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HOLDING TOOLS FOR PREFORM SINTERING

Abstract

An installation for sintering a preform includes a sintering furnace in which a load is disposed, wherein the load includes a revolution preform disposed around at least one holding tool, the at least one holding tool including a disk and a crown present on the periphery of the disk, the crown being made of compressible material capable of being eliminated by thermal oxidation, a portion of the preform being in contact with the crown before sintering.

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Background/Summary

TECHNICAL FIELD

[0001] The present invention relates to the production of revolution parts made of composite material, in particular of the oxide/oxide type, and, more particularly, to the maintenance of the fibrous preforms intended to form such parts during high-temperature treatments implemented in particular during debinding or sintering steps. In particular, the present invention relates to the production of parts intended to constitute all or part of the rear-body parts of civil aeronautical engines such as exhaust cones.

PRIOR ART

[0002] For the manufacture of composite material parts, in particular of the oxide/oxide type, it is known to produce a fibrous preform, to impregnate it with one or more matrix precursors then to carry out a sintering operation to densify said fibrous preform. The impregnation of the fibrous preform can be carried out in a well-known manner by placing the fibrous preform in a mold and injecting a slurry comprising a liquid phase loaded with matrix precursor particles into said preform. A filter disposed in the mold allows to evacuate the liquid phase of the slurry while retaining the matrix precursor particles in the preform. Such a method is described in particular in documents US2017334791A1 and US2021046671A1. Then, the matrix precursor particles present in the fibrous preform are sintered in order to form the matrix in the porosities of said preform.

[0003] An organic binder, for example PVA, can be added to the liquid phase of the slip to ensure the impregnated preform holds after drying and before sintering.

[0004] However, it is noted that the preforms thus impregnated can deform during the high-temperature treatments required for the debinding or sintering operations. Indeed, since the matrix precursor particles are not bound inside the preform and the matrix is not yet formed, the impregnated preform has very reduced strength and can in particular become oval. The risk of deformation is even more marked in the case of parts with a very thin thickness and/or a slender shape.

[0005] To overcome these unwanted deformations, it has been considered to integrate stiffeners into the parts, or to thicken the portions of the parts most exposed to the risk of deformation. However, these methods have many disadvantages, and in particular cause an undesirable increase in the mass of the parts.

DISCLOSURE OF THE INVENTION

[0006] In order to overcome the aforementioned disadvantages, the invention proposes an installation for sintering a revolution preform comprising a sintering furnace in which a load is disposed, the installation being characterized in that the load comprises a revolution preform disposed around at least one holding tool, the holding tool(s) comprising a disk and a crown present on the periphery of the disk, the crown being made of compressible material capable of being eliminated by thermal oxidation, a portion of the preform being in contact with the crown before sintering.

[0007] Such an installation ensures that the shape of the fiber preform is maintained during the sintering and possibly debinding steps, without requiring an increase in the mass of the final part obtained. The presence of a layer of compressible material between the disk and the preform allows to compensate for radial thermal expansions between said disk and said preform, to ensure contact between the holding tool and the preform when the latter is not self-supporting or when the latter has reduced strength, in particular before the start of sintering.

[0008] “Material capable of being eliminated by thermal oxidation” means here a material the majority of the volume of which decomposes by oxidation when exposed to high temperatures. Thus, the crown made of such a material is capable of holding the fiber preform during a possible debinding operation and preferably until the start of sintering, then can sufficiently decompose by oxidation to allow a clearance to be created between the part obtained by sintering and the holding tool oxidized on its edges. The part obtained can therefore be easily separated from the holding tool after the sintering step. Furthermore, when the part cools after the sintering operation and therefore sees its diameter decrease by thermal shrinkage, the disappearance of the majority of the crown by oxidation allows to avoid contact between the cooled part and the oxidized holding tool, which further limits the risks of damaging the part.

[0009] According to one embodiment of the invention, the compressible material is expanded graphite.

[0010] Expanded graphite is a particularly compressible material and is able to absorb significant differences in thermal expansion. Furthermore, expanded graphite has oxidation properties that are particularly suitable for a sintering furnace atmosphere. Indeed, in the non-inert and oxidizing atmosphere of a sintering furnace, expanded graphite does not oxidize significantly in temperature ranges that are too low to allow sintering, and oxidizes rapidly in temperature ranges that are high enough to allow sintering.

[0011] According to another embodiment of the invention, the disk is made of monolithic ceramic.

[0012] The disk is therefore easy to manufacture while having a coefficient of thermal expansion close to the coefficient of thermal expansion of the preform. Indeed, a monolithic ceramic disk is less expensive and time-consuming to manufacture than a disk made of ceramic matrix composite material.

[0013] According to another embodiment of the invention, at least one holding tool is disposed at one end of the preform along its axis of revolution.

[0014] According to another embodiment of the invention, the revolution preform comprises matrix precursor particles in its porosities.

[0015] The invention further relates to a method for manufacturing a composite material revolution part comprising the following steps: [0016] impregnating a fibrous preform of revolution at least by matrix precursor particles, [0017] placing the fibrous preform of revolution comprising the matrix precursor particles around at least one holding tool, the holding tool(s) comprising a crown made of compressible material and a concentric disk, the crown comprising a first surface in contact with the periphery of the disk and a second surface opposite the first surface in contact with an internal face of the preform, [0018] sintering the fibrous preform comprising the matrix precursor particles in order to form a matrix in the porosities of said fibrous preform to obtain a composite material part, the majority of the compressible material of the crown being decomposed by oxidation at the end of the sintering step, [0019] removing the holding tool(s) from the composite material part obtained.

[0020] According to one embodiment of the invention, the compressible material is expanded graphite.

[0021] According to another embodiment of the invention, the step of impregnating the fibrous preform also comprises the impregnation of said preform with a binder, the method further comprising a step of debinding the fibrous preform of revolution disposed around the holding tool before the sintering step.

[0022] According to another embodiment of the invention, a positioning and centering device is used during the step of placing the fiber preform around the holding tool(s), the positioning device comprising at least one rod and one support, the end of the fiber preform along its axis of revolution furthest from the portion of the fiber preform in contact with the holding tool resting on

the support, said support being fixed to the rod and the holding tool(s) being fixed to the rod by their center during the placement step.
[0023] The use of such a positioning device makes it easier to mount the holding tool(s) in the fiber preform and ensures satisfactory centering, while limiting the risk of damaging said preform during this mounting operation.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0024] FIG. **1** is a schematic perspective view of a fibrous preform of revolution.
[0025] FIG. **2** is a schematic sectional view of an impregnation tool in which the preform of FIG. **1** is disposed.
[0026] FIG. **3** is a schematic exploded perspective view of a holding tool mounted in the impregnated fiber preform of FIGS. **1** and **2**.
[0027] FIG. **4** is a schematic sectional view of a device for positioning the holding tool of FIG. **3** in the fiber preform.
[0028] FIG. **5** is a schematic sectional view of a sintering installation according to the invention comprising the impregnated fibrous preform held by the holding tool of FIG. **3**.
[0029] FIG. **6** is a schematic sectional view of the installation of FIG. **5** comprising a composite material part obtained by sintering the impregnated fiber preform.
DESCRIPTION OF THE EMBODIMENTS
[0030] The method for manufacturing a part made of thermostructural composite material, preferably of the oxide/oxide type, in accordance with the present invention begins with the production of a fibrous preform intended to form the fibrous reinforcement of the part.
[0031] An example of a fiber preform **10** is illustrated in FIG. **1**. The preform **10** has a shape of revolution with an axis of revolution X. Thus, the preform **10** comprises an external face **10***a* and an internal face **10***b*. The fiber preform **10** may in particular have a cylindrical shape, a truncated cone shape, a bulb shape or else a combination of these shapes. The fiber preform **10** may have a maximum cross-section with a diameter greater than 700 mm.
[0032] The fiber preform **10** can thus be produced at least in part by stacking plies or folds obtained by two-dimensional (2D) weaving. The fiber preform **10** can also be produced at least in part by stacking plies or folds obtained by three-dimensional (3D) weaving. “Two-dimensional weaving” means here a conventional weaving method by which each weft thread passes from one side to the other of threads of a single warp layer or vice versa. “Three-dimensional weaving” means here a weaving by which warp threads pass through several layers of weft threads, or weft threads pass through several layers of warp threads. The preform **10** can also be produced at least in part by sheets of unidirectional (UD) fibers.
[0033] The fiber preform **10** can be obtained by laying ribbons or by automated fiber placement (AFP), by draping, or by filament winding.
[0034] Finally, the preform **10** can be obtained at least in part by braiding or knitting.
[0035] The fibrous preform **10** may be formed from fibers made of one of the following materials: alumina, mullite, silica, an aluminosilicate, a borosilicate, silicon carbide, carbon, or a mixture of several of these materials.
[0036] When the fibrous preform **10** is produced, it is impregnated with one or more matrix precursors. Preferably, the fibrous preform **10** is impregnated with a slip. The impregnation of the fibrous preform **10** with a slip can be carried out by placing said preform **10** in a mold closed by a rigid counter-mold, the mold and the counter-mold defining an internal volume having the shape of the part to be manufactured. The impregnation of the fibrous preform **10** can also be carried out under a flexible membrane, as illustrated in FIG. **2**. The impregnation of the fibrous preform **10**

under a flexible membrane is, in a well-known manner, particularly suitable for the manufacture of parts of slender shape and low thickness, in particular by allowing better control of the dimensions of the part.
[0037] In the example illustrated in FIG. **2**, the fibrous preform **10** is disposed in an impregnation tool **500**. Said impregnation tool **500** comprises a mold, which includes on the one hand an impregnation chamber **501** in which a fibrous preform **10** is disposed and on the other hand a compaction chamber **502**.
[0038] A slip **5** comprises a liquid phase in which particles **51** of a matrix precursor are dispersed. More particularly, the slip may correspond to a suspension containing a liquid phase and a powder of matrix precursor particles. The liquid phase may in particular consist of water, ethanol or any other liquid in which it is possible to suspend the desired powder. The pH of the liquid phase of the slip can be adapted according to the nature of the particles, for example water with an acid pH in the case of an alumina powder.
[0039] An organic binder can also be added (water-soluble PVP or PVA for example). This binder ensures the consistency of the raw material, possibly after drying and before debinding and sintering.
[0040] The slip may for example correspond to an aqueous suspension consisting of alumina powder whose average particle size (D50) is comprised between 0.1 μm and 1 μm and whose volume fraction is comprised between 5% and 50%, the suspension being acidified by nitric acid (pH comprised between 1.5 and 4). In addition to alumina, the refractory oxide particles may also be made of a material selected from mullite, silica, an aluminosilicate, an aluminophosphate, zirconia, a carbide, a boride, a nitride and carbon. Depending on their basic composition, the refractory oxide particles can be further mixed with particles of alumina, zirconia, aluminosilicate, rare earth oxides, rare earth disilicates (used for example in environmental or thermal barriers) or any other filler allowing specific functions to be added to the final material (carbon black, graphite, silicon carbide, etc.).
[0041] The slip **5** is intended to be injected into the impregnation chamber **501** and a compression fluid **6** is intended to be injected into the compaction chamber **502**. Thus, the impregnation chamber **501** includes one or more inlet orifices **511** allowing the introduction of the slip **5** into said impregnation chamber **501**. The inlet orifice(s) **511** of the impregnation chamber **501** may be equipped with a valve. The impregnation chamber **501** may also include one or more outlet orifices **512** allowing the liquid phase of the slip **5** to be evacuated. Similarly, the compaction chamber **502** includes one or more inlet orifices **521** allowing the compression fluid **6** to be introduced into said compaction chamber **502**, and one or more outlet orifices **521** allowing the compression fluid **6** present in said compaction chamber **502** to be sucked in and evacuated. The inlet and outlet orifices **521** of the compaction chamber **502** may be the same, or at least partly the same, as in the example illustrated in FIG. **2**. The inlet orifice(s) **521** of the compaction chamber **502** may be equipped with a valve.
[0042] The compression fluid **6** can for example be water or oil.
[0043] The impregnation chamber **501** may include a filtration stratum **540** interposed between the fibrous preform **10** and the outlet orifice(s) **512** of the impregnation chamber **501**. The filtration stratum **540** allows to retain the matrix precursor particles **51** of the slip **5** in the preform **10** while allowing the liquid phase of the slip **5** to pass, the liquid phase of the slip **5** being evacuated via the outlet orifice(s) **512** of the impregnation chamber **501**.
[0044] The filtration stratum **540** comprises a first face **540***a* and a second face **540***b*, opposite the first face **540***a*. Preferably, the internal face **10***b* of the preform **10** rests on the second face **540***b* of the filtration stratum **540**. Thus, the second face **540***b* of the filtration stratum **540** has a shape adapted to the shape of the internal face **10***b* of the preform **10***b*. Preferably, the filtration stratum **540** is therefore a volume of revolution with an axis of revolution X.
[0045] The filtration stratum **540** may for example be made of microporous polytetrafluoroethylene

(PTFE) but also of plaster or paper. To produce the filtration stratum **540**, it is possible for example to use a material having a pore size comprised between 1 μm and 5 μm. The filtration stratum **540** may have a resulting permeability comprised between 10.sup.−14 m.sup.2 and 10.sup.−15 m.sup.2.
[0046] A rigid perforated element (not shown) may be interposed between the filtration stratum **540** and the outlet orifice(s) **512** of the impregnation chamber **501**. Such a rigid perforated element is described in particular in document US 20190134848 A1. The function of this rigid perforated element is to facilitate the evacuation of the liquid phase having passed through the filtration stratum **540** via the outlet orifice(s) **512**, regardless of its outlet point at the first face **540***a* of the filtration stratum **540**. To further facilitate the evacuation of the liquid phase of the slip **5**, the rigid perforated element may include cutouts or cavities between its openings.
[0047] A distribution element (not shown) may optionally be disposed between the filtration stratum **540** and the rigid perforated element if applicable, said distribution element having a permeability greater than that of the filtration stratum **540**. Such a distribution element allows to obtain a more uniform flow rate of the liquid phase inside the filtration stratum **540**.
[0048] The impregnation chamber **501** and the compaction chamber **502** of the mold are separated by a flexible membrane **530**. The flexible membrane **530** is placed facing the external face **10***a* of the preform **10**. The membrane **530** comprises a first surface **530***a* and a second surface **530***b* opposite the first surface **530***a*. The first surface **530***a* of the membrane **530** is placed facing the preform **10**. The first surface **530***a* of the membrane **530** is present on the side of the impregnation chamber **501**, and the second surface **530***b* of the membrane **530** is present on the side of the compaction chamber **502**.
[0049] The membrane **530** can allow to apply pressure to the slip **5** present in the impregnation chamber **501** in order to cause said slip **5** to penetrate into the fibrous preform **10**. The membrane **530** can also allow to apply a compacting pressure to the fibrous preform **10** disposed in the impregnation chamber **501**. The pressure applied by the membrane **530** is produced by the compression fluid **6** which, by applying pressure to the membrane **530**, deforms the membrane **530** against the fibrous preform **10**. The pressure applied by the compression fluid **6** to the membrane **530** can also allow to hold said membrane **530** in place against the fibrous preform **10** if the pressure increases in the impregnation chamber **501**. Thus, the first surface **530***a* of the membrane **530** can be intended to be in contact with the fibrous preform **10** when the compaction chamber **502** is filled with the compression fluid **6**.
[0050] The membrane **530** is for example made of silicone, or for example of a rubber-type material. The membrane **530** can be reinforced with glass or polyester fibers. The membrane **530** must be made of a material resistant to the temperatures to which said membrane **530** may be subjected during the complete process, as well as to the fluids with which the membrane **530** will be in contact. The membrane **530** must have a compressibility consistent with the dimensional tolerance sought for the part.
[0051] The impregnation of the fibrous preform **10** can be carried out by first injecting the slip **5** into the impregnation chamber **501**, then by injecting the compression fluid **6** into the compaction chamber **502**. The compression fluid **6** applies pressure to the slip **5** through the membrane **530**. The compression fluid **6** imposes pressure on the entire membrane **530** and, consequently, on the entire slip **5** present above the preform **10**.
[0052] The pressure applied by the membrane **530** to the slip **5** and to the fibrous preform **10** is preferably reduced, so as to cause the slip **5** to penetrate into the preform **10** and sufficiently compact said preform **10** to allow the liquid phase of the slip **5** to be drained by the filtration stratum **540** without degrading the fibrous preform **10**. In combination with the application of pressure to the slip by the compression fluid **6**, pumping, for example by means of a primary vacuum pump (not shown in FIG. **2**), can be carried out at the outlet orifice(s) **512** of the impregnation chamber **501**. This pumping is optional. In addition, the impregnation tool **500** may be provided with heating means, such as resistive elements integrated into the walls, in order to

increase the temperature in the compaction chamber **502** and to facilitate the evacuation of the liquid phase of the slip by evaporation. The filtration stratum **540** allows to retain the matrix precursor particles **51** present in the slip **5** inside the porosities of the preform **10**, said particles **51** thus gradually being deposited in the fibrous preform **10**. These particles **51** allow to form the matrix after sintering.

[0053] According to a variant, the impregnation of the fibrous texture **10** can be carried out by first injecting the compression fluid **6**, then the slip **5**, for example according to the method described in document US 2021046671 A1. The injections of the compression fluid **6** and the slip **5** can also be carried out simultaneously, or at least partly simultaneously. Furthermore, the injection of the slip can be completed before completing the injection of the compression fluid, or the injection of the compression fluid can be completed before completing the injection of the slip.

[0054] The impregnation of the fibrous preform **10** can also be carried out with several slips. The impregnation of the fibrous preform **10** can also be carried out using infusion-type techniques, injection molding techniques known as “RTM” or submicron powder suction techniques known as “APS”.

[0055] When the fibrous preform **10** is suitably impregnated, it can be removed from the impregnation tool **500**. The impregnated fibrous preform **10** can be removed from the impregnation tool **500** after a drying phase, preferably at a temperature greater than 60° C. and less than 90° C., which allows to evacuate the remainder of the liquid phase still present. Thus, the porosities of the fibrous preform **10** are partially filled by the matrix precursor particles **51**, as illustrated in FIG. **3**.

[0056] The fibrous preform can also be made from pre-impregnated layers or plies as described above. Thus, the fibrous preform can for example be made in a well-known manner by draping layers or plies obtained by two-dimensional or three-dimensional weaving pre-impregnated with a slip as described above, or by automated placement of pre-impregnated fibers or fibrous textures. Such a fibrous preform is then placed in an autoclave, then demolded to be ready for sintering.

[0057] Before proceeding with the sintering, and if necessary the debinding, of the fibrous preform **10** comprising the matrix precursor particles **51**, said fibrous preform **10** is disposed around at least one holding tool **100**, as illustrated in FIG. **3**.

[0058] Each holding tool **100** comprises at least one disk **110** and a crown **120**. The disk **110** and the crown **120** are concentric. The disk **110** comprises two opposite circular faces **110***a* and **110***b* and a lateral face **110***c*, said lateral face **110***c* connecting the upper circular face **110***a* to the lower circular face **110***b*. The lateral face **110***c* of the disk **110** may have a geometry adapted to the portion of the internal face **10***b* with which the tool **100** is in contact. Thus, the lateral face **110***c* of the disk **110** may be cylindrical or frustoconical.

[0059] When the holding tool **100** is disposed in the fiber preform **10**, the axis of revolution of the general shape of the disk **110** may coincide with the axis of revolution X of the preform **10**. More generally, when the holding tool **100** is disposed in the fiber preform **10**, the axis of revolution of the general shape of the holding tool **100** may coincide with the axis of revolution X of the preform **10**. Thus, preferably, the holding tool **100** extends perpendicular to the axis of revolution X of the preform **10** when it is deposited inside said preform **10**.

[0060] Preferably, the holding tool(s) **100** are disposed at one end of the fiber preform **10** along the axis of revolution X. In particular, a holding tool **100** is preferably disposed at the end of the largest radius of the fiber preform **10** along the axis of revolution X. Indeed, the ends of the preform **10** along its axis of revolution X are more fragile and more sensitive to deformations, in particular when they have a large radius: it is therefore more judicious to place the holding tool(s) in these sensitive portions of the preform **10**.

[0061] The disk **110** may comprise one or more through-orifices **111** and **112**. Thus, said through-orifices **112** open on the one hand onto the upper circular face **110***a* of the disk **110**, and on the other hand onto the lower circular face **110***b* of said disk **110**. Said through-orifices **111** and **112** may serve as a grip or attachment zone to facilitate handling of the tool **100**. The disk **110** may comprise a through-orifice **111** centered on the axis of revolution of the disk **110**, that is to say centered on the axis of revolution of the lateral face **110***c* of the disk **110**. Thus, the axis of revolution of said through-orifice **111** coincides with the axis of revolution of the disk **110**, that is to say coincides with the axis of revolution of the lateral face **110***c* of the disk **110**. The disk **110** may then have an annular shape. The through-orifices **111** and **112** also allow to lighten the disk **110**. The through-orifice(s) **112** of the disk **110** not comprising the axis of revolution of the disk **110** are preferably disposed angularly in a regular manner around the axis of the disk **110**, as illustrated in FIG. **3**. The through-orifice(s) **112** of the disk **110** not comprising the axis of revolution of the disk **110** are preferably of identical size and their axes are located at an identical distance from the axis of the disk **110**. Such regularity of placement and dimensioning of the through-orifices of the disk **110** allows to maintain a regular thermal expansion of the disk **110** in the radial direction. The through-orifice(s) **112** of the disk **110** not comprising the axis of revolution of the disk **110** may have a diameter greater than 50 mm.

[0062] The crown **120** comprises a first face **120***a* disposed in contact with the lateral face of the disk **110**. Thus, the crown **120** comprises a first face **120***a* disposed in contact with the periphery of the disk **110**. The crown **120** also comprises a second face **120***b*, opposite the first face **120***a* of said crown **120**, intended to be in contact with the fibrous preform **10** comprising the particles **51**. More precisely, the second face **120***b* of the crown **120** is intended to be in contact with a reduced portion of the internal face **10***b* of the preform **10** comprising the particles **51**. When the holding tool is mounted in the fibrous preform **10**, the crown **120** comprises the first surface **120***a* in contact with the periphery of the disk **110** and the second surface **120***b* opposite the first surface **120***a* in contact with a portion of the internal face **10***b* of the preform **10**. Thus, the second face **120***b* of the crown **120** has a geometry adapted to the portion of the internal face **10***b* with which said second face **120***b* is in contact. Thus, the second face **120***b* of the crown **120** can for example be cylindrical or frustoconical.

[0063] Preferably, the disk **110** is made of monolithic ceramic. Monolithic ceramic is understood to mean a ceramic without fibrous reinforcement, the porosity of which can be comprised between 0% and 81%, and preferably between 10% and 40%.

[0064] The more porous the monolithic ceramic, the easier, lighter and more inexpensive the disk **110** is to machine.

[0065] The disk **110** may be made of mullite. If the disk **110** is made of mullite, it may comprise 60% to 80% alumina, and preferably 65% to 70% alumina. Indeed, a disk **110** made of mullite with such percentages of alumina allows reduced thermal expansion of said disk **110**, and therefore reduced compression of the crown **120**, while ensuring contact between the holding tool **100** and the preform **110** up to high temperatures, and in particular up to temperatures higher than the sintering start temperature. Mullite also has the advantage of being inexpensive.

[0066] The disk **110** is preferably made of alumina. Indeed, a disk **110** made of alumina has a coefficient of thermal expansion almost identical to the coefficient of the preform to be held, which allows to limit the thickness of the crown **120**.

[0067] The disk **110** may also be made of a ceramic matrix composite material of the CMC type, for example of the C/SiC or SiC/SiC type. In particular, if the part to be manufactured is a part made of a composite material of the C/SiC type, a disk made of a composite material of the C/SiC type may be selected, and if the part to be manufactured is a part made of a composite material of the SiC/SiC type, a disk made of a composite material of the SiC/SiC type may be selected.

[0068] Preferably, the coefficient of thermal expansion of the material of the disk **110** is close to the coefficient of thermal expansion of the fiber preform **10**. Thus, preferably, the value of the coefficient of linear thermal expansion in the radial direction of the material of the disk **110** is comprised between 90% and 110% of the value of the coefficient of thermal expansion in the radial direction of the material of the preform **10**. In particular, the coefficient of linear thermal expansion of the material of the disk **110** may be comprised between 5×10.sup.−6 K.sup.−1 and 8×10.sup.−6

K.sup.−1, and preferably between 6×10.sup.−6 K.sup.−1 and 7.5×10.sup.−6 K.sup.−1. Indeed, such values promote reduced expansion of the material of the disk **110** in order to limit the compression of the crown **120** against the preform **10** while ensuring contact between the holding tool **100** and the preform **110** up to high temperatures, and in particular up to temperatures above the sintering start temperature.

[0069] The material of the crown **120** is a compressible material, that is to say a material capable of compressing by at least 20% when the disk **110** expands and presses said compressible material against the internal face **10***b* of the fiber preform **10**. Preferably, the compressible material of the crown **120** is capable of compressing by at least 30% when the disk **110** expands and presses said compressible material against the internal face **10***b* of the fiber preform **10**.

[0070] Thus, the crown **120** is preferably made of expanded graphite, which is for example in the form of flexible graphite sheets. The expanded graphite also has the advantage of being able to be easily wound around the disk **110**. The crown **120** can also be made of felt, for example carbon.

[0071] The crown **120** mounted between the disk **110** and the internal face **10***b* of the preform **10** as described above may have a thickness in the radial direction comprised between 2 mm and 15 mm depending on the thermal expansion of said disk **110** and said preform **10**. The thickness of the crown **120** is determined in a well-known manner by calculations of the thermal expansion of the preform **10**, the crown **120** and the disk **110**, so as to ensure contact between said crown **120** and the internal face **10***b* of the preform **10** at least until the start of the sintering step. In particular, if the disk **110** is made of mullite, the crown **120** may have a thickness in the radial direction comprised between 5 mm and 15 mm depending on the thermal expansion of said disk **110** and said preform **10**. If the disk **110** is made of alumina, the crown **120** may have a thickness in the radial direction comprised between 2 mm and 12 mm depending on the thermal expansion of said disk **110** and said preform **10**.

[0072] Preferably, the compressible material of the crown **120** is capable of decomposing by oxidation in an oxidizing atmosphere and at high temperature. In particular, the compressible material of the crown **120** may be configured to be mostly decomposed by oxidation during a sintering step in air. In particular, the compressible material of the crown **120** may be configured to be mostly decomposed by oxidation from a temperature value comprised between 600° C. and 1200° C. Furthermore, the compressible material of the crown **120** may be configured to be mostly unaltered by oxidation during a debinding step. In particular, the compressible material of the crown **120** may be configured to be mostly unaltered by oxidation up to 400° C., and preferably up to 600° C. A compressible material made of expanded graphite may meet such properties. Under an inert atmosphere, as is the case during a pyrolysis operation or during a chemical infiltration operation in the gas phase, expanded graphite does not oxidize. Under an atmosphere very low in oxygen, expanded graphite has a very slow oxidation kinetics up to the sintering temperature.

[0073] Preferably, the materials of the disk **110** and the crown **120** are selected so that the crown **120** is very little compressed at room temperature, when the holding tool **100** is placed on the internal face **10***b* of the preform **10**, and is very little compressed during the possible debinding of said preform **10**. Thus, the tool **100** applies a very low pressure on the preform **10** at the time of its placement, in order to limit the risk of damage to said preform **10**, and applies a very low pressure on the preform **10** at the time of its possible debinding, when said preform **10** has a weak strength and consequently an increased risk of deformation.

[0074] Several holding tools **100** as described above can be disposed in the fiber preform **10**, provided that their placement in said preform **10** is possible while taking into account the variations in section of said preform.

[0075] In order to facilitate the positioning of the holding tool **100** inside the preform **10** and to avoid damaging said preform, an additional positioning device **200** may be used, as illustrated in FIG. **4**. This additional positioning device **200** allows in particular to ensure good centering between the holding tool **100** and the fiber preform **10**.

[0076] In the example illustrated in FIG. **4**, the additional positioning device **200** comprises a rod **220** and a foot **250** intended to support the mass of the positioning device **200** when the latter is mounted with the fiber preform **10** and the holding tool **100**. The foot **250** comprises an orifice or a bore **251** allowing the fixing of the rod **220**. The rod **220** is preferably threaded. If the rod **220** is threaded, the bore **251** of the foot **250** is preferably threaded.
[0077] The positioning device **200** may further comprise a support **240** including a central through-orifice or bore **241**, which may or may not be threaded. Thus, the support **240** of the device **200** is capable of being fixed to the rod **220**, said rod **220** passing through the support **240** via the central bore **241**. The support **240** is preferably maintained at a non-zero distance from the foot **250**, for example by means of nuts. The support **240** is intended to accommodate and be in contact with one end of the fiber preform **10** along its axis of revolution X. Preferably, the support **240** is intended to accommodate the end of the fiber preform **10** along its axis of revolution X furthest from the portion of the fiber preform **10** that accommodates the holding tool **100**, in order to facilitate the assembly of the positioning device **200**, the holding tool **100** and the preform **10**. Preferably, the support **240** is intended to accommodate the end of the fiber preform **10** along its axis of revolution X having the smallest radius. The support **240** can be in contact with the external face **10***a* of the fiber preform **10**. The support **240** can be produced by additive manufacturing, in order to obtain a support **240** shape that is as suitable as possible for the end of the preform **10** in contact with the support **240** when said preform **10** is mounted with the positioning device **200**.
[0078] Preferably, one of the through-orifices **111** of the disk **110** allows the passage of the rod **220** of the positioning device **200**. Said through-orifice **111** allowing the passage of the rod **220** can be threaded. The axis of this through-orifice **111** is preferably coincident with the axis of the disk **110**.
[0079] The positioning device **200** may further comprise at least one platen **230** including a central through-orifice or bore **231**, which may or may not be threaded. Thus, the platen **230** of the device **200** is capable of being fixed to the rod **220**, said rod **220** passing through the platen **230** via the bore **231**. The platen **230** may be intended to fix a holding tool **100** to the rod **220** of the positioning device **200**, or to hold a holding tool **100** during positioning. For this purpose, the platen **230** comprises an assembly face **232** intended to be in contact with the upper circular face **110***a* of the disk **110** of a holding tool **100**. Thus, preferably, the positioning device **200** comprises a platen **230** for each holding tool **100**.
[0080] The through-orifice(s) **112** of the disk **110** distinct from the orifice **111** allowing the passage of the rod **220** can facilitate assembly with the positioning device **200**, by allowing access to the platen **230** or to the nuts. Thus, preferably, the through-orifice(s) **112** of the disk **110** distinct from the orifice **111** are of sufficient size to allow the passage of a hand or a suitable tightening tool.
[0081] The positioning device **200** may also comprise a plate **210** including a central orifice or bore **211**, which may or may not be threaded. The central orifice **211** is configured to allow the rod **220** to pass through. The plate **210** is in particular fixed to the rod **220** by means of nuts, as illustrated in FIG. **4**. The plate **210** comprises an assembly face **213** intended to be at least partly in contact with the end of the fiber preform **10** opposite the support **240**. Preferably, the assembly face **213** of the plate **110** is also intended to be in contact with the lower circular face **110***b* of the disk **110** of a holding tool **100**. Preferably, the plate **210** of the positioning device **200** comprises one or more through-orifices **212**. The through-orifice(s) **212** are disposed such that, when the fiber preform **10** is mounted with the positioning device **200**, the through-orifice(s) **212** of the plate **210** are disposed in the extension of the through-orifice(s) **112** of the holding tool **100**.
[0082] When the preform **10**, the holding tool **100** and the positioning device **200** are mounted together, the platen(s) **230** are present between the support **240** and the plate **210**, and each holding tool **100** is present between at least one platen **230** and the plate **210**, as illustrated in FIG. **4**.
[0083] When the holding tool(s) **100** have been properly mounted in the fiber preform **10** by means of the positioning device **200**, the assembled assembly comprising the positioning device **200**, the holding tool **100** and the fiber preform **10** can be turned over. The positioning device **200** allows to

turn over the fiber preform **10** without handling it directly, which is advantageous since the latter is not yet sintered, and therefore fragile and sensitive to deformation. When the turning is complete, the fiber preform **10** is then preferably supported by the plate **210**. When the turning is complete, the positioning device **200** can be removed completely or partially. Preferably, when the turning is complete, the plate **210** is left in contact with the preform **10** and the remainder of the positioning device **200** is removed, and in particular the rod **220**, the platen(s) **230**, the support **240** and the foot **250** if used are removed.

[0084] Preferably, the plate **210** comprises one or more through-orifices **212** distinct from the central through-orifice **211** allowing the passage of the rod **220**. When the assembly face of the plate **210** is in contact with a holding tool **100**, at least a portion of the through-orifice(s) **212** of the plate **210** are located in the extension of at least a portion of the through-orifice(s) **112** of the holding tool **100**. Indeed, the plate **210** can be kept as a support for the preform **10** during the sintering and, where appropriate, debinding operations. Such through-orifices **212** on the plate **210** are thus capable of allowing the burnt gases to pass during sintering or any imperfections that need to be evacuated during sintering or debinding. The material of the plate **210** may then have properties compatible with a sintering or debinding step, for example by having chemical inertness and thermal expansion suitable for such methods. The plate **210** may possibly have undergone prior treatment in order to stabilize its material and avoid interference with the sintering step.

[0085] The fiber preform **10** held by the holding tool(s) **100** is then disposed in a sintering furnace **300**, as illustrated in FIG. **5**. As explained above, the fiber preform **10** preferably rests on the plate **210** in the sintering furnace. The sintering furnace **300** comprises at least one chamber **310** in which the fiber preform **10** held by the holding tool(s) **100** is disposed, resting or not on the plate **210** of the positioning device **200**. The sintering furnace **300** comprises heating devices **320**. The sintering furnace **300** may be a gas furnace operating at atmospheric pressure, the furnace being heated by one or more gas burners. The gases produced by the burners, after having heated the furnace, are extracted by an extractor in order to leave room for the gases formed continuously by the combustion.

[0086] The sintering furnace **300** may optionally comprise one or more gas inlet orifices **311** opening into the chamber **310** and one or more gas outlet orifices **312** from the chamber **310**, as illustrated in FIGS. **5** and **6**. The gas inlet orifice(s) and the gas outlet orifice(s) may be at least partly coincident.

[0087] The atmosphere in the chamber **310** of the sintering furnace **300** conventionally comprises oxygen, which allows to obtain a decomposition of the compressible material of the crown **120** by oxidation. However, preferably, the oxygen content of the atmosphere of the chamber **310** of the sintering furnace **300** is limited, in order to limit the oxidation kinetics of the compression material of the crown **120** and not to prematurely oxidize said compressible material of the crown **120**, and in particular in order not to oxidize the majority of the compressible material of the crown **120** before the start of sintering of the matrix precursor particles in the preform **10**.

[0088] The temperature increase in the sintering furnace **300** receiving the fiber preform **10** can be done gradually.

[0089] If the fibrous preform **10** comprises a binder, the temperature increase of the sintering furnace **300** allows to debind the preform, before reaching the temperatures allowing the sintering of said preform **10**. The temperature of the chamber **310** of the furnace **300** is for example comprised between 200° C. and 450° C. during the debinding of the fibrous preform **10**.

[0090] The temperature of the chamber **310** of the furnace **300** further increases until reaching the temperatures allowing the sintering of the preform **10**. The temperature of the chamber **310** of the furnace **300** is for example comprised between 1000° C. and 1200° C. during the sintering of the fibrous preform **10**, and in particular during the sintering of the matrix precursor particles present in the fibrous preform **10**. The sintering step allows to form a matrix in the porosities of the preform **10**, so as to obtain a part **1** made of composite material as illustrated in FIG. **6**. The part **1** made of

composite material comprises an external face **1**_a_, having a geometry substantially identical to the geometry of the external face **10**_a_ of the preform **10**, and an internal face **1**_b_, having a geometry substantially identical to the geometry of the internal face **10**_b_ of the preform **10**.
[0091] After debinding, the debinded fibrous preform **10** is particularly fragile and sensitive to deformations. It is therefore important that the compressible material of the crown **120** is preserved during the debinding of the preform **10**, and preferably at least until the start of sintering of said preform **10**. Indeed, when sintering begins, the matrix precursor particles present in the porosities of the preform are sintered and the matrix begins to form in said porosities of the preform, improving its strength and hold. Thus, preferably, the oxidation of the compressible material of the crown **120** must be very limited during debinding, relatively low until the start of the sintering operation and significant during the sintering operation. Preferably, when the sintering operation is completed as illustrated in FIG. **6**, the majority of the compressible material of the crown **120** has disappeared to facilitate the removal of the holding tool(s) **100** from the composite material part **1**, and to avoid the risk of contact between the disk **110** and the internal face **1**_b_ of the composite material part **1** during its cooling. In particular, in the atmospheric conditions of the sintering furnace **300**, the compressible material can begin to decompose by oxidation from 400° C. with very slow kinetics, then can decompose by oxidation with faster kinetics from a temperature comprised between 600° C. and 700° C., and finally with very fast kinetics from 900° C. A compressible material having such properties can for example be expanded graphite, as described above.
[0092] The contact between the holding tool **100** and the internal face **10**_b_ of the preform **10** can also be maintained throughout the entire sintering step.
[0093] Preferably, the compressible material is selected so as not to alter the fibrous preform **10** or the chamber **310** of the oven **300** during its decomposition.
[0094] The debinding step can be carried out in an installation different from the sintering installation, the load comprising the fibrous preform and the holding tool(s) being transported at the end of the debinding step in a sintering installation according to the invention.
[0095] The sintering step thus allows to form the matrix in the porosities of the fiber preform **10**, in order to obtain the desired composite material part. The installation and the method of the invention are particularly suitable for producing parts intended to constitute all or part of aeronautical engine rear-body parts, or all or part of combustion chambers. Generally speaking, the composite material revolution part may have a maximum cross-section of diameter greater than 700 mm.
[0096] The expression “comprised between . . . and . . . ” must be understood as including the limits.

Claims

1. An installation for sintering a revolution preform comprising a sintering furnace wherein a load is disposed, wherein the load comprises a revolution preform disposed around at least one holding tool, the at least one holding tool comprising a disk and a crown present on a periphery of the disk, the crown being made of compressible material capable of being eliminated by thermal oxidation, a portion of the preform being in contact with the crown before sintering.
2. The installation according to claim 1, wherein the compressible material is expanded graphite.
3. The installation according to claim 1, wherein the disk is made of monolithic ceramic.
4. The installation according to claim 1, wherein the at least one holding tool is disposed at one end of the preform along its axis of revolution.
5. The installation according to claim 1, wherein the revolution preform comprises matrix precursor particles in its porosities.
6. A method for manufacturing a composite material revolution part comprising: impregnating a fibrous preform of revolution at least by particles of one or more matrix precursors, placing the

fibrous preform of revolution comprising the matrix precursor particles around at least one holding tool, the at least one holding tool comprising a disk and a crown present on a periphery of the disk, the crown being made of compressible material capable of being eliminated by thermal oxidation, a portion of the preform being in contact with the crown, sintering the fibrous preform comprising the matrix precursor particles in order to form a matrix in the porosities of said fibrous preform to obtain a composite material part, the majority of the compressible material of the crown being decomposed by oxidation at the end of the sintering, removing the at least one holding tool from the composite material part obtained.

7. The method according to claim 6, wherein the compressible material is expanded graphite.

8. The method according to claim 6, wherein the impregnating of the fibrous preform also comprises the impregnation of said preform with a binder, the method further comprising debinding the fibrous preform of revolution disposed around the holding tool before the sintering.

9. The method according to claim 6, wherein a positioning and centering device is used during the placing the fiber preform around the at least one holding tool, the positioning device comprising at least one rod and one support, an end of the fiber preform along its axis of revolution furthest from the portion of the fiber preform in contact with the holding tool resting on the support, said support being fixed to the rod and the at least one holding tool being fixed to the rod by their center during the placement step.