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(54) **COMPRESSOR BLADES**

(57) This disclosure concerns aerofoils (24) for an axial flow compressor (14). The compressor (14) has an array of aerofoils (14B, 24) angularly spaced about its axis of rotation (11). The aerofoils (24) have leading (32) and trailing (34) edges extending in a direction spanning a flow region defined between a radially inner rotor component (14A) and a radially outer casing (14C). Each aerofoil (24) has opposing pressure (36) and suction (38) surfaces extending between the leading (32) and trailing (34) edges and terminating at a free end (30) of the aerofoil. Each aerofoil (24) leans towards the pressure surface (36) by an angle of between 10° and 80° in the vicinity of the aerofoil tip (30). The aggressive negative lean towards the tip (30) may help reduce over-tip leakage flow in use.

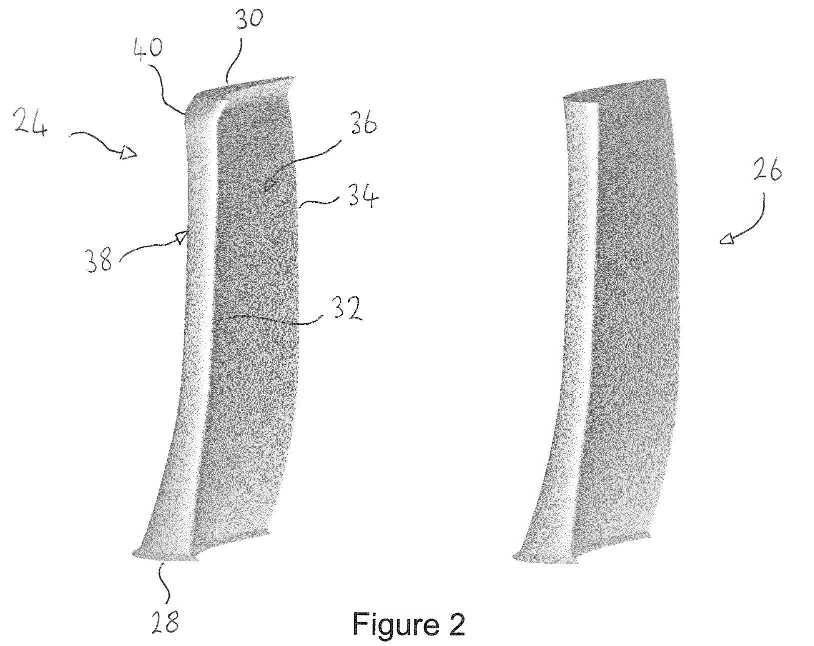

Figure 2

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Description

BACKGROUND OF THE INVENTION

[0001] The present disclosure concerns fluid-washed components of axial flow machines, e.g. such as gas turbine engines. More specifically, the disclosure concerns blades and/or vanes used to drive or redirect flow through an axial flow machine.

[0002] It is generally desirable to reduce flow over the tip of blades or vanes in an axial flow machine. Such leakage flow between the rotor and stator occurs based on the pressure difference between opposing sides/surfaces of a blade and the clearance of the blade tip from the opposing casing structure. Tip leakage flows cause efficiency losses and significant effort is expended in the design of the opposing rotor and stator portions to minimise such losses, i.e. by minimising the clearance between the tips of the rotor blades and the surrounding casing. Similarly it is desirable to minimise the gap between the tips of stator vanes and the opposing rotor wall.

[0003] Despite such efforts, practical considerations of tolerances, thermal expansion, etc mean that tip leakage flow remains an ongoing efficiency loss in axial compressors. The efficiency is degraded not only by the volume of fluid passing over the tip from the pressure to the suction side of the aerofoil, but also by the subsequent mixing losses when the leakage flow mixes with the mainstream flow downstream of the compressor blade/vane.

[0004] It is known to use shrouded blades to reduce tip leakage losses but the use of blade shrouds requires an unwanted mass at the tip of the blade. Shrouded blades thus create a number of mechanical issues and are generally undesirable.

[0005] US 2008/0213098 A1 and corresponding EP 1 953 344 A1 disclose an attempt to resolve tip leakage problems by providing a winglet at the compressor blade tip, characterised by a sharp curvature, i.e. a corner, at the tip compared to the remainder of the blade. The benefits disclosed for such a winglet comprise a reduction in driving pressure difference across the blade tip, a reduction in tip clearance and the shielding of aerodynamic shocks of the flow against interaction with the casing.

[0006] It is an aim of the present disclosure to provide an additional/alternative way of reducing tip leakage. It may be considered an aim to promote a fluid flow regime in the vicinity of the tip gap that reduces or mitigates tip leakage losses.

BRIEF SUMMARY OF THE INVENTION

[0007] According to a first aspect of the disclosure there is provided an axial flow compressor having an axis of rotation and comprising an array of aerofoils angularly spaced about said axis, the aerofoils comprising leading and trailing edges extending in a direction spanning a flow region defined between a radially inner rotor component and a radially outer casing, each aerofoil comprising opposing pressure and suction surfaces extending between the leading and trailing edges and terminating at a free end of the aerofoil, wherein each aerofoil leans towards the pressure surface by an angle of between 10° and 80° in the vicinity of the free end of the aerofoil.

[0008] The vicinity of the free end of the aerofoil may comprise a minority of the height of the aerofoil towards the free end. The vicinity of the free end of the aerofoil may include the free end of the aerofoil. The vicinity of the free end may be close to the free end. The vicinity of the free end of the aerofoil may comprise up to 20% or 15% of the aerofoil height. The vicinity of the free end of the aerofoil may comprise less than or equal to 12%, 10% or 8% of the aerofoil height. The angle that the aerofoil leans towards the pressure surface by may be the angle between the aerofoil and the radial direction. The angle that the aerofoil leans towards the pressure surface by may be the angle between the free end of the aerofoil and the radial direction.

[0009] The vicinity of the free end of the aerofoil may comprise greater than 3%, 4% or 5% of the aerofoil height. A specific aerofoil lean over 5-10% of the blade height towards its free end may be used specifically for the purpose of tip leakage reduction.

[0010] The lean towards the pressure surface may be referred to herein as a negative lean. The lean may represent a relatively aggressive change in orientation of the aerofoil, e.g. a change in orientation of between 20° and 80°. The angle formed at the tip relative to a radial direction (e.g. the angle of lean) may be in the vicinity of 40-60°. Thus the total change in orientation in the vicinity of the free end may be greater than the angle at the tip if the aerofoil has a positive lean over an aerofoil region adjacent the vicinity of the free end.

[0011] Each aerofoil may lean towards the pressure surface by an angle of at least 10°, 20°, 30° or 40° in the vicinity of, or at, the free end of the aerofoil.

[0012] Each aerofoil may lean towards the pressure surface by an oblique angle of less than or equal to 75°, 70°, 65°, 60°, 55°, 50° or 45° in the vicinity of, or at, the free end. An aerofoil change in orientation or negative lean in the vicinity of the tip of approximately 50-60° may be used.

[0013] A change in orientation of the aerofoil towards the tip may be used to trigger separation of the flow over the aerofoil surface in the vicinity of the tip gap. This may reduce the effective flow area for flow over the tip between the pressure and suction surfaces.

[0014] The lean towards the pressure surface may be over a majority of the chord length, such as all, or substantially all, of the chord length. The lean may be substantially constant over the chord length of the aerofoil or may vary over the chord length, e.g. having a greater lean towards the trailing edge.

[0015] The aerofoil cross-section profile may remain substantially constant through the height of the aerofoil in the vicinity of the free end.

[0016] The aerofoil may lean away from a radial direction towards the axis of rotation of the compressor in the vicinity of the free end.

[0017] The aerofoil may be angled and/or curved towards the pressure surface in the vicinity of the free end.

[0018] The lean towards the pressure surface may be relative to a radial direction defined with respect to the axis of rotation. Additionally or alternatively, the lean towards the pressure surface in the vicinity of the free end may be defined with respect to the orientation, or average orientation, of the remainder of the aerofoil. Thus the orientation may be defined in absolute/Cartesian or relative terms.

[0019] The remainder of the aerofoil (e.g. the remainder of the aerofoil height) may lean towards either the pressure or suction surface. The remainder of the aerofoil may comprise a positive lean of less than 40°, 30 °, 20° or 10°.

[0020] The aerofoil may comprise a negative turning point or height. The lean of the aerofoil towards the pressure side may increase from the turning point/height to the tip. The rate of change of orientation of the aerofoil may increase from the turning point/height to, or towards, the tip. The aerofoil may comprise two turning points.

[0021] The angular orientation of the aerofoil at the tip may be less than or equal to 45°, 40° or 35° from the orientation of the aerofoil at the turning point/height.

[0022] The aerofoil may be smoothly contoured/curved from the turning point/height to the free end.

[0023] Any of the angular definitions provided herein with respect to the aerofoil, or a blade or vane may be references to the component as a whole or else a longitudinal section thereof, e.g. from the root to the tip.

[0024] The aerofoils may be mounted to the compressor rotor, e.g. blades. The aerofoils may be mounted to a compressor drum. Additionally or alternatively the aerofoils may be mounted to the compressor casing/stator, e.g. vanes.

[0025] A gap may be provided between the free end of the aerofoils and the opposing casing/rotor surface.

[0026] According to a further aspect of the disclosure, there is provided a blade for an axial flow machine, the blade comprising leading and trailing edges extending from a root of the blade to a tip of the blade. The blade comprises opposing major surfaces extending between the leading and trailing edges and terminating at a blade tip. The blade leans towards the pressure surface by an angle of between 10° and 80° in the vicinity of the blade tip.

[0027] The blade may be an aerofoil. The opposing major surfaces may be a pressure surface and a suction surface. The vicinity of the blade tip may include the blade tip. The vicinity of the blade tip may be a minority of the height of the aerofoil towards the tip.

[0028] The blade may be a compressor blade. A rotor or rotor drum may be provided comprising one or more of the compressor blades.

[0029] Each blade may lean towards the pressure surface by an oblique angle of less than or equal to 75°, 70°, 65°, 60°, 55°, 50°, 45°, 40°, 35°, 30°, 25°, 20° or 15° in the vicinity of, or at, the blade tip.

[0030] According to a further aspect of the disclosure, there is provided a stator vane for an axial flow machine the vane comprising leading and trailing edges extending from a base of the vane to a tip of the vane, the vane comprising opposing major surfaces extending between the leading and trailing edges and terminating at a vane tip, wherein the vane leans towards the pressure surface by an angle of between 10° and 80° in the vicinity of the tip.

[0031] A stator or casing may be provided comprising one or more of the stator vanes.

[0032] According to a further aspect there may be provided a gas turbine engine comprising any or any combination of a compressor, a blade, a rotor, a vane or a stator/casing according to a preceding aspect of the disclosure.

[0033] The skilled person in the art will understand that any of the essential or preferable features defined in relation to any one aspect of the disclosure may be applied to any further aspect, where practicable. Accordingly the invention may comprise various alternative configurations of the features defined above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] Practicable embodiments are described in further detail below by way of example only with reference to the accompanying drawings, of which:

Fig. 1 shows a schematic longitudinal half-section through a gas turbine engine;

Fig. 2 shows a front three-dimensional view of an example of a compressor blade according to the disclosure alongside a datum blade;

Fig. 3 shows a three-dimensional view from the side of the blade examples of Fig. 2; and,

Fig. 4 shows a schematic two-dimensional front view of the leading edge of a blade according to the disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0035] It is known that a conventional compressor blade may have a slight lean evenly distributed over its height/span. It is a general focus of this disclosure to provide a far more aggressive change in blade/vane orientation, purposely in a restricted region of the blade/vane towards its tip.

[0036] It has been found by the inventors that the change in orientation of the aerofoil as discussed herein can trigger flow separation from the aerofoil surface at or close to the tip. Triggering flow separation in this manner means that the boundary layer becomes detached from the surface, thereby creating a turbulent flow regime which reduces the effective flow area through the tip clearance gap. This causes chaotic flow behaviour/eddies as the separated boundary layer interacts with faster flow further from the rigid surface.

[0037] It will be appreciated that there is a difference between the maximum available flow area defined by the gap itself (i.e. the clearance between opposing rigid surfaces) and the effective flow area caused by the pressure distribution/gradient in the gap.

[0038] For this purpose, it has been found that a change in orientation in the region of 20-70° in the final portion of the blade/vane close to the tip, e.g. an angle of approximately 50-60° relative to a radial direction, or the remainder of the blade/vane, is generally optimal and that it is not desirable for the aim of the present disclosure to cause a change in direction approaching 90°, akin to a winglet.

[0039] Turning now to Fig. 1, a gas turbine engine is generally indicated at 10, having a principal and rotational axis 11. The engine 10 comprises, in axial flow series, an air intake 12, a propulsive fan 13, an intermediate pressure compressor 14, a high-pressure compressor 15, combustion equipment 16, a high-pressure turbine 17, an intermediate pressure turbine 18, a low-pressure turbine 19 and an exhaust nozzle 20. A nacelle 21 generally surrounds the engine 10 and defines both the intake 12 and the exhaust nozzle 20.

[0040] The gas turbine engine 10 works in the conventional manner so that air entering the intake 12 is accelerated by the fan 13 to produce two air flows: a first air flow into the intermediate pressure compressor 14 and a second air flow which passes through a bypass duct 22 to provide propulsive thrust. The intermediate pressure compressor 14 compresses the air flow directed into it before delivering that air to the high pressure compressor 15 where further compression takes place.

[0041] The compressed air from the high-pressure compressor 15 is directed into the combustion equipment 16 where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through, and thereby drive the high, intermediate and low-pressure turbines 17, 18, 19 before being exhausted through the nozzle 20 to provide additional propulsive thrust. The high 17, intermediate 18 and low 19 pressure turbines drive respectively the high pressure compressor 15, intermediate pressure compressor 14 and fan 13, each by a suitable interconnecting shaft.

[0042] Other gas turbine engines to which the present disclosure may be applied may have alternative configurations. By way of example such engines may have an alternative number of interconnecting shafts (e.g. two) and/or an alternative number of compressors and/or turbines. Further the engine may comprise a gearbox provided in the drive train from a turbine to a compressor and/or fan.

[0043] The present concept was devised for use within the compressor, i.e. the intermediate 14 or high 15 pressure compressor of engine 10. However the disclosure is not limited thereto and may be applied to other axial flow machines that suffer from tip gap flow losses, causing flow efficiency losses.

[0044] As shown in Fig. 1 the compressor 14 comprises a compressor drum 14A and a plurality of rows of compressor blades 14B mounted thereto. Each row of blades comprises a radial array of angularly spaced blades. Surrounding the compressor is a casing 14C arranged around the common axis 11 to define an annular flow passage between the compressor drum 14A and casing 14C.

[0045] The casing 14C comprises a plurality of rows of stator vanes 14D mounted thereto. Each row of vanes 14D comprises a radial array of angularly spaced vanes. Successive compressor stages comprise paired rows of blades 14B and vanes 14C.

[0046] Blades depend outwardly from the rotor drum 14A towards the casing 14C and terminate at a free end, or tip, with a small clearance from the casing, thereby leaving a tip gap. Vanes 14D depend inwardly from the casing towards the drum 14A and terminate at a free end, or tip, with a small clearance from the drum, thereby leaving a tip gap. Thus the blades 14B and vanes 14D span the majority of the annular flow passage.

[0047] The following description proceeds in relation to compressor blades. However it will be appreciated by the skilled person that the general principles, geometric features and potential benefits disclosed herein may also apply to stator vanes. It is intended that the scope of this disclosure encompasses the fluid washed components of both stator and rotor components of axial flow machines. Both vanes and blades typically have the same tip gap issues discussed herein.

[0048] Turning now to Figs. 2-4, there is shown an example of an individual blade 24 according to the disclosure alongside a datum blade 26. The blade 24 is aerofoil-shaped in section over its entire height from its root end 28 to its tip 30. A conventional root formation is not shown but would be provided at the end 28 for mounting the blade on the drum 14A.

[0049] The blade 24 has a leading edge 32, a trailing edge 34 and opposing convex/pressure 36 and concave/suction 38 faces extending between the leading and trailing edges.

[0050] Depending on the direction of rotation of the compressor, the pressure and suction surfaces may be opposingly oriented and the aerofoil curvature (i.e. the sectional profile) may be mirrored.

[0051] In Figs. 2-4, there is shown a change in orientation of the blade 24, whereby the blade is bent/curved towards the pressure side 36 close to the tip 30. The change in orientation may be referred to herein as a lip region 40. The lip region 40 is shown in an exaggerated/schematic manner in Fig. 4. In Figs. 3 and 4 the lip region 40 is shown in the same orientation so that comparison can be draw between the different schematic and three-dimensional views.

[0052] At the tip 30, the end face of the blade lies in a tangential/circumferential plane with respect to the axis of rotation. Therefore the end face is generally perpendicular to a height/radial direction of the blade but obliquely angled relative to the blade (e.g. the pressure and/or suction surfaces thereof) in the lip region 40. The internal angle formed between the end face at the tip and the direction of the blade is thus equal to the angle of lean in the lip region 40. This may result in the end face area being greater than that of the cross-sectional area of the blade.

[0053] In Fig. 4, there is shown a turning point A at which the blade 24 (e.g. the leading edge 32 or a centreline thereof) starts to lean negatively towards pressure side 36. The point A may be considered to comprise a line, e.g. a chord line, along the blade 24 when viewed from the side or in cross section. The line is of substantially constant height in this example but the relevant region of the blade could vary between the leading 32 and trailing 34 edges within the limits disclosed herein.

[0054] At the point/line A, the blade turns towards the pressure side, whereas the remainder of the blade has a generally neutral or positive lean.

[0055] The angular orientation of the blade 24 (or leading edge 32) increases gradually from point A towards the tip 30 such that a maximum lean angle is achieved at the tip.

[0056] Fig. 4 shows a blade height, L, and a height, L1, from point A to the tip 30. The height L1 may thus define the portion of the blade height L that comprises the lip region 40.

[0057] The angle, β, is defined as the angle formed between the blade 24 or leading edge 32 and a radial direction R with respect to the axis of rotation of the compressor in use.

[0058] Further details of the turning point A and max lean angle β can be defined as follows:

> $L1/L \leq 0.05\text{-}0.1$ (i.e. lip region height of 5%-10% or less of the blade height);
>
> $\beta_{max} \leq 60°$ (i.e. a max negative lean of 60° between point A and the tip);
>
> a maximum change in orientation of 80° between point A and the tip (e.g. if the blade has a positive lean leading up to point A from the root)
>
> a smooth transition from point A to the tip.

[0059] Any or any combination of the above details may be used to define a component according to aspects of the present disclosure.

[0060] The local negative lean at the tip of the aerofoil increases the angle of attack of the over-tip leakage flow (from pressure to suction side), which increases the blockage in the tip gap, thus reducing the effective tip gap area and resultant leakage flow. The aerodynamic performance of the blade/vane and axial flow compressor as a whole can thus be achieved. Whilst it is not a limitation of aspects of this disclosure, it is feasible that a leakage flow reduction of e.g. 3-7% may be achieved. When considered in conjunction with the mixing losses created as the leakage flow mixes with the mainstream flow through the compressor, it will be appreciated that such aero-efficiency improvements can have a significant impact on performance.

[0061] Diminishing returns are experience for higher angles of blade lean in the lip region 40. For a conventional blade, such as datum blade 26, the lift distribution is spread over the whole blade height/span. A negative lean of the magnitude proposed by the present disclosure is generally undesirable for overall aerodynamic efficiency of the blade and so it is proposed to concentrate a relatively aggressive change in orientation to the tip region only.

[0062] The design of the remainder of the blade may be modified slightly to accommodate the lip region 40. For example a positive lean may be provided in the leading edge 32 and/or blade 24 leading up to the turning point/line A, as can be seen in Fig. 4.

[0063] Further/alternative definitions of a blade/vane may be made according to the extremes of the depth of the blade/vane in a lateral/circumferential direction, e.g. when viewed front on as shown in Fig. 4. The depth dimension, S, can be defined as shown in Fig. 4, which may be divided into negative, S1, and positive, S2, components relative to a radial line R1 coinciding with the leading edge 32 at its base/root end 28. Thus the blade may be characterised by S1>0 (i.e. a negative location at the tip); S1=0 (i.e. a neutral location at the tip) ; or, $S_{tip}<S2$ (i.e. a positive location at the tip). Similarly the value of S in the tip region 40 may be greater than, equal to, or less than the value of S for the remainder of the blade/vane. Any such relationship may be used in conjunction with any other relationship or geometric feature defined herein as an aspect of the disclosure.

[0064] In different aspects of the disclosure, the blade/vane may have a more conventional lean of less than 20°, 15° or 10° spread over the remainder of the blade/vane height, as well as a more aggressive lean towards the tip as described herein.

[0065] Aside from any aero-performance benefits attributed to the modified blade/vane design, the negative lean could also help with the tip rubbing the casing liner since the leaning tip would act more akin to a cutting tool and hence provide a cleaner rub. This may reduce the heat resulting from a tip rubbing against the casing which is linked with the tip cracking.

[0066] It will be understood that the invention is not limited to the embodiments above-described and various modifications and improvements can be made without departing from the concepts described herein. Except where mutually exclusive, any of the features may be employed separately or in combination with any other features and the disclosure extends to and includes all combinations and subcombinations of one or more features described herein.

Claims

1. An axial flow machine (10, 14) having an axis of rotation (11) and comprising an array of aerofoils (14B, 24) angularly spaced about said axis (11), each aerofoil (24) comprising:

   leading (32) and trailing (34) edges extending in a direction spanning a flow region defined between a radially inner rotor component (14A) and a radially outer casing (14C), the leading (32) and trailing (34) edges terminating at a free end (30) of the aerofoil (24);
   opposing pressure (36) and suction (38) surfaces extending between the leading (32) and trailing (34) edges;
   wherein each aerofoil (24) leans towards the pressure surface (36) by an angle of between 10° and 80° in the vicinity (40) of the free end (30) of the aerofoil.

2. A machine (10, 14) according to claim 1, wherein the vicinity (40) of the free end of the aerofoil comprises less than 15% of the aerofoil height.

3. A machine (10, 14) according to claim 1, wherein the vicinity (40) of the free end of the aerofoil comprises less than or equal to 12% of the aerofoil height.

4. A machine (10, 14) according to any preceding claim, wherein each aerofoil (24) leans towards the pressure surface (36) by an angle of between 30° and 60° in the vicinity of the free end of the aerofoil.

5. A machine (10, 14) according to any preceding claim, wherein each aerofoil (24) leans towards the pressure surface in the vicinity (40) of the free end (30) of the aerofoil (24) over the whole chord length between the leading (32) and trailing (34) edges.

6. A machine (10, 14) according to any preceding claim, wherein the aerofoil cross-section profile remains substantially constant through the height of the aerofoil (24) in the vicinity (40) of the free end (30).

7. A machine (10, 14) according to any preceding claim, wherein the free end (30) of the aerofoil (24) has an end face that is obliquely angled relative to the orientation of the aerofoil (24) in the vicinity (40) of the free end (30).

8. A machine (10, 14) according to any preceding claim, wherein the free end (30) of the aerofoil (24) faces radially outwardly relative to the axis of rotation (11).

9. A machine (10, 14) according to any preceding claim, wherein each aerofoil (24) leans away from a radial direction (R) towards the circumferential direction in the vicinity (40) of the free end (30).

10. A machine (10, 14) according to any preceding claim, wherein each of the pressure (36) and suction (38) surfaces are smoothly curved towards the pressure surface (36) in the vicinity (40) of the free end (30).

11. A machine (10, 14) according to any preceding claim, wherein each aerofoil (24) has a negative turning point (A) defining the boundary between the vicinity of the free end (30) of the aerofoil (24) and a remainder of the aerofoil, wherein the lean of the aerofoil (24) towards the pressure side (36) increases from the turning point (A) to the free end (30).

12. A machine (10, 14) according to any preceding claim, wherein the angular orientation of the aerofoil (24) at the free end (30) is less than or equal to 60° from a radial direction (R) with respect to the axis of rotation (11).

13. A machine (10, 14) according to any preceding claim, wherein the array of aerofoils (24) are an array of blades (14B) mounted to a rotor (14A) of the axial flow machine (10, 14) and the free ends (30) of the blades (24) face an opposing rotor casing (14C).

14. A machine (10, 14) according to any preceding claim, comprising a compressor (14) of a gas turbine engine (10), wherein the compressor comprises the array of aerofoils.

15. An aerofoil (24) for an axial flow compressor (14), the aerofoil (24) comprising leading (32) and trailing (34) edges extending over a height of the aerofoil from a root (28) of the aerofoil (24) to a tip (30) of the aerofoil, the aerofoil (24) comprising opposing major surfaces (36, 38) extending between the leading (32) and trailing (34) edges and terminating at the tip (30), wherein the aerofoil (24) leans towards a pressure surface (36) by an angle of between 10° and 80° over a minority of the height of the aerofoil towards the tip (30).

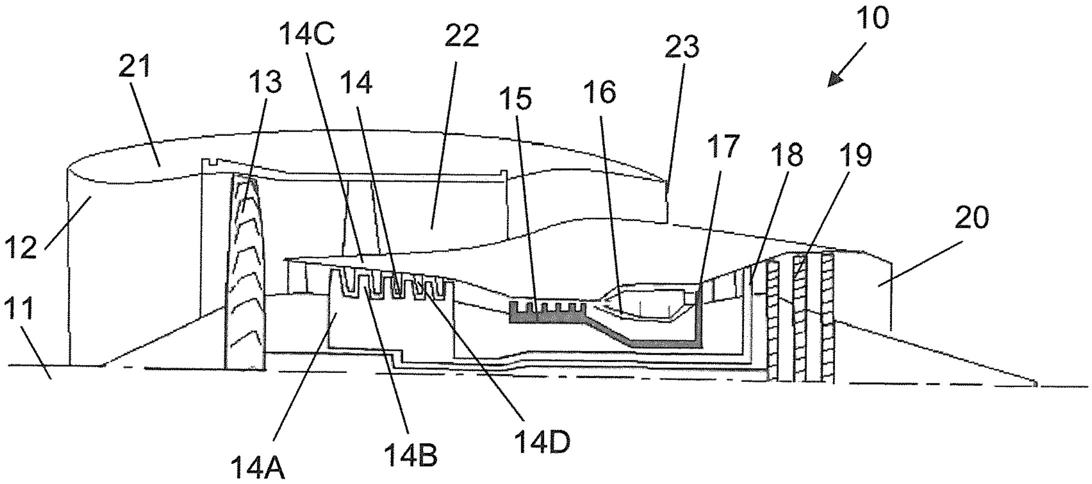

Figure 1

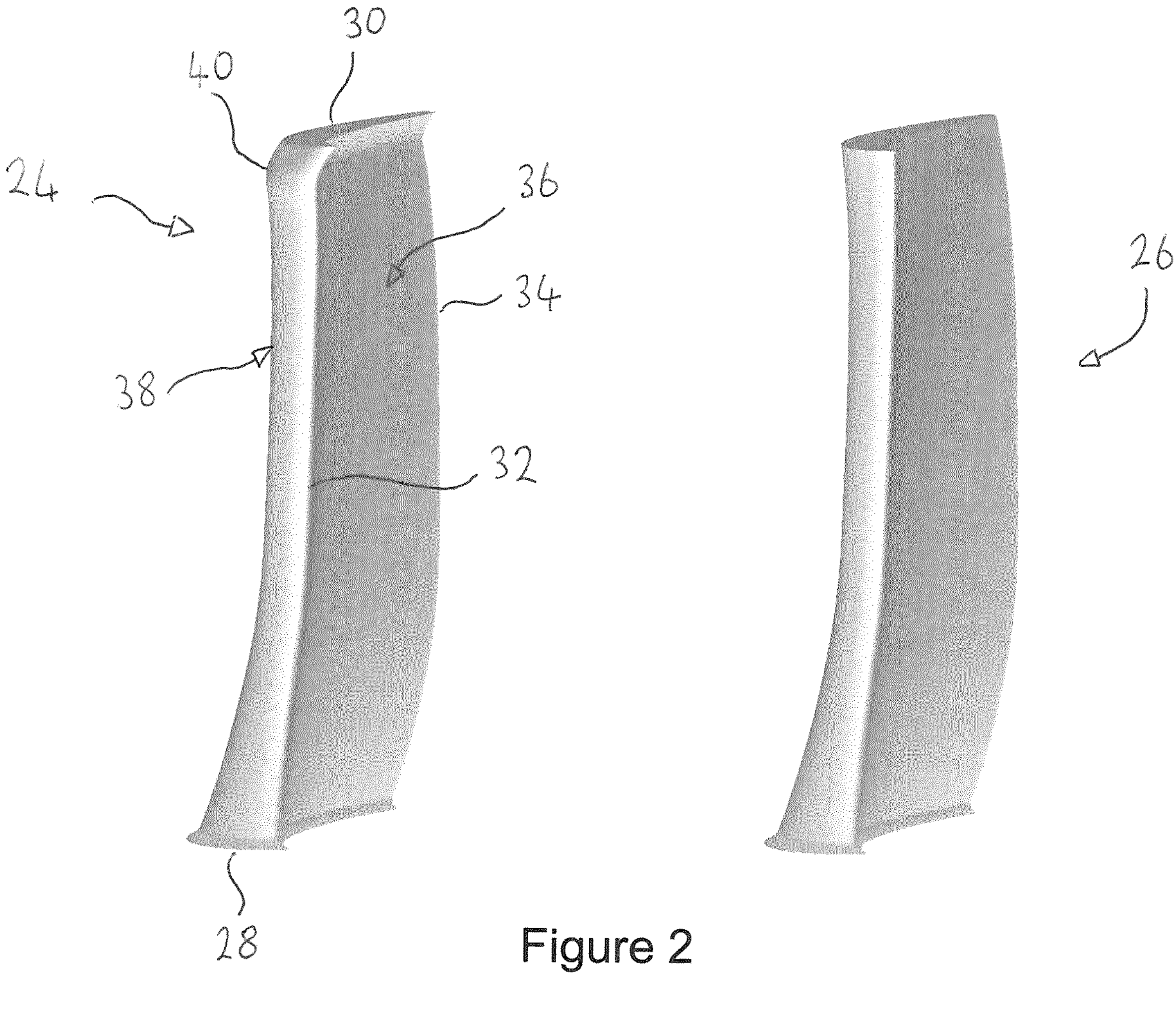

Figure 2

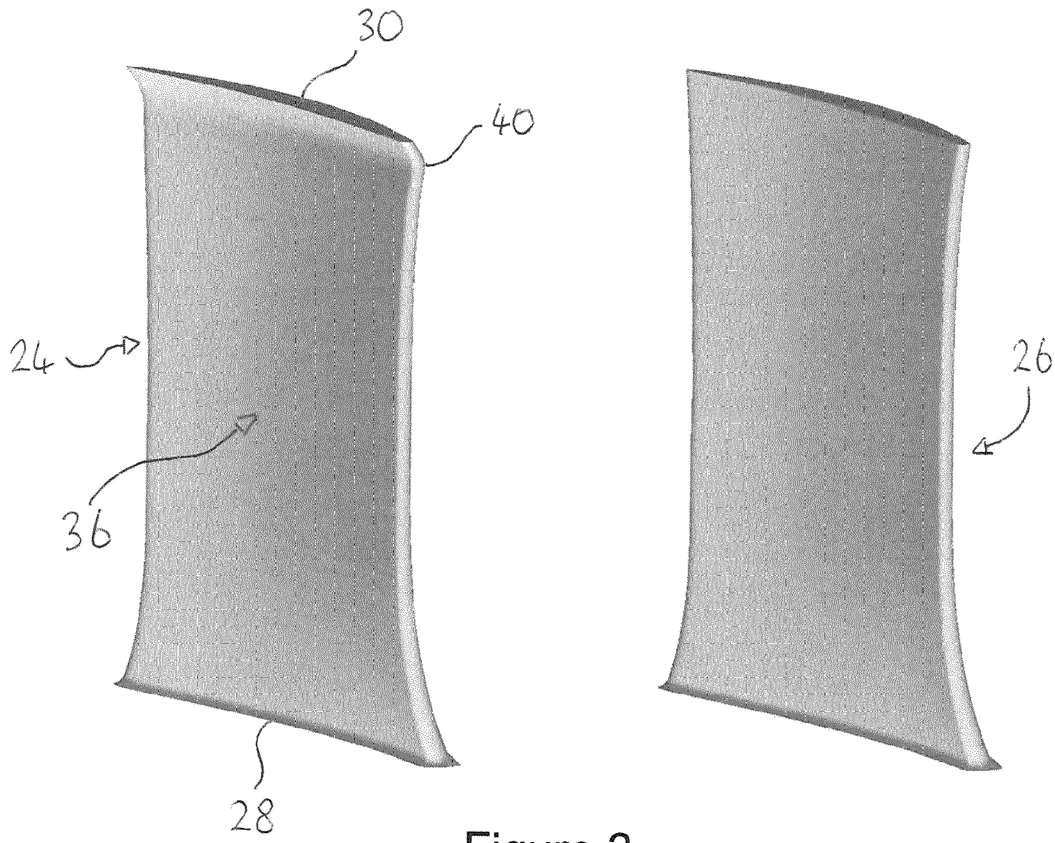

Figure 3

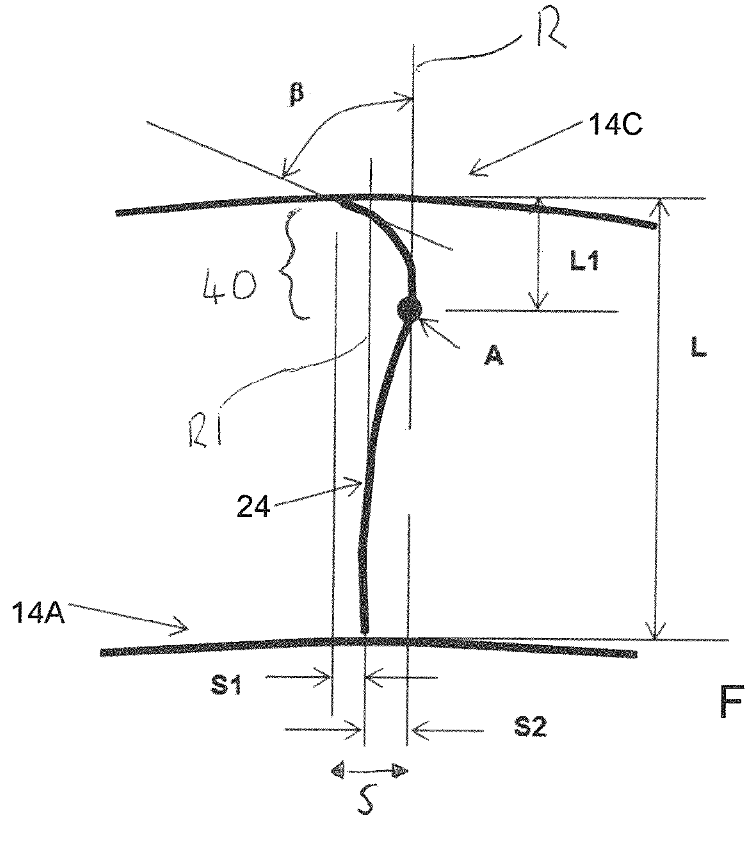

Figure 4

Europäisches Patentamt
European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 17 17 5536

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	GB 946 794 A (COLCHESTER WOODS) 15 January 1964 (1964-01-15) * page 1 - page 2; claims 1,2; figures 1-4 *	1-10, 12-15	INV. F01D5/20 F04D29/32 F04D29/68
X	WO 2014/109959 A1 (UNITED TECHNOLOGIES CORP [US]) 17 July 2014 (2014-07-17) * paragraph [0041] - paragraph [0057]; claims 1-19; figures 1-7 *	1-10, 12-15	
X	US 2012/243975 A1 (BREEZE-STRINGFELLOW ANDREW [US] ET AL) 27 September 2012 (2012-09-27) * paragraph [0020] - paragraph [0030]; claims 1-5, 16-20; figures 1-4 *	1-15	
X	EP 2 990 602 A1 (PRATT & WHITNEY CANADA [CA]) 2 March 2016 (2016-03-02) * paragraph [0008] - paragraph [0020]; claims 1,2,4-6, 8, 10; figures 1-3 *	1-15	TECHNICAL FIELDS SEARCHED (IPC)
X,D	US 2008/213098 A1 (NEEF MATTHIAS [DE] ET AL) 4 September 2008 (2008-09-04) * paragraph [0023] - paragraph [0035]; claims 12-26; figures 1-7 *	1-10, 12-15	F01D F04D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	10 January 2018	Balice, Marco

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
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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 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 17 5536

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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