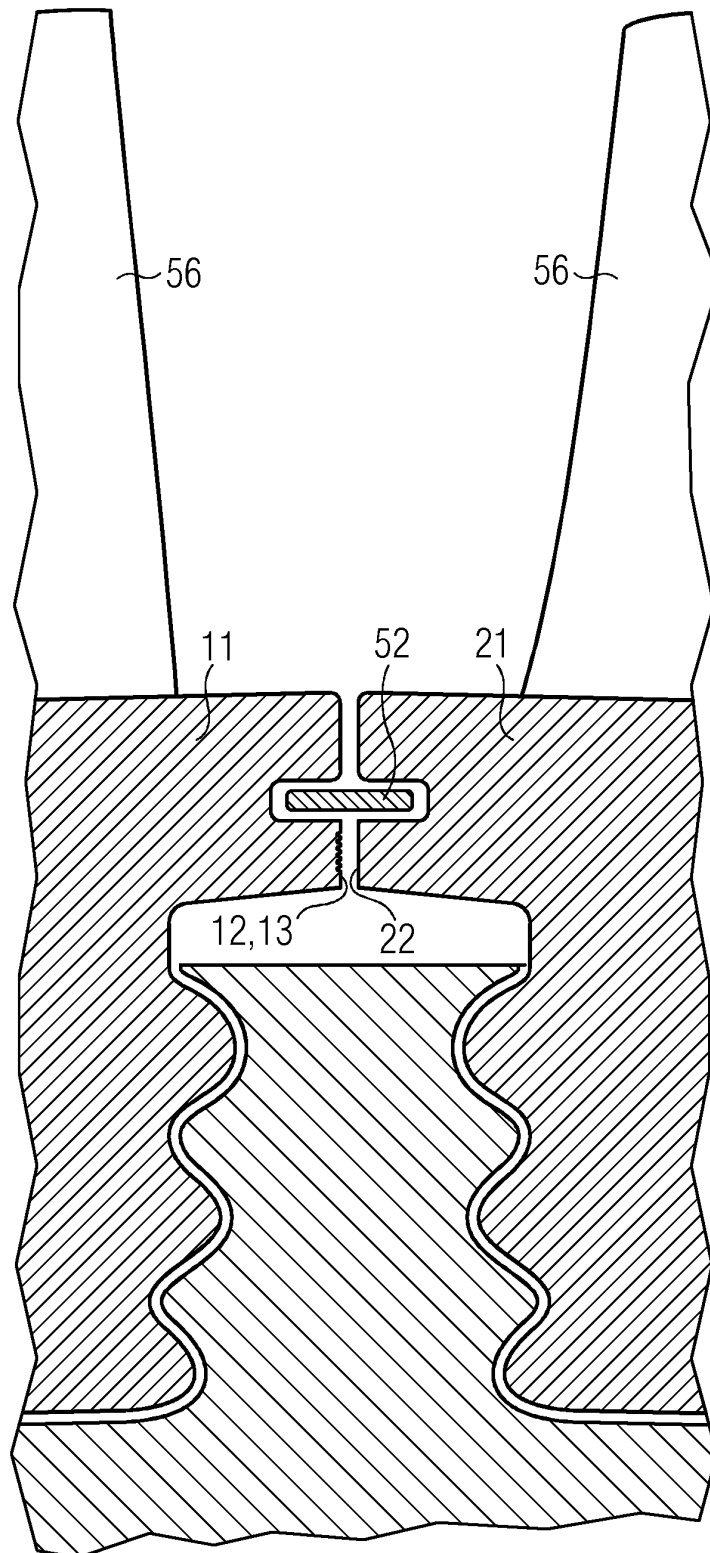


FIG 2

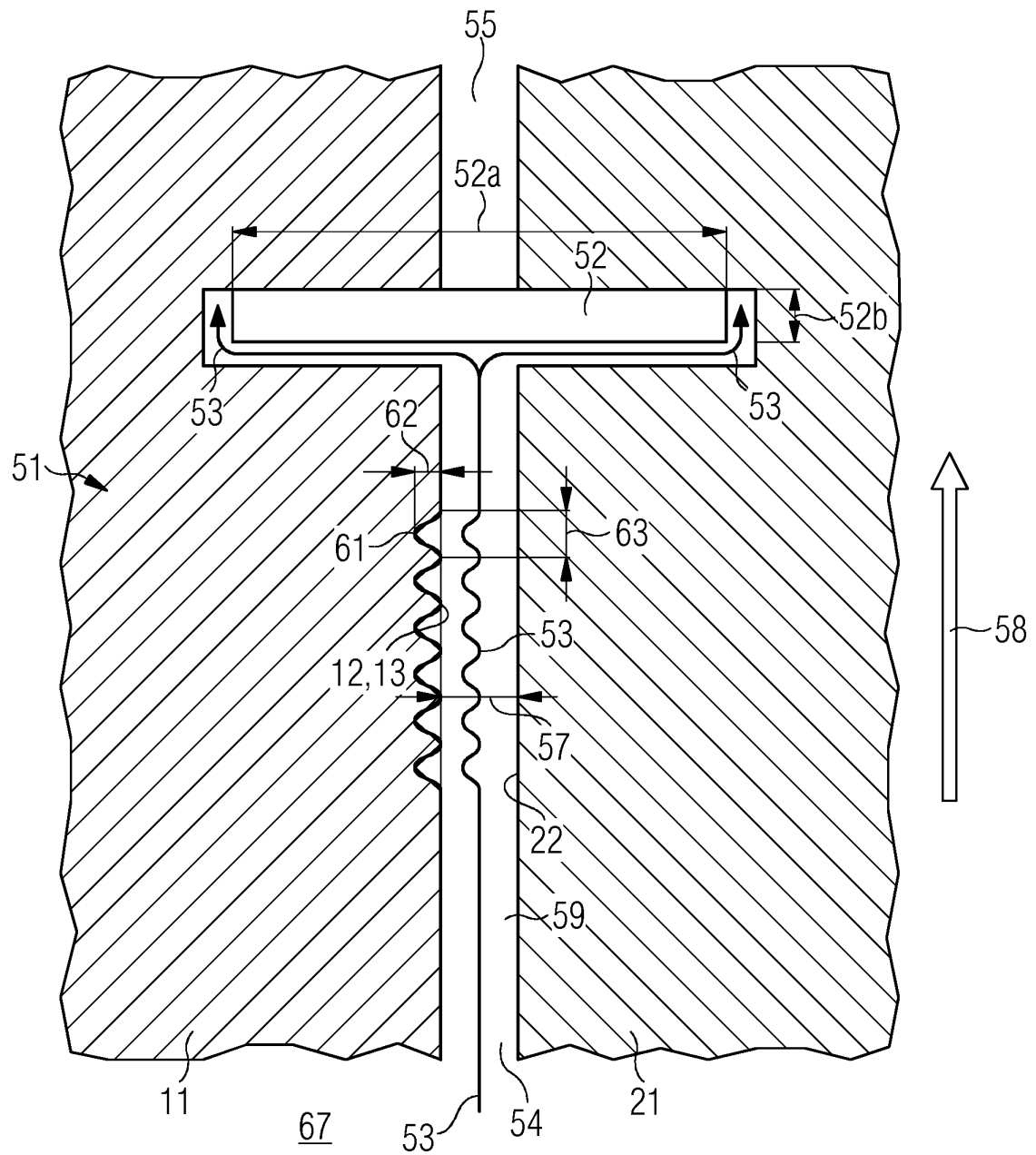


FIG 3

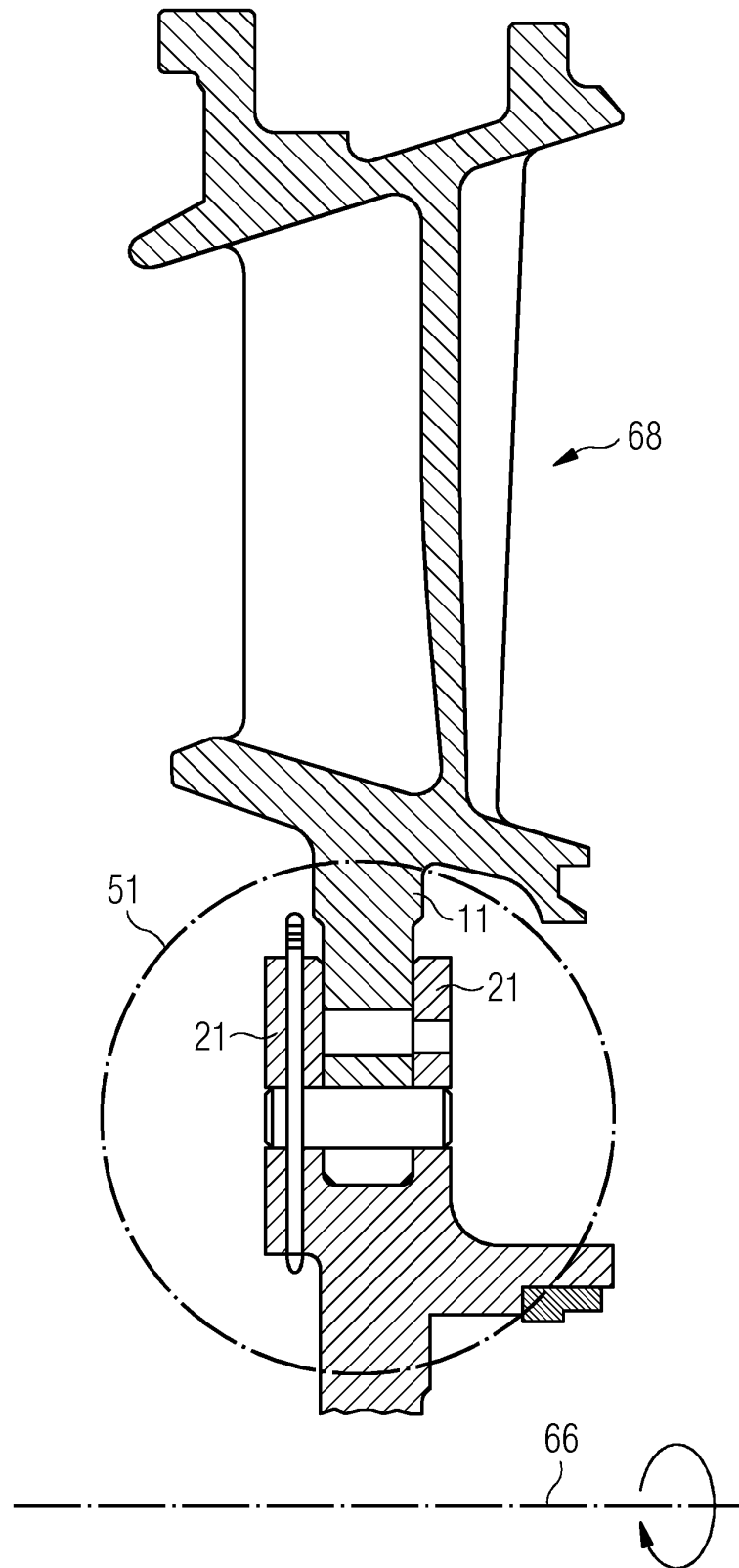


FIG 4

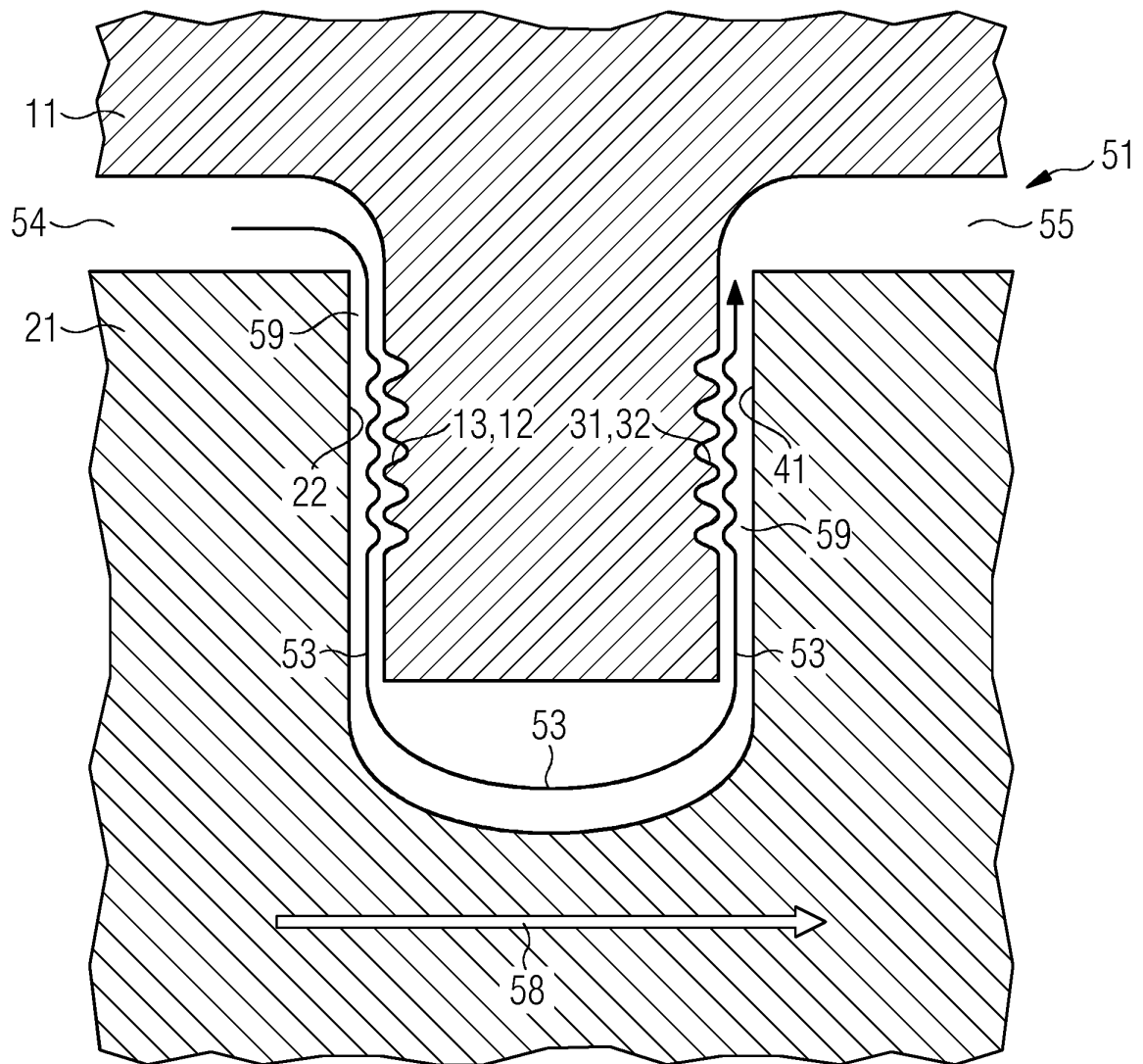


FIG 5

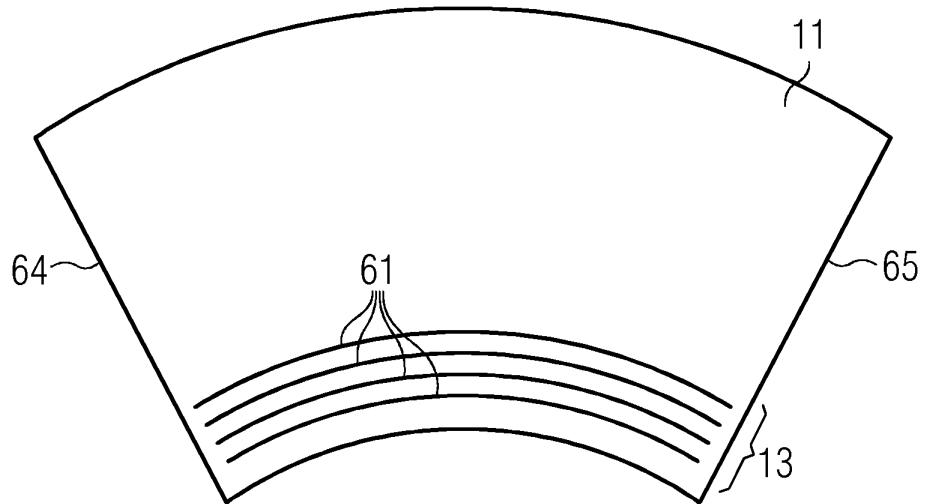
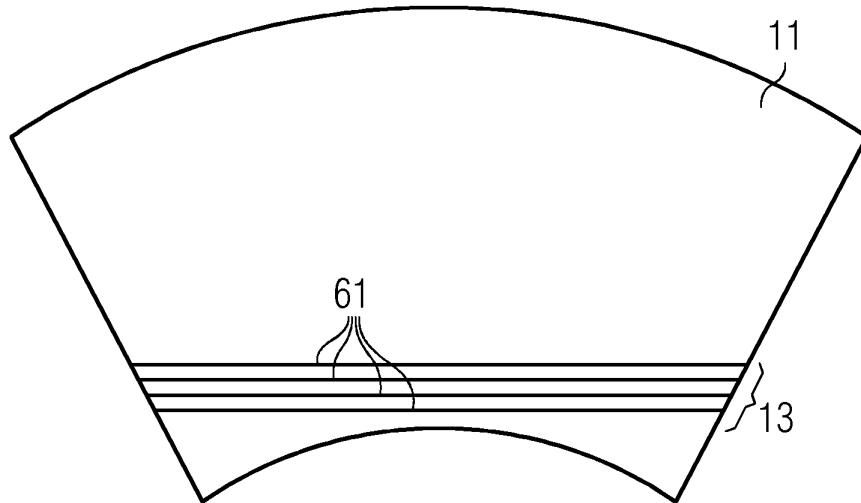


FIG 6





EUROPEAN SEARCH REPORT

Application Number
EP 13 15 5933

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 515 000 A1 (ALSTOM TECHNOLOGY LTD [CH]) 16 March 2005 (2005-03-16) * paragraph [0016] - paragraph [0021] * * abstract; figures 2,3 *	1-6,8, 10-12	INV. F01D11/00 F01D11/02
X	DE 198 14 442 A1 (MITSUBISHI HEAVY IND LTD [JP]) 1 October 1998 (1998-10-01) * column 3, line 18 - column 4, line 16 * * abstract; figures 1-3 *	1-3,7-12	
X	EP 0 919 701 A1 (MITSUBISHI HEAVY IND LTD [JP]) 2 June 1999 (1999-06-02) * paragraph [0008] * * paragraph [0022] - paragraph [0024] * * paragraph [0030] * * abstract; figures 1-3 *	1-5,8-12	
X	US 2009/160135 A1 (TURINI GABRIELE [IT] ET AL) 25 June 2009 (2009-06-25) * paragraph [0002] * * paragraph [0021] - paragraph [0022] * * abstract; figure 5 *	1,2, 10-12	TECHNICAL FIELDS SEARCHED (IPC)
X	GB 2 447 892 A (ROLLS ROYCE PLC [GB]) 1 October 2008 (2008-10-01) * the whole document *	1,2, 10-12	F01D
X A	EP 2 407 641 A1 (SIEMENS AG [DE]) 18 January 2012 (2012-01-18) * paragraph [0001] * * paragraph [0018] - paragraph [0022] * * abstract; figures *	1,2,7, 10,11 9	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 31 July 2013	Examiner O'Shea, Gearóid
CATEGORY OF CITED DOCUMENTS 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		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	

EPO FORM 1503 03.02 (P04C01)

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

EP 13 15 5933

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
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

31-07-2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1515000 A1	16-03-2005	EP 1515000 A1	16-03-2005
		US 2005100439 A1	12-05-2005
DE 19814442 A1	01-10-1998	CA 2230217 A1	30-09-1998
		DE 19814442 A1	01-10-1998
		JP H10274003 A	13-10-1998
EP 0919701 A1	02-06-1999	CA 2263746 A1	17-12-1998
		DE 69818947 D1	20-11-2003
		DE 69818947 T2	15-07-2004
		EP 0919701 A1	02-06-1999
		JP H112104 A	06-01-1999
		JP 3310907 B2	05-08-2002
		US 6149387 A	21-11-2000
		WO 9857045 A1	17-12-1998
US 2009160135 A1	25-06-2009	NONE	
GB 2447892 A	01-10-2008	NONE	
EP 2407641 A1	18-01-2012	CN 102985639 A	20-03-2013
		EP 2407641 A1	18-01-2012
		EP 2593644 A1	22-05-2013
		WO 2012007158 A1	19-01-2012
		WO 2012007506 A1	19-01-2012

EPO FORM P0459

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