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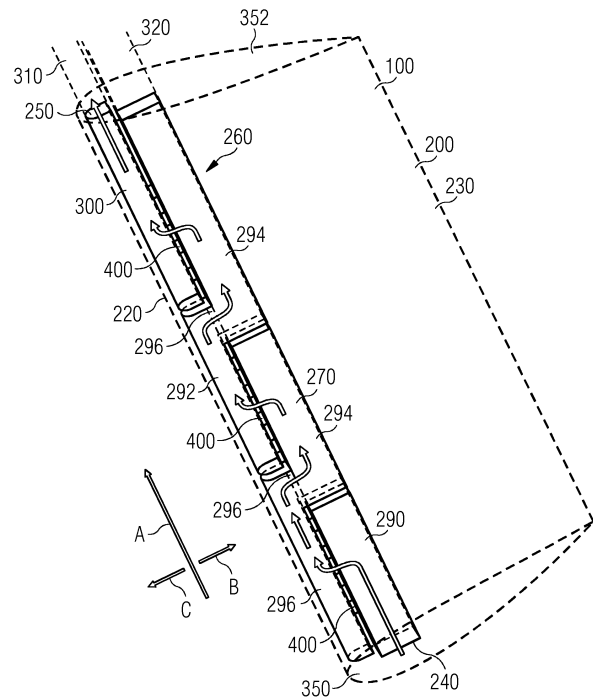
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(54) **TURBINE AEROFOIL**

(57) A turbine aerofoil (100) for a turbo machine. The aerofoil (100) comprises a main body portion (200) defined by a leading edge (220) and a trailing edge (230). The main body portion (200) has a flow inlet (240) and flow outlet (250). A leading edge cooling chamber (260) is defined within the leading edge (220) of the main body portion (200). The leading edge cooling chamber (260) extends between the flow inlet (240) and the flow outlet (250). The leading edge cooling chamber (260) comprises a first sub chamber (280) and a second sub chamber (300), the first sub chamber (280) being in flow series between the flow inlet (240) and the second sub chamber (300). The second sub chamber (300) is in flow series between first sub chamber (280) and the flow outlet (250). The first sub chamber (280) is divided into a first section (292) and second section (294) in fluid communication via an intermediate section (296). The first section (292) of the first sub chamber (280) and the second sub chamber (300) extend in a first column (310) along at least part of the leading edge (220). The second section (294) extends in a second column (320) provided between the first column (310) and the trailing edge (230). The first sub chamber (280) is in flow communication with the second sub chamber (300) via a flow passage (400) which extends between the second section (294) of the first sub chamber (280) and the second sub chamber (300).

FIG 9



Description

[0001] The present disclosure relates to a turbine aerofoil.

[0002] In particular the disclosure is concerned with a turbine aerofoil for a turbo machine.

Background

[0003] Gas turbines generally include a rotor with a number of rows of rotating rotor blades which are fixed to a rotor shaft and rows of stationary vanes between the rows of rotor blades which are fixed to the casing of the gas turbine. When a hot and pressurized working fluid flows through the rows of vanes and blades it transfers momentum to the rotor blades and thus imparts a rotary motion to the rotor while expanding and cooling. The vanes are used to control the flow of the working medium so as to optimize momentum transfer to the rotor blades.

[0004] A typical gas turbine rotor blade and/or stator vane comprise an aerodynamically formed aerofoil portion which allows a transfer of momentum when the hot and pressurized working fluid flows along the aerofoil section.

[0005] Rotor blades and stator vanes tend to be hollow, for example comprising a plenum through which cooling air is forced.

[0006] Impingement cooling may be employed. To achieve this, a pair of cooling chambers 1, 2 may be provided towards the leading edge 4 of an aerofoil, each chamber 1, 2 extending the full height of the aerofoil, for example as shown in Figure 1. Cooling air supplied to the rear most chamber 2 is directed through small passages 3 into the forward most chamber 1 to impinge on the internal surface of the leading edge 4 of the aerofoil. However a demerit of this arrangement is that cooling air entering from one end of the rear most chamber 2 progressively becomes warmer as it passes along the aerofoil, and hence the cooling effect when it impinges on the leading edge is diminished as distance from the flow inlet increases. Hence such an arrangement may not provide a suitable level of cooling at all engine conditions, and hence may limit the maximum working temperature of the engine.

[0007] Hence a cooling arrangement for a component which provides a greater degree of cooling is highly desirable.

Summary

[0008] According to the present disclosure there is provided an apparatus as set forth in the appended claims. Other features of the invention will be apparent from the dependent claims, and the description which follows.

[0009] Accordingly there may be provided a turbine aerofoil (100) for a turbo machine. The aerofoil (100) may comprise a main body portion (200) defined by a leading edge (220) and a trailing edge (230). The main body por-

tion (200) may have a flow inlet (240) and flow outlet (250). A leading edge cooling chamber (260) may be defined within the leading edge (220) of the main body portion (200). The leading edge cooling chamber (260) may extend between the flow inlet (240) and the flow outlet (250). The leading edge cooling chamber (260) may comprise a first sub chamber (280) and a second sub chamber (300), the first sub chamber (280) being in flow series between the flow inlet (240) and the second sub chamber (300). The second sub chamber (300) may be in flow series between first sub chamber (280) and the flow outlet (250). The first sub chamber (280) may be divided into a first section (292) and second section (294) in fluid communication via an intermediate section (296). The first section (292) of the first sub chamber (280) and the second sub chamber (300) may extend in a first column (310) along at least part of the leading edge (220). The second section (294) may extend in a second column (320) provided between the first column (310) and the trailing edge (230). The first sub chamber (280) may be in flow communication with the second sub chamber (300) via a flow passage (400) which extends between the second section (294) of the first sub chamber (280) and the second sub chamber (300).

[0010] The cooling arrangement of the present disclosure thus provides efficient leading edge impingement cooling of a blade or vane compared to known impingement configurations because the same air may be used to cool the leading edge in a first section 292 of the sub chamber and then passed through flow passages (i.e. impingement holes) configured to generate impingement flow jets which cool the leading edge surface of an adjacent sub chamber.

[0011] The leading edge cooling chamber (260) may further comprise a fourth sub chamber (290) in flow series between the flow inlet (240) and the first sub chamber (280), the fourth sub chamber (290) extending in the second column (320). The fourth sub chamber (290) may be in flow communication with the first sub chamber (280) via a further flow passage (400) which extends between the fourth sub chamber (290) and the first section (292) of the first sub chamber (280). This is advantageous as further efficient leading edge cooling using impingement flow is provided.

[0012] The aerofoil may further comprise a third sub chamber (270) in flow series between the flow inlet (240) and the first sub chamber (280), the third sub chamber (270) divided into a first section (292) and a second section (294) in fluid communication via an intermediate section (296). The first section (292) may extend in the first column (310). The second section (294) may extend in the second column (320). The third sub chamber (270) may be in flow communication with the first sub chamber (280) via a further flow passage (400) which extends between the second section (294) of the third sub chamber (270) and the first section (292) of the first sub chamber (280). This is advantageous as further efficient leading edge cooling using impingement flow is provided.

[0013] The leading edge cooling chamber (260) may further comprise a fourth sub chamber (290) in flow series between the flow inlet (250) and the third sub chamber (270), the fourth sub chamber (290) extending in the second column (320); the fourth sub chamber (290) being in flow communication with the third sub chamber (270) via a further flow passage (400) which extends between the fourth sub chamber (290) and the first section (292) of the third sub chamber (270). This is advantageous as further efficient leading edge cooling using impingement flow is provided.

[0014] The first section (292) and second section (294) may define a first flow direction (A) along the leading edge (220); and the intermediate section (296) may define a second flow direction (B) away from the leading edge (220) towards the trailing edge (230). This arrangement is advantageous as it provides a means for the re-use of impingement air between sub chambers.

[0015] The flow passage (400) may define a flow path in a third direction (C) in a direction away from the trailing edge (230) towards the leading edge (220). This is advantageous as it results in the delivery of impingement air.

[0016] There may be provided a plurality of said flow passages (400) between the sub chambers. This is advantageous as it results in the delivery of impingement air to multiple locations.

[0017] At least some of the plurality of flow passages (400) may define flow paths in the third direction (C) away from the trailing edge (230) towards the leading edge (220) and at an angle to the second flow direction (B) to direct flow towards the wall of the first section (292) which faces the intermediate section (296), and at least some of the remaining flow passages (400) may define flow paths in the third direction (C) parallel to the second direction (B). This is advantageous as it results in the delivery of impingement air to multiple targeted locations to maximise effective cooling.

[0018] The main body portion (200) may extend from a base portion (350) spaced apart from a tip portion (352) by the main body portion (200), the flow outlet (250) being provided in the tip portion (352). This provides an advantageous means of ejecting the used cooling air.

[0019] The flow outlet (250) may be provided proximate to the leading edge (220) in line with the first column (310). This provides an advantageous means of ejecting the used cooling air.

[0020] The tip portion (352) may comprise a tip wall (354) which extends from the aerofoil leading edge (220) to the aerofoil trailing edge (230); the tip wall (352) defining the flow outlet (250) towards the trailing edge (230). This provides an advantageous means of ejecting the used cooling air.

[0021] A tip wall passage (356) may extend from the leading edge (220) to the trailing edge (230), the flow outlet (250) being provided as an opening in the tip wall passage (356) towards the trailing edge (230). This provides an advantageous means of ejecting the used cool-

ing air.

[0022] The turbine aerofoil (100) may be one of a rotor blade or stator vane.

[0023] Hence there is provided a component, for example an aerofoil, for a turbo machine, for example a gas turbine engine. The aerofoil may be configured to have a cooling chamber in its leading edge which is divided into impingement sub-chambers arranged in series, the overall effect of which is to substantially increase the amount of cooling whilst using less mass flow of cooling air.

[0024] The cooling arrangement of the present disclosure may be used in an aerofoil component without film cooling, for example a high pressure stage of a gas turbine.

Brief Description of the Drawings

[0025] Examples of the present disclosure will now be described with reference to the accompanying drawings, in which:

Figure 1 shows an example configuration of a leading edge cooling chamber of the related art;

Figure 2 shows a schematic representation of an example of a turbo machine;

Figure 3 shows an enlarged region of a section of a turbine of the turbo machine shown in Figure 1;

Figure 4 shows an end view of the rotor blades shown in Figures 1, 2;

Figures 5, 6 show examples of rotor blades having leading edge cooling chambers according to the present disclosure;

Figures 7, 8, 9 shows different views of an example of a leading edge cooling chamber according to the present disclosure;

Figure 10 shows an enlarged view of a region of an alternative example a leading edge cooling chamber arrangement according to the present disclosure;

Figures 11, 12 and 13 show different views of the leading edge cooling chamber including a tip region fluid outlet; and

Figure 14 shows an example of an alternative arrangement to that shown in figures 11, 12 and 13, including a trailing edge fluid outlet.

Detailed Description

[0026] The present disclosure relates to a turbine aerofoil for a turbo machine. The turbo machine may be a

gas turbine engine, and the component may be a rotor blade or stator vane.

[0027] By way of context, Figure 2 shows an example of a gas turbine engine 60 in a sectional view, which illustrates the nature of components according to the present disclosure (for example rotor blades and stator vanes) and the environment in which they operate. The gas turbine engine 60 comprises, in flow series, an inlet 62, a compressor section 64, a combustion section 66 and a turbine section 68, which are generally arranged in flow series and generally in the direction of a longitudinal or rotational axis 70. The gas turbine engine 60 further comprises a shaft 72 which is rotatable about the rotational axis 70 and which extends longitudinally through the gas turbine engine 60. The rotational axis 70 is normally the rotational axis of an associated gas turbine engine. Hence any reference to "axial", "radial" and "circumferential" directions are with respect to the rotational axis 70.

[0028] The shaft 72 drivingly connects the turbine section 68 to the compressor section 64. In operation of the gas turbine engine 60, air 74, which is taken in through the air inlet 62 is compressed by the compressor section 64 and delivered to the combustion section or burner section 66. The burner section 66 comprises a burner plenum 76, one or more combustion chambers 78 defined by a double wall can 80 and at least one burner 82 fixed to each combustion chamber 78. The combustion chambers 78 and the burners 82 are located inside the burner plenum 76. The compressed air passing through the compressor section 64 enters a diffuser 84 and is discharged from the diffuser 84 into the burner plenum 76 from where a portion of the air enters the burner 82 and is mixed with a gaseous or liquid fuel. The air/fuel mixture is then burned and the combustion gas 86 or working gas from the combustion is channelled via a transition duct 88 to the turbine section 68.

[0029] The turbine section 68 may comprise a number of blade carrying discs 90 or turbine wheels attached to the shaft 72. In the example shown, the turbine section 68 comprises two discs 90 which each carry an annular array of turbine assemblies 12, which each comprises an aerofoil 14 embodied as a turbine blade 100. Turbine cascades 92 are disposed between the turbine blades 100. Each turbine cascade 92 carries an annular array of turbine assemblies 12, which each comprises an aerofoil 14 in the form of guiding vanes (i.e. stator vanes 96), which are fixed to a stator 94 of the gas turbine engine 60.

[0030] Figure 3 shows an enlarged view of a stator vane 96 and rotor blade 100. Arrows "A" indicate the direction of flow of combustion gas 86 past the aerofoils 96, 100. Arrows "B" show air flow passages provided for sealing, and arrows "C" indicate cooling air flow paths for passing through the stator vanes 96. Cooling flow passages 101 may be provided in the rotor disc 90 which extend radially outwards to feed an air flow passage 103 in the rotor blade 100.

[0031] The combustion gas 86 from the combustion chamber 78 enters the turbine section 58 and drives the turbine blades 100 which in turn rotate the shaft 72 to drive the compressor. The guide vanes 96 serve to optimise the angle of the combustion or working gas 86 on to the turbine blades.

[0032] Figure 4 shows a view of the rotor blades 100 looking upstream facing the flow "A" shown in Figure 3.

[0033] Each rotor blade 100 comprises an aerofoil portion 104, a root portion 106 and a platform 108 from which the aerofoil extends.

[0034] The rotor blades 100 are fixed to the rotor disc 102 by means of their root portions 106, through which the flow passage 101 may extend. The root portions 106 have a shape that corresponds to notches (or grooves) 109 in the rotor disc 90, and are configured to prevent the rotor blade 100 from detaching from the rotor disc 102 in a radial direction as the rotor disc 102 spins.

[0035] The aerofoil portion 104 has a flow inlet 103 which, as described above, in situ will be in flow communication with a cooling passage 101 or other fluid source.

[0036] The inlet (shown as "103" in Figure 3) may be provided as a single passage, or a plurality of passages. The aerofoil portion 104 further comprises a flow outlet, or a plurality of flow outlets.

[0037] Where the term flow inlet and flow outlet are used, this may be taken to mean a single inlet and/or outlet, or a plurality of inlets and/or a plurality of outlets. Hence a subdivided inlet may feed the aerofoil and/or a subdivided outlet may provide an exhaust path from the aerofoil.

[0038] Figures 5, 6 show turbine aerofoils of the present disclosure. Although some features of an aerofoil are shown in figures 5, 6 it is substantially only the main body portion 200 which is of relevance to the configuration of the cooling arrangement of the present disclosure, which may be applied to rotor blades and stator vanes. That is to say, in the examples shown the leading edge cooling chamber is provided in turbine rotor blades 100, although it will be appreciated that it could also be provided in turbine stator vanes 96.

[0039] Hence there may be provided a turbine aerofoil 100 for a turbo machine, the aerofoil 100 comprising a main body portion 200. In use the main body 200 will be gas washed, which is to say will be in the main flow of the turbine, and thus exposed to exhaust gases flowing over the external surfaces of the aerofoil.

[0040] The main body portion 200 (i.e. aerofoil portion 104) may comprise a suction surface wall 202, having a suction surface 204, and a pressure surface wall 212, having a pressure surface 214. The turbine aerofoil 100 defines a leading edge 220 and a trailing edge 230. Hence the suction surface wall 202 and the pressure surface wall 212 may meet at the leading edge 220 and trailing edge 230.

[0041] Different examples of the cooling chamber arrangement of the present disclosure, present in the example of Figures 5, 6, is shown in Figures 7 to 14. In

some of these figures the outline of features of the aerofoil may be shown in dotted lines, and only example representations of the cooling chamber is shown. That is to say, the flow path is represented although the material which would surround and define the cooling chamber (for example as shown in Figures 5, 6) is not shown in detail.

[0042] The main body portion 200 extends from a base (i.e. root) portion 350 spaced apart from a tip portion 352 by the main body portion 200.

[0043] The main body portion 200 is provided with a flow inlet 240 (for example, in flow communication with, or the same as, the fluid inlet 103 described previously) and a flow outlet 250. The aerofoil 100 further comprises a leading edge cooling chamber 260 defined within the leading edge 220 of the main body portion 200, the leading edge cooling chamber 260 extending at least part of the distance between the flow inlet 240 and the flow outlet 250. That is to say, the leading edge cooling chamber 260 is provided between the flow inlet 240 and the flow outlet 250, but additional passages/flow sections may be provided upstream and downstream of the leading edge cooling chamber 260.

[0044] As shown in the example of figures 7 to 9, 11 to 14 the leading edge cooling chamber 260 comprises a first sub chamber 280 and a second sub chamber 300, the first sub chamber 280 being in flow series between the flow inlet 240 and the second sub chamber 300, the second sub chamber 300 being in flow series between first sub chamber 280 and the flow outlet 250.

[0045] The first sub chamber 280 is divided into a first section 292 and second section 294 in fluid communication via an intermediate section 296. The first section 292, second section 294 and intermediate section 296 are different regions of the sub chamber, described as sections merely to delineate the different zones into which the sub chamber is divided.

[0046] The first section 292 of the first sub chamber 280 and the second sub chamber 300 extend in a first column 310 along at least part of the leading edge 220, the second section 294 extending in a second column 320 provided between the first column 310 and the trailing edge 230. The first sub chamber 280 is in flow communication with the second sub chamber 300 via a flow passage 400 which extends between the second section 294 of the first sub chamber 280 and the second sub chamber 300.

[0047] It will be appreciated that the term "column" is used to identify a region of the aerofoil in which features are provided, rather than a column per se. The dotted lines in the figures marked as 310, 320 illustrate the locations of the columns 310, 320 relative to one another and the other features of the aerofoil.

[0048] In the example shown in Figures 7 to 9 there is further provided a third sub chamber 270 in flow series between the flow inlet 240 and the first sub chamber 280, the third sub chamber 270 divided into a first section 292 and a second section 294 in fluid communication via an

intermediate section 296. The first section 292 extends in the first column 310, and the second section 294 extends in the second column 320. The third sub chamber 270 is in flow communication with the first sub chamber 280 via a further flow passage 400 which extends between the second section 294 of the third sub chamber 270 and the first section 292 of the first sub chamber 280.

[0049] In the example shown in Figure 7 to 9 the leading edge cooling chamber 260 further comprises a fourth sub chamber 290 in flow series between the flow inlet 250 and the third sub chamber 270, the fourth sub chamber 290 extending in the second column 320. The fourth sub chamber 290 is in flow communication with the third sub chamber 270 via a further flow passage 400 which extends between the fourth sub chamber 300 and the first section 292 of the third sub chamber 280.

[0050] In the Example of Figures 11 to 14, there is no "third sub chamber 270". Instead the fourth sub chamber 290 in these examples is in flow series between the flow inlet 250 and the first sub chamber 280. However, as in the examples of Figure 7 to 9, the fourth sub chamber 290 extends in the second column 320. In the examples of Figures 11 to 14, the fourth sub chamber 290 is in flow communication with the first sub chamber 280 via a further flow passage 400 which extends between the fourth sub chamber 290 and the first section 292 of the first sub chamber 280.

[0051] Hence although the terms "third" and "fourth" are used, these terms are intended to describe different features, and are not intended to mean that for a fourth sub chamber to be present there must be a third sub chamber. That is to say, as shown in the examples of Figures 11 to 14 there may be provided only first, second and fourth sub chambers.

[0052] In Figures 12 to 14 the fourth sub chamber 290 is illustrated as extending away from the first sub chamber 280. As shown in Figure 14, the fourth sub chamber 290 may define a passage which extends in the root portion 90 of the aerofoil, the end of which may be provided as the flow inlet 240.

[0053] In both examples (Figures 7 to 9 and Figures 11 to 14) the first section(s) 292 extend in the first column 310 along at least part of the leading edge 220. That is to say, first section(s) 292 extend(s) over some of the extent of the leading edge 220. The second section(s) 294 extend(s) in the second column 320. The second column 320 may be parallel to and adjacent to the first column 310. The second column 320 may be provided between the first column 310 and the trailing edge 230.

[0054] In the example of Figures 7 to 9 the second section 294 of the third sub chamber 270 may be provided between the first section 292 of the first sub-chamber 280 and the trailing edge 230. The third sub-chamber 270 is provided in flow communication with the first sub-chamber 280 via a flow passage 400 which extends between the second section 294 of the third sub-chamber 270 and the first section 292 of the first sub-chamber 280. That is to say, the third sub-chamber 270 may be

in flow communication with the first sub-chamber 280 via only a flow passage 400, or plurality of flow passages 400 which extend between the second section 294 of the third sub-chamber 270 and the first section 292 of the first sub-chamber 280.

[0055] Hence in both examples, the downstream column 320 is vertically divided in two or more compartments, so all the flow passing through the first sub chamber also passes through the impingement holes (passages 400). Hence the cooling chamber is configured so the same cooling flow will pass through the impinging holes (passages) 400 between each sub chamber.

[0056] The first section 292 and second section 294 define a first flow direction "A" along the leading edge 220, as shown in the figures. That is to say, flow direction A is in the direction from the base portion 350 to the tip portion 352 of the rotor blade/vane (i.e. the tip of the aerofoil).

[0057] The intermediate section 296 defines a second flow direction "B" away from the leading edge 220 towards the trailing edge 230. Direction B is at an angle to the first direction A. For Example, direction B may be inclined to the flow direction A. In another example, direction B may be at right angles to the flow direction A, as shown in the figures.

[0058] As described above in relation to the other sub chambers, there may be provided a plurality of flow passages 400 which extend between the sub chambers. The flow passages 400 define a flow path in a third direction "C" in a direction away from the trailing edge 230 towards the leading edge 220. That is to say, the third direction C may be parallel to the second flow direction B, but in an opposite direction to flow direction B, as shown in Figures 7, 8, 9.

[0059] In the example of figures 9, 10, 14 at least some of the plurality of flow passages 400 define flow paths in the third direction C away from the trailing edge 230 towards the leading edge 220 and at an angle to the second flow direction B. At least some of the remaining flow passages 400 define flow paths in the third direction C parallel to the second direction B.

[0060] In the example of Figure 14, at least some of the plurality of flow passages 400 define flow paths in the third direction C away from the trailing edge 230 towards the leading edge 220 and at an angle to the second flow direction B to direct flow towards a region 308 of the wall of the first section 292 which faces the intermediate section 296.

[0061] That is to say, there may be provided a plurality of flow passages 400 between sub chambers at least some of which define flow paths in the third direction C in a direction away from the trailing edge 230 towards the leading edge 220 at an angle to the second flow direction B to direct flow towards the wall of the leading edge 220 defined by (i.e. opposite/facing) the intermediate section 296 of the sub-chamber into which flow is being directed. An example of this is shown in figure 14.

[0062] Flow direction C may be in the range of 10° to

80° to the first direction A. In another example, flow direction C may be at an angle of 30° to 50° to first direction A. In another example, flow direction C may be at an angle of 20° to 90° to first direction A.

[0063] The flow outlet 250 is provided in the tip portion 352, for example as shown in figures 5 to 9, 11 to 13. Hence the flow outlet 250 may be provided proximate to the leading edge 220 in line with the first column 310.

[0064] In an alternative example, for example as shown in figure 14, the tip portion 352 comprises a tip wall 354 which extends from the aerofoil leading edge 220 to the aerofoil trailing edge 230, the tip wall 354 defining the flow outlet 250 towards the trailing edge 230.

[0065] The tip portion 352 may define a tip wall passage 356 extending from the leading edge cooling chamber 260 and the leading edge 220 to the trailing edge 230, or at least towards the trailing edge 230, the flow outlet 250 being provided towards the trailing edge 230.

[0066] The diameter (i.e. flow area) of all of the passages 400 may be the same.

[0067] The total flow area between sections 292, 294 (i.e. the total area of all of the flow passages 400 between each sub chamber) may be the same.

[0068] The same number of flow passages 400 may be provided between each of the sub chambers.

[0069] The relationship between "*distance between the exit of the passage 400 and the surface of the sub chamber the air ejected from the passage impinges upon*" and "*passage diameter*" may have a value in the range of (Distance)/(passage diameter) >1 and (Distance)/(passage diameter) <6.

[0070] The flow area of the intermediate section 296 of each sub chamber 270, 280 may be greater than the flow area of the passages 400 which they feed. Hence the flow passages 400 define a flow restriction relative the intermediate section 296.

[0071] In operation, that is to say when the turbo-machine is operating, cooling fluid (for example, compressed air) is delivered to the flow inlet 240 and then passes along the leading edge cooling chamber 260.

[0072] Hence in the examples of Figures 7 to 9, the cooling air first travels through the fourth sub-chamber 290 and then through the flow passage(s) 400 to impinge on the internal surface of the leading edge defined by the first section 292 of the third sub-chamber 270. The impingement increases the heat transfer to the air thus cooling the internal surface of the leading edge 220 of the aerofoil. The air then travels through the intermediate section 296 into the second section 294 of the third sub-chamber 270 and then through the flow passage(s) 400 into the first section 292 of the first sub-chamber 280 to impinge on the internal surface of the leading edge 220 defined by the first section 292 of the first sub-chamber 280. The flow then passes through the intermediate section 296 of the first sub-chamber 280 into the second section 294 and then into the second sub-chamber 300 via the flow passage(s) 400. In other examples one of more further sub chambers akin to the first and third sub

chambers 270, 280 may be provided between the first sub chamber 270 and the second sub chamber 300.

[0073] In the examples of Figures 11 to 14, the cooling air first travels through the fourth sub-chamber 290 and then through the flow passage(s) 400 to impinge on the internal surface of the leading edge 220 defined by the first section 292 of the first sub-chamber 280. The flow then passes through the intermediate section 296 of the first sub-chamber 280 into the second section 294 and then into the second sub-chamber 300 via the flow passage(s) 400.

[0074] In the example shown the final stage of the cooling is for the cooling air to travel through the flow passage(s) 400 which extend between the second section 294 of the first sub-chamber 280 and the second sub-chamber 300 to impinge on the internal surfaces of the leading edge 220 defined by the second sub-chamber 300. The cooling air then travels along the length of the third sub-chamber 300 to be delivered to the flow outlet 250. As described above, the flow outlet 250 may be provided towards the leading edge 220 or the trailing edge 230 of the aerofoil.

[0075] In examples where the flow passage(s) 400 are angled, for example as shown in figure 14, then the same impingement action is achieved, but different regions of the internal surface of the leading edge may be reached, for example the region 308 facing the intermediate section, as shown in Figure 14.

[0076] The use of the same mass flow to impinge on the internal surface of sub chambers in sequence results in a reduction of the required mass flow consumption compared to examples of the related art. Additionally the heat pick up (i.e. heat transfer) from the cooling fluid starting from the same inlet temperature is increased relative to examples of the related art. This is the case even though cooling fluid temperature increases because heat transfer to the cooling fluid at the leading edge is greater than in examples of the related art.

[0077] The configuration is such that flow through passages 400 are not affected by transverse flow, which reduces heat flux/transfer in examples of the related art.

[0078] Hence there is provided an aerofoil with an enhanced cooling arrangement. This cooling arrangement of the present disclosure provides substantially enhanced cooling per mass flow unit of cooling air used. Hence a system (for example a turbine system) comprising the leading edge cooling chamber arrangement of the present disclosure may provide significantly better and more efficiently cooled aerofoils using less cooling air than examples of the related art.

[0079] Thus the arrangement of the present disclosure improves the performance of a cooling system by reducing the mass flow consumption and improving the life of a an aerofoil component.

[0080] Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and

the contents of all such papers and documents are incorporated herein by reference.

[0081] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0082] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0083] The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A turbine aerofoil (100) for a turbo machine, the aerofoil (100) comprising :
a main body portion (200) defined by :

a leading edge (220) and a trailing edge (230), the main body portion (200) having a flow inlet (240) and flow outlet (250);

a leading edge cooling chamber (260) defined within the leading edge (220) of the main body portion (200), the leading edge cooling chamber (260) extending between the flow inlet (240) and the flow outlet (250);

the leading edge cooling chamber (260) comprising a first sub chamber (280) and a second sub chamber (300),

the first sub chamber (280) being in flow series between the flow inlet (240) and the second sub chamber (300), the second sub chamber (300) in flow series between first sub chamber (280) and the flow outlet (250);

the first sub chamber (280) being divided into a first section (292) and second section (294) in fluid communication via an intermediate section (296);

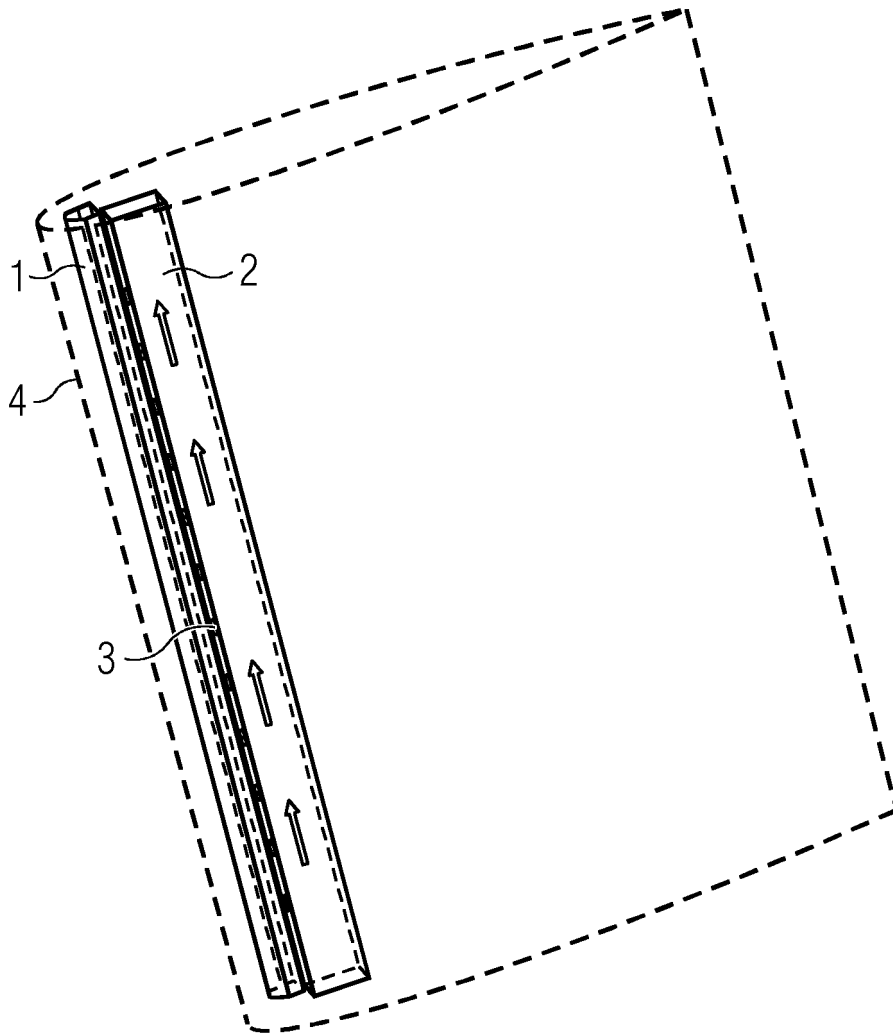
the first section (292) of the first sub chamber (280) and the second sub chamber (300) extending in a first column (310) along at least part of the leading edge (220);

the second section (294) extending in a second column (320) provided between the first column (310) and the trailing edge (230);

the first sub chamber (280) in flow communica-

- tion with the second sub chamber (300) via a flow passage (400) which extends between the second section (294) of the first sub chamber (280) and the second sub chamber (300).
2. A turbine aerofoil (100) for a turbo machine as claimed in claim 1 wherein the leading edge cooling chamber (260) further comprises a fourth sub chamber (290) in flow series between the flow inlet (240) and the first sub chamber (280), the fourth sub chamber (290) extending in the second column (320); the fourth sub chamber (290) being in flow communication with the first sub chamber (280) via a further flow passage (400) which extends between the fourth sub chamber (290) and the first section (292) of the first sub chamber (280).
 3. A turbine aerofoil (100) for a turbo machine as claimed in claim 1 further comprising :
 - a third sub chamber (270) in flow series between the flow inlet (240) and the first sub chamber (280), the third sub chamber (270) divided into a first section (292) and a second section (294) in fluid communication via an intermediate section (296); the first section (292) extending in the first column (310) the second section (294) extending in the second column (320); the third sub chamber (270) in flow communication with the first sub chamber (280) via a further flow passage (400) which extends between the second section (294) of the third sub chamber (270) and the first section (292) of the first sub chamber (280).
 4. A turbine aerofoil (100) for a turbo machine as claimed in claim 3 wherein the leading edge cooling chamber (260) further comprises a fourth sub chamber (290) in flow series between the flow inlet (250) and the third sub chamber (270), the fourth sub chamber (290) extending in the second column (320); the fourth sub chamber (290) being in flow communication with the third sub chamber (270) via a further flow passage (400) which extends between the fourth sub chamber (290) and the first section (292) of the third sub chamber (270).
 5. A turbine aerofoil (100) for a turbo machine as claimed in any one of the preceding claims wherein the first section (292) and second section (294) define a first flow direction (A) along the leading edge (220); and the intermediate section (296) defines a second flow direction (B) away from the leading edge (220) towards the trailing edge (230).
 6. A turbine aerofoil (100) for a turbo machine as claimed in any one of claims 1 to 5 wherein the flow passage (400) defines a flow path in a third direction (C) in a direction away from the trailing edge (230) towards the leading edge (220).
 7. A turbine aerofoil (100) for a turbo machine as claimed in any one of the preceding claims wherein there are provided a plurality of said flow passages (400) between the sub chambers.
 8. A turbine aerofoil (100) for a turbo machine as claimed in claim 7 wherein at least some of the plurality of flow passages (400) define flow paths in the third direction (C) away from the trailing edge (230) towards the leading edge (220) and at an angle to the second flow direction (B) to direct flow towards the wall of the first section (292) which faces the intermediate section (296), and at least some of the remaining flow passages (400) define flow paths in the third direction (C) parallel to the second direction (B).
 9. A turbine aerofoil (100) for a turbo machine as claimed in any one of the preceding claims wherein the main body portion (200) extends from a base portion (350) spaced apart from a tip portion (352) by the main body portion (200), the flow outlet (250) being provided in the tip portion (352).
 10. A turbine aerofoil (100) for a turbo machine as claimed in claim 9 wherein the flow outlet (250) is provided proximate to the leading edge (220) in line with the first column (310).
 11. A turbine aerofoil (100) for a turbo machine as claimed in claim 9 wherein the tip portion (352) comprises a tip wall (354) which extends from the aerofoil leading edge (220) to the aerofoil trailing edge (230); the tip wall (352) defining the flow outlet (250) towards the trailing edge (230).
 12. A turbine aerofoil (100) for a turbo machine as claimed in claim 9 wherein a tip wall passage (356) extending from the leading edge (220) to the trailing edge (230), the flow outlet (250) being provided as an opening in the tip wall passage (356) towards the trailing edge (230).
 13. A turbine aerofoil (100) for a turbo machine as claimed in any one of the preceding claims, wherein the turbine aerofoil (100) is one of a rotor blade or stator vane.

FIG 1 PRIOR ART



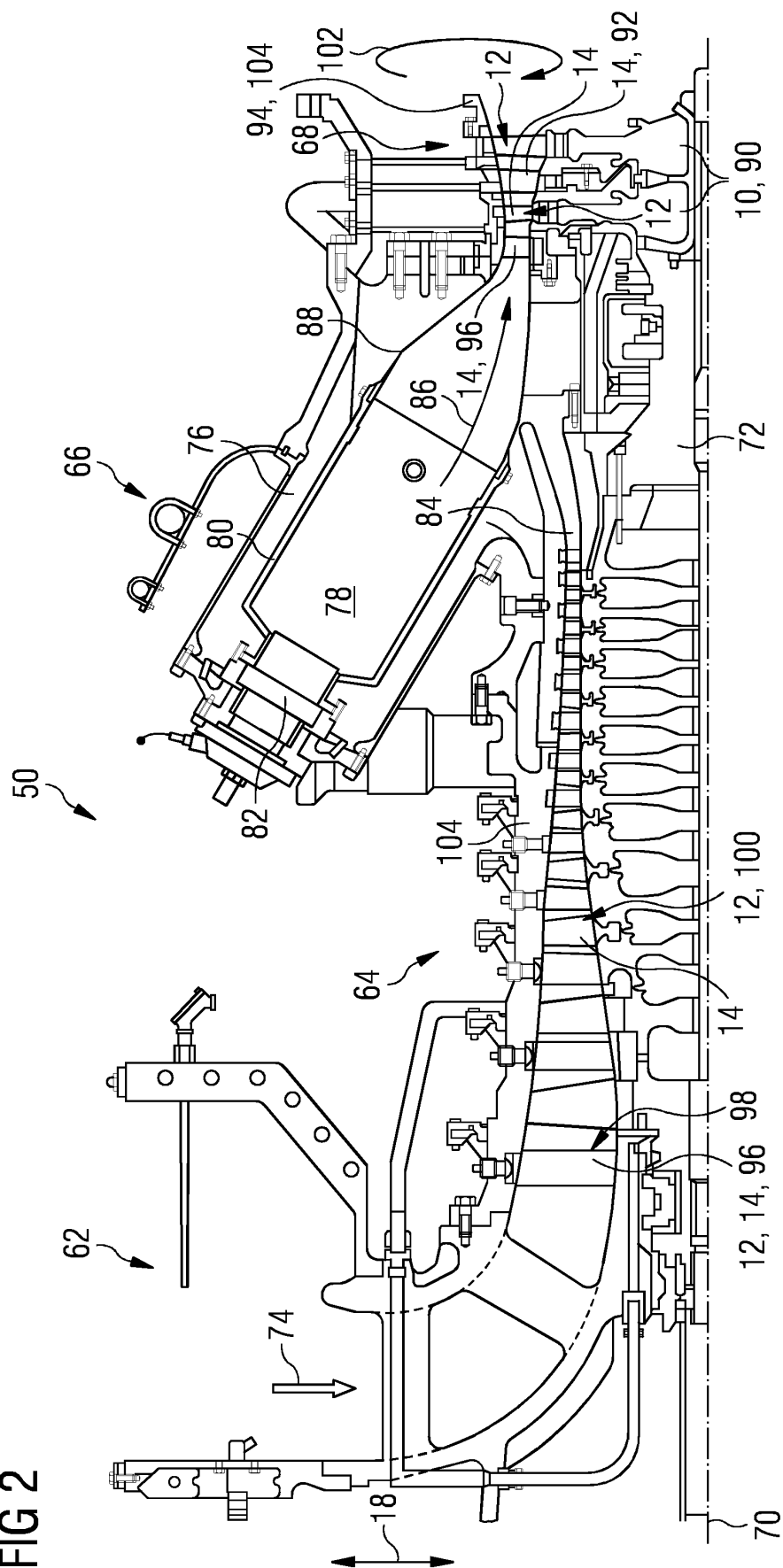


FIG 3

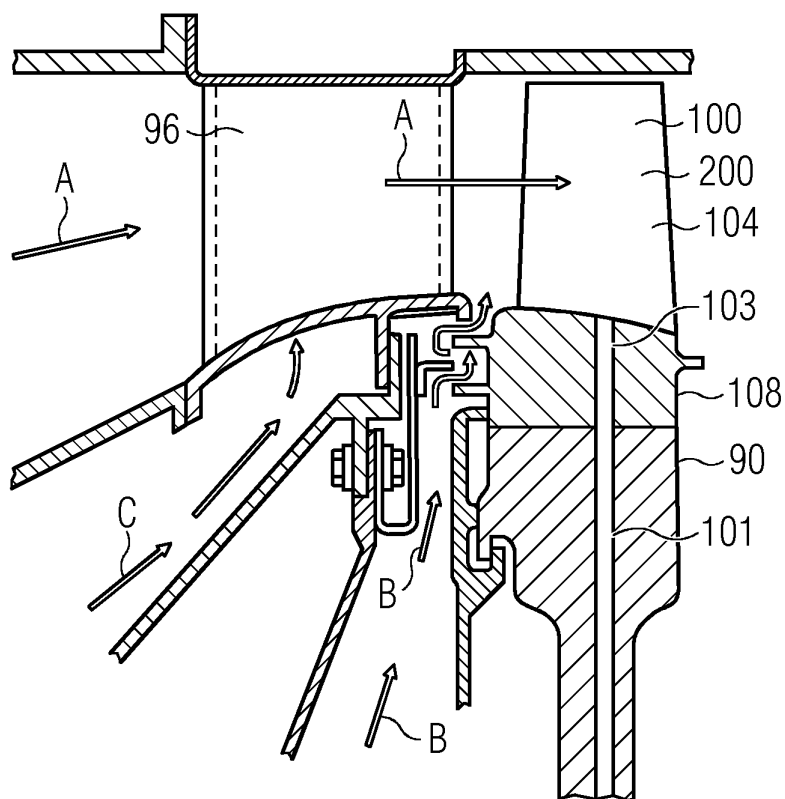


FIG 4

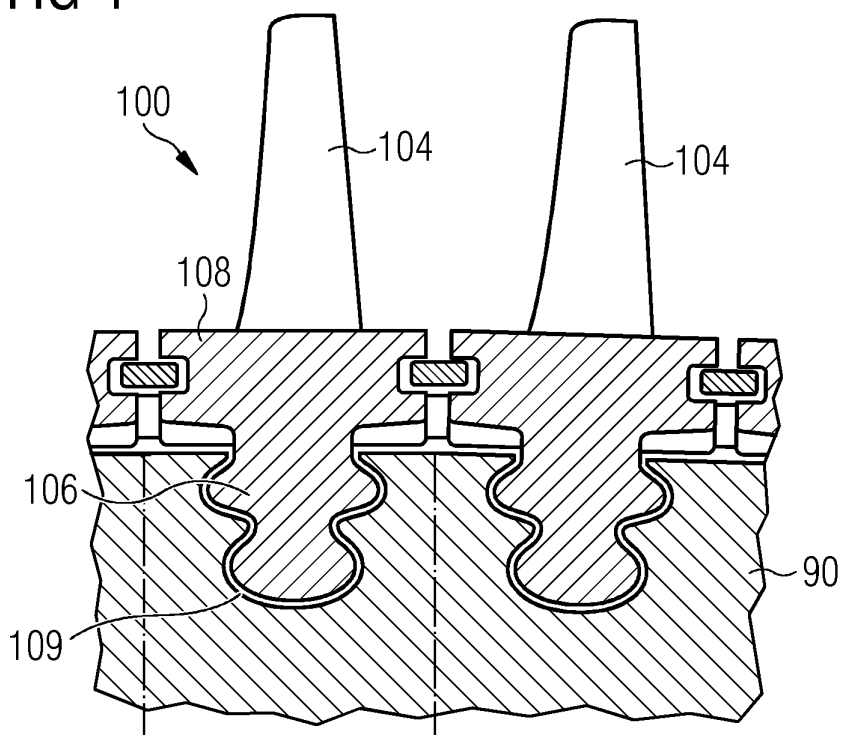


FIG 5

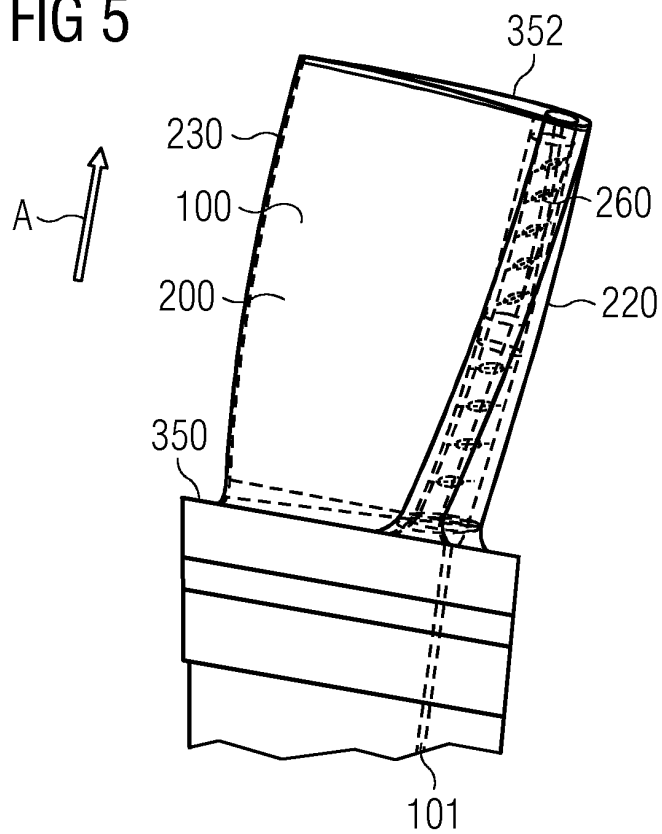


FIG 6

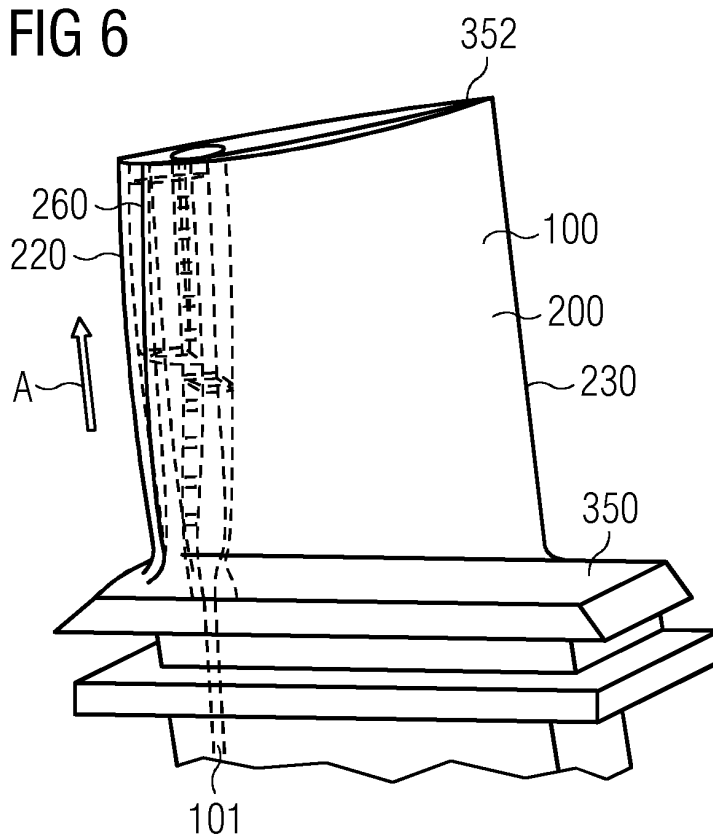


FIG 7

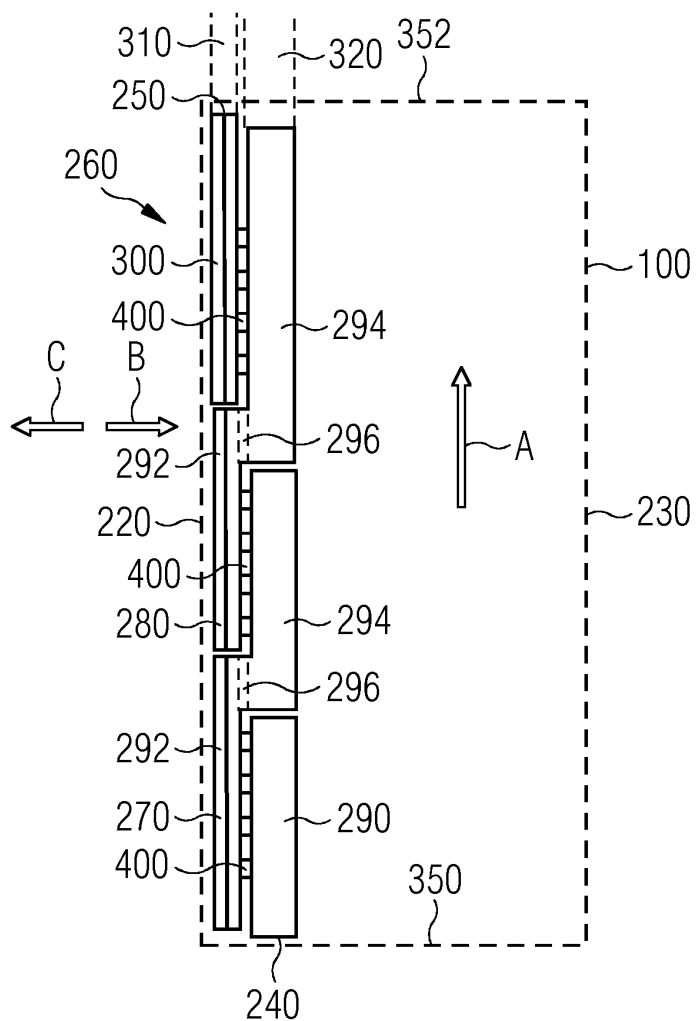


FIG 8

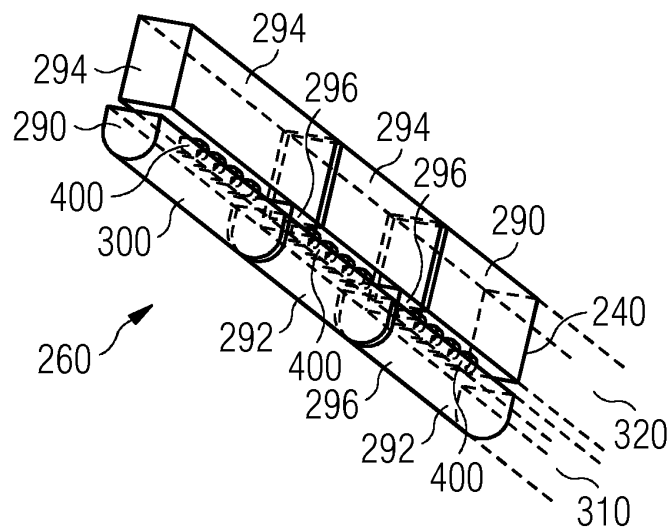


FIG 9

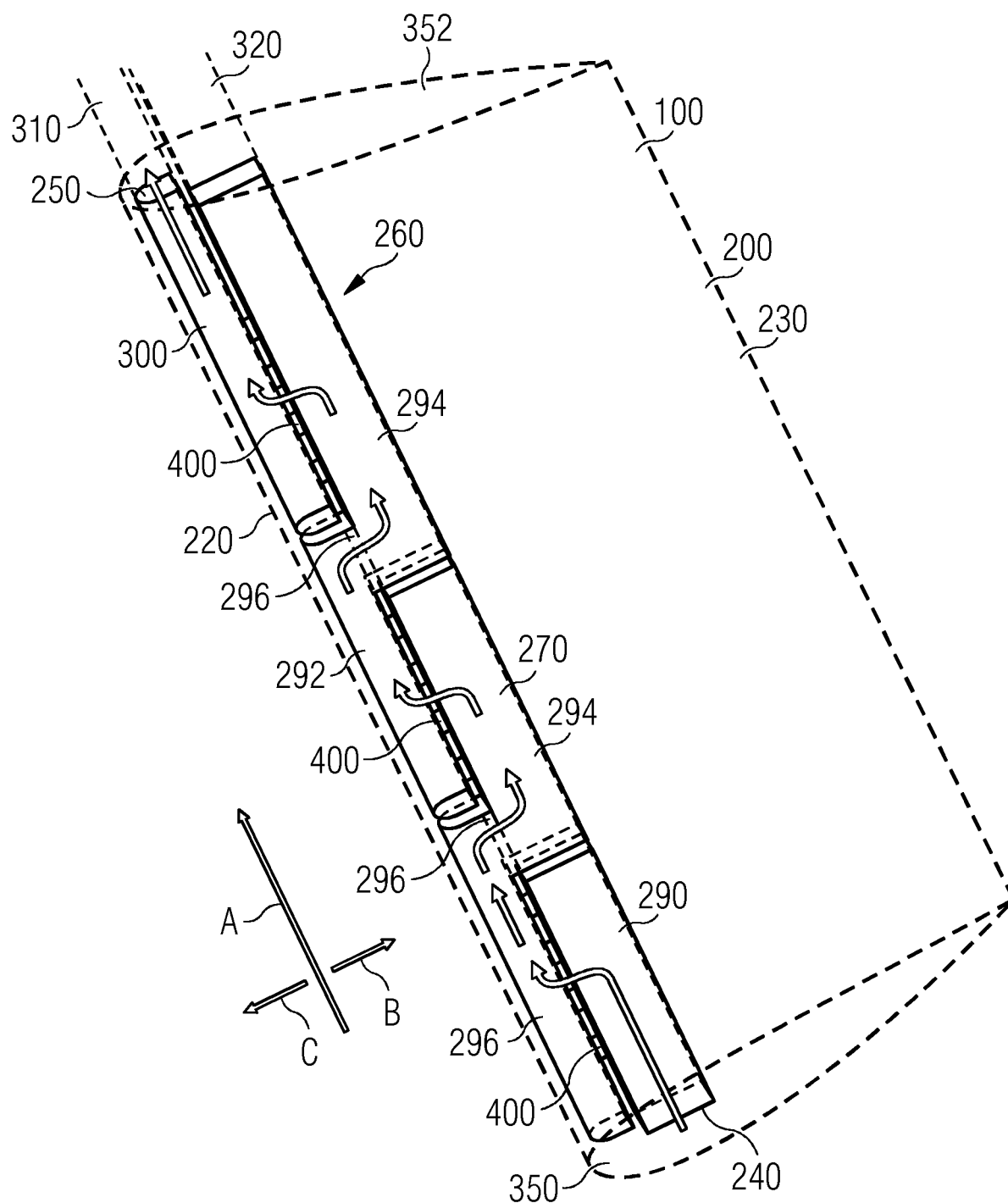


FIG 10

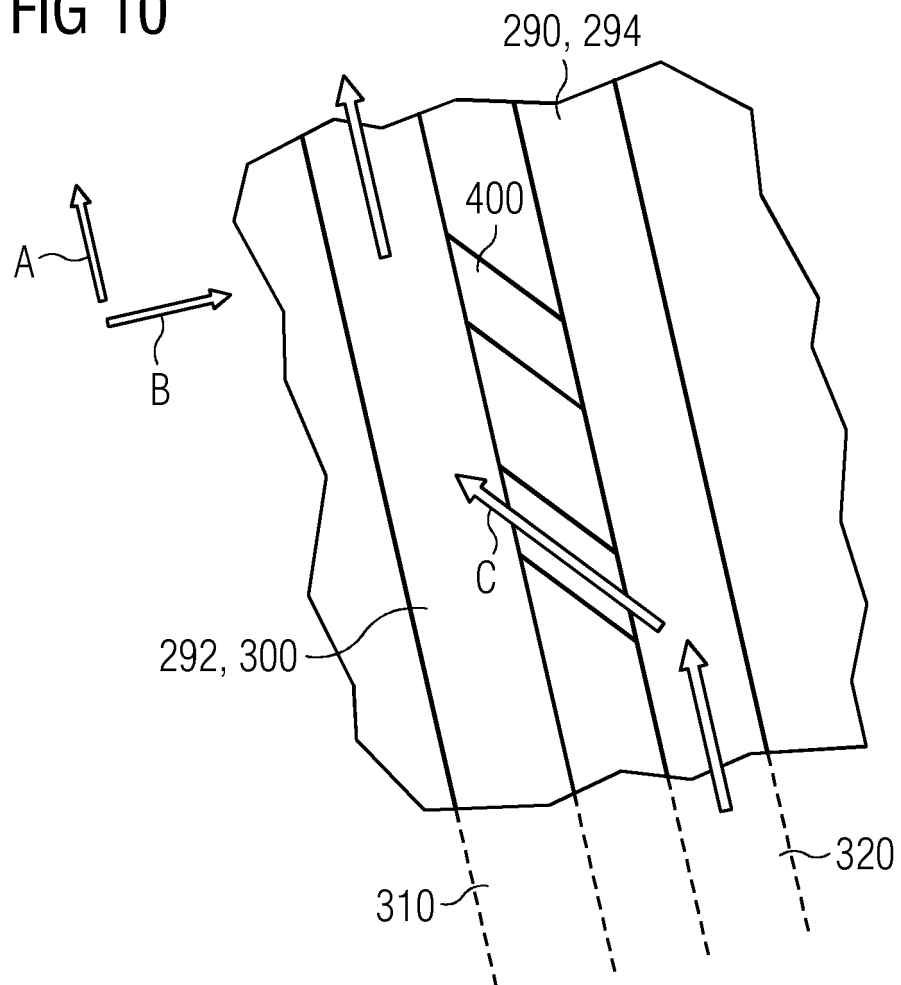


FIG 11

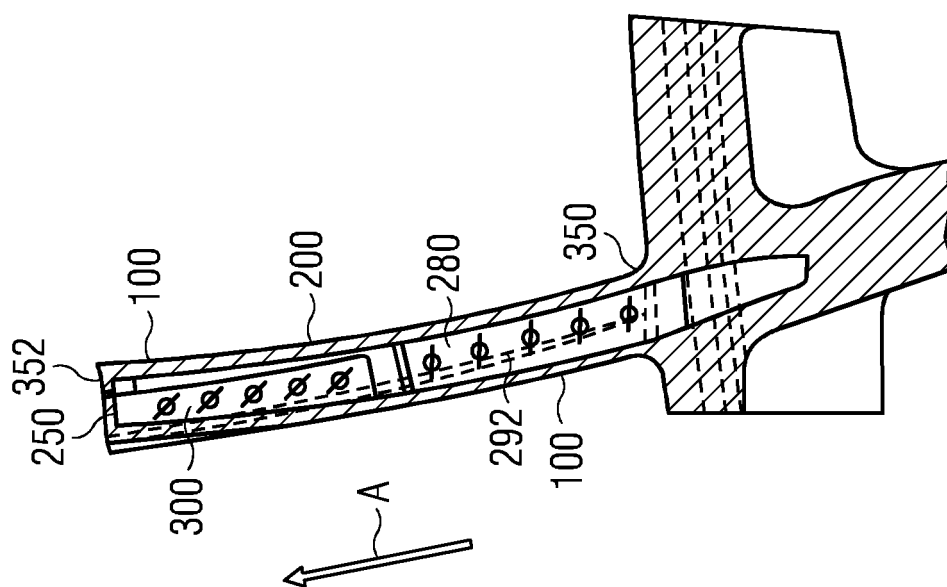


FIG 12

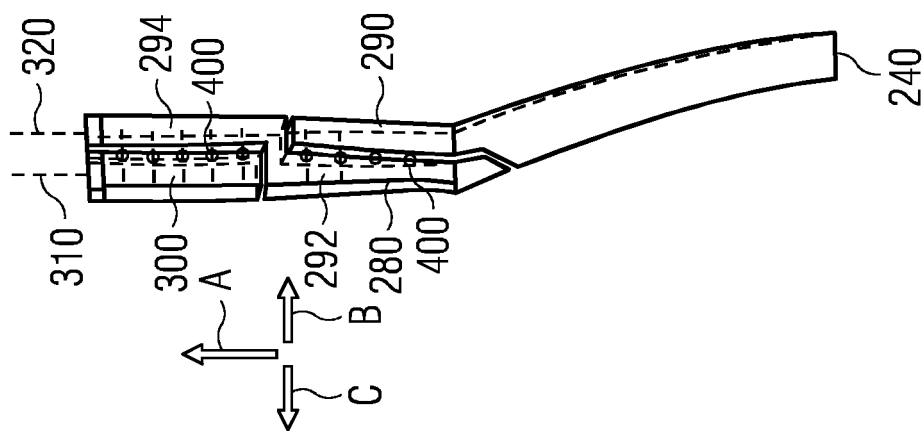


FIG 13

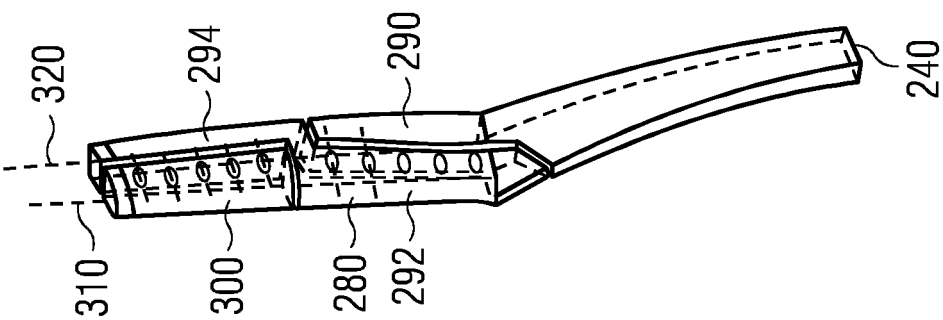
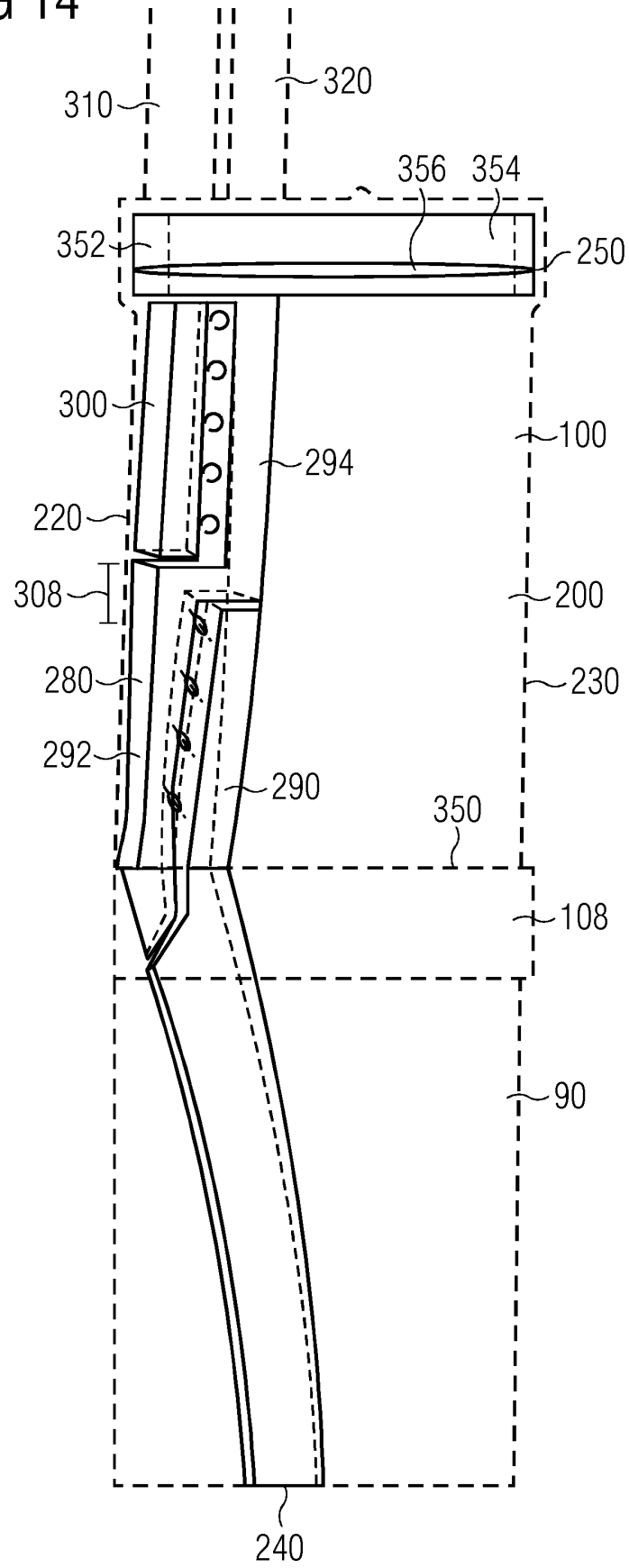


FIG 14





EUROPEAN SEARCH REPORT

Application Number
EP 18 20 6713

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Y	US 5 464 322 A (CUNHA FRANCISCO J [US] ET AL) 7 November 1995 (1995-11-07) * abstract * * figures 2,3,4 * * column 2, line 11 - column 2, line 44 * * column 4, line 11 - column 6, line 59 *	1-13	
A	FR 2 311 176 A1 (BBC BROWN BOVERI & CIE [CH]) 10 December 1976 (1976-12-10) * figures 1,2 *	1-13	
A	WO 2008/133758 A2 (SIEMENS POWER GENERATION INC [US]; LIANG GEORGE [US]) 6 November 2008 (2008-11-06) * abstract * * page 5, paragraph 2 - page 12, paragraph 2 * * figures 1-5 *	1-13	TECHNICAL FIELDS SEARCHED (IPC) F01D B22D B22C
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 18 April 2019	Examiner Payr, Matthias
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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The members are as contained in the European Patent Office EDP file on
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