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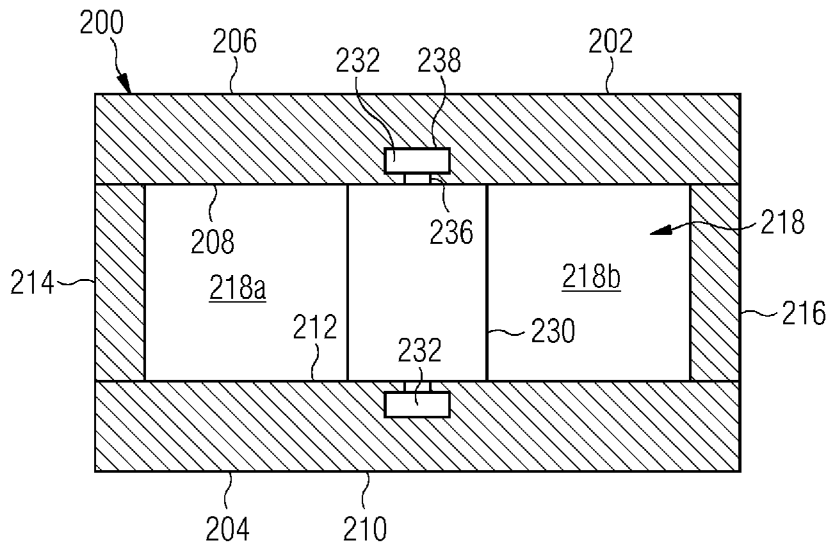
(54) **Title:** AEROFOIL

FIG 3



(57) **Abstract:** An aerofoil (200) for turbo machinery. The aerofoil comprises a first wall (202) having an outer surface (206) and an inner surface (208), and a second wall (204) having an outer surface (210) and an inner surface (212). The first wall and second wall extend from a common leading edge (214) to a common trailing edge (216). The first wall (202) and second wall (204) are spaced apart between the leading edge (214) and trailing edge (216) such that their inner surfaces (208, 212) define a cavity (218). A third wall (220) and fourth wall (222) are provided at opposite ends of the cavity (218), which each extend between the first wall (202) and second wall (204). An insert member (230) extends from one of the first wall (202), second wall (204), third wall (220) and/or fourth wall (222).

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AEROFOIL

The present disclosure relates to an aerofoil.

In particular the disclosure is concerned with an aerofoil which is a turbine rotor blade or stator vane for turbomachinery.

Background

Modern turbines often operate at extremely high temperatures. The effect of temperature on the turbine blades, stator vanes and surrounding components can be detrimental to the efficient operation of the turbine and can, in extreme circumstances, lead to distortion and possible failure of such components.

In order to overcome this risk, high temperature turbines may include hollow rotor blades or stator vanes, which comprise a plenum through which cooling air is forced. The plenum may be divided by internal walls (or “ribs”) which are formed integrally with the aerofoil structure. The structures may be manufactured by investment casting around a ceramic core.

However, forming of the internal walls in such a process can be problematic, leading to complications (e.g. distortions or flaws in the walls) which are difficult or impossible to remedy, and hence result in scrapping of the whole component. Such problems may be mitigated by trial and error, which leads to time consuming and costly developments in order to achieve a final design.

WO 2011/021693 discloses is a turbine cooling structure whereby the inner walls of a front cooling passage and a rear-side cooling passage, which are defined by dividing the inside of a turbine stator vane using a reinforcement rib, are cooled by impingement cooling.

EP1947295 (A1) discloses a blade insert body inserted in a convectional cooling channel of convectional cooling blade of a jet engine and shortens the cross section of the convectional cooling channel. The jet engine is operated with the blade insert body fixed in the convectional cooling channel of the blade. The axial-flow turbo compressor blade or the axial-flow turbine blade are insertable and their convectional cooling channel extends radially.

Hence an aerofoil, and its method of manufacture, which inherently reduces the risk of flaws during manufacture is highly desirable.

Summary

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

Accordingly there may be provided an aerofoil 200 for turbo machinery. The aerofoil may comprise a first wall 202 having an outer surface 206 and an inner surface 208; a second wall 204 having an outer surface 210 and an inner surface 212; the first wall and second wall extending from a common leading edge 214 to a common trailing edge 216; the first wall 202 and second wall 204 spaced apart between the leading edge 214 and trailing edge 216 such that their inner surfaces 208, 212 define a cavity 218. There may also be provided a third wall 220 and fourth wall 222 provided at opposite ends of the cavity 218, which each extend between the first wall 202 and second wall 204. There may also be provided an insert member 230 which extends from one of the first wall 202, second wall 204, third wall 220 and/or fourth wall 222.

The insert member 230 may extend between two of the first wall 202, second wall 204, third wall 220 and/or fourth wall 222.

The insert member 230 may extend between the first wall 202 and second wall 204 to thereby divide the cavity 218 between the leading edge 214 and trailing edge 216.

The insert member 230 may extend between the third wall 220 and fourth wall 222 to thereby divide the cavity 218 between the first wall 202 and second wall 204.

The insert member 230 may be fused to the wall(s) 202, 204, 220, 222 from which it extends.

The insert member 230 may comprise an engagement feature 232 for fixing the insert member 230 relative to the wall 202, 204, 220, 222 from which it extends.

The engagement feature 232 may comprise : a neck region 236 which extends from the insert member 230; and a head region 238 which extends from the neck region 236; the head region 238 being wider than the neck region 236 such that the head region 238 and neck region 236 form a re-entrant feature for engagement with the aerofoil wall 202, 204, 220, 222.

The insert member 230 may define a flow aperture 240 which extends from one side of the insert member 230 through to an opposite side of the insert member 230.

The insert member 230 may define a first flow passage 250 which extends through the insert member 230, the insert member 230 first flow passage 250 being aligned with a supply passage 252 in the wall(s) 202, 204, 220, 222 of the aerofoil 200 from which the insert member 230 extends.

The supply passage 252 may be provided in the third wall 220 and/or fourth wall 222 of the aerofoil 200, and the first flow passage 250 may be in flow communication the supply passage 252.

The insert member 230 may comprise: a middle wall section 254 a first wing section 256, which extends from the middle wall section 254; the first flow passage 250 being provided in the first wing section 256; a second wing section 258, which extends from the middle wall section 254 in a direction away from the first wing section 256; a second flow passage 260 being provided in the second wing section 258; the second flow passage 258 being in flow communication with the supply passage 252.

There may also be provided a method of manufacturing an aerofoil 200, the aerofoil comprising: a wall 202, 204, 220, 222 which defines at least part of a cavity 218 within the aerofoil 200; an insert member 230 which extends from the wall 202, 204, 220, 222; the method comprising the steps of : manufacturing the insert member 230 by a first manufacturing process; and then forming the aerofoil wall 202, 204, 220, 222 by a second manufacturing process so as to fix the insert member 230 relative to the wall 202, 204, 220, 222.

The insert member 230 may comprise an engagement feature 232, and the wall 202, 204, 220, 222 is formed around the engagement feature 232.

The first manufacturing process may different to the second manufacturing process.

The first manufacturing process may be an additive manufacturing process; and the second manufacturing process comprises a casting process.

Hence there is provided an aerofoil and a method of manufacture of an aerofoil in which an internal wall (i.e. an insert member) is manufactured separately to the main structure of the aerofoil. Thus problems of the related art relating to distortions and other flaws in internal wall structures may be avoided as the internal insert member is manufactured separately and may be quality checked prior to inclusion in the manufacture of the remainder of the aerofoil structure. Additionally the method allows for manufacturing of insert member geometries and detail which may not be possible by conventional manufacturing processes.

Brief Description of the Drawings

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

Figure 1 shows a schematic sectional view of an example of a gas turbine engine which comprises an aerofoil according to the present disclosure;

Figure 2 shows an enlarged view of examples of aerofoils of the arrangement shown in Figure 1;

Figure 3 shows a schematic cross sectional view through an example of an aerofoil according to the present disclosure;

Figures 4 to 7 show different views of an insert member according to the present disclosure;

Figure 8 shows a schematic cross sectional plan view of another example of an aerofoil according to the present disclosure;

Figure 9 shows a schematic cross section of a further example of an aerofoil according to the present disclosure; and

Figure 10 shows a cross sectional view of a further example of an aerofoil according to the present disclosure.

Detailed Description

Figure 1 shows an example of a gas turbine engine 60 in a sectional view which may comprise an aerofoil according to the present disclosure. 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 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.

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.

Figure 2 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 arrow “C” indicates cooling air flow paths for passing through the stator vanes 96. Cooling flow passages 252 may be provided in the rotor disc 90 which extend radially outwards to feed the rotor blade 100.

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 guiding vanes 96 serve to optimise the angle of the combustion or working gas 86 on to the turbine blades.

Figure 3 shows a plan view cross section of a schematic representation of an aerofoil 200, which may be either of the stator vane 96 or rotor blade 100. That is to say, aerofoil 200 represents a sectional view from the direction indicated by arrows E in Figure 2.

The aerofoil 200 is shown schematically and omits many technical features, and is presented as an indication of an example of the present disclosure. It is not intended to show the actual geometry of a functional aerofoil. The aerofoil 200 may thus be a rotor blade or stator for a turbine for turbo machinery, for example a gas turbine engine.

The aerofoil comprises a first wall 202 and a second wall 204. The first wall 202 and second wall 204 may define opposing suction and/or pressure sides of the aerofoil 202. The first wall has an outer surface 206 and an inner surface 208. The second wall has an outer surface 210 and an inner surface 212. The first wall 202 and second wall 204 extend from a common leading edge 214 to a common trailing edge 216. The first wall 202 and second wall 204 are spaced apart between the leading edge 214 and trailing edge 216 such that their inner surfaces 208, 212 define a cavity 218. The cavity 218 thus extends the distance between the leading edge 214 and the trailing edge 216. However in other examples the cavity may span only part of the distance between the leading edge 214 and trailing edge 216.

The aerofoil 200 may further comprise a third wall 220 and a fourth wall 222 provided at opposite ends of the cavity 218. These are not shown in Figure 3, but are shown in Figure 2. That is to say the third wall 220 closes, or at least partially closes, the cavity at the base (i.e. root) of the aerofoil, and the fourth wall 222 closes, or at least partially closes, the cavity 218 at the tip or outer end of the aerofoil, depending on the design of the stator vane or rotor blade.

The aerofoil further comprises a discrete insert member 230. The discrete insert member 230 may be manufactured by a different and/or separate process to the remainder of the aerofoil 200, as will be described.

The insert member 230 extends from the first wall 202 to the second wall 204. However, as will be shown in later examples, the insert member 230 may also extend between the third wall 220 and fourth wall 222. Indeed, as shown in Figure 3, the insert 230 may extend all of the way from the third wall 220 to the fourth wall 222. That is to say, the discrete insert member 230 extends from at least one of the first wall, second wall, third wall and/or fourth wall. Alternatively or additionally, the discrete insert member 230 extends from between at least two of the first wall, second wall, third wall and/or fourth wall.

Hence in one example (not shown) the insert member 230 may extend from only one wall (to form, for example, a baffle plate) and may extend towards, but not all of the way to, one or more of the other walls. In another example the insert member 230 may extend between two of the first wall 202, second wall 204, third wall 220 and/or fourth wall 222.

As shown in Figure 3, the insert member 230 extends between all four walls thereby dividing the cavity 218 into two sub cavities 218A, 218B. That is to say, the insert member 230 extends between the first wall 202, and second wall 204, to thereby divide the cavity 218 between the leading edge 214 and trailing edge 216. Clearly in order to do this, the insert member 230 must also seal, or at least partially seal, against the third wall 220 and fourth wall 222.

As will be described later, the insert member 230 is formed before forming the walls of the aerofoil 200. That is to say, the insert member 230 is formed by a manufacturing process which is separate to the process which forms the walls 202, 204, 220, 222 of the aerofoil 200. The insert member 230 is joined (that is to say fixed) to a wall of the aerofoil 200. The insert member 230 may be fused to the wall of the aerofoil 200 from which it extends. That is to say, the ends of the insert member 230 and the surface of the walls of the aerofoil to which it is joined may, during the manufacturing process, be brought into the molten state so that the materials at the interface of the insert 230 and aerofoil walls 202, 204, 220, 222 become fused.

Additionally, or alternatively, the insert member 230 may comprise engagement features 232 for fixing the insert member 230 relative to the wall 202, 204, 220, 222 from which it extends.

An example of the insert member is shown in Figures 4 to 7. The insert member 230 comprises a main body 234. The engagement feature 232 comprises a neck region 236 which extends from the main body 234 of the insert member 230, and a head region 238 which extends from the neck region 236. Hence the head region 238 is spaced apart from the main body 234 by the neck region 236. The head region 238 is wider than the neck region 236 such that the head region 238 and neck region 236 form a re-entrant feature 237 for engagement with the aerofoil wall 202, 204, 220, 222. The re-entrant feature 237 may be formed by other shapes than the rectangular head and neck portions shown. For example, the head may be circular, part-circular, triangular or a truncated triangle. Other shapes are possible. Indeed where the engagement feature is fused to the wall(s) 202, 204, 220, 222 the engagement feature does not need to define a re-entrant feature.

As best shown in Figures 5, 7 the neck region 236 and head region 238 may extend substantially along the full length of a side of the main body 234, thereby forming a re-entrant groove 237 which therefore also extends along the full length of a side of the main body 234. The engagement feature 232 may be a in the form of a stud, button or mushroom and may be generally symmetric about an axis extending generally normal to the surface of the insert member it extends from. A number of such engagement features 232 may be present along the surface and in a line, e.g. generally in the radial direction.

An engagement feature 232 may be provided on opposing sides of the main body 234. Alternatively, an engagement feature may only be provided on one side of the main body 234. A pair of engagement features 232 may be provided on opposing sides of the main body 234. Hence the insert member 230 may comprise one or two pairs of engagement features 232 (i.e. for engagement with two walls or four walls respectively).

The representation of the insert member 230 in the Figures is entirely schematic. The relative dimensions of the side of the main body 234 as well as the neck region 236 and head 238 may vary compared to that shown.

As can be seen in Figure 3, the wall, for example wall 202, is formed around the head region 238 and extends between the head region 238 into the space 237 between the head region 238 and the main body 234 of the insert member 230 to thereby engage with the engagement feature 232 and hold the insert member 230 in a fixed position relative to the wall 202.

Figure 8 shows an alternative example of an aerofoil with an insert member 230 according to the present disclosure. In this example the insert member 230 defines a flow aperture 240 which extends from one side of the main body 234 of the insert member 230 through to an opposite side of the main body 234 of the insert member 230. That is to say, in Figure 8 there is shown an aperture 240 which extends through a region of the main body 234, but which does not extend the full height of the main body 234. A plurality of apertures 240 may be provided in the main body 234, each extending from one side of the insert member 230 through to an opposite side of the insert member 230.

Hence the example shown in Figure 8 is similar to the example shown in Figure 3, except for the provision of the aperture, or apertures, 240. Figure 8 also shows a rounded leading edge 214, which may, or may not, be present in the example of Figure 3.

Figure 9 shows an alternative example of an aerofoil 200 according to the present disclosure. In this example the insert member 230 defines a first flow passage 250 which extends through the insert member 230. The insert member 230 first flow passage 250 is in flow communication a supply passage 252 in one or more of the walls 202, 204, 220, 222 of the aerofoil 200 from which the insert member extends. That is to say the first flow passage 250 is in flow communication with a supply passage 252. The supply passage 252 may be a passage through another component or structure, for example a component/structure which support/carries the aerofoil. For example the supply passage 252 may be defined by the flow route indicated by C in Figure 2, where the flow route C is defined by walls of the turbomachine. Alternatively the supply passage 252 may be a passage through the rotor disc 90 which mounts the rotor blade 100 as shown in Figure 2. In the example of Figure 9 the first flow passage 250 is in flow communication with the supply passage 252 provided in the third wall 220 and/or fourth wall 222 of the aerofoil 200.

As shown in Figure 9, the insert member 230 comprises a middle wall section 254, a first wing section 256 which extends from the middle wall section 254, the first flow passage 250 being provided in the first wing section 256. The insert member of Figure 9 also comprises a second wing section 258 which extends from the middle wall section 254 in a direction away from the first wing section 256. A second flow passage 260 is provided in the second wing section 258. The second flow passage

258 is in flow communication with the supply passage 252. The first flow passage 250 and second flow passage 260 are linked by a series of apertures 262 which extend between sides of the middle wall section 254. A plurality of apertures 262 may be provided along the height of the middle wall section 254.

In the examples shown in Figure 9 the first wing section 256 extends from the middle wall section 254 part, but not all, of the way towards the common leading edge 214. Hence there is a gap maintained between the first wing section 256 and the inner surfaces 208, 212 of the walls 202, 204. Likewise the second wing section 258 extends from the middle wall section 254 in a direction away from the first wing section 256 part, but not all, of the way towards the common trailing edge 216. Hence there is a gap provided between the second wing section 258 and the inner surfaces of the walls 202, 204 which define the cavity 218B.

In the example of Figure 10, the features of the aerofoil are similar to that shown in the earlier Figures. In the particular case of Figure 10, the example relates to a rotor blade for a turbine. In this example only a part of a cross section of the rotor blade is shown, being the region where the insert member 230 is engaged with the fourth wall 222 (i.e. the blade tip), and extends from the fourth wall 222 to the third wall 220 (not shown) to thereby divide the cavity 218 between the first wall 202 and second wall 204. That is to say, whereas in the preceding examples the insert member 230 divides the cavity 218 between the leading edge 214 and trailing edge 216, in the example of Figure 10 the insert member 230 extends between the leading edge and the trailing edge to divide the cavity 218 longitudinally along the length of the aerofoil 200. The insert member 230 of the Figure 10 example may comprise any of the features of the insert member 230 examples previously described.

An aerofoil according to the present disclosure may be manufactured by the method of first manufacturing the insert member 230 by a first manufacturing process, and then forming the aerofoil walls 202, 204, 220, 222 by a second manufacturing process so as to fix the insert member 230 relative to the wall 202, 204, 220, 222. The first manufacturing process may be an additive manufacturing process.

An additive manufacturing process is a method by which material is formed together in a progressive way to form a product. For example selective laser deposition, or other such 3D printing type methods. The second manufacturing process may comprise a casting process. For example an investment casting method, or other method comprising a casting process.

Hence after production of the insert member 230, the insert member 230 may be included in a core member (for example a ceramic core die) which defines the internal features of the aerofoil being formed. As is well known, the core may then be mounted in a wax material and placed in a mould casing into which a molten material may be flowed which displaces the wax to flow around the engagement features 232 of the insert member 230. Alternatively the molten material may fuse or bond with the sides of the insert member 230. That is to say the insert member 230 comprises an engagement feature 232, and the wall, or walls 202, 204, 220, 222 are formed around the engagement feature 232.

The insert member 230 may be held in the core die either by using the form of the insert member (i.e. engaging with an outer surface of the insert member) or the engagement feature 232.

Hence the first manufacturing process is different and/or separate to the second manufacturing process.

In an alternative example, the second manufacturing process may be the same as the first manufacturing process. That is to say, both the insert member 230 and the walls of the aerofoil may be formed by an additive manufacturing process, such as selective laser melting. In such an example the insert member 230 is manufactured first, and then the other material for the walls is provided around the insert member 230.

Put another way the insert member 230 is provided as an insert, that is to say a preformed element, which is not formed at the same time as the walls of the aerofoil. Put another way the insert member 230 is manufactured independently of the walls of the aerofoil, and formed prior to the walls of the aerofoil.

The insert member 230 may be formed from a first material, and the walls of the aerofoil 200 are formed from a different material.

The insert 230 may be formed from a suitable nickel based super alloy, with the final material choice being dependent upon operating requirements (e.g. temperature, pressure, strength) and interaction response (e.g. due to thermal expansion and contraction, vibration and stress) with the base material of the aerofoil. Examples of such alloys include IN738, IN939, Rene80, Alloy247.

The walls of the aerofoil may also be formed from a suitable nickel based super alloy, with the final material choice being dependent upon operating requirements (e.g. temperature, pressure, strength). Examples of such alloys include IN738, IN939, Rene80, Alloy247.

The material which forms the insert 230 may be different to the material which forms the walls of the aerofoil. However the properties of the materials of the insert 230 and the walls of the aerofoil must be matched for desired properties, for example thermal expansion and contraction, fatigue and creep resistance.

Hence there is provided an aerofoil, and a method for manufacturing an aerofoil, which provides for greater certainty of structural integrity, as well as providing great flexibility of design of internal walls of an aerofoil.

Additionally the associated casting process may be simplified as core die features for forming internal walls of aerofoils, which are in themselves complex to manufacture, are not required, or required to a lesser extent.

The apparatus and method of the present disclosure provide an opportunity to increase the performance of turbine blades and vanes. For example the insert member 230 could be provided with complex geometry not possible by conventional investment casting techniques, for example defining complex cooling hole geometry or wall shape, prior to inclusion into the walls of the aerofoil.

Additionally features of core die and hence subsequent casting may be removed, which may impact on the structure of the aerofoil, allowing for removal of extra wall thickness in regions where it is provided only to allow casting of internal walls. Hence a component of the present invention may thus be lighter than an aerofoil made by a conventional method, which reduces loading during operation.

Using less material in the casting process also directly reduces cost as less material is used to manufacture the aerofoil.

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.

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.

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.

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 method of manufacturing an aerofoil (200), the aerofoil comprising:

a wall (202, 204, 220, 222) which defines at least part of a cavity (218) within the aerofoil (200);

an insert member (230) which extends from the wall (202, 204, 220, 222);

the method comprising the steps of :

manufacturing the insert member (230) by a first manufacturing process; and then

forming the aerofoil wall (202, 204, 220, 222) by a second manufacturing process so as to fix the insert member (230) relative to the wall (202, 204, 220, 222).

2. A method of manufacturing an aerofoil (200) as claimed in claim 1 wherein

the insert member (230) comprises an engagement feature (232), and

the wall (202, 204, 220, 222) is formed around the engagement feature (232).

3. A method of manufacturing an aerofoil (200) as claimed in claim 1 or 2 wherein

the first manufacturing process is different to the second manufacturing process.

4. A method of manufacturing an aerofoil (200) as claimed in claim 3 wherein

the first manufacturing process is an additive manufacturing process.

5. A method of manufacturing an aerofoil (200) as claimed in claim 3 or claim 4 wherein

the second manufacturing process comprises a casting process.

6. An aerofoil (200) for turbo machinery comprising:

a first wall (202) having

an outer surface (206) and an inner surface (208);

a second wall (204) having

an outer surface (210) and an inner surface (212);

the first wall and second wall extending from a common leading edge (214) to a common trailing edge (216);

the first wall (202) and second wall (204) spaced apart between the leading edge (214) and trailing edge (216) such that their inner surfaces (208, 212) define a cavity (218);

a third wall (220) and fourth wall (222) provided at opposite ends of the cavity (218),

which each extend between the first wall (202) and second wall (204);

an insert member (230) which extends from one of the first wall (202), second wall (204), third wall (220) and/or fourth wall (222).

7. An aerofoil (200) as claimed in claim 6, wherein

the insert member (230) extends between two of the first wall (202), second wall (204), third wall (220) and/or fourth wall (222).

8. An aerofoil (200) as claimed in claim 7, wherein

the insert member (230) extends between the first wall (202) and second wall (204)

to thereby divide the cavity (218) between the leading edge (214) and trailing edge (216).

9 An aerofoil (200) as claimed in claim 3, wherein

the insert member (230) extends between the third wall (220) and fourth wall (222)

to thereby divide the cavity (218) between the first wall (202) and second wall (204).

10. An aerofoil (200) as claimed in any one of claims 6 to 9, wherein

the insert member (230) is fused to the wall(s) (202, 204, 220, 222) from which it extends.

11 An aerofoil (200) as claimed in any one of claims 6 to 10, wherein

the insert member (230) comprises an engagement feature (232) for fixing the insert member (230) relative to the wall (202, 204, 220, 222) from which it extends.

12. An aerofoil (200) as claimed in claim 11, wherein

the engagement feature (232) comprises :

a neck region (236) which extends from the insert member (230); and

a head region (238) which extends from the neck region (236);

the head region (238) being wider than the neck region (236) such that the head region (238) and neck region (236) form a re-entrant feature for engagement with the aerofoil wall (202, 204, 220, 222).

13. An aerofoil (200) as claimed in any one of claims 6 to 12, wherein

the insert member (230) defines a flow aperture (240) which extends from one side of the insert member (230) through to an opposite side of the insert member (230).

14. An aerofoil (200) as claimed in any one of claims 6 to 12, wherein

the insert member (230) defines a first flow passage (250) which extends through the insert member (230),

the insert member (230) first flow passage (250) being aligned with a supply passage (252) in the wall(s) (202, 204, 220, 222) of the aerofoil (200) from which the insert member (230) extends.

15 An aerofoil (200) as claimed in claim 14, wherein

the supply passage (252) is provided in the third wall (220) and/or fourth wall (222) of the aerofoil (200), and

the first flow passage (250) is in flow communication the supply passage (252).

16. An aerofoil (200) as claimed in claim 14 or claim 15, wherein :

the insert member (230) comprises:

a middle wall section (254)

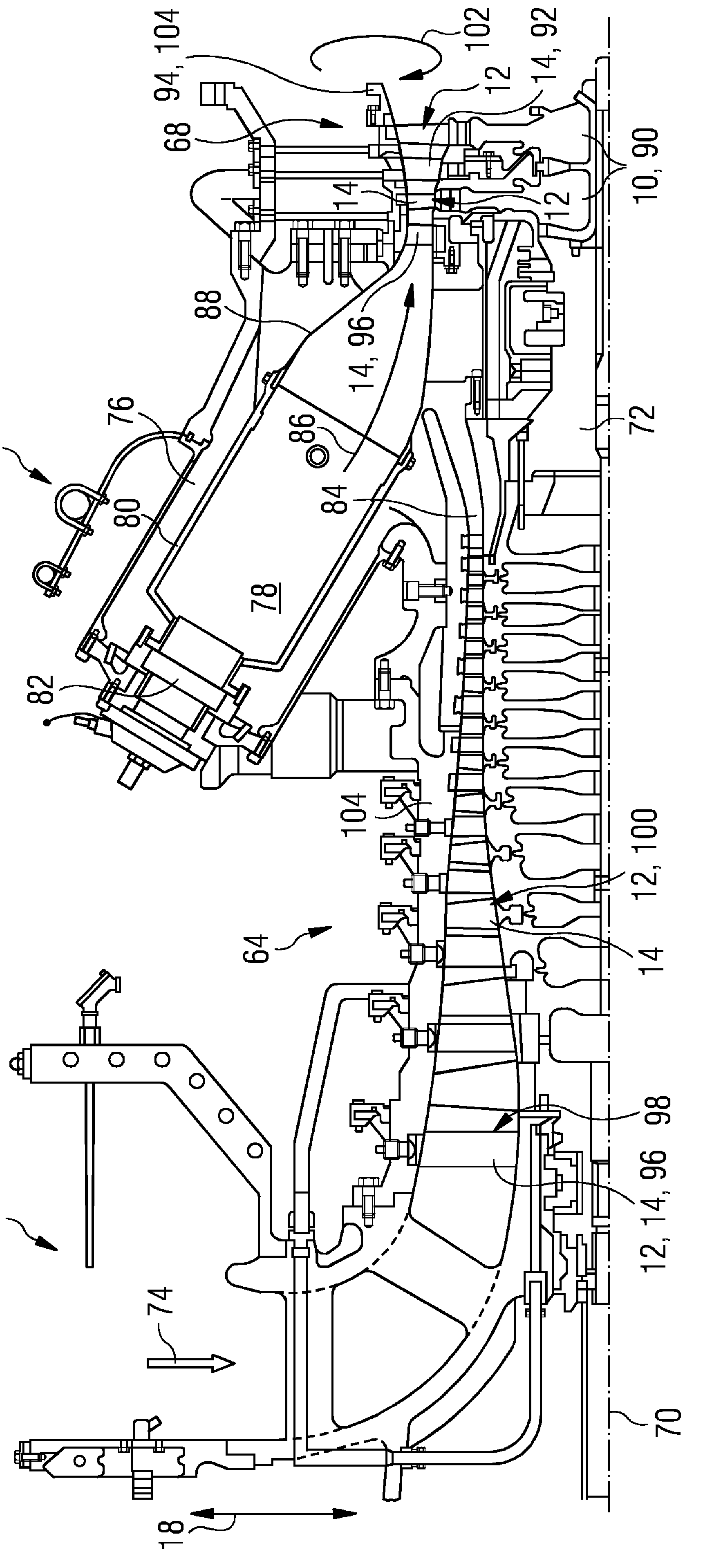
a first wing section (256), which extends from the middle wall section (254);

the first flow passage (250) being provided in the first wing section (256);

a second wing section (258), which extends from the middle wall section (254) in a direction away from the first wing section (256);

a second flow passage (260) being provided in the second wing section (258);

the second flow passage (258) being in flow communication with the supply passage (252).


94, 104
102
12
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14
12
10, 90
88
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76
66
86
72
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82
50
104
12, 100
64
14
62
98
12, 14, 96
74
70
18

FIG 1

FIG 2

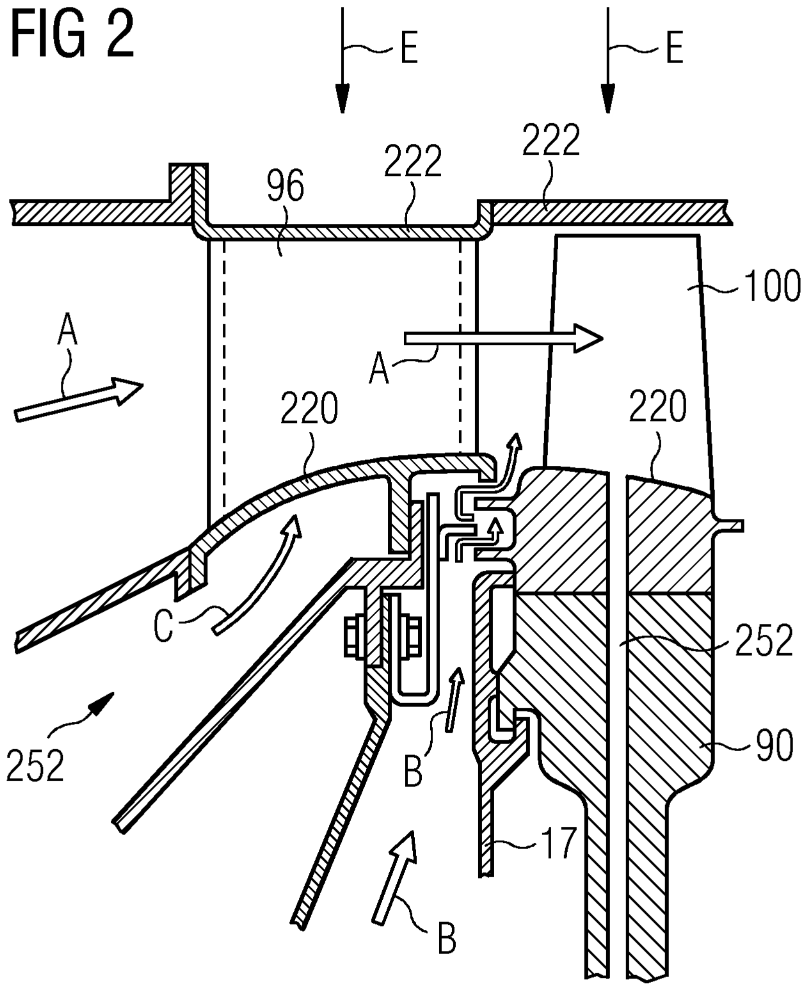

E
E
96
222
222
100
A
A
220
220
C
252
252
B
B
90
17

FIG 3

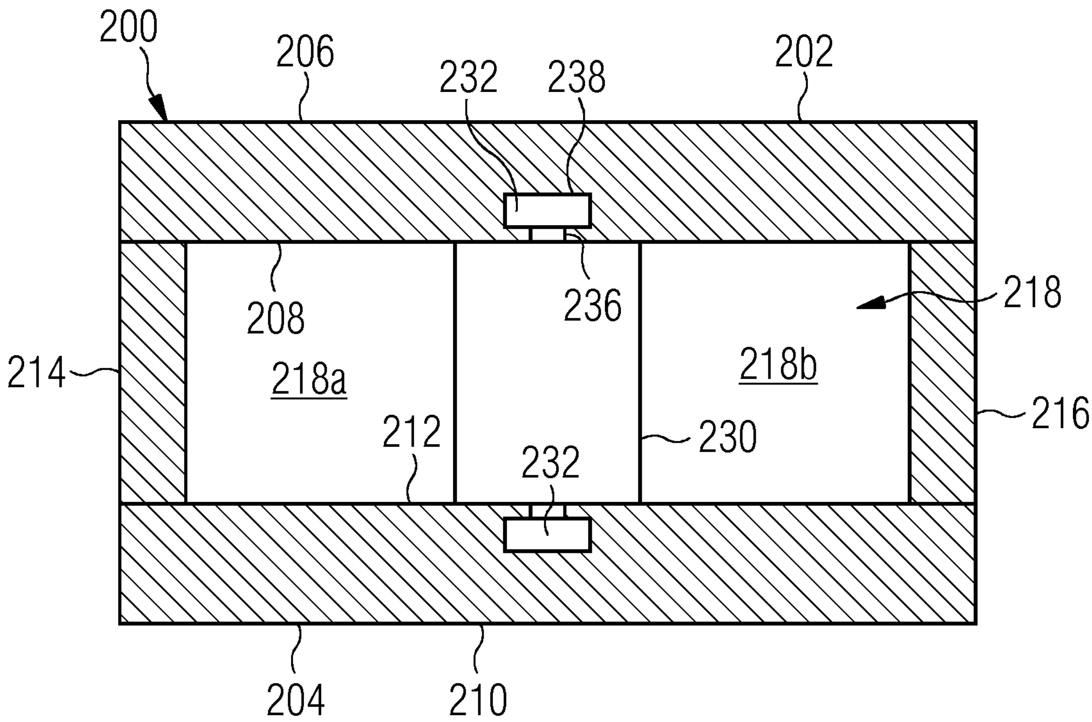

200
206
202
232
238
236
218
208
214
218a
218b
216
212
230
232
204
210

FIG 4

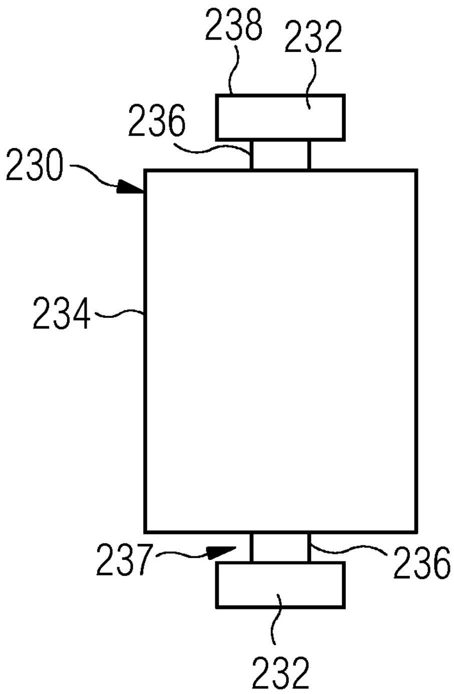


FIG 6

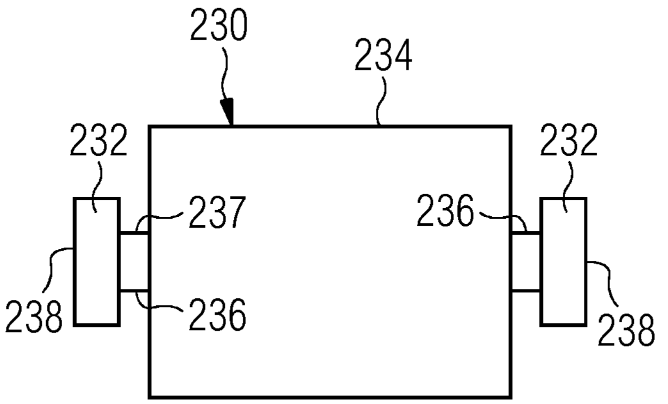


FIG 5

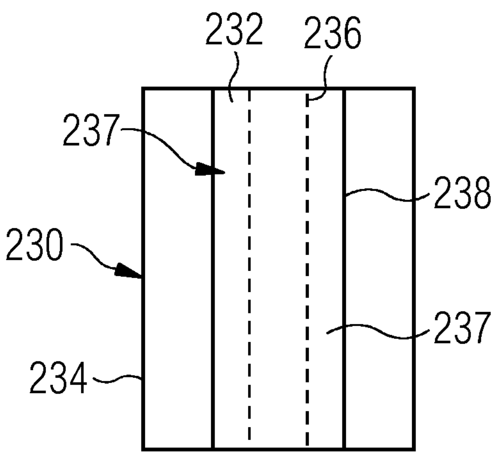


FIG 7

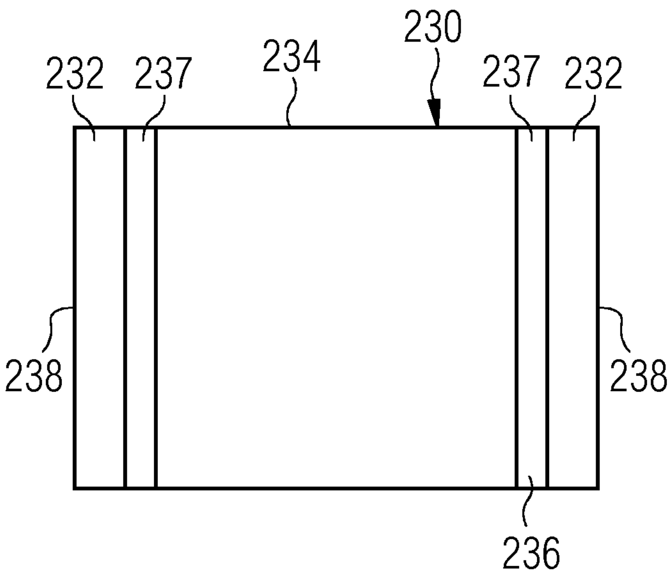


FIG 8

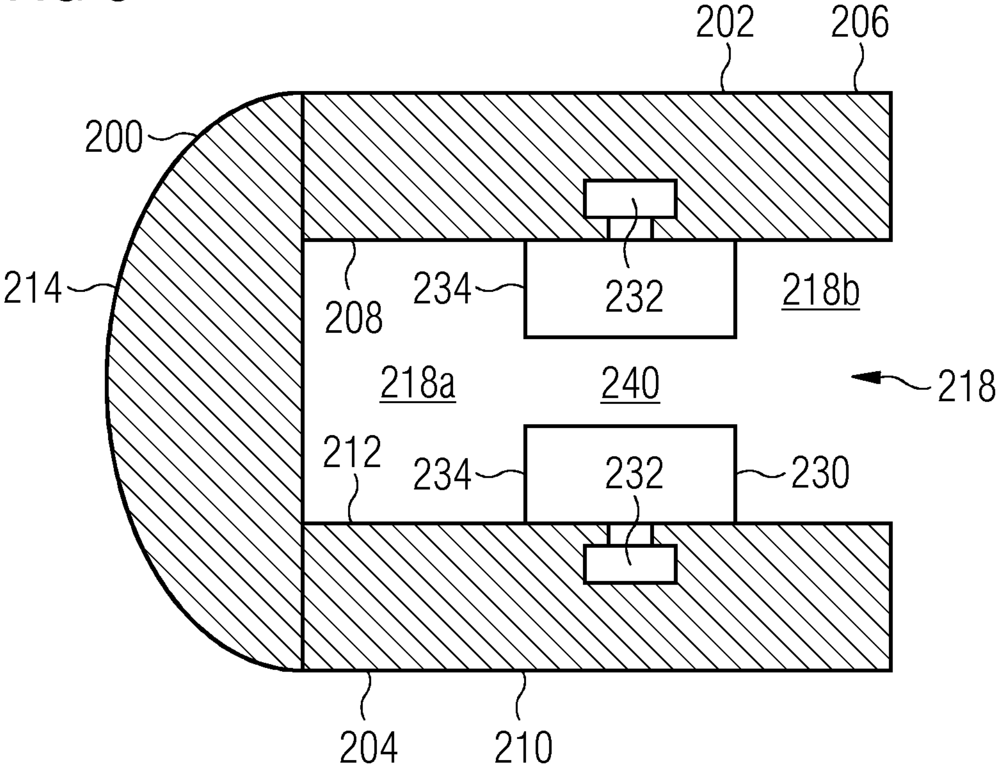

202
206
200
214
208
234
232
218b
218a
240
218
212
234
232
230
204
210

FIG 9

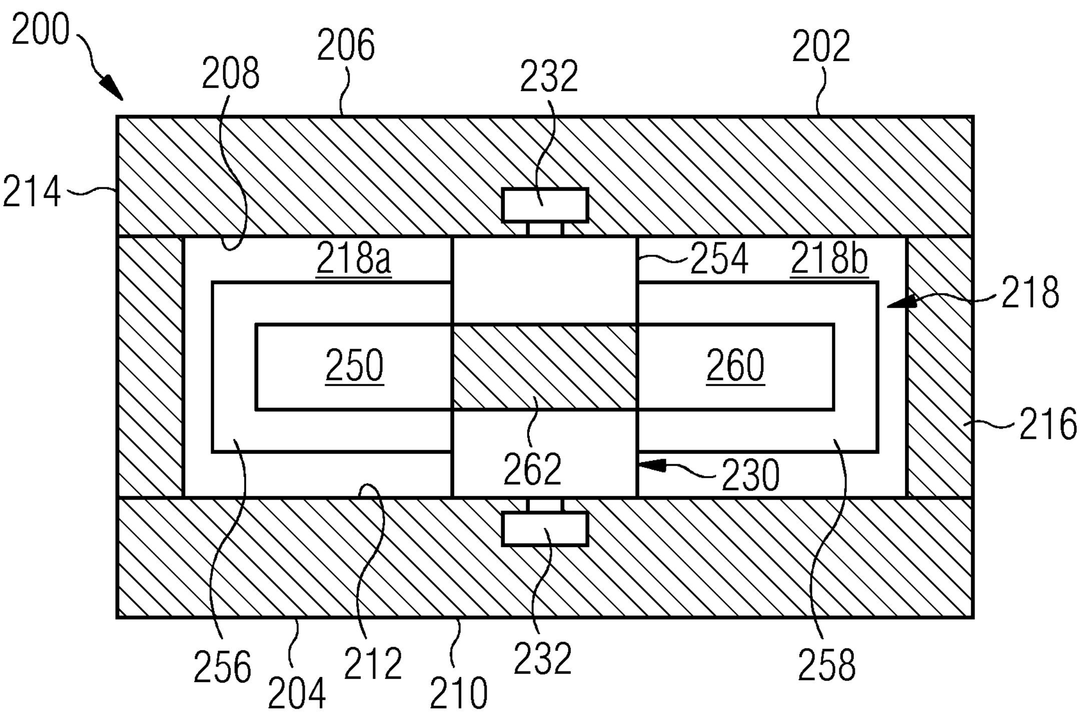
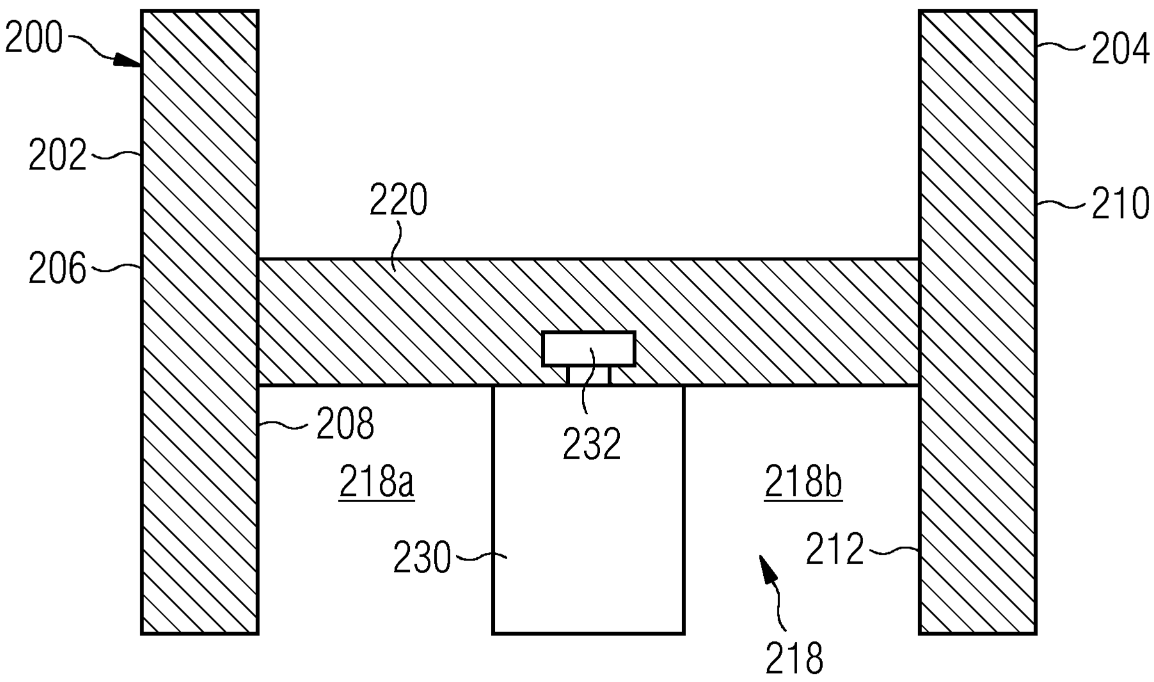

200
206
202
208
232
214
218a
254
218b
218
250
260
216
262
230
256
204
212
210
232
258

FIG 10



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2018/060002

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01D5/18
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2011/021693 A1 (IHI CORP [JP]; MIZOGAMI YOUSUKE [JP]; KUROKI HIROSHI [JP]) 24 February 2011 (2011-02-24) figures 1-3 -----	6
X	WO 2016/058900 A1 (SIEMENS AG [DE]) 21 April 2016 (2016-04-21) page 9, line 10 - line 21; figure 1 page 7, line 9 - page 8, line 3 -----	1-6, 10-12
X	US 5 259 730 A (DAMLIS NICHOLAS [US] ET AL) 9 November 1993 (1993-11-09) page 2, column 3, line 10 - line 59; figure 1 -----	1-3, 10-12
A	EP 2 703 601 A1 (ALSTOM TECHNOLOGY LTD [CH]) 5 March 2014 (2014-03-05) figure 2 -----	12

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 July 2018	13/09/2018

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Delaitre, Maxime

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2018/060002

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-6, 10-12

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-6, 10-12

   Airfoil with a cavity and an insert with fixation means to attach the insert member to the walls of the cavity.

   ---

2. claims: 7-9

   Airfoil with a cavity and an insert member located in a particular way for dividing the cavity.

   ---

3. claims: 13-16

   Airfoil with a cavity and an insert member and cooling means to cool the airfoil.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2018/060002

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2011021693 A1	24-02-2011	JP 2011043118 A	03-03-2011
		WO 2011021693 A1	24-02-2011
WO 2016058900 A1	21-04-2016	CN 107075954 A	18-08-2017
		DE 102014220787 A1	14-04-2016
		EP 3191690 A1	19-07-2017
		US 2017306766 A1	26-10-2017
		WO 2016058900 A1	21-04-2016
US 5259730 A	09-11-1993	NONE	
EP 2703601 A1	05-03-2014	AU 2013221909 A1	20-03-2014
		CN 103696810 A	02-04-2014
		EP 2703601 A1	05-03-2014
		JP 6016739 B2	26-10-2016
		JP 2014047788 A	17-03-2014
		KR 20140029282 A	10-03-2014
		RU 2013140190 A	10-03-2015
		US 2014234088 A1	21-08-2014