A method is provided for simultaneously coating a plurality of pattern set-ups with refractory material in a single operation during the production of ceramic shell molds. An array of circumferentially spaced pattern set-ups is mounted for rotation about a horizontal axis so that each set-up is moved about the axis between a raised position and a lowered position in which the set-up is at least partially immersed in refractory material. In one preferred embodiment of the invention provision is made for rotating each set-up about its longitudinal axis during the coating operation.

8 Claims, 6 Drawing Figures
METHOD FOR FORMING CERAMIC SHELL
MOLDS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a division of application Ser. No. 172,035 filed Aug. 16, 1971, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates generally to the art of investment casting, and more specifically to ceramic shell molding techniques of precision casting wherein shell molds suitable for casting metal are prepared by building up layers of refractory material around disposable patterns which are subsequently removed from the mold.

As is known to those familiar with the art of investment casting, ceramic shell molds are prepared using patterns which are replicas of the parts to be cast in metal and which are formed of an expendable material. These patterns are attached to a sprue member to form what is known as a "set-up." The formation of a shell mold around the set-up is accomplished by dipping it into a refractory slurry of controlled viscosity followed by directional draining to coat the patterns uniformly. After draining excess slurry from the set-up, the slurry coating is sanded or stuccoed while wet with coarser refractory particles, such as by dipping the set-up into an air-fluidized bed of dry refractory material. The result is a coat of ceramic material having refractory particles embedded in the surface. This coat is hardened, usually by air drying at room conditions. After the first coat is sufficiently hard and dry, the steps of dipping, draining, stuccoing and drying are repeated until a refractory shell having a sufficient thickness to resist the stresses occurring in subsequent operations has been built up around the set-up. The usual shell thickness is from one-eighth inch to about one-half inch, although thicker or thinner shells may be formed for special situations. The set-up including the disposable patterns is then removed from the shell mold and the mold prepared for the casting operation.

In order to obtain a satisfactory shell mold for casting metal, it is necessary to form dense, void-free coatings around the set-up. This requires the set-up to be carefully rotated so that the slurry will flow over and coat all areas of the set-up uniformly. A satisfactory coating is particularly difficult to obtain when the workpiece patterns have relatively complex shapes, including holes, slots, narrow passageways, surface detail and the like. The viscosity of the slurry is often such that it will not easily flow into and cover the complex portions of the patterns. There is also a tendency for air to be trapped in restricted areas of the patterns and/or in previously applied coatings so as to weaken the shell mold and produce voids which may result in the castings being scrapped. Further, when the set-up consists of a large number of closely spaced patterns, there is a tendency for a substantial amount of the slurry to be retained between the patterns so as to form relatively thick wall portions in these areas. The thick wall portions are difficult to dry properly and may crack when heated, such as during the pattern removal operations and/or when the molds are fired prior to casting.

An important advance in the art of ceramic shell molding is described in U.S. Pat. No. RE. 26,495, issued Dec. 3, 1968 to Claude H. Watts et al. As disclosed in that patent, the pattern set-up is horizontally positioned for rotation about its longitudinal axis so that rows of patterns on the set-up can be moved into and out of a slurry bath by rotating the set-up. The rotation of the set-up on its horizontal axis has been found to produce excellent coating results and to avoid the problems discussed above. As the set-up is rotated to move the rows of patterns into and out of the slurry, the angular positions of the patterns are continuously changed. As a result, the slurry can run over all portions of the patterns and fill all of the pattern cavities and other difficult-to-fill areas so as to produce a uniform coating. By rotating the pattern set-up on a horizontal axis following the coating operation, it is also possible to obtain improved directional draining of excess slurry and to prevent the slurry from being trapped between closely spaced patterns so as to form thick, difficult-to-dry wall areas.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a method for simultaneously applying slurry coatings to a plurality of pattern set-ups in a single operation so as to obtain the several advantages described in the above-referenced U.S. Pat. No. RE. 26,495.

In accordance with the preferred embodiments of the present invention, a plurality of pattern set-ups are supported by a fixture which is mounted for rotation about an axis transverse to the vertical height of a slurry tank. The set-ups are supported at locations disposed about the axis of rotation of the fixture and are spaced radially from the axis. When the fixture is rotated, each pattern set-up is revolved about the axis of the fixture between a lowered position in which the set-up is at least partially immersed in the slurry and a raised position. In one preferred embodiment, provision is made for rotating each of the pattern set-ups about its longitudinal axis during the coating operation. A cover or hood may be associated with the tank to form a vacuum chamber in which the fixture is disposed so that the slurry and the set-ups can be subjected to vacuum conditions when the set-ups are being rotated and coated with slurry.

A primary advantage obtained by the invention is that it makes it possible to produce relatively small diameter set-ups in a practical and economical manner. This is of particular benefit to investment foundries whose operations are limited by the capacity of their melting furnaces and other equipment and which do not require the sophisticated mold making apparatus of the size used by larger foundries. The new method and apparatus for simultaneously coating a plurality of set-ups in a single operation reduce the costs of making shell molds and are especially suitable for the production of small diameter molds compatible to the operations of small foundries.

Other objects, advantages and a fuller understanding of the invention will be had from the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view taken on the line 1—1 of FIG. 2 and shows an assembly of pattern set-ups supported by a fixture in accordance with this invention;
FIG. 2 is an end elevational view of the assembly shown in FIG. 1.

FIG. 3 is a vertical elevation, partially in cross-section, showing the assembly of FIG. 1 mounted for a coating operation according to one embodiment of this invention;

FIG. 4 is a vertical elevation, partially in cross-section, showing the assembly of FIG. 1 mounted for a coating operation according to another embodiment of this invention;

FIG. 5 is a cross-sectional view taken on the line 5--5 of FIG. 4; and

FIG. 6 is a top plan view with portions eliminated of the arrangement shown in FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings and to FIGS. 1 and 2 in particular, there is shown a fixture 10 which supports a plurality of pattern set-ups 11. The fixture 10 is comprised of a pair of disks 12 which are suitably secured to a rod 13 in axially spaced locations.

Each of the set-ups 11 is of a typical construction including a plurality of workpiece patterns 20 which project from the outside wall of a sprue member 21. In accordance with conventional practice, the workpiece patterns 20, which are replicas of the parts to be cast and include the necessary gates and risers, are formed of an expendable material, such as wax, a synthetic resin, or a wax and resin composition.

The sprue members 21 are generally cylindrical. As shown, each such sprue member may be comprised of a tube 22 made of cardboard or other relatively stiff material, and a corrugated cardboard sleeve 23 which surrounds the tube 22. The sleeve 23 is axially corrugated in its inner surface while the outer surface of the sleeve is smooth. The smooth outer cylindrical wall of the sleeve 23 is provided with a thin coating of wax or the like to which the patterns 20 are attached. A rod 24 extends longitudinally through each set-up 11 and the ends of the tube 22 are closed by disks 25 which are secured to the rod 24 by any suitable means. Each set-up is completed by annular plates 26 which are secured to the disks 25. The plates 26 project circumferentially beyond the sleeve 23 a sufficient distance to prevent the shell forming material from being built up around the ends of the set-up.

It is to be understood that the described construction of the sprue members 21 can be varied and that the illustrated structure is not limiting of the invention. For example, the body of each sprue member may be formed by an injection molded wax tube. According to another conventional practice, the sprue members may comprise metal tubes coated with wax.

In accordance with the present invention, the set-ups 11 are supported in circumferentially spaced locations around the outer peripheries of the disks 12. The longitudinal axes of the set-ups defined by the rods 24 are radially spaced from and are preferably parallel to the axis of the fixture 10 defined by the rod 13. As shown in FIG. 2, the ends of the rods 24 are received in slots or notches formed in the disks 12 and are held in place by keepers 27. The keepers 27 are removably fastened to the disks 12 in any suitable manner, as by screws 28, in order to permit the set-ups 11 to be mounted on and removed from the fixture 10.

FIG. 3 illustrates one preferred manner of coating the set-ups 11 with refractory slurry. As shown, a refractory slurry bath 35 is provided in a tank 36. The fixture 10 is mounted above the bottom of the tank 36 for rotation about a horizontal axis defined by the rod 13. One end of the horizontally extending rod 13 is engaged in a rotatable drive cup or shaft socket 38. A motor 39 is mounted on a plate 40 at one end of the tank 36 and has its output shaft in driving connection with the cup or shaft socket 38 for rotating the fixture 10. The other end of the rod 13 is received within a spring-biased, axially movable socket 41 which is rotatably journaled within a sleeve 42 of a mounting assembly 43. The mounting assembly 43 is supported by a plate 44 connected to the tank 36.

The fixture 10 is mounted for rotation by first inserting one end of the fixture rod 13 in the socket 41 which is then pressed inwardly relative to the sleeve 42 to permit the other end of the fixture rod 13 to be inserted in the drive cup 38. When the spring-biased socket 41 is released, the socket is urged outwardly of the sleeve 42 so that the fixture 10 is firmly supported for rotation by the motor 39.

In accordance with conventional practices, a suitable refractory slurry used for coating the pattern set-ups 11 consists essentially of a suspension of fine refractory powder, such as zircon (zirconium silicate) and fused silica, in a binder solution comprised mainly of colloidal silica sol and small amounts of an organic film former, a wetting agent, and a defoaming agent. The refractory powder usually is minus 100 mesh.

In forming the slurry coatings around the pattern set-ups 11, the fixture 12 is rotated relatively slowly by the motor 39, for example, about 5 rpm, so that each set-up is lowered into the slurry 35 at one side of the tank 36 and is raised out of the slurry at the other side of the tank. The rotative movement of the fixture constantly changes the angular positions or attitudes of the various patterns 20. This constant changing of the attitudes of the various patterns is advantageous, since the excess slurry is caused to run over the patterns as they are rotated out of the bath and around the rod 13, thereby resulting in uniform pattern coverage.

It is usually desirable to apply at least the initial slurry coatings under a vacuum in order to remove occluded air in the slurry and to prevent formation of air bubbles on the surfaces of the patterns. Such a procedure is particularly advantageous with patterns having intricate surface detail and difficult-to-fill areas, such as small recesses and cavities, which tend to trap air during rotation of the fixture.

As shown in FIG. 3, a removable cover 45 is provided for the tank 36. The cover 45 is engageable with a tank seal member 46 to form a vacuum chamber 47 in which the fixture 10 and the set-ups 11 are disposed. A fitting 48 is mounted through an end of the cover 45 and is adapted to be connected by a vacuum line (not shown) to a suitable vacuum pump or the like. When the cover 45 has been moved to the closed position against the seal 46, a vacuum is drawn in the chamber 47 to remove any air bubbles from the slurry 35, and the fixture 10 is rotated while the slurry is under the vacuum. It will be understood that the vacuum treatment of the slurry may be effected either during each such coating operation or during only selected applications of the slurry to the set-ups. In some instances, the use of a vacuum treatment can be eliminated entirely.
Subsequent to the described coating operation the coated set-ups 11 are stuccoed with coarse refractory materials, such as by rotating the fixture 10 to move the coated set-ups 11 through an air-fluidized bed of refractory materials. The stuccoed coatings are then allowed to harden, as by forced air drying. Additional slurry coatings may be applied in the same manner, stuccoed and allowed to harden until a ceramic shell of the desired thickness has been produced around each pattern set-up.

FIGS. 4, 5 and 6 illustrate another preferred arrangement and procedure for coating the pattern set-ups 11 with refractory slurry. According to this embodiment of the invention, the pattern set-ups 11 are supported by a fixture 10a in substantially the same manner as described above in connection with FIGS. 1 and 2 except that the set-ups are mounted for rotation about their longitudinal axes. The ends of the set-up rods 24 are journaled in sleeves 60. The sleeves 60 are mounted in the notches formed in the plates 12a around their outer peripheries and are held in place by keepers (not shown) similar to the keepers 27 described above.

As shown in FIGS. 4, 5 and 6, a refractory slurry bath 61 is provided in a tank 62. The tank 62 is mounted in a housing 63 so that at least one end wall 64 of the tank is spaced inwardly from the adjacent end wall 65 of the housing. A cover 66 cooperates with the housing 63 to form a vacuum chamber 67 over the slurry bath 61. In its closed position, the edges of the cover are engaged against a seal ring 68.

The fixture 10a is supported for rotation about a horizontal axis in the same manner as described above in connection with FIG. 3. One end of the fixture rod 13a is engaged in a drive cup or shaft socket 38 which is driven by a motor 39a supported on a plate 70. The other end of the rod 13a is engaged in a spring-biased, axially movable cup or socket 41 of a mounting assembly 43 which is supported on a plate 71.

Provision is made for rotating each of the pattern set-ups 11 about its longitudinal axis as the fixture 10a is rotated about the horizontal axis defined by the rod 13a. A ring-type gear 75 having teeth in its inner and outer peripheries is freely rotatable on the fixture rod 13a between the tank end wall 64 and the end wall 65 of the housing 63. As shown in FIG. 5, the gear 75 has a central hub portion 76 which receives the rod 13a and radially extending spider arms 77. The hub portion 76 is mounted between removable members 78 which are fixed to the rod 13a so that the gear 75 is free to rotate relative to the rod while being restrained against axial movement. Pinions 80 are secured to the ends of the set-up rods 24 and engage the inner teeth of the gear 75 so that rotation of the gear is effective to rotate each of the individual set-ups 11. The gear 75 is rotated by a motor 81 mounted on the plate 70. A pinion 82 is fixed to the drive shaft of the motor 81 and engages the outer teeth of the gear 75.

In a preferred manner of operation, the fixture 10a is rotated by the motor 39a to cause the set-ups 11 to rotate about the rod 13a, whereby each of the set-ups is moved between an upper position above the rod 13a and a lower position in which the set-up is at least partially immersed in the slurry. As shown in FIGS. 4 and 5, only the lower portion of each set-up is immersed in the slurry when the set-up is in the lowered position. The motor 39a is preferably operated intermittently to rotate the fixture 10a step-wise, whereby each set-up is held in the lowered position for a predetermined length of time. The motor 81 may be operated to continuously rotate the set-ups about their longitudinal axes during the coating operation. By rotating the set-ups about their longitudinal axes at the same time they are revolved about the rod 13a, excess slurry is drained from the set-ups to prevent the formation of thick wall portions between the closely spaced patterns. If desired, the coating operation may be carried out under a vacuum in the manner described above in connection with FIG. 3.

Many modifications and variations of the invention will be apparent to those skilled in the art in the light of the foregoing detailed disclosure. Therefore, it is to be understood that, within the scope of the appended claims, the invention can be practiced otherwise than as specifically shown and described.

What is claimed is:

1. In the production of investment casting molds by building up refractory layers around pattern set-ups, a method of applying refractory material to a plurality of pattern set-ups in a single operation comprising the steps of mounting an array of several pattern set-ups for rotation as a group about an axis transverse to the vertical, the pattern set-ups being spaced radially from said axis and arranged about it with their ends lying in planes transverse to said axis so that when the array is rotated each pattern set-up is moved about said axis between a lowered position and a raised position, rotating the array and moving each set-up to change the angular positions of its outer peripheral proportions, and applying fluent refractory material to the set-ups in the array, whereby the material is caused to uniformly cover the outer peripheral portions of the set-ups as their angular positions are changed.

2. In the production of investment casting molds by building up refractory layers around pattern set-ups, a method of applying refractory material to a plurality of pattern set-ups in a single operation comprising the steps of mounting an array of several pattern set-ups for rotation as a group about an axis transverse to the vertical height of a tank containing fluent refractory material, the pattern set-ups being spaced radially from said axis and arranged about it with their ends lying in planes transverse to said axis so that when the array is rotated each pattern set-up is moved about said axis between a lowered position in which it is at least partially immersed in the refractory material and a raised position in which the set-up is above the refractory material and rotating the array of pattern set-ups through the refractory material while moving each set-up to change the angular positions of its outer peripheral portions so that they are uniformly covered by the refractory material.

3. A method as claimed in claim 2 wherein said refractory material is a slurry, and including the step of placing the slurry under vacuum during rotation of the array.

4. A method as claimed in claim 2 in which at least some of said set-ups of said array are individually rotated about their longitudinal axes.

5. A method as claimed in claim 4 including the step of periodically interrupting rotation of said array when at least some of said set-ups are in said lowered position.
6. A method as claimed in claim 1 wherein the set-ups are held against rotation about their own axes as the array is rotated.

7. A method as claimed in claim 1 wherein the set-ups are individually rotated about their own axes as the array is rotated.

8. A method of making refractory molds by building up refractory layers around pattern set-ups, said method being characterized by the procedure of handling several pattern set-ups as a group during formation of the refractory layers around the set-ups in the group and including the steps of:
   a. grouping a plurality of pattern set-ups in an array so that the set-ups are circumferentially spaced from each other about an axis and so that the ends of the set-ups lie in planes transverse to said axis,
   b. processing the array of several pattern set-ups through a coating operation in which refractory slurry is applied to each set-up in a single operation,
   c. processing said array of several pattern set-ups through a stuccoing operation in which refractory particles are applied to the coated set-ups of the array in a single operation,
   d. hardening the stuccoed coatings around the set-ups,
   e. repeating the coating and stuccoing operations to build up refractory layers around each set-up in the array, and
   f. removing the set-ups from the array after refractory layers of the desired thickness have been formed,
   g. at least one of said operations being carried out by the steps of:
      i. mounting the array of set-ups for rotation about said axis with said axis being transverse to the vertical height of a tank containing fluent refractory material and so that when the array is rotated each pattern set-up is moved about said axis between the lowered position in which it is at least partially immersed in the refractory material and a raised position in which the set-up is above the refractory material,
      ii. rotating the array of pattern set-ups through the refractory material while moving each set-up to change the angular positions of its outer peripheral portions so that they are uniformly covered by the refractory material.

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