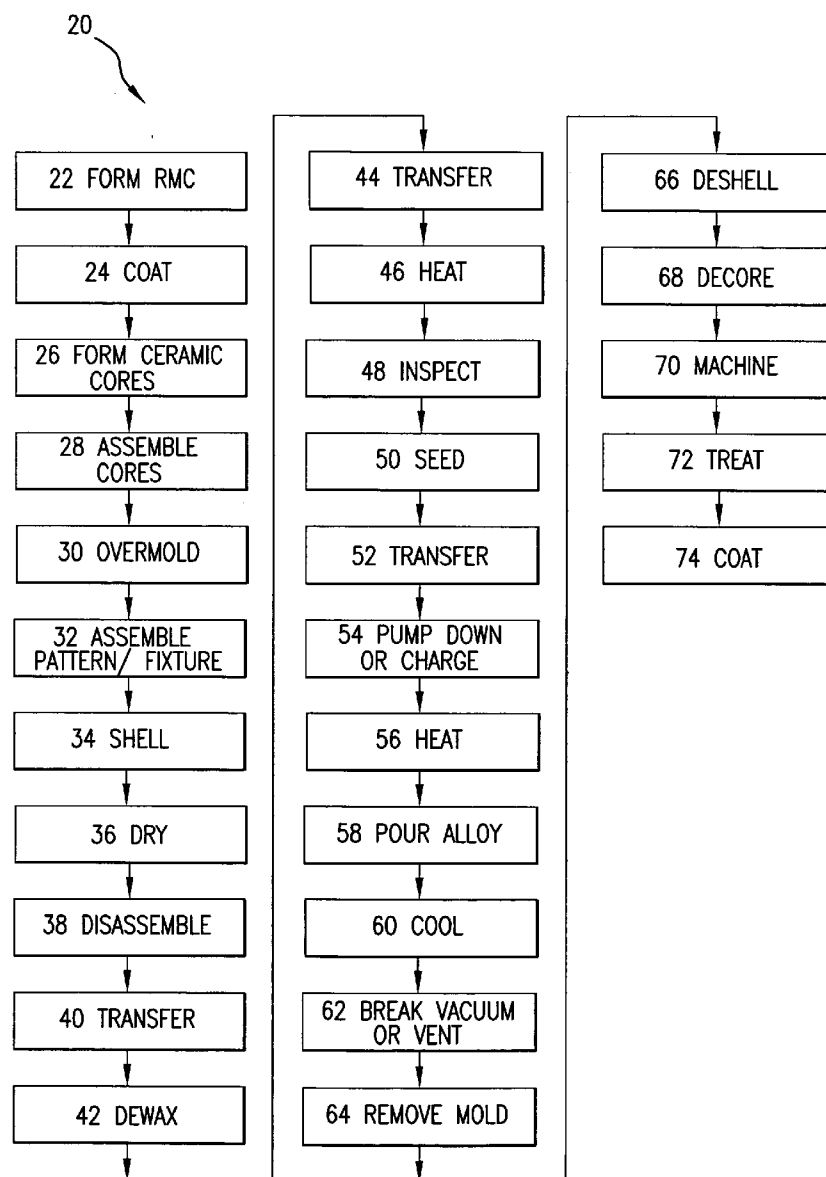




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(19) **United States**(12) **Patent Application Publication****Verner et al.**(10) **Pub. No.: US 2007/0068649 A1**(43) **Pub. Date: Mar. 29, 2007**(54) **METHODS AND MATERIALS FOR
ATTACHING CERAMIC AND REFRACTORY
METAL CASTING CORES**(22) Filed: **Sep. 28, 2005****Publication Classification**(76) Inventors: **Carl R. Verner**, Windsor, CT (US);
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NEW HAVEN, CT 06510-2802 (US)(57) **ABSTRACT**

A slurry is used to secure a metallic casting core to a ceramic casting core. The slurry may be introduced between the metallic and ceramic casting cores and hardened. The slurry may comprise zircon and aqueous colloidal silica.

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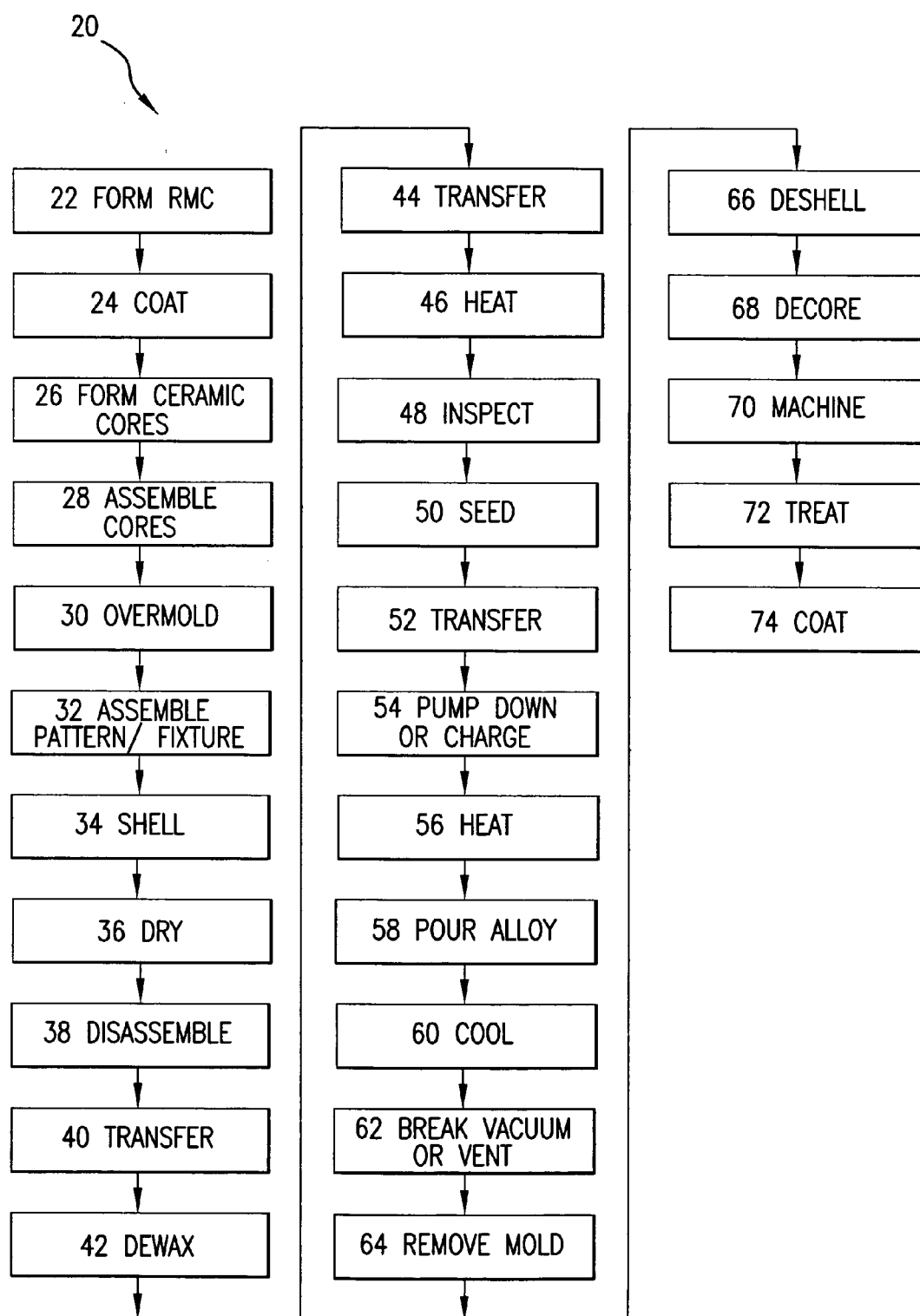


FIG. 1

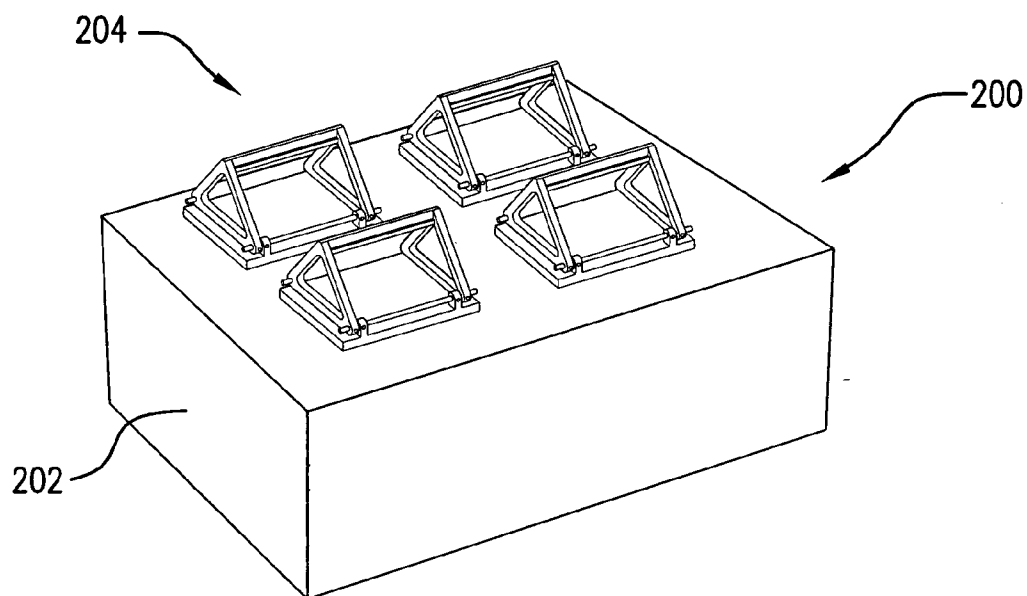


FIG. 2

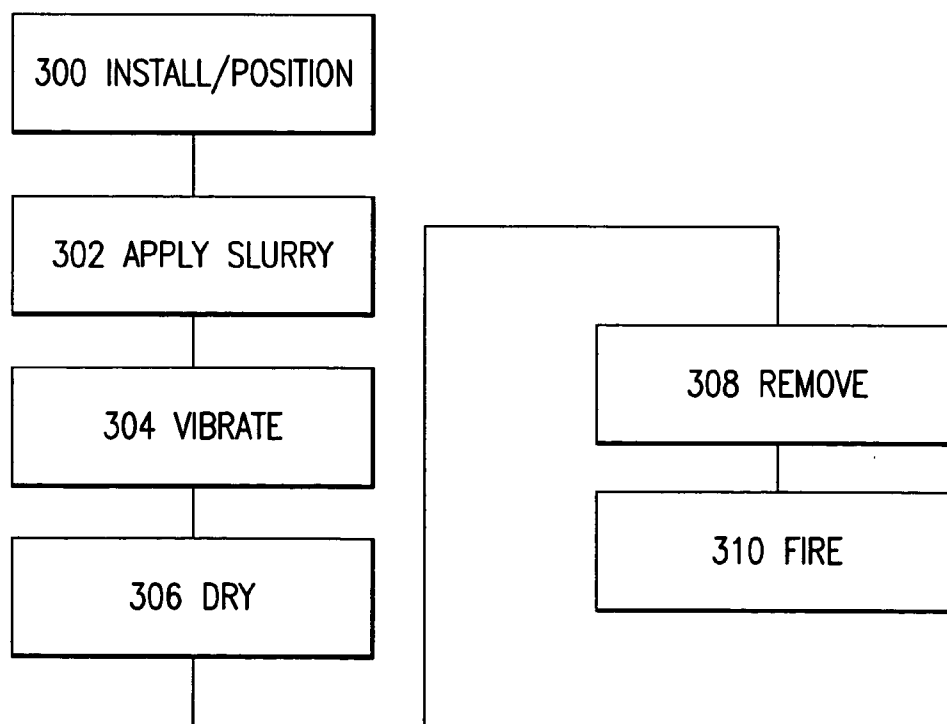


FIG. 4

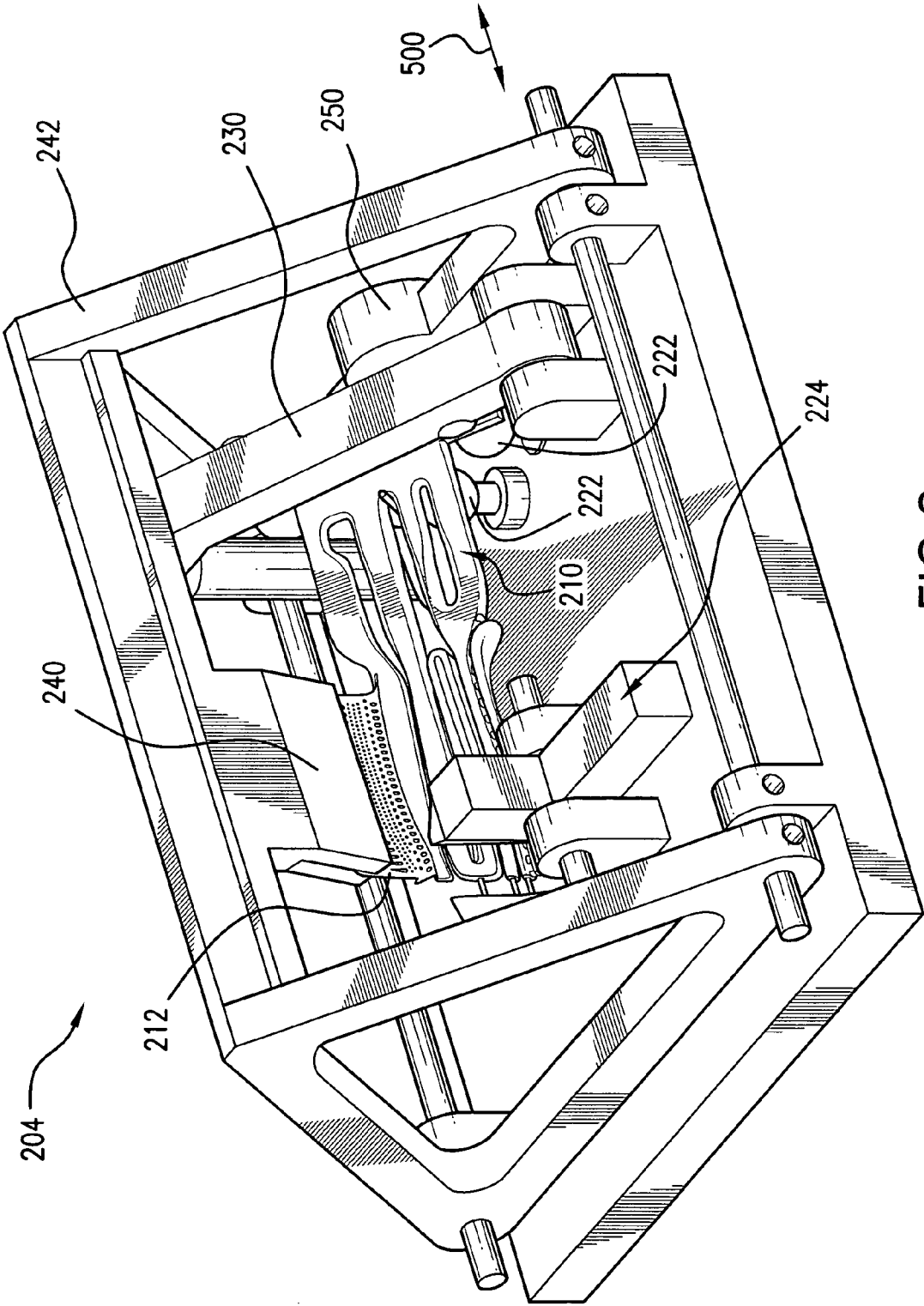


FIG. 3

METHODS AND MATERIALS FOR ATTACHING CERAMIC AND REFRACTORY METAL CASTING CORES

BACKGROUND OF THE INVENTION

[0001] The invention relates to investment casting. More particularly, the invention relates to investment casting core assemblies.

[0002] Investment casting is commonly used in the aerospace industry. Various examples involve the casting of gas turbine engine parts. Exemplary parts include various blades, vanes, seals, and combustor panels. Many such parts are cast with cooling passageways. The passageways may be formed by sacrificial casting cores.

[0003] Exemplary cores include ceramic cores, refractory metal cores (RMCs), and combinations thereof. In exemplary combinations, the ceramic cores may form feed passageways whereas the RMCs form cooling passageways extending from the feed passageways through walls of the associated part. The cores may be assembled to each other and secured with a ceramic adhesive. An exemplary ceramic adhesive is alumina-based. For example, the adhesive may comprise alumina powder and a binder such as colloidal silica.

[0004] After the initial casting of the part (e.g., from a nickel- or cobalt-based superalloy), the casting shell and core(s) are destructively removed. Exemplary shell removal is principally mechanical. Exemplary core removal is principally chemical. For example, the cores may be removed by chemical leaching. Exemplary leaching involves use of an alkaline solution in an autoclave. Exemplary leaching techniques are disclosed in U.S. Pat. Nos. 4,141,781, 6,241,000, and 6,739,380.

SUMMARY OF THE INVENTION

[0005] Accordingly, one aspect of the invention involves a method for attaching a metallic casting core to a ceramic casting core. An insertion portion of the metallic casting core is inserted into a receiving portion of the ceramic casting core. A slurry is introduced between the metallic casting core and the ceramic casting core.

[0006] In various implementations, the metallic casting core may comprise a refractory metal-based substrate (e.g., optionally coated). The method may be used to form a turbine blade core assembly or a turbine vane core assembly. The slurry may be heated to harden. The metallic casting core and ceramic casting core may be vibrated during the introducing. The inserting may be performed with the ceramic casting core in a green state. The slurry may comprise zircon and aqueous colloidal silica.

[0007] Another aspect of the invention involves an apparatus for manufacturing a casting core assembly. The apparatus has means for holding a ceramic casting core. The apparatus has means for holding a metallic casting core with an insertion portion received in a receiving portion of the ceramic casting core. The apparatus has means for vibrating the ceramic casting core and the metallic casting core.

[0008] In various implementations, the means for holding may include means for adjusting relative position of the ceramic casting core and metallic casting core.

[0009] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a flowchart of an exemplary investment casting process.

[0011] FIG. 2 is a view of a core assembly apparatus.

[0012] FIG. 3 is a view of a single fixture of the apparatus of FIG. 2 for holding investment casting cores during their attachment.

[0013] FIG. 4 is a flowchart of an exemplary core attachment process.

[0014] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0015] In various manufacturing contexts, the binders of ceramic adhesives may have adverse reactions with additional items such as refractory metal cores. As an alternative, a specialized slurry has been developed to secure cores based upon shelling slurries. The exemplary slurry consists essentially of a combination of: zircon and aqueous colloidal silica in a 79:21 weight ratio; a surfactant; and sufficient additional water to achieve the desired viscosity. Exemplary ranges for the zircon to colloidal silica ratio are 70:30 through 80:20.

[0016] An exemplary surfactant is essentially a linear alcohol-based surfactant available from Solvay Chemicals, Inc. of Houston, Tex. under the trademark ANTAROX BL 225. An exemplary surfactant amount is 0.05-0.15%, by volume, more narrowly under 0.1% such as 0.7-0.9%. An optional additive is polydimethyl siloxanes (available from Hydrolabs, Inc. of Wayne, N.J. under the trademark BURST RSD-10) in a small amount (e.g., 0.005-0.015%, by volume) to aid in bubble rupture. The exemplary slurry has a density in the range of 2.87-2.96 g/cm³. The exemplary slurry has a pH in the range of 9.0-10.5. The exemplary slurry has a viscosity of 25 (+/-2) centiPoise (cP). However, other viscosities may be appropriate for particular situations, especially thinner slurries (e.g., 18-25 cP).

[0017] FIG. 1 shows an exemplary method 20 for forming an investment casting mold. Other methods are possible, including a variety of prior art methods and yet-developed methods. One or more metallic core elements are formed 22 (e.g., of refractory metals such as molybdenum and niobium by stamping or otherwise cutting from sheet metal) and coated 24. Suitable coating materials include silica, alumina, zirconia, chromia, mullite and hafnia. Preferably, the coefficient of thermal expansion (CTE) of the refractory metal and the coating are similar. Coatings may be applied by any appropriate line-of sight or non-line-of sight technique (e.g., chemical or physical vapor deposition (CVD, PVD) methods, plasma spray methods, electrophoresis, and sol gel methods). Individual layers may typically be 0.1 to 1 mil thick. Layers of Pt, other noble metals, Cr, Si, W, and/or Al, or other non-metallic materials may be applied to the

metallic core elements for oxidation protection in combination with a ceramic coating for protection from molten metal erosion and dissolution.

[0018] One or more ceramic cores may also be formed 26 (e.g., of or containing silica in a molding and firing process). One or more of the coated metallic core elements (hereafter refractory metal cores (RMCs)) are assembled 28 to one or more of the ceramic cores. As noted above, the assembly may include use of a ceramic slurry discussed below. The core assembly is then overmolded 30 with an easily sacrificed material such as a natural or synthetic wax (e.g., via placing the assembly in a mold and molding the wax around it). There may be multiple such assemblies involved in a given mold.

[0019] The overmolded core assembly (or group of assemblies) forms a casting pattern with an exterior shape largely corresponding to the exterior shape of the part to be cast. The pattern may then be assembled 32 to a shelling fixture (e.g., via wax welding between end plates of the fixture). The pattern may then be shelled 34 (e.g., via one or more stages of slurry dipping, slurry spraying, or the like). After the shell is built up, it may be dried 36. The drying provides the shell with at least sufficient strength or other physical integrity properties to permit subsequent processing. For example, the shell containing the invested core assembly may be disassembled 38 fully or partially from the shelling fixture and then transferred 40 to a dewaxer (e.g., a steam autoclave). In the dewaxer, a steam dewax process 42 removes a major portion of the wax leaving the core assembly secured within the shell. The shell and core assembly will largely form the ultimate mold. However, the dewax process typically leaves a wax or byproduct hydrocarbon residue on the shell interior and core assembly.

[0020] After the dewax, the shell is transferred 44 to a furnace (e.g., containing air or other oxidizing atmosphere) in which it is heated 46 to strengthen the shell and remove any remaining wax residue (e.g., by vaporization) and/or converting hydrocarbon residue to carbon. Oxygen in the atmosphere reacts with the carbon to form carbon dioxide. Removal of the carbon is advantageous to reduce or eliminate the formation of detrimental carbides in the metal casting. Removing carbon offers the additional advantage of reducing the potential for clogging the vacuum pumps used in subsequent stages of operation.

[0021] The mold may be removed from the atmospheric furnace, allowed to cool, and inspected 48. The mold may be seeded 50 by placing a metallic seed in the mold to establish the ultimate crystal structure of a directionally solidified (DS) casting or a single-crystal (SX) casting. Nevertheless the present teachings may be applied to other DS and SX casting techniques (e.g., wherein the shell geometry defines a grain selector) or to casting of other microstructures. The mold may be transferred 52 to a casting furnace (e.g., placed atop a chill plate in the furnace). The casting furnace may be pumped down to vacuum 54 or charged with a non-oxidizing atmosphere (e.g., inert gas) to prevent oxidation of the casting alloy. The casting furnace is heated 56 to preheat the mold. This preheating serves two purposes: to further harden and strengthen the shell; and to preheat the shell for the introduction of molten alloy to prevent thermal shock and premature solidification of the alloy.

[0022] After preheating and while still under vacuum conditions, the molten alloy is poured 58 into the mold and

the mold is allowed to cool to solidify 60 the alloy (e.g., after withdrawal from the furnace hot zone). After solidification, the vacuum may be broken 62 and the chilled mold removed 64 from the casting furnace. The shell may be removed in a deshelling process 66 (e.g., mechanical breaking of the shell).

[0023] The core assembly is removed in a decoring process 68 to leave a cast article (e.g., a metallic precursor of the ultimate part). Inventive multi-stage decoring processes are described below. The cast article may be machined 70, chemically and/or thermally treated 72 and coated 74 to form the ultimate part. Some or all of any machining or chemical or thermal treatment may be performed before the decoring.

[0024] FIG. 2 shows details of an apparatus 200 for assembling the cores. The apparatus includes a shake table 202 for vibrating the assemblies. Each assembly is held by a fixture 204 atop the shake table. Exemplary assemblies (FIG. 3) are of molded ceramic feedcores 210 and refractory sheet trailing edge slot RMCs 212. FIG. 3 shows further details of the exemplary fixtures 204. The fixtures include a base 220 for mounting to the shake table.

[0025] The fixture includes features for holding an associated feedcore 210. These features may include a plurality of tooling balls 222 precisely fixed on the base to engage the feedcore 210. A clamp 224 may be mounted on the base to engage the feedcore after the feedcore is placed against the tooling balls. A pivotal retaining bar 230 may be positioned to engage a root portion of the feedcore to retain the feedcore in position.

[0026] The fixture includes features for holding an associated RMC 212 relative to the associated feedcore. In the exemplary engagement, a leading end portion of the RMC is inserted within a slot in a trailing leg of the feedcore. The RMC-holding features may include a clamp 240 grasping a trailing end portion of the RMC. The clamp may be mounted to a gantry structure 242. The exemplary gantry structure is slidably mounted for movement along a direction 500. The gantry (and thus the RMC) position may be controlled by a micrometer mechanism 250. The exemplary micrometer mechanism biases the gantry against the root end of the feedcore to provide fine adjustment of the position of the RMC along the feedcore.

[0027] After installation and positioning 300 (FIG. 4) of the cores, a bead of the slurry may be applied 302 to their joint. Vibration 304 with the shake table may cause the slurry to infiltrate the joint. After infiltration, the slurry may be allowed to dry 306. The slurry application may be performed with the feedcore in a green state. Thereafter, the core assembly may be removed 308 and fired 310 to cure the feedcore. The firing may also further harden the slurry to more strongly attach the cores. The firing may be separate from or coincident with the shell firing previously described.

[0028] Advantageously, the slurry has a viscosity effective to facilitate its shake-assisted infiltration into the joint. The drying shrinkage, however should not be so great as to risk mechanical failure. Also, the coefficient of thermal expansion should be effective to maintain engagement during the heatings associated with firing and casting. The exemplary properties and composition discussed above are believed particularly effective.

[0029] One or more embodiments of the present invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. For example, the principles may be implemented as modifications of existing or yet-developed processes in which cases those processes would influence or dictate parameters of the implementation. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A method for attaching a metallic casting core to a ceramic casting core comprising:

inserting an insertion portion of the metallic casting core into a receiving portion of the ceramic casting core; and

introducing a slurry between the metallic casting core and the ceramic casting core.

2. The method of claim 1 wherein:

the metallic casting core comprises a refractory metal-based substrate.

3. The method of claim 1 used to form a turbine blade core assembly or a turbine vane core assembly.

4. The method of claim 1 further comprising:

heating the slurry to harden the slurry.

5. The method of claim 1 further comprising:

vibrating the metallic casting core and the ceramic casting core during the introducing.

6. The method of claim 1 wherein:

the inserting is performed with the ceramic casting core in a green state.

7. The method of claim 1 wherein the slurry comprises zircon and aqueous colloidal silica.

8. The method of claim 6 wherein:

the slurry has an aqueous colloidal silica content of 20-30%, by weight, of a zircon content.

9. The method of claim 1 wherein:

the slurry comprises a surfactant.

10. The method of claim 1 wherein the slurry has:

a density of 2.87-2.96 g/cm³;

a pH of 9-10.5; and

a viscosity of 25 $\pm$ 2 cP.

11. The method of claim 1 wherein the slurry has:

a density of 2.87-2.96 g/cm³;

a pH of 9-10.5; and

a viscosity of 18-27 cP.

12. A method comprising:

using a slurry comprising zircon and aqueous colloidal silica to secure a metallic casting core to a ceramic casting core.

13. The method of claim 12 further comprising:

heating the slurry to harden the slurry.

14. An apparatus comprising:

means for holding a ceramic casting core;

means for holding a metallic casting core with an insertion portion received in a receiving portion of the ceramic casting core; and

means for vibrating the ceramic casting core and the metallic casting core.

15. The apparatus of claim 14 in combination with:

said ceramic casting core;

said metallic casting core; and

a slurry comprising zircon and aqueous colloidal silica between the metallic casting core and the ceramic casting core and being vibrated by the means for vibrating.

16. The apparatus of claim 14 wherein the means for holding the metallic casting core comprises:

means for adjusting a relative position of the ceramic casting core and the metallic casting core.

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