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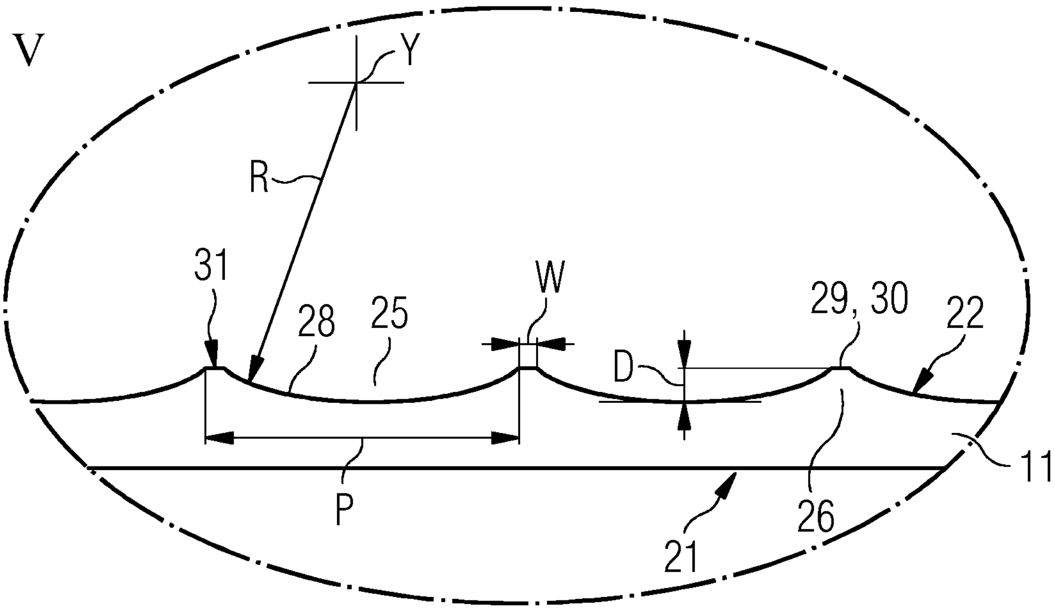
(54) **TURBOMACHINE COMPONENT WITH A CORRUGATED COOLED WALL AND A METHOD OF MANUFACTURING**

(57) The invention is directed to a turbomachine component (10) arrangeable in a turbomachine (1), particularly a gas turbine engine, the turbomachine component (10) built in parts from a curved or planar panel (11), the panel (11) comprising a first surface (21) and a second surface (22), wherein the turbomachine component (10) is arrangeable such that, during operation of the turbomachine (1), the first surface (21) is affected by thermal radiation (23) and the second surface (22) is affected by a cooling fluid (24) travelling along the second surface (22). The second surface (22) comprises a plurality of alternating elongated depressions (25) and elongated elevations (26), wherein the depressions (25) are formed each as an elongated concave groove (27). This design allows easier manufacturing.

The invention furthermore is directed to a method of manufacturing.

FIG 2



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Description

Field of the invention

[0001] The invention relates to a turbomachine (or rotating machine) component, particularly a gas turbine engine component in a hot region of a gas turbine engine, in which a hot wall is cooled via a corrugated surface.

Background of the invention

[0002] Gas turbine engines like other rotating machines comprise sections wherein a cool fluid is guided and other regions in which a hot fluid is guided through the engine. In the gas turbine engine typically ambient air as a fairly cool fluid may be compressed by a compressor section and provided to a combustor in which the substantially cool fluid (at least cooler than the working conditions within the combustor) will be burned together with fuel to provide a driving force for a subsequent turbine section - an expansion turbine - in which a hot fluid from the combustor will drive rotor blades of the turbine to drive again a shaft. The compressed air will also be used to cool hot engine parts, particularly in the combustor or expansion turbine section.

[0003] In the combustor or in the downstream sections past the combustor hot temperatures can occur on components that are guiding the hot fluid through the gas turbine engine. The temperatures can be up to 1,500 °C. Nevertheless, materials used typically in a gas turbine engine cannot withstand temperatures above 800 °C. Therefore, these components may need to be cooled or a specific coating is required to protect the component. Cooling may be implemented in a way that a fraction of the air or the fluid from the compressor is extracted - i.e. branched off from a main fluid path - and guided to the component which needs to be cooled. Cooling then can be performed at the to be cooled part by different measures, for example impingement cooling, film cooling, effusion cooling, transpiration cooling and/or convection cooling.

[0004] The provision of cooling functionality on the other hand reduces the efficiency of the gas turbine engine. Therefore it is the goal to limit the cooling as much as possible so that the efficiency does not downgrade and is maximised. It needs to be considered though, that the lifetime of the component depends largely on the conditions such that the component will not experience a temperature that goes above a designed temperature level.

[0005] The temperature level experienced by a component may vary at different locations of the component. For example an upstream region of a combustion liner wall may experience hotter temperatures than a downstream region of the same combustion liner. Therefore, the downstream region may not require the same amount of cooling as the upstream region. On the other hand, a cooling channel of a specific length may be more efficient at a first end of the cooling passage assuming the cooling air may be cooler at the first end than at a downstream end of the cooling passage, because the cooling air has taken the heat from the to be cooled component which is resulting in a temperature rise of the cooling air.

[0006] Components to be cooled in a gas turbine engine are mainly located at a combustion chamber, an expansion turbine section, a transition piece in between, or possibly at an exhaust.

[0007] One known technology to improve cooling of a component that experiences thermal energy or thermal heat is to provide ribs or other protrusions onto one side of the component along which cooling fluid is guided, with the effect of a better heat transfer so that in consequence the material of the component is cooled.

[0008] Depending on the size or shape of the component specific production methods may be applied to generate turbulators, e.g. casting to create ribs on internal surfaces inside hollow blades, welding or brazing onto external surfaces, or machining off material from a component to create turbulators as a residual at the surface.

[0009] Dependent upon the design of the individual component, manufacturing of turbulators - like ribs - at a surface of that component can require a lot of effort during production of the component.

Summary of the invention

[0010] The present invention seeks to provide an improved way of providing an alternative to a rib structure with rectangular shape for a cooling side of hot components in a gas turbine engine or other turbomachines or rotating machines or even other machines that experience life-limiting temperatures. Particularly the invention reduces also the manufacturing efforts and manufacturing time.

[0011] This objective is achieved by the independent claims. The dependent claims describe advantageous developments and modifications of the invention.

[0012] The invention is directed to a turbomachine component (or rotating machine component), arrangeable in a turbomachine like a gas turbine engine, wherein the turbomachine component is built in parts from a curved or planar panel, the panel comprising a first surface and a second surface. The turbomachine component is arrangeable such that, during operation of the turbomachine, the first surface - and consequently the panel - is affected by thermal radiation, i.e. thermal heat.

[0013] The second surface is affected by a cooling fluid travelling along the second surface, particularly to cool the panel. The second surface comprises a plurality of alternating elongated depressions and elongated elevations, wherein the depressions are formed each as an elongated concave groove.

[0014] Thus, a corrugated wall is provided of a specific shape to support convective cooling.

[0015] The invention is advantageous as the shape of the surface provides good cooling properties. And additionally the form of elongated concave grooves allows easy manufacturing, as a single one of the concave grooves can be machined off in a single pass by a milling tool without the need to equip the milling tool with different set of cutters. A single cutter may be used to mill the concave shape of a section of the elongated concave groove.

[0016] In a cross section, the concave shape is a section of an ellipse. In a specific embodiment, the shape may be a section of a circle. An ellipse or a circle can be created by a rotating milling cutter about a rotating axis; an ellipse can be formed if the rotating milling cutter is angled compared to the direction of relative movement of the milling cutter in respect of the panel.

[0017] A circle can be formed if the rotating axis of the milling cutter is perpendicular to the to be generated elongated groove. Thus, the concave groove follows in cross-section a shape of a part of an arc of a circle when the cross-section is taken from a direction perpendicular to ridges of one of the elevations.

[0018] The component may particularly be located in a combustion chamber, in a burner section, in a transition duct or in a turbine section of a gas turbine engine. Possibly it may also be located at a casing or at an exhaust of a gas turbine engine. The depressions and elevations on the second surface are present to provide cooling of the component which is affected by the hot-working media - in general: affected by thermal energy - which is in contact with at least one surface of the component, specifically the first surface. The cooling fluid may particularly be air taken from a compressor section of a gas turbine engine. But other sources of cooling fluid could be used, e.g. ambient air. The cooling fluid may be pressurised.

[0019] In case of a combustion chamber part, the component may be for example a combustion chamber liner. Such a combustion chamber liner may itself be curved. Therefore, in case the panel is curved, the concave groove forms a segment of skewed circular cylindrical recess following a contour of the panel.

[0020] In gas turbine engines most components are formed such that they are arranged cylindrically about a main axis of the gas turbine engine. E.g. heat shields may be segments of a full cylindrical surface. But each segment may be considered substantially flat or planar. In case the panel is planar or substantially planar, the concave groove forms a segment of circular cylindrical recess.

[0021] Preferably the first surface is free of elevations and recesses. In case of a panel being substantially planar, also the first surface is preferably planar.

[0022] As already said, the depressions may be manufactured by machining the depressions into the second surface. Under machining a process is understood that removes surface material from a component, particularly milling.

[0023] The depressions may be manufactured by machining the depressions into the second surface via a milling cutter, wherein one of the milling cutter and the second surface follows a rotation along a circular arc section. Additionally the milling cutter or the second surface will be moved continuously or step-wise in direction of the elongation of the elongated concave groove to machine off an expanded surface section. Eventually an elongated groove is generated.

[0024] Several milling cutters will machine off several grooves in parallel time. Alternatively after a complete groove is created, the panel will be repositioned so that a further groove can be created.

[0025] In an embodiment the elevations may form a ridge, preferably with a substantial flat surface. In this case the elevations may form a leveled ridge.

[0026] The ridges of the elevations may be arranged substantially parallel to another.

[0027] Furthermore the ridges of the elevations may be arranged substantially perpendicular to a flow direction of a cooling fluid along the second surface during operation of the turbomachine.

[0028] Selecting a geometry of the second surface and the orientation in respect of the expected cooling fluid flow direction allows that no film of cooling fluid attaches to the second surface, which would counteract the cooling effect for the hot panel.

[0029] Also an angled orientation of the grooves and elevations in respect of the expected cooling fluid flow may be advantageous. Thus, ridges of the elevations may be arranged angled to a flow direction of the cooling fluid along the second surface during operation of the turbomachine, wherein an angle of attack of the cooling fluid onto the ridges is between -60° and +60° in respect of a direction perpendicular to the ridges. Possibly also advantageous are also angles between -30° and +30°. The direction perpendicular to the ridges is defined by 0°.

[0030] Obviously the angles can also be taken between a direction of the cooling fluid flow and an orientation of the ridges, which will be called in the following as angle of attack. An angle of attack of 90° refers to a cooling fluid being perpendicular to the main expanse of the ridges. By this definition a preferred angle of attack may be between 30° and 90°. Possibly also advantageous are also angles of attack between 60° and 90°. Particularly, in one embodiment, the cooling fluid may be angled, that means that the 90° orientation may be excluded from the previously mentioned ranges.

[0031] The depressions and the elevations may be sized and oriented to act as turbulators for the cooling fluid during operation of the turbomachine.

[0032] Particularly, the geometry of the second surface may be defined according to the following characteristics to enable good cooling effect with sufficient turbulences and without having a film of cooling fluid attached to the second surface:

- A width W may be defined as an average transversal width of a levelled top surface of the levelled ridge.
- A depth D may be defined as a maximum depth of one of the depressions in relation to a maximum height of the ridge of an adjacent one of the elevations.
- A radius R may be defined for a radius of the concave groove, with the radius taken in a plane perpendicular to an expanse of the groove and perpendicular to the first surface of the panel.
- A pitch P may be defined for a shortest transversal distance between two adjacent elevations of the elevations.
- Based on these definitions preferred geometry may be defined like the following:

(a) The depressions and elevations may be configured such that W/D is in the range of $0 \leq \frac{W}{D} \leq 50$, preferably $0.5 \leq \frac{W}{D} \leq 20$.

(b) The depressions and elevations may be configured such that R/D is in the range of $1 \leq \frac{R}{D} \leq 50$, preferably $15 \leq \frac{R}{D} \leq 35$.

(c) The depressions and elevations may be configured such that P/D is in the range of $1 \leq \frac{P}{D} \leq 25$, preferably $10 \leq \frac{P}{D} \leq 20$.

[0033] The location and/or size and/or orientation of the depressions and elevations will allow specific adaptations to temperature circumstances, to increase or decrease a cooling effect.

[0034] A top level surface of the ridge may have a homogeneous height, i.e. defining a levelled top surface. The levelled top surface (31) of the levelled ridge may be parallel to the first surface or to the second surface prior to the machining of the second surface.

[0035] As previously indicated the invention may be applied to a component in which the panel is located in a hot region of the gas turbine engine. Particularly the panel is at least one of: a combustion chamber wall, a combustion chamber liner, a transition duct downstream of a combustion chamber, a heat shield, an expansion turbine intermediate duct, an exhaust nozzle of an expansion turbine, and a casing.

[0036] Manufacturing methods may be slightly different, dependent on the shape of the component. To generate a fraction of a concave groove which later can be extended to an elongated concave groove a panel - or the turbomachine comprising the panel - without substantial surface structure - i.e. being flat or planar, possibly following a general curvature - will be provided to a milling machine. According to the invention a manufacturing process is performed in which a section of a depression is cut into the second surface of the panel. This cutting is performed by rotating the milling cutter and/or the turbomachine component relative to another such that the milling cutter machines a segment of a concave groove, particularly a segment of a circular cylindrical groove, into the second surface.

[0037] To complete an elongated groove the panel will be repositioned afterwards in a repetitive way - in a first direction -, each time followed by the previously mentioned cutting step, so that a continuous groove is generated.

[0038] To generate more than a single groove several cutters will be operated that way at the same time, or the panel will be repositioned such that performing the previously mentioned steps would create a further groove parallel to the already machined groove(s).

[0039] Several of the grooves may be substantially parallel and equidistant. The geometry of parallel grooves and parallel elevations may be identical to another.

[0040] The panel, throughout this document, is a component with a major expanse following a planar or curved plane and with a minor expanse in a perpendicular direction. Preferably it may be built from sheet metal or at least would follow a shape of a typical sheet metal.

[0041] The base material may also be a cast component with similar geometry like a sheet metal, i.e. comprising at least a subcomponent in form of a panel.

[0042] Such a sheet metal or a panel is frequently used for components to guide hot fluids through a channel and/or to separate hot fluids from surroundings. Additionally sheet metals and panels may be used to apply cooling onto one of its surfaces.

[0043] Hot fluids typically are combusted products, e.g. a mixture of air and fuel after combustion.

[0044] Cooling fluids are typically compressed air, compressed by a compressor of a gas turbine engine or by a separate compressor. Cooling air as cooling fluid can be provided from the compressor via pipes or via some kind of passages or channels within a casing. After the cooling air has been passed the second surface it may be released via passages into the hot working media stream.

[0045] The cooling effect generally is driven by the heat transfer coefficient, the temperature difference and the contact area between a metal component and cooling air along the cooled second surface. Besides the discussed convectional cooling from one side of a panel, possibly other methods of cooling may also be present in the same component, e.g. incorporated cooling channels within sub-sections of the component. It may worth noticing that the heat transfer coefficient is generally also dependent on the cooling air velocity. Also a boundary layer of air - a kind of air cushion - may counteract the cooling effect, while a cushion of air at the hot side surface may be beneficial as leading to film cooling.

[0046] When in explaining the features of the invention reference is taken to cross sectional areas, it needs to be understood that generally a cross section is taken at a plane defined by (a) a vector defining a shortest distance between adjacent elevations and (b) a vector perpendicular to the first surface. The vector defining a shortest distance between adjacent elevations may substantially also be a main direction of a cooling fluid flow.

[0047] The discussed component may be a complex three dimensional component. Nevertheless, it may have at least a section in which it has a plate-like or panel-like appearance, possibly curved around a hot working gas passage, e.g. an annular or cylindrical combustion chamber or an annular passage through an expansion turbine. A panel or plate may be a solid element but may also be built from a sheet metal and formed into the wanted shape. The panel may only define a segment of an annular passage and several of these define the complete annular passage.

[0048] The component may be built preferably from metal or any other heat conductive chemical element.

[0049] As already indicated, the invention is directed to a turbomachine component and also to a manufacturing method to produce such a turbomachine component. Furthermore, the invention is also related to a turbomachine which includes such a turbomachine component. Specifically, the invention is also directed to a gas turbine engine including such component.

[0050] It has to be noted that embodiments of the invention have been described with reference to different subject matters. In particular, some embodiments have been described with reference to apparatus type claims whereas other embodiments have been described with reference to method type claims. Some effects may only be realized during operation of the apparatus. However, a person skilled in the art will gather from the above and the following description that, unless otherwise notified, in addition to any combination of features belonging to one type of subject matter also any combination between features relating to different subject matters, in particular between features of the apparatus type claims and features of the method type claims is considered as to be disclosed with this application.

[0051] The aspects defined above and further aspects of the present invention are apparent from the examples of embodiment to be described hereinafter and are explained with reference to the examples of embodiment.

Brief description of the drawings

[0052] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematical drawings, of which:

FIG. 1: shows a longitudinal section of a section of a combustion chamber;
FIG. 2: shows a magnified view of the detail V of figure 1;
FIG. 3: illustrates an angled view of s segment of a combustion chamber liner with the given surface structure according to the invention;
FIG. 4: illustrates how the machining is performed at a conical component;
FIG. 5: shows a magnified view about the relation between the machining tool and the machined surface.

[0053] The illustrations in the drawings are schematical. It is noted that for similar or identical elements in different figures, the same reference signs will be used to denote the same or equivalent features.

[0054] Some of the features and especially the advantages will be explained for an assembled gas turbine, but obviously the features can be applied also to single components of the gas turbine but may show the advantages only once assembled and during operation. But when explained by means of a gas turbine during operation none of the details should be limited to a gas turbine solely while in operation. As the invention is inspired to counteract problems of temperatures in consequence of combustion processes, the features can also applied to different types of machines that experience high temperatures.

Detailed description of the invention

[0055] A gas turbine engine may serve as one example of a turbomachine. The gas turbine - short for gas turbine engine - comprises an air inlet at one end followed by a compressor stage in which incoming air is compressed for application to one or more combustors as combustion devices, which may be annular or so-called can-annular or silo type, the can-annular ones being distributed circumferentially around the turbine axis. Fuel is introduced into the combustors and mixed in there with a major part of the compressed air taken from the compressor. Hot gases with high velocity as a consequence of combustion in the combustors are directed to a set of turbine blades within a turbine section, being guided (i.e. redirected) by a set of guide vanes. The turbine blades and a shaft - the turbine blades being fixed to that shaft - form the rotor and are rotated about an axis as a result of the impact of the flow of the hot gases. The rotating rotor also is equipped with blades of a compressor stage and therefore also rotates blades of the compressor stage, with the consequence that the compressed air supply to the combustors is provided by these rotating compressor blades (due to interaction of rotating compressor blades with stationary compressor vanes) once in operation. There may be more than one rotor in the gas-turbine engine.

[0056] Figure 1 shows a cross sectional view of a part of a combustor section of a gas turbine engine representing a turbomachine 1, particularly a cross section of a combustion chamber 105. The combustion chamber 105 may for example be annular or can-annular (i.e. formed by a plurality of combustor cans all arranged about an axis of the gas turbine engine). A burner 106 may be present at an upstream end of the combustion chamber 105. The combustion chamber 105 is depicted in a way that the main fluid flow 100 of combusted products is in right hand direction in the drawing plane. The burner 106 is only depicted in an abstract way.

[0057] The cross section is taken through an axis of rotation X of the gas turbine engine, particularly - in case of an annular combustor - through an axis of rotation X of annular combustor. A radial direction may be defined in a direction perpendicular to the axis of rotation.

[0058] The combustion chamber 105, particularly its liner, as a turbomachine component 10 is shown in a cross sectional view. According to figure 1 a double shell liner is shown, with an outer wall 101 and an inner wall 102 ("inner" and "outer" in respect of the combustion chamber 105). The combustion chamber will house a flame generating thermal radiation 23. Cooling fluid 24, i.e. particularly compressed air provided from the compressor of the gas turbine, is traveling at the outside of the combustion chamber liner through a liner passage 103. The cooling fluid flow direction may be different depending on the spot of location. One direction of the cooling fluid flow at a specific location is indicated by an arrow with the reference numeral 24.

[0059] The turbomachine component 10 may have at least one panel 11, i.e. the inner wall 102 of the combustion chamber liner, comprising a first surface 21 and a second surface 22. In case of an annular combustion chamber a radial inwards and a radial outwards liner wall (inwards liner wall 102' and outwards liner wall 102") may each comprise a panel 11 according to the invention.

[0060] The turbomachine component 10 may be a complex three dimensional structure. The panel 11 may be curved in axial direction X (like indicated in the cross section of FIG. 1 at a downstream end of the liner) and also curved around the path for the working media in circumferential direction or curved around the axis of rotation X. Nevertheless you could consider the panel 11 as being planar, particularly if you analyse just a sub section of the overall component. The panel 11 may substantially be fairly thin material, i.e. with larger expanse in two directions and small expanse in width. Particularly a curved or contoured plate-like panel 11 may be made from sheet metal and formed into the desired form. It may also be a cast component.

[0061] The second surface 22 of the panel 11 is also shown in the figure and is directed to a cooled side, i.e. facing a cooling air cavity - in the figure the liner passage 103 - for guiding the cooling fluid 24, the cooling air cavity surrounding the combustion chamber 105. The opposite surface of the panel 11 is the first surface 21 and is facing the hot working media within the combustion chamber 105.

[0062] Within the combustion chamber 105, during operation, air and fuel is combusted generation thermal radiation 23, leading to heating up the panel 11. The main source of thermal radiation 23 may be a flame at an upstream end of the combustion chamber 105. At this upstream end - at least at the upstream end, maybe along the full length or most of the length of the inner wall 102 or alternatively just limited to the upstream end - it may be advantageous to provide cooling elements at the second surface 22. According to the invention the second surface 22 comprises a plurality of alternating elongated depressions 25 and elongated elevations 26, wherein the depressions 25 are formed each as an elongated concave groove 27, all explained in more detail in accordance with the FIG. 2 and 3.

[0063] Still referring to FIG. 1 the orientation of the elevations 26 and depressions 25 are substantially perpendicular or possibly angled (e.g. 10°, 20°, 30°, 40°, 50°, or 60° or any value in between) to a local fluid flow direction of the cooling fluid 24. This should provide sufficient heat transfer to cool the panel 11.

[0064] Now referring to FIG. 2 and 3, the alternating elongated depressions 25 and elongated elevations 26 are shown in more detail. FIG. 2 and 3 show in more detail a section V of the combustion liner as identified by an ellipse in FIG. 1. FIG. 2 shows a cross-sectional view in the same plane as FIG. 1. FIG. 3 shows an angled three-dimensional view of the same combustion liner section V. In FIG. 3 the drawing plane of FIG. 1 and 2 is a shown fictitious plane identified by reference numeral 40.

[0065] This fictitious plane 40 and the drawing plane of FIG. 2 is a plane perpendicular to an expanse of the groove 27 and perpendicular to the first surface 21 of the panel 11.

[0066] According to FIG. 2 a section of the panel 11 is shown, with a substantially flat first surface 21 and a contoured second surface 22. The second surface 22 shows repetitively depressions 25 and elevations 26, which extend perpendicular to the drawing plane to elongated elements. The depressions 25 smoothly merge to the elevations 26. The form of the depressions 25 and the elevations 26 follow a concave groove 27, which again is elongated in direction perpendicular to the drawing plane. The elevations 26 itselves are formed as leveled ridges with top surfaces 31. Each ridge has a kink between a first one of the curved groove 27 and one of the top surfaces 31 and a further kink from that top surface 31 to a consecutive curved groove 27.

[0067] The groove 27 is concave. According to the shown embodiment the groove 27 even shows a circular cylindrical shape, i.e. the groove 27 forms a segment of circular cylindrical recess and the follows the shape of an arc of a circle in the given cross-sectional view. The radius of this circular cylindrical recess is indicated as radius R, which is shown as a radius about an axis Y. This axis Y is preferably perpendicular to the drawing plane and parallel to the elongation of the grooves 27.

[0068] It is the goal that cross flowing cooling fluid (in FIG. 1 identified as cooling fluid 24) provides heat transfer between the panel 11 and the cooling fluid 24. The dimensions of the second surface structures can be defined as pitch P between two elevations 26, the depth D of the groove 27, defined as a maximum depth of one of the depressions 25 in relation to a maximum height of the ridge 30 of an adjacent one of the elevations 26; and by a width W which is defined as an average transversal width - i.e. in the drawing plane - of the levelled top surface 31 of the levelled ridge 30.

[0069] Preferably, to gain cooling effect via convective cooling, the dimension may be in the range of:

$$0 \leq \frac{W}{D} \leq 50, \quad 1 \leq \frac{R}{D} \leq 50, \quad \text{and} \quad 1 \leq \frac{P}{D} \leq 25.$$

[0070] In the shown example W/D may be 0.8, so showing a substantially narrow ridge. R/D may be 12, so that about roughly 40° of a cylinder wall is present as a groove. P/D may also be 12, defining that the grooves are fairly flat. As mentioned before, different configuration values may also be applicable.

[0071] FIG. 3 explicitly shows the configuration of FIG. 2 and explicitly shows that the grooves 27, the depressions 25, the elevations 26 are elongated along the second surface 22. FIG. 3 also depicts that the panel 11 may be curved itself.

[0072] The shown design is advantageous as a single milling cutter can be used to create the shape of a concave groove 27. This simplifies the manufacturing process of surface machining. The difference lies in the cutting head compared to rectangular turbulators. In the case of the rectangular turbulators the cutter angle may need to be changed several times to generate sharp corners whereas in the wave form it is possible to use a circular cutter which does not need any manual adjustment. It reduces the manufacturing lead-time as well as labor-tool interaction drastically. In consequence the manufacturing costs are reduced. Even though manufacturing is simplified, the cooling effect and the overall gas turbine efficiency remain intact.

[0073] The usage of the milling cutter and the milling tool is shown in FIG. 4 and 5.

[0074] FIG. 4 shows a milling cutter 200 with a circular shape, which will follow a rotational path so that a segment of the groove 27 is machined at a specific location. Later the panel 11 and/or the milling cutter 200 will be repositioned to another so that the milling cutter 200 will create a further segment of the groove 27. The original material width of the panel 11 is indicated by a dotted line and the reference numeral 201. According to Fig. 4 the machining is performed at groove 27', groove 27" has already been created, and groove 27"' would be the next groove to be machined.

[0075] The rotational path of the milling cutter 200 may be perpendicular to the expanse of the groove 27, as implied in all the shown figures. The rotational path of the milling cutter 200 may also be angled to the groove 27 which would allow grooves that do not follow the arc of a circle but follow an elliptical path.

[0076] These grooves 27', 27", 27 "', as mentioned in relation to FIG. 4, are also indicated in FIG. 5. As shown in FIG. 5 the component 10, if - at least in parts - being rotational symmetric, may be placed on a rotatable platform 210. One groove after another is machined into a surface of the component 10 via a milling cutter 200, particularly its cutter head. The cutter head may provide a lateral movement compared to the main rotation of the rotatable platform 210. The lateral movement will create a segment of the groove 27', which will be completed by the rotation of the rotatable platform 210.

[0077] According to FIG. 5 already machined surfaces are shown with solid lines. Surfaces to be machined are identified with dashed lines.

[0078] This machining process may be called lathing.

[0079] As you can see, once the machining process is completely performed, the component 10 and its surface 22 will show a plurality of grooves 27', 27'', 27"', etc. at its radial outwards surface. The component 10 can then be installed e.g. as an outer wall 102" (see FIG. 1) of a combustion chamber liner. In a similar way an inner wall 102' can be machined.

[0080] Previously the invention was explained in conjunction with a combustion chamber liner. Other elements of a gas turbine engine or other types of rotating machine that experience strong heat can also be equipped with these features. For example in a gas turbine engine, a transition duct can be equipped with this surface structure. Also heat shields, for example use in the combustion chamber or at the turbine section of a gas turbine engine, can be equipped accordingly. Furthermore the invention can be applied for exhaust nozzles in gas turbines or turbine shrouds. Besides, the invention can also be used for a casing located in a hot region of an engine. In case of combustion chamber liners, the corrugated feature can be applied to a surface of the single liner facing away from the combustion chamber or in case of a double liner (as shown in the figures), being located in a passage defined by the double liner. In both cases the machined surface will be facing away from the combustion chamber interior, after it has been installed.

[0081] Beyond that, other types of machines can use this inventive feature as long as cooling air may be provided to that component. As a gas turbine engine has a compressor included into the system in which air is compressed which can be used also as cooling air, and due to the temperature levels at a gas turbine engine, the invention is specifically advantageous to be incorporated in a gas turbine engine.

Claims

1. Turbomachine component (10) arrangeable in a turbomachine (1), particularly a gas turbine engine,
the turbomachine component (10) built in parts from a curved or planar panel (11), the panel (11) comprising a first surface (21) and a second surface (22),
wherein the turbomachine component (10) is arrangeable such that, during operation of the turbomachine (1), the first surface (21) is affected by thermal radiation (23) and the second surface (22) is affected by a cooling fluid (24) travelling along the second surface (22),
wherein the second surface (22) comprises a plurality of alternating elongated depressions (25) and elongated elevations (26), wherein the depressions (25) are formed each as an elongated concave groove (27).

2. Turbomachine component (10) according to claim 1,
characterised in that
the concave groove (27) follows in cross-section a shape of a part of an arc of a circle when the cross-section is taken from a direction perpendicular to ridges (29) of one of the elevations (26).

3. Turbomachine component (10) according to claims 1 or 2,
characterised in that
in case the panel (11) is planar, the concave groove (27) forms a segment of circular cylindrical recess, and/or
in case the panel (11) is curved, the concave groove (27) forms a segment of skewed circular cylindrical recess following a contour of the panel (11).

4. Turbomachine component (10) according to claim XY,
characterised in that
the depressions (25) are manufactured by machining the depressions (25) into the second surface (22).

5. Turbomachine component (10) according to claim XY,
characterised in that
the depressions (25) are manufactured by machining the depressions (25) into the second surface (22) via a milling cutter, wherein one of the milling cutter and the second surface (22) follows a rotation along a circular arc section (28).

6. Turbomachine component (10) according to claim XY,
characterised in that
ridges (29) of the elevations (26) are arranged angled to a flow direction of the cooling fluid (24) along the second surface (22) during operation of the turbomachine (1), wherein an angle of attack of the cooling fluid (24) onto the ridges (29) is between -60° and +60° in respect of a direction perpendicular to the ridges (29).

7. Turbomachine component (10) according to claim XY,
characterised in that
the elevations (26) are each formed as a levelled ridge (30).

8. Turbomachine component (10) according to claim XY,

characterised in that
a width W is defined as an average transversal width of a levelled top surface (31) of the levelled ridge (30), and a depth D is defined as a maximum depth of one of the depressions (25) in relation to a maximum height of the ridge (30) of an adjacent one of the elevations (26),

wherein the depressions (25) and elevations (26) are configured such that W/D is in the range of $0 \leq \frac{W}{D} \leq 50$,

preferably $0.5 \leq \frac{W}{D} \leq 20$.

9. Turbomachine component (10) according to claim XY,
characterised in that
the depressions (25) and the elevations (26) are sized and oriented to act as turbulators for the cooling fluid (24) during operation of the turbomachine (1).

10. Turbomachine component (10) according to claim XY,
characterised in that
a radius R is defined for a radius of the concave groove (27), with the radius taken in a plane (40) perpendicular to an expanse of the groove (27) and perpendicular to the first surface (21) of the panel (11), and
a depth D is defined as a maximum depth of one of the depressions (25) in relation to a maximum height of the ridge (30) of an adjacent one of the elevations (26),

wherein the depressions (25) and elevations (26) are configured such that R/D is in the range of $1 \leq \frac{R}{D} \leq 50$,

preferably $15 \leq \frac{R}{D} \leq 35$.

11. Turbomachine component (10) according to claim XY,
characterised in that
a pitch P is defined for a shortest transversal distance between two adjacent elevations (26) of the elevations (26), and a depth D is defined as a maximum depth of one of the depressions (25) in relation to a maximum height of the ridge (30) of an adjacent one of the elevations (26),

wherein the depressions (25) and elevations (26) are configured such that P/D is in the range of $1 \leq \frac{P}{D} \leq 25$,

preferably $10 \leq \frac{P}{D} \leq 20$.

12. Manufacturing method of a turbomachine component (10), particularly a gas turbine engine component for usage in a combustor or an expansion turbine of a gas turbine engine, comprising the steps of:

a) providing a milling machine with a milling cutter (200); and
b) providing to the milling machine a turbomachine component (10) comprising a panel (11), the panel (11) comprising a substantially flat first surface (21) and a substantially flat second surface (22); and
c) cutting into the second surface (22) of the panel (11) a section of a depression (25) by rotating the milling cutter (200) and/or the turbomachine component (10) relative to another such that the milling cutter (200) machines a segment of a concave groove (27), particularly a segment of a circular cylindrical groove, into the second surface (22).

13. Manufacturing method of a turbomachine component (10) according to claim 12,
characterized in that
the relative rotating in step c) comprises a step of rotating the milling cutter (200) about an axis of rotation (Y).

14. Manufacturing method of a turbomachine component (10) according to claims 12 or 13,
comprising the further step of:

d) repositioning of the panel (11) in reference to the milling machine laterally to a plane of rotation of the milling cutter (200); and
f) further execution of step c) so that a previously cut section of the depression is extended by a further cut

section into the second surface (22); and
g) plural repetition of consecutively executed steps d) and f);

wherein an elongated first depression (27) is machined.

15. Manufacturing method of a turbomachine component (10) according to claim 14, comprising the further step of:

h) repositioning of the panel (11) in reference to the milling machine lateral to a milling path as defined by steps c) to g) and parallel to the second surface (22); and
i) performing steps c) to g) for cutting an elongated further depression (27’) into the second surface (22) parallel to the elongated first depression (27).

FIG 1

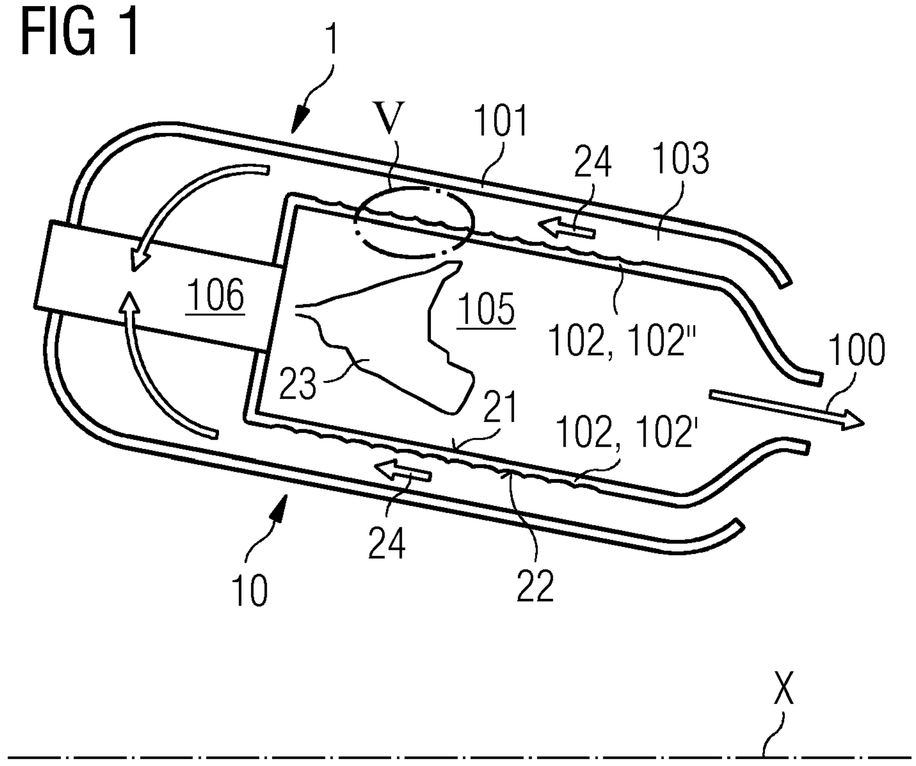

1
V
101
24
103
106
105
102, 102''
100
23
21
102, 102'
10
24
22
X

FIG 2

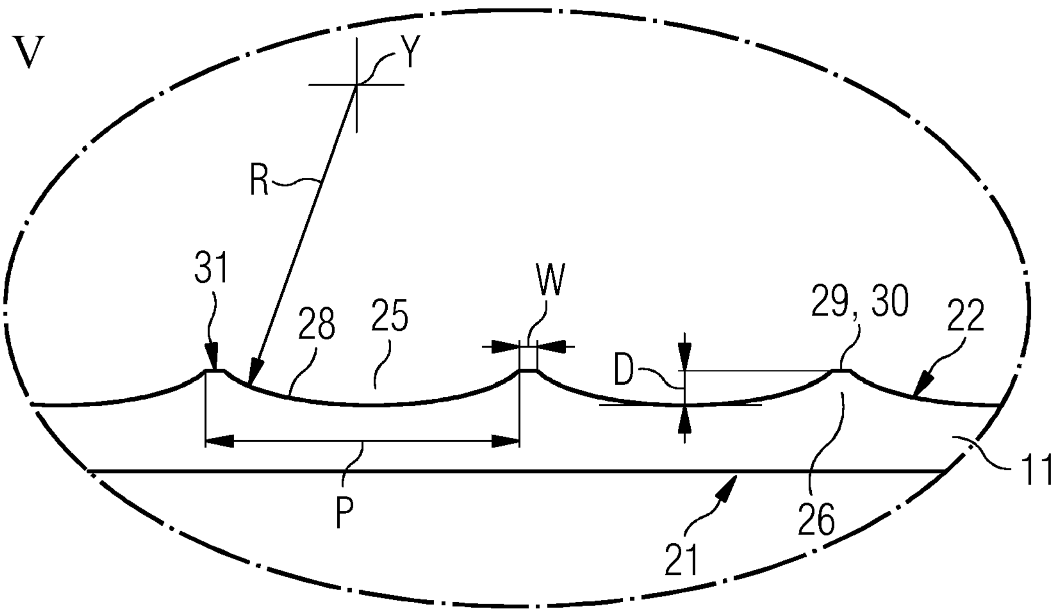

V
Y
R
31
28
25
W
D
29, 30
22
P
11
26
21

FIG 3

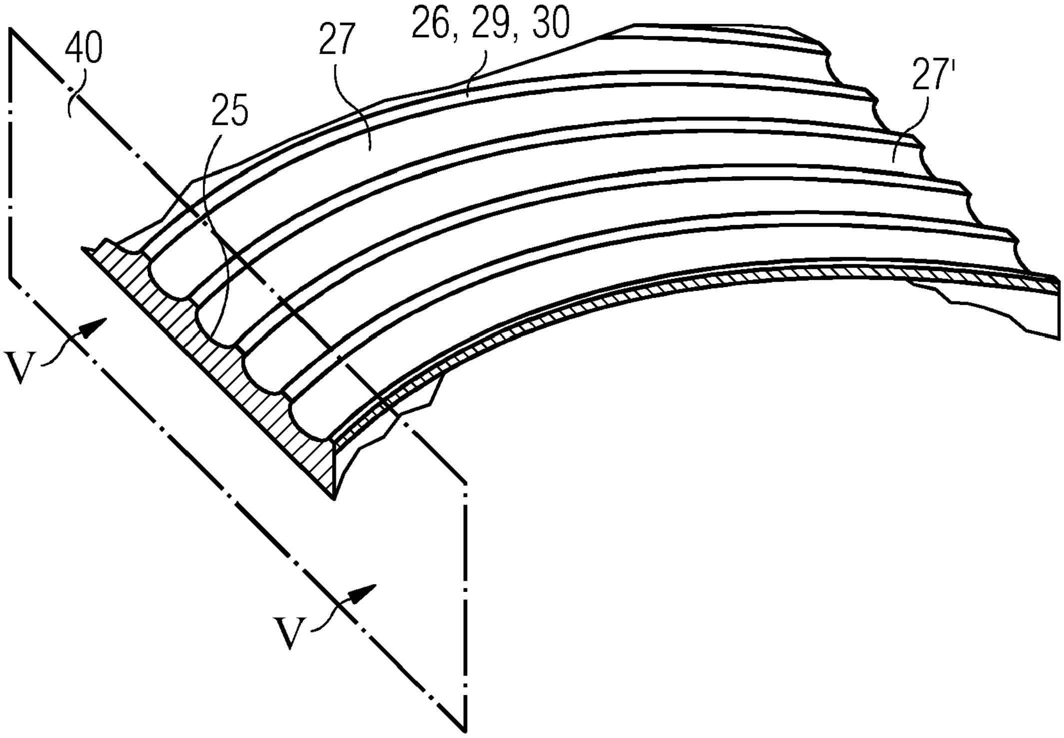


FIG 4

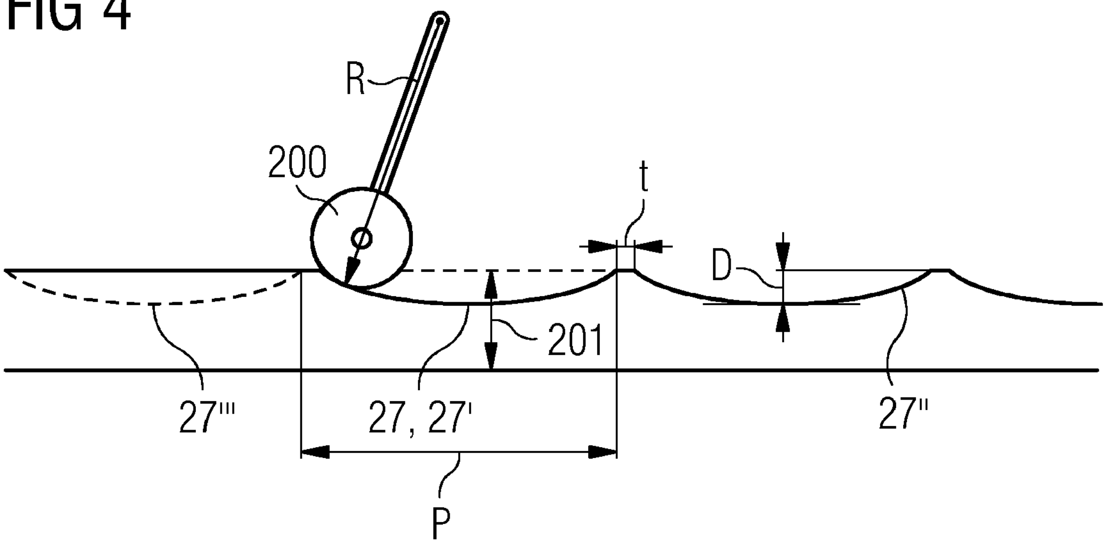
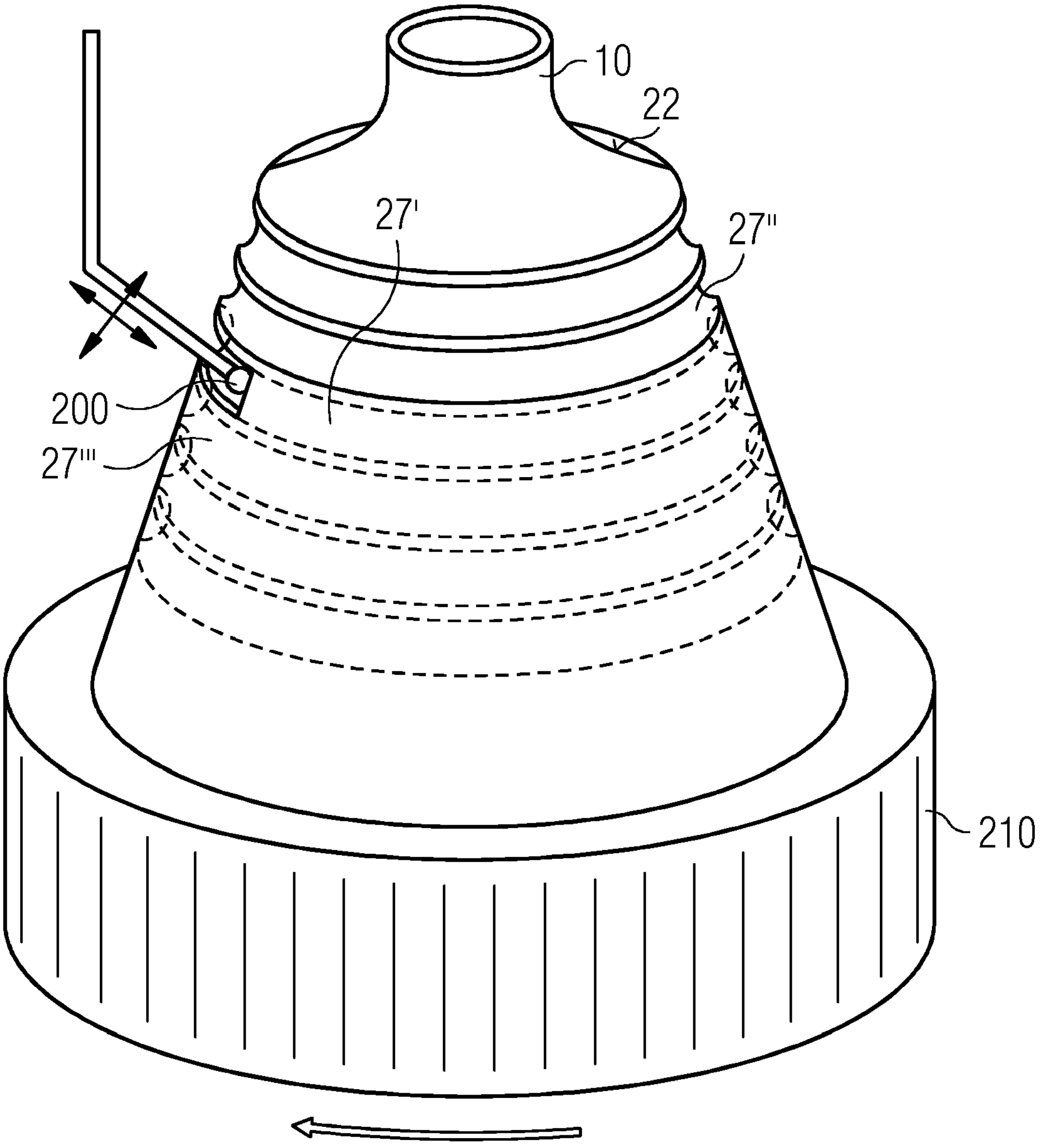


FIG 5



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EUROPEAN SEARCH REPORT

Application Number
EP 16 16 3258

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X	US 2010/223931 A1 (CHILA RONALD JAMES [US] ET AL) 9 September 2010 (2010-09-09) * page 4, paragraph 33 - page 5, paragraph 38 * * figures 6-7D * -----	1,4,5, 7-9, 12-15	INV. F23R3/00
X	US 2004/079082 A1 (BUNKER RONALD SCOTT [US]) 29 April 2004 (2004-04-29) * page 2, paragraph 26 - paragraph 29 * * figures 4,5 * -----	1-3,6,7, 9-11	
X	US 5 353 865 A (ADIUTORI EUGENE F [US] ET AL) 11 October 1994 (1994-10-11) * column 3, line 56 - column 4, line 61 * * column 6, line 7 - line 19 * * column 7, line 1 - line 16 * * figures 1,2A * -----	1-4,7,9	

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F23R

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	7 September 2016	Gavriliu, Costin

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