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(54) **Gas turbine shrouded blade**

(57) Provided is a gas turbine blade (5) comprising an airfoil (25) axial chord (21) at a shroud corresponding to 100% span (30) that is between about 4% to about

10% shorter than the axial chord (21) at about 90% span (30). The axial chord (21) reduction enables the fitting of a smaller and therefore a lighter full shroud (27) that otherwise would be the case.

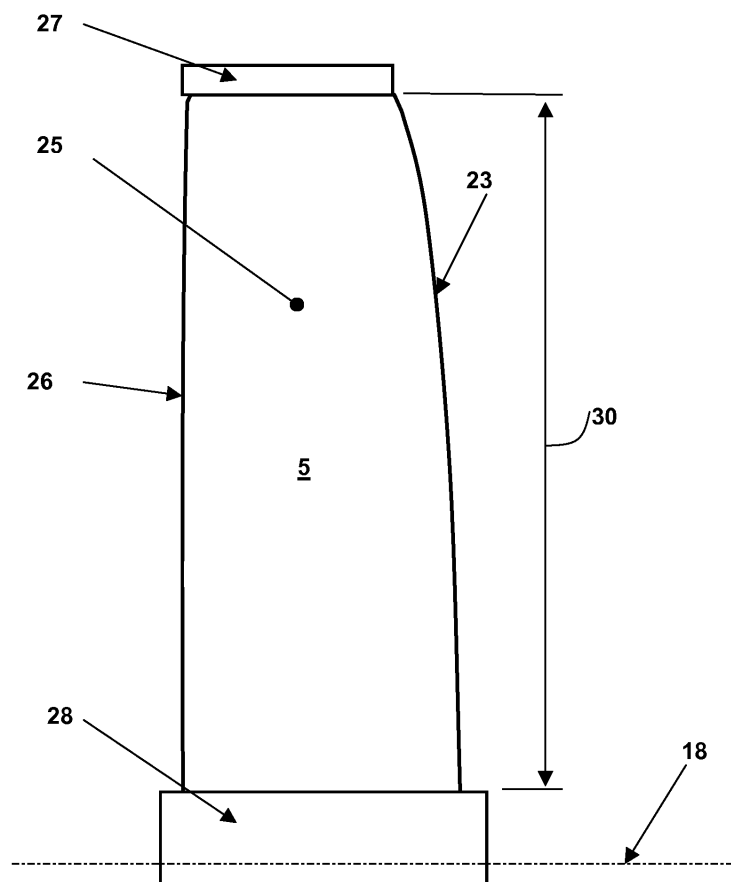


FIG. 4

Description

FIELD OF THE INVENTION

5 **[0001]** The invention relates generally to gas turbine blades and more specifically to low pressure gas turbine shrouded blades.

STATE OF THE ART

10 **[0002]** Gas turbine blades are rotating airfoil shaped components designed to convert thermal energy from a combustor into mechanical work in order to turn a shaft. Performance of a turbine can be enhanced by sealing the outer edge of the blade tip to prevent combustion gases from escaping from the flow path to the gaps between the blade tip and the outer casing. A common manner of sealing the gap between the blade tips and the turbine casing is through shrouds fitted to the tip of the airfoil of the blade.

15 **[0003]** Additional rotational loads are created by the mass of the shroud. These rotational loads increase stresses in the airfoil and so shrouded blades require heavier designs than non-shrouded blades to ensure equivalent cyclic fatigue life. Increasing the blade weight however comes at a cost of reduced aerodynamic efficiency. Where the benefits of a shroud are outweighed by reduced aerodynamic efficiency there is a need to find an alternative solution.

20 **[0004]** Although blade design is a compromise between aerodynamic efficiency and mechanical integrity, a blades design is not defined solely by design limits. Throughout the design process the designer has a limited freedom to influence the final design. For example a designer, to address the above problem, may specify a partial shroud having reduced weight. While partial shrouds are less aerodynamically efficient than full shrouds in certain blade arrangements and for certain conditions a partially shrouded blade may produce an optimised design point during the iterative design process.

25 **[0005]** US Pat No. 6,491,498 provides another solution that involves removing excess weight in the shroud by means of tapered shroud pockets. In this way the range of blade size in which a full shroud can be optimally fitted is increased although it still remains limited.

30 **[0006]** These solutions partially solve the problem of shroud weight and form only a selection of possible solutions. Due to differing operating conditions and the need to further improve efficiencies there is a continuous need to seek further improved blades.

SUMMARY OF THE INVENTION

35 **[0007]** The invention is intended to provide an improved blade design with improved aerodynamic efficiency that addresses the problems of shroud weight.

[0008] This problem is solved by means of the subject matter of the independent claim. Advantageous embodiments are given in the dependant claims.

40 **[0009]** The invention provides a blade design that enables a blade to have a full shroud where otherwise a partial shroud maybe favoured. The invention is based on the idea of shortening the chord length towards the airfoil end distal to the hub so as to reduce the weight of the shroud. In this way the blade has the aerodynamic benefits of a full shroud together with the benefit of reduced shroud weight.

45 **[0010]** An aspect provides a gas turbine blade comprising a hub with an airfoil, extending radially from the hub. The airfoil having a leading edge; a trailing edge; a span defined by the radial height of the airfoil, normalized by the airfoil radial length between the hub and an airfoil end radially distal from the hub; and an axial chord normalized along the span by the axial chord at the hub to form a normalized axial chord. The blade further comprises a full shroud at the radially distal end of the airfoil. The gas turbine blade is characterized by a normalized axial chord at 100% span that is between about 4% to about 10% shorter than the normalized axial chord at 90% span. In a further aspect the normalized axial chord at 100% span is limited to being about 6% shorter than the normalized axial chord at about 90% span. In a yet further aspect the normalized axial chord at 100% span is limited to being about 6% shorter than the normalized axial chord at about 90% span while at the same time normalized chord at 100% span is limited to being about 6% shorter than the normalized chord at about 90% span.

50 **[0011]** Reducing the axial chord length generally reduces aerodynamic efficiency, however it was found that losses caused by reducing the axial chord at the distal end can be overcompensated by the efficiency gain of a full shroud.

55 **[0012]** A further aspect, derived directly from 3D simulation, provides a gas turbine blade earlier described having a chord normalized by the chord at the hub wherein the normalized axial chord carried to +/- 1 % and the normalized chord carried to +/- 1 %, at different spans conform to Table 1.

Table 1

Span (%)	Normalized axial chord (%)	Normalized chord (%)
0	100	100
10	95	99
15	93	98
30	88	94
50	81	91
85	70	89
90	68	88
100	62	82

[0013] In a further aspect the previously described gas turbine blade is a stage 2 or stage 3 gas turbine blade of a low pressure turbine.

[0014] Other objectives and advantages of the present invention will become apparent from the following description, taken in connection with the accompanying drawings wherein by way of illustration and example, an embodiment of the invention is disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] By way of example, an embodiment of the invention is described more fully hereinafter with reference to the accompanying drawings, in which:

Figure 1 is a simplified schematic view of a gas turbine in which an embodiment of the invention can be suitably employed;

Figure 2 is a side cut view of the low or high pressure turbine of Fig. 1 showing stages;

Figure 3 is a perspective view of a shaft of the gas turbine of Fig 1 showing an X ray view through blade shrouds of fitted blades of the invention fitted to the shaft; and

Figure 4 is side view of the blade of Fig 3.

DETAILED DESCRIPTION OF THE INVENTION

[0016] Preferred embodiments of the present invention are now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the invention. It may be evident, however, that the invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to facilitate description of the invention.

FIG. 1 shows a gas turbine 1 in which a gas turbine blade 5, shown in FIGs 3 and 4, of the invention could be applied. The gas turbine 1 functions by firstly mixing air compressed in a compressor 10 with fuel. The mixture is then burnt in a first combustor 11. The combustion gases from the first combustor 11 are then feed through a high pressure turbine 12 into a second combustor 13 where further fuel is added. The combustion gases from the second combustor 13 are then feed into a low pressure turbine 14. The high pressure turbine 12 and the low pressure turbine 14 coupled to a common shaft 17 drive the compressor 10 and a generator 15, which generates power.

FIG. 2 shows stages 3 of a low 12 or high pressure turbine 14 comprising a non rotating vane 4 and a rotating blade 5 wherein by convention each stage 3 is numbered consecutively in the direction of gas flow starting from one.

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FIG. 3 shows a row of blades 5 fitted on a shaft 17 of a compressor 10, high pressure turbine 12 or low pressure turbine 14 of a gas turbine 1 of FIG. 1. Shown also are dimensions used throughout this specification. These include:

- throat 20: the minimum distance between two fitted airfoils 25;
- axial chord 21: the length of the projection of the airfoil 25 as set in a gas turbine 1 onto a line parallel to the turbine axis 18 and is the characteristic axial length of the airfoil 25; and
- chord 22: the length of the straight line connecting the leading edge 26 and trailing edge 23 of an airfoil 25 and is the characteristic longitudinal length of the airfoil 25.

[0017] The axial chord 21 and chord 22 can be normalized by using reference lengths at 0% span 30, as shown in FIG. 4 where the span 30 of the airfoil 25 is defined as the radial extension of the airfoil 25 from the hub 28 to the full shroud 27. That is 0% span 30 corresponds to the point at which the airfoil 25 extends from the hub 28 and 100% span 30 is the point where a shroud 27 is fitted to the airfoil 25.

[0018] FIG. 4 shows a side view of an exemplary embodiment of a blade 5. The blade 5 has a hub 28. Extending radially, that is normal from the turbine axis 18, from the hub 28 is an airfoil 25 with a leading edge 26 and a trailing edge 23. At the end of the airfoil 25, radially distal from the hub 28, is a full shroud 27. A full shroud 27 is a shroud that is capable of covering the throat 20 between two fitted airfoils 25 as shown in FIG. 3.

[0019] An exemplary embodiment of the invention will now be described with refer to the gas turbine blade 5 shown in FIGs 3 and 4. In this blade 5, from about 90% span 30 to 100% span 30 the normalized axial chord 21 reduces preferably by about 6% but could be reduced anywhere between about 4% about 10%.

[0020] In another exemplary embodiment, the normalized axial chord 21 reduces between 90% span 30 to 100% span 30 by about 6% while the normalized chord 22 between the same span 30 range reduces by about 6%.

[0021] The reduced axial chord 21 results in an overall reduced radially distal end size of the airfoil 25. As a result a smaller full shroud 27 can be fitted than may otherwise be the case resulting in improved blade 5 aerodynamic efficiency.

[0022] A more detailed exemplary embodiment, corresponding to an arrangement for a particular gas turbine 1 machine optimised by 3D aerodynamic and lifetime simulation, has a normalized axial chord 21 carried to +/- 1 % and normalized chord 22, carried to +/- 1%, at different spans 30 as tabulated in Table 1.

[0023] Any of the exemplary embodiments may be stage 3 two or stage 3 three blades 5, as shown on FIG. 2, of a low pressure turbine 14. This location is the region of a turbine most likely to benefit from the invention due to the combination of blade 5 size, blade 5 cooling requirements and blade 5 service. Blades 5 having any of the configurations of the exemplary embodiments could however be suitable for use in other turbine services and locations dependant on the particular turbine and stage operating conditions.

[0024] Although the invention has been herein shown and described in what is conceived to be the most practical and preferred embodiment, it is recognized that departures can be made within the scope of the invention, which is not to be limited to details described herein but is to be accorded the full scope of the appended claims so as to embrace any and all equivalent devices and apparatus.

REFERENCE NUMBERS

[0025]

- | | |
|----|-----------------------|
| 1 | Gas turbine |
| 3 | Stage |
| 4 | Vane |
| 5 | Blade |
| 10 | Compressor |
| 11 | First combustor |
| 12 | High pressure turbine |
| 13 | Second combustor |
| 14 | Low pressure turbine |
| 15 | Generator |
| 17 | Shaft |
| 18 | Shaft/ turbine axis |
| 20 | Throat |
| 21 | Axial chord |
| 22 | Chord |
| 23 | Trailing edge |
| 25 | Airfoil |

- 26 Leading edge
- 27 Shroud
- 28 Hub
- 30 Span

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Claims

1. A gas turbine blade (5) comprising:

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a hub (28);
an airfoil (25), extending radially from the hub (28), having;

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a leading edge (26);
a trailing edge (23);
a span (30) that defines the radial height of the airfoil (25), normalized by the airfoil's (25) radial length between the hub (28) and an airfoil (25) end radially distal from the hub (28); and
an axial chord (21) normalized along the span (30) by the axial chord (21) at the hub (28) to define a normalized axial chord (21),

20

the gas turbine blade (5) further comprising a full shroud (27) at the radially distal end of the airfoil (25),

the gas turbine blade (5) **characterized by** a normalized axial chord (21) at 100% span (30) is between about 4% to about 10% shorter than the normalized axial chord (21) at about 90% span (30).

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2. The gas turbine blade (5) of claim 1 wherein the normalized axial chord (21) at 100% span (30) is about 6% shorter than the normalized axial chord (21) at 90% span (30).
3. The gas turbine blade (5) of claim 2 having a chord (22) normalized by the chord (22) at the hub (28) to define a normalized chord (22) wherein the normalized chord (22) at 100% span (30) is about 6% shorter than the normalized chord (22) at 90% span (30).
4. The gas turbine blade (5) of claim 1 having a chord (22) normalized by the chord (22) at the hub (28) to define a normalized chord (22) wherein the normalized axial chord (21) carried to +/- 1 % and normalized chord (22) carried to +/-1%, at different spans (30) conform to the following table

30

35

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45

50

Span (%) (30)	Normalized axial chord (%)(21)	Normalized chord (%) (22)
0	100	100
10	95	99.
15	93	98
30	88	94
50	81	91
85	70	89
90	68	88
100	62	82

5. The gas turbine blade (5) of any one of claims 1 to 5 wherein the gas turbine blade (5) is a low pressure turbine (14) stage 2 or stage 3 blade (5).

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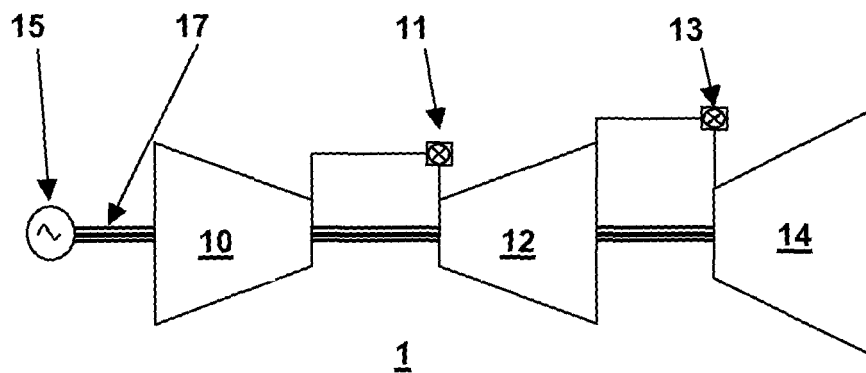


FIG. 1

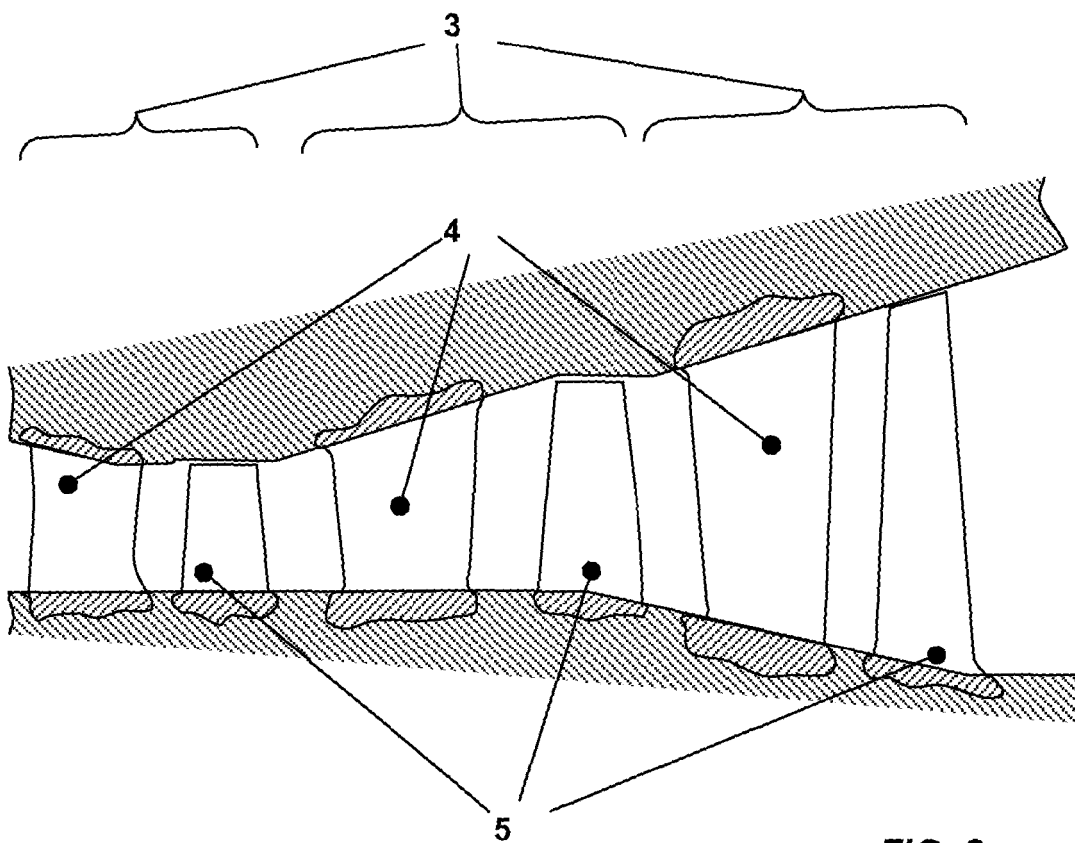


FIG. 2

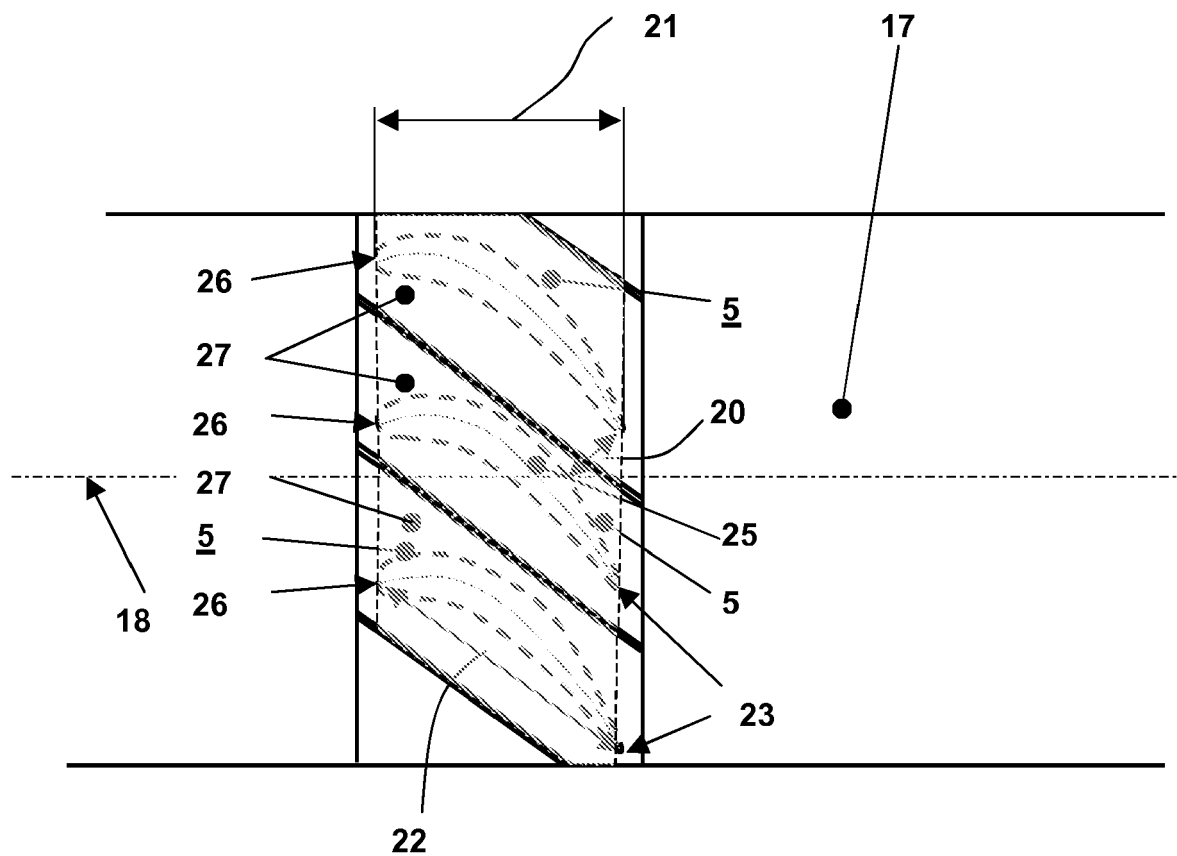


FIG. 3

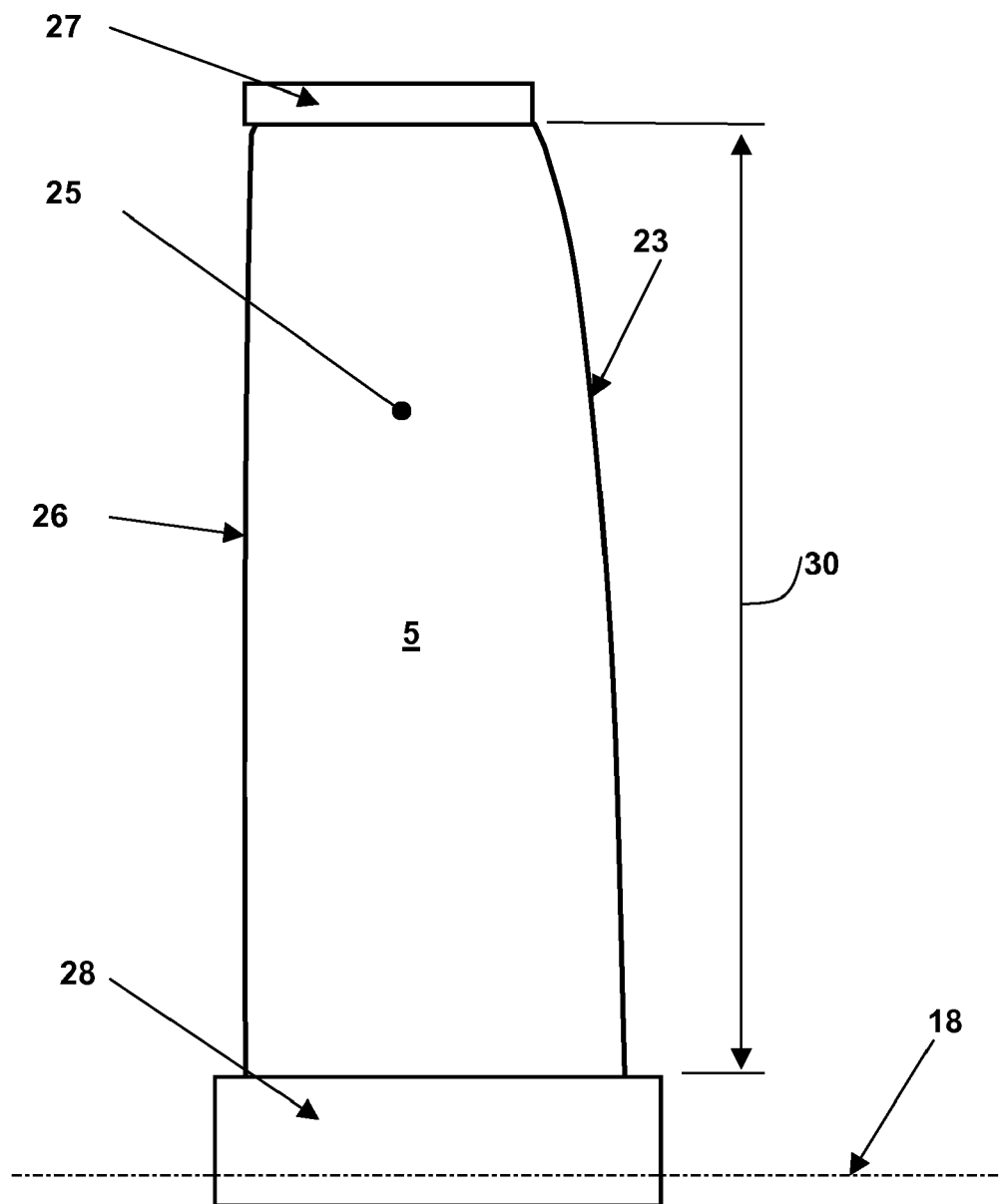


FIG. 4



EUROPEAN SEARCH REPORT

Application Number
EP 09 15 3485

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 1 612 372 A (ALSTOM TECHNOLOGY LTD [CH]) 4 January 2006 (2006-01-04) * paragraph [0001] * * paragraph [0017] * * paragraph [0020] * * figures 1,3 *	1-5	INV. F01D5/22 F01D5/14
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A	US 2005/214120 A1 (MILLER JEFF H [US] ET AL) 29 September 2005 (2005-09-29) * paragraph [0035] * * figure 6 *	1	
A	US 5 156 529 A (FERLEGER JUREK [US] ET AL) 20 October 1992 (1992-10-20) * column 3, line 1 - line 2 * * figure 5 *	1	TECHNICAL FIELDS SEARCHED (IPC) F01D F04D
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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 28 July 2009	Examiner Rapenne, Lionel
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			

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EPO FORM 1503 03.82 (P04C01)

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

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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28-07-2009

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REFERENCES CITED IN THE DESCRIPTION

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