The invention describes a method of casting a metal comprising the following steps: fabricating a pattern from wax or plastic having the geometry to generate a desired object, fabricating an investment mold from the wax, placing the mold in an open pressure vessel, filling the investment mold with a molten metal alloy, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time, depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled investment mold, and extracting the desired object from the investment mold.
CASTING DEVICE AND ASSOCIATED METHOD FOR INVESTMENT CASTING WITH IMPROVED MECHANICAL PROPERTIES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 62/124,015 filed Dec. 6, 2014, which hereby is incorporated herein in its entirety by reference thereto.

FIELD OF THE INVENTION

[0002] The present invention is directed generally to manufacturing metal objects and more specifically to a method to investment cast metal objects.

BACKGROUND

[0003] Investment casting is a metal casting process by which a duplicate metal object is cast from a pattern which is destroyed in the process of making the mold or casting. Investment casting is an industrial process based on and also called lost wax casting. The term “investment casting” can also refer to an object produced via the investment casting process. From 5,000 years ago when beeswax formed the pattern to today’s high-technology waxes, the castings allow the production of components with excellent surface finish, high dimensional accuracy, and extreme intricacy in a variety of metals and high-performance alloys. Investment castings are produced in specialized factories commonly referred to as foundries. Investment casting is generally more expensive per unit than die casting or sand casting. Investment casting can produce complicated shapes that would be difficult or impossible with other methods and requires little surface finishing and only minor post-machining. It is used to produce common everyday metal objects as well as intricate aerospace and military components. Cast objects can be made of the model itself, the direct method; or of a copy of a model, the indirect method.

[0004] A master pattern or the desired object is fabricated, although this step is often replaced with a digital CAD model. A negative cavity mold is made of the master pattern or from the CAD model. Wax patterns are created from the negative cavity mold by injecting heated liquid wax into the chilled negative cavity mold. The wax pattern is then removed from the negative cavity mold, or alternatively in lower volume applications, a 3D printed plastic pattern from a CAD model is used. Depending on the application, multiple wax patterns may be created so that they can all be cast at once. The multiple patterns are attached to a wax sprue, with the result as a wax pattern cluster, or tree. The ceramic mold, known as the investment mold, is produced by three repeating steps: coating, stuccoing, and hardening. The first step involves dipping the assembled and prepared cluster into a slurry of fine refractory material and then letting any excess drain off so a uniform surface is produced. This fine material is used first to give a smooth surface finish and reproduce fine details. In the second step, the cluster is stuccoed with a ceramic particle by dipping it into a fluidized bed, placing it in a rainfall-sander, or by applying by hand. Finally, the coating is allowed to harden. These steps are repeated until the investment mold is the required thickness. Another method is to secure the pattern and tree in a container and pour a slurry around it which hardens for the full-mold or solid-mold variant of the process. The investment mold is then allowed to completely dry. It is then placed in a favorable position, typically upside down, to drain and is placed in a furnace or autoclave to melt out and/or vaporize the wax. The investment mold is then subjected to a burnout and preheat to remove any moisture and residual wax and to sinter the mold. The investment mold is then placed cup-upwards and filled with molten metal. The cast part is allowed to cool and fully solidify. Once solidified, the investment mold is removed by vibration, water blast, or a chemical process. The sprue is trimmed away leaving the final desired object(s). The molding process proceeds generally along the following 10 steps:

[0005] Step #1: Fabricate a master pattern or create a CAD model.

[0006] Step #2: A negative cavity mold is made of the master pattern or CAD model.

[0007] Step #3: Produce the wax patterns from the negative cavity mold or 3D printed plastic pattern.

[0008] Step #4: Assemble the wax patterns into a pattern cluster, or tree.

[0009] Step #5: The ceramic mold, known as the Investment mold, is produced by repeating the steps: coating, stuccoing, and hardening.

[0010] Step #6: Turn the investment mold upside down and place it in a furnace or autoclave and melt out and/or vaporize the wax.

[0011] Step #7: Burnout of the investment mold to remove any moisture and residual wax and sinter the mold.

[0012] Step #8: Place the investment mold pouring cup upwards, and fill the investment mold with molten metal.

[0013] Step #9: Allow the metal to cool and fully solidify.

[0014] Step #10: Break away the investment mold and trim the cast object.

SUMMARY OF THE INVENTION

[0015] The present invention is directed generally to manufacturing cast metal objects and more specifically to a method and device to investment cast metal objects.

[0016] One embodiment of the present invention describes a method of casting a metal alloy comprising the following steps: fabricating a pattern from wax or plastic having the appropriate geometry to generate a desired object to be cast, fabricating an investment mold from the wax or plastic, placing the investment mold in an open pressure vessel, filling the investment mold with a molten metal alloy, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time said predetermined measured time sufficient for the molten metal to cool and solidify, depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled investment mold, and extracting the desired object from the investment mold.

[0017] Another embodiment of the present invention describes a method of casting a metal alloy comprising the following steps: fabricating a pattern from wax or plastic having the appropriate geometry to generate a desired object to be cast, fabricating an investment mold from the wax or plastic, placing the investment mold in an open pressure vessel, filling the investment mold with a molten metal alloy, immediately thereafter closing and pressure sealing the pres-
sure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time said predetermined measured time sufficient for the molten metal to cool and solidify, withdrawing the inert gas from the sealed pressure vessel and transferring said inert gas into a reusable storage device thereby depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled investment mold, and extracting the desired object from the investment mold.

[0018] Another embodiment of the present invention describes a method of casting a metal alloy comprising the following steps: fabricating a pattern from wax or plastic having the appropriate geometry to generate a desired object to be cast, fabricating an investment mold from the wax or plastic, filling the investment mold with a molten metal alloy, placing the investment mold in an open pressure vessel, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time said predetermined measured time sufficient for the molten metal to cool and solidify, withdrawing the inert gas from the sealed pressure vessel and transferring said inert gas into a reusable storage device thereby depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled investment mold, and extracting the desired object from the investment mold.

[0019] Another embodiment of the present invention describes a method of casting a metal alloy comprising the following steps: fabricating a pattern from wax or plastic having the appropriate geometry to generate a desired object to be cast, fabricating an investment mold from the wax or plastic, placing the investment mold in an open pressure vessel, filling the investment mold with a molten metal alloy, packing loose sand around the metal filled investment mold and held by a container, immediately thereafter closing and pressure sealing the pressure vessel, pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time said predetermined measured time sufficient for the molten metal to cool and solidify, withdrawing the inert gas from the sealed pressure vessel and transferring said inert gas into a reusable storage device thereby depressurizing the sealed pressure vessel, opening the pressure vessel and removing the metal filled investment mold, and extracting the desired object from the investment mold.

[0020] Another embodiment of the present invention describes a device for casting a metal alloy comprising the following elements: a pressure vessel head, a pressure vessel base incorporating a surface to support a sand casting mold, a vertical travel guide in mechanical communication with the pressure vessel head and the pressure vessel base, said pressure vessel head and pressure vessel base incorporating interlocking members capable of forming a pressure seal when interlocked, and an actuator capable of engaging the interlocking members thereby forming a pressure seal when the pressure vessel head is in mechanical communication with the pressure vessel base.

[0021] The above summary of the present invention is not intended to describe each illustrated embodiment or every implementation of the present invention. The figures and the detailed description which follow more particularly exemplify these embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The invention may be more completely understood in consideration of the following detailed description of various embodiments of the invention in connection with the accompanying drawings, in which:

[0023] FIG. 1 shows a schematic representation of a pressure vessel shown in the open configuration. The pressure vessel may be comprised of a pressure vessel head, a vertical travel guide, and a pressure vessel base which is designed to form a pressure seal when in mechanical communication with the pressure vessel head.

[0024] FIG. 2 shows the pressure vessel depicted in FIG. 1 incorporating an investment mold placed on the pressure vessel base.

[0025] FIG. 3 shows the pressure vessel depicted in FIG. 1 in the closed and unlocked, i.e. non-pressurized, configuration.

[0026] FIG. 4 shows the pressure vessel depicted in FIG. 1 in the closed and pressurized configuration while in airway communication with an external source of a pressurized inert gas.

[0027] FIG. 5 shows the pressure vessel depicted in FIG. 1 incorporating an investment mold with loose sand packed around it held by a container and placed on the pressure vessel base.

[0028] While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

[0029] The present invention is directed generally to manufacturing metal objects and more specifically to a device and method to investment cast metal objects. One embodiment of the present invention is depicted schematically in FIGS. 1 through 5, highlighting the apparatus to pressurize an encased metal filled investment mold with an inert gas.

[0030] FIG. 1 depicts a pressure vessel 10 shown in the open configuration. The pressure vessel 10 may be comprised of a pressure vessel head 12, a vertical travel guide 14, and a pressure vessel base 16 which is designed to form a pressure seal when in mechanical communication with the pressure vessel head 12.

[0031] In one embodiment of the present invention, an investment mold 20 (see FIG. 2) having the appropriate internal geometry to generate a desired object to be cast may be placed on a planar substrate 18 which is part of the pressure vessel base 16. Once in place, the investment mold 20 may be filled with a molten metal, preferably an aluminum alloy. Immediately after filling the investment mold 20 with molten metal, the pressure vessel head 12 may be lowered and placed in mechanical communication with the pressure vessel base 16. In placing the pressure vessel head 12 in mechanical communication with the pressure vessel base 16, care may be taken to align the male interlocking elements 22A adhered to the bottom of the pressure vessel head 12 with the female counterpart interlocking elements 22B adhered to the pressure vessel base 16 as shown in FIG. 3. Once properly
aligned, a linear actuator 24 attached to the pressure vessel base 16 may be energized which in turn may interlock the male and female locking elements thereby pressure sealing the pressure vessel.

[0032] Once the pressure seal has been established, an external source of an inert pressurized gas, preferably helium, may be inserted into the pressure sealed vessel by way of a valve 26 incorporated into the wall of the pressure vessel base 16 as depicted in FIG. 4. In one embodiment of the present invention, the inert gas may pressurize the sealed vessel in the range of 50 to 180 pounds per square inch. The sealed, inert gas pressurized vessel may remain pressurized for a predetermined time commensurate with the size of the investment casting mold and the volume of molten metal encased therein.

[0033] In one embodiment of the present invention, the investment mold 29 may be encased within loose sand 28 and confined within container 30, as depicted in FIG. 5.

[0034] In a preferred embodiment of the present invention, the pressure vessel and the external source of inert gas may be configured to reclaim and purify for later reuse the inert gas used previously in the process of pressurizing the pressure vessel as described above.

[0035] The present invention should not be considered limited to the particular examples described above, but rather should be understood to cover all aspects of the invention as fairly set out in the attached claims. Various modifications, equivalent processes as well as numerous structures to which the present invention may be applicable will be readily apparent to those of skill in the art of casting metal objects. For example, the invention anticipates other geometrical configurations for the pressure vessel including but not limited to a horizontal design in contrast to the vertical configuration outlined in the above description. Also, the present invention anticipates that the time for the molten aluminum to cool and fully solidify while still encased within the pressure chamber may depend upon the volume of molten aluminum poured, and in many cases, the ratio of volume-to-surface area of the encased aluminum, and one of ordinary skill in the art may make that determination theoretically or by experimentation.

The following claims are intended to cover such modifications and devices.

1 claim:

1. A method of casting a metal alloy comprising the following steps:
   fabricating a pattern from wax or plastic having the appropriate geometry to generate a desired object to be cast;
   placing the investment mold in an open pressure vessel;
   filling the investment mold with a molten metal alloy;
   immediately thereafter closing and pressure sealing the pressure vessel;
   pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;
   said predetermined measured time sufficient for the molten metal to cool and solidify;
   depressurizing the sealed pressure vessel;
   opening the pressure vessel and removing the metal filled investment mold; and
   extracting the desired object from the investment mold.

2. The method of claim 1 wherein the investment mold may be comprised of aluminosilicate stucco, fused silica, crystalline silica, colloidal silica, zircon, alumina, zirconium oxide, silica sand (SiO₂), chromite sand (FeCr₂O₄), zircon sand (Zr-

SiO₂), staurolite, graphite, organic and inorganic binders consisting of latex polymers, water-soluble polymers, and combinations thereof.

3. The method of claim 1 wherein the inert gas may be helium, argon, nitrogen, oxygen or combinations thereof.

4. The device of claim 1 wherein the sealed pressure vessel is pressurized to a value in the range of 50 to 180 pounds per square inch with the inert gas.

5. A method of casting a metal alloy comprising the following steps:
   fabricating a pattern from wax or plastic having the appropriate geometry to generate a desired object to be cast;
   placing the investment mold in an open pressure vessel;
   filling the investment mold with a molten metal alloy;
   immediately thereafter closing and pressure sealing the pressure vessel;
   pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;
   said predetermined measured time sufficient for the molten metal to cool and solidify;
   withdrawing the inert gas from the sealed pressure vessel and transferring said inert gas into a reusable storage device thereby depressurizing the sealed pressure vessel;
   opening the pressure vessel and removing the metal filled investment mold; and
   extracting the desired object from the investment mold.

6. The method of claim 5 wherein withdrawing the inert gas from the sealed pressure vessel may include filtering and separating unwanted gaseous compounds prior to transferring the said inert gas into a reusable storage device.

7. A method of casting a metal alloy comprising the following steps:
   fabricating a pattern from wax or plastic having the appropriate geometry to generate a desired object to be cast;
   placing the investment mold with a molten metal alloy;
   immediately thereafter closing and pressure sealing the pressure vessel;
   pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;
   said predetermined measured time sufficient for the molten metal to cool and solidify;
   withdrawing the inert gas from the sealed pressure vessel and transferring said inert gas into a reusable storage device thereby depressurizing the sealed pressure vessel;
   opening the pressure vessel and removing the metal filled investment mold; and
   extracting the desired object from the investment mold.

8. The method of claim 7 wherein withdrawing the inert gas from the sealed pressure vessel may include filtering and separating unwanted gaseous compounds prior to transferring the said inert gas into a reusable storage device.

9. A method of casting a metal alloy comprising the following steps:
   fabricating a pattern from wax or plastic having the appropriate geometry to generate a desired object to be cast;
   placing the investment mold in an open pressure vessel;
   filling the investment mold with a molten metal alloy;
   encasing the investment mold in sand;
   immediately thereafter closing and pressure sealing the pressure vessel;
pressurizing the sealed pressure vessel with an inert gas for a predetermined measured time;
said predetermined measured time sufficient for the molten metal to cool and solidify;
withdrawing the inert gas from the sealed pressure vessel and transferring said inert gas into a reusable storage device thereby depressurizing the sealed pressure vessel;
opening the pressure vessel and removing the metal filled investment mold; and
extracting the desired object from the investment mold.

10. The method of claim 9 wherein withdrawing the inert gas from the sealed pressure vessel may include filtering and separating unwanted gaseous compounds prior to transferring the said inert gas into a reusable storage device.

11. A device for casting a metal alloy comprising the following elements:
   a pressure vessel head;
   a pressure vessel base incorporating a surface to support an investment mold;
   a vertical travel guide in mechanical communication with the pressure vessel head and the pressure vessel base;
said pressure vessel head and pressure vessel base incorporating interlocking members capable of forming a pressure seal when interlocked; and
an actuator capable of engaging the interlocking members thereby forming a pressure seal when the pressure vessel head is in mechanical communication with the pressure vessel base.

12. The device of claim 11 wherein the pressure vessel base incorporates a unidirectional valve device to receive an inert gas from an external source.

13. The device of claim 11 wherein the pressure vessel base incorporates a bidirectional valve device with the means to receive an inert gas from an external source and exhaust said inert gas into an external source for later reuse.

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