

GAS TURBINE

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Field of the Invention

The present invention lies in the filed of gas turbines. It is related to gas turbines according to the preamble of claim 1.

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Background of the Invention

It is common practice to provide blades or vanes of gas turbines with some form of cooling in order to withstand the high temperatures of the hot gases flowing through such turbines. Typically, cooling ducts are provided within the airfoil of the blades or vanes, which are supplied in operation with pressurised cooling air derived from the compressor part of the gas turbine. Usually, the cooling ducts have the convoluted form of a serpentine, so that there is one flow of cooling fluid or cooling air passing through the airfoil in alternating and opposite directions.

However, such a convoluted passageway necessarily requires bends, which give rise to pressure losses without heat transfer. Furthermore, as there is only one flow of cooling fluid, it is difficult to adapt this flow to the various cooling requirements existing at different locations of the airfoil.

To achieve more flexibility in the cooling of the airfoil, it has been already proposed (US-B2-6,874,992) to provide the airfoil with a plurality of cooling passages comprising a plurality of inlet passages along which cooling air flows from the base towards the tip region of the blade and a plurality of return passages along which cooling air flows from the tip towards the base region of the blade, whereby at least some of said inlet and return passages being connected by a common chamber located within the tip region of the blade.

However, as these known cooling passages are in fluid communication with each other by means of said common chamber located within the tip region of the blade, it is still difficult to adjust the individual mass flows of cooling fluid flowing through the various cooling passages.

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Another problem, which is related to the supply of the cooling fluid through the root of the blade or vane, may be explained with reference to Fig. 1-3:

According to Fig. 1 a blade 10 of a gas turbine comprises an airfoil 14 with a leading edge 17 and a trailing edge 16. The airfoil 14 extends along a longitudinal axis X of said blade between a lower end and a blade tip 15. At the lower end of said airfoil 14, a blade root 12 is provided for being attached to a groove 31 in a rotor 11 of said gas turbine. A hollow blade core 18 is arranged within said airfoil 14 and extends along the longitudinal axis X between said blade root 12 and said blade tip 1. The blade core 18 is provided for the flow of a cooling fluid, which enters said blade core 18 through a blade inlet 20 at said blade root 12 and exits said blade core 18 through at least one dust hole (not shown in Fig. 1, 2) at said blade tip 15. The cooling fluid (cooling air) is supplied by means of a rotor bore 19, which runs through the rotor 11 and is in fluid communication with said blade inlet 20 of said blade 10.

As shown in Fig. 1, the direction of the rotor bore 19 is aligned with the blade orientation, i.e. the longitudinal axis X. A unique passage smoothly distributes the flow all over the cross section of the duct further above the blade inlet 20. However, the area/shape of the rotor bore exit 19, which is cylindrical, and the inlet 20 of the blade, which is race-track shaped, are different, leading to a non-continuous interface (see Fig. 3, the common area is shaded).

The consequences of this design are:

- 30 (a) The flow accelerates through the relatively small common area between the exit of the rotor bore 19 and the blade inlet 20. This produces flow separation near the blade inlet 20, leading to local low values of the internal

heat transfer coefficient. Hot metal temperature regions may be detected further downstream of the blade. In addition, the pressure loss is increased.

(b) The orientation of the rotor bore 19 is not flexible. If positioned inclined with respect to the blade (see rotor bore 19' in Fig. 2), the flow separation area gets expanded and the situation worsens. This is particularly critical if the flow separation zone extends above the inner diameter platform 13 of the blade 10 (Fig. 2).

(c) Since the flow does not get uniform up to a height far enough from the blade inlet 20, no webs can be positioned below the inner diameter platform 13. Therefore, this configuration does not allow to having a multi-pass design.

Description of the invention

It is therefore an objective of the invention, to provide a gas turbine with a cooled blade, which allows for a flexible design and rating of the cooling passages, and especially allows for a multi-pass design.

This objective is achieved by the measures according to the characterizing part of claim 1, i.e. a rotor bore is provided with a diffuser-shaped rotor bore exit, such that the cross section area of the rotor bore exit at the interface between rotor bore and blade inlet covers the cross section area of the blade inlet.

According to one embodiment of the invention, an interface plenum is provided at the interface of said blade inlet and said rotor bore exit between the bottom surface of said blade root and the upper surface of said blade-root-receiving rotor groove, said interface plenum being designed to have a plenum bleed of cooling fluid to the outside of the blade root at the leading edge side or trailing edge side.

Advantageously, said blade root has a blade root height h in longitudinal direction, and said interface plenum has a plenum gap δ with a ratio δ/h of $0.02 \leq \delta/h \leq 0.05$, and preferably $\delta/h = 0.03$.

According to another embodiment of the invention, said blade core is split into a plurality of parallel cooling fluid ducts, wherein each of said cooling fluid ducts is in fluid communication with said blade inlet and has a dust hole at said blade tip, wherein a plurality of longitudinally extending not necessarily parallel webs is
5 provided within said blade core for splitting said blade core into said plurality of cooling fluid ducts, and wherein, for an optimized cooling of said blade, an individual cross section area and an individual cooling fluid mass flow is associated with each of said plurality of cooling fluid ducts. Advantageously, said individual cross section areas and/or said individual cooling fluid mass flows of
10 said cooling fluid ducts are equal within $\pm 25\%$.

According to still another embodiment of the invention, said rotor bore is obliquely positioned in a axial plane with respect to said longitudinal axis of said blade, wherein the angle β of deviation between said rotor bore and said longitudinal axis
15 is in the range $0^\circ < |\beta| \leq 30^\circ$, and preferably $\beta = 13^\circ$.

According to still another embodiment of the invention, said diffuser-shaped rotor bore exit has a diffuser angle α , consisting of the angles α_1 and α_2 . The diffuser can be symmetrical, for example $\alpha_1 = 11^\circ$ and $\alpha_2 = 11^\circ$, or non-symmetrical as
20 defined by α_1 and α_2 . According to this the angular aperture of the both angles can be $7^\circ \leq \alpha_1 \leq 13^\circ$, and $7^\circ \leq \alpha_2 \leq 13^\circ$.

According to still another embodiment of the invention, said blade root has a blade root height h in longitudinal direction, said blade inlet has a maximum width w , and
25 the ratio h/w is $2.0 \leq h/w \leq 3.5$, preferably $h/w = 2.5$.

Brief Description of the Drawings

30 The subject matter of the invention will be explained in more detail in the following text with reference to preferred exemplary embodiments, which are illustrated in the attached drawings, in which:

- Fig. 1 shows a side view of a cooled rotor blade according to a first embodiment of a previous blade with a longitudinally extending rotor bore;
- 5 Fig. 2 shows a side view of a cooled rotor blade according to a second embodiment of a previous blade with an obliquely oriented rotor bore;
- Fig. 3 shows the mismatch between the rotor bore exit and the blade inlet in a previous blade according to Fig. 1 or 2;
- 10 Fig. 4 shows a side view of a cooled rotor blade according to an embodiment of the invention with an obliquely oriented rotor bore comprising a diffuser-shaped rotor bore exit;
- 15 Fig. 5 shows in a side view a detail of the blade tip of a blade according to a second embodiment of the invention with a plurality of individually adjustable parallel cooling ducts;
- 20 Fig. 5a Flow cross section of Fig. 5 and
- Fig. 6 shows in a side view a detail of the blade root of the blade according to Fig. 5 with an bleeding interface plenum at the interface between the blade root and the bottom of the root-receiving rotor groove, including a focusing figure of the diffuser
- 25 with the both angles α_1 and α_2 .

Detailed Description of the preferred Embodiments

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According to the invention several measures are taken (Fig. 4-6), that substantially contribute to solve the problems/limitations described above:

- (a) An interface plenum 28 (Fig. 6) is created underneath the blade inlet 20 of the blade 30 by leaving some gap δ between the rotor upper surface in the rotor groove 23 and the bottom surface of the blade root 12, confined by the fir-tree of the rotor 11.
- 5 (b) The rotor bore exit 24 is reworked with a diffuser-shaped (conical) form extending over the whole width w of the blade inlet 20.
- (c) A part of the cooling fluid flow is conveniently bled from the leading edge side (17) or trailing edge side (16) of the plenum slot (28).
- 10 Both the interface plenum 28 and the diffuser-shaped rotor bore exit 24 acting to decelerate the cooling fluid flow and to extend it along the whole width w of the blade inlet 20. The bleeding flow from the interface plenum slot 28 supports this task (especially if the rotor bore 23 is inclined).
- 15 The benefits of this configuration are:
- (a) By the time the coolant reaches the inlet section of the blade 10, flow conditions are quite even all over the cross-section of the blade inlet 20. The coolant is therefore better distributed across the entire cross-section of the blade 30, mitigating or cancelling the presence of flow separation (Fig.
- 20 4). If flow separation still exists, it is confined well below the inner diameter platform 13 anyway, even for quite short shanks.
- (b) Inlet pressure losses are reduced.
- (c) The stream manages to quickly adapt to the orientation of the blade 10 regardless of the feed direction of the rotor bore 23. As a consequence, the
- 25 invention allows inclining the rotor bore 23 feeding the blade 10 if the rotor design requires so (Fig. 4).
- (d) Further, as the feed coolant conditions are already quite uniform sufficiently below the inner diameter platform 13, the invention allows the introduction of webs 25, 26 for a multi-pass cooling design with independent passages
- 30 (blade 30 in Fig. 5, 6). In particular, a 3-pass design with two webs 25, 26 and three parallel ducts 27a, 27b and 27c is chosen as best compromise between cooling effectiveness and weight. Such a design is more effective than the current unique passage design, because it allows a better control

of the local mass flow m_1 , m_2 , and m_3 through the entire core section 18.

The control of the flow split through each of the ducts 27a, 27b and 27c is done with dust holes positioned at the blade tip 15 (see arrows at the blade tip in Fig. 5), which can be size-customized independently. This design

5 adds in addition cold material to the cross-section to successfully carry a blade shroud if required.

(e) All benefits mentioned above are managed with very little change/redesign of the blade.

10 For an optimized cooling of the 3-pass blade 30 in Fig. 5, 6 an individual cross section area A_1 , A_2 , A_3 and an individual cooling fluid mass flow m_1 , m_2 , m_3 is associated with each of ducts 27a, 27b, 27c. Favourably, the individual cross section areas A_1 , A_2 , A_3 and/or the individual cooling fluid mass flows m_1 , m_2 , m_3 of the ducts 27a, 27b, 27c are chosen to be equal with each other within $\pm 25\%$.

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Furthermore it is advantageous that the rotor bore 23 is obliquely positioned in a axial plane with respect to the longitudinal axis X of the blade 10, 30, whereby the angle β of deviation between the rotor bore 23 and the longitudinal axis X is in the range $0^\circ < |\beta| \leq 30^\circ$. Preferably, $\beta = 13^\circ$.

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It is also advantageous, that the diffuser-shaped rotor bore exit 24 has a diffuser angles α_1 and α_2 . The diffuser can be symmetrical, for example $\alpha_1 = 11^\circ$ and $\alpha_2 = 11^\circ$, or non-symmetrical as defined by α_1 and α_2 . According to this the angular aperture of the both angles can be

25 $7^\circ \leq \alpha_1 \leq 13^\circ$, and $7^\circ \leq \alpha_2 \leq 13^\circ$.

Preferably, the blade root 12 has a blade root height h in longitudinal direction, and the interface plenum 28 has a plenum gap δ , such that the ratio δ/h is in the range of $0.02 \leq \delta/h \leq 0.05$, and preferably $\delta/h = 0.03$. This leads to a plenum bleed flow m_b , which is a fixed part of the cooling supply flow m_s with a ratio of $m_b/m_s = 0.2 \pm 20\%$.

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Finally, the blade root 12 has a blade root height h in longitudinal direction, and the blade inlet 20 has a maximum width w , and the ratio h/w lies in the range $2.0 \leq h/w \leq 3.5$, and is preferably $h/w = 2.5$.

LIST OF REFERENCE NUMERALS

	10,30	Blade (gas turbine)
	11	Rotor
5	12	Blade root
	13	Platform (inner diameter)
	14	Airfoil
	15	Blade tip
	16	Trailing edge
10	17	Leading edge
	18	Blade core
	19,19',23	Rotor bore
	20	Blade inlet
	21	Pressure side
15	22	Suction side
	24	Rotor bore exit (diffuser shaped)
	25,26	Web
	27a,b,c	Duct
	28	Interface plenum
20	29	Plenum bleed
	31	Rotor groove
	α	Diffuser angle made up of α_1 and α_2
	α_1, α_2	Diffuser angles
	β	Angle of deviation
25	δ	Plenum gap
	h	Blade root height
	w	Maximum width
	X	Longitudinal axis
	A_1, A_2, A_3	Cross section area
30	m_1, m_2, m_3	Mass flow
	m_b	Plenum bleed flow
	m_s	Cooling supply flow

Claims

1. Gas turbine with a rotor and a blade being attached to said rotor, wherein said blade comprises an airfoil with a leading edge and a trailing edge
5 extending along a longitudinal axis of said blade between a lower end and a blade tip, a blade root at the lower end of said airfoil provided for being removably received by a groove in said rotor, and a hollow blade core arranged within said airfoil and extending along the longitudinal axis between said blade root and said blade tip, said blade core being provided
10 for the flow of a cooling fluid, which enters said blade core through a blade inlet at said blade root and exits said blade core through at least one dust hole at said blade tip, and is supplied by means of a rotor bore, which runs through the rotor and is in fluid communication with said blade inlet of said blade, whereby said blade inlet has a cross section area which exceeds the
15 cross section area of said rotor bore in at least one direction, wherein said rotor bore is provided with a diffuser-shaped rotor bore exit, such that the cross section area of the rotor bore exit at the interface between rotor bore and blade inlet covers the cross section area of the blade inlet, wherein an interface plenum is provided at the interface of said blade inlet
20 and said rotor bore exit between the bottom surface of said blade root and the upper surface of said blade-root-receiving rotor groove and said interface plenum is designed to have a plenum bleed of cooling fluid to the outside of the blade root at the leading edge side or trailing edge side.
- 25 2. Gas turbine according to claim 1, characterized in that said blade core is split into a plurality of parallel cooling fluid ducts, wherein each of said cooling fluid ducts is in fluid communication with said blade inlet and has a number of dust holes at said blade tip.
- 30 3. Gas turbine according to claim 2, characterized in that each cooling fluid ducts has at least a dust hole at said blade tip.

4. Gas turbine according to claim 2, characterized in that a plurality of longitudinally extending parallel webs is provided within said blade core for splitting said blade core into said plurality of cooling fluid ducts.
- 5 5. Gas turbine according to one of the claims 2 to 4, characterized in that, for an optimized cooling of said blade, an individual flow cross section area and an individual cooling fluid mass flow is associated with each of said plurality of cooling fluid ducts.
- 10 6. Gas turbine according to claim 5, characterized in that the flow cross section area is a cross-sectional area of passage which is normal to direction of the flow.
- 15 7. Gas turbine according to one of the claims 1 to 6, characterized in that said rotor bore is obliquely positioned in an axial plane with respect to said longitudinal axis of said blade.
- 20 8. Gas turbine according to claim 7, characterized in that the angle β of deviation between said rotor bore and said longitudinal axis is in the range $0^\circ < |\beta| \leq 30^\circ$, and preferably $\beta = 13^\circ$.
- 25 9. Gas turbine according to one of the claims 1 to 8, characterized in that said diffuser-shaped rotor bore exit has a diffuser angles (α_1 , α_2), whereas the diffuser is symmetric or non symmetric, with an angular aperture of the both angles of $7^\circ \leq \alpha_1 \leq 13^\circ$, and $7^\circ \leq \alpha_2 \leq 13^\circ$.
- 30 10. Gas turbine according to claim 1, characterized in that said blade root has a blade root height h in longitudinal direction, and said interface plenum has a plenum gap δ with a ratio δ/h of $0.02 \leq \delta/h \leq 0.05$, and preferably $\delta/h = 0.03$.

11. Gas turbine according to one of the claims 1 to 10, characterized in that said blade root has a blade root height h in longitudinal direction, said blade inlet has a width w , and the ratio h/w is $2.0 \leq h/w \leq 3.5$, preferably $h/w = 2.5$.
- 5 12. Gas turbine according to claim 5, characterized in that said individual cross section areas and/or said individual cooling fluid mass flows of said cooling fluid ducts are equal within $\pm 25\%$.