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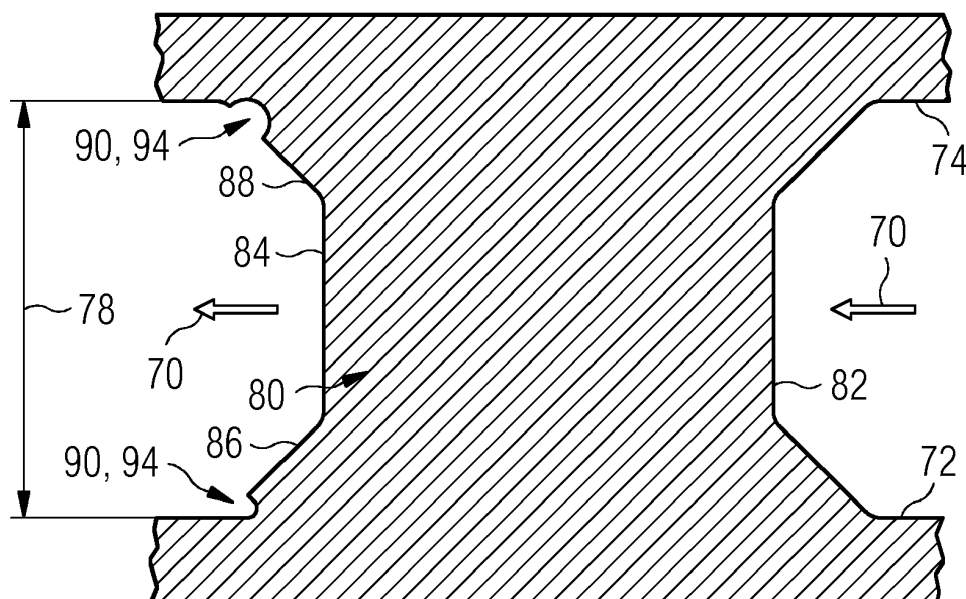
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Siemens AG**Postfach 22 16 34****80506 München (DE)**(54) **A GAS TURBINE SECTION WITH IMPROVED STRUT DESIGN**

(57) A gas turbine section for an annular gas path is presented. The annular gas path is defined through a gas turbine engine. The gas turbine section includes an inner and an outer gas path walls that are concentrically arranged about an axis and adapted to form together at least a part of the annular gas path defined through the gas turbine engine. The gas turbine section includes at least one strut extending generally radially relative to the axis from the inner to the outer gas path walls. The strut

has a leading edge, adapted to be positioned upstream relative to the annular gas path, and a trailing edge, adapted to be positioned downstream relative to the annular gas path. The strut further includes a cut-out. The cut-out is positioned at the trailing edge and is contiguous with the inner gas path wall or the outer gas path wall. Corresponding methods of designing and manufacturing a gas turbine section.

FIG 9**EP 3 241 989 A1**

Description

[0001] The present invention relates to gas turbines, and more particularly to struts for use in gas turbine engines.

[0002] Struts are circumferentially-disposed, radially-extending elements spanning a gas path of a gas turbine engine between an inner gas path wall and an outer gas path wall. The inner and the outer gas path wall together form at least a part of the annular gas path of the gas turbine engine. The struts are used for structural purposes and/or to redirect i.e. de-swirl or pre-swirl the gas path flow. Struts may be used in the compressor section, in the turbine section and in exhaust sections of a gas turbine engine. The struts bear load of the parts of the gas turbine engine and are subjected to various degrees of mechanical and thermal stresses, depending upon the location of the struts, for example struts of the compressor section are subjected primarily to mechanical stress whereas the struts of the turbine section or exhaust section are subjected to both mechanical and thermal stresses.

[0003] In the struts, maximum stress concentrations are observed at the trailing edges mainly at junction of the trailing edge with the inner gas path wall and/or at junction of the trailing edge with the outer gas path wall. The load within the strut is distributed such that stress concentration at the junctions of the trailing edge with the outer and the inner gas path wall are very high, mostly because the trailing edge is thinner or narrower compared to other sections of the strut. The high concentration of stress at the junctions can easily cross the threshold of the junction to develop faults at the trailing edge of the strut and/or the junctions of the trailing edge and the inner or the outer gas path walls. The chances of failure, for example crack development and/or propagation, are comparatively higher at the trailing edge of the struts at the junctions of the trailing edge of the strut with the inner and/or the outer gas path walls. The risk is present during operation of the gas turbine engine and is heightened when the gas turbine engine is operated at full capacity or in cases of worst case loading such as resulting from a blade failure. Furthermore, the risk of failure is greater in the turbine sections and exhaust sections of the gas turbine engine because of presence of greater temperatures in these sections.

[0004] To make the struts stronger to be able to adequately withstand the mechanical and/or the thermal stresses, the struts are often made thicker in cross-section or provided with buttresses. Furthermore, irrespective of the location of the struts, the presence of struts creates losses in air/gas flow in the gas turbine engine. Additionally, making the struts thicker or wider and/or providing the struts with buttresses further causes losses and disturbances in the air/gas flow through the gas turbine engine segments. Therefore, an improvement in strut design is desired.

[0005] Thus the object of the present disclosure is to

provide a gas turbine section with an innovative strut design. The strut design is desired to be such that chances of failure are reduced. The strut design is also desired to be conducive to the air/gas flow within the gas turbine engine by not interfering with the streamline shape that struts usually have.

[0006] The above objects are achieved by a gas turbine section according to claim 1, a gas turbine engine according to claim 14, a method for designing a gas turbine section according to claim 15, and a method for manufacturing a gas turbine section according to claim 19, of the present technique. Advantageous embodiments of the present technique are provided in dependent claims. Features of claims 1, 14, 15 and 19 may be combined with features of claims dependent on them respectively, and features of dependent claims can be combined together.

[0007] In a first aspect of the present technique, a gas turbine section for an annular gas path is presented. The annular gas path is defined through a gas turbine engine, generally in the turbine section and/or downstream of the turbine section relative to a direction of the flow of gas. The gas turbine section includes an inner gas path wall and an outer gas path wall. The inner gas path wall and the outer gas path wall are concentrically arranged about an axis and adapted to form together at least a part of the annular gas path defined through the gas turbine engine. The gas turbine section also includes at least one strut extending generally radially relative to the axis from the inner gas path wall to the outer gas path wall. The strut has a leading edge and a trailing edge. The leading edge is adapted to be positioned upstream relative to the annular gas path and the trailing edge is adapted to be positioned downstream relative to the annular gas path. The strut further includes a cut-out. The cut-out is positioned at the trailing edge and is contiguous with the inner gas path wall or the outer gas path wall.

[0008] In absence of the cut-out, the load within the strut is distributed such that stress concentration at the junctions of the trailing edge with the outer and the inner gas path wall are very high, mostly because the trailing edge is thinner or narrower compared to other sections of the strut. The cut-out removes a portion of the trailing edge of the strut, adjoining the inner or the outer gas path wall, that is subjected to the high stress concentrations. As a result of the cut-out, depending upon where the cut-out is located, load within the strut, especially where the trailing edge of the strut is connected to or joined with the outer or the inner gas path wall, is redistributed and thus the cut-out at least partially removes the high stress concentration at the junction of the trailing edge of the strut and the outer or the inner gas path wall, depending upon where the cut-out is located, because the strut material is not present at the location of the cut-out and therefore is unable to be subjected to any load. The load which was being concentrated at the trailing edge at the junctions gets redistributed to other thicker sections of the strut which are able to bear the load better compared to

the thin trailing edge and have a higher threshold than the junctions of the trailing edge and the inner or the outer gas path wall.

[0009] Thus the cut-out of the present technique aids in load redistribution within the strut and the inner or the outer gas path wall, especially at the junction of the trailing edge and the inner and/or the outer gas path wall, in such a way that the load is presented to the thicker sections of the strut and to segments where the thicker sections of the strut join the inner and/or the outer gas path wall. The load redistribution helps in increased chances of maintaining structural integrity during normal operation of the gas turbine engine and/or during worst case loading for example the imbalance load resulting from a blade failure.

[0010] The dimensions of the cut-out at the trailing edge of the strut are chosen such that load redistribution within the strut is optimized.

[0011] In an embodiment of the gas turbine section, a height of the cut-out from the inner gas path wall or the outer gas path wall, depending upon where the cut-out is located, is between 5 percent and 15 percent of a distance between the inner gas path wall and the outer gas path wall measured radially relative to the axis. This provides a dimension of the cut-out that is conducive to maintaining an overall streamlined shape of the strut and thus minimizing airflow disturbances, if any, caused by introduction of the cut-out.

[0012] In another embodiment of the gas turbine section, wherein the strut includes a buttress and the cut-out is positioned within the buttress. The buttress helps in reducing stress localization by increasing contact area between the trailing edge of the strut and the inner or the outer gas path wall where the buttress is present.

[0013] In another embodiment of the gas turbine section, a height of the cut-out from the inner gas path wall or the outer gas path wall with which the cut-out is contiguous is between 20 percent and 50 percent of a height of the buttress from the inner gas path wall or the outer gas path wall with which the buttress is contiguous. This provides a dimension of the cut-out within the buttress that is conducive to maintaining an overall streamlined shape of the strut and thus minimizing airflow disturbances, if any, caused by introduction of the cut-out within the buttress.

[0014] In another embodiment of the gas turbine section, the cut-out has an opening with an angle between 50 degree and 80 degree. The opening limited within this range provides a dimension of the cut-out that is conducive to maintaining an overall streamlined shape of the strut and thus minimizing airflow disturbances, if any, caused by introduction of the cut-out.

[0015] In another embodiment of the gas turbine section, the strut includes an additional cut-out. In this embodiment, the cut-out is positioned at the trailing edge and is contiguous with the inner gas path wall whereas the additional cut-out is also positioned at the trailing edge and is contiguous with the outer gas path wall. Thus,

junction of the trailing edge and the inner gas path wall as well as the junction of the trailing edge and the outer gas path wall each have cut-outs, namely the cut-out and the additional cut-out, respectively. In another embodiment the cut-out is at the junction of the trailing edge and the outer gas path wall, whereas the additional cut-out is at the junction of the trailing edge and the inner gas path wall. Thus load redistribution is performed at both the junctions simultaneously.

[0016] In another embodiment of the gas turbine section, a height of the additional cut-out from the inner gas path wall or the outer gas path wall, depending upon where the additional cut-out is located, is between 5 percent and 15 percent of a distance between the inner gas path wall and the outer gas path wall measured radially relative to the axis. This provides a dimension of the additional cut-out that is conducive to maintaining an overall streamlined shape of the strut and thus minimizing airflow disturbances, if any, caused by introduction of the additional cut-out.

[0017] In another embodiment of the gas turbine section, the strut includes an additional buttress and the additional cut-out is positioned within the additional buttress. The additional buttress helps in reducing stress localization by increasing contact area between the trailing edge of the strut and the inner or the outer gas path wall where the additional buttress is present.

[0018] In another embodiment of the gas turbine section, a height of the additional cut-out from the inner gas path wall or the outer gas path wall with which the additional cut-out is contiguous is between 20 percent and 50 percent of a height of the additional buttress from the inner gas path wall or the outer gas path wall with which the additional buttress is contiguous. This provides a dimension of the additional cut-out within the additional buttress that is conducive to maintaining an overall streamlined shape of the strut and thus minimizing airflow disturbances, if any, caused by introduction of the additional cut-out within the additional buttress.

[0019] In another embodiment of the gas turbine section, the additional cut-out has an opening with an angle between 50 degree and 80 degree. The opening limited within this range provides a dimension of the additional cut-out that is conducive to maintaining an overall streamlined shape of the strut and thus minimizing airflow disturbances, if any, caused by introduction of the additional cut-out.

[0020] In another embodiment of the gas turbine section, the strut has a cross-section having a symmetrical aerofoil shape. In yet another embodiment of the gas turbine section, the strut has a cross-section having a cambered aerofoil shape. Thus the present technique is implemented in struts of different types.

[0021] In a second aspect of the present technique, a gas turbine engine is presented. The gas turbine engine includes a gas turbine section according to the first aspect of the present technique described hereinabove.

[0022] In a third aspect of the present technique, a

method for designing a gas turbine section for an annular gas path is presented. The annular gas path is defined through a gas turbine engine, generally in the turbine section and/or downstream of the turbine section relative to a direction of the flow of gas. The gas turbine section includes an inner gas path wall and an outer gas path wall. The inner gas path wall and the outer gas path wall are concentrically arranged about an axis and adapted to form together at least a part of the annular gas path defined through the gas turbine engine. The gas turbine section also includes at least one strut extending generally radially relative to the axis from the inner gas path wall to the outer gas path wall. The strut has a leading edge and a trailing edge. The leading edge is adapted to be positioned upstream relative to the annular gas path and the trailing edge is adapted to be positioned downstream relative to the annular gas path. In the method, a stress analysis of the strut is performed. The stress analysis is performed under conditions representative of various operational stages and/or fault modes of the gas turbine engine. Thereinafter, in the method, a region of high stress concentration within the strut positioned at the trailing edge of the strut and adjacent to the inner gas path wall or the outer gas path wall is determined. Finally in the method, a cut-out positioned at the trailing edge. The cut-out is positioned contiguous with the inner gas path wall or the outer gas path wall such that a material of the strut in the region of high stress concentration so determined is removed.

[0023] In an embodiment of the method according to the second aspect of the present technique, the cut-out is same as the cut-out described in the first aspect of the present technique.

[0024] In another embodiment of the method, the method includes determining an additional region of high stress concentration within strut positioned at the trailing edge of the strut and adjacent to the inner gas path wall or the outer gas path wall. The region and the additional region are adjacent to different gas path walls selected from the inner gas path wall and the outer gas path wall. Furthermore in the method, an additional cut-out is placed in the strut such that the additional cut-out is positioned at the trailing edge and contiguous with the inner gas path wall or the outer gas path wall. The placing of the additional cut-out is such that a material of the strut in the region of high stress concentration so determined is removed. The additional cut-out is same as the additional cut-out described hereinabove in the first aspect of the present technique.

[0025] In a fourth aspect of the present technique, a method for manufacturing a gas turbine section is presented. The gas turbine section is for an annular gas path defined through a gas turbine engine. In the method the gas turbine section is designed according to the third aspect of the present technique. Thereafter, one or more parts of the gas turbine section, besides the cut-out, are casted and finally the cut-out is formed either by casting along with the casting of the one or more parts of the gas

turbine section or by machining subsequent to the casting of the one or more parts of the gas turbine section.

[0026] In an embodiment of the method according to the fourth aspect of the present technique, the method further includes forming an additional cut-out by casting along with the casting of the one or more parts of the gas turbine section or by machining subsequent to the casting of the one or more parts of the gas turbine section.

[0027] The above mentioned attributes and other features and advantages of the present technique and the manner of attaining them will become more apparent and the present technique itself will be better understood by reference to the following description of embodiments of the present technique taken in conjunction with the accompanying drawings, wherein:

FIG 1 shows part of a turbine engine in a sectional view and in which a gas turbine section of the present technique is incorporated;

FIG 2 schematically illustrates an embodiment of the gas turbine section of the present technique;

FIG 3 schematically illustrates a part of the gas turbine section depicting a single strut;

FIG 4 schematically illustrates a cross-section of the part of the gas turbine section of FIG 3;

FIG 5 schematically illustrates an exemplary embodiment of a cross-section of the strut viewed in a radial direction;

FIG 6 schematically illustrates another exemplary embodiment of a cross-section of the strut viewed in the radial direction;

FIG 7 schematically illustrates a cross-section of the part of the gas turbine section of FIG 3 with buttresses;

FIG 8 schematically illustrates cross-sections of the strut viewed in a radial direction at different planes of the strut along the radial direction;

FIG 9 schematically illustrates an exemplary embodiment of the strut of the present technique depicting a cut-out and an additional cut-out in the strut;

FIG 10 schematically illustrates an exemplary embodiment of a possible dimension of the cut-out and/or the additional cut-out of the strut of FIG 9;

FIG 11 schematically illustrates another exemplary embodiment of yet another possible dimension of the cut-out and/or the additional cut-

out of the strut of FIG 9;

FIG 12 schematically illustrates a strut without the cut-out and/or the additional cut-out schematically representing different regions of the strut with varying stress distributions within the strut;

FIG 13 schematically illustrates a strut with the cut-out and/or the additional cut-out schematically representing different regions of the strut with varying stress distributions within the strut as compared to FIG 12; and

FIG 14 schematically illustrates the strut with a cut-out and/or an additional cut-out schematically depicting more material removed from the strut and also schematically representing resultant different regions of the strut with varying stress distributions within the strut as compared to FIG 13; in accordance with aspects of the present technique.

[0028] Hereinafter, above-mentioned and other features of the present technique are described in details. Various embodiments are described with reference to the drawing, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purpose of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more embodiments. It may be noted that the illustrated embodiments are intended to explain, and not to limit the invention. It may be evident that such embodiments may be practiced without these specific details.

[0029] FIG. 1 shows an example of a gas turbine engine 10 in a sectional view. The gas turbine engine 10 comprises, in flow series, an inlet 12, a compressor or compressor section 14, a combustor section 16 and a turbine section 18 which are generally arranged in flow series and generally about and in the direction of a longitudinal or rotational axis 20. The gas turbine engine 10 further comprises a shaft 22 which is rotatable about the rotational axis 20 and which extends longitudinally through the gas turbine engine 10. The shaft 22 drivingly connects the turbine section 18 to the compressor section 14.

[0030] In operation of the gas turbine engine 10, air 24, which is taken in through the air inlet 12 is compressed by the compressor section 14 and delivered to the combustion section or burner section 16. The burner section 16 comprises a burner plenum 26, one or more combustion chambers 28 and at least one burner 30 fixed to each combustion chamber 28. The combustion chambers 28 and the burners 30 are located inside the burner plenum 26. The compressed air passing through the compressor 14 enters a diffuser 32 and is discharged from the diffuser 32 into the burner plenum 26 from where a portion of the air enters the burner 30 and is mixed with a gaseous or

liquid fuel. The air/fuel mixture is then burned and the combustion gas 34 or working gas from the combustion is channelled through the combustion chamber 28 to the turbine section 18 via a transition duct 17.

[0031] This exemplary gas turbine engine 10 has a cannular combustor section arrangement 16, which is constituted by an annular array of combustor cans 19 each having the burner 30 and the combustion chamber 28, the transition duct 17 has a generally circular inlet that interfaces with the combustor chamber 28 and an outlet in the form of an annular segment. An annular array of transition duct outlets form an annulus for channelling the combustion gases to the turbine 18.

[0032] The turbine section 18 comprises a number of blade carrying discs 36 attached to the shaft 22. In the present example, two discs 36 each carry an annular array of turbine blades 38. However, the number of blade carrying discs could be different, i.e. only one disc or more than two discs. In addition, guiding vanes 40, which are fixed to a stator 42 of the gas turbine engine 10, are disposed between the stages of annular arrays of turbine blades 38. Between the exit of the combustion chamber 28 and the leading turbine blades 38 inlet guiding vanes 44 are provided and turn the flow of working gas onto the turbine blades 38.

[0033] The combustion gas from the combustion chamber 28 enters the turbine section 18 and drives the turbine blades 38 which in turn rotate the shaft 22. The guiding vanes 40, 44 serve to optimise the angle of the combustion or working gas on the turbine blades 38.

[0034] The turbine section 18 drives the compressor section 14. The compressor section 14 comprises an axial series of vane stages 46 and rotor blade stages 48. The rotor blade stages 48 comprise a rotor disc supporting an annular array of blades. The compressor section 14 also comprises a casing 50 that surrounds the rotor stages and supports the vane stages 48. The guide vane stages include an annular array of radially extending vanes that are mounted to the casing 50. The vanes are provided to present gas flow at an optimal angle for the blades at a given engine operational point. Some of the guide vane stages have variable vanes, where the angle of the vanes, about their own longitudinal axis, can be adjusted for angle according to air flow characteristics that can occur at different engine operations conditions. The casing 50 defines a radially outer surface 52 of the passage 56 of the compressor 14. A radially inner surface 54 of the passage 56 is at least partly defined by a rotor drum 53 of the rotor which is partly defined by the annular array of blades 48.

[0035] The present technique is described with reference to the above exemplary turbine engine having a single shaft or spool connecting a single, multi-stage compressor and a single, one or more stage turbine. However, it should be appreciated that the present technique is equally applicable to two or three shaft engines and which can be used for industrial, aero or marine applications.

[0036] The terms upstream and downstream refer to the flow direction of the airflow and/or working gas flow through the engine unless otherwise stated. The terms forward and rearward refer to the general flow of gas through the engine. The terms axial, radial and circumferential are made with reference to the rotational axis 20 of the engine, unless otherwise stated.

[0037] The basic idea of the invention is removal of material from thin highly stressed areas, i.e. trailing edge of the strut primarily at junctions of the trailing edge with inner and/or outer gas path walls, in such a way that the load path within the strut is moved towards thicker parts of the strut, thus reducing the maximum stress levels. By only removing local highly stressed areas or regions, the streamlined shape of the strut is only modified locally, thus minimising airflow disturbance that could result from such removals.

[0038] FIG 2 shows an exemplary embodiment of a gas turbine section 1 in which the present technique is implemented. The gas turbine section 1 forms a part of the annular gas flow path. The gas turbine section 10 includes an inner gas path wall 72 and an outer gas path wall 74. The inner gas path wall 72 and the outer gas path wall 74 are concentrically arranged about an axis 75 and together form at least a part 76 of the annular gas path. The gas turbine section 1, hereinafter also referred to as the section 1, may be positioned in the path of hot gas flow for example a part of the annular gas flow represented in FIG 1 by reference numeral 71 in the turbine section 18. The section 1 may also form part of exhaust section (not shown), generally downstream of the turbine section 18, of the gas turbine engine 10 hereinafter also referred to as the turbine 10 or the engine 10.

[0039] The outer gas path wall 74 is inner face or inner surface, i.e. the surface facing the rotational axis 20, of an outer casing (not shown), for example sections of a casing (not shown) in the turbine section 18 comparable to the casing 50 of the compressor section 14 as shown in FIG 1. The outer casing and thus the outer gas path wall 74 are connected to the engine mountings (now shown) and helps to transfer the load of the engine 10 to the engine mountings. The inner gas path wall 72 is outer face or outer surface, i.e. the surface facing radially away from the rotational axis 20, of an inner casing (not shown). The inner casing includes within the inner casing the rotor bearing and other parts of the engine 10 for example shaft 22.

[0040] In the section 1, at least one strut 80, and preferably a plurality of such struts 80, are conventionally disposed circumferentially side-by-side to form an annular array spanning through the part 76 of the annular gas path. The struts 80 extend generally radially relative to the axis 75 from the inner gas path wall 72 to the outer gas path wall 74. The axis 75 may be same as the rotational axis 20 of the engine 10 as shown in FIG 1. The radial direction is shown in FIG 2 by reference numeral 79. Fabrication of the struts 80 and other parts 72, 74 of the section 1 can be done by a combination of casting,

machining and welding. Rotor loads are transmitted through the one or more struts 80 from the inner casing, i.e. the inner gas path wall 72, to the outer casing, i.e. the outer gas path wall 74, and sequentially to the engine mountings.

[0041] FIGs 3 to 14 show example of a single such strut 80. FIG 3 shows that the strut 80 comprises in this example an airfoil shape having sidewalls (not shown) extending between the radially spaced-apart inner 72 and the outer gas path walls 74. The strut 80 has a leading edge 82, hereinafter also referred to as the LE 30, and a trailing edge 84 hereinafter also referred to as the TE 84, with reference to the gas flow through the annular gas path of the engine 10. FIG 3 shows the strut 80 as it appears from its LE 82 and FIG 4 shows the strut 80 as it appears cross-sectionally when viewed from a direction mutually perpendicular to the axis 75 and the direction 79 of FIG 2.

[0042] In FIG 4, the gas, during operation of the engine 10, flows in a direction represented by reference numeral 70. FIGs 5 and 6 depict two exemplary possibilities of cross-sections of the strut 80 and showing the gas flow direction 70. FIGs 5 and 6 are depictions of cross-sections of the strut 80 when viewed along the direction 79. When a gas flow approaches the strut 80, i.e. the LE 82 of the strut 80, the flow separates to pass around either side of the strut 80, and then the flow reattaches downstream of the strut 80 after passing along the TE 84 of the strut 80.

[0043] Furthermore, as shown in FIG 7, each strut 80 may have buttresses for example a buttress 86 at the TE 84 adjacent to the inner gas path wall 72, hereinafter also referred to as the inner wall 72, and an additional buttress 88 at the TE 84 adjacent to the outer gas path wall 74, hereinafter also referred to as the outer wall 74. As a result of the presence of the buttress 86 and the additional buttress 88 cross-sections of the strut 80 at different planes along the direction 79 will be different in area. FIG 8 schematically illustrates cross-sections of the strut 80 along the direction 79 at different planes depicted by reference numerals 2, 3 and 4 in the strut 80. As can be seen from FIG 8, the cross-section of the strut 80 along the plane 2 i.e. the plane passing through the additional buttress 88 and the cross-section of the strut 80 along the plane 4 i.e. the plane passing through the buttress 86 are greater than the cross-section of the strut 80 along the plane 3 i.e. the plane passing neither through the additional buttress 88 nor the buttress 86.

[0044] The present invention is an improved design for the strut 80 that has been described hereinabove with reference to FIGs 1 to 8. According to the present technique, the strut 80 includes a cut-out 90, as depicted in FIG 9. The strut 80 may additionally include an additional cut-out 94, as depicted in FIG 9. The cut-out 90 and the additional cut-out 94 have been explained in further details hereinafter with reference to FIGs 9 to 14.

[0045] According to the present technique, the section 1 of FIGs 2 to 8 includes the cut-out 90. The cut-out 90

positioned at the trailing edge 84 and is contiguous with or adjacent to the inner gas path wall 72 or the outer gas path wall 74, and in case where the strut 80 includes the buttress 86 and/or the additional buttress 88 as parts of the trailing edge 84 of the strut 80, the cut-out 90 is present in the buttress 86 and the additional cut-out 94 is present in the additional buttress 88, as shown in FIG 9.

[0046] It may be noted that it is well within the scope of the present technique that the cut-out 90 is at the TE 84, with or without the buttress 86, adjacent to either the inner wall 72 or the outer wall 74. Additionally, it is well within the scope of the present technique that when the cut-out 90 is at the TE 84, with or without the buttress 86, adjacent to the inner wall 72 then the additional cut-out 94 is at the TE 84, with or without the additional buttress 88, adjacent to the outer wall 74. Similarly, when the cut-out 90 is at the TE 84, with or without the buttress 86, adjacent to the outer wall 74 then the additional cut-out 94 is at the TE 84, with or without the additional buttress 88, adjacent to the inner wall 72. The cut-out 90, and the additional cut-out 94 when present, are at the TE 84 when no buttresses are present and are at the TE 84 within the buttress when the buttresses i.e. the buttress 86 and/or the additional buttress 88 are present as part of the TE 84.

[0047] As shown in FIG 10, an opening 92 of the cut-out 90 at the inner gas path wall 72 may be between 50 degrees and 80 degrees and preferably 70 degrees. Similarly, an opening 96 of the additional cut-out 94 at the inner gas path wall 72, when the cut-out 90 is at the outer wall 74, may be between 50 degrees and 80 degrees and preferably 70 degrees.

As shown in FIG 11, a height 91 of the cut-out 90 from the inner gas path wall 72 is between 20 percent and 50 percent of a height 87 of the buttress 86 from the inner gas path wall 72. The height 91 may be understood as the vertical drop onto the adjacent gas path wall, chosen from the inner wall 72 and the outer wall 74, from a tip of the TE 84 created as a result of the cut-out 90. The height 87 of the buttress 86 may be understood as the vertical drop onto the adjacent gas path wall, chosen from the inner wall 72 and the outer wall 74, from a point where the TE 84 shows the steepest angle i.e. a point where the buttress part of the TE 84 joins rest of the TE 84 or the vertical part of the TE 84. In another embodiment (not shown) the height 91 of the cut-out 90 from the outer gas path wall 74 is between 20 percent and 50 percent of the height 87 of the buttress 86 from the outer gas path wall 74. In an additional embodiment (FIG 11) of the section 1 a height 95 of the additional cut-out 94 from the inner gas path wall 72 is between 20 percent and 50 percent of a height 89 of the additional buttress 88 from the inner gas path wall 72. Similarly, in yet another additional embodiment (not shown) of the section 1 the height 95 of the additional cut-out 94 from the outer gas path wall 74 is between 20 percent and 50 percent of the height 89 of the additional buttress 88 from the outer gas path wall 74.

[0048] Referring to FIG 11 in combination with FIG 9, the height 91 of the cut-out 90 from the inner gas path wall 72 is between 5 percent and 15 percent of a distance 78, as shown in FIG 9, between the inner wall 72 and the outer wall 74. The distance 78 is measured radially relative to the axis 75. In another embodiment (not shown) the height 91 of the cut-out 90 from the outer gas path wall 74 is between 5 percent and 15 percent of the distance 78. In an additional embodiment as shown in FIG 11 of the section 1 the height 95 of the additional cut-out 94 from the inner gas path wall 72 is between 5 percent and 15 percent of the distance 78. Similarly, in yet another additional embodiment (not shown) of the section 1 the height 95 of the additional cut-out 94 from the outer gas path wall 74 is between 5 percent and 15 percent of the distance 78.

[0049] It may be noted that as depicted in FIG 5 the strut 80 may have a cross-section having a symmetrical aerofoil shape or as depicted in FIG 6 the strut 80 may have a cross-section having a cambered aerofoil shape.

[0050] According to the second aspect of the present technique, the section 1 is part of the engine 10 shown in FIG 1.

[0051] According to the third aspect of the present technique, a method for designing the section 1 is presented. The section 1 includes the inner wall 72, outer wall 74 and one or more struts 80 as described hereinabove with reference to FIGs 1 to 11. In the method, a stress analysis for the strut 80 is performed. The stress analysis is performed under conditions representative of various operational stages, for example idle stage, take-off stage, climb stage, cruise stage, etc. and fault modes of the gas turbine engine 10 for example when a blade failure occurs. The stress analysis is performed manually or in a software generated model representative of the section 1 along with at least one strut 80. Such stress analysis is commonly known and pervasively used in testing and designing of engines 10 and their respective parts such as the section 1 and thus has not been described herein in details for sake of brevity.

[0052] From the stress analysis so performed, several regions with varying stress distribution or load distribution are obtained. From there regions, at least one region of high stress concentration is determined within the strut 80. From different regions showing high stress concentrations, the region which is positioned at the trailing edge 84 of the strut 80 and adjacent to the inner wall 72 or the outer wall 74 is determined or selected. FIG 12 schematically represents a model of a section of the strut 80 depicting several regions namely 101, 102, 103, 104, 105 and 106 as examples. The region 101 has been shown to have high or highest stress concentrations and is located at the TE 84 and adjoining to or contiguous with the inner wall 72 and thus the region 101 is selected or determined.

[0053] In the method, thereafter, the cut-out 90 is placed by positioning the cut-out 90 at the trailing edge 84 and contiguous with the inner wall 72 such that the

effect is of removal of at least a part of a material of the strut 80 in the region 101. The cut-out 90 is same as the cut-out 90 explained hereinabove with reference to FIGs 1 to 11. FIG 13 shows the model of FIG 12 in which the cut-out 90 has been positioned and thus at least a part of the region 101 is removed. Similarly, FIG 14 shows the model of FIG 13 in which the cut-out 90 with a bigger size has been positioned and thus the region 101 is removed entirely.

[0054] In another embodiment of the method for designing the section 1, the method includes determining an additional region (not shown) of high stress concentration within strut 80 positioned at the trailing edge 84 of the strut 80 and adjacent to the inner wall 72 or the outer wall 74. The region 101 and the additional region are adjacent to different gas path walls selected from the inner wall 72 and the outer wall 74. Furthermore in the method, an additional cut-out 94 is placed in the strut 80 such that the additional cut-out 94 is positioned at the trailing edge 84 and contiguous with the inner wall 72 or the outer wall 74. The placing of the additional cut-out 94 is such that the effect is removal of at least a part of a material of the strut 80 from the additional region. The additional cut-out 94 is same as the additional cut-out 94 explained hereinabove with reference to FIGs 1 to 11.

[0055] According to a fourth aspect of the present technique, a method for manufacturing the gas turbine section 1 is presented. In the method the section 1 is designed according to the third aspect of the present technique described hereinabove. Thereafter, one or more parts of the gas turbine section 1 such as segments of the outer casing having the outer wall 74, segment of the inner casing having the inner wall 72, the one or more struts 80 besides the cut-out 90, are casted and finally the cut-out 90 is formed either by casting along with the casting of the one or more parts of the gas turbine section 1 or by machining subsequent to the casting of the one or more parts of the gas turbine section 1.

[0056] In an embodiment of the method according to the fourth aspect of the present technique, the method further includes forming an additional cut-out 94 by casting along with the casting of the one or more parts of the gas turbine section 1 or by machining subsequent to the casting of the one or more parts of the gas turbine section 1.

[0057] The cut-out 90, and the additional cut-out 94, as used in the present disclosure may be understood as piece cut out from the strut 80 or a burrow or hole in the strut 80 or a cave in the strut 80 or a missing portion of the strut 80 which would have been present in a conventionally shaped strut 80 if no cut-out 90 or the additional cut-out 94 were present in the strut 80.

[0058] While the present technique has been described in detail with reference to certain embodiments, it should be appreciated that the present technique is not limited to those precise embodiments. Rather, in view of the present disclosure which describes exemplary

modes for practicing the invention, many modifications and variations would present themselves, to those skilled in the art without departing from the scope and spirit of this invention. The scope of the invention is, therefore, indicated by the following claims rather than by the foregoing description. All changes, modifications, and variations coming within the meaning and range of equivalency of the claims are to be considered within their scope.

10 List of Reference Characters

[0059]

1	gas turbine section
2	plane adjacent to the outer gas path wall
3	plane in-between the outer and the inner gas path walls
4	plane adjacent to the inner gas path wall
10	gas turbine engine
12	inlet
14	compressor section
16	combustor section or burner section
17	transition duct
18	turbine section
19	combustor cans
20	longitudinal or rotational axis
22	shaft
24	air
26	burner plenum
28	combustion chamber
30	burner
32	diffuser
34	combustion gas or working gas
36	blade carrying discs
38	turbine blades
40	guiding vanes
42	stator
44	inlet guiding vanes
46	vane stages
48	rotor blade stages
50	casing
52	radially outer surface
53	rotor drum
54	radially inner surface
56	passage
70	direction of gas flow
71	part of annular gas flow path
72	inner gas path wall
74	outer gas path wall
75	axis
76	part of the annular gas path
78	distance between the inner and the outer gas path walls
79	radial direction
80	strut
82	leading edge
84	trailing edge
86	buttress

87 height of the buttress
 88 additional buttress
 89 height of the additional buttress
 90 cut-out
 91 height of the cut-out
 92 opening of the cut-out
 94 additional cut-out
 95 height of the additional cut-out
 96 opening of the additional cut-out
 101 first region
 102 second region
 103 third region
 104 fourth region
 105 fifth region
 106 sixth region

Claims

1. A gas turbine section (1) for an annular gas path defined through a gas turbine engine (10), the gas turbine section (1) comprising:

- an inner gas path wall (72) and an outer gas path wall (74), wherein the inner gas path wall (72) and the outer gas path wall (74) are concentrically arranged about an axis (75) and adapted to form at least a part (76) of the annular gas path,
 - at least one strut (80) extending generally radially relative to the axis (75) from the inner gas path wall (72) to the outer gas path wall (74), and wherein the strut (80) comprises:

- a leading edge (82) and a trailing edge (84), wherein the leading edge (82) is adapted to be positioned upstream relative to the annular gas path and the trailing edge (84) is adapted to be positioned downstream relative to the annular gas path and wherein the strut (80) comprises a cut-out (90) positioned at the trailing edge (84) and contiguous with the inner gas path wall (72) or the outer gas path wall (74) .

2. The gas turbine section (1) according to claim 1, wherein a height (91) of the cut-out (90) from the inner gas path wall (72) or the outer gas path wall (74) with which the cut-out (90) is contiguous is between 5 percent and 15 percent of a distance (78) between the inner gas path wall (72) and the outer gas path wall (74) measured radially relative to the axis (75).

3. The gas turbine section (1) according to claim 1 or 2, wherein the strut (80) comprises a buttress (86) and the cut-out (90) is positioned within the buttress (86).

4. The gas turbine section (1) according to claim 3, wherein a height (91) of the cut-out (90) from the inner gas path wall (72) or the outer gas path wall (74) with which the cut-out (90) is contiguous is between 20 percent and 50 percent of a height (87) of the buttress (86) from the inner gas path wall (72) or the outer gas path wall (74) with which the buttress (86) is contiguous.

5. The gas turbine section (1) according to any of claims 1 or 4, wherein the cut-out (90) has an opening (92) with an angle between 50 degree and 80 degree.

6. The gas turbine section (1) according to any of claims 1 to 5, wherein the strut (80) comprises an additional cut-out (94) and wherein the cut-out (90) is positioned at the trailing edge (84) and is contiguous with the inner gas path wall (72) and the additional cut-out (94) is positioned at the trailing edge (84) and is contiguous with the outer gas path wall (74).

7. The gas turbine section (1) according to any of claims 1 to 5, wherein the strut (80) comprises an additional cut-out (94) and wherein the cut-out (90) is positioned at the trailing edge (84) and is contiguous with the outer gas path wall (74) and the additional cut-out (94) is positioned at the trailing edge (84) and is contiguous with the inner gas path wall (72).

8. The gas turbine section (1) according to claim 6 or 7, wherein a height (95) of the additional cut-out (94) from the inner gas path wall (72) or the outer gas path wall (74) with which the additional cut-out (94) is contiguous is between 5 percent and 15 percent of a distance (78) between the inner gas path wall (72) and the outer gas path wall (74) measured radially relative to the axis (75).

9. The gas turbine section (1) according to any of claims 6 to 8, wherein the strut (80) comprises an additional buttress (88) and the additional cut-out (94) is positioned within the additional buttress (88).

10. The gas turbine section (1) according to claim 9, wherein a height (95) of the additional cut-out (94) from the inner gas path wall (72) or the outer gas path wall (74) with which the additional cut-out (94) is contiguous is between 20 percent and 50 percent of a height (89) of the additional buttress (88) from the inner gas path wall (72) or the outer gas path wall (74) with which the additional buttress (88) is contiguous.

11. The gas turbine section (1) according to any of claims 6 to 10, wherein the additional cut-out (94) has an opening (96) with an angle between 50 degree and 80 degree.

12. The gas turbine section (1) according to any of claims 1 to 11, wherein the strut (80) has a cross-section having a symmetrical aerofoil shape or a cross-section having a cambered aerofoil shape.

13. A method for designing a gas turbine section (1) for an annular gas path defined through a gas turbine engine (10), the gas turbine section (1) comprising an inner gas path wall (72) and an outer gas path wall (74), wherein the inner gas path wall (72) and the outer gas path wall (74) are concentrically arranged about an axis (75) and adapted to form at least a part (76) of the annular gas path, and at least one strut (80) extending generally radially relative to the axis (75) from the inner gas path wall (72) to the outer gas path wall (74), and wherein the strut (80) comprises a leading edge (82) and a trailing edge (84), wherein the leading edge (82) is adapted to be positioned upstream relative to the annular gas path and the trailing edge (84) is adapted to be positioned downstream relative to the annular gas path, the method comprising:

- performing a stress analysis for the strut (80), wherein the stress analysis is performed under conditions representative of various operational stages and fault modes of the gas turbine engine (10),

- determining a region (101) of high stress concentration within strut (80) from the stress analysis so performed, wherein the region (101) is positioned at the trailing edge (84) of the strut (80) and is adjacent to the inner gas path wall (72) or the outer gas path wall (74); and

- placing a cut-out (90) positioned at the trailing edge (84) and contiguous with the inner gas path wall (72) or the outer gas path wall (74) such that at least a part of a material of the strut (80) in the region (101) of high stress concentration so determined is removed.

14. The method according to claim 13, further comprising:

- determining an additional region of high stress concentration within strut (80) positioned at the trailing edge (84) of the strut (80) and adjacent to the inner gas path wall (72) or the outer gas path wall (74) and wherein the region (101) and the additional region are adjacent to different gas path walls (72, 74) selected from the inner gas path wall (72) and the outer gas path wall (74); and

- placing an additional cut-out (94) positioned at the trailing edge (84) and contiguous with the inner gas path wall (72) or the outer gas path wall (74) such that at least a part of a material of the strut (80) in the additional region of high

stress concentration so determined is removed.

15. A method for manufacturing a gas turbine section (1) for an annular gas path defined through a gas turbine engine (10), the method comprising:

- designing the gas turbine section (1) according to any of claims 13 to 13;

- casting one or more parts of the gas turbine section (1), besides the cut-out (90); and

- forming the cut-out (90) by casting along with the casting of the one or more parts of the gas turbine section (1) or by machining subsequent to the casting of the one or more parts of the gas turbine section (1).

16. The method according to claim 15, further comprising forming an additional cut-out (94) by casting along with the casting of the one or more parts of the gas turbine section (1) or by machining subsequent to the casting of the one or more parts of the gas turbine section (1).

FIG 1

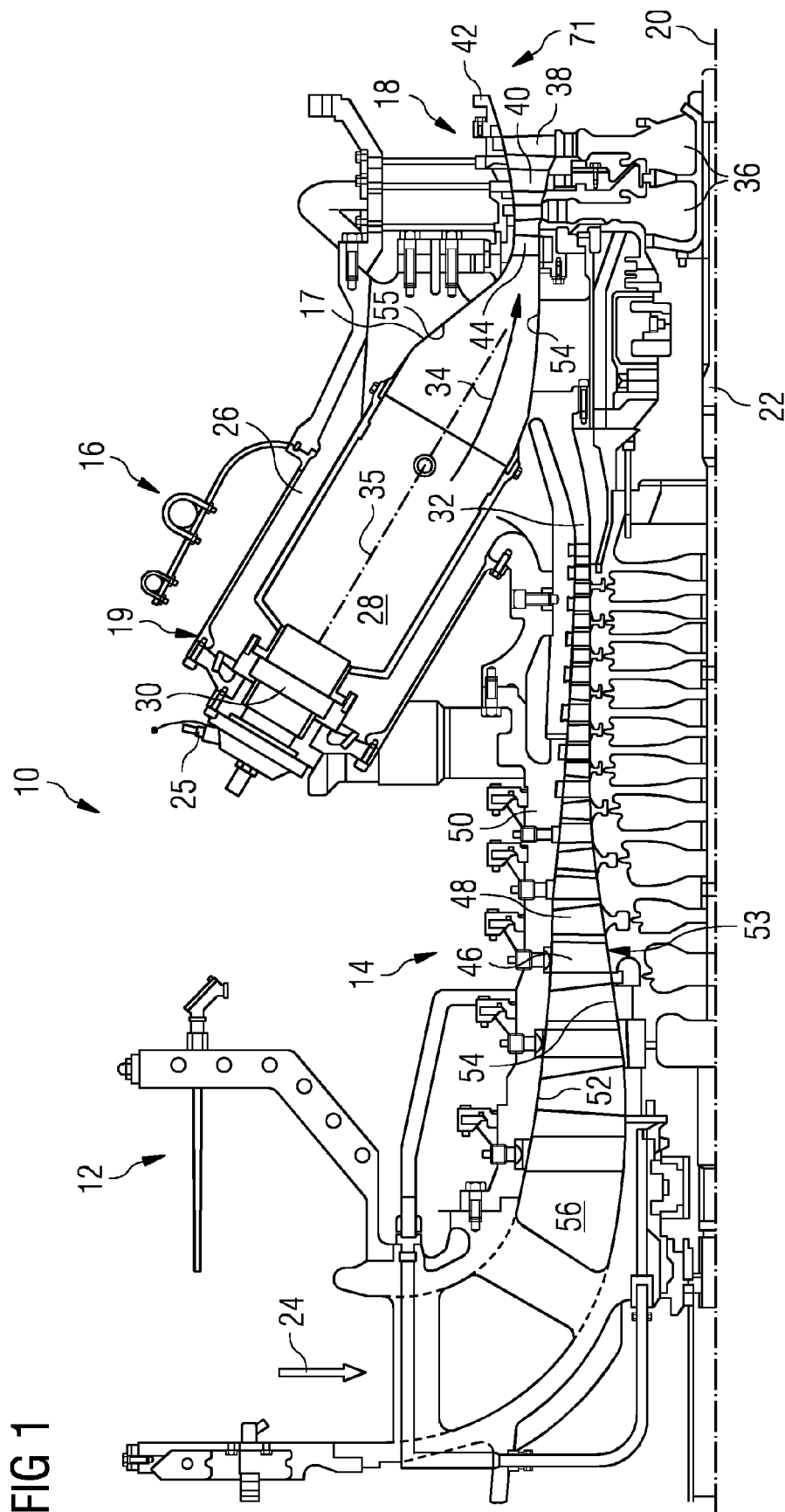


FIG 2

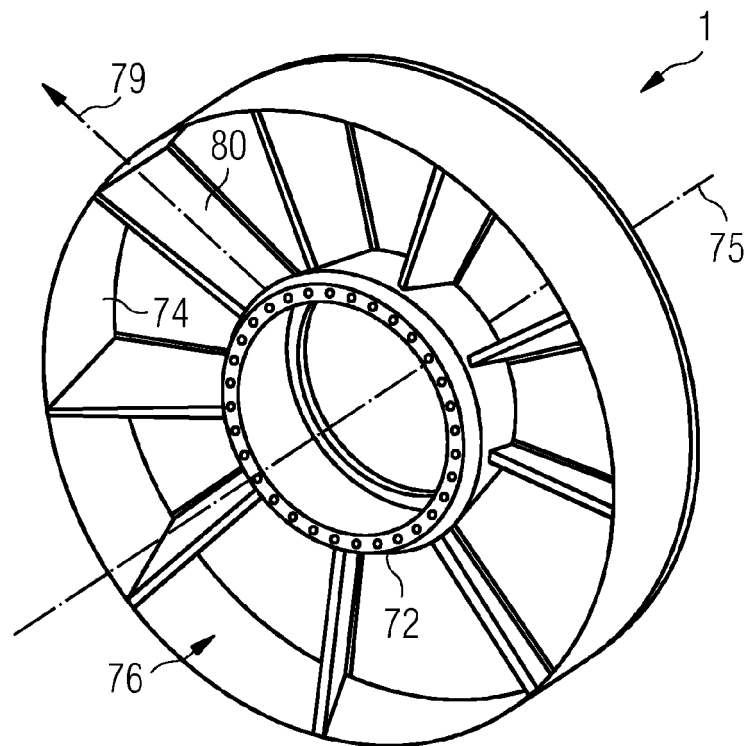


FIG 3

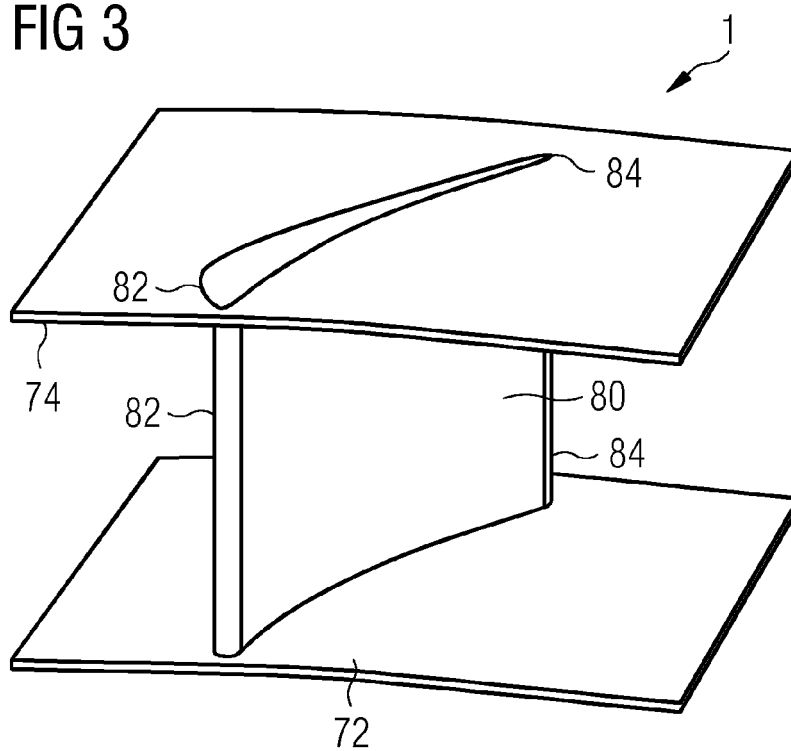


FIG 4

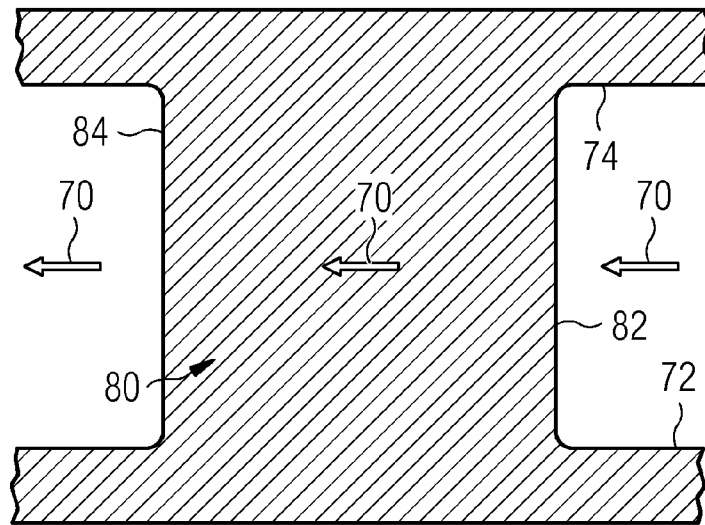


FIG 5

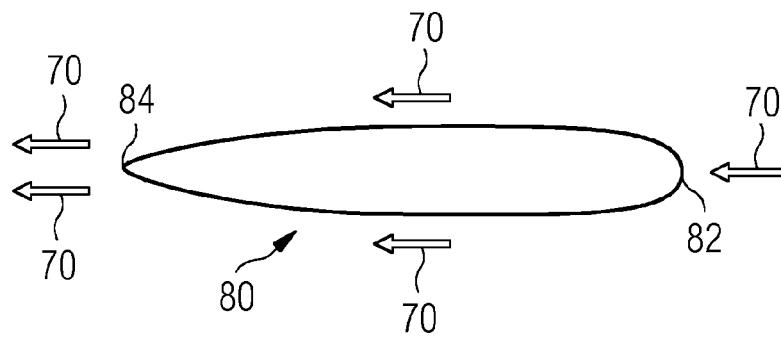


FIG 6

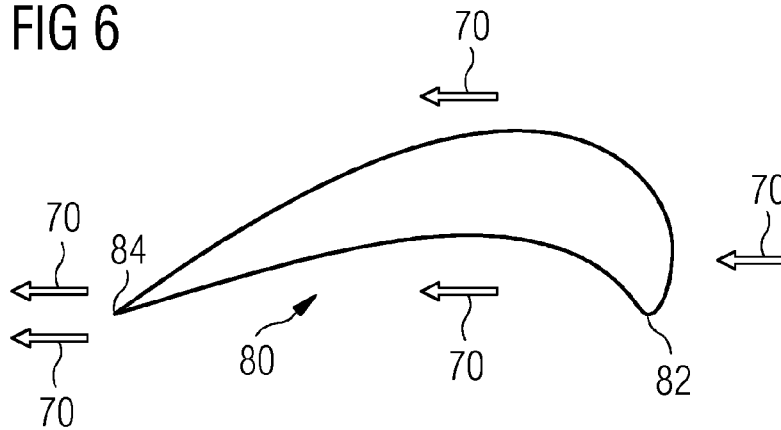


FIG 7

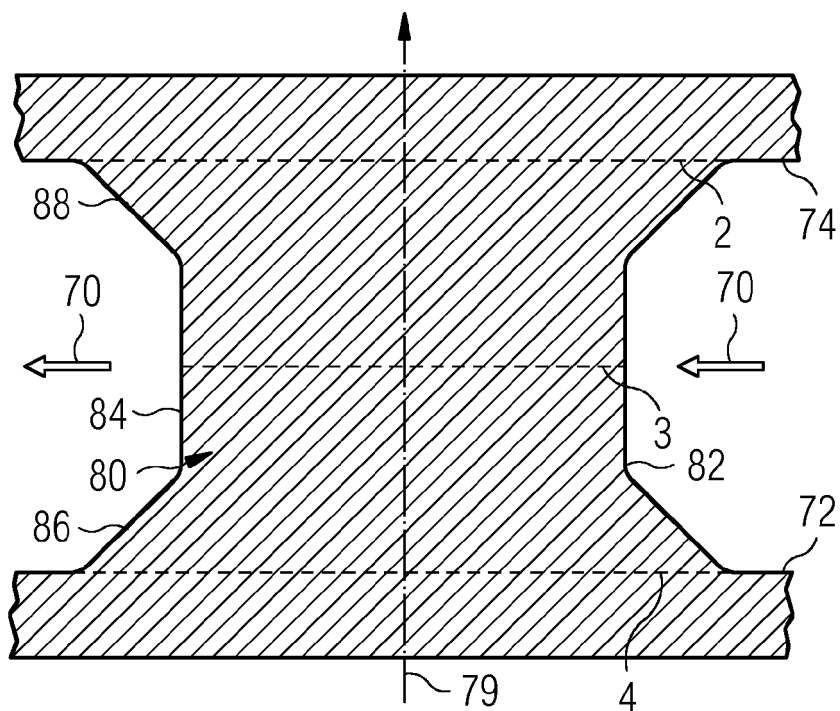


FIG 8

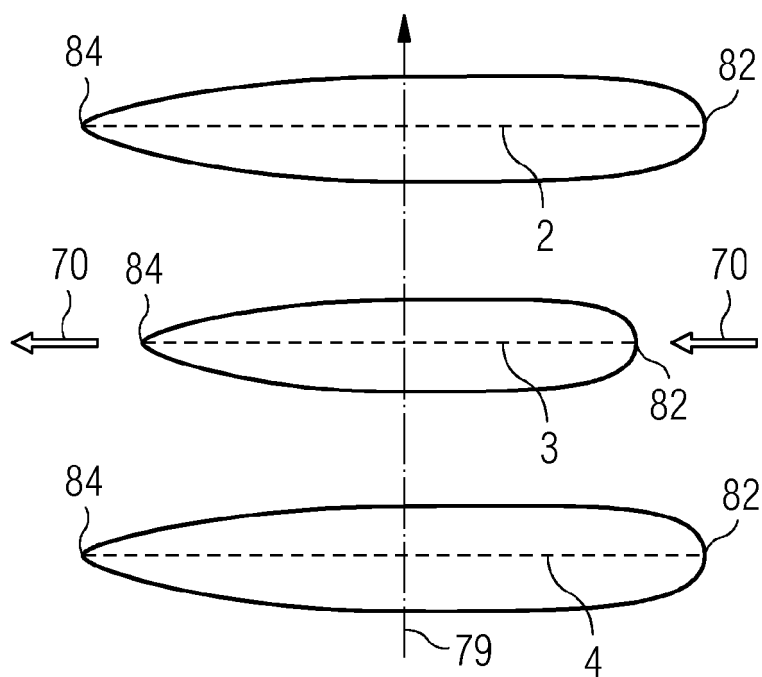


FIG 9

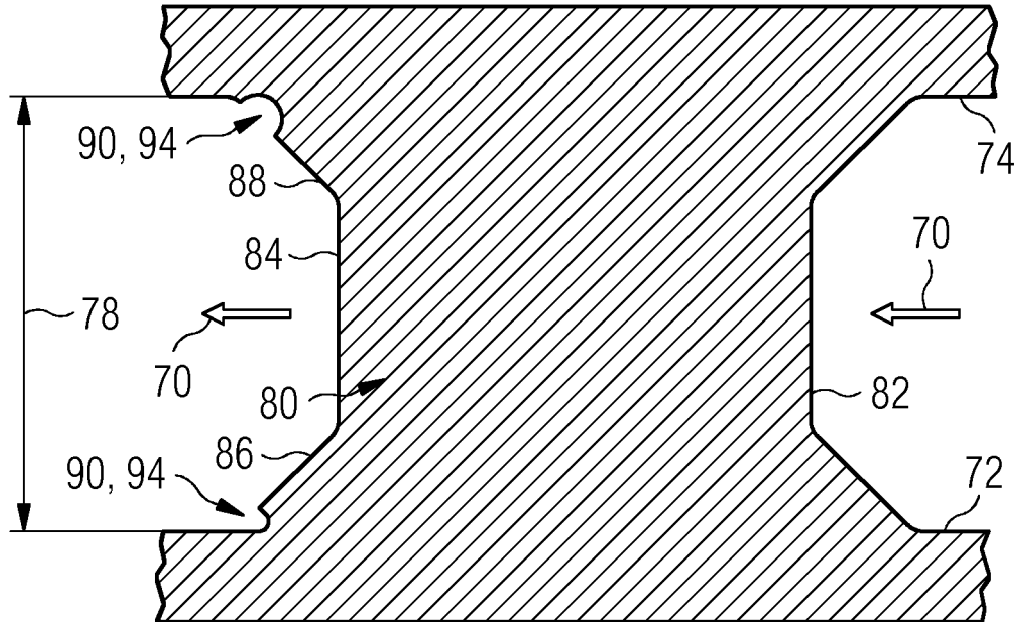


FIG 10

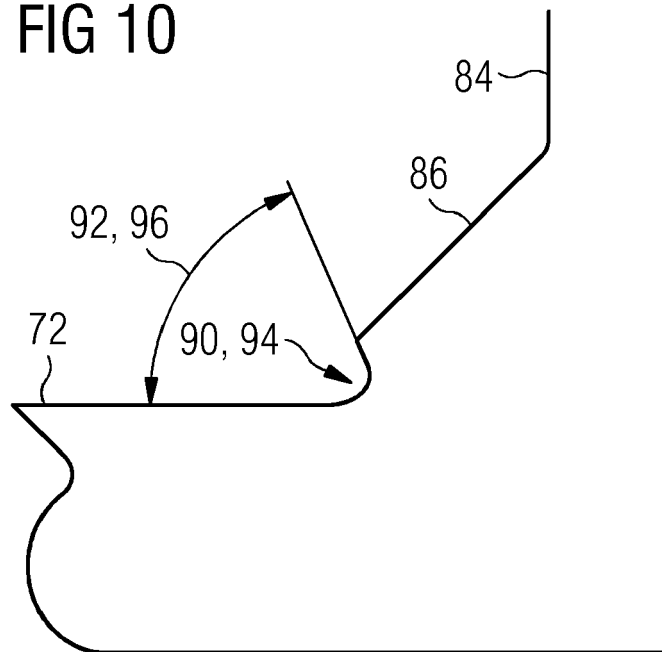


FIG 11

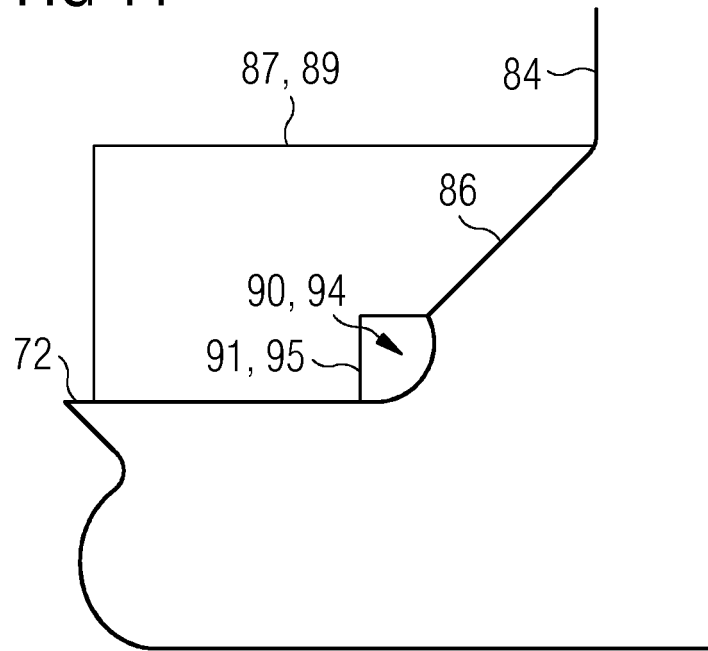


FIG 12

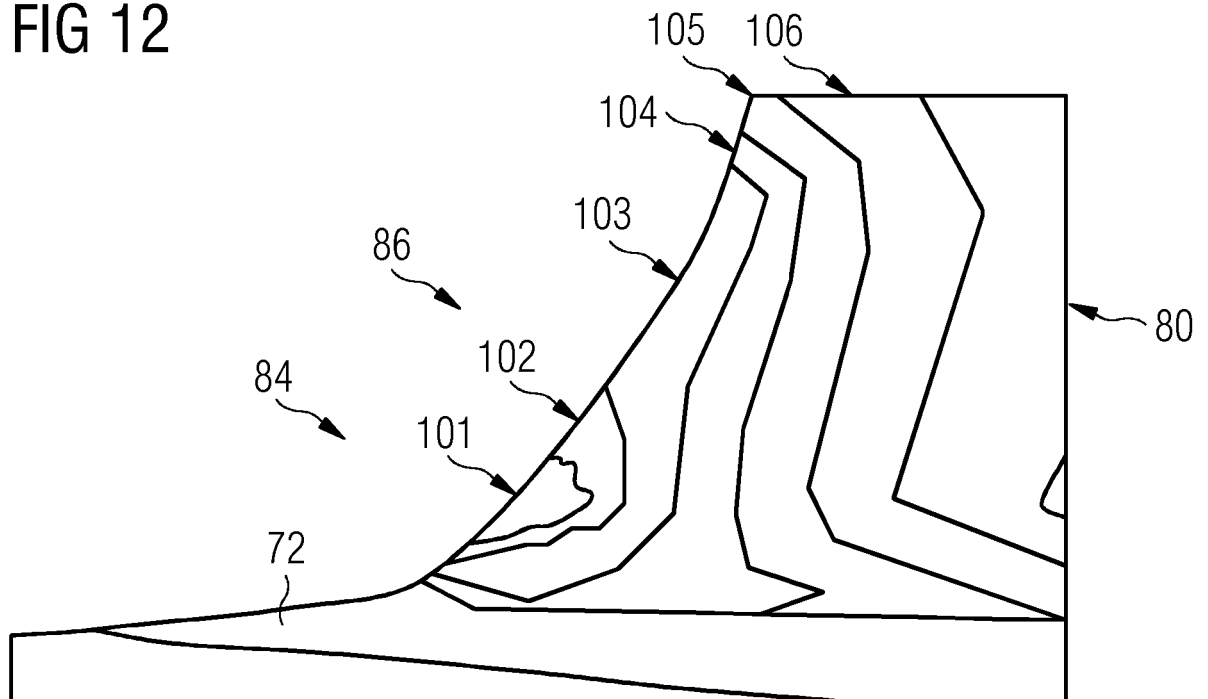


FIG 13

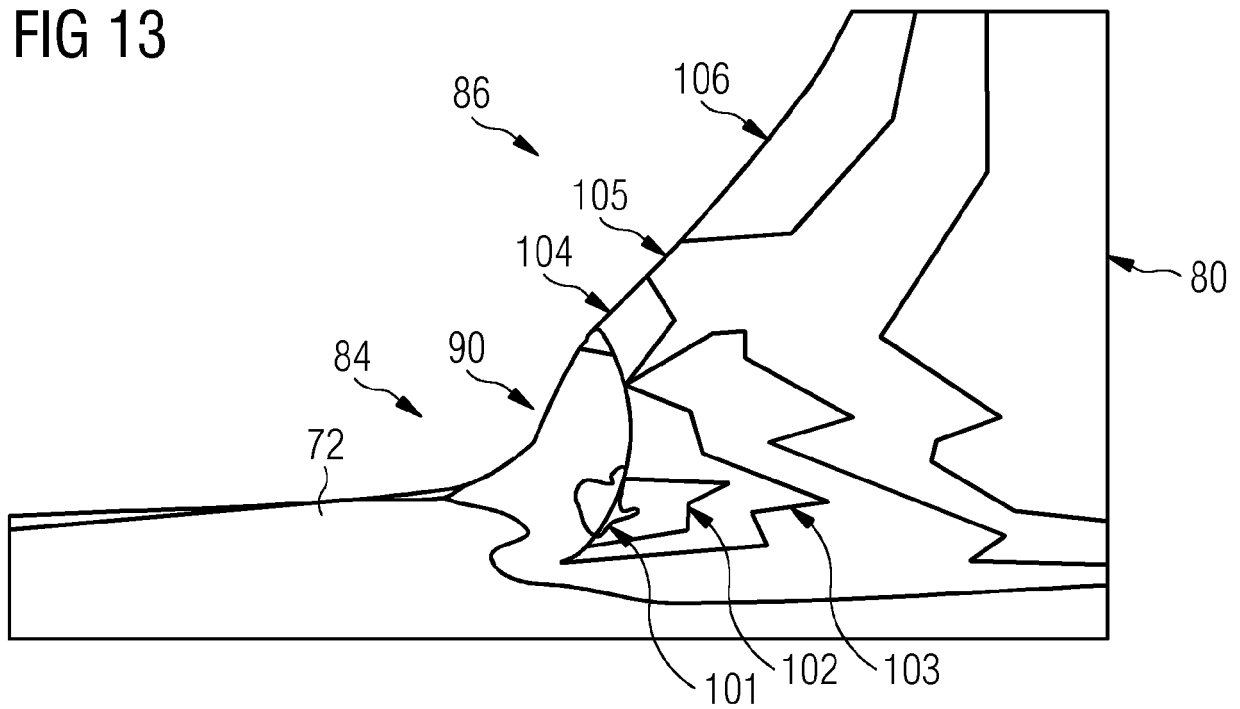
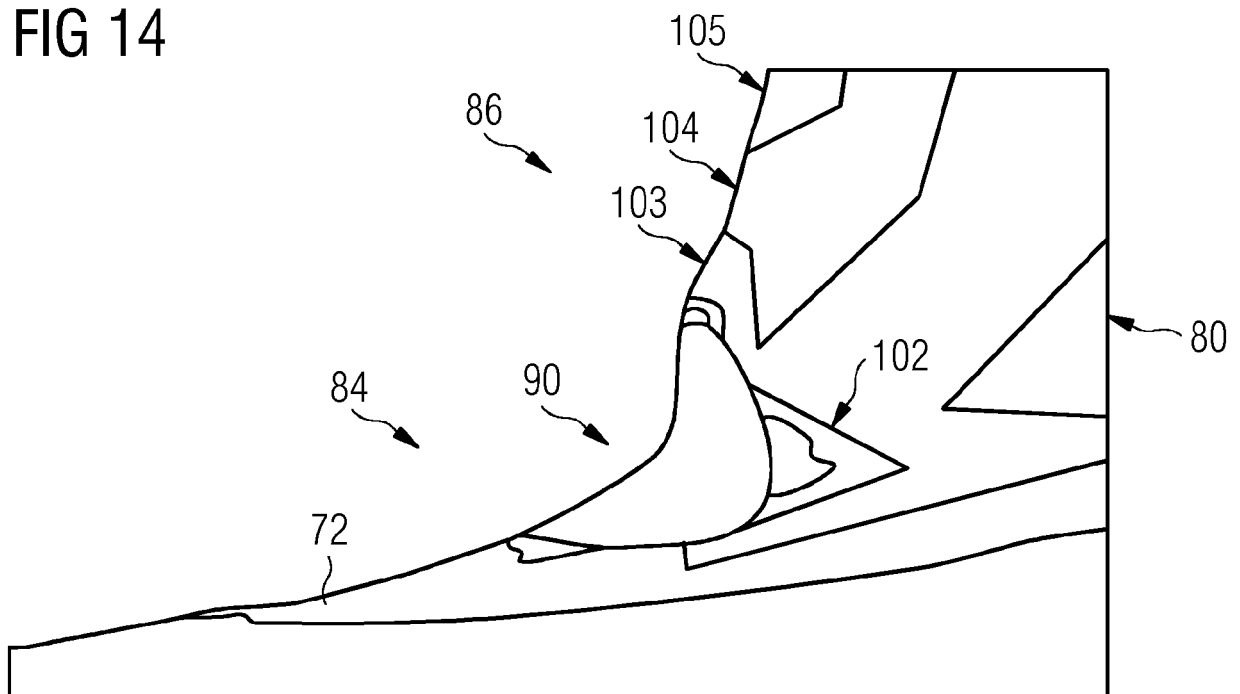


FIG 14





EUROPEAN SEARCH REPORT

 Application Number
 EP 16 16 8422

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			F01D
Place of search		Date of completion of the search	Examiner
Munich		5 October 2016	Delaitre, Maxime
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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