

Turbomachine blade with fluidically cooled shroud

Technical field

5 The invention relates to a turbomachine blade with a fluidically cooled shroud according to the preamble of claim 1.

Prior art

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On account of the high turbine inlet temperatures which are normal nowadays in modern gas turbines or gas turbosets, at least the blades of the first turbine stages must often be cooled.

15 To cool the blades, a cooling fluid, frequently air, which has been extracted from the compressor, is passed through flow passages inside the airfoil. The cooling is effected by convective heat transfer from the passage walls to the cooling fluid. The heated cooling
20 fluid is then often delivered through bores in the region of the trailing edge of the blade into the blade surroundings. A turbine blade fluidically cooled in this way has been disclosed, for example, by US Patent 4 820 123 or also by European Patent Application EP 0
25 649 975 A1.

On account of the ever increasing turbine inlet temperatures of modern gas turbines, it is also often necessary to cool all the components which are subjected to the flow of hot gas. Therefore, not only
30 the airfoil but also the blade root has to be cooled. Furthermore, in particular blades of stators are often provided with shroud elements, which are then likewise to be at least partly cooled. A conventional method for cooling the shroud elements is for some of the cooling
35 fluid which flows through the airfoil for cooling the latter to be passed through a cooling-fluid bore provided in the shroud element and for it to then be delivered outward into the surroundings of the blade.

From here, the released cooling fluid ultimately passes via component gaps into the main flow of the turbine. However, due to the inflow of the cooling fluid via component gaps, flow losses of the main flow are caused
5 on the one hand. Furthermore, the delivered cooling fluid is often still not thermally consumed for cooling purposes, so that this also results in a thermodynamic loss. A higher cooling-fluid mass flow is required for a required cooling capacity. Both these factors lead to
10 a deterioration in the efficiency of the gas turbine or gas turboset. Cooling of the blades which is not adapted may also lead to a reduced service life of the blades.

In the case of fluidically cooled shroud elements known
15 from the prior art, uneven distribution of the cooling capacity is also often to be observed. This often affects in particular the corner regions of the shroud elements. This may lead to the corner regions of the shroud elements not being adequately cooled and in this
20 case to "hot spots".

On the other hand, uniform distribution of the cooling capacity over the shroud element is also often not required, but rather there are regions which have to be cooled to a greater extent, and other regions which
25 necessitate only a lower degree of cooling. The cooling effect of the cooling fluid is therefore often not optimal.

Summary of the invention

30 The invention is intended to provide a remedy here. The object of the invention is therefore to specify a turbomachine blade of the type mentioned at the beginning with which the disadvantages of the prior art
35 are reduced or avoided.

The invention helps to cool more effectively a turbomachine blade designed with a shroud element or to increase the cooling effectiveness of a cooling-fluid

mass flow to be used for the cooling. The invention also helps to cool the regions of the turbomachine blade which are to be cooled in each case in adaptation to the requirements.

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This object is achieved according to the invention by the turbomachine blade as claimed in claim 1. Further advantageous configurations of the invention are found in the subclaims.

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The turbomachine blade designed according to the invention comprises a blade root, a blade tip and an airfoil. The airfoil extends between the blade root and the blade tip in a blade longitudinal direction and has a suction side and a pressure side. Furthermore, the blade tip is provided with a shroud element. At least one throughflow passage which extends in the blade longitudinal direction runs inside the airfoil. Furthermore, a shroud cooling passage is formed in the shroud element at least along a section of the latter, this shroud cooling passage being connected via an opening to the throughflow passage, and a cooling fluid being passed through this shroud cooling passage during operation of the turbomachine blade. The shroud cooling passage is preferably of slot-shaped design. Furthermore, at least one flow-guiding element for guiding the cooling-fluid flow flowing through the shroud cooling passage is arranged in the shroud cooling passage and/or in an inflow or outflow to or from the shroud cooling passage.

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The flow-guiding element serves essentially to guide at least some of the cooling-fluid flow flowing through the shroud cooling passage. In this case, the flow-guiding element causes the cooling-fluid flow to flow through the shroud cooling passage in a desired manner in such a way that a cooling capacity which is suited to the requirements and is variable in sections within the shroud cooling passage is achieved. On the one

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hand, the cooling efficiency of the cooling fluid used is therefore improved, and, on the other hand, the risk of the formation of hot spots is reduced, as a result of which the operational reliability of the
5 turbomachine blade is increased overall.

In addition, however, the flow-guiding element can also fulfill further functions. Thus, for example, due to the arrangement according to the invention of a flow-guiding element, the component surface available for
10 the heat transfer can also be enlarged. Increased heat transfer and thus a locally increased cooling capacity can be achieved in the relevant region as a result of the component surface enlarged relative to the cooling-fluid flow.

15 The at least one flow-guiding element may be arranged in the shroud cooling passage. However, it may also be expediently arranged in the inflow to or outflow from the shroud cooling passage, for example in the throughflow passage close to the opening, in such a way
20 that an effect on the flow in the shroud cooling passage is brought about as a result. In the inflow, this is the case, for example, when some of the cooling fluid flowing in the throughflow passage is directed through the flow-guiding element past the inflow to the
25 shroud cooling passage or is specifically fed to the shroud cooling passage. In the outflow, this is the case, for example, when the cooling fluid flowing out of the throughflow passage is discharged by the flow-guiding element in a specific manner.

30 According to an expedient configuration of the invention, the flow-guiding element is designed as a cooling rib. A plurality of cooling ribs are expediently arranged in the shroud cooling passage.

35 The cooling ribs are designed with a minimum thickness at which heat is dissipated by the cooling rib to an appreciable degree. The cooling ribs are therefore normally about 3-10 mm thick. Furthermore, the cooling

ribs expediently extend over the entire clearance height of the shroud passage.

Cooling ribs act on the one hand in the sense of a flow-guiding element by the flow being guided along the cooling rib. Furthermore, however, cooling ribs also bring about a local increase in the heat transfer between the cooling fluid and the shroud cooling passage. For this purpose, the cooling ribs are preferably designed in one piece with the shroud cooling passage.

The cooling rib or the plurality of cooling ribs are expediently integrally cast in the shroud cooling passage. The cooling ribs are therefore already produced together with the blade during the casting of the blade. As a rule, rework of the cooling ribs is no longer necessary after the casting, in particular since an increased surface roughness produces better heat transfer, a factor which is usually desirable here.

The shroud cooling passage runs in the shroud element expediently essentially parallel to an inner surface of the shroud element and expediently extends over the entire shroud element. The shroud element is subdivided into a pressure-side region, a central region and a suction-side region.

The shroud cooling passage extends at least partly over the pressure-side region of the shroud element and likewise at least partly over the suction-side region of the shroud element. In this case, the flow-guiding element or elements is/are preferably arranged in the pressure-side region of the shroud cooling passage and/or in the suction-side region of the shroud cooling passage in such a way that the cooling-fluid flow produces greater cooling capacity in the pressure-side region of the shroud cooling passage than in the suction-side region of the shroud cooling passage during operation of the turbomachine blade. The

pressure-side region of a shroud element is normally subjected to higher aerodynamic and thermal loading. Due to a greater cooling capacity of the cooling-fluid flow of the shroud cooling passage in the pressure-side region of the shroud element, the pressure-side region of the shroud element can be thermally relieved, so that the shroud element experiences largely homogeneous thermal loading overall.

10 According to a further advantageous development of the invention, an inflow of the cooling fluid to the shroud cooling passage is effected in a first region of the shroud element and an outflow from the shroud cooling passage is effected in a second region of the shroud element, the first region being arranged upstream of the second region with regard to a main flow of the turbomachine blade. The flow-guiding elements arranged in the pressure-side region of the shroud cooling passage then expediently run essentially parallel to the direction of the main flow, and the flow-guiding elements arranged in the suction-side region of the shroud cooling passage run essentially transversely to the direction of the main flow. This leads to the cooling-fluid flow forming increasingly in the pressure-side region of the shroud cooling passage. At the same time, an increased heat transfer coefficient compared with the suction-side region of the shroud cooling passage is thus also obtained here on account of the higher flow velocities of the cooling fluid in the pressure-side region of the shroud cooling passage. The expression "essentially parallel to the direction of the main flow" comprises deviations from the direction of the main flow of 0° to plus/minus 45° . The expression "essentially transversely to the direction of the main flow" comprises deviations from the direction running transversely to the direction of the main flow of 0° to plus/minus 45° .

According to a further expedient configuration of the invention, the flow-guiding element is designed as a flow baffle plate. A flow baffle plate fulfills essentially only the function of the flow guidance.

5 Heat conduction only takes place to a minor extent on account of the relatively small thickness of the flow baffle plate of only a few millimeters. A flow baffle plate may, but need not always, extend over the entire clearance height of the shroud cooling passage.

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A first throughflow passage and a second throughflow passage which extend in each case in the blade longitudinal direction are expediently arranged inside the airfoil. The first throughflow passage is
15 preferably connected at its blade-root-side end to the cooling-fluid feed and at its blade-tip-side end to the blade-tip-side end of the second throughflow passage. The second throughflow passage is connected at its blade-root-side end to at least one cooling-fluid
20 discharge. The shroud cooling passage has at least one inlet opening and at least one outlet opening, the inlet opening of the shroud cooling passage opening into the first throughflow passage and the outlet opening of the shroud cooling passage opening into the
25 second throughflow passage. The cooling-fluid mass flow is fed via the first throughflow passage to the shroud cooling passage, flows through the shroud cooling passage and is at least mostly discharged again via the second throughflow passage.

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The first throughflow passage and the second throughflow passage are expediently connected to one another via a further, direct connection. This direct connection serves to allow some of the total cooling-
35 fluid mass flow to pass directly from the first throughflow passage into the second throughflow passage without first having to flow through the shroud cooling passage. The total cooling-fluid mass flow may

therefore be greater than the cooling-fluid mass flow which is used for cooling the shroud cooling passage. The total cooling-fluid mass flow fed via the first throughflow passage is therefore divided, on the one
5 hand, into the cooling-fluid mass flow which is directed through the shroud cooling passage in order to cool the shroud element and, on the other hand, into a further cooling-fluid mass flow which passes via the further connection directly into the second throughflow
10 passage.

The first throughflow passage is expediently arranged in the airfoil in such a way as to adjoin a leading edge of the airfoil, and the second throughflow passage is expediently arranged in the airfoil in such a way as
15 to adjoin a trailing edge of the airfoil. The fresh cooling fluid consequently flows first along the airfoil leading edge, which is subjected to high thermal loading, then through the shroud cooling passage and finally along the airfoil trailing edge,
20 which is subjected to low thermal loading. This leads to adapted cooling of the turbomachine blade and to high cooling effectiveness of the cooling fluid used. Furthermore, at least one pair of further throughflow passages which in each case extend in the blade
25 longitudinal direction are expediently arranged between the first throughflow passage and the second throughflow passage in the airfoil. The throughflow passages are connected to one another in such a way that a serpentine-like passage course is formed overall
30 in the airfoil.

A flow baffle plate is preferably arranged only in the region of the outlet opening. Here, the flow baffle plate arranged in the region of the outlet opening
35 ensures that the cooling fluid discharging from the shroud cooling passage flows uniformly into the second throughflow passage. If the second throughflow passage is connected to the first throughflow passage via a

further, direct connection, the flow baffle plate is expediently arranged in such a way that the cooling fluid discharging from the shroud cooling passage is uniformly admixed with the cooling fluid flowing in via
5 the direct connection.

According to a preferred embodiment of the invention, the cooling-fluid discharge comprises at least one outflow opening which is arranged in the region of the
10 airfoil trailing edge. For the cooling-fluid discharge, it will usually be expedient for a multiplicity of outflow openings to be arranged in the region of the airfoil trailing edge in a uniformly distributed manner over the airfoil length. The cooling fluid consumed
15 therefore flows via the at least one outflow opening or via the multiplicity of outflow openings into the main flow. In this case, due to a configuration of the outflow openings which is known to the person skilled in the art, the outflow is advantageously effected in
20 such a way that the outflowing cooling fluid forms a cooling film over the airfoil trailing edge downstream of the outflow openings. As a result, the airfoil trailing edge is cooled especially effectively on the one hand. On the other hand, the mixing losses produced
25 by the admixing of the cooling fluid with the main flow can thus be minimized.

According to an expedient development of the invention, at least one opening which communicates with the blade
30 surroundings is arranged in at least one corner region of the shroud cooling passage, via which opening cooling fluid flows from the shroud cooling passage into the blade surroundings during operation of the turbomachine blade. Due to the arrangement of the at
35 least one opening in the corner region of the shroud cooling passage, at least some of the cooling fluid located in the corner region is discharged through the opening into the surroundings. The constant outflow of

cooling fluid through the at least one opening prevents a wake zone from forming in the corner region. A wake zone is often the cause of a local formation of hot spots.

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According to an expedient use of the invention, the turbomachine blade is developed as a turbine blade of a gas turbine or a gas turboset, in particular as a stator part of a turbine.

10 In particular, considerable advantages with regard to the service life of the blades are obtained if all the blades of an inlet guide wheel of a turbine are designed in the manner according to the invention. The functioning of the gas turbine can then also be changed
15 to the effect that a higher inlet temperature overall can be adjusted in the turbine, or the temperature profile over the blade height can be made more uniform. A temperature profile of the turbine inlet flow which drops in each case in the direction of the boundary
20 walls is often necessary nowadays in order to avoid overheating of the boundary walls.

However, the turbomachine blade designed according to the invention may also be used in principle in a rotor
25 of a gas turbine or a gas turboset.

Brief description of the drawings

The invention is explained in more detail below with
30 reference to an exemplary embodiment illustrated in the figures. In the drawing:

figure 1 shows a greatly simplified illustration of a
gas turboset;

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figure 2 shows a longitudinal section through a turbomachine blade designed according to the invention;

figure 3 shows a detailed view of the turbomachine blade from figure 2;

5 figure 4 shows the shroud segment of figure 2 in a bottom view.

Only the elements and the components essential for the understanding of the invention are shown in the
10 figures.

The exemplary embodiment shown is to be understood purely instructively and is intended to serve for the better understanding but not as a restriction of the subject matter of the invention.

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Ways of implementing the invention

Shown in figure 1 is a highly schematic illustration of a gas turobset as is familiar to the person skilled in the art and as is frequently used for the generation of
20 electricity or for stationary and mobile drives, such as aircraft drives for example. The gas turboset shown by way of example comprises as essential subassemblies a compressor 2, a combustion chamber 3 and a turbine 4.
25 Incoming ambient air is compressed in the compressor 2 and fed to the combustion chamber 3. In the combustion chamber 3, fuel is admixed with the compressed air and the mixture is burned. By means of the turbine 4, the hot gas produced in the combustion chamber 3 is
30 expanded to perform work. In the stationary turbine plant shown in figure 1, the turbine 4 is connected via a shaft 5 to both the compressor 2 and a further power consumer 6, for example a generator serving to generate electricity, and drives the latter via the shaft 5. It
35 is of course also possible for the gas turboset to be of multi-shaft construction, having a plurality of turbines and combustion chambers arranged in between, having a plurality of compressors and coolers arranged

in between, and the like. These embodiments are familiar to the person skilled in the art and merely put the invention into an application-relevant context, for which reason they are not described in more detail
5 at this point.

A turbomachine blade 10 (in brief: blade) designed according to the invention is shown in figures 2 to 4. Figure 2 shows a longitudinal section through the
10 fluidically internally cooled blade 10 designed according to the invention, whereas figure 3 reproduces the blade tip 13 of the blade 10 in a detailed view. Figure 4 shows a bottom view of the shroud element 14 of the blade 10.

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Here, the blade 10 is designed as the blade of a stator of a turbine, specifically as a blade of an inlet guide wheel of a turbine, and may be used, for example, in the turbine 4 of the gas turboset 1. However, the
20 invention may also be applied to a rotor blade of a turbine or to blades used in another way.

As shown in figure 2, the blade 10 comprises a blade root 11 with a cooling-fluid feed 12, a blade tip 13
25 which is formed with a shroud element 14, and an airfoil 15. The airfoil 15 extends in the blade longitudinal direction SL between the blade root 11 and the blade tip 13 and has an airfoil leading edge 16 and an airfoil trailing edge 17.

30 The main flow of the turbine flows through the blade in figure 2 from right to left according to arrow 18, the flow duct being defined on the casing side by the blade root 11 and on the hub side by the shroud element 14.

As can be seen from the longitudinal section according
35 to figure 2, a total of four throughflow passages 19a - 19d are arranged inside the airfoil, these throughflow passages 19a - 19d each extending essentially in the blade longitudinal direction SL. At their ends, the

throughflow passages 19a - 19d are connected to one another in such a way that a serpentine-like cooling-passage course in the airfoil 15 is formed overall. Here, the throughflow passage adjoining the airfoil leading edge 16 is designated as first throughflow passage 19a, and the throughflow passage adjoining the airfoil trailing edge 17 is designated as second throughflow passage 19b. The throughflow passages arranged between the first and the second throughflow passage are designated in the direction of the main flow as third throughflow passage 19c and as fourth throughflow passage 19d.

The first throughflow passage 19a is connected at its blade-root-side end to the cooling-fluid feed 12 and at its blade-tip-side end, via the third and the fourth throughflow passage 19c and 19d, to the blade-tip-side end of the second throughflow passage. The second throughflow passage is in turn connected at the blade-root side to a cooling-fluid discharge passage 20 which extends along the airfoil trailing edge 17. Furthermore, a multiplicity of outflow openings 21 are arranged at the airfoil trailing edge 17, via which outflow openings 21 the cooling fluid flows off from the cooling-fluid discharge passage 20 into the surroundings of the blade. The outflow openings 21 are arranged in an approximately uniformly distributed manner over the airfoil length.

Here, as cooling fluid, air is branched off from the compressor region and fed via the cooling-fluid feed 12 to the first throughflow passage 19a. From here, the air 29a, following the serpentine-like cooling passage course, flows through the airfoil 15. Due to the low temperature of the cooling fluid compared with the hot turbine main flow, convective heat transfer occurs along the walls of the throughflow passages and thus cooling of the airfoil 15 occurs. At the end of the second throughflow passage 19b, the cooling fluid

heated up to then and thus largely consumed passes into the cooling-fluid discharge passage 20 and is distributed from here approximately uniformly to the outflow openings 21. The cooling fluid ultimately
5 passes via the outflow openings 21 to the outside of the airfoil and thus into the turbine main flow. Here, when flowing out of the outflow openings 21, the cooling fluid additionally forms a cooling film at the trailing edge, this cooling film protecting the thin
10 trailing edge from the hot main flow.

In order to cool the shroud element 14 in addition to the airfoil 15, a shroud cooling passage 22 is arranged in the shroud element 14. The shroud cooling passage
15 22, which is of slot-shaped design here, is connected via an inlet opening 23 to the first throughflow passage 19a and via an outlet opening 24 to the second throughflow passage 19b.

20 According to the flow guidance shown in figure 2, the cooling fluid serving to cool the shroud element 14 is extracted from the total mass flow of cooling fluid fed through the first throughflow passage 19a and is fed to the shroud cooling passage 22 via the inlet opening 23.
25 After flowing through the shroud cooling passage 22, most of the cooling fluid is discharged via the outlet opening 24 into the second throughflow passage 19b, where the cooling fluid 29b used for cooling the shroud element 14 is brought together again with that cooling
30 fluid 29a which has been directed through the third and fourth throughflow passages 19c and 19d. From there, the cooling fluid passes jointly into the cooling-fluid discharge passage 20 and via the outflow openings 21 into the turbine main flow.

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The shroud cooling passage 22 shown in figure 2 is formed in the shroud element 14 so as to extend over

the entire shroud element essentially parallel to the inner surface 14i of the latter.

To this end, the blade tip 13 shown in figure 2 comprises a first facing 25 which covers the airfoil 5 15. Furthermore, a respective closure web 26a and 26b is arranged in the region of the airfoil leading edge 16 and in the region of the airfoil trailing edge 17 and in each case extends from the first facing 25 perpendicularly to the latter. Between the closure webs 10 26a and 26b, a further facing 27 is arranged at a distance from the first facing 25 in such a way that the intermediate space between the first facing 25 and the further facing 27 results in the shroud cooling passage 22. The inlet opening 23 and the outlet opening 15 24 are formed in the first facing 25. Whereas the blade root 11, the airfoil 15, the first facing 25 and the closure webs 26a and 26b are produced as a one-piece casting, the further, second facing 27 is inserted between the closure webs only after completion of the 20 casting and is fixed via a groove connection 28a and 28b. Here, the further, second facing 27 comprises two layers 27a and 27b.

As can readily be seen in particular from figures 3 and 25 4, flow-guiding elements 30, 31-d1 - 31-d11, 31-s1 - 31-s12, 32 are additionally arranged in the shroud cooling passage 22 and in the region of the outflow from the shroud cooling passage 22. The flow-guiding elements 30, 31-d1 - 31-d11, 31-s1 - 31-s12, 32 serve 30 to guide the cooling-fluid flow 29b flowing through the shroud cooling passage.

As shown in figure 4, cooling ribs 30, 31-d1 - 31-d11, 31-s1 - 31-s12 are arranged as flow-guiding elements inside the shroud cooling passage 22. Furthermore, a 35 flow baffle plate 32 is arranged as flow-guiding element in the outflow region from the shroud cooling passage 22.

Here, both the cooling ribs 30, 31-d1 - 31-d11, 31-s1 - 31-s12 arranged in the shroud cooling passage 22 and the flow baffle plate 32 arranged in the outflow region are integrally cast.

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The cooling ribs 30, 31-d1 - 31-d11, 31-s1 - 31-s12 provided in the shroud cooling passage 22 serve to guide the cooling-fluid flow 29b flowing through the shroud cooling passage 22. The cooling-fluid flow is
10 guided by means of the cooling ribs 30, 31-d1 - 31-d11, 31-s1 - 31-s12 in a predetermined manner through the shroud cooling passage 22 in such a way that an optimum cooling effect of the shroud cooling passage 22 is achieved, in the course of which the cooling intensity
15 produced in the individual regions of the shroud cooling passage 22 varies.

To this end, the shroud element 14 is subdivided into a pressure-side region 34d, a central region 34z and a suction-side region 34s. The shroud cooling passage 22
20 extends over all three regions of the shroud element 14.

Formed in the region of the airfoil 15 in the shroud cooling passage 22 is a central cooling rib 30 having a contour which is similar to the airfoil 15 but
25 essentially only borders the region of the throughflow passages 19a - 19d. By means of the central cooling rib 30 contoured in this way, the cooling fluid in the shroud cooling passage 22 is directed around the cavity region of the airfoil 15. The cavity region is
30 approximately the region in which the throughflow passages 19a - 19d are arranged and which is therefore subjected to only low thermal loading or is cooled anyway.

Furthermore, as shown in figure 4, the cooling ribs
35 31-d1 - 31-d11 arranged in the pressure-side region 34d of the shroud cooling passage 22 are oriented differently from the cooling ribs 31-s1 - 31-s12 arranged in the suction-side region 34s of the shroud

cooling passage 22. Here, the cooling ribs 31-d1 - 31-d11 arranged in the pressure-side region 34d of the shroud cooling passage 22 run essentially parallel to the direction of the main flow of the blade, whereas
5 the cooling ribs 31-s1 - 31-s12 arranged in the suction side region 34s of the shroud cooling passage 22 run essentially transversely to the direction of the main flow of the blade. It has been found that the cooling-fluid flow thereby produces a greater cooling capacity
10 in the pressure-side region 34d of the shroud cooling passage 22 than in the suction-side region 34s of the shroud cooling passage 22 during operation of the turbomachine blade.

The cooling fluid flows via the inlet opening 23
15 arranged in the upstream region of the shroud element into the shroud cooling passage 22. Due to the centrally arranged cooling rib 30, which has a contour similar to the airfoil but essentially bordering only the region of the throughflow passages 19a - 19d, the
20 cooling fluid entering the shroud cooling passage 22 is distributed either to the pressure-side region 34d of the shroud cooling passage 22 or to the suction-side region 34s of the shroud cooling passage 22. The cooling fluid in both cases first of all flows through
25 a respective inflow section in which no cooling ribs are arranged. The inflow sections free of cooling ribs serve to enable the cooling fluid to effectively spread out over the entire width of the shroud cooling passage 22. This is followed in each case by sections in which
30 the cooling ribs 31-d1 - 31-d11 and 31-s1 - 31-s12, respectively, are arranged. In the pressure-side region 34d of the shroud cooling passage 22, the cooling ribs 31-d1 - 31-d11 run essentially parallel to the direction of the main flow of the blade. In this case,
35 the expression "essentially parallel to the direction of the main flow" comprises deviations from the direction of the main flow of 0° to plus/minus 45°. In the suction-side region 34s of the shroud cooling

passage 22, the cooling ribs 31-s1 - 31-s12 run essentially transversely to the direction of the main flow. In this case, the expression "essentially transversely to the direction of the main flow"

5 comprises deviations from the direction running transversely to the direction of the main flow of 0° to plus/minus 45° .

At the discharge from the cooling ribs 31-d1 - 31-d11 arranged in the pressure-side region 34d, the cooling
10 fluid flows again into a collecting section free of cooling ribs and must flow from there around the tip of the centrally arranged cooling rib 30 in order to finally reach the outlet opening 24 of the shroud cooling passage 22.

15 In the suction-side region 34s, the cooling fluid is first of all directed away from the centrally arranged cooling rib 30 in the direction of the corner region of the shroud cooling passage 22 by a first group 31-s1 - 31-s5 and is then fed back again in the direction of
20 the centrally arranged cooling rib 30 via a second group of cooling ribs 31-s7 - 31-s10. A cooling rib 31-s6 connected to the centrally arranged cooling rib and arranged between the first and the second group prevents the cooling fluid from being able to flow
25 directly along the centrally arranged cooling rib 30. Here, downstream of the second group of cooling ribs 31-s7 - 31-s10 and directly upstream of the outlet opening 24, two further cooling ribs 31-s11 and 31-s12 which run parallel to the direction of the main flow of
30 the blade are arranged in the suction-side region 34s of the shroud cooling passage. These two further cooling ribs 31-s11 and 31-s12 prevent cooling fluid from flowing to the outlet opening 24 over the shortest path after discharge from the second group of cooling
35 ribs 31-s7 - 31-s10, but rather cause flow to occur in the region directly around the outlet opening 24.

However, in addition to the guidance of the cooling-fluid flow through the shroud cooling passage, in each

case the surface of the shroud cooling passage 22 is also enlarged locally by means of the cooling ribs 31-d1 - 31-d11 and 31-s1 - 31-s12. This leads to an increase in the heat transfer in the regions around the cooling ribs, so that, in this way, the cooling capacity in these regions is in each case increased locally.

On the whole, a distribution and orientation of the cooling ribs effected in this way results in the cooling fluid flowing through in such a way as to cover the surface of the regions 34d, 34s of the shroud cooling passage 22 which are to be cooled. In the process, the cooling fluid 29b flowing through the shroud cooling passage cools the pressure-side region 34d of the shroud cooling passage 22 more intensively than the suction-side region 34s of the shroud cooling passage 22. This is due to the fact that, when comparing the two regions, an increased amount of heat is introduced into the pressure-side region by the main flow, this also being especially desirable. The cooling efficiency of the cooling fluid used for the cooling is also increased as a result. Furthermore, the risk of hot spots forming in particular inside the shroud element is considerably reduced.

On the other hand, the flow baffle plate 32 arranged in the outflow region from the shroud cooling passage serves essentially only to guide the flow. The flow baffle plate 32 causes the cooling fluid 29b discharging from the shroud cooling passage 22 via the outlet opening 24 to be admixed uniformly, and with the lowest possible mixture losses, with the remaining cooling-medium flow 29a flowing through the throughflow passages 19a - 19d. To this end, the flow baffle plate 32 is positioned approximately centrally in the transition region from the fourth throughflow passage 19d to the second throughflow passage 19b in such a way

that, on the one hand, the cooling fluid 29a coming from the fourth throughflow passage 19d is guided essentially on the underside of the flow baffle plate 32 and is deflected in the direction of the second
5 throughflow passage 19b and, on the other hand, the cooling fluid 29b coming from the shroud cooling passage 22 is guided essentially on the top side of the flow baffle plate 32. The cooling-air flows 29a and 29b until then acting in the same direction are then mixed
10 downstream of the flow baffle plate 32. By the cooling-fluid flows 29a and 29b being mixed in this way, the formation of flow vortices is largely avoided, so that only very small aerodynamic mixing losses occur. This mixing virtually free of flow losses reacts in turn
15 directly on the cooling-fluid flow 29b inside the shroud cooling passage 22. In particular, the directed mixing prevents the occurrence of a backpressure of the cooling-fluid flow 29b inside the shroud cooling passage 22.
20 Here, however, no flow baffle plate is arranged in the region of the inlet opening 23.

Furthermore, as shown in figure 4, an opening 33-s is arranged here in the suction-side corner region of the
25 shroud cooling passage 22, via which opening 33-s the shroud cooling passage 22 communicates with the blade surroundings. During operation of the turbomachine blade, cooling fluid discharges from the shroud cooling passage 22 through this opening into the blade
30 surroundings. In this case, the primary function of the opening 33-s, which is designed as a bore, is to draw off dust that has collected in the suction-side corner region.

35 Further openings 33-d1 - 33-d4 ... which are designed as bores are located in the pressure-side boundary wall of the shroud cooling passage, the openings 33-d1 - 33-d4 ... being arranged approximately equally

over the boundary wall. In an arrangement of the blade in a turbine, a shroud element, of expediently identical construction, of an adjacent blade adjoins the pressure-side boundary wall. During operation of the turbomachine blade, cooling fluid flows from the shroud cooling passage into the gap between the shroud elements of the blades adjacent to one another and cools the walls defining the gap.

10 It has been found that reliable and efficient cooling of the shroud element 14 over the entire operating range of the turbine is ensured by the embodiment of the blade 10 according to the invention. Hot spots are therefore reliably avoided. This leads to an increased service life of the blades.

15 In addition to reliable and efficient cooling of the shroud element, adequate and efficient cooling of the entire blade is ensured by the arrangement of the throughflow passages 19a - 19d of the blade shown in figures 2 to 4 and of the resulting cooling-fluid flow through the airfoil. The flow guidance selected here for the cooling fluid leads to improved cooling effectiveness of the cooling fluid overall compared with conventional blades known from the prior art.

25 The turbomachine blade 10 shown in figures 2 to 4 only represents an exemplary embodiment of the invention, it being possible for this embodiment to be readily modified in many different ways by the person skilled in the art. Thus, for example, the outflow openings at the blade trailing edge may be dispensed with, and the cooling-fluid discharge may be effected via a cooling-fluid discharge passage arranged in the blade.

List of designations

	1	Gas turboset
	2	Compressor
5	3	Combustion chamber
	4	Turbine
	5	Shaft
	6	Power consumer
	10	Turbomachine blade
10	11	Blade root
	12	Cooling-fluid feed
	13	Blade tip
	14	Shroud element
	14i	Inner surface of the shroud element
15	15	Airfoil
	16	Airfoil leading edge
	17	Airfoil trailing edge
	18	Direction of the main flow
	19a	First throughflow passage
20	19b	Second throughflow passage
	19c	Third throughflow passage
	19d	Fourth throughflow passage
	20	Cooling fluid discharge passage
	21	Outflow opening
25	22	Shroud cooling passage
	23	Inlet opening
	24	Outlet opening
	25	First facing
	26a, 26b	Closure webs
30	27	Second facing
	27a, 27b	Layers
	28a, 28b	Groove connection
	29a	Cooling-fluid flow through the throughflow passages
35	29b	Cooling-fluid flow through the shroud cooling passage
	29b-s	Cooling-fluid flow through the suction-side region of the shroud cooling passage

29b-d Cooling-fluid flow through the pressure-side
 region of the shroud cooling passage

30 Central cooling rib

31-d1 - 31-d11 Cooling ribs in the pressure-side region
5 of the shroud cooling passage

31-s1 - 31-s12 Cooling ribs in the suction-side region
 of the shroud cooling passage

32 Flow baffle plate

33-s Opening in the suction-side region of the
10 shroud cooling passage

33-d1 - 33-d4 Openings in the pressure-side region of
 the shroud cooling passage

34d Pressure-side region of the shroud cooling
 passage

15 34s Suction-side region of the shroud cooling
 passage

34z Zentral region of the shroud cooling passage

SL Blade longitudinal direction

Patent claims

1. A turbomachine blade (10), in particular a turbine blade of a gas turbine or gas turboset, having a blade
5 root (11), a blade tip (13) and an airfoil (15) which extends between the blade root (11) and the blade tip (13) in a blade longitudinal direction and has a suction side and a pressure side, a shroud element (14) being arranged on the blade tip, and at least one
10 throughflow passage (19a, 19b) which extends in the blade longitudinal direction being arranged inside the airfoil (15), and a shroud cooling passage (22) being formed in the shroud element (14) at least along a section of the latter, this shroud cooling passage (22)
15 being connected via an opening to the throughflow passage, and a cooling fluid flowing through this shroud cooling passage (22) during operation of the turbomachine blade, characterized in that at least one flow-guiding element for guiding at least some of the
20 cooling-fluid flow flowing through the shroud cooling passage is arranged in the shroud cooling passage and/or in an inflow or outflow to or from the shroud cooling passage.
- 25 2. The turbomachine blade as claimed in claim 1, characterized in that the flow-guiding element is a cooling rib (30, 31-d1 - 31-d11, 31-s1 - 31-s12).
3. The turbomachine blade as claimed in claim 2,
30 characterized in that a plurality of cooling ribs (30, 31-d1 - 31-d11, 31-s1 - 31-s12) are arranged in the shroud cooling passage.
4. The turbomachine blade as claimed in either of
35 claims 2 and 3, characterized in that the cooling rib or the plurality of cooling ribs (30, 31-d1 - 31-d11, 31-s1 - 31-s12) are integrally cast in the shroud cooling passage (22).

5. The turbomachine blade as claimed in one of the preceding claims, characterized in that the shroud cooling passage (22) is of slot-shaped design.

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6. The turbomachine blade as claimed in one of the preceding claims, the shroud element being subdivided into a pressure-side region (34d), a central region (34z) and a suction-side region (34s), and the shroud cooling passage (22) extending at least partly over the pressure-side region (34d) of the shroud element and at least partly over the suction-side region (34s) of the shroud element, characterized in that the flow-guiding element/elements (30, 31-d1 - 31-d11, 31-s1 - 31-s12, 32) is/are arranged in the pressure-side region of the shroud cooling passage and/or in the suction-side region of the shroud cooling passage in such a way that the cooling-fluid flow produces greater cooling capacity in the pressure-side region of the shroud cooling passage than in the suction-side region of the shroud cooling passage during operation of the turbomachine blade.

7. The turbomachine blade as claimed in claim 6, characterized in that an inflow of the cooling fluid to the shroud cooling passage (22) is effected in a first region of the shroud element and an outflow from the shroud cooling passage (22) is effected in a second region of the shroud element, the first region being arranged upstream of the second region with regard to a main flow of the turbomachine blade, and the flow-guiding elements (31-d1 - 31-d11) arranged in the pressure-side region (34d) of the shroud cooling passage running essentially parallel to the direction of the main flow, and the flow-guiding elements (31-s1 - 31-s12) arranged in the suction-side region (34s) of the shroud cooling passage running essentially transversely to the direction of the main flow.

8. The turbomachine blade as claimed in one of the preceding claims, characterized in that a flow-guiding element (30) having a contour similar to the airfoil and bordering essentially the region of the at least one throughflow passage is arranged in the shroud cooling passage.

9. The turbomachine blade as claimed in one of the preceding claims, characterized in that the flow-guiding element is a flow baffle plate (32).

10. The turbomachine blade as claimed in one of the preceding claims, characterized in that a first throughflow passage (19a) and a second throughflow passage (19b) which extend in each case in the blade longitudinal direction are arranged inside the airfoil (15), and the first throughflow passage (19a) is connected at the blade-root-side end to a cooling-fluid feed (12) and at the blade-tip-side end to the blade-tip-side end of the second throughflow passage (19b), and the second throughflow passage (19b) is connected at the blade-root-side end to a cooling-fluid discharge (20, 21), and the shroud cooling passage comprises an inlet opening (23) and an outlet opening (24), the inlet opening (23) of the shroud cooling passage (22) opening into the first throughflow passage (19a) and the outlet opening (24) of the shroud cooling passage (22) opening into the second throughflow passage (19b).

11. The turbomachine blade as claimed in claim 10, characterized in that a flow baffle plate (32) is arranged only in the region of the outlet opening (24).

12. The turbomachine blade as claimed in one of the preceding claims, characterized in that at least one opening (33-s, 33-d1 - 33-d4) which communicates with the blade surroundings is arranged in at least one

corner region of the shroud cooling passage, via which opening (33-s, 33-d1 - 33-d4) cooling fluid flows from the shroud cooling passage into the blade surroundings during operation of the turbomachine blade.

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13. The turbomachine blade as claimed in one of the preceding claims, characterized in that the turbomachine blade (10) is the blade of a stator of a turbine.

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14. The turbomachine blade as claimed in one of the preceding claims, characterized in that the first throughflow passage (19a) is arranged in the airfoil (15) in such a way as to adjoin the airfoil leading edge (16), and the second throughflow passage (19b) is arranged in the airfoil (15) in such a way as to adjoin the airfoil trailing edge (17).

15. The turbomachine blade as claimed in one of the preceding claims, characterized in that, furthermore, at least one pair of further throughflow passages (19c, 19d) which in each case extend in the blade longitudinal direction are arranged between the first throughflow passage (19a) and the second throughflow passage (19b) in the airfoil in such a way that the throughflow passages (19a - 19d) form a serpentine-like passage course in the airfoil (15).

16. The turbomachine blade as claimed in one of the preceding claims, characterized in that the cooling-fluid discharge comprises at least one outflow opening (21) arranged in the region of the airfoil trailing edge.

17. A turbine stator having a multiplicity of turbomachine blades arranged side by side at the periphery, at least one turbomachine blade (10) being designed as claimed in one of the preceding claims.

18. The turbine stator as claimed in claim 17, characterized in that the turbine stator is an inlet guide wheel of a turbine.

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19. A gas turboset having at least one turbomachine blade (10) as claimed in one of the preceding claims 1 to 16.