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(54) **Shrouded turbine blade with cooling air outlet port on the blade tip and corresponding manufacturing method**

(57) The present invention relates to a turbine blade (1) for an axial turbo-machine having a blade body (10), extending in a radial direction (11) between a blade root (12) and a blade tip (13), wherein the blade body (10) is provided with at least one inner passage (15) for a cooling

medium and at least one outlet port (16) to exhaust the cooling medium from the inner passage (15) to the outer side of the blade tip (13). According to the invention, the outlet port (16) comprises a port axis (17), which is inclined to the radial direction (11).

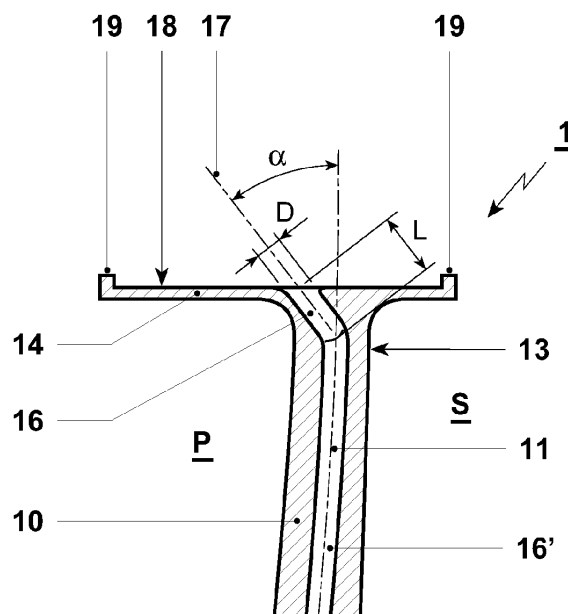


FIG. 4

Description

[0001] The present invention relates to a turbine blade, preferably for a gas turbine, with a blade body, extending in a radial direction between a blade root and a blade tip, wherein the blade body is provided with at least one inner passage for a cooling medium and at least one outlet port to exhaust the cooling medium from the inner cooling medium passage to the outer side of the blade tip.

STATE OF THE ART

[0002] Patent application WO 2005/106206 A1 shows a turbine blade for a gas turbine with a blade body, extending in a radial direction between a blade root and a blade tip. On the blade tip a blade shroud is arranged, and within the blade body an inner passage for a cooling medium, such as air, is arranged, shown as a hole within the blade body extending in radial direction. The hole forms an outlet port, which is arranged on the outer platform of the blade shroud. Cooling medium can be exhausted through the outlet port, which leads to a cooling effect at that portion of the shroud. The outlet port extends along the radial direction in such a way, that the outlet port is perpendicular to the surface formed by the outer platform of the blade shroud.

[0003] This arrangement of the outlet port leads to disadvantages in exhausting the cooling air from the inner cooling air passage to the outer platform of the blade shroud, in particular due to the turbulent flow conditions in that area. Moreover, the radial alignment of the outlet port does not allow recovery of pumping power.

DISCLOSURE OF THE INVENTION

[0004] Therefore, it is an object of the present invention to eliminate the above mentioned disadvantages. In particular it is an object of the present invention to provide improved outlet ports in the blade tip and in particular in a blade shroud.

[0005] This objective is achieved by a turbine blade according to claim 1 and a method according to claim 9 of the present invention. Preferred embodiments of the invention are defined by the dependent claims.

[0006] The basic idea of this invention comprises an outlet port for the cooling medium at the tip of the blade, wherein the longitudinal axis of the outlet port is inclined to the radial direction.

[0007] The outlet port according to the present invention comprises an alignment having a tangential component parallel to the rotating direction. The longitudinal axis of the outlet port is inclined with respect to the radial direction having an inclination angle. The inclined alignment of the port axis leads to an improvement of the pressure behavior of the exhausted cooling medium. In particular the tangential component of the exhaust cooling medium velocity allows the recovery of pumping power.

[0008] According to another preferred embodiment the outlet port extends from the inner cooling medium passage to the outer side of the blade tip in the inclined port axis.

[0009] Alternatively, the outlet port comprises an inner section extending in the radial direction and passing into a section formed by the outlet port in the inclined port axis.

[0010] The present invention comprising an outlet port with a longitudinal axis inclined to the radial direction is not limited to an outlet port featuring a single axis, which is inclined to the radial direction. In particular, the advantage of the present invention is also achieved, when only a part of the outlet port features a longitudinal axis, which is inclined to the radial direction. Thus, the outlet port may comprise an inner section extending in the radial direction and passing into a section formed by the inventive outlet port featuring a longitudinal axis, which is inclined to the radial direction. In both cases, the advantage of the present invention, namely an improved recovery of pumping power, can be obtained.

[0011] In a preferred embodiment, the turbine blade comprises a blade shroud comprising an outer platform, wherein the outlet port leads into the outer platform. The outer platform is an integral part provided with the blade body, and at least one outlet port passes through the blade shroud and leads into the surface of the outer platform.

[0012] Another preferred embodiment comprises an inclination angle between the inclined port axis and the radial direction, which amounts 20° to 80°, preferred 40° to 60° and most preferred 45°. According to yet another embodiment the outlet port may feature at least in its end section a curvature, and the port axis, which is inclined to the radial direction, represents the tangential axis in the transition of the outlet port to the surface of the blade body, in particular the surface of the blade shroud within the outer platform. When the inclination angle amounts between 30° and 50°, in particular 35° to 45°, the recovery of pumping power has shown optimal results.

[0013] The turbine blade features an airfoil cross section having a pressure side and a suction side, the outlet port being inclined into the direction of the pressure side. Thus, the outlet port is inclined in the rotational direction of the turbine blade. According to another advantageous embodiment of the present invention the outlet port extent along its longitudinal axis features a length and a diameter, wherein the length to diameter ratio $L/D = 1$ to 3 and preferred $L/D = 2$. The length of the outlet port is defined by the distance between the inner passage for the cooling medium and the surface of the blade tip, or the surface of the outer platform of the blade shroud, respectively. The diameter refers to an outlet port with a circular cross section. According to a preferred embodiment, the length of the outlet port amounts at least two times the diameter of the outlet port.

[0014] Another preferred embodiment of the turbine blade according to the invention features side rails on the outer platform of the shroud. The side rails extend

radially outward from the platform and preferably delimitate the outer platform at least lateral to the rotation direction of the turbine. The side rails increase the stiffness of the blade shroud and decrease the deformation and bending in the radial outward direction with the time of turbine operation. Moreover, the side rails improve the dynamic behavior in the gap between the blade shroud and the stator ring of the turbine. Consequently, the advantage of the inventive arrangement of the outlet port combined with side rails in the blade shroud enhances the positive effects of the invention.

[0015] According to yet another preferred embodiment of the present invention at least one added material section is applied to the port area of the outlet port on the blade tip, wherein the outlet port is formed in the added material section. This leads to the advantage that existing turbine blades can be refitted according to the present invention, and the turbine blades can be retroactively provided with outlet ports according to the present invention. Usually, the outlet port extends in the radial direction, and when a material section is added on the blade tip, the outlet port can pass through the added material section in a port axis, which is then inclined to the radial direction.

[0016] The objective of the present invention is furthermore achieved by a method for providing a turbine blade for a gas turbine with a blade body, extending in a radial direction between the blade root and the blade tip, wherein the blade body is provided with at least one inner passage for a cooling medium and at least one outlet port to exhaust the cooling medium from the inner passage to the outer side of the blade tip, and wherein the method comprises the steps of applying at least one added material section to the port area of the outlet port and forming an outlet port in the added material section having a longitudinal axis being inclined to the radial direction.

[0017] This method is suitable to provide existing turbine blades with outlet ports according to the present invention. An added material section can be applied to the blade tip, which represents the port area of the outlet port, advantageously featuring the same material as the material of the blade body. The forming of an outlet port may be done in the added material section by drilling a through hole.

[0018] In particular, the at least one added material section can be applied to the port area of the outlet port by means of welding, preferably build-up welding. This build-up welding technology forms a well-known technology for repairing turbine blades.

[0019] According to a preferred embodiment, the outlet port is formed by applying at least one added material section to the port area by forming a hole in the added material section extending in a radial direction and being aligned with the section of the outlet port, and arranging a closure means on the added material section which closes the outer mouth of the hole, and forming a lateral hole into the added material section extending along a port axis inclined to the radial direction and thus featuring

an intersection with the hole extending in radial direction. The hole-forming in the added material section can be performed mechanically or by EDM-technology or by ECM-technology or other suitable means.

PREFERRED EMBODIMENTS OF THE INVENTION

[0020] The aforementioned components as well as the claimed components and the components to be used in accordance with the invention in the described embodiments, are not subject to any limitation with respect to their size, shape, material selection and technical concept such that the selection criteria known in the pertinent field can be applied without limitations.

[0021] Additional details, characteristics and advantages of the object of the invention are disclosed in the dependent claims and the following description of the respective figures, which show preferred embodiments in an exemplary fashion of the subject matter according to the invention in conjunction with the accompanying figures, wherein:

Figure 1 shows a perspective view of an embodiment of a turbine blade,

Figure 2 a side-view of the turbine blade of figure 1,

Figure 3 a top-view of the turbine blade comprising a port outlet,

Figure 4 a cross-sectional view of the turbine blade according to line IV-IV in Fig. 3 and

Figure 5 another embodiment of a turbine blade with a retroactively added outlet port according to the present invention.

[0022] Figures 1 and 2 show a turbine blade 1 in a perspective view (Figure 1) and in a side-view (Figure 2). The turbine blade 1 features a blade body 10 and the blade body 10 extends in a radial direction 11 between a blade root 12 and a blade tip 13. A blade shroud 14, is arranged at the blade tip 13, the blade shroud 14 contributing to a controlled and a minimized leakage flow in the gap between the blade tip 13 and a stator casing of the turbine. Moreover, the blade shroud 14 arranged on the blade tip 13 minimizes vibration amplitudes of the turbine blade 1. The blade shroud 14 shown in the figures comprises an outer platform 18 extending in a plane essentially parallel to the stator opposite of the blade tip 13 and the outer platform 18 may comprise two or more fins 23.

[0023] A passage 15 for a cooling medium is arranged within the blade body 10, and the passage 15 is pressurized by cooling air, for example. At least one outlet port 16, as shown in figure 2, forms a channel between the passage 15 and the outer platform 18. By means of the cooling medium heat from the walls of the turbine blade

1 is dissipated and the thermal stress of the blade material is reduced.

[0024] Figure 3 shows a top-view of the turbine blade 1 with the blade body 10, extending between the blade root 12 and the blade tip 13. An outlet port 16, is arranged in the blade body 10, which breaks through the blade shroud 14. The embodiment of the turbine blade 1 shows an outer platform 18 which features side rails 19 extending radially outward from the platform 18 and delimiting the outer platform 18 laterally to the rotation direction 20 of the turbine.

[0025] According to the present invention, the outlet port 16, shown in figure 3, features a longitudinal axis 17 which is inclined to the radial direction 11, as shown in the cross-sectional view of the following figure 4.

[0026] Figure 4 shows a cross sectional view of a turbine blade 1 comprising a blade body 10. In an exemplary fashion an inner section 16' of an outlet port 16 is shown within the blade body 10. The inner section 16' of the outlet port 16 extends in a radial direction 11, and in the blade tip 13 of the outlet port 16 extends along a port axis 17, which is inclined towards the radial direction 11.

[0027] As shown in the figure, the outlet port 16 features the port axis 17 inclined towards the radial direction 11 passing through the outer platform 18 of the blade shroud 14. The inclination angle is indicated with α , and the port axis 17 is inclined to a pressure side P, forming the opposite side of the suction side S of the blade body 10. The inclination of the port axis 17 and thus the outlet port 16 results to an improved recovery of pumping power. As further shown, the outlet port 16 features a diameter D and a length L, wherein the relation between D/L features the value 2.

[0028] Figure 5 shows another embodiment of the turbine blade 1 with a blade body 10 and a blade shroud 14 arranged on the blade tip 13. An inner passage 15 for the cooling medium is shown within the blade body 10 and an outlet port 16 forms a connection between the cooling medium chamber 15 and the outer platform 18 of the blade shroud 14. The outlet port 16 extends along the radial direction 11, and the turbine blade 1 comprising the aforementioned features forms a turbine blade 1 according to the state of the art.

[0029] According to the invention, an added material section 21 is applied to the area of the outlet port 16. The added material section 21 is welded on the surface of the outer platform 18 and features an extending outlet port 16'', which is arranged in a radial direction 11 and forms a hole which elongates the outlet port 16' in the radial direction 11. The extending outlet port 16'' is drilled into the added material section 21, either by means of mechanical drilling or by means of EDM-technology or ECM-technology. After drilling the extending outlet port 16'', a closure means 22 is applied to the mouth of the extending outlet port 16'' in the added material section 21. Thus, the extending outlet port 16'' is closed in the radial direction 11. Afterwards, an inclined outlet port 16''' is arranged in the added material section 21 along a port

axis 17, which is inclined to the radial direction 11 and the inclined outlet port 16''' forms an intersection with the extending outlet port 16''. By means of these method-steps of forming an outlet port 16 by forming the hole section 16'' and 16''', existing turbine blades 1 can be retroactively performed with an outlet port 16 featuring a port axis 17 at least in a port section which is inclined to the radial direction 11.

[0030] The present invention is not limited to the above described embodiments, which represent examples only and can be modified in various ways within the scope of protection, defined by the patent claims. Thus, the invention is also applicable to different embodiments, in particular of the design of the blade body 10 and the blade shroud 14.

[0031] List of reference numerals

1	turbine blade
10	blade body
11	radial direction
12	blade root
13	blade tip
14	blade shroud
15	passage for a cooling medium
16	outlet port
16'	inner section of outlet port
16''	extending outlet port
16'''	inclined outlet port
17	longitudinal axis of outlet port 16
18	outer platform
19	side rail
20	rotation direction
21	added material section
22	closure means
23	fin
α	inclination angle
P	pressure side
S	suction side

- L length of outlet port
- D diameter of outlet port

Claims

1. A turbine blade (1) for an axial turbo-machine having a blade body (10), extending in a radial direction (11) between a blade root (12) and a blade tip (13), wherein the blade body (10) is provided with at least one inner passage (15) for a cooling medium and at least one outlet port (16) to exhaust the cooling medium from the inner passage (15) to the outer side of the blade tip (13),
characterised in that a longitudinal axis (17) of the outlet port (16) is inclined relative to the radial direction (11).
2. A turbine blade (1) according to claim 1,
characterised in that the outlet port (16) is connected to a channel (16') extending in the radial direction (11).
3. A turbine blade (1) according to claim 1 or 2, wherein a blade shroud (14) is arranged on the blade tip (13) having an outer platform (18), wherein the outlet port (16) is arranged on the outer platform (18).
4. A turbine blade (1) according to claim 3,
characterised in that the inclination angle (α) between the inclined port axis (17) and the radial direction (11) amounts 20° to 80°, preferred 40° to 60° and most preferred 45°.
5. A turbine blade (1) according to one of the previous claims, **characterised in that** the turbine blade (1) comprises a pressure side (P) and a suction side (S), wherein the outlet port (16) is inclined in the direction of the pressure side (P).
6. A turbine blade (1) according to one of the previous claims, **characterised in that** the outlet port (16) extending in the port axis (17) features a length (L) and a diameter (D), wherein the relation between the length (L) and the diameter (D) amounts $L/D = 1$ to 3 and preferred $L/D = 2$.
7. A turbine blade (1) according to claim 3 - 6,
characterised in that the outer platform (18) comprises side rails (19) extending radially outward from the platform (18) of the shroud (14) and preferably delimiting the outer platform (18) at least laterally to the rotational direction (20) of the turbine.
8. A turbine blade (1) according to one of the previous claims, **characterised in that** at least one added material section (21) is applied to the port area of

the outlet port (16) on the blade tip (13), wherein the outlet port (16) extending along the port axis (17) is formed in the added material section (21).

9. A method for providing a turbine blade (1) for a gas turbine with a blade body (10), extending in a radial direction (11) between a blade root (12) and a blade tip (13), wherein the blade body (10) is provided with at least one inner passage (15) for a cooling medium and at least one outlet port (16) to exhaust the cooling medium from the inner passage (15) to the outer side of the blade tip (13), wherein the method is **characterised in** at least the following steps:
 - applying at least one added material section (21) to the area of the outlet port (16),
 - forming an extending outlet port (16'') in the added material section (21) which comprises a port axis (17) being inclined to the radial direction (11).
10. A method according to claim 9,
characterised in that the at least one added material section (21) is applied to the area of the outlet port (16) by means of welding.
11. A method according to claim 9 or 10,
characterised in that the extending outlet port (16'') is formed by:
 - applying at least one added material section (21) to the area of the outlet port (16'),
 - forming the radially extending portion of the outlet port (16'') in the added material section (21), being aligned with the outlet port (16'),
 - applying a closure means (22) to the added material section (21) which closes the radially extending portion of the outlet port (16''),
 - forming an inclined outlet port (16''') into the added material section (21) extending along a port axis (17) inclined to the radial direction (11) thereby creating an intersection with the radially extending portion of the outlet port (16'') in radial direction (11).

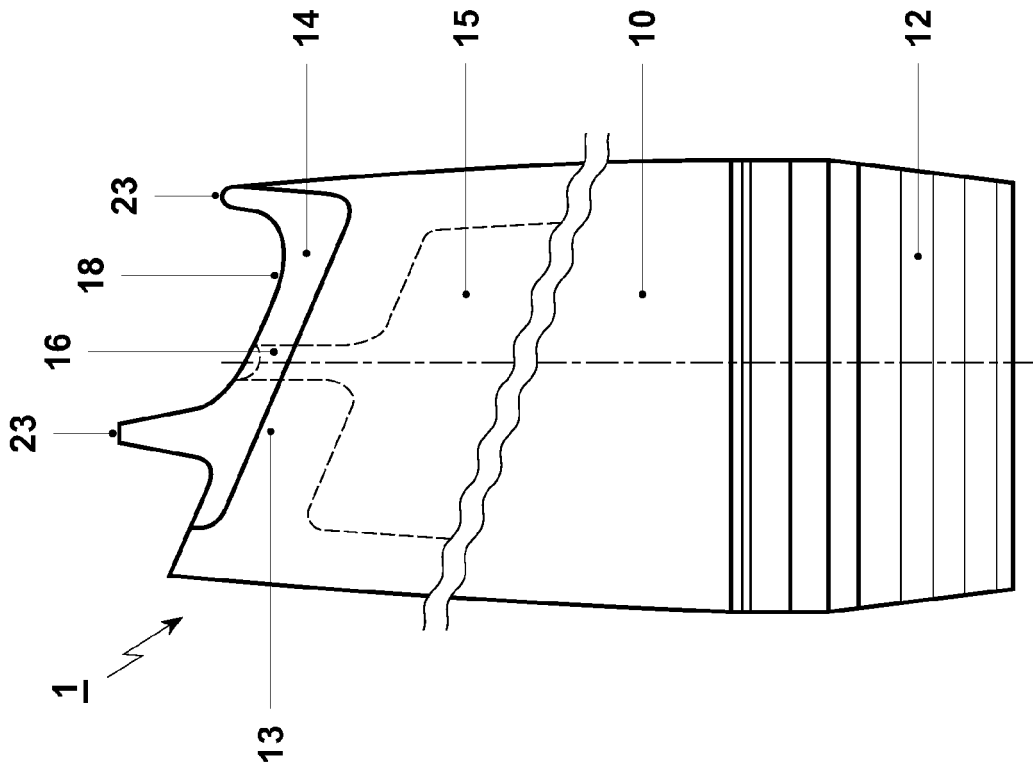


FIG. 2

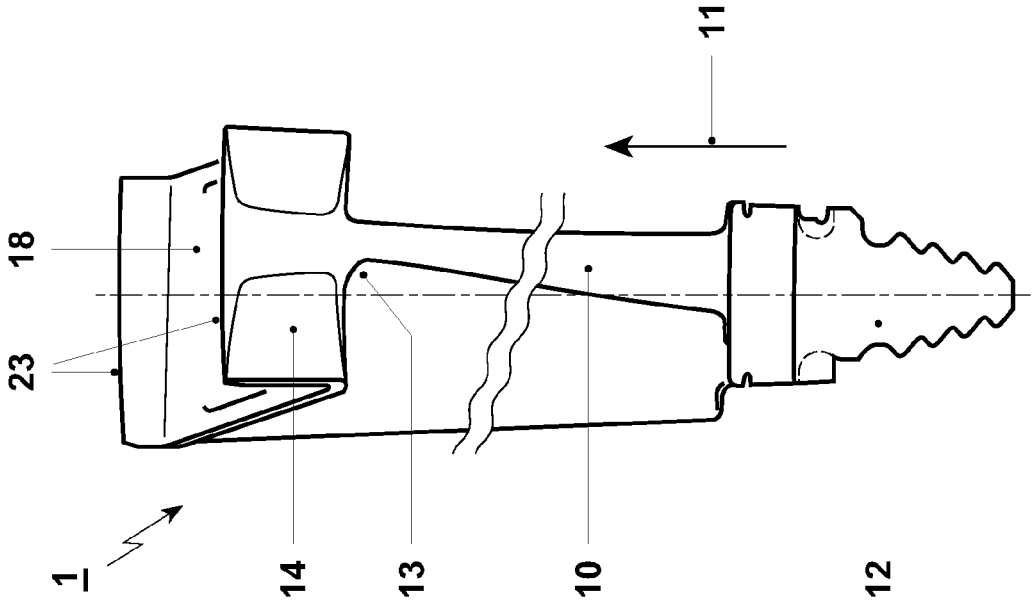
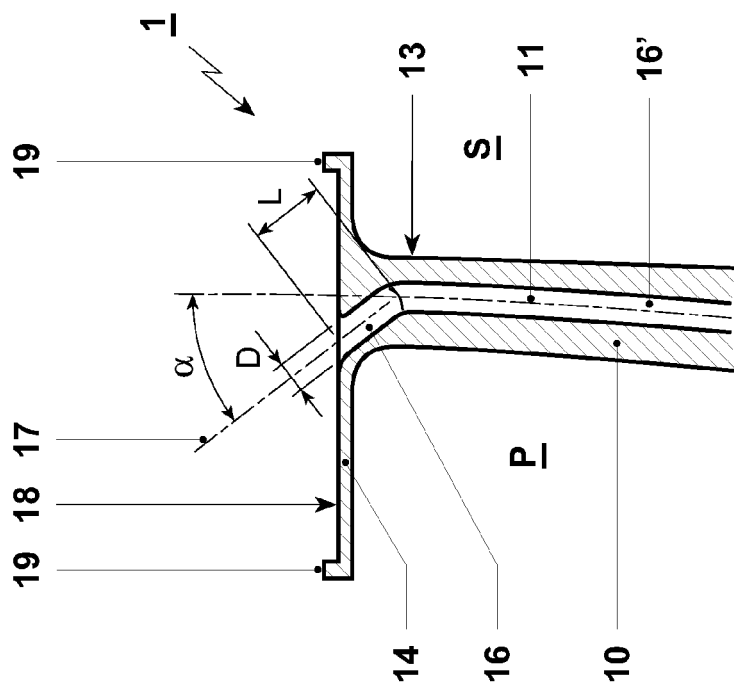
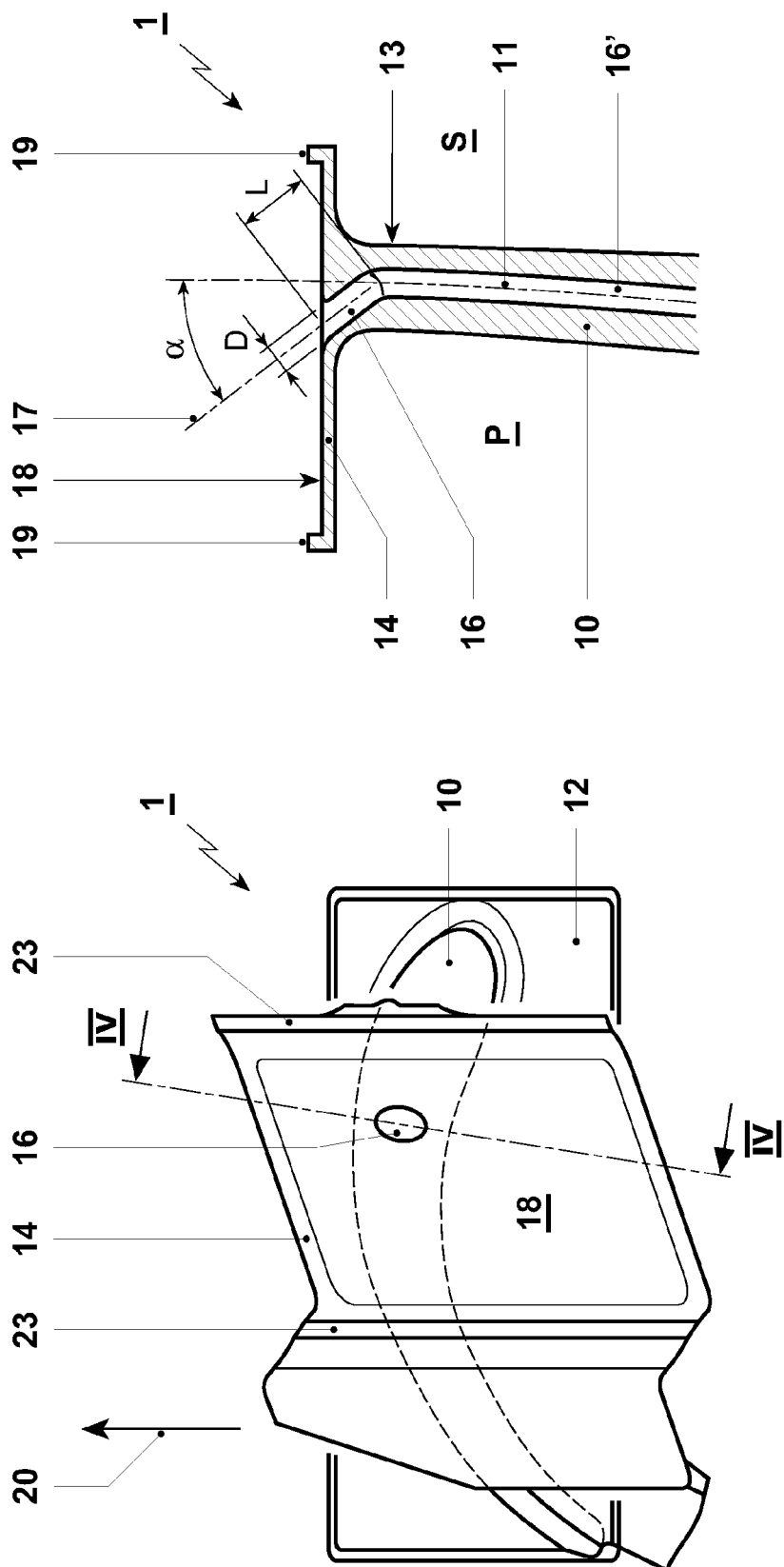
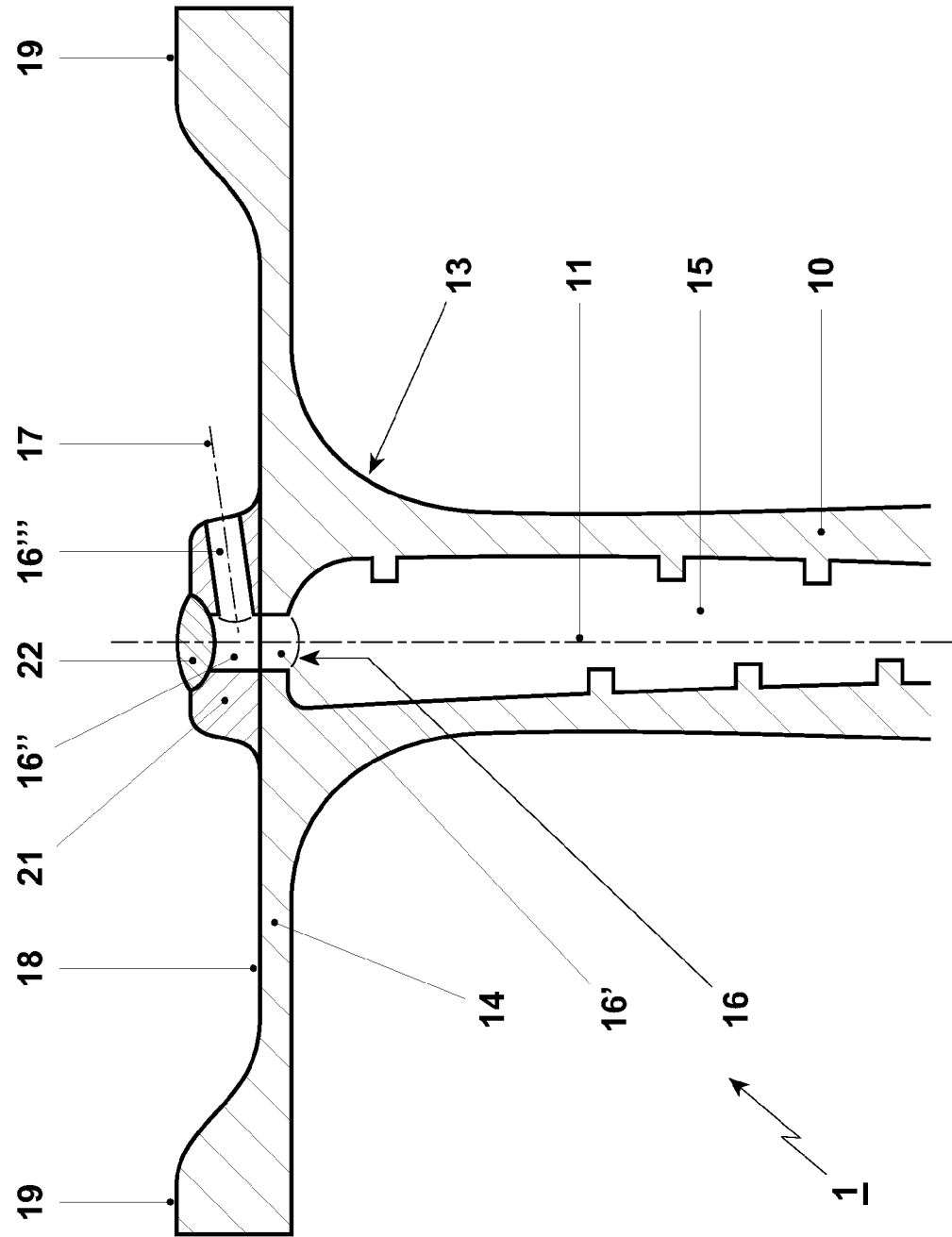


FIG. 1







EUROPEAN SEARCH REPORT

Application Number
EP 11 19 5390

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 2 149 675 A2 (GEN ELECTRIC [US]) 3 February 2010 (2010-02-03)	1-10	INV. F01D5/22
Y	* figures *	8-11	
X	EP 1 219 781 A2 (ALSTOM POWER NV [NL] ALSTOM SWITZERLAND LTD [CH] ALSTOM TECHNOLOGY LTD) 3 July 2002 (2002-07-03)	1-7	
Y	* figures 2,3 *	8-11	
X	DE 199 04 229 A1 (ASEA BROWN BOVERI [CH]) 10 August 2000 (2000-08-10)	1-6	
Y	* figures 1, 2,4,8,11,13,14 *	8-11	
X	JP 58 047104 A (KOGYO GIJUTSUIN) 18 March 1983 (1983-03-18)	1-7	
Y	* figures *	8-11	
X	GB 1 605 335 A (ROLLS ROYCE) 18 December 1991 (1991-12-18)	1-7	
Y	* figures 4,6 *	8-11	
X	US 2007/065283 A1 (SEKIHARA MASARU [US] ET AL) 22 March 2007 (2007-03-22)	1-6	TECHNICAL FIELDS SEARCHED (IPC)
Y	* figures 5a, 5b, 6a, 6b *	8-11	F01D
X	GB 2 384 275 A (ROLLS ROYCE PLC [GB]) 23 July 2003 (2003-07-23)	1-5,7	
Y	* figures *	8-11	
X	EP 1 041 247 A2 (GEN ELECTRIC [US]) 4 October 2000 (2000-10-04)	1-5	
Y	* figure 10 *	8-11	
Y	EP 1 749 967 A2 (ROLLS ROYCE PLC [GB]) 7 February 2007 (2007-02-07)	8-11	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 29 February 2012	Examiner Raspo, Fabrice
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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ON EUROPEAN PATENT APPLICATION NO.**

EP 11 19 5390

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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29-02-2012

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2149675	A2	03-02-2010	CA 2672806 A1 29-01-2010
			EP 2149675 A2 03-02-2010
			JP 2010031865 A 12-02-2010
			US 2010024216 A1 04-02-2010

EP 1219781	A2	03-07-2002	DE 10064265 A1 04-07-2002
			EP 1219781 A2 03-07-2002
			US 2002098078 A1 25-07-2002

DE 19904229	A1	10-08-2000	NONE

JP 58047104	A	18-03-1983	NONE

GB 1605335	A	18-12-1991	FR 2667353 A1 03-04-1992
			GB 1605335 A 18-12-1991
			IT 1235672 B 21-09-1992

US 2007065283	A1	22-03-2007	JP 4628865 B2 09-02-2011
			JP 2006316750 A 24-11-2006
			US 2007065283 A1 22-03-2007

GB 2384275	A	23-07-2003	NONE

EP 1041247	A2	04-10-2000	EP 1041247 A2 04-10-2000
			JP 4514885 B2 28-07-2010
			JP 2000297604 A 24-10-2000
			US 2001048878 A1 06-12-2001

EP 1749967	A2	07-02-2007	EP 1749967 A2 07-02-2007
			US 2007031241 A1 08-02-2007

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

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Patent documents cited in the description

- WO 2005106206 A1 [0002]