(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 938 448 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
04.07.2018 Bulletin 2018/27

(21) Application number: **13868294.3**

(22) Date of filing: **12.12.2013**

(51) Int Cl.:
B22C 9/10 *(2006.01)* ***B22F 3/12*** *(2006.01)*

(86) International application number:
PCT/US2013/074555

(87) International publication number:
WO 2014/105436 (03.07.2014 Gazette 2014/27)

(54) MULLITE-CONTAINING INVESTMENT CASTING CORE

MULLITHALTIGER FEINGUSSKERN

NOYAU DE MOULAGE DE PRÉCISION À MODÈLE PERDU CONTENANT DE LA MULLITE

(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

(30) Priority: **28.12.2012 US 201213729077**

(43) Date of publication of application:
04.11.2015 Bulletin 2015/45

(73) Proprietor: **United Technologies Corporation**
Farmington, CT 06032 (US)

(72) Inventor: **BOCHIECHIO, Mario P.**
Vernon, Connecticut 06066 (US)

(74) Representative: **Dehns**
St. Brides House
10 Salisbury Square
London EC4Y 8JD (GB)

(56) References cited:
US-A- 3 833 385
US-A- 4 767 479
US-A- 5 394 933
US-A- 5 612 393
US-A1- 2003 075 300
US-A1- 2005 070 651
US-A1- 2006 086 478
US-A1- 2008 027 163
US-A1- 2010 122 789
US-A1- 2010 276 103
US-B1- 8 286 689

- **DALLAVALLE J M ET AL: "Fitting Bimodal Particle Size Distribution Curves, Comparison of methods", INDUSTRIAL AND ENGINEERING CHEMISTRY,, vol. 43, no. 6, 1 June 1951 (1951-06-01), pages 1377-1380, XP002637120, DOI: 10.1021/IE50498A032**

EP 2 938 448 B1

Description

BACKGROUND

[0001] This disclosure relates to investment casting and, more particularly, to investment casting cores.

[0002] Investment casting is known and used to cast metallic components with relatively complex geometries. For example, gas turbine engine components, such as airfoils that have internal passages, are made by investment casting. To form the internal passages or other relatively complex geometrical features, a core is provided which represents a positive projection of negative features that are to be formed in the casting process. A wax material is then provided around the core in the shape of the component to be cast. A shell is then formed around the wax and the wax is removed to form a cavity between the core and the surrounding shell into which molten metal is poured to form the shape of the component. After solidification of the metal, the core is removed using known techniques to provide the cast component.

[0003] US 2005/070651 discloses an investment casting core comprising a mullite-containing core body.

SUMMARY

[0004] An investment casting core according to an exemplary aspect of the present disclosure includes a mullite-containing core body and characterised by the investment casting core comprising a metallic core body joined to the mullite-containing core body, wherein the coefficient of thermal expansion of the mullite-containing core body is within 2% of the coefficient of thermal expansion of the metallic core body.

[0005] In a further non-limiting embodiment of any of the foregoing examples, the mullite-containing core body has, by weight, 40% or greater of mullite.

[0006] In a further non-limiting embodiment of any of the foregoing examples, the mullite-containing core body has, by weight, 40-90% of mullite.

[0007] In a further non-limiting embodiment of any of the foregoing examples, the mullite-containing core body has a material selected from the group consisting of alumina, silica, magnesia, yttria, calcia, zirconium silicate and combinations thereof.

[0008] In a further non-limiting embodiment of any of the foregoing examples, the mullite-containing core body has, by weight, 40-90% of mullite and 60-5% of silica.

[0009] In a further non-limiting embodiment of any of the foregoing examples, the mullite-containing core body has a material selected from the group consisting of magnesia, yttria, calcia and combinations thereof.

[0010] In a further non-limiting embodiment of any of the foregoing examples, the mullite-containing core body has zirconium silicate.

[0011] In a further non-limiting embodiment of any of the foregoing examples, the metallic core body is selected from the group consisting of molybdenum, tungsten, tantalum, rhenium, niobium and combinations thereof.

[0012] In a further non-limiting embodiment of any of the foregoing examples, the mullite-containing core body has, by weight, 80-90% mullite, 15-5% silica, 2.5- 10% alumina, 0-2.5% zircon, 0-5% of one or more of: calcia, magnesia and yttria.

[0013] In a further non-limiting embodiment of any of the foregoing examples, the mullite-containing core body has a multi-modal or bi-modal grain size distribution.

[0014] A method of making an investment casting core according to an exemplary aspect of the present disclosure includes: providing a mullite-containing powder; forming the mullite-containing powder into a green body; and sintering the green body to form a mullite-containing core body; and characterised by joining the mullite-containing core body to a metallic core body, wherein the coefficient of thermal expansion of the mullite-containing core body has a coefficient of thermal expansion within 2% of the coefficient of thermal expansion of the metallic core body.

[0015] A further non-limiting embodiment of any of the foregoing examples includes providing the mullite-containing powder in a blend with a binder, and the forming includes molding the blend into the green body.

[0016] In a further non-limiting embodiment of any of the foregoing examples, the mullite-containing powder has at least a bi-modal particle size distribution of mullite particles.

[0017] In a further non-limiting embodiment of any of the foregoing examples, the mullite-containing powder has a material selected from alumina, silica, magnesia, yttria, calcia, zirconium silicate and combinations thereof in a powder with at least a bi-modal particle size distribution.

[0018] A further non-limiting embodiment of any of the foregoing examples includes selecting a composition of the mullite-containing powder to obtain a coefficient of thermal expansion in the mullite-containing core body that matches a coefficient of thermal expansion of the metallic core body.

[0019] A method of investment casting according to an exemplary aspect of the present disclosure includes: casting a metallic component at least partially around an investment casting core that has a mullite-containing core body; and characterised by the investment casting core further comprising a metallic core body joined to the mullite-containing core body, wherein the coefficient of thermal expansion of the mullite-containing core body is within 2% of the coefficient of thermal expansion of the metallic core.

[0020] A further non-limiting embodiment of any of the foregoing examples includes the mullite-containing core body that has a material selected from the group consisting of alumina, silica, magnesia, yttria, calcia, zirconium silicate and combinations thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The various features and advantages of the present disclosure will become apparent to those skilled in the art from the following detailed description. The drawings that accompany the detailed description can be briefly described as follows.

Figure 1 shows an example investment casting core that has a mullite-containing core body.

Figure 2 shows an example method of making an investment casting core and an example method of investment casting.

DETAILED DESCRIPTION

[0022] Figure 1 schematically illustrates selected portions of an example investment casting core 20 (hereafter "core 20"). As can be appreciated, the core 20 is shown schematically for purposes of description and the actual geometry will depend on the design features of the cast component. As an example, the cast component can be an airfoil for a gas turbine engine, however, the examples herein are also applicable to other engine components or non-engine components.

[0023] The core 20 includes a mullite-containing core body 22. A "body" is a main or central foundational part, distinct from subordinate features, such as coatings or the like that are supported by the underlying body and depend primarily on the shape of the underlying body for their own shape.

[0024] In the investment casting of metallic components, such as from a superalloy material, the mechanical characteristics of a core influence the quality of the investment casting process and component. As an example, when molten metallic material is cast around a core, solidification of the metallic material exerts a force on the core. If the Young's Modulus is to high, the core will resist the solidification forces and may undesirably cause high internal stresses in the cast component or "hot tearing" of the component. In this regard, the mullite-containing core body 22 has a composition that provides "crushability" of the core 20 during investment casting. That is, the core 20 is tailored to "crush" under the solidification forces to reduce internal stresses and hot tearing.

[0025] In one example, the mullite-containing core body 22 has a composition that has, by weight, 40% or greater of mullite. In a further example, the mullite-containing core body 22 has, by weight, 40-90% of mullite.

[0026] In further examples, additional materials are used with the mullite to adjust a coefficient of thermal expansion ("CTE") of the mullite-containing core body 22 and/or as processing aids. For example, the mullite-containing core body 22 has one or more materials selected from: alumina, silica, magnesia, yttria, calcia, zirconium silicate or combinations thereof. The alumina, silica, magnesia, yttria and calcia may be added to adjust the CTE. The yttria, calcia and zirconium silicate may be added as processing aids (yttria and calcia) to facilitate sintering when making the mullite-containing core body 22 or as grain growth inhibitors (zirconium silicate). In one further example, the mullite-containing core body 22 has, by weight, 40-90% of mullite and 60 - 5 % silica. In further examples, the mullite-containing core body can also include up to 25% by weight of alumina, up to 5% by weight of magnesia, up to 5% by weight of yttria, up to 5% by weight of calcia and up to 10% by weight of zirconium silicate. Further, the mullite-containing core body 22 can have a grain size that has a grain size distribution that is equal to or approximately equal to a powder size distribution, such as a bi-modal or multi-modal particle size distribution as discussed below. This, the grain size distribution can be multi-modal or bi-modal.

[0027] The core 20 has a shape that corresponds to negative features that are to be formed in the investment cast component, such as gas turbine engine airfoils. In this regard, the illustrated core 20 has elongated limbs 24 and branches 26 that extend off of the limbs 24. It is to be understood, however, that the core 20 may alternatively have different geometries than shown, depending upon the features that are to be formed in the investment cast component.

[0028] In a further example, the core 20 can be a multi-material core that, in addition to the mullite-containing core body 22, also has a metallic core body 28 that is joined with the mullite-containing core body 22. For example, the metallic core body 28 is a refractory metal core. In one example, the refractory metal is selected from molybdenum, tungsten, tantalum, rhenium, niobium and combinations thereof.

[0029] The metallic core body 28 can be joined to the mullite-containing core body 22 using an adhesive material. For instance, the adhesive material is applied the joining surface of the mullite-containing core body 22, the metallic core body 28 or both in the form of slurry, such as a colloidal silica-based slurry. The colloidal silica based adhesive slurry will be comprised of materials of similar composition to the main core body: mullite, alumina, zirconia silicate to act as filler material as well as to ensure compatibility with the main body core. Upon drying of the slurry, the colloidal silica serves as a binder adhesive to secure the mullite-containing core body 22 and the metallic core body 28 together. Alternatively, other types of adhesives and ceramic materials could be used including adhesive systems based upon, ethyl silicate, sodium silicate, collidial alumina, colloidal yttria, colloidal zirconia.

[0030] The composition of the mullite-containing core body 22 can be tailored with regard to CTE to closely match the CTE of the metallic core body 28. For example, for the given refractory metals described above, mullite provides a relatively close match in CTE. The mullite composition can be modified with the alumina, silica, magnesia or combinations thereof to modify the CTE of the mullite-containing core body 22 in accordance with the CTE of the selected refractory metal of the metallic core body 28. In one example, the CTE of the mullite-containing core body 22 is within about 2% of the CTE of the metallic core body 28. The close match between the coefficients of thermal expansion provides a more durable joint with improved dimensional stability and thus the ability to achieve tighter tolerances and increased quality.

[0031] Figure 2 illustrates an example method 30 of making the investment casting core 20. The method 30 includes steps 32, 34 and 36. Step 32 includes providing a mullite-containing powder, step 34 includes forming the mullite-containing powder into a green body, and step 36 includes sintering the green body to form the mullite-containing core body 22.

[0032] In a further example, step 32 includes providing the mullite-containing powder in a blend with a binder and then in step 34 molding the blend to form the green body. For example, the binder can be a thermoplastic material, a wax material or a wax material with viscosity modifiers, such as stearate. In one example, the blend includes approximately 10-20% by weight of the binder material and a remainder of the mullite-containing powder.

[0033] The composition of the mullite-containing powder can be tailored according to the desired composition of the mullite-containing core body 22. That is, the mullite-containing powder can include mullite powder and powders of any or all of the other above-described materials of alumina, silica, magnesia, yttria, calcia and zirconium silicate.

[0034] In a further example, the mullite-containing powder has at least a bi-modal particle size distribution. The bi-modal distribution provides a blend of coarse and fine particles that facilitate forming the green body with relatively large sections and also with relatively thin sections. That is, the multi-modal particle size distribution facilitates filling a mold to form a relatively complex green body shape. Powders of the added materials in addition to the mullite can also include a multi-modal particle size distribution for similar purposes. Given this description, one of ordinary skill in the art will be able to determine a bimodal or multi-modal distribution to meet their particular needs. As examples, multi-modal distributions are described in "Fitting Bimodal Particle Size Distribution Curves" J. M. Dallavalle et. al., Ind. Eng. Chem., 1951, 43 (6), pp 1377-1380, and Reed, James, Introduction to the principles of ceramic processing, New York, A Wiley-Interscience publication, 1995.

[0035] As also shown in Figure 2, a method 40 of investment casting can be implemented after forming the mullite-containing core body 22. The method 40 includes casting a metallic component at least partially around the investment casting core 20 that has the mullite-containing core body 22. The details of investment casting, aside from the core 20 and mullite-containing core body 22, are generally known and therefore will not be described in further detail herein. As can also be appreciated, the methods 30 and 40 need not be conducted together. That is, the methods 30 and 40 can be mutually independent.

[0036] Although a combination of features is shown in the illustrated examples, not all of them need to be combined to realize the benefits of various embodiments of this disclosure. In other words, a system designed according to an embodiment of this disclosure will not necessarily include all of the features shown in any one of the Figures or all of the portions schematically shown in the Figures. Moreover, selected features of one example embodiment may be combined with selected features of other example embodiments.

[0037] The preceding description is exemplary rather than limiting in nature. Variations and modifications to the disclosed examples may become apparent to those skilled in the art that do not necessarily depart from the essence of this disclosure. The scope of legal protection given to this disclosure can only be determined by studying the following claims.

Claims

1. An investment casting core (20) comprising:
   a mullite-containing core body (22); and **characterised by** the investment casting core comprising a metallic core body (28) joined to the mullite-containing core body, wherein the coefficient of thermal expansion of the mullite-containing core body (22) is within 2% of the coefficient of thermal expansion of the metallic core body.

2. The investment casting core as recited in claim 1, wherein the mullite-containing core body has, by weight, 40% or greater of mullite, preferably wherein the mullite-containing core body has, by weight, 40-90% of mullite.

3. The investment casting core as recited in claim 1 or 2, wherein the mullite-containing core body has a material selected from the group consisting of alumina, silica, magnesia, yttria, calcia, zirconium silicate and combinations thereof.

4. The investment casting core as recited in any preceding claim, wherein the mullite-containing core body has, by weight, 40-90% of mullite and 60-5% of silica.

5. The investment casting core as recited in any preceding claim, wherein the mullite-containing core body has a material selected from the group consisting of magnesia, yttria, calcia and combinations thereof, or wherein the mullite-containing core body has zirconium silicate.

6. The investment casting core as recited in any preceding claim, wherein the metallic core body is selected from the group consisting of molybdenum,

tungsten, tantalum, rhenium, niobium and combinations thereof.

7. The investment casting core as recited in any preceding claim, wherein the mullite-containing core body has, by weight, 80-90% mullite, 15-5% silica, 2.5-10% alumina, 0-2.5% zircon, 0-5% of one or more of: calcia, magnesia and yttria.

8. The investment casting core as recited in any preceding claim, wherein the mullite-containing core body has a multi-modal or bi-modal grain size distribution.

9. A method of making an investment casting core (20), the method comprising:

providing a mullite-containing powder;
forming the mullite-containing powder into a green body; and
sintering the green body to form a mullite-containing core body (22);
and **characterised by** joining the mullite-containing core body to a metallic core body (28), wherein the coefficient of thermal expansion of the mullite-containing core body (22) has a coefficient of thermal expansion within 2% of the coefficient of thermal expansion of the metallic core body.

10. The method as recited in claim 9, including providing the mullite-containing powder in a blend with a binder, and the forming includes molding the blend into the green body, and/or wherein the mullite-containing powder has at least a bi-modal particle size distribution of mullite particles.

11. The method as recited in claim 9 or 10, wherein the mullite-containing powder has a material selected from alumina, silica, magnesia, yttria, calcia, zirconium silicate and combinations thereof in a powder with at least a bi-modal particle size distribution.

12. The method as recited in any of claims 9 to 11, further comprising selecting a composition of the mullite-containing powder to obtain a coefficient of thermal expansion in the mullite-containing core body that matches a coefficient of thermal expansion of the metallic core body.

13. A method of investment casting, the method comprising:
casting a metallic component at least partially around an investment casting core (20) that has a mullite-containing core body (22); and **characterised by** the investment casting core further comprising a metallic core body (28) joined to the mullite-containing core body, wherein the coefficient of thermal expansion of the mullite-containing core body (22) is within 2% of the coefficient of thermal expansion of the metallic core.

14. The method as recited in claim 13, wherein the mullite-containing core body has a material selected from the group consisting of alumina, silica, magnesia, yttria, calcia, zirconium silicate and combinations thereof.

Patentansprüche

1. Feingusskern (20), umfassend:
einen mullithaltigen Kernkörper (22); und **dadurch gekennzeichnet, dass** der Feingusskern einen metallischen Kernkörper (28) umfasst, der mit dem mullithaltigen Kernkörper verbunden ist, wobei der Wärmeausdehnungskoeffizient des mullithaltigen Kernkörpers (22) nicht mehr als 2 % vom Wärmeausdehnungskoeffizienten des metallischen Kernkörpers abweicht.

2. Feingusskern nach Anspruch 1, wobei der mullithaltige Kernkörper 40 Gewichts-% oder mehr Mullit aufweist, wobei vorzugsweise der mullithaltige Kernkörper 40-90 Gewichts-% Mullit aufweist.

3. Feingusskern nach Anspruch 1 oder 2, wobei der mullithaltige Kernkörper ein Material aufweist, das aus der Gruppe bestehend aus Aluminiumoxid, Siliciumdioxid, Magnesiumoxid, Yttriumoxid, Calciumoxid, Zirconiumsilicat und Kombinationen davon ausgewählt ist.

4. Feingusskern nach einem der vorhergehenden Ansprüche, wobei der mullithaltige Kernkörper 40-90 Gewichts-% Mullit und 60-5 Gewichts-% Siliciumdioxid aufweist.

5. Feingusskern nach einem der vorhergehenden Ansprüche, wobei der mullithaltige Kernkörper ein Material aufweist, das aus der Gruppe bestehend aus Magnesiumoxid, Yttriumoxid, Calciumoxid und Kombinationen davon ausgewählt ist, oder wobei der mullithaltige Kernkörper Zirconiumsilicat aufweist.

6. Feingusskern nach einem der vorhergehenden Ansprüche, wobei der metallische Kernkörper aus der Gruppe bestehend aus Molybdän, Wolfram, Tantal, Rhenium, Niob und Kombinationen davon ausgewählt ist.

7. Feingusskern nach einem der vorhergehenden Ansprüche, wobei der mullithaltige Kernkörper 80-90 Gewichts-% Mullit, 15-5 Gewichts-% Siliciumdioxid, 2,5-10 Gewichts-% Aluminiumoxid, 0-2,5 Gewichts-

% Zirkon, 0-5 Gewichts-% von einem oder mehreren von Calciumoxid, Magnesiumoxid und Yttriumoxid aufweist.

8. Feingusskern nach einem der vorhergehenden Ansprüche, wobei der mullithaltige Kernkörper eine multimodale oder bimodale Korngrößenverteilung aufweist.

9. Verfahren zum Herstellen eines Feingusskerns (20), wobei das Verfahren Folgendes umfasst:

Bereitstellen eines mullithaltigen Pulvers;
Formen des mullithaltigen Pulvers zu einem Grünling; und
Sintern des Grünlings zum Ausbilden eines mullithaltigen Kernkörpers (22);
und **gekennzeichnet durch** das Verbinden des mullithaltigen Kernkörpers mit einem metallischen Kernkörper (28), wobei der Wärmeausdehnungskoeffizient des mullithaltigen Kernkörpers (22) einen Wärmeausdehnungskoeffizienten aufweist, der nicht mehr als 2 % vom Wärmeausdehnungskoeffizienten des metallischen Kernkörpers abweicht.

10. Verfahren nach Anspruch 9, beinhaltend das Bereitstellen des mullithaltigen Pulvers in einer Mischung mit einem Bindemittel und wobei das Formen das Gussformen der Mischung in den Grünling beinhaltet und/oder wobei das mullithaltige Pulver zumindest eine bimodale Korngrößenverteilung von Mullitpartikeln aufweist.

11. Verfahren nach Anspruch 9 oder 10, wobei das mullithaltige Pulver ein Material, das aus Aluminiumoxid, Siliciumdioxid, Magnesiumoxid, Yttriumoxid, Calciumoxid, Zirconiumsilicat und Kombinationen davon ausgewählt ist, in einem Pulver mit zumindest einer bimodalen Partikelgrößenverteilung aufweist.

12. Verfahren nach einem der Ansprüche 9 bis 11, ferner umfassend das Auswählen einer Zusammensetzung des mullithaltigen Pulvers zum Erhalten eines Wärmeausdehnungskoeffizienten im mullithaltigen Kernkörper, der einem Wärmeausdehnungs-koeffizienten des metallischen Kernkörpers entspricht.

13. Feingussverfahren, wobei das Verfahren Folgendes umfasst:
Gießen einer metallischen Komponente zumindest teilweise um einen Feingusskern (20) herum, der einen mullithaltigen Kernkörper (22) aufweist; und **dadurch gekennzeichnet, dass** der Feingusskern ferner einen metallischen Kernkörper (28) umfasst, der mit dem mullithaltigen Kernkörper verbunden ist, wobei der Wärmeausdehnungskoeffizient des mullithaltigen Kernkörpers (22) nicht mehr als 2 % vom Wärmeausdehnungskoeffizienten des metallischen Kerns abweicht.

14. Verfahren nach Anspruch 13, wobei der mullithaltige Kernkörper ein Material aufweist, das aus der Gruppe bestehend aus Aluminiumoxid, Siliciumdioxid, Magnesiumoxid, Yttriumoxid, Calciumoxid, Zirconiumsilicat und Kombinationen davon ausgewählt ist.

Revendications

1. Noyau de moulage de précision à modèle perdu (20) comprenant :
un corps de noyau contenant de la mullite (22) ; et **caractérisé par** le noyau de moulage de précision à modèle perdu comprenant un corps de noyau métallique (28) joint au corps de noyau contenant de la mullite, dans lequel le coefficient d'expansion thermique du corps de noyau contenant de la mullite (22) ne dépasse pas 2 % du coefficient d'expansion thermique du corps de noyau métallique.

2. Noyau de moulage de précision à modèle perdu selon la revendication 1, dans lequel le corps de noyau contenant de la mullite présente en poids 40 % ou plus de mullite, de préférence dans lequel le corps de noyau contenant de la mullite présente, en poids, 40 à 90 % de mullite.

3. Noyau de moulage de précision à modèle perdu selon la revendication 1 ou 2, dans lequel le corps de noyau contenant de la mullite présente un matériau sélectionné dans le groupe composé d'alumine, de silice, de magnésie, d'yttrium, de calcium, de silicate de zirconium et de combinaisons de ceux-ci .

4. Noyau de moulage de précision à modèle perdu selon une quelconque revendication précédente, dans lequel le corps de noyau contenant de la mullite présente en poids 40 à 90 % de mullite et 60 à 5 % de silice.

5. Noyau de moulage de précision à modèle perdu selon une quelconque revendication précédente, dans lequel le corps de noyau contenant de la mullite présente un matériau sélectionné dans le groupe composé de magnésie, d'yttrium, de calcium et de combinaisons de ceux-ci, ou dans lequel le corps de noyau contenant de la mullite présente du silicate de zirconium.

6. Noyau de moulage de précision à modèle perdu selon une quelconque revendication précédente, dans lequel le corps de noyau métallique est sélectionné dans le groupe composé de molybdène, de tungstène, de tantale, de rhénium, de niobium et de combinaisons de ceux-ci.

7. Noyau de moulage de précision à modèle perdu selon une quelconque revendication précédente, dans lequel le corps de noyau contenant de la mullite présente en poids 80 à 90 % de mullite, 15 à 5 % de silice, 2,5 à 10 % d'alumine, 0 à 2,5 % de zircon, 0 à 5 % d'un ou de plusieurs de : calcium, magnésie et yttrium.

8. Noyau de moulage de précision à modèle perdu selon une quelconque revendication précédente, dans lequel le corps de noyau contenant de la mullite présente une distribution granulométrique multimodale ou bimodale.

9. Procédé de fabrication d'un noyau de moulage de précision à modèle perdu (20), le procédé comprenant :

la fourniture d'une poudre contenant de la mullite ;
la formation de la poudre contenant de la mullite dans un corps vert ; et
le frittage du corps vert pour former un corps de noyau contenant de la mullite (22) ;
et **caractérisé par** la jonction du corps de noyau contenant de la mullite à un corps de noyau métallique (28), dans lequel le coefficient d'expansion thermique du corps de noyau contenant de la mullite (22) présente un coefficient d'expansion thermique qui ne dépasse pas 2 % du coefficient d'expansion thermique du corps de noyau métallique.

10. Procédé selon la revendication 9, incluant la fourniture de la poudre contenant de la mullite dans un mélange avec un liant, et la formation inclut le moulage du mélange dans le corps vert, et/ou dans lequel la poudre contenant de la mullite présente au moins une distribution granulométrique bimodale de particules de mullite.

11. Procédé selon la revendication 9 ou 10, dans lequel la poudre contenant de la mullite présente un matériau sélectionné parmi l'alumine, la silice, la magnésie, l'yttrium, le calcium, le silicate de zirconium et des combinaisons de ceux-ci dans une poudre avec au moins une distribution granulométrique bimodale.

12. Procédé selon l'une quelconque des revendications 9 à 11, comprenant en outre la sélection d'une composition de la poudre contenant de la mullite pour obtenir un coefficient d'expansion thermique dans le corps de noyau contenant de la mullite qui correspond à un coefficient d'expansion thermique du corps de noyau métallique.

13. Procédé de moulage de précision à modèle perdu, le procédé comprenant :

le moulage d'un composant métallique au moins partiellement autour d'un noyau de moulage de précision à modèle perdu (20) qui présente un corps de noyau contenant de la mullite (22) ; et **caractérisé par** le noyau de moulage de précision à modèle perdu comprenant en outre un corps de noyau métallique (28) joint au corps de noyau contenant de la mullite, dans lequel le coefficient d'expansion thermique du corps de noyau contenant de mullite (22) ne dépasse pas 2 % du coefficient d'expansion thermique du noyau métallique.

14. Procédé selon la revendication 13, dans lequel le corps de noyau contenant de la mullite présente un matériau sélectionné dans le groupe composé d'alumine, de silice, de magnésie, d'yttrium, de calcium, de silicate de zirconium et de combinaisons de ceux-ci.

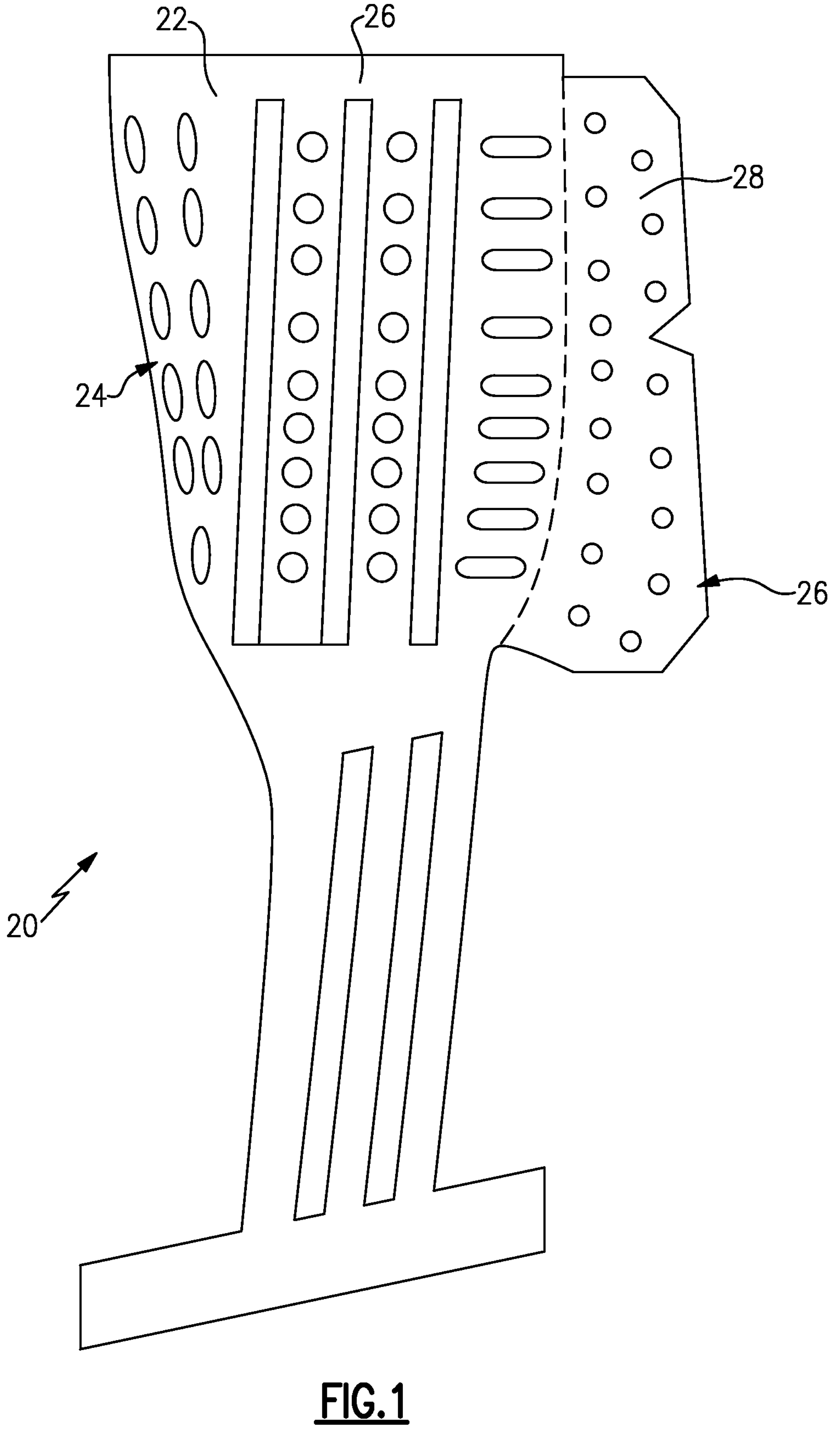

FIG.1

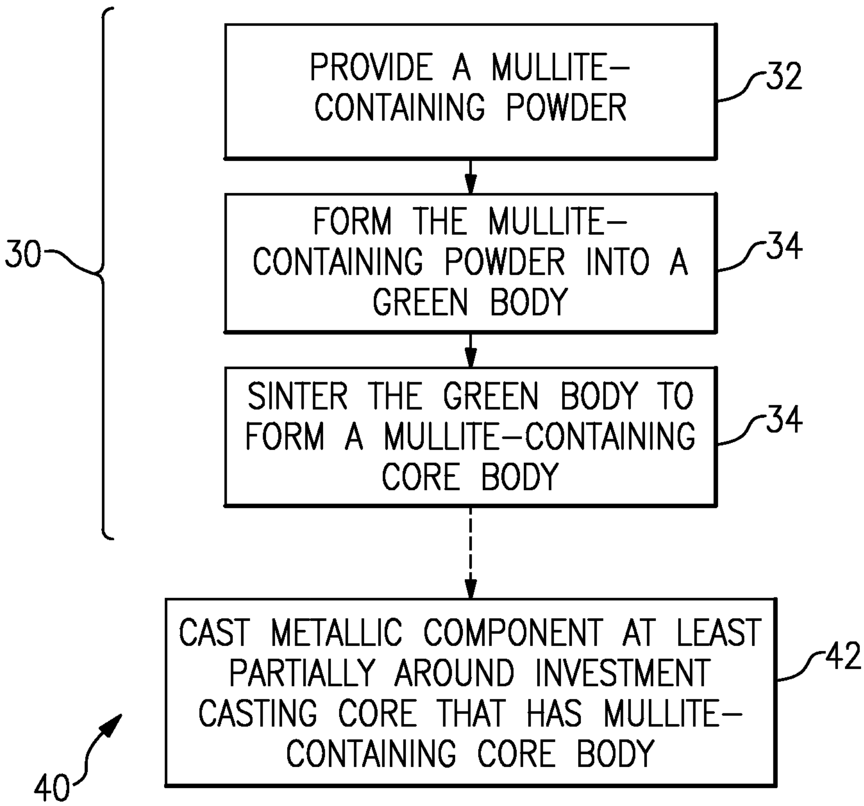
PROVIDE A MULLITE-CONTAINING POWDER
32
FORM THE MULLITE-CONTAINING POWDER INTO A GREEN BODY
34
SINTER THE GREEN BODY TO FORM A MULLITE-CONTAINING CORE BODY
34
30
CAST METALLIC COMPONENT AT LEAST PARTIALLY AROUND INVESTMENT CASTING CORE THAT HAS MULLITE-CONTAINING CORE BODY
42
40

FIG.2

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 2005070651 A **[0003]**

Non-patent literature cited in the description

- **J. M. DALLAVALLE.** Fitting Bimodal Particle Size Distribution Curves. *Ind. Eng. Chem.,* 1951, vol. 43 (6), 1377-1380 **[0034]**
- **REED ; JAMES.** Introduction to the principles of ceramic processing. Wiley-Interscience publication, 1995 **[0034]**