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(71) **Applicant** *(for all designated States except US)*: **ALSTOM TECHNOLOGY LTD** [CH/CH]; Brown Boveri Strasse 7, CH-Baden 5400 (CH).

(72) **Inventors; and**
(75) **Inventors/Applicants** *(for US only)*: **NAIK, Shailendra** [GB/CH]; Birkenweg 26B, CH-5412 Gebenstorf (CH). **PATHAK, Gaurav Milan** [GB/CH]; Hoehtalstrasse. 23, CH-5408 Ennetbaden (CH).

(74) **Common Representative**: **ALSTOM TECHNOLOGY LTD**; CHTI Intellectual Property, Brown Boveri Str. 7/664/2, CH-Baden 5401 (CH).

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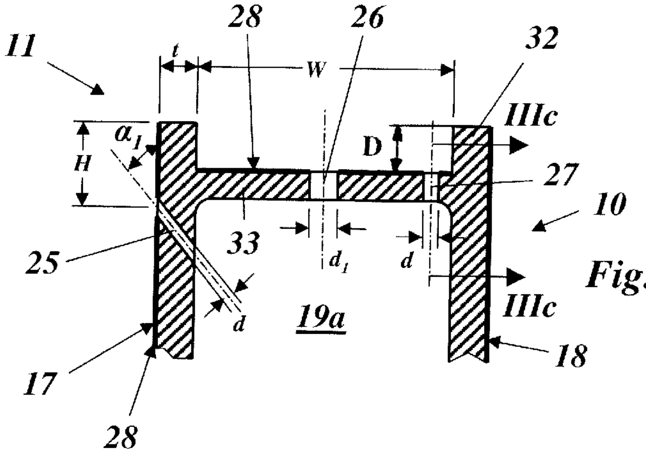


Fig.3a

(57) Abstract: A cooled blade (10) for a gas turbine comprising an airfoil section which extends in the radial direction of the turbine or in the longitudinal direction of the blade (10) between a platform and a blade tip (11) which is provided with a cap (33), which airfoil section (12) is bounded transversely with respect to the longitudinal direction by a leading edge and a trailing edge and has a pressure face (17) and a suction face (18), with cooling channels (19) extending in the radial direction between the platform and the blade tip (11) in the interior of the airfoil section, which cooling channels (19) can be acted upon by a cooling air flow from the platform (13). In the case of a blade (10) such as this, the blade tip is cooled better in that first cooling holes (25) for convection cooling are provided on the pressure face (17) of the blade (10), and second cooling holes (27) for film cooling are provided on the suction side (18) of the blade (10), through the cap (33) of the blade (10), in the blade tip (11) from the cooling channels (19), and distributed over the blade width.

WO 2010/108809 A1

BLADE FOR A GAS TURBINE WITH COOLED TIP CAP

Technical Field

The present invention relates to the field of gas turbine technology, and relates in particular to a cooled blade for a gas turbine as claimed in the preamble of claim 1.

Prior Art

The efficiency of gas turbines depends substantially on the temperature of the hot gas that expands in the turbine when performing work. In order to be able to raise the efficiency, the components (stator blades, rotor blades, heat accumulating segments, etc), must not only be produced from particularly resistant materials but must also be cooled as effectively as possible during operation. Various methods have been developed for blade cooling in the prior art, and can be used alternatively or together. One method is to pass a cooling medium, generally compressed cooling air, from the gas-turbine compressor, through the interior of the blades in cooling channels, and to allow it to emerge into the hot gas channel through cooling holes arranged in a distributed manner. The cooling channels may in this case pass through the interior of the blade more than once in a serpentine shape (see for example WO-A1-2005/068783). The heat transfer between the cooling medium and the walls of the blade can in this case be improved by using suitable elements (turbulators) to produce additional turbulence in the cooling medium flow, or by using impingement cooling. In another method, the cooling medium can emerge from the interior of the blade such that a film of cooling medium is formed on the blade surface, and protects the blade (film cooling).

It is particularly important to cool the blade tip. The blade tip is furthest away from the blade root, through which the cooling air is supplied. Particular attention must therefore be paid to its cooling. Furthermore, cooling that is as uniform as possible must be achieved in all operating states, and the consumption of cooling medium should be restricted to what is necessary, in order to avoid disadvantageously influencing the efficiency of the machine.

DE-A1-199 44 923 discloses a comparatively complex solution for cooling the blade tip.

Description of the Invention

This is the purpose of the invention. The object of the invention is therefore to provide a cooled blade for a gas turbine which is distinguished in particular by better cooling in the area of the blade tip.

The object is achieved by the totality of the features of independent claim 1. The major aspect of the invention is that first cooling holes for convection cooling are provided on the pressure face of the blade, and second cooling holes for film cooling are provided on the suction face of the blade, through the cap of the blade, in the blade tip from the cooling channels, and distributed over the blade width. The combination of convection cooling on the pressure face and film cooling on the suction face of the blade tip results in particularly effective and stable cooling without this having any disadvantageous influence on the efficiency.

According to a first embodiment of the invention, the first and second cooling holes comprise at least sections in the form of cylindrical bores with a predetermined first diameter.

Especially, the first cooling holes are in the form of long cylindrical bores which run obliquely upwards and include a first angle of between 25° and 35°, preferably of approximately 30°, with the outer surface of the blade.

According to second embodiment of the invention, the first cooling holes open into the environment of the blade with a fan-shaped section of the bore.

According to a third embodiment of the invention, those of the first cooling holes arranged outside the trailing edge of the blade open into the environment of the blade with a 3D symmetric fan-shaped section of the bore, whereby said 3D symmetric fan-shaped section has a first aperture angle having a range of 10° to 50°, and being preferably about 24°, and a second aperture angle perpendicular to said first aperture angle, said second aperture angle having a range of 5° to 25°, and being preferably about 12°.

According to a fourth embodiment of the invention, those of the first cooling holes arranged outside the trailing edge of the blade include a second angle of between 15° and 45°, preferably of approximately 30°, with the outer surface of the blade.

According to a fifth embodiment of the invention, those of the first cooling holes arranged at the trailing edge of the blade open into the environment of the blade with a 2D symmetric fan-shaped section of the bore, whereby said 2D symmetric fan-shaped section has a third aperture angle having a range of 10° to 40°, and being preferably about 20°.

According to a sixth embodiment of the invention, those of the first cooling holes arranged at the trailing edge of the blade include a third angle of between 5° and 45°, preferably of approximately 30°, with the outer surface of the blade.

According to a seventh embodiment of the invention, those of the first cooling holes arranged at the trailing edge of the blade have a bore of a predetermined first length, which is subdivided into said 2D symmetric fan-shaped section and a cylindrical section of a predetermined second length, whereby the ratio of said second length and said first length is in the range of 0.2 to 0.7, and is preferably about 0.5.

According to a ninth embodiment of the invention, the first cooling holes are arranged along the pressure face in a row with a predetermined first periodicity, and the ratio between said first periodicity and said first diameter is in the range of 3 to 8, and is preferably about 6.

According to a tenth embodiment of the invention, the second cooling holes pass through the cap of the blade in a radial direction, whereby the second cooling holes are in the form of long cylindrical bores which run obliquely upwards and include an angle of 0° to 45°, preferably of approximately 30°, with the longitudinal axis of the blade.

According to an eleventh embodiment of the invention, the second cooling holes are arranged along the suction face in a row with a predetermined second periodicity, and the ratio between said second periodicity and said first diameter is in the range of 3 to 8, and is preferably about 6.

According to another embodiment of the invention, said first cooling holes exit into the environment of the blade at a predetermined height below the upper end of the blade tip, and the ratio between said height and said first diameter is in a range between 5 and 10, and is preferably about 6.5.

According to another embodiment of the invention, there are dust holes arranged along the cap between said leading edge and trailing edge, and said dust holes have a second diameter, such that the ratio between said second diameter and said first diameter is between 1.2 and 4.5.

According to another embodiment of the invention, the cap of the blade is bounded at the edge on its upper face by a circumferential blade crown, and the second cooling holes open into the outside area within the blade crown.

Preferably, said blade has a blade crown at the blade tip, which is bounded by a circumferential rail having a predetermined thickness, whereby the width between the opposing rails varies with the distance along the chord line, such that t/W is between 0.05 and 0.15 for κ/κ_0 between 0 and 0.3, and that t/W is between 0.15 and 0.3 for κ/κ_0 larger than 0.3 and up to 1.0, κ_0 being the overall chord line length.

And, additionally, relating the blade tip geometry, the following ratios are preferring:

D/W = 0.1 to 0.3	for κ/κ_0	0 to 0.3;
D/W = 0.1 to 0.8	for κ/κ_0	>0 to 1.0;

whereas D means the depth of the tip crown and W means the width, according Fig. 3a.

Brief explanation of the figures

The invention will be explained in more detail in the following text with reference to exemplary embodiments and in conjunction with the drawing. The drawing shows only those elements which are essential for immediate understanding of the invention. The same elements are provided with the same reference symbols in the various figures, in which:

Figure 1 shows a cross-sectional profile through an airfoil section of a blade, which is suitable for implementing the invention;

Figure 2 shows the arrangement of the cooling holes in the blade tip according to one preferred exemplary embodiment of the invention;

Figure 2a shows in detail some of the film cooling holes at the suction side of the blade according to Figure 2;

Figure 3a shows part of a longitudinal section through the blade of Figure 2, wherein the film cooling holes at the pressure side of the blade are in the form of simple cylindrical bores;

Figure 3b shows part of a longitudinal section through the blade of Figure 2, wherein the film cooling holes at the pressure side of the blade exit section of a 2D or 3D fan-shaped form;

Figure 3c shows the preferred inclination of the film cooling holes at the suction side of the blade according to Figure 2;

Figure 4a, 4b show different longitudinal sections of the first film cooling holes outside the trailing edge at the pressure side of the blade in Figure 2;

Figure 4c	shows the boundary of the exit of the first film cooling holes according to Figure 4a, 4b;
Figure 5a, 5c	show different longitudinal sections of the first film cooling holes at the trailing edge at the pressure side of the blade in Figure 2; and
Figure 5b	shows the boundary of the exit of the first film cooling holes according to Figure 5a, 5c.

Approaches to implementation of the invention

The invention relates to a cooled gas turbine blade which is particularly suitable for implementation of the invention. The blade (10 in Figures 1, 2), which is a rotor blade, has an airfoil section (12 in Figure 2), which extends in the radial direction of the turbine and extends in the radial direction between a platform (not shown), which bounds the hot gas channel, and a blade tip (11 in Figure 2). In this case, it should be noted that the following statements are not restricted exclusively to a rotor blade, and they can also relate to a stator blade, to the appropriate extent. The airfoil section 12 has a leading edge 15 and a trailing edge 16 (Figure 1), and has a (concave) pressure face 17 and a (convex) suction face 18 in the form of an airfoil profile. A blade root (not shown) is formed underneath the platform, and is used to mount the blade 10 in a groove provided for this purpose in the rotor (or, in the case of a stator blade, in the housing surrounding the rotor).

Cooling channels 19a, 19b, 19c and 20 (Figure 1) through which cooling air flows run in the radial direction in the interior of the airfoil section 12, and this cooling air enters the blade 10 as a cooling air flow through appropriate cooling air inlets (not shown) in the blade root. The cooling channels 19a, 19b and 19c are connected to one another by means of a serpentine-like channel structure. The cooling air flowing through the cooling channels 19a, 19b and 19c cools the blade 10 from the inside and emerges to the outside at different points through cooling holes or cooling openings. The cooling channel 20 is specifically used to cool the leading edge 15. In order to improve the internal cooling, turbulators (not shown) in the form of obliquely positioned ribs can be provided in the cooling channels 19a, b, c and 20 and lead to swirling of the cooling air, and therefore to an improvement in the heat transfer.

As shown in the exemplary embodiment in Figure 2, first, comparatively long cooling holes 25 for convection cooling are provided, distributed over the blade width, from the cooling channels 19 and 19a, b, c in the blade tip 11, passing to the outside on the pressure face 17 of the blade 10. Second cooling holes 27 are passed to the outside through the cap 33 of the blade 10, for film cooling on the suction face 18 of the blade 10. A particularly advantageous cooling effect is achieved by the combination of convection cooling on the pressure face 17 and film cooling on the suction face 18 of the blade.

The first and second cooling holes 25 and 27, respectively, may have the form of cylindrical bores in the simplest embodiment (Figure 3a) and can be introduced into the blade 10 by appropriate drilling methods (EDM, laser drilling). The first cooling holes 25 are advantageously in the form of holes or bores which run obliquely upwards, in order to achieve the necessary hole length. They preferably include a first angle α_1 of between 25° and 35°, preferably of approximately 30°, with the outer surface 17 of the blade 10.

In general, the first and second cooling holes (25a,b in Figure 2 and Figure 3b) comprise only sections in the form of cylindrical bores with a predetermined first diameter d. They therefore open advantageously into the environment of the blade 10 with a fan-shaped section (29, 30 in Figures 4 a-c, 5a+b) of the bore.

There are two different kinds 25a (see Figure 4a) and 25b (see Figure 5a) of first cooling holes provided at the pressure side (17) of the blade 10: Those of the first cooling holes arranged outside the trailing edge 16 of the blade 10, i.e. first cooling holes 25a, preferably open into the environment of the blade 10 with a 3D (3-dimensional) symmetric fan-shaped section 29 of the bore, which is shown in Figures 4a, 4b and 4c. Said 3D symmetric fan-shaped section 29 has a first aperture angle $2\varphi_1$ (Figure 4b) having a range of 10° to 50°, and being preferably about 24°, and a second aperture angle φ_2 (Figure 4a) perpendicular to said first aperture angle $2\varphi_1$. Said second aperture angle φ_2 has a range of 5° to 25°, and is preferably about 12°. Furthermore, these first cooling holes 25a arranged outside the trailing edge 16 of the blade 10 include a second angle α_2 of between 15° and 45°, preferably of approximately 30°, with the outer surface 17 of the blade 10 (Figure 4a).

Those of the first cooling holes 25b arranged at the trailing edge 16 of the blade 10 preferably open into the environment of the blade 10 with a 2D (2-dimensional) symmetric fan-shaped section 30 of the bore (Figures 5a, 5b and 5c). Said 2D symmetric fan-shaped section 30 has a third aperture angle $2\varphi_3$ (Figure 5a), which has a range of 10° to 40°, and is preferably about 20°. These first cooling holes 25b arranged at the trailing edge 16 of the blade 10 include a third angle α_3 (Figure 5c) of between 5° and 45°, preferably of approximately 30°, with the outer surface 17 of the blade 10.

As can be seen in Figure 5a, those of the first cooling holes 25b arranged at the trailing edge 16 of the blade 10 have a bore of a predetermined overall length L. This overall length L is subdivided into the aforementioned 2D symmetric fan-shaped section 30 and a cylindrical section of a second length L_1. The ratio L_1/L of both lengths lies in the range of 0.2 to 0.7, and is preferably about 0.5.

Figure 2 shows, that the first cooling holes 25a and 25b are arranged along the pressure face 17 in a row with a (first) periodicity P_1. It is advantageous to choose a certain ratio P_1/d between this periodicity P_1 and the diameter d (see Figure 3a) of the cooling hole bores. This ratio is chosen to be in the range of 3 to 8, and is preferably about 6.

Accordingly, the second cooling holes 27 are arranged along the suction face 18 in a row with a (second) periodicity P_2. Again, the ratio P_2/d_1 between the second periodicity P_2 and the diameter d lies in the range of 5 to 8, and is preferably about 6.

In the exemplary embodiment illustrated in Figure 3, the blade 10 is closed at the blade tip 11 at the top by a flat cap 33, which is surrounded on the upper face by a circumferential rail-like blade crown 32. As can be seen in

Figures 3a and 3b, the second cooling holes 27 pass through the cap 33 of the blade 10 in a radial direction. They are in the form of long cylindrical bores which run obliquely upwards and include an angle γ of 0° to 45°, preferably of approximately 30˚, with the longitudinal axis of the blade 10 (Figure 3c).

The first cooling holes 25 open into the outside area underneath the cap 33 of the blade 10. They exit into the environment of the blade 10 at a predetermined height H below the upper end of the blade tip 11 (Figure 3a). The ratio H/d between said height H and the diameter d is in a range between 5 and 10, and is preferably about 6.5.

The second cooling holes 27 are arranged on the opposite face and pass through the cap 33 of the blade 10 in the radial direction, opening into the outside area within the blade crown 32.

Also within the blade crown 32 dust holes 26 are provided and arranged along the cap 33 between the leading edge 15 and trailing edge 16 (Figure 2). These dust holes 26, which are used to remove dust particles from the interior cooling channels, each have a diameter d_1, such that the ratio d_1/d between the diameter d_1 and the bore diameter d (see Figure 3a) is between 1.2 and 4.5.

As has already been said, the blade 10 is provided with a blade crown 32 at the blade tip 11, which blade crown 32 is bounded by a circumferential rail having a predetermined thickness t (Figure 3a). The width W between the opposing rails varies with the distance κ along the chord line (Figure 2), such that t/W is between 0.05 and 0.15 for $\kappa/\ \kappa_0$ between 0 and 0.3, and that t/W is between 0.15 and 0.3 for $\kappa/\ \kappa_0$ larger than 0.3 and up to 1.0, κ_0 being the overall chord line length; And, additionally, relating the blade tip geometry, the following ratios are preferring: D/W = 0.1 to 0.3 for $\kappa/\ \kappa_0$0 to 0.3 and D/W = 0.1 to 0.8 for $\kappa/\ \kappa_0$ >0 to 1.0, whereas D means the depth of the tip crown and W means the width, according Fig. 3a.

Finally, in addition to the described cooling, the surfaces of the pressure face 17 and suction face 18 as well as the upper face of the cap 33 are provided with a thermal protection layer (Thermal Barrier Coating TBC) 28.

List of reference symbols

10	Blade (gas turbine)
11	Blade tip
12	Airfoil section
15	Leading edge
16	Trailing edge
17	Pressure face
18	Suction face
19a,b,c	Cooling channel
20	Cooling channel
21,22	Bend
23,24	Cooling hole
25,25a,25b,27	Cooling hole
26	Dust hole, particle openings
28	Thermal protective layer (Thermal Barrier Coating TBC)
29	3D fan-shaped section
30	2D fan-shaped section
32	Blade crown
33	Cap
$\alpha_1,\alpha_2,\alpha_3$	angle
γ	angle
φ_1,φ_2	angle (aperture)
P_1, P_2	Periodicity
d,d_1	Diameter
H	Height
W	Width
D	Depth of the tip crown
t	Thickness
κ	Distance (along chord line)
κ_0	Chord line length

Patent Claims

1. Cooled blade (10) for a gas turbine, comprising an airfoil section (12) which extends in the radial direction of the turbine or in the longitudinal direction of the blade (10) between a platform and a blade tip (11) which is provided with a cap (33), which airfoil section (12) is bounded transversely with respect to the longitudinal direction by a leading edge (15) and a trailing edge (16) and has a pressure face (17) and a suction face (18), with cooling channels (19a, b, c; 20) extending essentially in the radial direction between the platform and the blade tip (11) in the interior of the airfoil section (12), through which cooling channels (19a, b, c; 20) a cooling medium flows, characterized in that first cooling holes (25; 25a,b) for convection cooling are provided on the pressure face (17) of the blades (10), and second cooling holes (27) for film cooling are provided on the suction face (18) of the blades (10), in the area of the blade tip (11) and operatively connected to the cooling channels (19a, b, c; 20) and distributed over the blade width, and in that the cooling medium is passed to the exterior in the area of the cap (33) and/or through the cap (33) of the blade (10).

2. The blade as claimed in claim 1, characterized in that the first and second cooling holes (25; 25a,b; 27) comprise at least sections in the form of cylindrical bores with a predetermined first diameter (d).

3. The blade as claimed in claim 2, characterized in that the first cooling holes (25) are in the form of long cylindrical bores which run obliquely upwards and include a first angle (α_1) of between 25° and 35°, preferably of approximately 30°, with the outer surface (17) of the blade (10).

4. The blade as claimed in claim 2, characterized in that the first cooling holes (25a,b) open into the environment of the blade (10) with a fan-shaped section (29, 30) of the bore.

5. The blade as claimed in claim 4, characterized in that those of the first cooling holes (25a) arranged outside the trailing edge (16) of the blade (10) open into the environment of the blade (10) with a 3D symmetric fan-shaped section (29) of the bore, whereby said 3D symmetric fan-shaped section (29) has a first aperture angle ($2\varphi_1$) having a range of 10° to 50°, and being preferably about 24°, and a second aperture angle (φ_2) perpendicular to said first aperture angle ($2\varphi_1$), said second aperture angle (φ_2) having a range of 5° to 25°, and being preferably about 12°.

6. The blade as claimed in claim 5, characterized in that those of the first cooling holes (25a) arranged outside the trailing edge (16) of the blade (10) include a second angle (α_2) of between 15° and 45°, preferably of approximately 30°, with the outer surface (17) of the blade (10).

7. The blade as claimed in claim 4, characterized in that those of the first cooling holes (25b) arranged at the trailing edge (16) of the blade (10) open into the environment of the blade (10) with a 2D symmetric fan-shaped section (30) of the bore, whereby said 2D symmetric fan-shaped section (30) has a third aperture angle ($2\varphi_3$) having a range of 10° to 40°, and being preferably about 20°.

8 The blade as claimed in claim 7, characterized in that those of the first cooling holes (25b) arranged at the trailing edge (16) of the blade (10) include a third angle (α_3) of between 5° and 45°, preferably of approximately 30°, with the outer surface (17) of the blade (10).

9. The blade as claimed in claim 7 or 8, characterized in that those of the first cooling holes (25b) arranged at the trailing edge (16) of the blade (10) have a bore of a predetermined first length (L), which is subdivided into said 2D symmetric fan-shaped section (30) and a cylindrical section of a predetermined second length (L_1), whereby the ratio (L_1/L) of said second length (L_1) and said first length (L) is in the range of 0.2 to 0.7, and is preferably about 0.5.

10. The blade as claimed in one of the claims 3 to 9, characterized in that the first cooling holes (25; 25a,b) are arranged along the pressure face (17) in a row with a predetermined first periodicity (P_1), and in that the ratio (P_1/d) between said first periodicity (P_1) and said first diameter (d) is in the range of 3 to 8, and is preferably about 6.

11. The blade as claimed in claim 1 or 2, characterized in that the second cooling holes (27) pass through the cap (33) of the blade (10) in a radial direction.

12. The blade as claimed in claim 11, characterized in that the second cooling holes (27) are in the form of long cylindrical bores which run obliquely upwards and include an angle (γ) of 0° to 45°, preferably of approximately 30°, with the longitudinal axis of the blade (10).

13. The blade as claimed in claim 11 or 12, characterized in that the second cooling holes (27) are arranged along the suction face (18) in a row with a predetermined second periodicity (P_2), and in that the ratio (P_2/d) between said second periodicity (P_2) and said first diameter (d) is in the range of 3 to 8, and is preferably about 6.

14. The blade as claimed in claim 3, characterized in that said first cooling holes (25) exit into the environment of the blade (10) at a predetermined height (H) below the upper end of the blade tip (11), and in that the ratio (H/d) between said height (H) and said first diameter (d) is in a range between 5 and 10, and is preferably about 6.5.

15. The blade as claimed in claim 2, characterized in that there are dust holes (26) arranged along the cap (33) between said leading edge (15) and trailing edge (16), and in that said dust holes (26) have a second diameter (d_1), such that the ratio (d_1/d) between said second diameter (d_1) and said first diameter (d) is between 1.2 and 4.5.

16. The blade as claimed in claim 11, characterized in that the cap (33) of the blade (10) is bounded at the edge on its upper face by a

circumferential blade crown (32), and in that the second cooling holes (27) open into the outside area within the blade crown (32).

17. The blade as claimed in one of the claims 1 to 16, characterized in that said blade has a blade crown (32) at the blade tip (11), which is bounded by a circumferential rail having a predetermined thickness (t), whereby the width (W) between the opposing rails varies with the distance (κ) along the chord line, such that t/W is between 0.05 and 0.15 for κ/κ_0 between 0 and 0.3, and that t/W is between 0.15 and 0.3 for κ/κ_0 larger than 0.3 and up to 1.0, κ_0 being the overall chord line length.

18. The blade as claimed in one of the claims 1 to 17, characterized in that said blade has a ratio D/W between 0.1 and 0.3 for κ/κ_0 between 0 and 0.3, and that the ratio D/W is between 0.3 and 0.8 for κ/κ_0 larger 0.3 and up to 1.0.

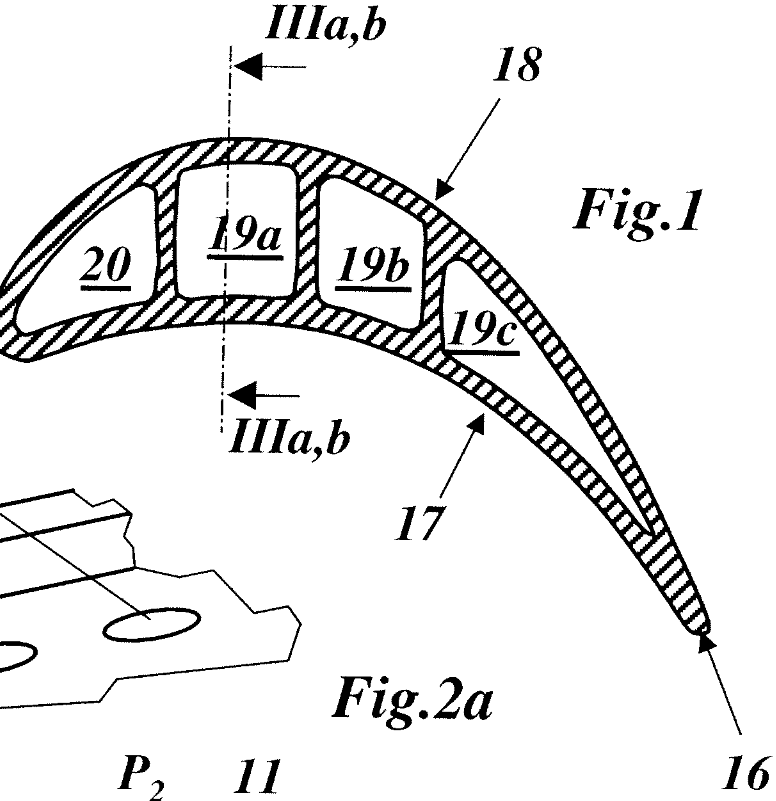


Fig.1

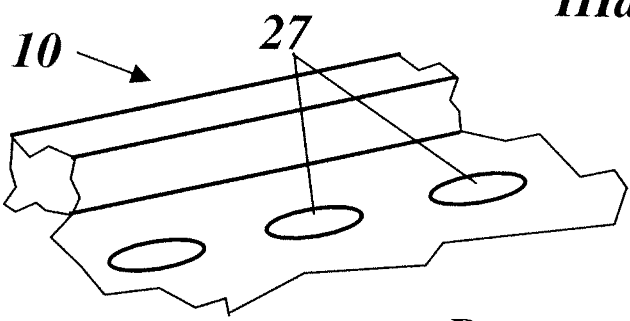


Fig.2a

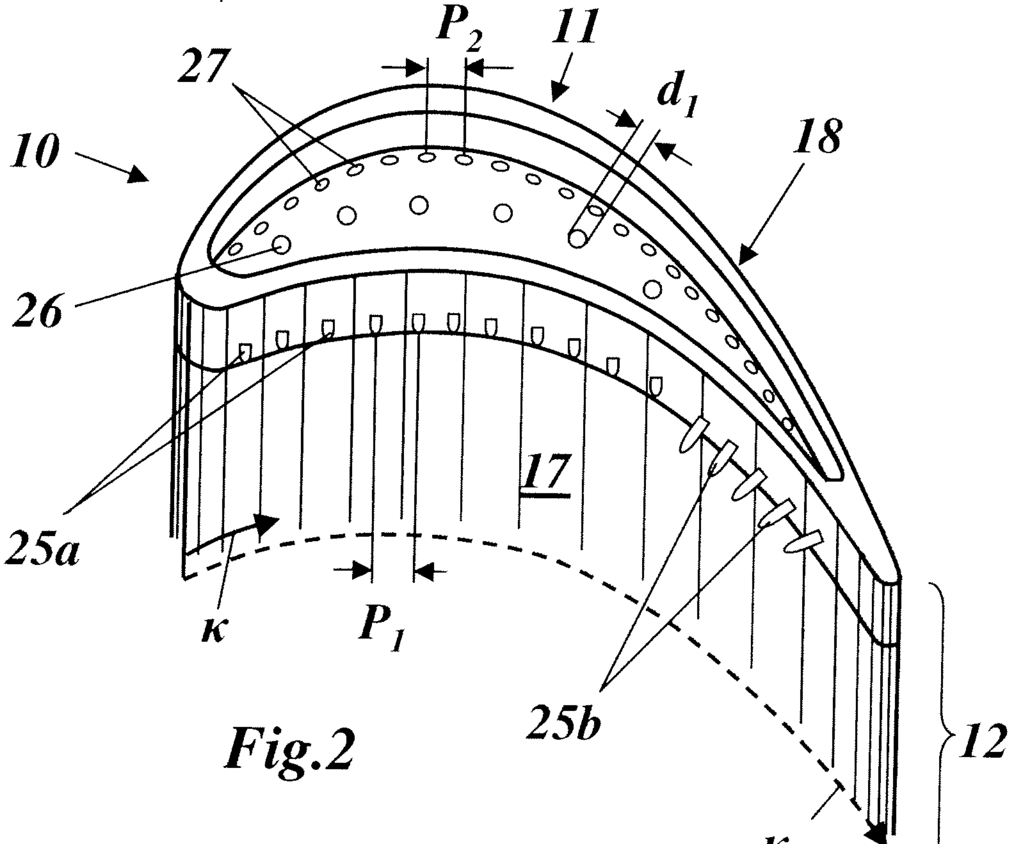


Fig.2

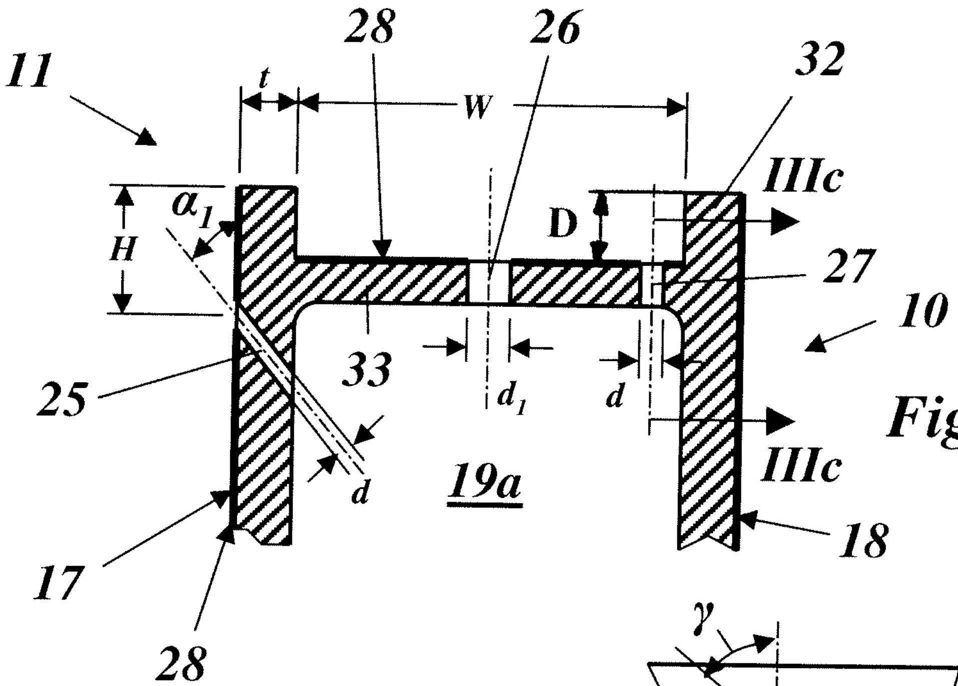


Fig.3a

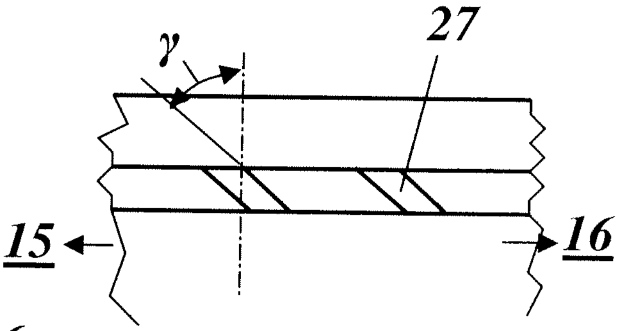


Fig.3c

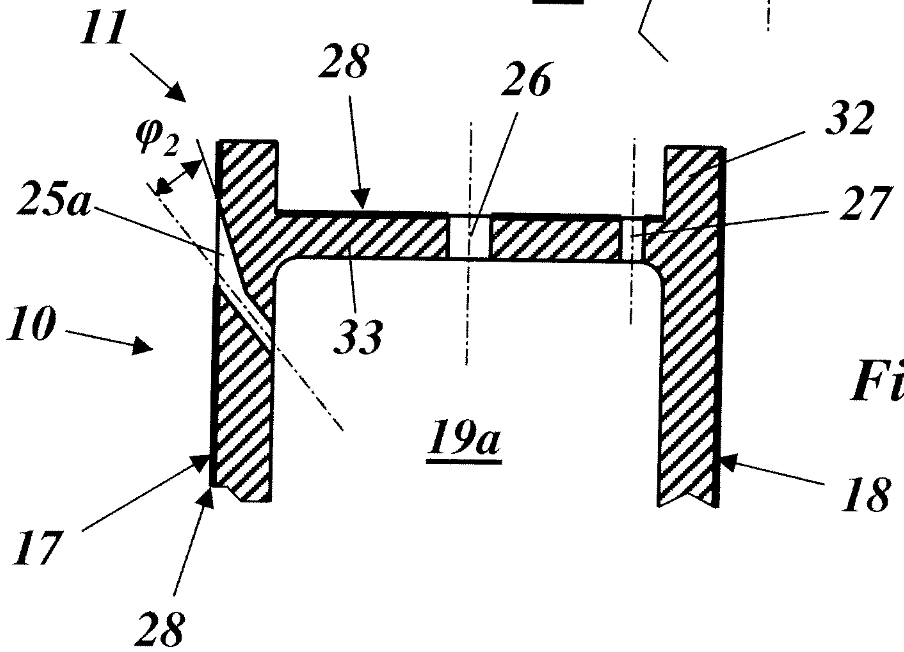


Fig.3b

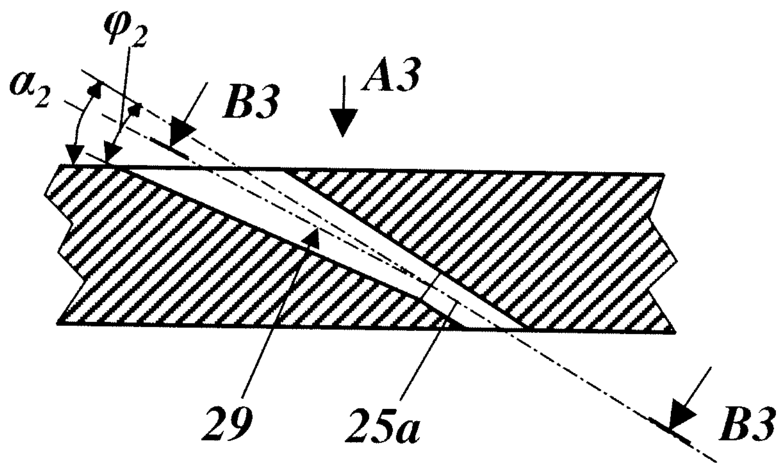


Fig.4a

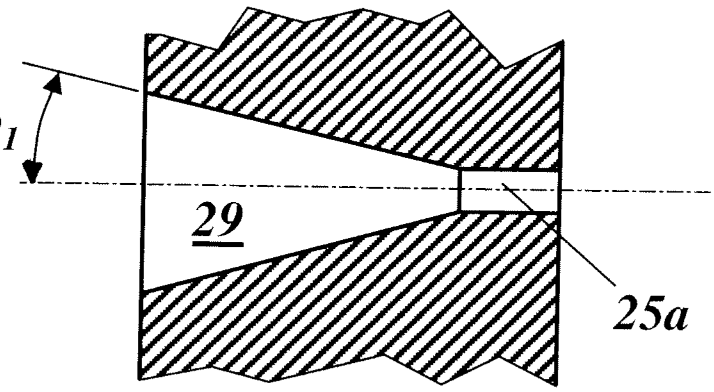
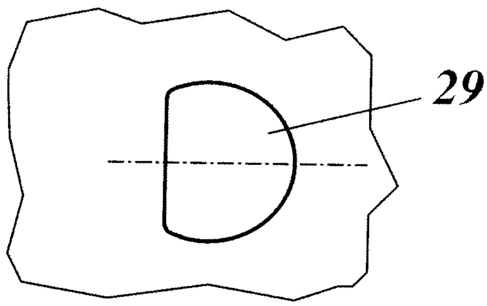


Fig.4b

B3-B3



A3

Fig.4c

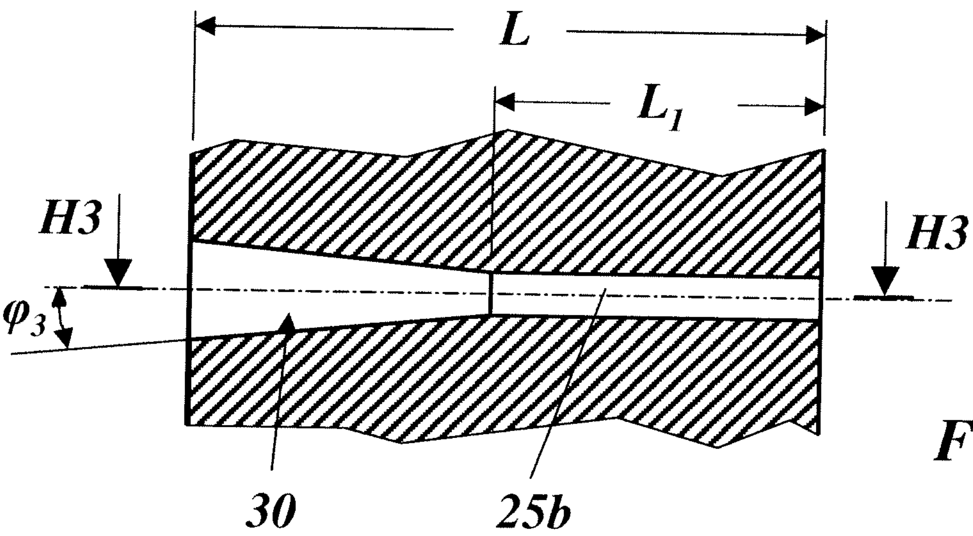
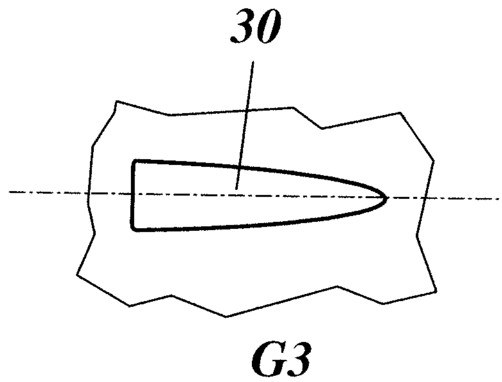
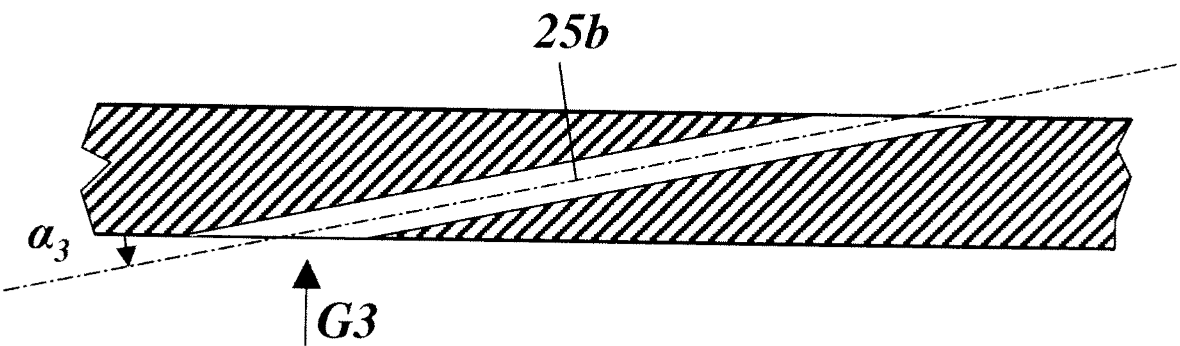


Fig.5a

Fig.5b





H3-H3

Fig.5c

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/053286

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D5/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

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X	US 2002/197160 A1 (LIANG GEORGE [US]) 26 December 2002 (2002-12-26) figures 2,3 pages 17-27 pages 40-43 -----	1-14,16
X	US 2008/118367 A1 (LIANG GEORGE [US] ET AL) 22 May 2008 (2008-05-22) paragraphs [0017] - [0023] figures 1,2 -----	1-3, 11-14, 16-18
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 July 2010	16/07/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	de la Loma, Andrés

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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