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(54) THERMAL MANAGEMENT IN LOST WAX CASTING

(57) Disclosed is a lost-wax method of casting a product, having steps of: attaching (100) temperature control elements to a wax assembly; encasing (110) the wax assembly and the temperature control elements in a ceramic mold; removing (120) the wax assembly from the ceramic mold; filling (130) the ceramic mold with molten material to form a cast part within the ceramic mold; and separating (140) the ceramic mold and the cast part from each other.

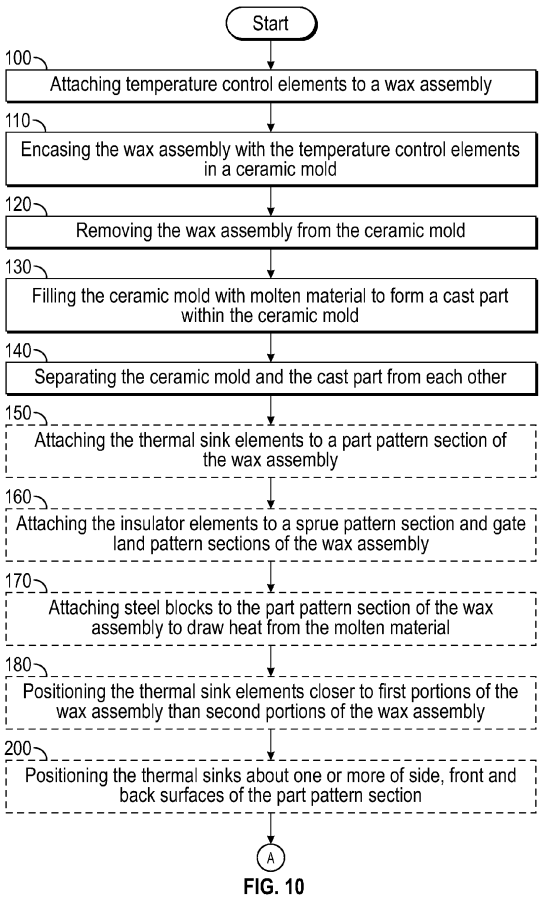

FIG. 10

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Description

BACKGROUND

[0001] The embodiments herein relate to casting of materials and more specifically to thermal management in lost wax casting.

[0002] Production of metal parts from lost-wax casting enables replication of parts on small and mass scales. Investment casting may include a wax part pattern of an article to be cast, which may be produced from a die mold. The component wax pattern may be connected with injected wax shapes on a wax assembly, which will typically possesses a pour-cup, down-sprue, wax ingates, and then the component pattern itself. The wax tree, with the part patterns, is then coated with a ceramic slurry to form a ceramic shell over its surface.

[0003] After ceramic slurry application, the wax assembly may then be withdrawn from the slurry and dried. The steps of coating and drying are repeated until a ceramic shell mold around the wax tree is of a sufficient thickness, which may depend on the weight of the cast assembly. The wax tree, with the ceramic shell, is then placed in a furnace pressurized steam de-waxer vessel removes the wax from the inside of the ceramic mold. The ceramic mold is then placed into a furnace to heat and sinter the ceramic particles to strengthen the mold to enable the receipt of a certain volume of molten metal.

[0004] The hardening may be in a separate thermal processing step. The ceramic mold is then ready for the casting of the part. Molten metal is poured into the pour-cup and passed through the sprue and ingates into the component cavity once defined by the wax assembly. After the metal has solidified, the ceramic shell is removed mechanically to reveal the metal components on the assembly. The cast components are then removed from the assembly, mechanically finished and inspected. The ceramic shell is mechanically removed, e.g., by blunt force (or other mechanical action), after the metal is hardened.

[0005] For Solid mold casting, the wax tree is placed within a flask, which is then filled with the ceramic slurry. The flask, with the hardened ceramic, may be placed in a furnace and heated to remove the wax, and to harden the ceramic coating. The hardening may be in a separate heat-treating step. The ceramic mold is then ready for casting. In this form of casting, molten metal is also poured into the pour-cup and then passes into the down-sprue and runner system to feed the component pattern(s). The ceramic is also mechanically removed after the metal is solidified. Parts cast from these processes should be relatively defect free to meet manufacturing needs.

BRIEF SUMMARY

[0006] Disclosed is a lost-wax method of casting a product, including: attaching temperature control elements to a wax assembly; encasing the wax assembly and the temperature control elements in a ceramic mold; removing the wax assembly from the ceramic mold; filling the ceramic mold with molten material to form a cast part within the ceramic mold; and separating the ceramic mold and the cast part from each other.

[0007] In addition to one or more of the above disclosed aspects of the method, or as an alternate, the temperature control elements are thermal sink elements and the method includes attaching the thermal sink elements to a part pattern section of the wax assembly.

[0008] In addition to one or more of the above disclosed aspects of the method, or as an alternate, when the temperature control elements are insulating elements, and the method includes attaching the insulating elements to a sprue pattern section and gate-land pattern sections of the wax assembly.

[0009] In addition to one or more of the above disclosed aspects of the method, or as an alternate, the temperature control elements are steel blocks of different sizes, and the method includes: attaching the steel blocks to the part pattern section to draw heat from the molten material.

[0010] In addition to one or more of the above disclosed aspects of the method, or as an alternate, the method further includes positioning the thermal sink elements closer to first portions of the part pattern section of the wax assembly than second portions of the part pattern section of the wax assembly, wherein the first portions are thicker than the second portions.

[0011] In addition to one or more of the above disclosed aspects of the method, or as an alternate, the method further includes positioning the thermal sink elements about one or more of side, front and back surfaces of the wax assembly.

[0012] In addition to one or more of the above disclosed aspects of the method, or as an alternate, the method further includes attaching the temperature control elements directly to the wax assembly.

[0013] In addition to one or more of the above disclosed aspects of the method, or as an alternate, the method further includes forming the ceramic mold about the wax assembly to a first thickness to define a first layer of the ceramic mold; and attaching the temperature control elements to the first layer of the ceramic mold.

[0014] In addition to one or more of the above disclosed aspects of the method, or as an alternate, the method further includes forming the ceramic mold about the wax assembly to a second thickness that is greater than the first thickness to encase the temperature control elements within the ceramic mold.

[0015] In addition to one or more of the above disclosed aspects of the method, or as an alternate, the method further includes forming the ceramic mold about the wax assembly to the second thickness by repeatedly: drenching the wax assembly in a ceramic slurry; and drying the ceramic slurry.

[0016] In addition to one or more of the above disclosed

aspects of the method, or as an alternate, the method further includes forming the ceramic mold about the wax assembly to the second thickness by: positioning the wax assembly in a flask; and filling the flask with a ceramic slurry.

[0017] In addition to one or more of the above disclosed aspects of the method, or as an alternate, the method further includes separating the ceramic mold and the cast part from each other by mechanical action.

[0018] In addition to one or more of the above disclosed aspects of the method, or as an alternate, the method further includes thermally removing wax from and firing the ceramic mold to sinter the ceramic and prepare the ceramic mold for casting.

[0019] Further disclosed is a mold assembly, including: a wax assembly including: a part pattern section; temperature control elements connected to the wax assembly, wherein: a ceramic mold encasing the wax assembly and the temperature control elements.

[0020] In addition to one or more of the above disclosed aspects of the mold assembly, or as an alternate, the temperature control elements include thermal sink elements spaced apart from each other and connected to the part pattern section.

[0021] In addition to one or more of the above disclosed aspects of the mold assembly, or as an alternate, mold assembly includes: a gate pattern section connected around an outer surface the part pattern section and defining a sprue pattern section and gate-land pattern sections; and the temperature control elements include insulating elements connected to the sprue pattern section and the gate-land pattern sections.

[0022] In addition to one or more of the above disclosed aspects of the mold assembly, or as an alternate, the temperature control elements are disposed between layers of ceramic in the ceramic mold.

[0023] Further disclosed is a ceramic mold defining: a part pattern chamber; a gate section formed around the part pattern chamber and defining a sprue and gate-lands; and temperature control elements encased in the ceramic mold.

[0024] In addition to one or more of the above disclosed aspects of the ceramic mold, or as an alternate, the temperature control elements include: thermal sink elements spaced apart from each other within the part pattern chamber.

[0025] In addition to one or more of the above disclosed aspects of the ceramic mold, or as an alternate, the temperature control elements include: insulating elements disposed within the sprue and the gate-lands.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The present disclosure is illustrated by way of example and not limited in the accompanying figures in which like reference numerals indicate similar elements.

FIG. 1 shows a wax assembly with temperature control elements according to an embodiment;

FIG. 2 shows the wax assembly encased in a ceramic mold as part of an investment casting process according to an embodiment;

FIG. 3 shows the wax assembly encased in the ceramic mold as part of a solid-mold casting process according to an embodiment;

FIG. 4 shows the ceramic mold, with the wax assembly removed, as part of an investment casting process according to an embodiment;

FIG. 5 shows the ceramic mold, with the wax assembly removed, as part of a solid-mold casting process according to an embodiment;

FIG. 6 shows the ceramic mold, including a sprue, a gate section and a part pattern chamber, filled with molten material as part of an investment casting process according to an embodiment;

FIG. 7 shows the ceramic mold, including a sprue, a gate section and a part pattern chamber, filled with molten material, as part of a solid-mold casting process according to an embodiment;

FIG. 8 shows a cast part, with the ceramic mold removed, as part of either the investment casting process or the solid mold process according to an embodiment;

FIG. 9 shows the cast part in a final form, with excess metal removed according to an embodiment; and

FIG. 10 is a flowchart showing a lost-wax method of casting a part according to an embodiment.

DETAILED DESCRIPTION

[0027] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0028] During investment and solid mold type lost-wax casting, molten metal may undesirably solidify within the sprue, runners or assembly gating as well as within the component to which the assembly gating is attached before reaching the part pattern chamber. This may, result in casting defects which would cause the need for rework and repair, or would scrap the parts. In addition, the molten metal may cool unevenly within the part pattern chamber due to a variation of geometries within the part pattern chamber. For example, a relatively large mass of molten metal at thicker portions of a part pattern may result in an excess of heat in the same location compared with a thinner portion of the part pattern. Thus, thicker portions

may cool more slowly than thinner portions of the part pattern within the part pattern chamber. The cooling dynamics may result in undesirable residual stress and strain in the final cast part.

[0029] As shown in FIG. 1, in view of the above identified concerns with lost wax investment and solid-mold type lost-wax casting, the disclosed embodiments utilize temperature control elements 100. The temperature control elements 100 take the form of thermal sink elements (or chillers) 100A1-100A5 (generally referenced as 100A). The thermal sink elements 100A are respectively applied to first portions 210A1, 210A2 (generally referenced as 210A) of a part pattern section 120 of a wax assembly 140 (or wax investment). As shown, the thermal sink elements 100A are applied to a side surface 125A, also referred to as an outer surface, of the part pattern section 120. However, the part pattern section 120 is three dimensional and thus has front and back surfaces 125B, 125C, identified schematically, and the thermal sink elements 100A may be applied there as well. For example, thermal sink elements 100A4, 100A5 are schematically shown for the front and back surfaces 125B, 125C, respectively.

[0030] The first portions 210A are relatively thick portions of the part pattern section 120 compared with, e.g., second portions 220B1, 220B2 (generally referenced as 220B) which may be near the respective first portions 210A. The thermal sink elements 100A are configured to provide for thermal control of the casting process by drawing out excess heat from molten material 180 utilized during the casting process. Faster solidification in areas of greater mass will result in more sound cast metal with less micro-porosity and macro-porosity defects. This is especially true if the area of larger mass is contained within regions of small mass where proper metal fill and solidification are not possible.

[0031] Additionally, the temperature control elements 100 take the form of insulating elements (or thermal barriers) 100B1-100B6 (generally referenced as 100B). The insulating elements 100B may be respectively applied to a sprue pattern section 190 and gate-land pattern sections 200A1-200A4 (generally referenced as 200A) of a gate pattern section 130 of the wax assembly 140. Insulating sections may be required. The insulating elements 100B are configured to provide for thermal control of the casting process by preventing heat from being drawn out of the molten material 180 (FIGS. 6-7) applied during the casting process.

[0032] The thermal sink elements 100A may be formed from conductive material such as metal or ceramic (SiC). The thermal sink elements 100A may have a higher thermal conductivity than the wax assembly 140 or a ceramic mold 150 (e.g., FIGS. 2-7) that is built around the wax assembly 140 as part of the casting process. The thermal sink elements 100A may be attached directly to the part pattern section 120 of the wax assembly 140, to the ceramic mold 150, or to the gate pattern section 130 in close proximity to the part pattern section 120. The thermal sink elements 100A may extract heat relatively quickly from the part pattern chamber 160 (FIGS. 2-7) to provide a cast part 170 that is relatively sound and defect free.

[0033] The insulating elements 100B may be applied in similar fashion in the gate pattern section 130 to slow down the solidification process for fabricating the cast part 170. The insulating elements 100B may be a ceramic with lower conductivity than the remainder of the ceramic mold 150. The insulating elements 100B may be formed of a material such as monolithic ceramics such as alumina, zircon, silica, etc., or a thermal barrier ceramic with controlled thermal conductivity such as yttria stabilized zirconia (YSZ), or a ceramic matrix composite which can control heat retention or dissipation in a controlled manner .

[0034] Thus, the disclosed process utilizes the temperature control elements 100 in situ in the investment casting and solid mold casting processes to affect a natural solidification rate of the molten material 180 (FIG. 8 and 9). The temperature control elements 100 may do this by directing and removing latent heat. This optimizes the solidification the molten material 180 to form a cast part 170 in the part pattern chamber 160. This process may improve product yields and reduce scrap and rework.

[0035] FIG. 2 shows an investment casting mold assembly 165 and includes the wax assembly 140 encased in the ceramic mold 150 as part of an investment casting process. FIG. 2 also shows the thermal sink elements 100A encased in the ceramic mold 150 and positioned against the part pattern section 120. The figure shows the insulating elements 100B encased in the ceramic mold 150 and located against the sprue pattern section 190.

[0036] FIG. 3 shows a solid-mold casting assembly 165A and includes the wax assembly 140 encased in the ceramic mold 150 as part of a solid-mold casting process. FIG. 3 also shows the thermal sink elements 100A encased in the ceramic mold 150 and located against the part pattern section 120. The figure also shows the insulating elements 100B encased in the ceramic mold 150 and located against the sprue pattern section 190 and the gate-land pattern sections 200A. FIG. 3 further shows the flask 230 for supporting the ceramic mold 150.

[0037] FIG. 4 shows the ceramic mold 150 with the wax assembly 140 removed as part of an investment casting process. FIG. 4 also shows the thermal sink elements 100A at the part pattern chamber 160, the insulating elements 100B at the sprue 190A and the gate-lands 200B1-200B5 (generally referenced as 200B) formed by removal of the wax assembly 140. FIG. 4 also shows the gate section 130A formed by removal of the wax assembly 140.

[0038] FIG. 5 shows the ceramic mold 150 with the wax assembly 140 removed as part of a solid-mold casting process. FIG. 5 also shows the thermal sink elements 100A at the part pattern chamber 160 formed by removal of the wax assembly 140, and the insulating elements 100B at the sprue 190A the gate-lands 200B formed by

removal of the wax assembly 140. FIG. 5 further shows the gate section 130A formed by removal of the wax assembly 140 and the flask 230 for supporting the ceramic mold 150.

[0039] FIG. 6 shows the ceramic mold 150, including the sprue 190A, the gate section 130A and the part pattern chamber 160, filled with molten material 180 as part of an investment casting process. FIG. 6 also shows the thermal sink elements 100A at the part pattern chamber 160 and the insulating elements 100B at the sprue 190A and the gate-lands 200B.

[0040] FIG. 7 shows the ceramic mold 150, including the sprue 190A, the gate section 130A and the part pattern chamber 160, filled with molten material 180 as part of a solid-mold casting process. FIG. 7 also shows the thermal sink elements 100A at the part pattern chamber 160 and the insulating elements 100B at the sprue 190A and the gate-lands 200B. FIG. 7 further shows the flask 230 for supporting the ceramic mold 150.

[0041] The insulating elements 100B prevent the molten material 180 from cooling and drying, e.g., at the sprue 190A and the gate-lands 200B. The thermal sink elements 100A remove excess heat from molten material 180 in the part pattern chamber 160 adjacent to where it is placed. Thus, placing the thermal sink elements 100A next to a thicker portion of the part pattern chamber 160 enable cooling at a similar rate as a thinner portion of the part pattern chamber 160.

[0042] FIG. 8 shows the cast part 170 with the ceramic mold removed as part of either the investment casting process or the solid mold process. Excess metal 170A is around the cast part 170 in locations corresponding to the sprue 190A and gate section 130A (e.g., FIGS. 6-7). FIG. 9 shows the cast part 170 in the final form, with the excess metal 170A removed.

[0043] FIG. 10 is a flowchart showing a lost-wax method of casting a part, i.e., to provide the cast part 170. As shown in block 100, the method includes attaching the temperature control elements 100 to the wax assembly 140. As shown in block 110, the method includes encasing the wax assembly 140 and the temperature control elements 100 in the ceramic mold 150. As shown in block 120, the method includes removing the wax assembly 140 from the ceramic mold 150. As shown in block 130 in FIG. 10, the method includes filling the ceramic mold 150 with molten material 180 to form the cast part 170 within the ceramic mold 150. As shown in block 140 the method includes separating the ceramic mold 150 and the cast part 170 from each other.

[0044] Additionally, as shown in block 150, the method may further include attaching the thermal sink elements 100A to the part pattern section 120 of the wax assembly 140. As shown in block 160, the method may further include attaching the insulating elements 100B to the sprue pattern section 190 and the gate-land pattern sections 200A of the wax assembly 140.

[0045] As shown in block 170, the method may further include attaching steel blocks (as the thermal sink elements 100A) to the part pattern section of the wax assembly 140 to draw heat from the molten material 180. As shown in block 180, the method may include positioning the thermal sink elements 100A closer to the first portions 210A of the part pattern section 120 of the wax assembly 140 than the second portions 220A of the part pattern section 120 of the wax assembly 140. As indicated, the first portions 210A are thicker than the second portions 220A. As shown in block 200, the method may include positioning the thermal sink elements 100A about one or more of side, front and back surfaces 125A-125C of the wax assembly 140.

[0046] As shown in block 220, the method further includes attaching the temperature control elements 100 directly to the part pattern section 120 of the wax assembly 140. In such embodiment the thermal sink elements 100A may be formed of metal having a melting temperature that is greater than the molten material 180. Thus, when molten material 180 contacts the thermal sink elements 100A, the thermal sink elements 100A will remain solid and not contaminate the molten material 180. Similarly, the insulating elements 100B are also formed of a material that will not contaminate the molten material 180, and may be, e.g., a ceramic as indicated above. The temperature control elements 100 may be attached the wax assembly 140 via, e.g., additional melted wax.

[0047] In one embodiment, as shown in block 230, the method may include forming the ceramic mold 150 about the wax assembly 140 to a first thickness to define a first layer of the ceramic mold 150. The method may include, as shown in block 240, attaching the temperature control elements 100 to the first layer of the ceramic mold 150. In this embodiment, a thin layer of ceramic may separate the temperature control elements 100 from the wax assembly 140. This minimizes a likelihood of cross contamination between the molten material 180 and either of the temperature control elements 100.

[0048] As shown in block 250, the method may further include forming the ceramic mold 150 about the wax assembly 140 to a second thickness that is greater than the first thickness. This action encases the temperature control elements 100 within the ceramic mold 150. With this configuration, the temperature control elements 100 are securely contained and structurally isolated within the ceramic mold 150.

[0049] In one embodiment, as shown in block 260, the method may further include forming layers of the ceramic mold 150 to build-up the ceramic mold 150 to the second thickness. This action forms the ceramic mold 150 about the wax assembly 140. Forming layers of the ceramic mold 150 may include encasing the wax assembly in a ceramic slurry, and drying the ceramic slurry, and repeating. In one embodiment, as shown in block 270, the method may further include positioning the wax assembly 140 in a flask 230. The method may further include, as shown in block 280, filling the flask 230 with the ceramic slurry. This action forms the ceramic mold 150 about the wax assembly 140.

[0050] As shown in block 290, the method may include mechanically separating, e.g., with application of blunt force (or other mechanical action, such as the utilization of a hammer or other impact implement), the ceramic mold 150 and the cast part 170 from each other. As shown in block 300, the method may further include thermally removing wax from and firing (e.g., applying fire or other similar heat source to) the ceramic mold 150 to sinter the ceramic and prepare the ceramic mold 150 for casting. Such heat treatment assists in strengthening the ceramic mold 150 so that it may withstand the temperature and the weight of the molten material 180.

[0051] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.

[0052] Those of skill in the art will appreciate that various example embodiments are shown and described herein, each having certain features in the particular embodiments, but the present disclosure is not thus limited. Rather, the present disclosure can be modified to incorporate any number of variations, alterations, substitutions, combinations, sub-combinations, or equivalent arrangements not heretofore described, but which are commensurate with the scope of the present disclosure. Additionally, while various embodiments of the present disclosure have been described, it is to be understood that aspects of the present disclosure may include only some of the described embodiments. Accordingly, the present disclosure is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.

Claims

1. A lost-wax method of casting a product, comprising:

attaching (100) temperature control elements to a wax assembly (140);
encasing (110) the wax assembly (140) and the temperature control elements in a ceramic mold;
removing (120) the wax assembly (140) from the ceramic mold;
filling (130) the ceramic mold with molten material to form a cast part within the ceramic mold; and
separating (140) the ceramic mold and the cast part from each other.

2. The method of claim 1, wherein:
the temperature control elements are thermal sink elements and the method includes attaching the thermal sink elements to a part pattern section (120) of the wax assembly.

3. The method of claim 1, wherein:
when the temperature control elements are insulating elements, and the method includes attaching the insulating elements to a sprue pattern section and gate-land pattern sections of the wax assembly.

4. The method of claim 2, wherein
the temperature control elements are steel blocks of different sizes, and the method includes:
attaching the steel blocks to the part pattern section to draw heat from the molten material.

5. The method of claim 2, further comprising:

positioning (180) the thermal sink elements closer to first portions of the part pattern section of the wax assembly than second portions of the part pattern section of the wax assembly, wherein the first portions are thicker than the second portions.
and/or further comprising:
positioning (200) the thermal sink elements about one or more of side, front and back surfaces of the wax assembly.

6. The method of any preceding claim, comprising:
attaching the temperature control elements directly to the wax assembly.

7. The method of any preceding claim, comprising:

forming the ceramic mold about the wax assembly to a first thickness to define a first layer of the ceramic mold; and
attaching the temperature control elements to the first layer of the ceramic mold.

8. The method of claim 7, comprising
forming the ceramic mold about the wax assembly to a second thickness that is greater than the first thickness to encase the temperature control elements within the ceramic mold.

9. The method of claim 8, further comprising
forming the ceramic mold about the wax assembly to the second thickness by repeatedly: drenching the wax assembly in a ceramic slurry; and drying the ceramic slurry or further comprising
forming the ceramic mold about the wax assembly to the second thickness by:

positioning the wax assembly in a flask; and

filling the flask with a ceramic slurry.

10. The method of any preceding claim, further comprising
separating the ceramic mold and the cast part from each other by mechanical action, or including thermally removing wax from and firing the ceramic mold to sinter the ceramic and prepare the ceramic mold for casting.

11. A mold assembly, comprising:
a wax assembly including:

a part pattern section;
temperature control elements connected to the wax assembly, wherein:
a ceramic mold encasing the wax assembly and the temperature control elements.

12. The mold assembly of claim 11, wherein:
the temperature control elements include thermal sink elements spaced apart from each other and connected to the part pattern section.

13. The mold assembly of claim 11 or 12, wherein:
the wax assembly includes:

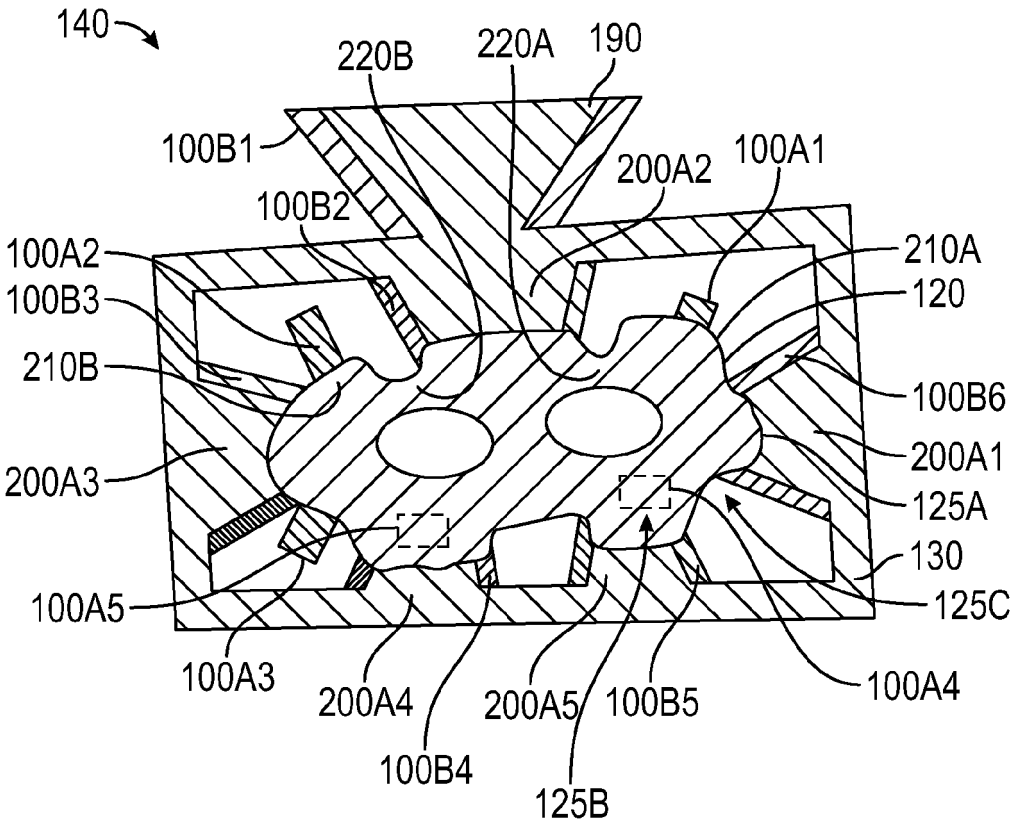
a gate pattern section connected around an outer surface the part pattern section and defining a sprue pattern section and gate-land pattern sections; and
the temperature control elements include insulating elements connected to the sprue pattern section and the gate-land pattern sections, and optionally wherein the temperature control elements are disposed between layers of ceramic in the ceramic mold.

14. A ceramic mold defining:

a part pattern chamber;
a gate section formed around the part pattern chamber and defining a sprue and gate-lands; and
temperature control elements encased in the ceramic mold.

15. The ceramic mold of claim 14, wherein:

the temperature control elements include:
thermal sink elements spaced apart from each other within the part pattern chamber, or wherein the temperature control elements include:
insulating elements disposed within the sprue and the gate-lands.


140
220B
220A
190
100B1
200A2
100A1
100B2
100A2
210A
100B3
120
210B
100B6
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200A5
100B5
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100B4
125B

FIG. 1

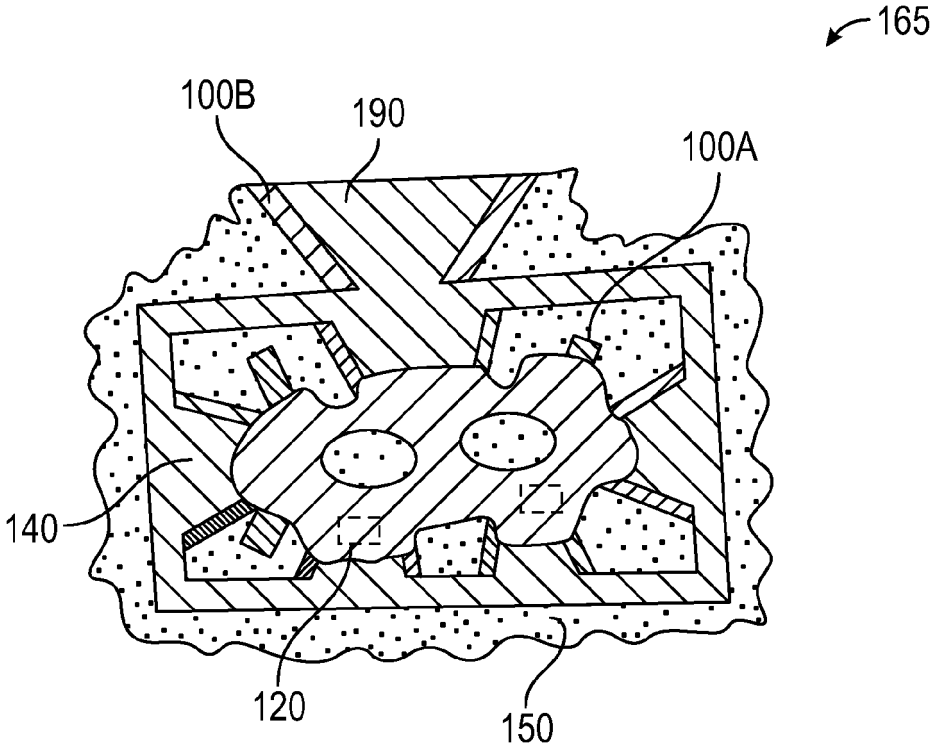
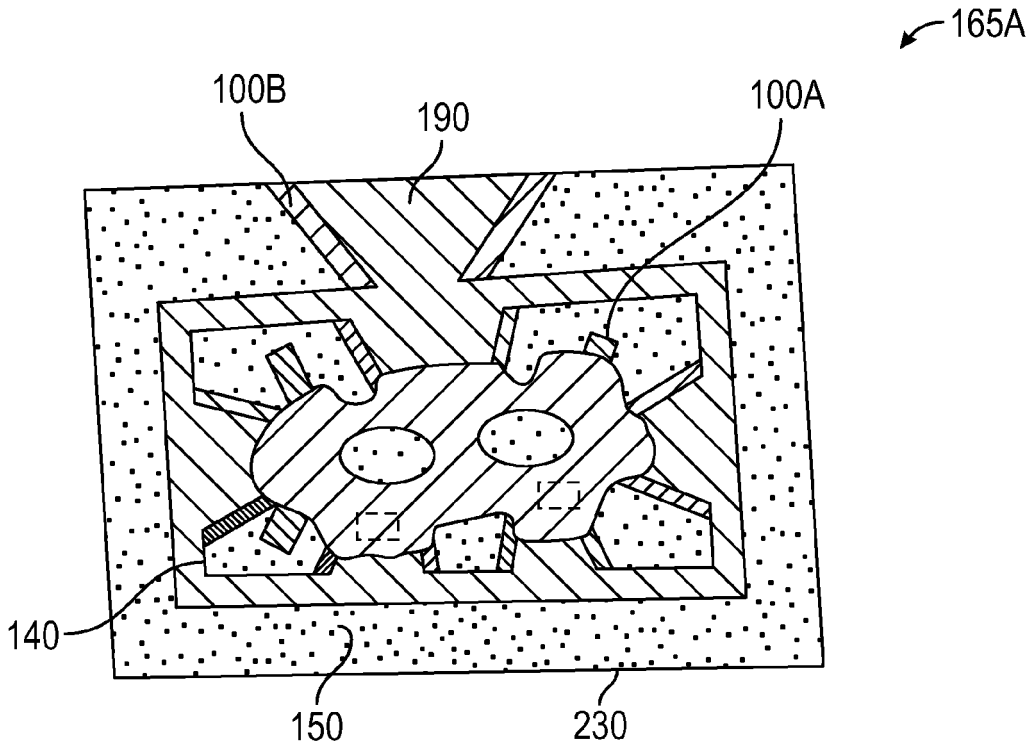

165
100B
190
100A
140
120
150

FIG. 2


165A
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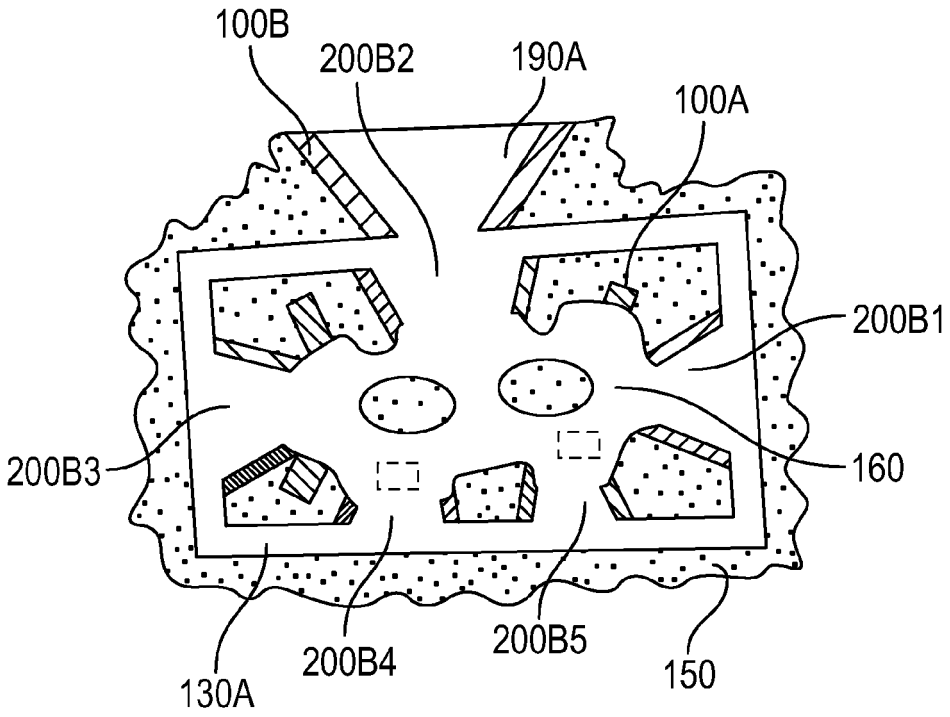
190
100A
140
150
230

FIG. 3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100A
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200B3
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130A
200B4
200B5
150

FIG. 4

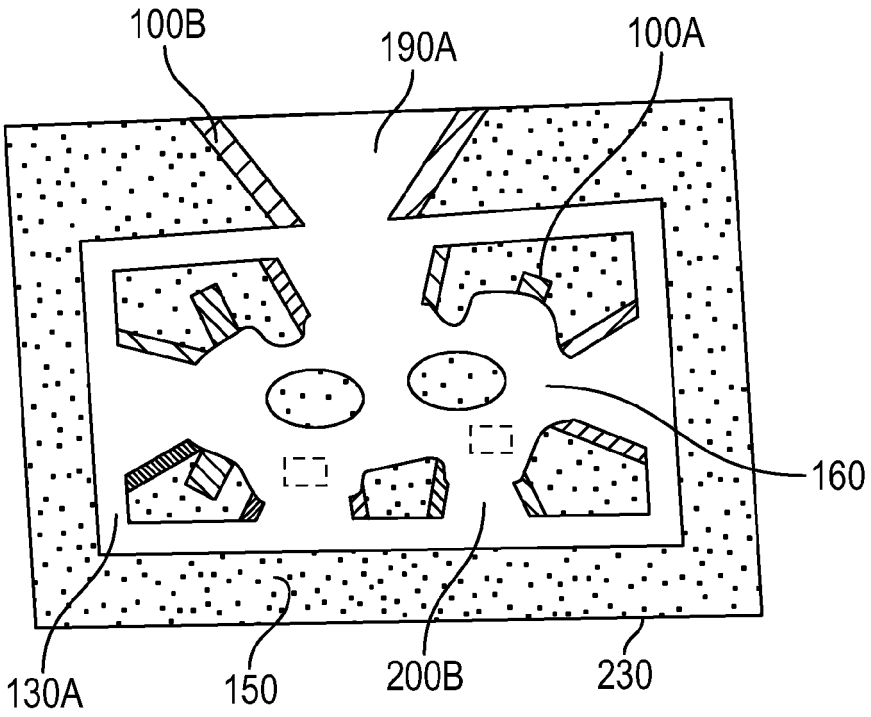
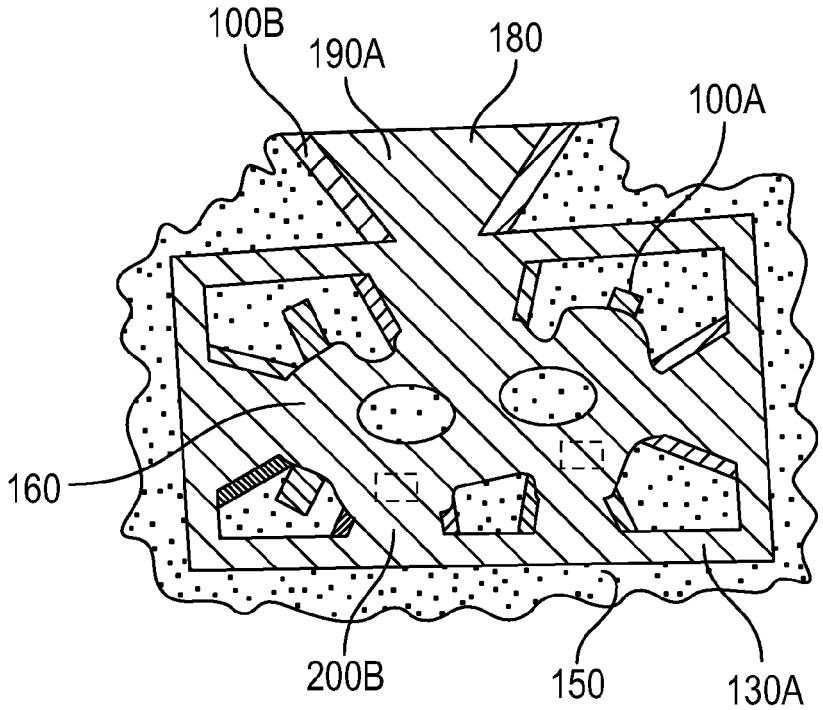

100B
190A
100A
160
130A
150
200B
230

FIG. 5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100A
160
200B
150
130A

FIG. 6

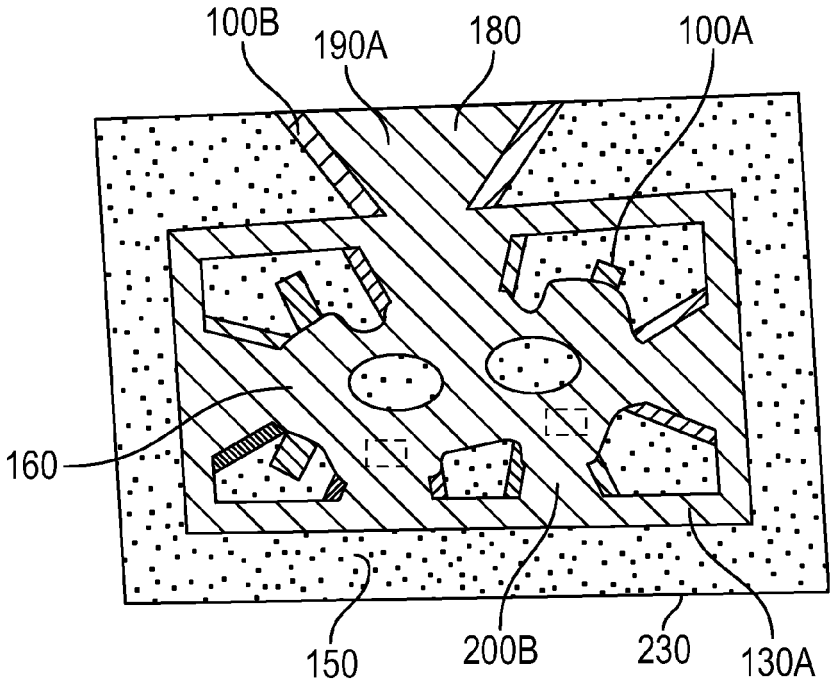

FIG. 7

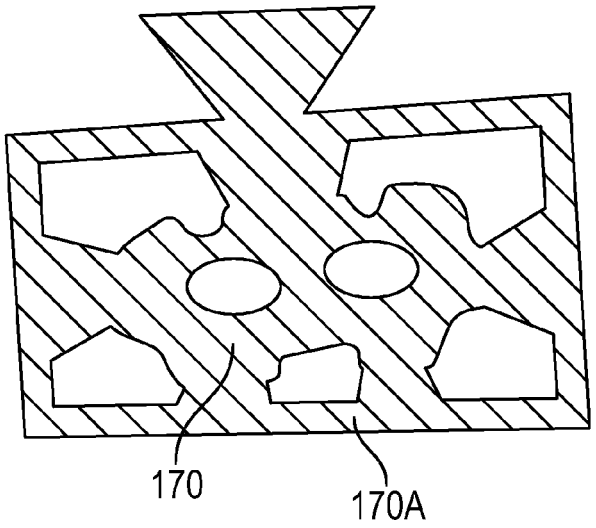

FIG. 8

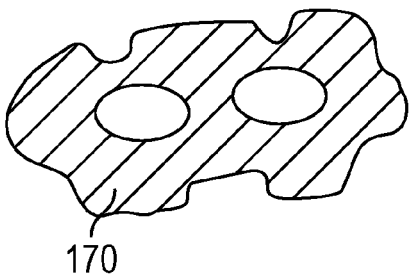

FIG. 9

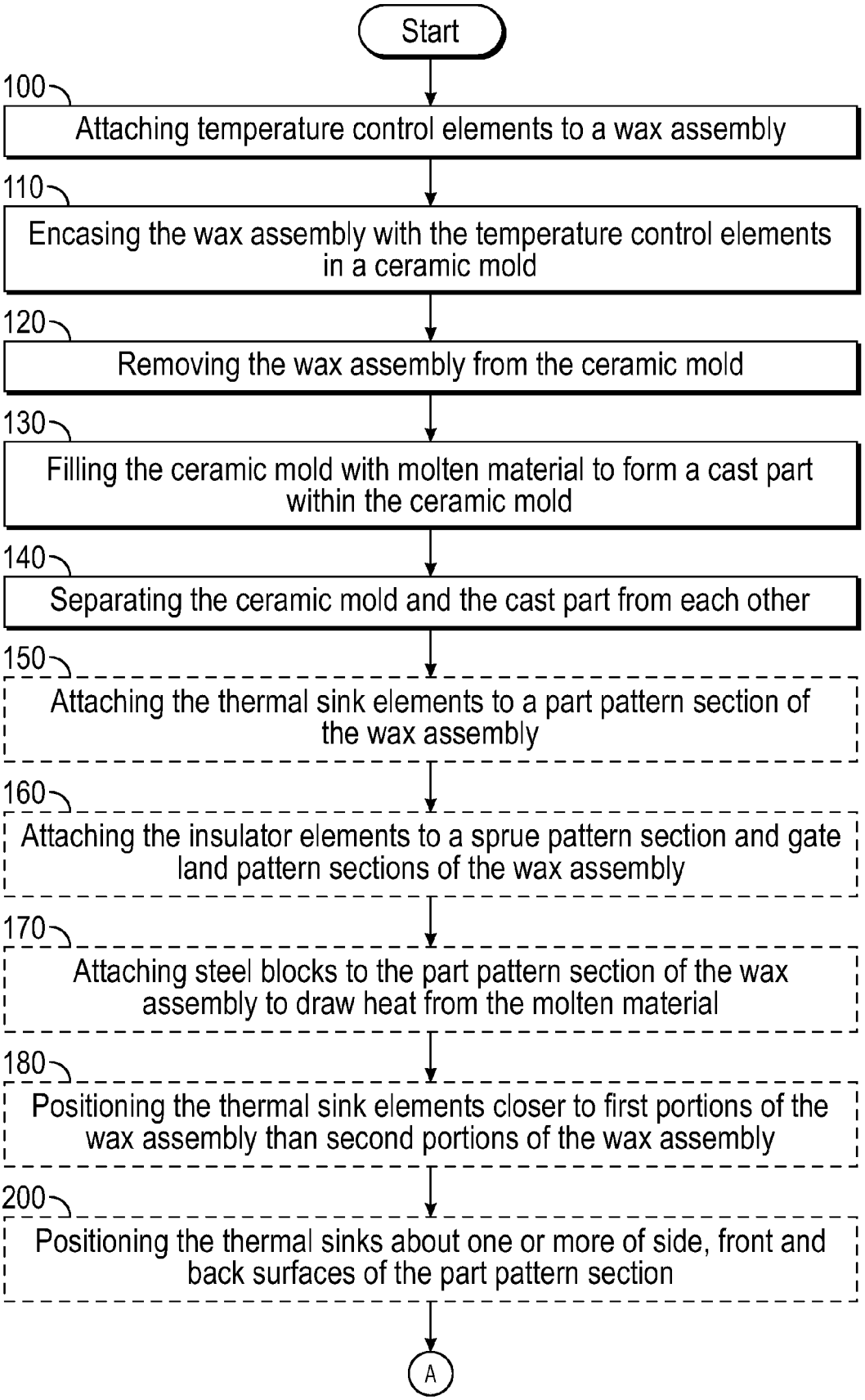
Start
100
Attaching temperature control elements to a wax assembly
110
Encasing the wax assembly with the temperature control elements in a ceramic mold
120
Removing the wax assembly from the ceramic mold
130
Filling the ceramic mold with molten material to form a cast part within the ceramic mold
140
Separating the ceramic mold and the cast part from each other
150
Attaching the thermal sink elements to a part pattern section of the wax assembly
160
Attaching the insulator elements to a sprue pattern section and gate land pattern sections of the wax assembly
170
Attaching steel blocks to the part pattern section of the wax assembly to draw heat from the molten material
180
Positioning the thermal sink elements closer to first portions of the wax assembly than second portions of the wax assembly
200
Positioning the thermal sinks about one or more of side, front and back surfaces of the part pattern section
A

FIG. 10

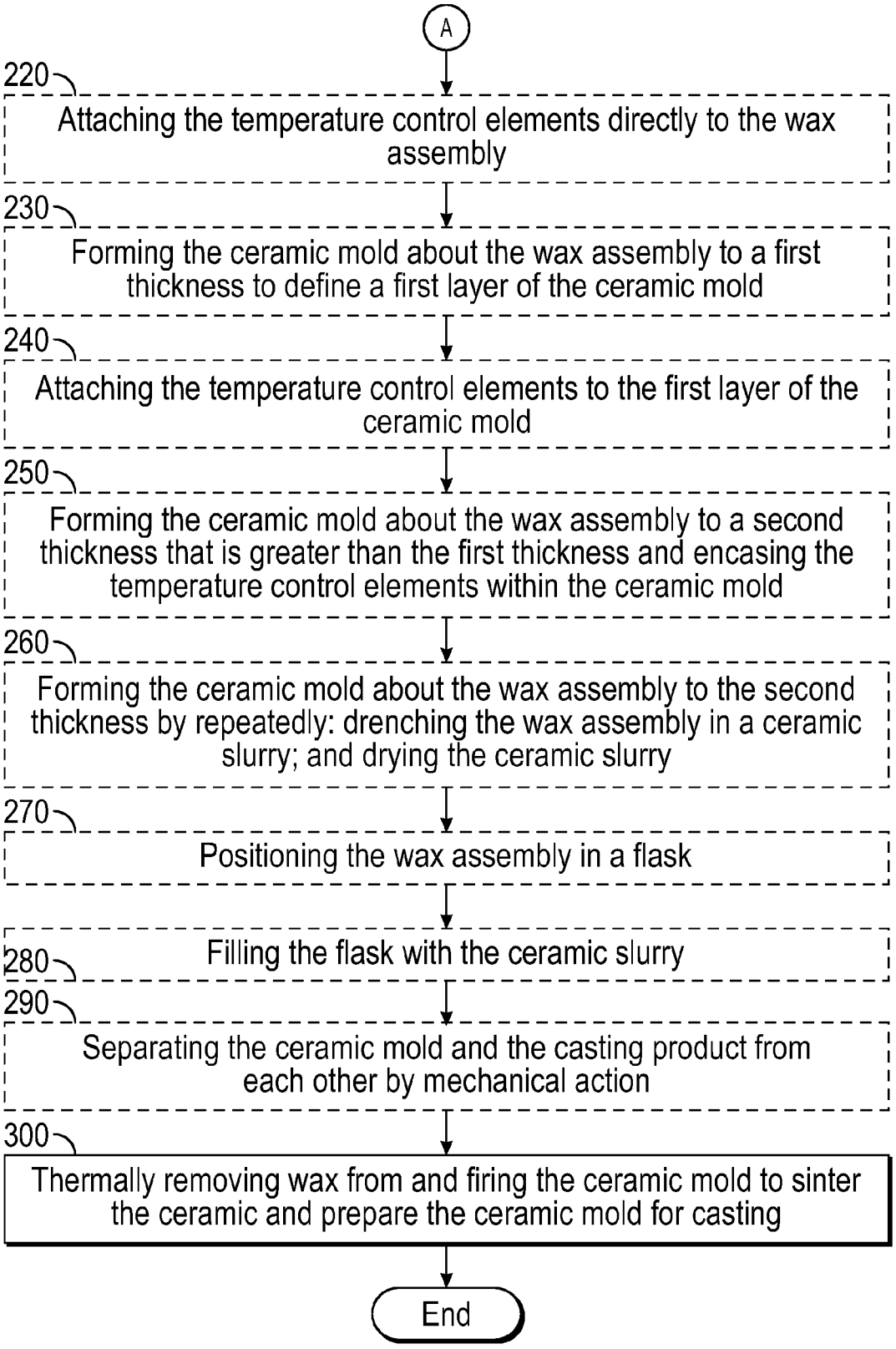

FIG. 10
(Continued)

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EUROPEAN SEARCH REPORT

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	14 July 2021	Porté, Olivier

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