(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 025 869 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
18.02.2009 Bulletin 2009/08

(51) Int Cl.:
F01D 5/18 *(2006.01)*

(21) Application number: **07113996.8**

(22) Date of filing: **08.08.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK RS

(71) Applicant: **Alstom Technology Ltd**
5400 Baden (CH)

(72) Inventors:
- **Konter, Maxim, Dr.**
5313, Klingnau (CH)
- **Soumine, Anton**
115093, Moscow (RU)
- **Vorontsov, Sergey**
129164, Moscow (RU)
- **Khanin, Alexander**
121601, Moscow (RU)

(54) Gas turbine blade with internal cooling structure

(57) A gas turbine rotating blade (1) comprises an internal cooling structure having at least three cooling air passages (5-7) in fluid connection with one another by means of turns (9, 10). An opening (12) provides an outlet for dissolved core material to be removed from the blade following casting of the cooling structure without any residue remaining within. According to the invention, the cooling structure comprises trip strips (13, 15) in the first and second passage (5, 6) with specified ratio of height to distance between trip strips and the trip strips (13) in the first passage being arranged at 90° with respect to the direction of airflow. In a particular embodiment, the trip strips (15) in the second passage (6) are arranged at angle of 45°. The design according to the invention assures sufficient airflow through first and second air passages (5, 6).

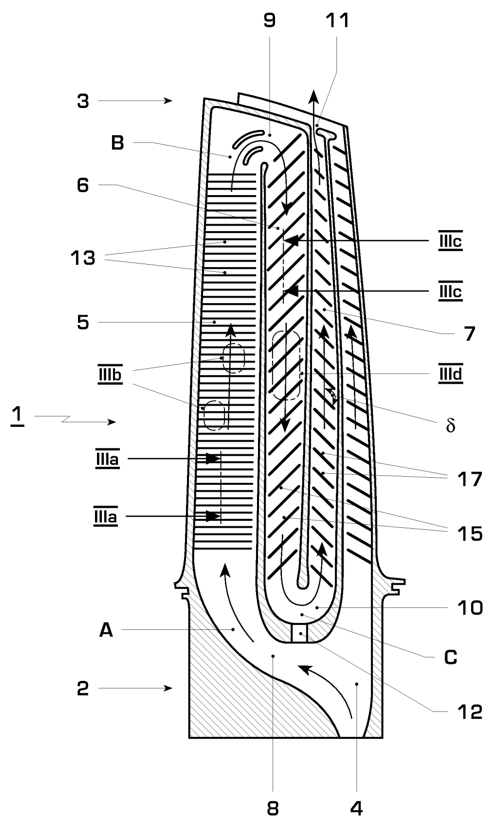

FIG. 2

EP 2 025 869 A1

Description

Technical field

[0001] The present invention relates to cast rotating blades for a gas turbine, and in particular to the design of an internal cooling structure within the blade.

Background art

[0002] Turbine blades for gas turbines are designed and manufactured to withstand high temperatures during the gas turbine operation. Such turbine blades comprise an internal cooling structure through which a cooling fluid, typically air, is passed. Cooling air is typically bled from a compressor of the gas turbine engine. This extraction of air however, reduces the overall performance of the engine. In order to minimize the effect on engine performance by minimizing the air consumption and yet assure sufficient cooling of the blade, the internal blade cooling structure is designed for optimal cooling efficiency. Such designs are disclosed for example in US 6,139,269, US 6,634,858 and US 5,403,159. Each is individually designed having complex arrangements of serpentine cooling structures including several passages extending in the blade longitudinal direction. Some of the passages connect to an inlet opening at the blade root, while other passages connect to an outlet opening at the blade tip or to a further longitudinal passage by means of a turn or bend of approximately 180°. The cooling structures furthermore comprise a multitude of trip strips arranged on the walls of the longitudinal passages, all of which oriented at approximately 45° to the direction of flow through the passage. Turbine blades with internal cooling structure of this type are cast, as a rule, by an investment casting process using a core defining the cooling structure. The core is made of a leachable material such as ceramic. Following the molding process, the ceramic core is removed from the blade by a leaching process.

[0003] The leaching process is difficult in regard to the removal of all of the dissolved core material in the region of the 180° turns. A risk remains that residual core material stays behind in the blade cooling channels and obstructs the flow of cooling media through the cooling passage. In order to reduce this risk, an opening is provided in the cooling structure wall in the region of the 180° turn for remaining core material to leach out. In some known gas turbine blades, as disclosed for example in US 6,634,858, this opening is again closed by means of a plate or plug.

Summary of invention

[0004] It is the object of the invention to provide a gas turbine rotating blade with an internal cooling structure having a design that allows improved and more cost efficient manufacturability over those of the state of the art while, at least, maintaining the existing cooling performance of the internal cooling structure.

[0005] A gas turbine rotating blade comprises an internal cooling structure having at least three cooling passages extending in the blade longitudinal direction, at least one inlet opening in the region of the blade root, and at least one outlet opening in the region of the blade tip leading from a cooling passage out of the blade. The blade furthermore comprises in its root region a plenum for cooling air, the inlet opening extending from this plenum to a cooling passage. The first cooling passage extends, in the direction of cooling fluid, from the blade root region to the blade tip region. The second cooling passage extends from the tip to the root region. First and second cooling passages are in fluid connection with one another in the region of the blade tip by means of a bend or turn in the region of the blade tip. The third cooling passage again extends from the root to the tip, while second and third cooling passages are in fluid connection with one another by means of a turn or bend in the region of the blade root.

[0006] In order for a core material to be removed from the bend by leaching out with a reduced risk of core material remaining in the bend, an opening is provided in the cooling structure wall extending from the plenum to the bend or turn in the blade root region from the second to the third cooling passage. The opening provides a direct fluid connection from the bend to the root of the blade and to the exterior of the blade. In particular, the opening and root region of the blade is such that a liquid fluid is allowed to flow directly and essentially in the longitudinal blade direction out of the blade internal cooling structure. This allows the fluid core material to exit the blade completely without having to pass through any back turns or dead zones, where dissolved core material could stay behind. Thus, it is prevented that fluid core material remains in the structure as residual fluid. The flow of cooling air through the blade internal cooling structure when the gas turbine is in operation is thus assured.

[0007] For purposes of simplified and more cost efficient manufacture of the gas turbine rotating blade, the opening at the bend or 180° turn of the internal structure near the root region is not closed up again prior to mounting on the rotor and operation of the gas turbine. Since said opening at the 180° turn has an effect on the aerodynamics of the internal cooling structure and distribution of the cooling air and thus on the overall cooling performance, the design of each cooling passage is individually adapted and optimized in view of cooling efficiency.

[0008] According to the invention, the first cooling passage extending in the direction of cooling fluid from the plenum in the root region to the tip region of the blade, comprises a plurality of turbulators or trip strips arranged at an angle of $90 \pm 10°$ to the direction of flow of the cooling fluid. Additionally, the second cooling passage, in fluid connection with the first cooling passage by means of a turn, comprises a plurality of trip strips or turbulators. Finally, in combination with the specific orientation of the trip strips in the first cooling passage, the trip strips in the first and second cooling passages are arranged and dimensioned such that the ratio between their height and the distance between adjacent trip strips is 10 ± 2.

[0009] In an exemplary embodiment of the invention, the trip strips in the second cooling passage are arranged at an angle of 45° ± 10° in relation to the flow direction. In a further exemplary embodiment, the third cooling passage comprises a plurality of trip strips arranged at an angle of 45° ± 10° from the direction of flow to the direction of the trip strip.

[0010] As mentioned above, the opening at the turn from the second to the third passage affects the cooling air distribution in the cooling structure. In particular, a non-plugged opening at that location would result in a reduction of the airflow from the plenum in the root region through the first and second passage and an increase of airflow from the plenum through the opening directly to the third passage. The specific design of trip strips in the first and second passage according to the invention allows an optimization of the cooling airflow and re-establishment of the airflow through the first and second passage. It thereby assures sufficient and uniform cooling of the entire blade.

The design of the trip strips according to the invention allows compensation of small hydraulic pressure losses from the beginning of the first passage to the beginning of the third passage. Compensation of the low-pressure losses is achieved by pumping forces in the first and second passages due to a convective temperature increase of the cooling air along these passages.

[0011] The flow dynamics of the cooling air are elaborated in connection with the figures.

[0012] As mentioned above, the design of the blade cooling structure according to the invention allows for optimized manufacturing due to the opening provided in the turn near the root of the blade. The design requires no measures following the casting for closing of the opening. The specific design of the trips strips in the cooling passages compensates for hydraulic pressure losses and thereby assures sufficient cooling within the first and second passages. The design therefore allows improved and simplified manufacturing while maintaining cooling performance.

Brief description of the drawings

[0013]

Figure 1 shows an exemplary gas turbine blade, to which the invention may be applied;

figure 2 shows a cross-sectional view of the blade of figure 1 along II-II showing an internal blade cooling structure according to the invention;

figures 3a and 3b show respectively, a cross-section of trip strips along IIIa-IIIa in figure 2 and trip strips in detail, in particular the arrangement and parameters of the trip strips in the first cooling passage of the blade cooling structure;

figures 3c and 3d show respectively, a cross-section of trip strips along IIIc-IIIc in figure 2 and trip strips in detail, in particular the arrangement and parameters of trip strips in the second cooling passage of the blade cooling structure.

Best modes for carrying out the invention

[0014] Figure 1 shows a rotating gas turbine blade 1 extending longitudinally from a blade root 2 to a blade tip section 3.

Figure 2 shows the internal cooling structure of the blade having a plenum 4 within the root region for cooling air entering the cooling structure, a plurality of at least three longitudinal cooling passages 5-7 extending from the plenum 4 at the root 2 to the tip 3, from the tip section 3 to the root 2, and from the root to the tip section 3, respectively. The longitudinal passages are in fluid connection with one another by means of turns 9 and 10 of approximately 180°.

[0015] The airflow passes, as indicated by arrows, from the plenum 4 through an inlet opening 8 at the beginning of the first cooling passage 5 (position A) to the end of the first passage at the tip of the blade (position B), and around a turn 9 of approximately 180°. It then flows along the second cooling passage 6 to a further 180° turn 10 (position C) connecting the second cooling passage 6 with the third cooling passage 7. The cooling air finally flows through the third cooling passage 7 to the tip of the blade and exits the cooling structure through an outlet opening 11 at the tip of the blade.

At the turn 10 near the root of the blade, an opening or channel 12 is provided for leaching out core material after casting and allowing all of the dissolved core material to run out of the cooling structure via the plenum 4 such that no core material remains in the turn 10. The opening 12 is left open during operation of the gas turbine. Through this opening 12, cooling air could pass more readily from the plenum 4 directly to the third cooling passage 7 rather than through first and second cooling passages 5 and 6. However, due to the particular design of the first and second cooling passages according to the invention, the pressure drop between position A and position B is such that a cooling airflow is assured through passages 5 and 6.

A pressure loss is due to hydraulic resistance and depends on the square of the air velocity, the shape of the channel, the degree of smoothness of the passage walls as well as the shape of turbulators or trip strips. The features according to the invention result in that the air pressure at position C at the beginning of the third passage 7 is lower than at position A at the beginning of the first passage 5.

[0016] Additionally, a pumping effect occurs due to the rotation of the blade during turbine operation. Due to the pumping effect the air pressure increases with increasing radius of the passage, specifically in proportion to the difference of the squares of the radii at a given angular speed. In the first passage 5 therefore, the pressure increases with increasing radius from position A to position B. In the second passage 6, the pressure decreases with decreasing radius from position B to position C, decreasing by the same magnitude as it increased in passage 5. The final effect would therefore be zero. Additionally however, a heat flux is picked up by the cooling air from the heat convective walls of the passages increasing the temperature of the cooling air. As a result, the temperature of the cooling air in the second passage 6 is higher than in the first passage 5. This temperature change also affects the pumping effect in the first and second passages. The higher temperature in the second passage results in that the pumping effect along the second passage 6 is smaller than in the first passage 5. Therefore, the pressure at position B is lower compared to that at position A, resulting in an effective cooling airflow along passages 5 and 6.

[0017] As mentioned above, the hydraulic resistance of a cooling passage depends from, among others, on the design of the passage, in particular the design of the turbulators or trip strips 13 and 15. Figure 2 shows an embodiment of the invention comprising in the first cooling passage 5 turbulators or trip strips 13 arranged at 90±10° in relation to the direction of cooling flow, as indicated by the arrow. Figure 3a shows in cross-section the parameters of the trip strips. Each trip strip has a height h measured from the wall 14 of the passage 5, and each trip strip 13 is arranged at a distance d from the adjacent trip strip. The height h and distance d are at a ratio of 10±2. The trip strips are shown having a rectangular shape. However, they can be of any other aerodynamically suitable cross-sectional shape as well. Figure 3b shows the orientation of the trip strips in relation to the direction of cooling air flow indicated by the angle α. The angle α is 90°± 10°.

[0018] Figure 2 further shows the second cooling passage 6 having trip strips 15. Similarly as in passage 5, the trip strips 15 in passage 6 are designed having a height h measured from the wall 16 of the passage 6 and distance d between them such that the ratio of height h to distance d is 10±2, as shown in figure 3c. Height h is measured from the wall of the passage, and distance d is measured between adjacent trip strips along the direction of cooling airflow.

[0019] The trip strips 15 in cooling passage 6 as shown in figure 2 are at a greater distance from each other compared to the distance between adjacent trip strips 13 in passage 5. However, the essential design features of cooling passages in order to assure a sufficient cooling air flow through passages 5 and 6 are the specific angular orientation of the trip strips in passage 5 and the ratio of height h to distance d between adjacent trip strips of 10±2 for both passages 5 and 6.

A further design feature, which enhances the cooling performance includes the specific angular orientation of the trip strips in passage 6. The trip strips are arranged at an angle β of 45±10° in relation to the direction of airflow, as shown in figure 3d.

[0020] The third passage 7 can also comprise turbulators 17 of any design in order to enhance cooling efficiency along that passage. In the exemplary embodiment shown, they are arranged at an inclination angle δ to the direction of airflow, the angle being 45±10° in relation to the direction of airflow.

Terms used in Figures

[0021]

1	rotating blade
2	blade root
3	blade tip
4	plenum for cooling air
5	first cooling air passage
6	second cooling air passage
7	third cooling air passage
8	inlet opening
9	turn
10	turn
11	outlet opening
12	outlet opening for core material
13	trip strips in first passage
14	cooling passage wall
15	trip strips in second passage
16	wall of second cooling passage
17	trip strips in third passage
h	trip strip height
d	distance between adjacent trip strips
α	orientation angle of trip strips 13
β	orientation angle of trip strips 15
δ	orientation angle of trip strips 17
A	position at beginning of cooling passage 5
B	position at end of cooling passage 5
C	position at bend from second passage 6 to third passage 7

Claims

1. Gas turbine rotating blade (1) comprising a blade root (2) and blade tip (3) and an internal cooling structure comprising
a first cooling air passage (5) extending essentially in the longitudinal direction of the blade from a plenum (4) in the blade root (2) to the blade tip (3), a second cooling air passage (6) extending from the blade tip (3) to the blade root (2) and a third cooling air passage (7) extending from the blade root (2) to the blade tip (3), the first passage (5) being in fluid connection with the second passage (6) by means of a first turn (9) in the region of the blade tip (3) and the second passage (6) being in fluid connection with the third passage (7) by means of a second turn (10) in the region of the blade root (2),

and the cooling structure further comprising an opening (12) extending from the second turn (10) to the plenum (4) providing a direct outlet for fluids from the blade

characterized by

the first and second cooling air passages (5, 6) each comprising a plurality of trip strips (13, 15), the trip strips (13) in the first cooling passage (5) being arranged at an angle (α) of $90 \pm 10°$ to the direction of cooling fluid flow in that first passage (5), and additionally, the trip strips (13, 15) in the first and second passages (5, 6) have a height (h) and a distance(d) between adjacent trip strips (13, 15), the ratio between the height (h) and the distance (d) being 10 ± 2.

2. Gas turbine rotating blade (1) according to claim 1
characterized by
the trip strips (15) in the second cooling passage (6) arranged at an angle (β) of $45° \pm 10°$ in relation to the direction of airflow.

3. Gas turbine rotating blade (1) according to claim 1 or 2
characterized by
the third cooling passage (7) comprising a plurality of trip strips (17) arranged at an angle (δ) of $45° \pm 10°$ in relation to the direction of airflow.

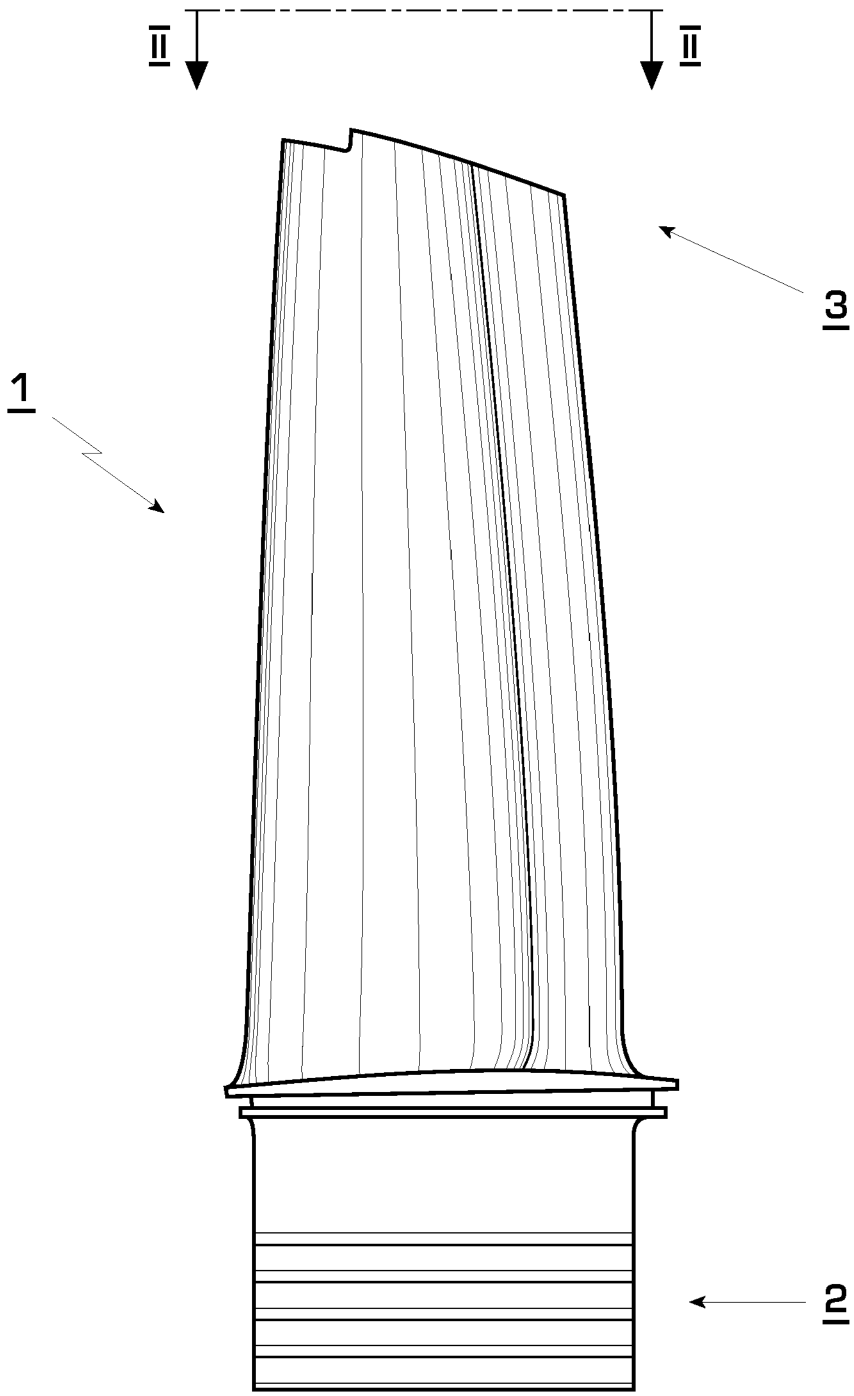

FIG. 1

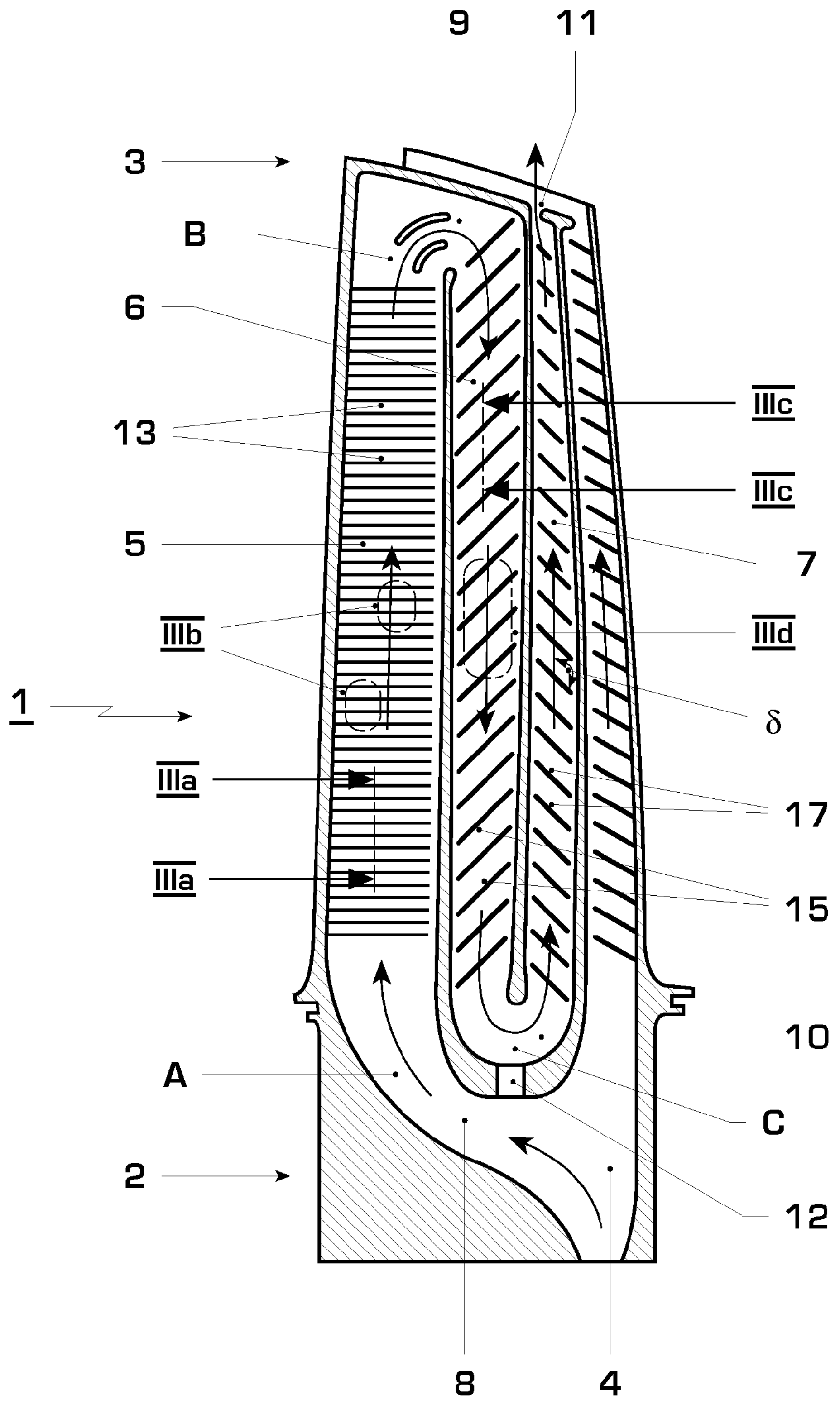

FIG. 2

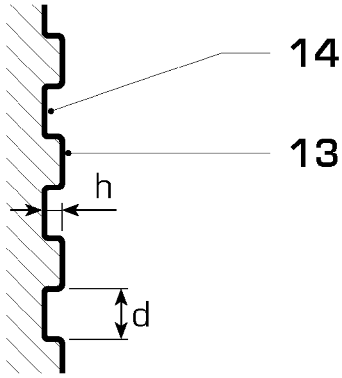

FIG. 3a

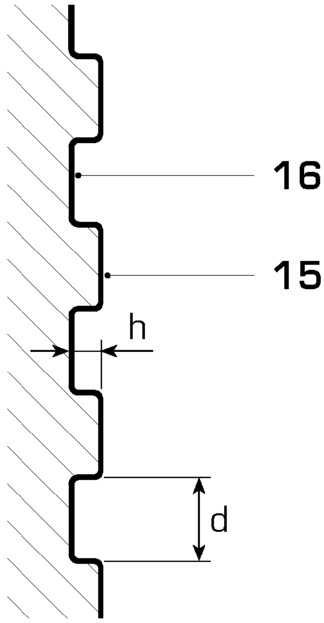

FIG. 3c

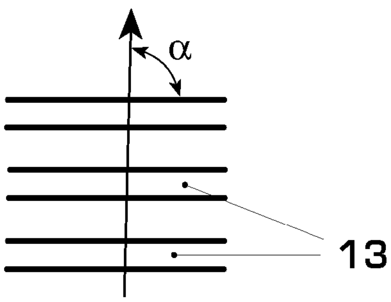

FIG. 3b

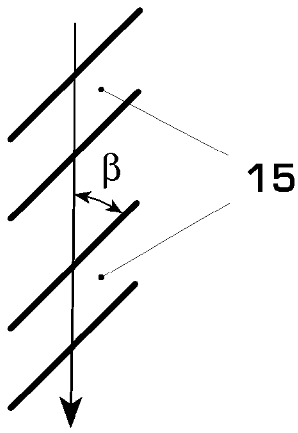

FIG. 3d

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 11 3996

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	US 4 278 400 A (YAMARIK GEORGE J ET AL) 14 July 1981 (1981-07-14) * column 3, line 40 - column 4, line 31; figure 1 *	1	INV. F01D5/18
Y	US 5 700 132 A (LAMPES ELIAS HARRY [US] ET AL) 23 December 1997 (1997-12-23) * column 6, lines 1-46; figures 1,3 *	1	
Y	GB 2 112 467 A (UNITED TECHNOLOGIES CORP) 20 July 1983 (1983-07-20) * page 3, lines 71-111; figure 1 *	1	
Y	US 5 232 343 A (BUTTS DON [US]) 3 August 1993 (1993-08-03) * column 4, lines 46-61; figures 1-3 *	1	

TECHNICAL FIELDS SEARCHED (IPC)
F01D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	10 January 2008	OECHSNER DE CONINCK

1

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

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 11 3996

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.

10-01-2008

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 4278400	A	14-07-1981	NONE			
US 5700132	A	23-12-1997	NONE			
GB 2112467	A	20-07-1983	DE	3248162	A1	07-07-1983
			FR	2519070	A1	01-07-1983
			IL	67382	A	30-06-1988
			IT	1155035	B	21-01-1987
			JP	1740028	C	15-03-1993
			JP	4024524	B	27-04-1992
			JP	58117303	A	12-07-1983
			SE	453847	B	07-03-1988
			SE	8207316	A	29-06-1983
			US	4775296	A	04-10-1988
US 5232343	A	03-08-1993	NONE			

EPO FORM P0459

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

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 6139269 A **[0002]**
- US 6634858 B **[0002] [0003]**
- US 5403159 A **[0002]**