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

(11) EP 2 316 593 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.05.2011 Bulletin 2011/18

(21) Application number: **10188114.2**

(22) Date of filing: **19.10.2010**

(51) Int Cl.:
B22C 7/02 *(2006.01)* ***B22C 9/04*** *(2006.01)*
B22C 9/24 *(2006.01)*

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

(30) Priority: **28.10.2009 US 589801**

(71) Applicant: **Howmet Corporation**
Whitehall, MI 49461-1895 (US)

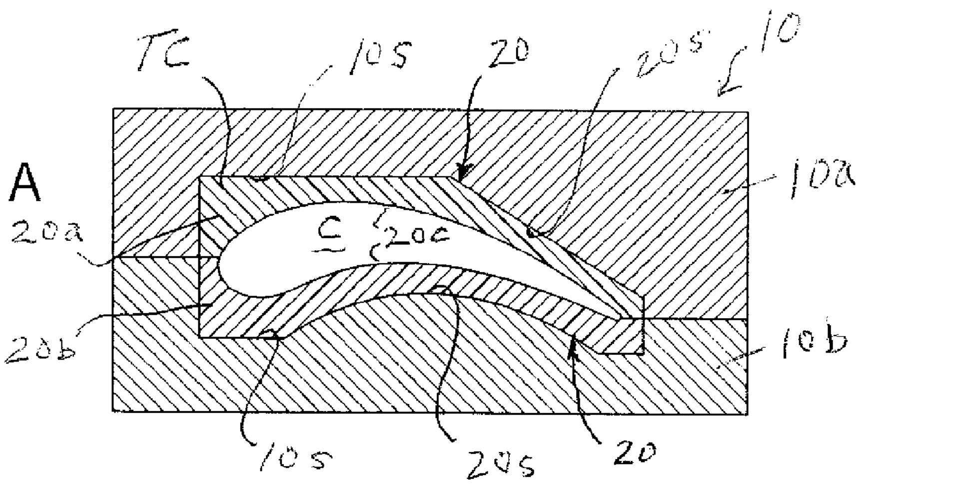
(72) Inventor: **Grunstra, Robert E.**
Spring Lake, MI 49456 (US)

(74) Representative: **Hoeger, Stellrecht & Partner**
Patentanwälte
Uhlandstrasse 14c
70182 Stuttgart (DE)

(54) **Fugitive core tooling and method**

(57) A ceramic core is produced by introducing a fluid ceramic core material, such as a ceramic slurry, into a core-shaped cavity formed at least in part by one or more fugitive core tooling liners residing in a back-up body, removing the ceramic core from the cavity, and removing the one or more fugitive tooling liners from the back-up die body and discarding them. The fugitive tooling liners and optional tooling inserts are used in one or more production cycles (e.g. ceramic slurry injection cycle) to make a single or multiple ceramic cores and then replaced with fresh (un-used) tooling liners and optional inserts to make other ceramic cores.

FIG. 1A



EP 2 316 593 A2

Description

FIELD OF THE INVENTION

[0001] The present invention relates to manufacture of a ceramic core for use in casting a hollow metallic article, such as a hollow turbine components, and more particularly, to tooling and a method for making a ceramic core.

BACKGROUND OF THE INVENTION

[0002] Most manufacturers of gas turbine engines are evaluating advanced multi-walled, thin-walled superalloy gas turbine airfoils (i.e. turbine blade or vane) which include intricate air cooling channels to improve efficiency of airfoil internal cooling to permit greater engine thrust and provide satisfactory airfoil service life. U.S. Patents 5 295 530 and 5 545 003 describe advanced multi-walled, thin-walled turbine blade or vane designs which include intricate air cooling channels to this end.

[0003] In casting hollow gas turbine engine blades and vanes (airfoils) and also shrouds having internal cooling passageways, a fired ceramic core is positioned in a ceramic investment shell mold to form internal cooling passageways in the cast airfoil. The fired ceramic core used in investment casting of hollow airfoils typically has an airfoil-shaped region with a thin cross-section leading edge region and trailing edge region. Between the leading and trailing edge regions, the core may include elongated and other shaped openings so as to form multiple internal walls, pedestals, turbulators, ribs, chambers, plenums, and similar features separating and/or residing in cooling passageways in the cast airfoil or cast shroud.

[0004] The ceramic core typically is formed to desired core configuration by injection molding, transfer molding or pouring of an appropriate fluid ceramic core material that includes one or more ceramic powders, a binder, and optional additives into a suitably shaped core molding die. After the green molded core is removed from the die, it is subjected to firing at elevated (superambient) temperature in one or more steps to remove the fugitive binder and sinter and strengthen the core for use in casting metallic material, such as a nickel or cobalt base superalloy typically used to cast gas turbine engine blades and vanes (airfoils).

[0005] Conventional core tooling requires expensive EDM machining for hardened tool steel permanent tooling and sophisticated machining techniques for tooling dies and tooling inserts, ribs, inserts, and other cooling features to be imparted to the core formed using the tooling. Unfortunately, the ceramic core materials are abrasive to tooling and result in wear of the tooling over time. Such tooling wear produces undesirable changes and inconsistencies in core geometry and performance of castings made with the cores over time.

[0006] The fired ceramic core then is used in manufacture of the shell mold by the well known lost wax process wherein the ceramic core is placed in a pattern molding die and a fugitive pattern is formed about the core by injecting under pressure pattern material, such as wax, thermoplastic and the like, into the die in the space between the core the inner die walls. The pattern typically has an airfoil-shaped region with a thin cross-section trailing edge region corresponding in location to trailing edge features of the core. The pattern also can include other features such as including, but not limited to, one or more platforms, shrouds and the like.

[0007] The fugitive pattern with the ceramic core therein is subjected to repeated steps to build up the shell mold thereon. For example, the pattern/core assembly is repeatedly dipped in ceramic slurry, drained of excess slurry, stuccoed with coarse ceramic stucco or sand, and then air dried to build up multiple ceramic layers that form the shell mold on the assembly. The resulting invested pattern/core assembly then is subjected to a pattern removal operation, such as steam autoclaving, to selectively remove the fugitive pattern, leaving the shell mold with the ceramic core located therein. The shell mold then is fired at elevated temperature to develop adequate shell mold strength for metal casting. Molten metallic material, such as a nickel or cobalt base superalloy, is cast into a preheated shell mold and solidified to produce an equiaxed grain, columnar grain or single crystal airfoil. The resulting cast airfoil includes the ceramic core therein so as to form internal cooling passageways upon removal of the core. The core can be removed by leaching or other conventional techniques, leaving a hollow cast metallic airfoil.

SUMMARY OF THE INVENTION

[0008] The present invention provides tooling for making a ceramic core wherein the core tooling employs one or more fugitive tooling liners and optional fugitive tooling inserts that are placed in a simple-geometry back-up or support body in a manner to form at least a portion of a core-shaped cavity and that eliminate the need for costly hardened/machined permanent steel tooling.

[0009] In an illustrative embodiment of the invention, each fugitive tooling liner includes an outer surface having a simple geometry to conform to that of an adjacent inner support surface of the back-up body and an inner surface that is configured to form desired core surface features when the tooling liners are placed in the back-up body with the tooling liners forming the core-shaped cavity. Optional fugitive inserts can be placed between the tooling liners to form ribs, holes, passages and other features on and/or in the ceramic core. The core-shaped cavity may have one or more airfoil-shaped surfaces in the production of a ceramic core for use in casting of a hollow airfoil, such as a hollow gas turbine blade or vane, or other hollow article.

[0010] A ceramic core is produced pursuant to a method embodiment of the invention by introducing a fluid ceramic core mixture typically under pressure into the core-shaped cavity formed at least in part by the fugitive tooling liners in the back-up body, removing the molded ceramic core from the cavity, and removing the fugitive tooling liners with the core or from the back-up die body (separately from the core) for discarding. The next ceramic core is produced using fresh (un-used) tooling liners and optional tooling inserts. Alternately, the fugitive tooling liners may be left in the back-up body and reused if the liners are in acceptable condition to this end. That is, the fugitive tooling liners and inserts are used in one or more production cycles (e.g. ceramic slurry injection cycles) to make a single ceramic core and then replaced with fresh (un-used) tooling liners and optional inserts.

[0011] Other advantages of the present invention will become more readily apparent from the following detailed description taken with following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Figure 1A is a cross-sectional view of tooling in accordance with an illustrative embodiment of the invention where facing tooling liners are employed.

Figure 1B is a cross-sectional view of tooling in accordance with another illustrative embodiment of the invention where facing tooling liners are employed to form only portions of the core molding surfaces and the back-up body surfaces form the remaining portions of the core molding surface.

Figure 2 is a cross-sectional view of still another embodiment of the invention wherein various types of fugitive inserts are placed between facing tooling liners.

Figure 3 is a perspective view of a core with fugitive liners/inserts wherein the core resides between facing fugitive tooling liners after removal from the back-up body.

Figure 4 is a perspective view of a core with the fugitive liners/inserts removed.

Figure 5 is an exploded view of the back-up bodies with the fugitive tooling liners and inserts between the liners showing where the inserts are pre-located into the liners.

DESCRIPTION OF THE INVENTION

[0013] The present invention provides tooling for making a ceramic core wherein the tooling employs one or more fugitive tooling liners and optional fugitive tooling inserts that are placed in a simple-geometry back-up or support body in a manner to form at least a portion of a core-shaped cavity and that eliminate the need for costly hardened/machined permanent steel tooling. Although the invention is described in detail below with respect to making a ceramic core having an airfoil shape for use in casting metallic airfoils, such as gas turbine engine blades and vanes, it is not so limited and can be used to make a ceramic core having any desired shape.

[0014] Referring to Figures 1-5, an illustrative embodiment of the invention provides tooling including a back-up or support body 10 and multiple fugitive tooling liners 20a, 20b disposed in the back-up body 10 to form at least a portion of a core-shaped cavity C.

[0015] The back-up body 10 comprises multiple parts (first and second parts 10a, 10b shown) positionable to form a tooling cavity TC to receive the tooling liners 20a, 20b. The multiple parts of the back-up body can be incorporated and positioned as an injection die of a conventional core injection machine.

[0016] Referring to Figures 1A, 1B and 5, the parts 10a, 10b of the back-up body 10 include interior flat and curved geometry surfaces 10s so as to provide a simple geometry that is not costly to machine. Although particular simple flat and curved surfaces 10s are shown, surfaces 10s of other simple geometry can be used including, but not limited to, easily-machined surfaces which are all curved or all flat, or a combination thereof, as well as other easy-to-machine surface profiles. The back-up body can be made of hardened steel or other material that can withstand the pressure of the liquid ceramic material introduced typically under pressure to form the ceramic core.

[0017] In Figure 1A, all core surfaces will be formed by the inner surfaces of the tooling liners 20a, 20b. However, the invention is not limited to this embodiment since simple surfaces of the core-shaped cavity and thus the core may be formed by surfaces of the permanent tooling; i.e. by surfaces BS on the back-up parts 10a, 10b, as shown in Figure 1B. Also, a single tooling liner 20a or 20b may be employed for simple core surfaces.

[0018] The core tooling includes one or more fugitive tooling liners 20. For purposes of illustration, the core tooling is shown including first and second fugitive tooling liners 20a 20b that are placed in the tooling cavity TC. Each first and second tooling liner includes an outer surface 20s having a simple flat and/or curved or other simple geometry to conform to or match that of an adjacent inner support surface 10s of an adjacent part of the back-up body 10 and an inner surface 10c that is configured to form desired core surface features when the tooling liners 20a, 20b are placed in the back-up body 10 in facing relation to form the core-shaped cavity C. Although the tooling liners are shown including flat and curved outer surfaces 20s that mate with an adjacent flat and curved surface 10s of the back-up body, other simple surfaces 20s can be used that match or mate with those of the adjacent parts of the back-up body 10. The tooling liners 20a, 20b can be designed to snap-fit into place in the parts 10a, 10b of the back-up body 10, or they can be held by releasable adhesive or releasable fasteners or clamps.

[0019] The inner surfaces 20c of the tooling liners form an air-foil core-shaped cavity C therebetween, Figure 1A, or at least a portion of the air-foil core-shaped cavity C, Figure 1B, when the tooling liners 20a, 20b are placed in the back-up body 10. As mentioned above, simple surfaces of the core-shaped cavity C and thus the core may be formed by surfaces BS of the back-up parts 10a, 10b, as shown in Figure 1B. The inner surfaces 20c are configured to form desired core surface features when the tooling liners 20a, 20b are placed in the back-up body 10 in facing or other relation to form at least a portion of the airfoil core-shaped cavity C.

[0020] The fugitive tooling liners typically are injection molded to shape using a suitable polymer, although other fugitive liner materials can be used including, but not limited to, polylactone, polyvinyl, and starch-modified polymers.

[0021] The core tooling can include one or more optional fugitive inserts 30a-30h placed between the tooling liners 20a, 20b and/or on the inner surfaces 20c of the tooling liners 20a, 20b, Figures 2 and 5. The inserts 30a-30h extending between the tooling liners can be used to form holes, passages and other through-openings in the ceramic core. The inserts 30a-30h disposed on the surface 20c of the tooling liners can be used to form core surface features such as ribs, channels, shrouds, chambers, back-locked features (e.g. a dovetail joint) not easily formed in a complicated end product core.

[0022] The fugitive inserts alternately can be provided as fugitive subassemblies where different inserts are provided in one subassembly to form through-passages and core surface features as shown for inserts 30a and 30b in Figure 2. The fugitive inserts can be injection molded on the liner surface 20c as shown for insert 30h in Figure 2, or as part of the liner surface as shown for insert 30g in Figure 2. The inserts 30a, 30b can be assembled from separately injection molded insert elements and located on the liner surface 20c. The fugitive inserts can comprise or be incorporated as a part of the final molded core to produce a composite core having certain fugitive features such as spacers, layers, through-extending fastener, and the like for use in subsequent investment mold forming processing.

[0023] The fugitive inserts can include connection features to the liner surface 20c that may be normal (perpendicular) to the liner surface 20c as shown for insert 30d in Figure 2. The fugitive inserts can also include connection features to the liner surface 20c that may be normal (perpendicular) to the parting plane PP of the cavity C as shown for inserts 30e, 30f in Figure 2.

[0024] A ceramic core is produced pursuant to a method embodiment of the invention by introducing a fluid ceramic core material, such as a ceramic slurry, typically under pressure into the core-shaped cavity C formed by the fugitive tooling liners 20a, 20b in the back-up body 10. The fluid ceramic material is introduced via a passage CP (Figure 1B) in the back-up body 10. After the ceramic core is molded and set, the molded green (unfired) core is removed by opening the parts 10a, 10b of the back-up body 10 and removing the molded green ceramic core. The fugitive tooling liners 20a, 20b are removed from the back-up die body with the molded green ceramic core, Figure 3, or separately from the molded green core and then discarded (not re-used). The optional fugitive inserts 30a-30h can be removed from the molded green ceramic core by thermal treatment to melt and/or vaporize them, solvent treatment to dissolve them, or other process that selectively removes the inserts from the molded core. A final core 100 remains as shown in Figure 4 with core interior and exterior features 100a-100h formed by the respective inserts 30a-30h that have been selectively removed.

[0025] The next ceramic core is produced using fresh (un-used) tooling liners 20a, 20b and optional fresh tooling inserts 30. That is, the fugitive tooling liners and inserts can be used in one production cycle (e.g. ceramic injection cycle) to make a single ceramic core and then replaced with fresh (un-used) tooling liners and optional inserts. Alternately, the fugitive tooling liners may be left in the back-up body 10 and reused if the tooling liners are in acceptable condition to this end. That is, the fugitive tooling liners and inserts can be used in multiple production cycles (e.g. ceramic slurry injection cycles) to make multiple ceramic cores and then replaced with fresh (un-used) tooling liners and optional inserts when the tooling liners are not longer in acceptable condition to this end. However, when back-locked core features are produced, the tooling liners are used only in one production cycle since they are destroyed to separate them from the core.

[0026] It will be apparent to those skilled in the art that various modifications and variations can be made in the embodiments of the present invention described above without departing from the spirit and scope of the invention as set forth in the appended claims.

Claims

1. Tooling for making a ceramic core, comprising a back-up body (10) and one or more fugitive tooling liners (20a, 20b) disposed in the back-up body (10) to form at least a portion of a core-shaped cavity (C).

2. The tooling of claim 1 wherein the back-up body (10) comprises multiple parts (10a, 10b) positionable to form a tooling cavity (TC) to receive the tooling liners (20a, 20b).

3. The tooling of claim 2 wherein first and second fugitive tooling liners (20a, 20b) are placed in the tooling cavity (TC) and each first and second tooling liner (20a, 20b) includes an outer surface (20s) having a simple geometry to match that of an adjacent inner support surface (10s) of an adjacent part of the back-up body (10) and an inner surface (20c) that is con-

figured to form at least a portion of the desired core surface features when the tooling liners (20a, 20b) are placed in the back-up body (10), and in particular, wherein the inner surfaces (20c) of the first and second fugitive tooling liners (20a, 20b) form all of the core surface, or wherein the inner surfaces (20c) of the first and second fugitive tooling liners (20a, 20b) form a portion of the core surface and surfaces of the back-up body form (10) remaining core surface.

4. The tooling of one of claims 1 to 3 wherein the back-up body (10) includes easily machined interior surfaces (10s), and, in particular, wherein the tooling liners (20a, 20b) include surfaces (20c) that mate with respective easily machined surfaces (10c) of the back-up body (10).

5. The tooling of one of claims 1 to 4 wherein the tooling liners (20a, 20b) comprise a polymer.

6. The tooling of one of claims 1 to 5 including one or more fugitive inserts between the tooling liners (20a, 20b), and/or including one or more fugitive inserts (30a, 30b) on the tooling liners (20a, 20b).

7. The tooling of one of claims 1 to 6 wherein the tooling liners (20a, 20b) form an airfoil-shaped cavity.

8. A method of making a ceramic core, comprising introducing a fluid ceramic core material into a core-shaped cavity formed at least in part by one or more fugitive tooling liners in a back-up body, removing the ceramic core from the cavity, and removing the one or more fugitive tooling liners from the back-up body.

9. The method of claim 8 wherein the steps thereof are repeated using fresh, un-used tooling liners to make another ceramic core, or wherein the steps thereof are repeated using the same tooling liners to make another ceramic core.

10. The method of claim 8 or 9 wherein the fluid ceramic material is introduced under pressure into the cavity.

11. The method of one of claims 8 to 10 including placing the tool liners in the back-up body so that surfaces of the tooling liners conform to easily machined surfaces of the back-up body.

12. The method of one of claims 8 to 11 including injection molding the tooling liners before placing them in the back-up body.

13. The method of one of claims 8 to 12 including discarding the used tooling liners.

14. The method of one of claims 8 to 13 wherein the core-shaped cavity is formed to have an airfoil shape.

15. The method of one of claims 8 to 14 including placing one or more fugitive inserts between the tooling liners, and/or placing one or more fugitive inserts on the tooling liners.

FIG. 1A

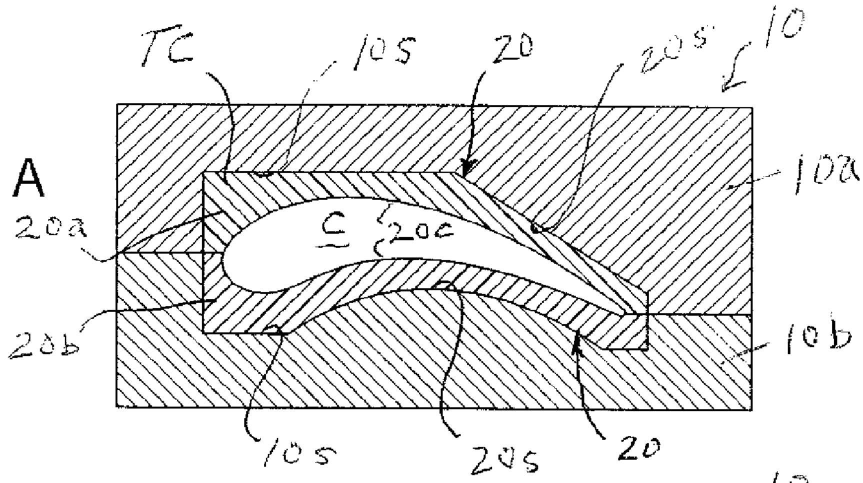
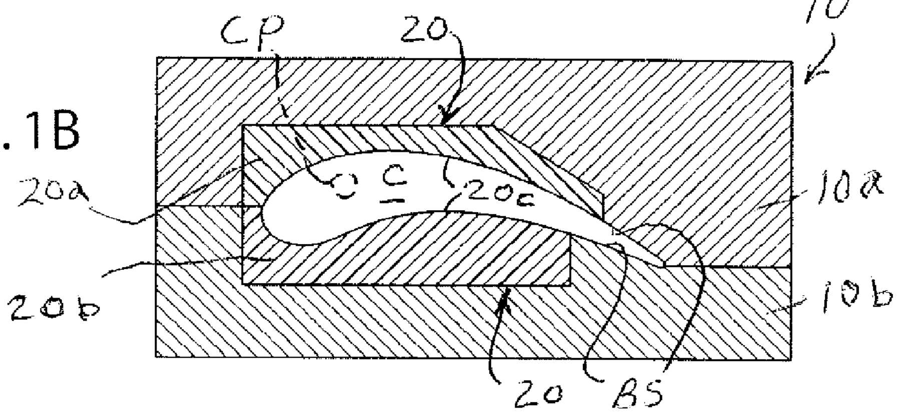


FIG. 1B



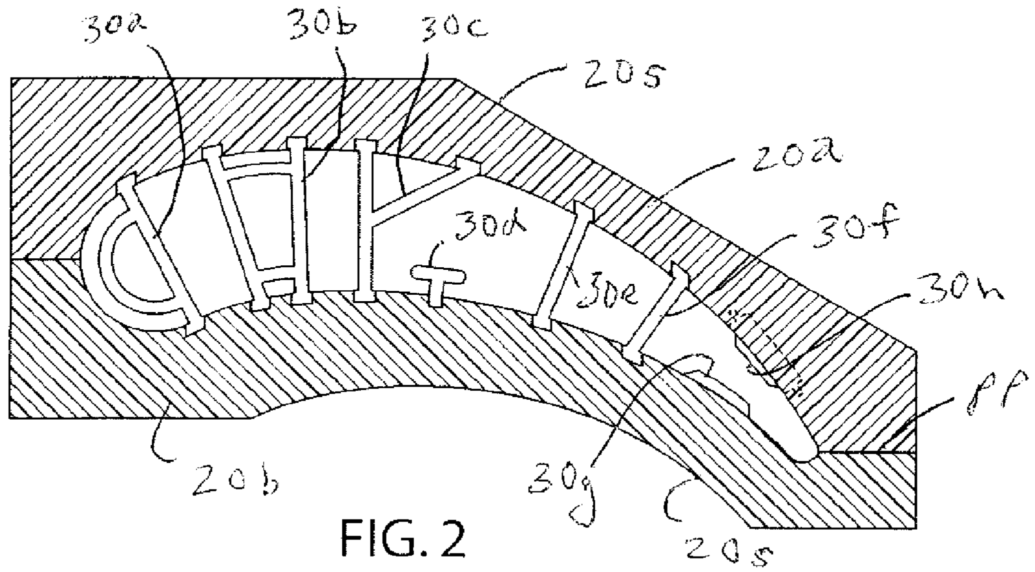
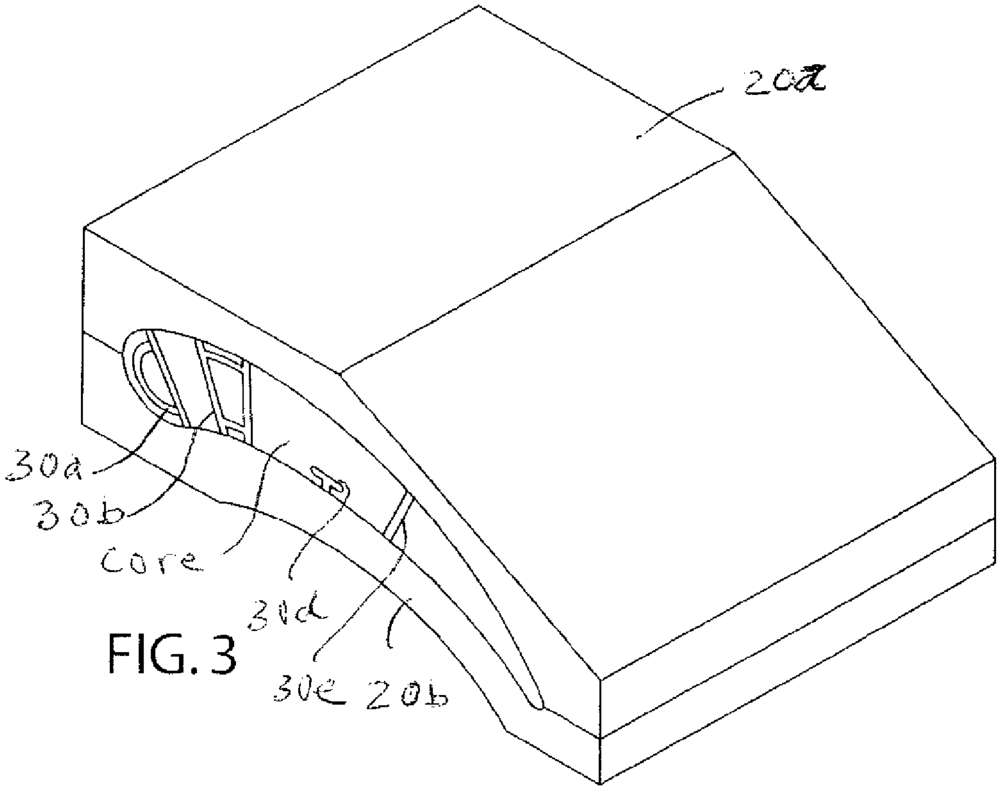


FIG. 2


20a
30a
30b
core
31d
30e
20b
FIG. 3

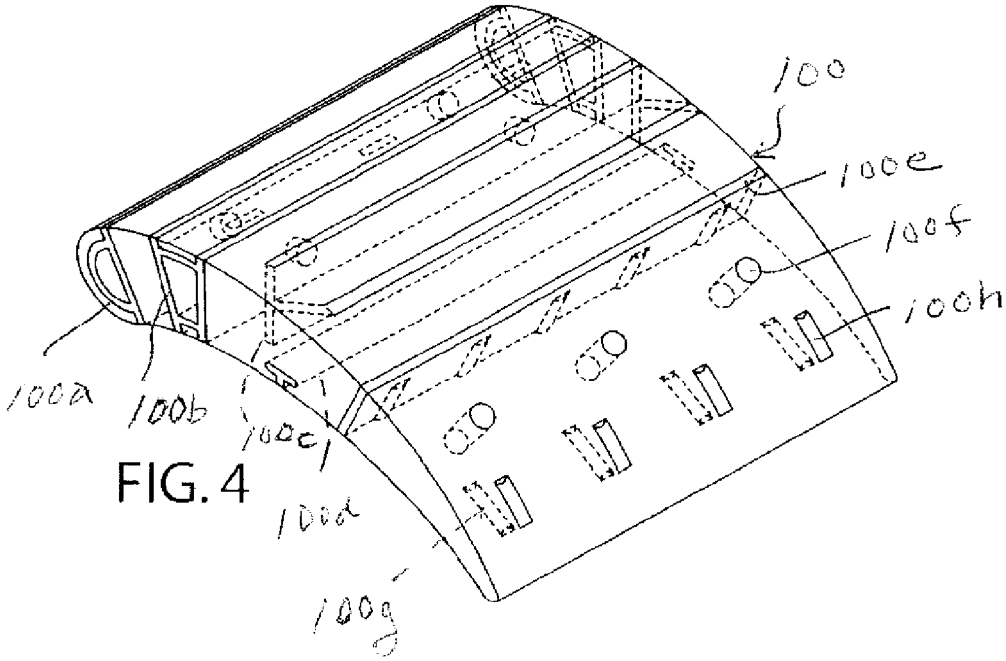
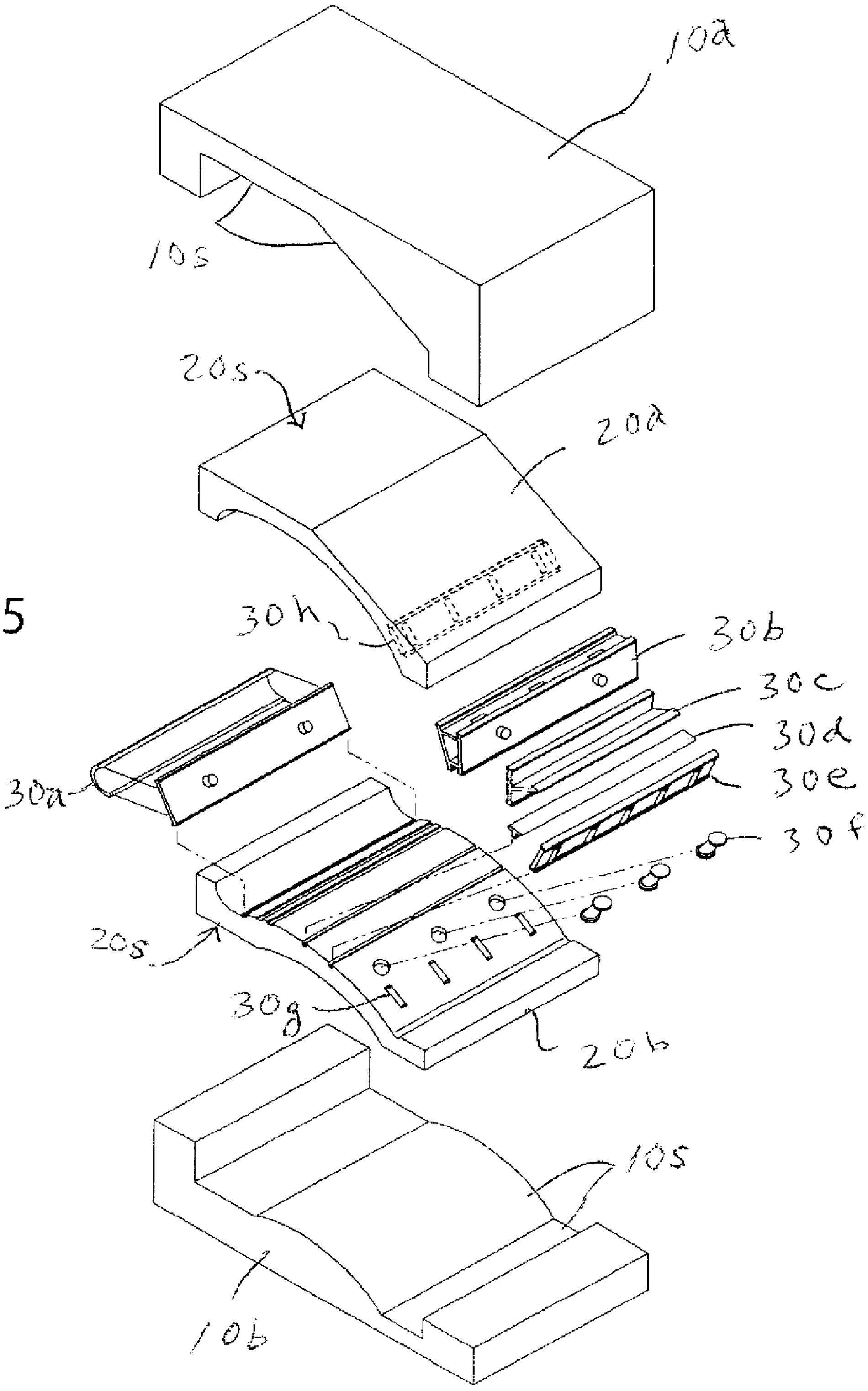

100
100e
100f
100h
100a
100b
100c
100d
100g
FIG. 4

FIG. 5



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 5295530 A **[0002]**
- US 5545003 A **[0002]**