METHOD OF CASTING METAL

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This invention relates to a casting method and apparatus that is particularly useful in the manufacture of shaped metal articles of intricate design.

It is well known that a considerable variety of casting methods have heretofore been devised. These include investment, plaster, permanent mold, die and shell mold casting methods as well as variations and special applications of each of these. It has been found difficult, however, efficiently to produce castings of intricate design, particularly a design which calls for a plurality of or even a multiplicity of thin sections such as interior or exterior reinforcing webs and webs formed by a large number of closely spaced holes, openings or indentations. Thus, for example, no successful method is believed heretofore to have been proposed for casting an article such as a tube sheet with the closely spaced holes cast into the sheet, or other articles having a similar intricate honeycomb type of pattern. One reason for this is that with heretofore proposed casting methods in which molten metal is introduced into a cavity formed by suitable mold members, the resistance to flow past closely spaced core members and the rapid absorption of heat from the molten metal combine to solidify the metal before it has had an opportunity completely to fill the intricate detail of the mold cavity.

As a result, such articles have generally been manufactured by casting the articles to the general shape desired and then drilling or otherwise machining the casting to provide the desired article.

We have discovered a novel and unique method of casting, and an apparatus therefor, which is applicable to casting generally and is particularly effective in casting shaped articles of intricate design. The apparatus in essence comprises a drag, a cope spaced from and in guided alignment with the drag, and means for plunging or thrusting the cope into a lake of solidifiable fluid in the drag.

In accordance with the method of the invention, a solidifiable fluid, e.g., molten metal, is formed in the drag and penetrated by a cope comprising at least one projecting core member, thus raising the level of the fluid in the cope member. Upon cooling, the fluid solidifies to a shape determined on the one hand by the cope and projecting core member and on the other hand by the shape of the drag.

In the preferred embodiment of the method of the invention as it is applied, for example, to the casting of metals into intricate patterns having a plurality of thin sections such as webs or the like, a drag is placed in a substantially horizontal position in a pit or other suitable area. The drag is constructed of any refractory material that is suitable, as will readily be appreciated by those skilled in the art, for the particular metal or alloy to be cast. It may be expendable, i.e., useful for only one casting, permanent in the sense of being useful for many castings, or of intermediate durability. Refractory materials that are suitable include resin-, cement-, silicate-, ethyl silicate- and oil-bonded sand, plaster of Paris, graphite, and metals that have substantially higher melting points than the metals to be cast. The drag is provided with suitable guiding means, such as a central shaft, a plurality of peripheral shafts or equivalents thereof, upon which there is aligned, in spaced relation to the drag, a permeable cope of bonded and cured molding sand having projecting therefrom a plurality of closely spaced core members corresponding to the voids or indentations desired in the casting.

For optimum results, the drag is flooded with a suitable non-oxidizing fluid, such as argon gas, that is heavier than air in order to avoid or to at least minimize the formation of an oxide film on the molten metal which is then poured or otherwise introduced into the drag to form a lake having a weight that is in excess of the weight of the final article to be cast. Before the metal has an opportunity to solidify, it is penetrated by the cope, which is inserted or plunged into the molten metal so as to complete the casting operation.

The rate of penetration of the cope is correlated, as will readily be apparent to those skilled in the art after reading this description, with such factors as the surface tension and resistance to flow of the molten metal and any oxide film formed thereon, and the rate at which trapped or evolved gases can be absorbed and dissipated by the porous cope and the core members thereof in particular, so as to achieve an adequate flow of the molten metal into all of the spaces between the closely spaced core pieces. After the metal has solidified, there has been an opportunity to cool and solidify, it is separated from the drag and the core, preferably by lifting the cope and casting out of the drag and re-integrating the cope. If desired or considered necessary, the article so cast may be subjected to sand blast or other surface treatment as well as to machining and the like.

While it is to be understood that the method of the invention is entirely applicable to the casting of articles of relatively simple shape and configuration, the method is believed to be most applicable, from an economic point of view, to the manufacture of cast metal articles having intricate designs that are practically unobtainable as cast by known casting methods. Thus, for example, the method is applicable to the casting of intricate parts of relatively unmachinable alloys such as "Ni-hard," a series of nickel-cast iron alloys, as well as to the manufacture of cast metal articles provided with a plurality of thin wall sections that ordinarily create difficulty in the design of adequate gates and risers in ordinary casting methods. Such thin walls may take the form of reenforcing or connecting web members or those formed by a multiplicity of closely spaced holes whether the holes be round, oblong, polygonal, tapered or untapered.

It will readily be appreciated from the description that the method of the invention has a number of outstanding advantages. One of the primary advantages is that it provides an economical method of producing castings of intricate design which heretofore required extensive machining. Another is that voids or indentations not readily reproducible by machining or other methods can easily be cast directly into the article. Thus, for example, it is possible by means of the present invention to cast a metal plate having a large number of closely spaced hexagonal, octagonal, or other shaped holes forming in effect a honeycomb pattern.

These and other advantages, as well as the utility of the invention, will become further apparent from the following detailed description, by way of example, of the manufacture of disc-shaped tube sheets approximately six feet in diameter and having of the order of...
15,000 holes approximately one-half inch in diameter spaced apart about one-eighth of an inch. It is to be understood, however, that this detailed description, made with reference to the accompanying drawing, is merely illustrative of the best mode now contemplated for practicing the invention.

In the drawing:

Figure 1 is a cross-section in elevation illustrating schematically the apparatus of the invention in the open position after a lake of molten metal has been formed.

Figure 2 is a view similar to Figure 1 but with the apparatus in the closed position; and

Figure 3 is a schematic view in perspective of the cast article formed in the operation illustrated in Figures 1 and 2.

A number of pie-shaped cope segments were first prepared from a working master pattern which consists essentially of a pie-shaped negative of the tube sheet 10, illustrated in Figure 3, the pattern being provided with a plurality of closely spaced and retractable pin members corresponding to the holes 11. The working master pattern was suitably cleaned and provided with a parting coating, as well known in the art, and placed in a molten bath. A plaster composition was then poured over the pattern with the pins in the extended, upwardly projecting position. The plaster was then allowed to set, whereafter the pins were retracted and the working master pattern was then parted from the resulting plaster mold.

The plaster mold was then turned upside down, i.e., with the holes down, and filled with a combination of resin-containing molding sand and "perlite," a puffed collapsible aluminum silicate. This was done by first filling the holes in the plaster cast and covering them to a thickness of the order of one-eighth to one-quarter of an inch with facing sand, backing this up with a layer of coarser molding sand, embedding suitable positioning and handling bolts in the sand, backing up the molding sand, except around the bolts and at the edges, with "perlite" containing about 30% by weight or 15% by volume bonding resin, and in some instances covering the whole with an approximately one-half inch layer of coarse molding sand and bonding resin.

The refractory mold material was compacted into the plaster mold and then baked for a time and at a temperature sufficient to cure the resin and transform the molding composition into a hard, strong but permeable cope section. The plaster was then disintegrated and removed by washing with a strong stream of water.

A number of pie-shaped cope sections sufficient to form a complete disc were then assembled on a suitable frame having a central bearing 12 and provided at intervals with risers to form a cope 14 having approximately 15,000 cylindrical core members 16 projecting downwardly from the cope proper.

A 17 of grey cast iron having an upstanding rim section 19 and a flat surface 20 was lifted out of an oven in which it had been maintained at a temperature of approximately 850° F. and placed into a pit, indicated generally by the reference numeral 21, after the insertion therein of an axial rod 22 having a suitable collar 24. The pit was then covered temporarily with a suitable insulating material such as asbestos sheeting to minimize cooling of the drag 17 while argon gas was flooded into the drag 17 to displace the air and the cope 14 was maneuvered into position and aligned on the shaft 22 by means of the bearing member 15 for coaxial alignment relative to the drag 17.

Molten aluminum alloy having a liquidus range of about 990 to 1175° F. and containing 4% copper, 1.4% magnesium and 2% nickel was then, after removal of the asbestos sheet cover, poured into the drag 17 at a temperature of about 150° F. to form a lake or puddle 26 and, immediately after cessation of the pouring operation, the cope 14 was lowered rapidly into the lake 20 of molten metal until the lower ends 27 of the core members 16 came into substantial abutment with the surface 20 of the drag 17. By reason of the displacement of the metal by the core members 16 and a portion of the cope proper, the molten metal was forced into the fine detail of the cope and into the risers, evaporated and trapped gases being absorbed and dissipated due to the permeability of the cope in general and the core members in particular.

The rapidity with which the cope was lowered was varied from casting to casting, in a series of tests, so that the time of penetration of the core members to their final position in the metal ranged between about one-half and about two and one-half seconds. For this operation, it was found that appreciably faster speeds of penetration are unnecessary and in fact to be avoided because the high pressures that are developed thereby force some of the metal into the facing layer of the cope and thus create rough spots on the surface of the casting, whereas appreciably slower speeds do not generate pressure quickly and high enough to force trapped and evolved gases completely out of the corners and fine detail of the cope relief or to overcome the surface tension of the metal to an extent sufficient to insure complete filling in of the detail before the metal solidifies.

In those instances in which the "perlite" interiors of the cope sections were covered with resin-bonded molding sand, the covering was broken up shortly after the cope was plunged into the lake of molten metal in order to weaken the cope still further and thus promote collapse of the "perlite" interior upon solidification and cooling of the metal in preference to distortion of the casting.

After allowing approximately fifteen minutes for the metal to cool and solidify, the cope and the casting were lifted bodily out of the drag 17 and the drag 17 was returned to the oven. The cope and its frame were then removed from the casting. Examination of the casting at this stage of the operation showed it to have surfaces free of defects, the lower surface formed by the surface 29 of the dish at the areas occupied by the core members 16 being a skin sufficiently thin to be translucent and almost transparent.

The casting was then subjected to conventional sand blasting process to blast away and remove the skin and for the purpose the drag 17 was subjected to light machining to remove the skin and thus uncover completely the holes 11 formed by the core members 16. X-ray examination of the casting showed it to be entirely sound despite the intricate and fine detail of the walls separating the closely spaced holes.

It is to be expected that various changes and modifications will readily become apparent to those skilled in the art upon reading this description. All such modifications are intended to be included within the scope of the invention as defined in the appended claims.

We claim:

1. Method for casting metal into a shaped article which comprises forming, in a drag, a lake of an amount of molten metal in excess of the amount required in the article, penetrating the lake with an expendable and substantially non-metallic cope forming a cavity with the drag and having permeability substantially throughout the mass of the cope for shaping the molten metal to the form of said article and displacing the surface metal in a generally upward direction so as to completely fill the article-forming cavity thus formed by the cope, and retaining the cope in the metal until the metal has solidified.

2. Method for casting metal into a shaped article which comprises forming, in a drag, a lake of an amount of molten metal in excess of the amount required in the article, penetrating the lake with an expendable and substantially non-metallic cope forming a cavity with the
the drag and having permeability substantially throughout the mass of the cope for forming the molten metal in a generally upward direction so as to fill the article-forming cavity thus formed by the cope, and retaining the cope in the metal until the metal has solidified, the rate of penetration by the cope being correlated with the surface tension and resistance to flow of the molten metal and any oxide film thereon and to the dissipation of trapped and evolved gases for promoting flow of the molten metal into all parts of the cavity.

3. Method for casting metal into a shaped article which comprises forming, in a drag, a lake of an amount of molten metal in excess of the amount required in the article, penetrating the lake with an expendable and substantially non-metallic cope forming a mold cavity with the drag, said mold cavity corresponding in shape to that required to form the article to be cast and said cope having permeability substantially throughout the mass of the cope, whereby the surface of the molten metal in the lake is displaced in a generally upward direction so as to fill the mold cavity and form the molten metal to the shape of said article, and retaining the cope in the metal until the metal has solidified.

4. Method for casting metal into a shaped article which comprises forming, in a drag, a lake of an amount of molten metal in excess of the amount required in the article, penetrating the lake with an expendable and substantially non-metallic cope forming a mold cavity with the drag, said mold cavity having risers and otherwise corresponding in shape to that required to form the article to be cast and said cope having permeability substantially throughout the mass of the cope, whereby the surface of the molten metal in the lake is displaced in a generally upward direction so as to fill the mold cavity, at least partially fill the risers and form the molten metal to the shape of said article, and retaining the cope in the metal until the metal has solidified.

5. Method for casting metal into a shaped article which comprises forming, in a drag, a lake of an amount of molten metal in excess of the amount required in the article, penetrating the lake with an expendable and substantially non-metallic cope forming a mold cavity with the drag, said cope having permeability substantially throughout the mass of the cope and at least one projecting core member, said mold cavity corresponding in shape to that required to form the article to be cast, whereby the surface of the molten metal in the lake is displaced in a generally upward direction so as to fill the mold cavity and form the molten metal to the shape of said article, and retaining the cope in the metal until the metal has solidified.

6. Method for casting metal into a shaped article which comprises forming, in a drag, a lake of an amount of molten metal in excess of the amount required in the article, penetrating the lake with an expendable and substantially non-metallic cope forming a mold cavity with the drag, said cope having permeability substantially throughout the mass of the cope and a plurality of closely spaced core members, said mold cavity corresponding in shape to that required to form the article to be cast, whereby the surface of the molten metal in the lake is displaced in a generally upward direction so as to fill the mold cavity and form the molten metal to the shape of said article, and retaining the cope in the metal until the metal has solidified.

7. Method for casting an aluminum alloy into a shaped article which comprises forming, in a drag, a lake of an amount of molten metal in excess of the amount required in the article, lowering into the lake an expendable and substantially non-metallic cope forming a cavity with the drag and having permeability substantially throughout the mass of the cavity for forming the molten metal to the shape of said article and displacing the surface metal in a generally upward direction so as to fill the article-forming cavity thus formed by the cope, and retaining the cope in the metal until the metal has solidified.

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