



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
09.03.2016 Bulletin 2016/10

(51) Int Cl.:
B22C 9/04 (2006.01) **B22C 9/10** (2006.01)
B22C 21/14 (2006.01)

(21) Application number: **15181567.7**

(22) Date of filing: **19.08.2015**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA

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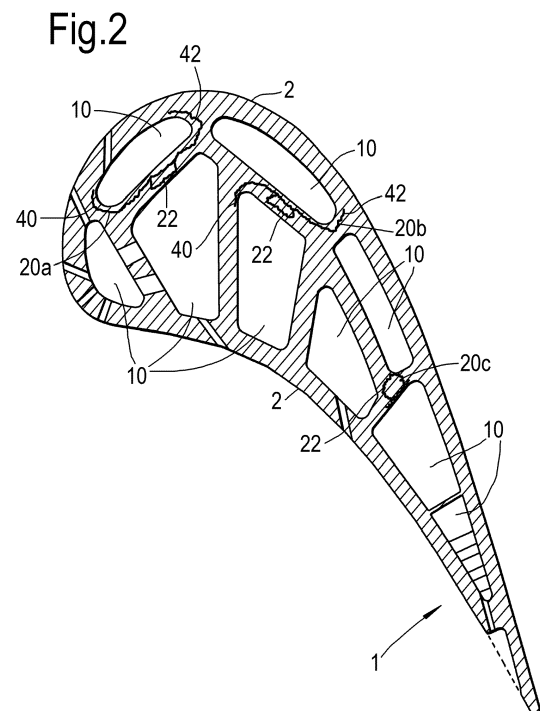
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(30) Priority: **05.09.2014 GB 201415725**

(54) **COMPONENTS FOR CASTING OF ENGINE PARTS**

(57) A process for investment casting of an engine part, such a high-performance turbine blade (B), having at least one internal cavity (C), in which at least one ceramic core member (10) defining the or a respective cavity (C) is maintained in a desired spatial position relative to at least one other component, e.g. another core member (10), of or within a die during at least part of the casting procedure, the at least one core member (10) being maintained in the desired spatial position by at least one support element (20a, 20b, 20c), wherein the or each support element (20a, 20b, 20c) comprises an elongate member, e.g. a length of platinum wire, configured to include therein at least one turn or coil (22, 24) with opposed sides (30, 32), the elongate member being positioned between the respective core member (10) and respective other component (10) with the opposed sides of its at least one turn or coil (22, 24) in space-maintaining relationship between the respective core member (10) and respective other component (10).



Description

TECHNICAL FIELD

[0001] This invention relates to components for use in casting of engine parts. More particularly, though not exclusively, it relates to components for use in investment casting of engine parts such as turbine blades.

BACKGROUND OF THE INVENTION AND PRIOR ART

[0002] Investment casting processes are widely used to create hollow, near net-shape metal components, e.g. turbine blades, by pouring molten metal into a ceramic mould of the desired final shape and subsequently removing the ceramic. The process is an evolution of the lost-wax process, wherein a component of the size and shape required in metal is manufactured in wax using wax injection moulding, which pattern is then dipped in ceramic slurry to create a shell; the wax is then removed and the shell fired in order to harden it. The resulting shell thus has one or more open cavities therewithin for receiving molten metal when poured inside, the cavities being of the size and shape required for the final component, e.g. a turbine blade.

[0003] Often engine parts are required to have complex internal cavities for the purpose of acting as internal cooling channels. To form such internal cavities, at least one, and often several, ceramic core(s) is/are required in order to define and form the internal channels during the casting process. The cores are manufactured separately and placed inside the wax pattern die prior to wax injection. After casting the alloy the cores are leached out with alkaline solution to leave the hollow metal component.

[0004] During the various stages of the metal casting process, these cores must be located within the wax injection die and held in clearly defined, stable relative positions until the metal solidifies around them. This accurate positioning is required *inter alia* for producing cast wall sections of accurate thicknesses and with optimum stress resistance properties. However, the ability to maintain such cores accurately in desired positions during the casting process is difficult and presents several practical problems.

[0005] Historically one well-used technique for maintaining cores in desired positions during the casting process has involved the use of platinum pins, e.g. of the order of 1 - 2 mm in diameter, which are passed transversely through the wax pattern prior to the application of the ceramic shell and thus hold the core in position relative to one or more neighbouring cores or other components within the die until the metal is cast. The platinum pins simply dissolve in the cast metal once it is poured and solidifies, which for many metal alloys destined for turbine blades and other engine parts is acceptable and does not adversely affect the properties of the resultant casting.

[0006] Other known proposals for tackling the same problem have included:

- using platinum chaplets to support the core walls, as disclosed for example in GB2281238A;
- forming ceramic "bumpers" on the core which locally touch one or more neighbouring cores or other components within the die and allow the desired wall section to be maintained during the casting process, as disclosed for example in US5296308; and
- using a platinum wire woven between and around multiple core passages to maintain the desired cast wall thickness, as disclosed for example in US4487246.

[0007] However none of these known proposals is wholly satisfactory and they all present additional problems. For instance:

- the cost of platinum is high, so the use of platinum pins, chaplets and wires, which all use relatively large amounts of the metal, is generally undesirable;
- the use of chaplets makes locating them accurately in the core body practically difficult;
- it is practically difficult to securely and accurately support a core in a given position relative to a neighbouring core or other component when the core wall is not generally parallel to the neighbouring core wall or component surface, as is the case with many turbine blade geometries, and so the above known techniques at best only have limited efficacy in ameliorating this particular problem;
- with the use of bumpers, in a single crystal metal casting (as is desirably the case with high-performance turbine blades) re-crystallisation near the site of the bumpers can cause problems with localised weaknesses, leading to deleterious lifing issues with the associated thin bumper wall;
- with the use of a woven platinum wire to hold core sections in place, the physical process of weaving the wire into the correct holding position is fiddly, difficult and time-consuming. It also tends not to produce a wall section with enough of a controlled thickness, since the wire can at best only define the relative positions of the cores approximately, and the arrangement of the woven wire itself is prone to bending, leading to positional inaccuracies.

SUMMARY OF THE INVENTION

[0008] It is thus a primary object of the present invention to ameliorate or at least partially solve at least some of the shortcomings of the above prior art techniques and to provide a system for the accurate positioning of cores within a die in an investment casting process which leads to greater accuracy and stability of the cores' positioning and thus can lead to cast metal walls having improved characteristics.

[0009] Aspects of the present invention relate to a process for investment casting of an engine part, a support element for use in the casting process, an engine part produced by the casting process, and an engine including a part made by the process.

[0010] In a first aspect of the present invention there is provided a process for investment casting of an engine part having at least one internal cavity, in which at least one core member defining the or a respective cavity is maintained in a desired spatial position relative to at least one other component of or within a die during at least part of the casting procedure, the at least one core member being maintained in the desired spatial position by at least one support element, wherein the or each support element comprises a drawn elongate member configured to include therein at least one turn with opposed sides, the drawn elongate member being positioned between the respective core member and respective other component with the opposed sides of its at least one turn in space-maintaining relationship between the respective core member and respective other component.

[0011] The support element may comprise a shaped wire, this allows the support element to be of a different material to the cast component. This is a particular advantage when the component comprises a superalloy. As it is desirable to match the material of the element with the casting, there is a significant cost advantage in a wire. Work hardening in the wire drawing process provides improved strength and permits cheaper materials to be used for the support elements in alternative to the cast component material.

[0012] The investment casting process of the invention may be used to cast a wide variety of engine parts, but it is especially applicable to the casting of high-performance engine parts such as turbine blades, such as for use in a gas turbine engines e.g. for aircraft. Such parts, which are often formed from high-performance metal alloys and required to have a single-crystal metal structure, are desirably formed with metal walls defining various, often complex, internal cavities for the passage of cooling air therethrough which have accurately controlled wall thicknesses and geometries. Thus the invention is especially applicable to the casting of such turbine blades and other high-performance engine parts.

[0013] In embodiments of the process of the invention the one or more cores whose spatial positioning is to be maintained in a controlled manner may be selected from any number and/or shape and/or geometry of one or more cores as may be necessary or desired for the casting of any given engine part.

[0014] In embodiments the at least one other component of or within the die may be one or more other cores also being positioned within an overall die within which the part is to be cast. Alternatively or additionally the at least one other component may be an element of the die itself, e.g. an internal surface of a die outer shell or wall. Indeed, in embodiments of the subject process the at

least one support element which characterises the present invention may be utilised to control the relative spatial positioning of any two or more neighbouring or adjacent walls, surfaces or elements of or within a die during an investment casting procedure.

[0015] In embodiments of the invention any number of the said support elements may be used to control the spatial positioning of any number of core members, depending for example on their physical geometries, the number and geometries of any neighbouring or adjacent cores or other component(s) of or within the die, and generally the degree to which appropriate supporting of the relevant core members(s) may be necessary or desirable for optimum stability and accuracy of positioning during the relevant part(s) of the investment casting procedure.

[0016] In some embodiments of the invention the at least one support element may preferably comprise an elongate member configured to include therein at least one loop with opposed sides.

[0017] In some embodiments the elongate member forming the or the respective support element may be configured into a looped member comprising a plurality of turns with opposed sides.

[0018] In some embodiments the elongate member may be configured so as to include a coil, e.g. a coil having any number of windings, such as from 2 up to about 5 or about 10 (or perhaps even up to about 15 or more) windings. The number of windings may be selected for example to give the support element any particular desired overall size and/or strength.

[0019] In some embodiments the coil or other looped member forming the or each support element may include at least one, optionally a pair of, free end portions, which may usefully be employed, in addition to the coiled or other looped or turn-containing portion thereof, for further supporting and/or positioning the respective core in its desired position relative to the one or more other components. For example one or both of the free end portions of the support element may be used to grip or attach itself to a or a respective part of the respective core to be positioned and/or of the respective other component.

[0020] In some embodiments of the invention the support element comprising the said coil-, or loop(s)-, or turn(s)-containing elongate member may be oriented, relative to a wall or surface of the core whose spatial position is to be maintained, with its coil, loop(s) or turn(s) bearing against the said core wall or surface with its axis of highest spring constant (i.e. maximum stiffness) generally substantially normal to the said core wall or surface (at least at or in the vicinity or region of its bearing thereagainst). Thus, in the case of a supporting element comprising a coil, it may preferably be oriented with its longitudinal winding axis generally substantially parallel to the said core wall or surface (at least at or in the vicinity or region of its bearing thereagainst).

[0021] However, in certain other embodiments the orientation of the coil-, or loop(s)-, or turn(s)-containing elongate member may be perpendicular to that defined

above, so that its longitudinal winding axis is generally substantially normal to the said core wall or surface (at least at or in the vicinity or region of its bearing thereagainst), whereby the support elongate element may act more as a true spring, taking advantage of its lower spring constant along its longitudinal winding axis.

[0022] In some embodiments the elongate member forming the or the respective support element may be formed from a length of wire. To form the said coil- or loop- or other turn-containing support element the wire may be formed into the required shape by any suitable means. For example it may be wound around a mandrel so as to adopt its desired shape and configuration. However, other winding apparatuses and techniques may alternatively so be used.

[0023] In many embodiments the or each elongate member forming the or the respective support element may usefully be formed of a material, especially a metal, whose residual presence in the cast engine part is tolerable or does not adversely affect the desired properties of the cast engine part. Thus, in practical embodiments of the process of the invention the one or more support elements may remain within the metal of the cast engine part, preferably by virtue of being dissolved or dispersed therein during the metal pouring and solidifying step, without any significant deleterious implications therefor.

[0024] Suitably the material used to form the or each support element in embodiments of the invention may be selected from a metal or metal alloy which is readily deformable (by virtue of its malleability) but preferably also of medium or low resilience, whereby it can be configured readily into the requisite form and shape by straightforward mechanical means, e.g. by manual or mechanical winding. Suitably the material used to form the support element in embodiments of the invention may be selected from one or more of: platinum, an alloy of platinum with one or more other metals, a platinum-nickel alloy, nickel, nickel coated with one or more other metals, and other metals, alloys or materials currently used for core-positioning components in known investment casting processes. A particularly preferred material may be platinum metal, e.g. in the form of platinum wire, such as with a diameter in the range of from about 0.1 to about 1 or 1.5 mm, preferably from about 0.25 to about 1 mm. Examples of suitable platinum wires are widely commercially available.

[0025] In some embodiments of the process of this first aspect of the invention, at least one of the respective core member and/or respective other component whose relative spatial positioning is to be controlled by the turn-containing elongate support element may include at least one surface formation for location therein of at least part of the or each said support element, whereby its positioning relative to the said respective core member and/or respective other component may be facilitated and/or more accurately assured.

[0026] Such one or more surface formations may take the form, for example, of one or more recesses, wells,

channels or passages formed a short distance (e.g. to a depth of from about 0.1 or 0.2 or 0.3 up to about 0.5 or 1.0 or 1.5 mm, or perhaps even up to about 2 or 3 or even 5 mm for larger scaled engine parts) into the outer surface or wall of the respective core or other component. Although the use of such recessed or other surface formations may typically result in some small localised increases in the resulting cast wall thickness at the sites of the surface formations on the relevant core members, this may generally be acceptable in practice, because such resultant features in the cast metal wall may be expected not to deleteriously affect the wall material's resulting physical properties, unlike small localised decreases in wall thicknesses, which may have the opposite effect.

[0027] In some embodiments such one or more said surface formations may be provided in one only of the said respective core or other component, preferably at the or each location or region at which the or respective support element(s) is/are to bear thereagainst to fulfil its/their supporting function. However, in other embodiments such one or more said surface formations may be provided in both of the said respective core and other component, at mutually generally opposite locations or regions thereon at which the or respective support element(s) is/are to bear thereagainst to fulfil its/their supporting function.

[0028] The provision and use of the above-defined one or more surface formations may be useful in certain embodiments not only for assisting optimum positioning of the or each relevant support element in its respective position on or against the relevant wall or outer surface of the relevant core to be supported, but also for the purpose of directing placement of particular ones of a plurality of support elements at correct ones of different sites or locations around any arrangement of one or more cores. This may be useful for example where a plurality of differently-configured support elements are provided each for placement at a specific or unique site or location on or between given core(s), and so may aid and speed up the task of assembling a particular overall core assembly within a die ready for investment casting. Colour-coding of specific support elements and their matching appropriate sites or locations on the relevant core(s) may further assist this task.

[0029] Embodiments of the invention may be applied to the positioning of one or more cores with respect to one or more other components of or within the die during any stage of an overall investment casting operation. For example embodiments of the invention may be applied in particular to the step of locating and positioning one or more ceramic cores within a die prior to the pouring of molten metal therein for the actual casting of the final metal part. Alternatively they may be applied to any earlier stage in an overall investment casting operation, such as the production of the initial wax pattern itself, where corresponding usefulness in being able to stably and accurately position one or more core members relative to

one or more other components may also present itself.

[0030] In a second aspect of the present invention there is provided a support element for use in a process according to the first aspect of the invention or any embodiment thereof.

[0031] Thus in embodiments of this second aspect of the invention there may be provided a support element for maintaining at least one core member in a desired spatial position relative to at least one other component of or within a die during at least part of a process for investment casting of an engine part having at least one internal cavity, in which the at least one core member defines the or a respective cavity, wherein the support element comprises a drawn elongate member configured to include therein at least one turn with opposed sides, the drawn elongate member being positionable between the respective core member and respective other component with the opposed sides of its at least one turn in space-maintaining relationship between the respective core member and respective other component.

[0032] Optional or preferred features of the support element of embodiments of this second aspect of the invention may correspond to any of the optional or preferred features of any embodiment support element defined herein in the context of the first, process, aspect of the invention.

[0033] In a third aspect of the present invention there is provided an engine part produced by a process according to the first aspect of the invention or any embodiment thereof.

[0034] In a fourth aspect of the present invention there is provided an engine, such as a gas turbine engine, including at least one part made by a process according to the first aspect of the invention or any embodiment thereof.

[0035] Particular or various embodiments of the invention may lead to one or more of any of the following advantages:

(i) Known core-supporting elements for use in existing investment casting processes typically do not lend themselves to maintaining and producing internal cast wall geometries and thicknesses at optimum required accuracies without compromising the designed wall geometry or requiring costly additional specialist platinum consumable items, as described above. Embodiments of the invention address and seek to at least partially ameliorate at least some such shortcomings. For example:

(ii) Embodiments of the invention may do away with the need for expensive, specialist-manufactured items such as platinum chaplets, e.g. as proposed in GB2281238A. This can also lead to reductions in amounts of platinum metal (an expensive precious metal) used, and in embodiments using platinum wire for making the subject support element(s), may utilise a commodity which may already be readily

available by virtue of being in use on-site in other contexts in the gas turbine engine industry.

(iii) Embodiments of the invention may do away with the currently preferred use of through-going pins (e.g. of platinum) which pass from one side of the pattern to be cast and keep the core element(s) in their desired spatial position(s). Generally this known technique only works if the pattern passage to be cast can be accessed from both sides thereof. This is frequently not the case with complex internal-cavitated engine parts like high-performance turbine blades, to which embodiments of the invention may be especially directed.

(iv) Embodiments of the invention may do away with the need for ceramic "bumpers" on the core(s), which are designed to locally touch neighbouring core(s) or other component(s) in order to maintain particular core spatial positioning(s) for creating particular desired cast wall geometries. However, since by their very nature such "bumpers" reduce the wall thickness in localised sections, they can lead to undesirable casting re-crystallisation, and can also act as a localised stress-raiser within the final cast part, both of which phenomena are undesirable in the production of modern high-performance engine parts like turbine blades.

(v) Embodiments of the invention may do away with the need for woven wires around and between plural core passages, e.g. as proposed in US4487246, for controlling particular cast wall geometries. Such woven wires do not provide accurate lateral positioning for cores in a linear bundle, as one proposal in US4487246 teaches. Thus embodiments of the present invention may be particularly useful in areas where enhanced precision of cast wall geometries is required. Moreover the use of woven wires as taught in US4487246 does not lend itself to the controlled positioning of pluralities of cores in the casting of engine parts with especially complex arrangements of plural internal cavities, as is often the case with modern high-performance turbine blades.

[0036] Within the scope of this application it is expressly envisaged that the various aspects, embodiments, examples and alternatives, and in particular the individual features thereof, set out in the preceding paragraphs, in the claims and/or in the following description and drawings, may be taken independently or in any combination. For example features described in connection with one embodiment are applicable to all embodiments, unless such features are incompatible.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of a modern high-performance turbine blade for use in an aircraft gas turbine engine, showing an arrangement of internal cavities to be formed by respective ceramic core members during the casting of the blade in an investment casting process;

Figure 2 is a cross-sectional view of the corresponding arrangement of core members for use in casting the blade of Figure 1, showing some (though not all, for clarity) of the core members being held in their desired relative spatial positions using some examples of specially formed and variously configured support elements in accordance with certain embodiments of the invention;

Figures 3(a) and (b) are side views of two further examples of specially formed and configured support elements suitable for use in embodiments of the invention;

Figure 4 is a cross-sectional view, corresponding to that of Figure 2 but omitting the support elements, of an arrangement of modified core members for use in alternative embodiments of the invention, in which the core members are provided with surface formations for assisting, and optionally also directing, placement of the various support elements in their correct positions and/or locations; and

Figure 5 is a cross-sectional view, corresponding to that of Figure 4, showing some (though not all, for clarity) of the variously configured support elements in position at their respective locations.

DETAILED DESCRIPTION OF EMBODIMENTS

[0038] Referring firstly to Figure 1, here there is shown by way of example an arrangement of complex-shaped internal cavities C within the body of a high-performance turbine blade B, such as of a gas turbine engine for use in aircraft. The various cavities C are defined by, and separated by, a network of walls M of cast metal, e.g. of a high-performance alloy grown as a single crystal during pouring thereof during an investment casting process. The general principles and stepwise procedures of such a casting process are well-known and widely commercially used, so need not be described in detail here.

[0039] Figure 2 shows the corresponding arrangement of ceramic internal cores 10 which are contained within an outer ceramic shell 2 in a die or mould (not shown) and ready for a metal-pouring stage of the investment casting procedure, which after completion of the pouring of the metal and its subsequent solidification results, after leaching out of the ceramic of the cores 10, the arrangement of cavities of the blade shown in Figure 1. The various cores 10 may themselves be made, and their particular general shapes designed and selected, in accordance with known investment casting principles and techniques, examples of which are already well-known and widely practised in the art.

[0040] As an important step in the preparation of the

arrangement of cores 10 shown in Figure 2 in readiness for the metal-pouring stage, it is important that the various cores 10 are spatially positioned as accurately as possible - both relative to each other and to the outer shell 2 - and as stably as possible, especially during the metal-pouring and any subsequent steps. This is so that the resulting metal-cast wall sections defining the various internal cavities within the blade have defined thicknesses and the cavities themselves defined geometries which are as accurate and consistent as possible, and within as narrow ranges of tolerances as possible.

[0041] To achieve and control this desired accurate spatial relative positioning of the various cores 10, a collection of support elements 20, such as 20a, 20b, 20c, etc, are employed to define predetermined spacings between particular portions of or sites on certain of the cores 10 and corresponding portions of or sites on neighbouring or adjacent cores 10.

[0042] It is to be understood that any number of support elements 20a, 20b, 20c, etc may be employed, depending for example on the number and arrangement of cores 10 and the precise portions thereof or sites thereon which need purposive separating and maintaining at carefully defined distances in order to maintain those cores in the desired mutually accurately defined spatial positional relationship. However, in Figure 2 only three such support elements 20a, 20b and 20c are shown for clarity.

[0043] Each support element 20a, 20b, 20c is configured as a looped or coiled length of wire, e.g. platinum wire (although certain other metal or metal alloy wires may be suitable instead). The wire may be of any suitable diameter, e.g. in the range of from about 0.25 to about 1 mm. Such wires are readily commercially available, and may even already be in use in other contexts in a given industrial site in the field of aircraft engine manufacture. However it will generally be preferred that the metal (or metal alloy) of the wire should be one that is compatible with - and not deleteriously affect the resultant physical properties of - the metal once it has been poured and solidified to form the required blade walls, since the metal wire support elements 20a, 20b, 20c will ultimately remain in the poured metal and be dissolved therein, as is currently the case with known platinum pins.

[0044] Each support element 20a, 20b, 20c is configured into its required shape for example by being wound manually or mechanically on an appropriately sized and shaped mandrel. Other known techniques for forming wound metal coils may alternatively be used.

[0045] Each support element 20a, 20b, 20c is shown here by way of example with a different shape and configuration, but it is to be understood that any desired shape and configuration of support elements may be employed, depending for example on the size and shape of the gap or spacing to be defined thereby and whether the support elements may for instance be designed to support just two adjacent or neighbouring cores 10, or perhaps even three (or possibly even more than three) adjacent or neighbouring cores 10, e.g. at a three-way

junction thereof. An example of the latter is the support element 20c as shown in Figure 2.

[0046] For better clarity, two further examples 20d, 20e of support elements suitable for use as support elements in accordance with embodiments of the invention are shown in Figures 3(a) and (b). Here each support element 20d, 20e is configured such that it comprises a central portion in the form of a coil 22, 24 with an appropriately selected number of turns or windings. These turns or windings collectively present two opposed sides 30, 32 of the relevant support element 20d, 20e, which in many preferred embodiments are those sides of the support element 20d, 20e which serve the primary locating and spatial positioning function. This primary functionality is shown by all three support elements 20a, 20b, 20c in Figure 2, where they can be seen to be supporting and maintaining in a defined spatial relationship the respective cores 10 upon or against which they are mounted or bear to fulfil their supporting and spacing function.

[0047] However, in the case of the example support element 20e of Figure 3(b), it is configured to additionally comprise a pair of terminal end portions 40, 42, one or both of which may serve a secondary locating and spatial positioning function, by virtue of being configurable so as to grip, grasp or otherwise engage or attach themselves to part of the relevant core 10. This same secondary functionality is also shown by the terminal end portions of the support elements 20a and 20b in Figure 2.

[0048] It is to be understood that many other examples of variously shaped and configured looped or coiled support elements 20 may be designed and utilised within embodiments of the invention, with those shown in Figures 2 and 3 being just a few illustrative examples.

[0049] As illustrated in Figure 2, each support element 20a, 20b, 20c is oriented at its respective location with its longitudinal coil axis generally parallel to the plane of the respective core outer walls against which it bears at the site of its placement thereagainst. This means that the maximum spring constant of the coil, which is directed along any transverse axis perpendicular to the coil's longitudinal winding axis, is exhibited by the support element in a direction generally substantially normal to the opposed core walls whose spacing is to be defined and maintained by the respective support element 20a, 20b, 20c. This therefore makes each coiled support element 20a, 20b, 20c appear relatively "stiff" in the direction in which it is intended to exert maximum spacing-maintaining force between the relevant cores 10.

[0050] Of course, however, in certain other alternative arrangements any one or more of the coiled support elements may be oriented oppositely, i.e. with its/their longitudinal winding axis(es) substantially normal to the relevant core walls. In this manner a less stiff spacing force may be able to be applied between adjacent cores, which may for example be useful if the invention is being applied for example to the spatial positioning of cores against portions of a wax pattern e.g. earlier in an overall investment casting process.

[0051] Turning to Figures 4 and 5 (in which features which correspond to those of the embodiments of Figure 2 are indicated with the same reference numerals but incremented by 100), here there is shown a modified embodiment in which some 110a of the cores 110 of any adjacent or neighbouring pair whose relative spatial positioning is to be controlled by the relevant coiled support elements 120f, 120g, 120h each has formed in its outer wall or surface a respective well, recess, channel or passage 180 for seating and location therein of the respective support element 120f, 120g, 120h, or at least a portion thereof, e.g. the central coiled portion thereof only, or possibly one of the terminal end portions thereof only. As shown in Figure 4, it may be desirable or appropriate that the wells, recesses, channels or passages 180 are formed in the walls of only some 110a (and not all) of the cores 100, for example in only those cores 110a which are intended to have a relevant support element 120f, 120g, 120h applied thereto.

[0052] Each respective well, recess, channel or passage 180 may be dimensioned appropriately to accommodate and securely seat and/or retain therein the relevant portion of the respective support element 120f, 120g, 120h, for example by having a depth in the range of about 0.1, 0.2 or 0.3 up to about 0.5, 1.0, 1.5, or even up to about 2 or 3 mm. The wells, recesses, channels or passages 180 may be formed by appropriate provision of correspondingly shaped and positioned surface formations in or on the original patterns from which the relevant cores 110a were formed in an earlier stage of the overall investment casting operation.

[0053] Where such wells, recesses, channels or passages 180 are provided in two facing walls of adjacent or neighbouring cores 110a, if desired or necessary their relative lateral positioning with respect to each other in the general planes of the respective core walls may be tailored to take account of any laterally offset relative positioning of the relevant portions of the respective support elements 120f, 120g, 120h which are to be accommodated in them.

[0054] Although the use of such wells, recesses, channels or passages 180 may typically result in some small localised increases in the resulting cast wall thickness at the sites thereof, in general this can be expected not to be a problem in practical terms, because such resultant features in the resulting cast metal wall may be expected not to deleteriously affect the wall material's resulting physical properties, unlike small localised decreases in wall thicknesses, which may have the opposite effect.

[0055] The provision of the various wells, recesses, channels or passages 180 in the walls of the cores 110a may be particularly useful not only for assisting optimum positioning of each of the support elements 120f, 120g, 120h in its respective position on or against the relevant core 110a, but also for the purpose of directing placement of particular ones of the support elements 120f, 120g, 120h at the correct sites at which they are designed to fit and be mounted. Colour-coding of respective support

elements relative to their respective intended core well, recess, channel or passage can usefully assist this task. This may be particularly useful in cases where a potentially large number of differently sized, shaped and configured support elements 120 may be provided for assembling into a required die of a complex arrangement of, and/or a large number of, core members 110, and differently-configured support elements need to be placed at predetermined unique locations on the various cores.

[0056] Embodiments of the invention may be put into practice in the positioning of one or more cores with respect to one or more other components of or within a die during any stage of an overall investment casting operation. Many embodiments, such as those described above in conjunction with the accompanying drawings, may be applied in particular to the step of locating and positioning one or more ceramic cores within a die prior to the pouring of molten metal therein for the actual casting of a final metal part. Alternatively certain other embodiments may be applied to any earlier stage in an overall investment casting operation, such as the production of the initial wax pattern itself, where corresponding usefulness in being able to stably and accurately position one or more core members relative to one or more other components may also present itself. In such a case, the subject looped or coiled support elements could be used to replace plastic chaplets in the wax, which may then remove the need to use P-pins, as currently, to locate the cores in the relevant die. In this case the orientation of the looped or coiled support elements between the adjacent or neighbouring cores with their longitudinal winding axis normal to the core wall, i.e. so that the support elements are used more like a conventional spring by loading the coil through the axis of lowest spring constant, may be more appropriate. Other possibilities for implementation of embodiments of the invention may also be envisaged in various other stages of an overall investment casting procedure.

[0057] It is to be understood that the above description of embodiments and aspects of the invention has been by way of non-limiting examples only, and various modifications may be made from what has been specifically described and illustrated whilst remaining within the scope of the invention as defined in the appended claims.

[0058] Throughout the description and claims of this specification, the words "comprise" and "contain" and variations of the words, for example "comprising" and "comprises", mean "including but not limited to", and are not intended to (and do not) exclude other moieties, additives, components, integers or steps.

[0059] Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

[0060] Furthermore, features, integers, components,

elements, characteristics or properties described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein, unless incompatible therewith.

Claims

1. A process for investment casting of an engine part (B) having at least one internal cavity (C), in which at least one core member (10) defining the or a respective cavity (C) is maintained in a desired spatial position relative to at least one other component (10, 2) of or within a die during at least part of the casting procedure, the at least one core member (10) being maintained in the desired spatial position by at least one support element (20) which comprises a different material to that from which the engine part (B) is to be cast, wherein the or each support element (20) comprises a drawn elongate member configured to include therein at least one turn (22, 24) with opposed sides (30, 32), the elongate member being positioned between the respective core member (10) and respective other component (10, 2) with the opposed sides of its at least one turn (22, 24) in space-maintaining relationship between the respective core member (10) and respective other component (10, 2).
2. A process as claimed in claim 1 wherein the support element comprises a wire.
3. A process according to claim 1 or claim 2 wherein the support element (20) is oriented, relative to a wall or surface of the core (10) whose spatial position is to be maintained, with its at least one turn (22, 24) bearing against the said core wall or surface either:
 - (i) with its axis of highest spring constant generally substantially normal to the said core wall or surface, at least at or in the vicinity or region of its bearing thereagainst; or
 - (ii) perpendicular to that defined in (i) above, whereby its longitudinal winding axis is generally substantially normal to the said core wall or surface, at least at or in the vicinity or region of its bearing thereagainst.
4. A process according to any of Claims 1 to 3, wherein the engine part (B) is a turbine blade for a gas turbine engine.
5. A process according any of Claims 1 to 4, wherein the at least one other component (10, 2) of or within the die (2) is selected from:
 - (i) one or more other cores (10) also being po-

- sitioned within an overall die within which the part (B) is to be cast; and/or
(ii) an element (2) of the die itself.
6. A process according to any of Claims 1 to 5, wherein the drawn elongate member forming the or the respective support element (20) is configured into a looped member comprising a plurality of turns (22, 24) with opposed sides (30, 32).
7. A process according to any preceding Claim, wherein the drawn elongate member is configured so as to include a coil (22, 24) having a plurality of windings.
8. A process according to any preceding Claim, wherein the drawn elongate member forming the support element (20) includes at least one free end portion (40, 42) for further supporting and/or positioning the respective core (10) in its desired position relative to the one or more other components (10, 2).
9. A process according to any preceding Claim, wherein the or each drawn elongate member forming the or the respective support element (20) is formed of a material whose residual presence in the cast engine part (B) is tolerable or does not adversely affect the desired properties of the cast engine part (B).
10. A process according to Claim 9, wherein the material used to form the support element (20) is selected from one or more of: platinum, an alloy of platinum with one or more other metals, a platinum-nickel alloy, nickel, nickel coated with one or more other metals, and other metals, alloys or materials currently used for core-positioning components in known investment casting processes.
11. A process according to any preceding Claim, wherein at least one of the respective core member (10) and/or respective other component (10, 2) whose relative spatial positioning is to be controlled by the turn-containing elongate support element (20) includes at least one surface formation (180) for location therein of at least part of the or each said support element (20), whereby its positioning relative to the said respective core member (10) and/or respective other component (10, 2) may be facilitated and/or more accurately assured.
12. A process according to Claim 11, wherein:
- (i) the said one or more said surface formations (180) is/are provided in one only of the said respective core (10) or other component (10, 2), at the or each location or region at which the or respective support element(s) (10) is/are to bear thereagainst to fulfil its/their supporting function;
- or
- (ii) the said one or more said surface formations (180) is/are provided in both of the said respective core (10) and other component (10, 2), at mutually opposite locations or regions thereon at which the or respective support element(s) (20) is/are to bear thereagainst to fulfil its/their supporting function.
13. A support element (20a, 20b, 20c, 20d, 20e) for maintaining at least one core member (10) in a desired spatial position relative to at least one other component (10, 2) of or within a die during at least part of a process for investment casting of an engine part (B) having at least one internal cavity (C), in which the at least one core member (10) defines the or a respective cavity (C), which comprises a different material to that from which the engine part (B) is to be cast, wherein the support element (20a, 20b, 20c, 20d, 20e) comprises a drawn elongate member configured to include therein at least one turn (22, 24) with opposed sides (30, 32), the elongate member being positionable between the respective core member (10) and respective other component (10, 2) with the opposed sides (30, 32) of its at least one turn (22, 24) in space-maintaining relationship between the respective core member (10) and respective other component (10, 2).
14. A gas turbine blade (B) produced by a process according to any one of Claims 1 to 12.
15. A gas turbine engine including at least one turbine blade (B) made by a process according to any one of Claims 1 to 12.

Fig.1

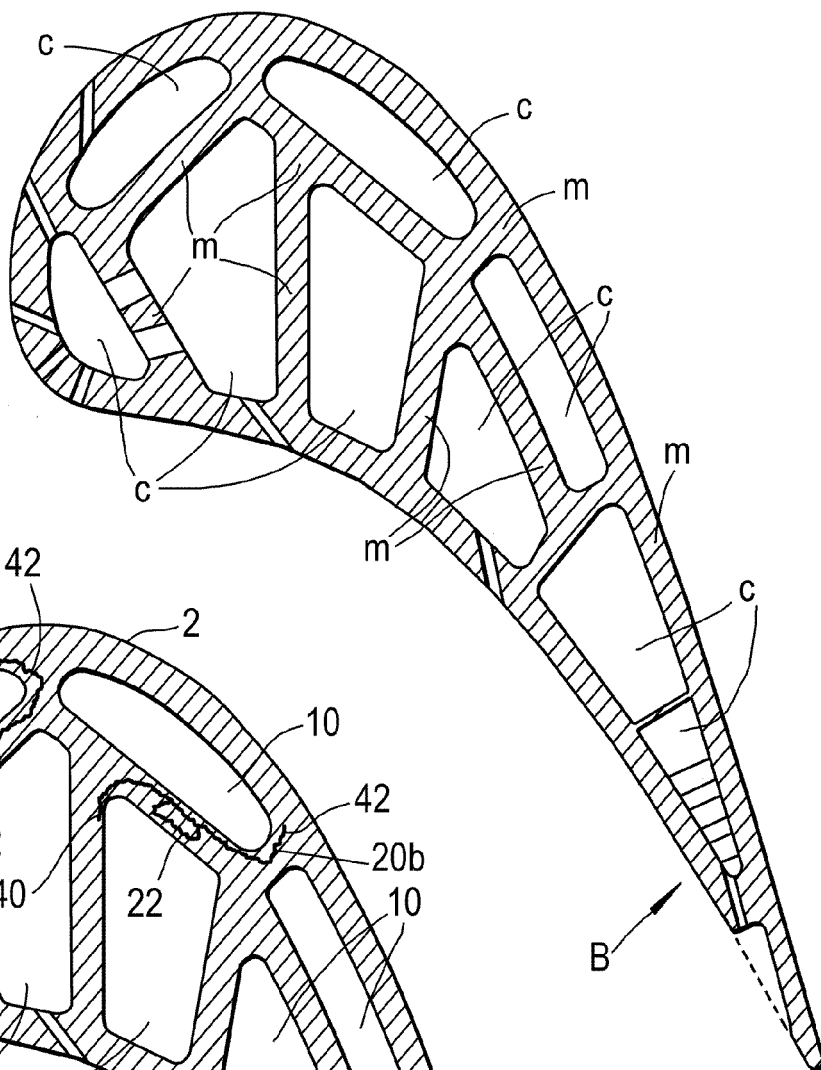
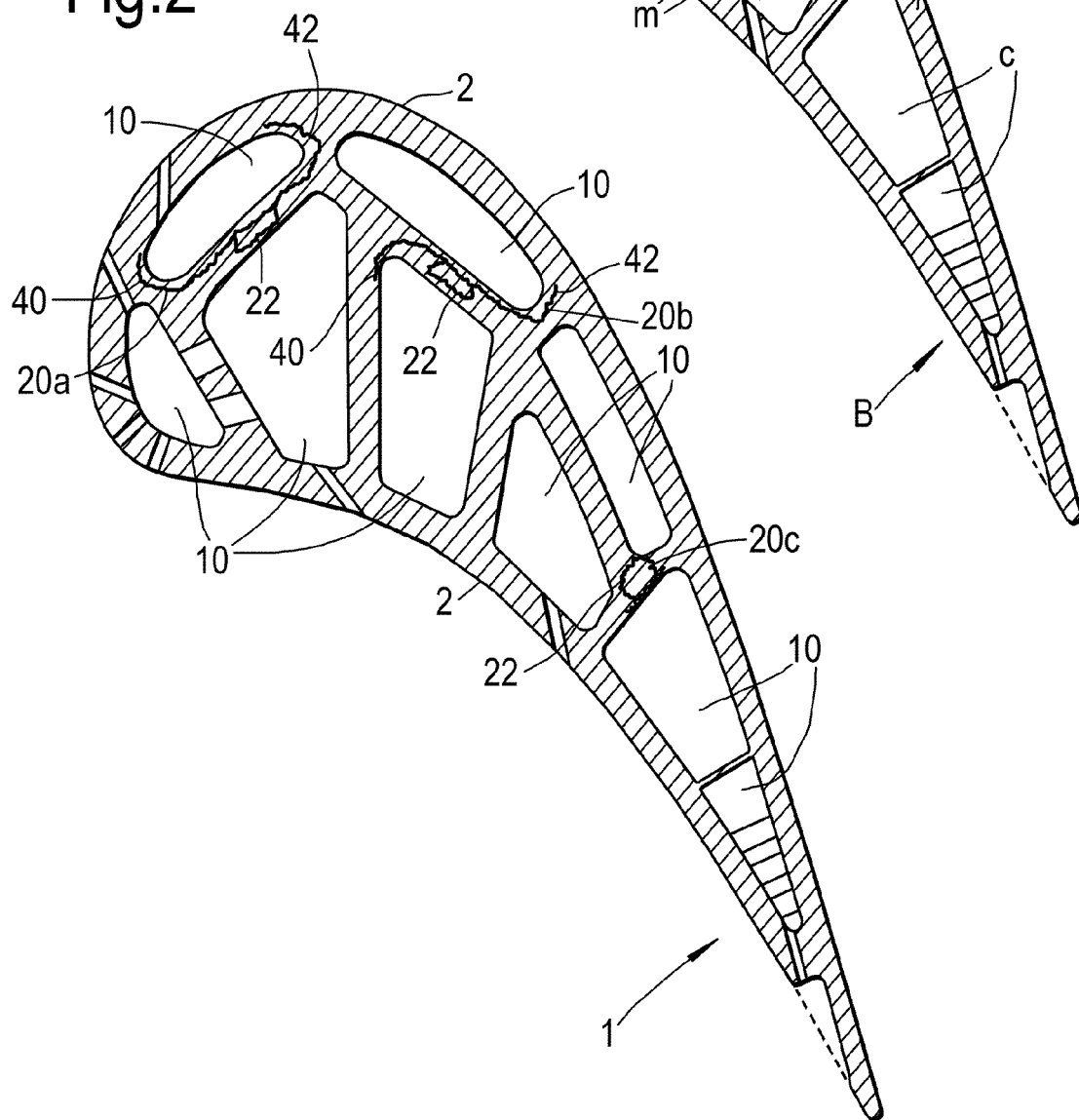


Fig.2



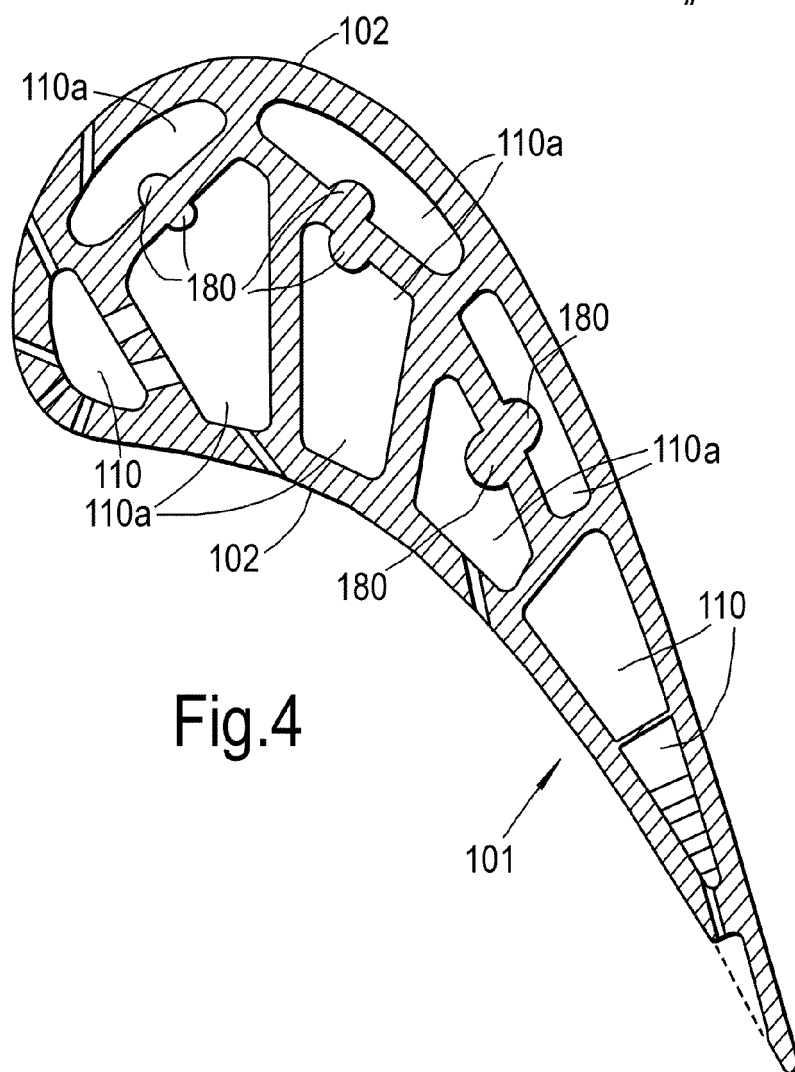
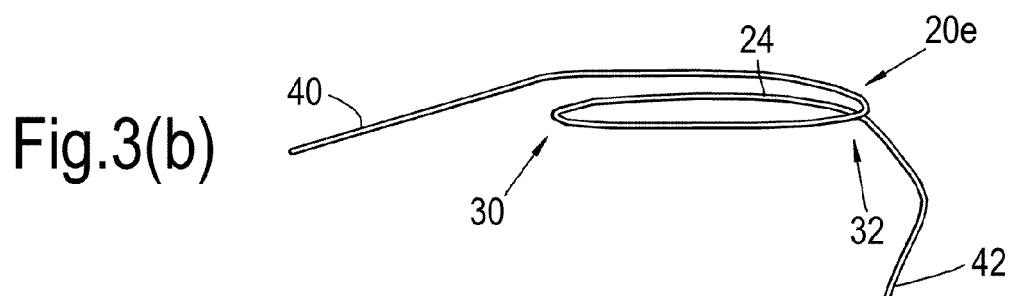
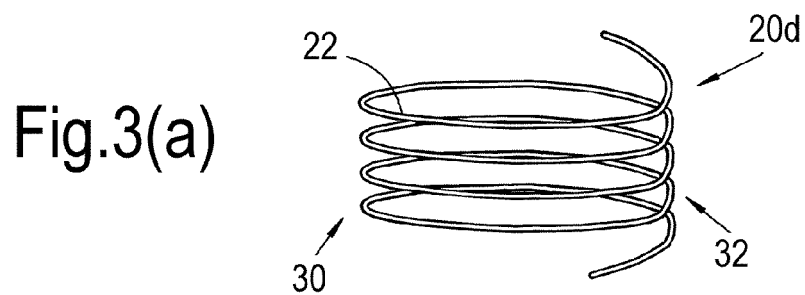
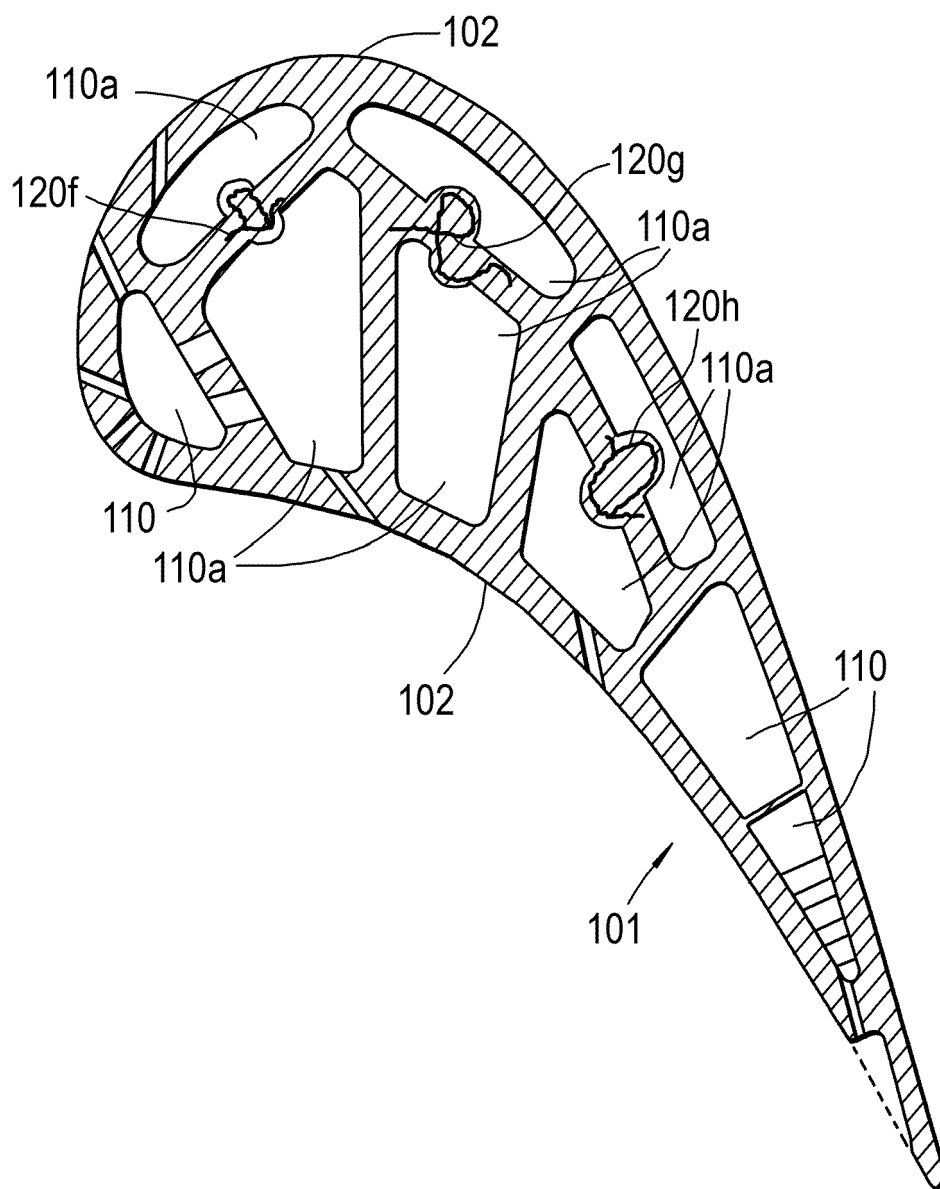


Fig.5





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