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680,698, now abandoned. Divided and this
application June 18, 1969, Ser. No.
834,300

[54] **CASTING METHOD**
26 Claims, 8 Drawing Figs.

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 [51] Int. Cl..... **B22c 9/02,**
B22d 27/02
 [50] Field of Search..... **164/20, 34,**
35, 41, 48, 49, 51, 138, 250, 251, 72, 267; 18/34
R, 38, DIG.33, DIG.13

[56]

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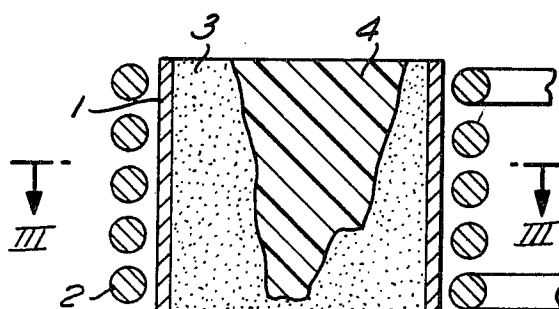
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ABSTRACT: A casting method using a mold of particulate material including magnetizable particles which is made shape-retaining by subjecting the shaped mold to a magnetic field of sufficient strength to fix the position of the particulate magnetizable mold-forming material.



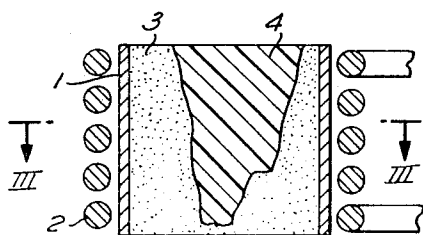


FIG. 1

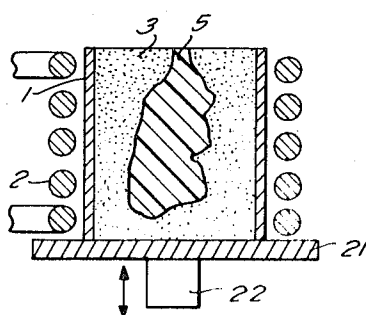


FIG. 2

FIG. 3

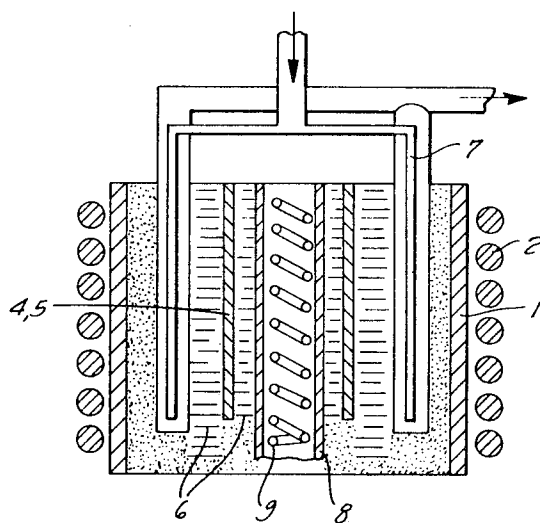
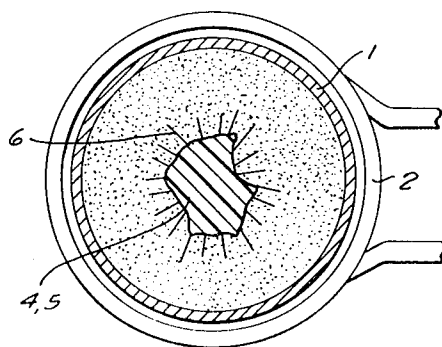


FIG. 4

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FIG. 5

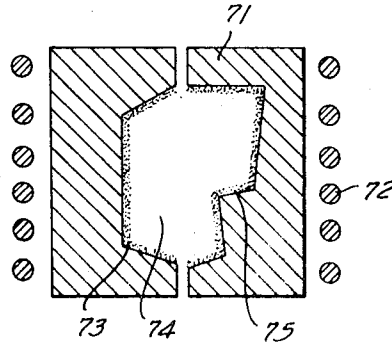
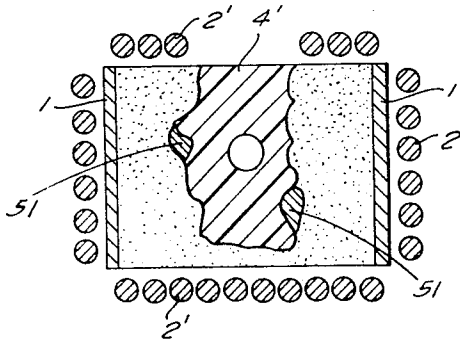


FIG. 7

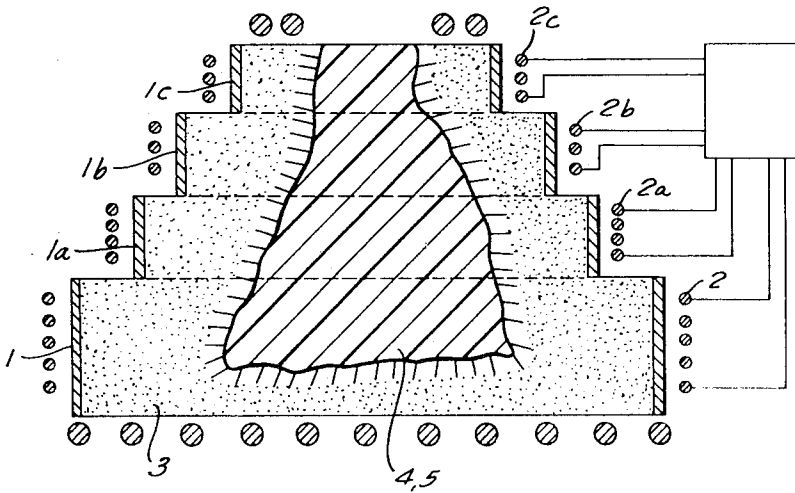


FIG. 6

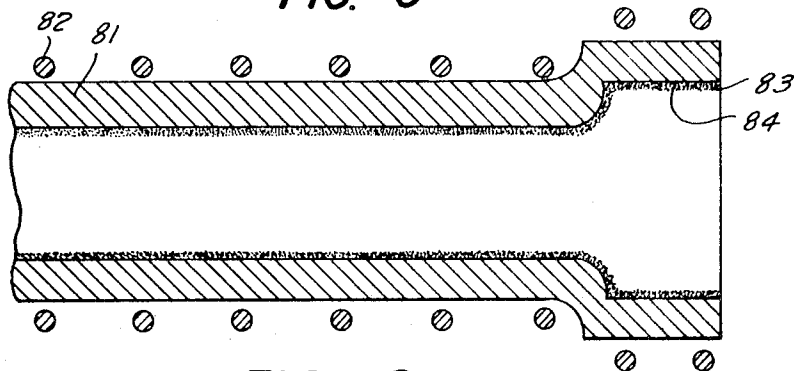


FIG. 8

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CASTING METHOD

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a divisional application of the copending application Ser. No. 680,698 filed Nov. 6, 1967 now abandoned.

BACKGROUND OF THE INVENTION

The present invention is concerned with a casting method and more particularly with use of a mold including a cavity into which liquid metal to be cast may be introduced.

Conventional molding processes include the use of ingot molds and the like, sand-casting processes and special modifications thereof.

In sand-casting, a mold-forming particulate material consisting essentially of natural or synthetic sand is utilized and the pattern is embedded therein. As binder for the sand or the like, synthetic plastic materials may be used.

A special casting method provides for patterns of foamed polystyrene and the like, for instance patterns made of the material commercially available under the trade name "Styropor." Such pattern is not removed from the mold but retained therein and, upon introduction of the metal to be cast, due to the high temperature thereof, the pattern will be subjected to combustion and will be gasified substantially without leaving any residue. The combustion gases pass through the interstices in the sand mold or the like. This method is widely used because making and storage of the pattern of foamed polystyrene or the like can be carried out in an extremely economical manner. However, obviously each pattern can be used only once.

However, conventional sand-molding methods are connected with the disadvantage that the shaping of the mold, i.e. the formation of the mold cavity corresponding to the shape of the article to be cast, requires a considerable length of time and, furthermore, that the sand has to be adequately pretreated.

It is an object of the present invention to provide a novel and highly advantageous method of casting, particularly of producing the mold which is not subject to the above-discussed disadvantages of the conventional sand-casting methods and which, furthermore, will improve the economics of the casting process.

Summary of the Invention

According to the present invention, a pattern is introduced into a particulate mass of mold-forming material so as to form a mold cavity therein. The mold-forming material includes particles of magnetizable material in an amount sufficient to rigidify the mold-forming material while the same is exposed to a magnetic field, so that the mold cavity formed in the mass by introduction of the pattern will be maintained and the thus-formed mold will remain shape-retaining during the entire length of exposure thereof to the magnetic field. The thus-formed mold is then subjected to the magnetic field so as to become rigidified, prior to introduction of the metal to be cast into the mold and at least during the initial period of introduction of the metal to be cast.

The casting arrangement for carrying out the above-described method, broadly comprises a casting box, activatable magnetic field-forming devices such as induction coils located adjacent the casting box, preferably surrounding the same, and possibly also including an induction coil in the interior of the casting box, depending on the shape of the article to be cast, and a magnetizable mass of particulate, mold-forming material located in the casting box and adapted to be magnetized so as to become shape-retaining while being subjected to the magnetic field.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the

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following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an elevational cross-sectional view of a casting arrangement in accordance with the present invention in which the pattern may be removed after formation of the mold cavity;

FIG. 2 is a cross-sectional elevational view of a casting arrangement or device in which the pattern consists of material which will be gasified upon introduction of the molten metal;

FIG. 3 is a cross-sectional view taken along line III—III of FIG. 1;

FIG. 4 is a cross-sectional elevational view of a device for producing tubular casting in accordance with the present invention;

FIG. 5 is a schematic elevational view in cross section of a casting arrangement according to the present invention and including means for producing a plurality of magnetic fields in which the lines of magnetic force may cross each other;

FIG. 6 is a schematic elevational view in cross section of a casting arrangement according to the present invention, wherein the casting box comprises a plurality of segments of different cross-sectional dimensions;

FIG. 7 is an elevational cross-sectional view of a permanent mold arrangement in accordance with the present invention; and

FIG. 8 is a cross-sectional longitudinal view of an arrangement for centrifugal casting in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to the present invention, the mass which is to be shaped by the pattern embedded therein and which after removal of the pattern will define the mold cavity which is to be filled with a material to be cast, must be of a certain consistency or, in other words, must be of such consistency as to be shape-retaining once the mold cavity has been formed therein.

Surprisingly, and—as far as known to us—in a manner never before suggested in the casting technique, magnetic force has been found to be capable to replace the conventional binding agents for sand and the like.

Accordingly, the present invention provides that the pattern is embedded in a mass of magnetizable particles of relatively small grain size and that this mass, after the mold cavity has been defined therein by introduction of the pattern (or by centrifugal force as will be described further below), is prior and possibly also during and after the casting, subjected to at least one magnetic field, such as the electric field produced by induction, whereupon the pattern, depending on the type thereof is removed from the shaped mold which is rigidified by being exposed to the magnetic field. Removal of the pattern may be carried out in conventional manner, for instance by physically removing the pattern, or by utilizing a pattern which will be gasified upon contact with the casting mass which is introduced into the mold cavity while the latter is maintained in a shape corresponding to that of the pattern by the magnetic field.

The magnetizable particles which form at least a portion of the mold-forming particulate mass preferably will have a particle size of below 0.7 mm. and most preferably between about 0.1 and 0.5 mm. In most cases it is preferred to utilize substantially spherical particles, however, in certain cases—as will be described further below—it is preferred to utilize elongated particles such as needles or chips.

Essentially, all magnetizable materials which can be made available in the form of small particles and which are capable of withstanding elevated temperatures to which they might be exposed during the casting process may be utilized. These include primarily natural magnetizable iron, iron and nickel alloys, as well as Fe_3O_4 and magnetizable ferrites with high remanence.

Upon passing electric current through the induction coils or the like, a magnetic field is formed which will rigidify the particulate molding material in the shape determined by the pattern introduced into the casting box and at least partially embedded in the molding or mold-forming material. The mold cavity, corresponding to the shape of the pattern is then formed either by removal of the pattern or by combustion of the latter.

According to a further development within the scope of the present invention, the magnetizable material such as iron or another magnetizable heavy metal or alloys thereof, or a magnetizable mineral such as magnetite will be utilized in the form of needle-shaped bodies or in sandlike configuration, or in the form of chips, for instance filings or borings, preferably within the above-described size limitations.

In cases where the metal to be cast is introduced as a molten mass of relatively high temperature which might heat the mold-forming magnetizable particulate material to a temperature at which the material would lose its magnetic properties, i.e., in cases in which the mold-forming material may be heated above the Curie point thereof, it has been found advantageous to use magnetizable particles of needle shape at least for forming the layer or zone directly adjacent to the pattern, which zone will come in direct contact with the molten metal and thus will be most exposed to heat.

To proceed in this manner will result in an arrangement of the needle-shaped particles in radial direction corresponding to the lines of force of the magnetic field so that the surface of the mold cavity or the surface of the wall defining the mold cavity will be formed by the points, or will include the points, of the needle-shaped particles. Upon introduction of the metal to be cast, thus primarily these points which come in direct contact with the metal will be heated and might be heated above the Curie point thereof. However, the opposite end portions of the needle-shaped particles will not be heated to such an extent and will remain under the influence of the magnetic field and consequently the entire particles will remain fixed in their position. By the time by which the needle-shaped particles might have been heated throughout to a temperature above their Curie point, the molten material will have formed a semisolid or solid skin along the mold cavity-forming wall of the mold material which has been rigidified by being exposed to a magnetic field, so that, due to the formation of such skin, heat demagnetization of the magnetizable particles will no longer affect the shape of the body being cast.

Preferably, the needle-shaped particles will have a length equal to between five and 20 times their diameters and the average diameter of the needles preferably will be below 0.7 mm. and most preferably between about 0.1 and 0.5 mm.

In order to control heat transfer and the fine structure of the mold, it is also within the scope of the present invention to utilize as mold-forming material a mixture of magnetizable particles and nonmagnetizable particles such as mineral sand. The admixed sand is not magnetizable, however, it will be maintained in fixed position by the surrounding magnetizable particles so that the entire mixture will be rigidified upon exposing the same to a magnetic field which directly affects only the magnetizable portion of the mixture. Sand being of much lower heat conductivity than the magnetizable particles, particularly if the latter consists of metal or alloys, will permit the desired control of heat transfer from the molten metal.

Experiments have shown that the mold-forming particulate material according to the present invention possesses an excellent permeability for gases. This may be particularly due to the fact that no compacting of the mold-forming material such as is conventionally carried out in the case of sand molds, will be required.

The method of the present invention is excellently suitable for forming molds by means of combustible patterns, for instance patterns of polystyrene foam or similarly acting foamed synthetic materials, which patterns are retained in the mold and will be gasified or burned practically without residue upon being contacted with the molten casting mass which eventually will completely fill the space previously occupied by the

combustible pattern. In this process, the high gas permeability of the mold-forming material which has been rigidified by being exposed to a magnetic field is of particular advantage.

The electromagnetic induction field which is required for rigidifying the magnetizable particles-containing mass is preferably produced by means of induction coils which are so arranged as to surround at least the sidewall of the casting box, preferably along its entire height and which may also extend outwardly of the bottom and top portion of the casting box.

If the casting box is of relatively great height, i.e., if the mold cavity and the pattern are of relatively great height, it is preferable to control the solidification of the molten casting material which is introduced into the mold cavity by subdividing the induction field into annular sections which preferably are individually controllable, for instance by suitable differentiation in the structure of the correlated induction coils or by separate control of the current flowing through the induction coils corresponding to the respective sections. In some cases it also will be advantageous to form the casting box of superposed sections which may be of different cross-sectional dimensions, preferably so that the thickness of the mold-forming material between the pattern and the wall of the casting box will remain more or less uniform, in other words, the dimensions of the individual sections of the casting box would be correlated in this case to the cross-sectional dimensions of the portion of the pattern which will be located in the respective section of the casting box.

It has been pointed out further above that the mold-forming particulate material may consist of a mixture of magnetizable and nonmagnetizable particles. Generally, the proportion of nonmagnetizable particles should not exceed about 40 percent of the weight of the mixture.

For instance, for a wall thickness of the mold-forming material of more than 25 mm., a mixture of 95 percent magnetizable and 5 percent nonmagnetizable constituents may be advantageously utilized, for a wall thickness of between 12 and 25 mm. the proportion of nonmagnetizable constituents may be increased, for instance to a mixture of 75 percent magnetizable and 25 percent nonmagnetizable constituents, and for relatively thin molds such as molds having a wall thickness of less than 12 mm. a mixture of 60 percent magnetizable and 40 percent nonmagnetizable particles may be utilized.

Since it is possible that under the influence of the force of gravity or of frictional forces, for instance during removal of the pattern, the surface portions of the mold defining the mold cavity may be damaged, it is proposed according to a further embodiment of the present invention to compensate for nonmagnetic forces which might act on the pattern of the cast body, or the molten material which is solidified in the mold cavity by subjecting the mold to induction fields the lines of force of which are not parallel to the lines of force of the induction field which causes rigidification of the mold-forming material. This is illustrated in FIGS. 5 and 6. In these cases, the electromagnetic effect of differently acting magnetic fields are utilized for the purpose of maintaining the mold in shape-retaining undamaged condition also after removal of the pattern so that the shape of the mold cavity will not be disturbed.

It is furthermore proposed according to the present invention that the magnetic or induction fields may be controlled in sections thereof depending on the type of material to be cast and its temperature, its degree of solidification and/or the type of magnetic mold-forming particles. Such control of sections of the magnetic field may be carried out with respect to the length of time for which the respective magnetic field is to be maintained and/or with respect to its magnetic force or field strength. These parameters which may be adjusted so as to best suit any given situation can be easily determined by one skilled in the art and will permit the casting process to proceed under optimum conditions.

In order to improve the surface characteristics of the cast metal body formed in the mold, or to facilitate separation of the cast metal body from the walls of the mold-forming material which defines the mold cavity, or in order to improve

the surface characteristics of the cavity-defining mold surface, the present invention also provides the application of a separating agent, coating or an agent for improving the surface characteristics of the cast metal body onto the mold cavity-forming face of the mold-forming material after the pattern has been removed from the mold. Such agent may be applied in more or less conventional manner by dusting, brushing, or spraying. For instance, it is possible in this manner to apply chromium or nickel to the surface of the cast metal body or to nitrate the same or to improve in other ways the quality of the solidifying skin of the cast metal body. It is also possible to apply tellurium coatings or the like to the inner face of the mold in order to obtain a white, hard surface structure, or to apply sulfur-containing agents which will improve sliding of the cast metal body relative to the inner mold face.

It is also within the scope of the present invention to control the solidification of the molten metal in the mold cavity by means of conventional variably controllable cooling arrangements.

The casting method of the present invention, the forming of the mold as well as the casting in the mold while the mold-forming material is still under the influence of a magnetic field and thus rigidified, can be controlled in a particularly advantageous manner by means of automatic control devices, particularly with respect to introduction of the molten metal to be cast and the control of the induction or magnetic fields.

The casting device used for the method of the present invention comprises a casting box and at least one electric coil preferably arranged about the perpendicular wall of a casting box for producing a magnetic field therein, as well as the mold-forming material consisting at least to a significant extent of particulate magnetic or magnetizable material of relatively small grain size in which the pattern may be embedded in order to form the mold cavity so that the molten metal may be introduced into the latter.

In order to facilitate the penetration of lateral openings, undercuts or grooves of the pattern by the magnetizable mold-forming material, it is frequently advantageous to tiltably support the casting device and/or provide means for subjecting the casting box to vibrations.

Patterns of foamed polystyrene may also be advantageously replaced with patterns of polyurethane foam.

The cooling of the molten casting material in the mold cavity or the rate of solidification of the same may be controlled in conventional manner by the provision of cooling coils through which a cooling fluid, possibly water or air, passes, or other bodies replacing such coils, or by blowing gases, for instance air, through the porous mold. The cooling coils or the like may be inserted into the mold cavity or may be outwardly arranged in a manner known to those skilled in the art.

The magnetizable mass of mold-forming material may be introduced into the casting box by means of a conventional conveying device, preferably while the casting box is subjected to vibration. For instance, vibration may be automatically started by mold-forming material contacting the bottom of the casting box. Prior to introduction of the mold-forming material preferably the pattern will have been inserted into the casting box so that the mold-forming material will now embed the pattern. When the mold-forming material reaches a predetermined height within the casting box, the vibrating device may be automatically shut off and, simultaneously or after some delay, the magnetic field or fields may be formed so as to rigidify the particulate mass of magnetizable mold-forming material.

Referring now to the drawing, and particularly to FIG. 1, the schematic elevational cross-sectional view of a casting device according to the present invention comprises a casting box 1, electric coil 2 which surrounds the sidewall of casting box 1 and serves for creating a magnetic or induction field within the casting box 1, and particulate mold-forming material 3 in which an upwardly flaring substantially conical pattern 4 is embedded. Mold-forming material 3 may consist of magnetizable small grain material, for instance of iron or other

magnetizable heavy metals or magnetizable minerals and may be in the shape of sandlike granules, i.e. more or less spherical small particles, of needles, or of chips such as borings and filings.

As soon as a current is made to flow through coil 2, an electromagnetic induction field will be created and will cause fixing of the particles of mold-forming material 3 which consists of magnetizable material so as to form a rigidified body of the mold-forming material 3. The magnetic force replaces thereby the binding agent which is conventionally utilized in sand molding. After application of the magnetic field, pattern 4 may be removed from the mold without thereby changing the configuration of the mold cavity which corresponds to the shape of the now-removed pattern 4. Thereafter, while maintaining the induction field, liquid or molten metal to be cast may be poured or otherwise introduced into the mold cavity.

The embodiment illustrated in FIG. 2 differs from what is shown in FIG. 1 by the replacement of pattern 4 with pattern 5 made of Styropor or other foamed synthetic material which upon introduction of the hot molten casting material will be gasified substantially without residue.

In order to prevent heating of the mold-forming material by the molten metal to a temperature above the Curie point of the magnetizable portion of the mold-forming material, which portion would be demagnetized by such heating, it is provided, as schematically illustrated in FIG. 3, to utilize in the zone directly adjacent pattern 4 or 5 (depending on whether a pattern according to FIG. 1 or FIG. 2 is used, magnetizable particles of elongated configuration, for instance needles or chips 6, whereas the remaining portion of the magnetizable material which is farther distant from the pattern and thus closer to the wall of the casting box may contain finely granular magnetizable material of different, preferably spherical shape.

If in the mold formed according to FIG. 1 or FIG. 2 a molten-metal mass is introduced having a temperature above the Curie point of the magnetizable portion of the mold-forming material, such as molten steel, then the points of needle 6 which are adjacent the mold cavity will lose their magnetic properties, however, even these needles 6 will be retained in their position because their opposite ends which are farther distant from the mold cavity will only slowly be heated to a temperature above their Curie point. When a temperature equal to or above the Curie point is reached by the end portions of needles 6 which are farther distant from the mold cavity, generally the casting mass adjacent the wall of the mold cavity will have been sufficiently cooled and rigidified so that loss of the magnetic properties of the needle-shaped originally magnetizable particles in the vicinity of the mold cavity will no longer affect the configuration of the latter.

It is noted in this connection, that it is also possible, as discussed further above, to form the mold-forming mass 3 of a mixture of a magnetizable and of a nonmagnetic material, the latter for instance being mineral sand, which nonmagnetic material due to its low heat conductivity will retard the rising of the temperature in radial direction from the mold cavity and thereby will also to some extent retard the solidification of the hot molten metal in the mold cavity. The admixture of sand thus will achieve two purposes. On the one hand, by retarding solidification of the molten casting material the fine structure thereof may be controlled in a desired manner, and on the other hand, by retarding heat transfer from the wall of the mold cavity into the mold-forming mass, increase of the temperature at the points of needles 6 which are farther distant from the mold cavity also will be retarded.

Furthermore, cooling of the mold-forming material as well as control of the speed of solidification of the molten casting material may be carried out in conventional manner by means of cooling coils 7 illustrated in FIG. 4.

FIG. 4 illustrates particularly utilization of the present invention in connection with the casting of tubular members. In order to assure fixing or rigidification of the mold-forming material also within the interior portion located inside the annular cavity, it may be advantageous to provide, as illustrated

in FIG. 4, a core portion 8 and in the interior thereof a further electric coil 9 which will produce an additional induction field. This arrangement may also be correspondingly utilized in the case of divided hollow patterns. It may be advantageous to utilize for the mold-forming material short lengths of wire or magnetizable materials of similar elongated shape which may be felt so that the removal of the pattern or of the cast body will not affect the shape of the mold cavity.

According to the embodiment illustrated in FIG. 5, an induction field will also be formed between the coils 2', surrounding the top and bottom portions of casting box 1. Coils 2' are particularly advantageous if the casting device is to be tilted in order to evenly distribute the mold-forming material and introducing the same into undercuts or other difficulty accessible portions of the pattern surface. This arrangement is also advantageous if, in view of the size of the pattern, during removal of the same frictional forces between the mold-forming material and the pattern as well as gravitational forces must be counteracted by providing an additional induction field.

FIG. 6 illustrates a casting device for casting bodies corresponding to a pattern of greatly varying cross-sectional dimensions and relatively great height. Such body, for instance, may be a machinery housing. In order to produce an effective induction field which should be uniform along the entire height of the casting device, it is advantageous in such cases to form the casting box of sections indicated as 1, 1a, 1b, and 1c of differing cross-sectional dimensions so that the distance of the pattern surface from the wall of the casting box will be substantially the same along the entire surface of the pattern. Accordingly, the casting box is formed of annular sections whereby the diameter of each superposed section is smaller than that of the section directly below. The individual sections of the casting box are surrounded by induction coils 2, 2a, 2b, and 2c of correspondingly varying diameters. Preferably, these induction coils are connected with control devices which permit separate control of the current flowing through the induction coils associated with each of the sections of the casting box, corresponding to the cooling of the casting metal in the mold cavity.

It has been pointed out further above that it is frequently desirable to subject the pattern forming particulate material to vibrations during the embedding of the pattern. Vibrating of the casting box with the pattern and the mold-forming material therein may be accomplished, as schematically illustrated in FIG. 2, by supporting the casting box on a plate 21 which is subjected to vibrations by operation of vibrator 22.

According to a further preferred embodiment of the present invention, it is provided that the casting box 1 is formed of individual elements which may be attached to each other whereby either each of the elements is provided with an electric coil for forming of a magnetic field, or has associated therewith at least part of such coil and the part coils may be connected to each other when connecting adjacent elements of the casting box. The connecting of these elements to form the complete casting box may be carried out in per se known manner with conventional screw or guide pin devices.

The actuating of the electric coils and the introduction of the mold-forming material may be carried out by hand or with automatic control.

It has been found that the method of the present invention will in many cases reduce the casting expenses by about 30 percent due to the shortening of the period of time required for forming the mold cavity.

The casting methods of the present invention are suitable for series casting as well as for casting of individual pieces.

Mass production of cast bodies including cast tubular elements is conventionally carried out by ingot casting, pressure casting, continuous casting, centrifugal casting and the like. The economic feasibility and the technological results of these and similar methods depend to a considerable extent on the useful life span of the permanent molds which are utilized thereby.

To increase the useful life span of the molds, the mold surface portions which are contacted by the molten casting material are frequently coated with materials such as finely granular refractory materials, which are suspended in a liquid carrier such as water, alcohol and the like and which, for instance by spraying, brushing, or immersion may be applied to the surface of the permanent mold. Such surface coatings or layers are connected with the disadvantage that the liquid carrier or solvent contained therein as well as binding agents which frequently are required generally produce gases or give off gases when contacted by the molten metal to be cast. Furthermore, since most of these coatings contain quartz as the basic constituent, a certain health hazard is created by quartz particles which are separated during the casting process.

It was therefore proposed to form such protective layers or coatings of dry materials which are not bound by binder materials or liquids. For instance quartz sand, ferrosilicon and the like were applied to the surface of the ingot mold. This, however, could be done only with respect to rotating permanent molds, for instance for producing cast pipes whereby, due to rotation of the mold about its axis and preferably due to a substantially uniform distance of the operative mold face from the axis of rotation, centrifugal forces caused an, although slight, adherence of these dry materials to the operating surface of the permanent mold. However, it was found that in many cases these forces did not suffice to prevent a "washing off" of the surface layers by the introduced molten casting material. Furthermore, these dry coating materials usually have a lower specific gravity than the molten casting material and this difference in the specific gravities favors separation of surface particles from the coating or layer upon contact with the introduced stream of molten casting material. This again results in a most undesirable mixing of material of the coating layer with the casting material and in an undesirable formation of the inner surface of the cast bodies formed by such centrifugal casting method.

According to a further embodiment of the present invention, the above-discussed difficulties and disadvantages may be overcome by forming a surface layer at the operative surface of the permanent mold which consists essentially of a particulate loose mass of magnetizable materials such as were described further above, for instance grains of iron, and to hold the particulate layer at the face of the permanent mold by a magnetic force, i.e. by applying a magnetic or induction field which will rigidify the particulate layer of magnetizable material. In this manner, a layer is formed interposed between the operative surface of the permanent mold and the molten metal which is introduced into the same, which layer is free of metallurgically harmful constituents and will not form gas upon being exposed to the high temperature of the molten metal. The layer can be easily removed, by simply shutting off the magnetic field, and consists of physiologically harmless material. Due to the relatively low heat conductivity of the material of the layer, particularly if the layer is formed of magnetizable mineral material, as compared with the heat conductivity of the permanent mold which may be formed of metal, the interposed layer will also retard the heat flow from the molten metal through the permanent mold and this is frequently desirable.

If nevertheless, under particularly unfavorable operating conditions, particles of the surface layer are incorporated in the molten casting material, such particles will be quickly dissolved in, for instance, molten ferrous material and thereby rendered harmless.

The last-described method of the present invention is of particular advantage for producing cast bodies in permanent molds by centrifugal casting. In this case, the method may be used for forming a particulate layer on the operative surface of water-cooled centrifugal molds, for instance in accordance with the De Lavand process, and the useful life span of the permanent mold will be prolonged thereby and the surface quality of the cylindrical bodies, such as cast pipes produced in the process will be improved.

It is also advantageous to utilize the above-described process in connection with the so-called Moore process. Thus, the magnetizable loose material may be introduced into a rotating mold so that under the influence of centrifugal forces a layer of between 5 and 10 mm. thickness (more or less) will be evenly formed on the operative face of the mold. Upon application of the magnetic field, this layer will be sufficiently rigidified so that the molten casting material may now be introduced into the thus-formed casting mold, without damaging the latter. After solidification of the metal melt in the mold, the magnetic field is shut off and the surface layer will thereupon trickle out of the mold thereby facilitating removal of the cast metal body.

The size of the magnetizable particles of which the surface layer is formed may be easily adjusted in per se conventional manner so that the degree of roughness of the operative face of the magnetically fixed particulate layer will suffice to prevent under the prevailing operating conditions sliding of the melt along the operative surface of the magnetically fixed layer. In order to prevent welding of magnetizable particles to the casting material, it is sometimes preferred to admix to the particulate magnetizable mass refractory material such as graphite, asbestos, zirconium oxide and the like, whereby the proportion of such nonmagnetic admixtures must be kept sufficiently low so as to not interfere with the fixing of the entire layer by magnetic force.

The particle size of the material of the surface layer preferably will be below 0.7 mm. and generally between 0.1 and 0.5 mm. however, in order to obtain a particularly smooth surface on the cast metal body, it is sometimes advisable to further reduce the particle size of the material of the surface layer, for instance to a particle size of between 0.1 and 0.03 mm.

The permanent mold may be made in conventional manner of various materials such as grey iron, steel, copper alloys, light metal, graphite and the like. If the material of the permanent mold is not per se magnetizable, it is possible to have the magnetic field penetrate through the permanent mold so as to cause fixing or rigidification of the particulate magnetizable layer at the operating surface of the mold.

Fire-resistant materials which may be admixed to the magnetizable particulate material further include aluminum oxide, olivine, chromite, and such refractory or fire-resistant material may be applied in proportions such as described further above, whereby again the maximum proportion of nonmagnetizable particles in the layer-forming mixture will depend on the desired thickness of the layer.

If the pulverulent material is per se a magnetic material and the permanent mold consists of magnetic or magnetizable materials such as cast iron or steel, then magnetic adherence between the particles and the mold may follow. However, if the mold is formed for instance of aluminum, then, as described previously, coils for instance of copper may be arranged to surround the permanent mold so that upon passages of current through such coils a magnetic field will be created which acts through the mold wall onto the particulate material forming a layer thereon.

The last-described method may be used in connection with permanent mold casting, die casting, continuous casting and centrifugal casting methods, in other words, it is applicable to practically all permanent mold casting processes.

FIGS. 7 and 8 illustrate casting arrangements with permanent molds.

As shown in FIG. 7, a permanent mold 71 is surrounded by induction coils 72 which serve for forming a magnetic field which will cause adherence of layer 73 formed of magnetizable particulate material to the mold cavity 74 defining face 75 of permanent mold 71.

The same principle is illustrated in FIG. 8 with respect to an arrangement for centrifugal casting. Permanent mold 81 is surrounded by induction coils 82 and the magnetic field formed by passing currents through induction coils 82 will cause adherence of layer 83 to the operating inner face 84 of the permanent mold 81.

It has been found that in some cases even better results may be achieved by coating individual particles of the magnetizable material with a layer of preferably fire-resistant material or a layer which simultaneously also will have a heat-insulating effect, such as graphite. Such coating of the magnetizable particles may be produced by spraying the particles with heavy hydrocarbon fractions, for instance diesel oil and subjecting the thus coated particles to conventional cracking conditions which will cause deposition of a dense carbon layer on the particles. Other per se known methods, for instance fluidized bed sintering and the like will permit in a simple manner to apply layers or coatings of other fire-resistant materials on the individual magnetizable particles.

If the configuration of the pattern is relatively complicated and uneven, it may be difficult, particularly in the case of cavity molds, to stabilize the magnetizable particles at certain portions of the pattern surface. In order to avoid application of a particularly strong electromagnetic field, it has been found advantageous in such cases to arrange at such portions of the pattern surface somewhat larger bodies of compact magnetizable material substantially in the manner in which this has already been done previously for influencing the solidification of the melt in molds of nonmagnetizable mineral material. This feature is illustrated in FIG. 5, wherein reference numeral 51 denotes two larger solid bodies of magnetizable material which are arranged at the pattern surface in order to provide a more even surface for embedding in the particulate mold-forming material.

Particularly when producing heavy cored castings with complicated surface configurations, it is possible that at the portions of the cross section at which magnetic field lines will emanate, after removal of the pattern, particles of the magnetizable mold-forming material will arrange themselves in the direction of the emanating lines of force and thereby deviations of the mold cavity from the shape of the pattern might occur.

This problem can be overcome in a simple manner by spraying onto the pattern and possibly onto the entire pattern plate an either heat or cold hardenable material to which is applied prior to hardening thereof the magnetizable particulate material. Such heat or cold hardenable materials are well known to those skilled in the art and include, for instance, furane resins, phenolic resins and also polyurethane resins which, by admixture of suitable hardeners also might be converted into a foam. The thickness of the thus-formed hardened layer in which prior to hardening thereof particles of the magnetizable material have been incorporated preferably will be between about 0.5 and 5 mm. It may be achieved in this manner that the magnetizable particles which are located directly adjacent the surface of the pattern will be bound by forces other than magnetic forces and thus will not be influenced by the direction of lines of force emanating at these areas or zones from the mold cavity forming magnetically fixed particulate material.

If necessary, it is also possible to apply a separating agent to the surface of the pattern prior to spraying the latter with the resin. Certain silicones, as well known in the art, may be excellently suitable as separating agent and application of the separating agents will facilitate removal of the pattern so that the magnetic particles-containing resin binder will remain in contact with the particulate magnetizable mold-forming material and will form, at least in the zones to which it has been applied, the mold cavity-defining surface. The binder material which will serve to fix particulate magnetizable material by other than magnetic forces may also be a quick hardening synthetic resin or an organic silicate as well as heat or cold hardenable inorganic materials, per se known to those skilled in the art.

The formation of the magnetic field has been described herein primarily as being accomplished by surrounding the casting box with at least one electric coil. However, in certain cases it has been found to be more advantageous to insert the casting box between the pole pieces of the yoke of a magnet.

In this manner, it is possible to obtain the required electromagnetic fixing of the magnetizable particles, or to produce or provide the required electromagnetic forces in casting boxes of varying sizes, without requiring induction coils of different dimensions.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of casting arrangements and devices differing from the types described above.

While the invention has been illustrated and described as embodied in a casting arrangement in which the mold cavity is defined by a mass of magnetizable particles which are subjected to a magnetic field, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. A method of metal casting comprising the steps of introducing a pattern of a material, which will be gasified upon contact with the liquid metal to be cast; into a particulate mass of mold-forming material including particles of magnetizable material in an amount sufficient to rigidify said mold-forming material while the same is exposed to a magnetic field so that a mold cavity formed in said mass by introduction of said pattern will be maintained and the thus-formed mold will remain shape-retaining during exposure to said magnetic field; subjecting the thus-formed mold to said magnetic field so as to rigidify said mold prior to introduction of metal to be cast into the same; and casting hot liquid metal into the thus-rigidified mold while gasifying said pattern.

2. A method of casting comprising the steps of forming a permanently shape-retaining mold having an inner surface; covering said inner surface of said mold with a thin layer of a particulate mass of material including particles of magnetizable material in an amount sufficient to rigidify said material while the same is exposed to a magnetic field so that said layer will retain its shape during exposure to said magnetic field and define a mold cavity; and subjecting said layer to said magnetic field so as to rigidify the same prior to introduction of metal to be cast into said mold cavity.

3. A method of metal casting comprising the steps of introducing a pattern into a particulate mass of mold-forming material so as to form a mold cavity in said mass, said mold-forming material including particles of magnetizable material selected from the group consisting of magnetizable heavy metals, magnetizable minerals and magnetizable ferrites with high remanence in an amount sufficient to rigidify said mold-forming material while the same is exposed to a magnetic field so that the mold cavity formed in said mass by introduction of said pattern will be maintained and the thus-formed mold will remain shape-retaining during exposure to said magnetic field; applying an adhesive to said pattern prior to introduction of the latter into said particulated mass of mold-forming material so that said adhesive upon contacting said particulate material causes at least partial adherence of particles located adjacent said pattern to each other; subjecting the thus-formed mold to said magnetic field so as to rigidify said mold; removing said pattern from said mold; and casting hot liquid metal into said mold cavity.

4. A method as described in claim 3, wherein said magnetizable material, at least in the zone of said mold cavity, is of needle shape, and orienting the needles during magnetizing said mass in such a manner that opposite points of said needles face respectively said mold cavity and away from the latter to thus prevent demagnetization of said needles during casting of hot liquid metal into said cavity.

5. A method as defined in claim 3, wherein said magnetizable particles are covered with a refractory coating.

6. A method as defined in claim 1, wherein said magnetizable material is selected from the group consisting of magnetizable heavy metals, magnetizable minerals and magnetizable ferrites with high remanence.

7. A method as defined in claim 1, wherein said magnetizable material is of sandlike, chip or needle shape.

8. A method as defined in claim 6, wherein said magnetizable material at least in the zone of said mold cavity is of needle shape.

9. A method as defined in claim 4, wherein said particulate mold-forming material consists essentially of a mixture of said magnetizable material and of a nonmagnetizable material of low heat conductivity.

10. A method as defined in claim 9, wherein said nonmagnetizable material is sand.

11. A method as defined in claim 1, wherein said pattern consists of foamed polystyrene.

12. A method as defined in claim 6, wherein said magnetic field is produced by activation of electric induction coils surrounding said mass of mold-forming material substantially along its entire height.

13. A method as defined in claim 12, wherein induction coils additionally arranged in the vicinity of the bottom and top portion of said mass of mold-forming material are activated so as to form a magnetic field.

14. A method as defined in claim 12, wherein the induction field formed by activation of said induction coils is subdivided into annular individually controllable portions.

15. A method as defined in claim 14, wherein magnetic fields are applied to said mold-forming material in such a manner as to rigidify the same and to counteract nonmagnetic forces acting on said pattern or the metal to be cast in the mold cavity.

16. A method as defined in claim 14, including the step of separately controlling intensity and period of application of portions of the magnetic field depending on the characteristics and temperature of the metal to be cast and the characteristics of said magnetizable particles.

17. A method as defined in claim 6, wherein a surface-improving agent is applied to the cavity-forming inner surface of said mass of mold-forming material prior to introduction of the metal to be cast into said mold cavity.

18. A method as defined in claim 17, wherein said surface-improving agent is adapted to improve the mold cavity-forming surface of said mold-forming material.

19. A method as defined in claim 17, wherein said surface-improving agent is adapted to improve the surface characteristics of the metal body being cast in said mold.

20. A method as defined in claim 6, wherein metal to be cast is introduced into said rigidified mold cavity and subjected therein to controlled cooling.

21. A method as defined in claim 2, wherein said permanently shape-retaining mold is a centrifugal mold, and said particulate magnetizable material is applied to the inner surface thereof by centrifugal force and held thereon by application of said magnetic field.

22. A method as defined in claim 2, wherein the particle size of said particulate mold-forming material is smaller than 0.7 mm.

23. A method as defined in claim 22, wherein the particle size of said particulate mold-forming material is between about 0.1 and 0.5 mm.

24. A method as defined in claim 1, wherein said magnetizable particles, respectively, are covered with a refractory coating.

25. A method as defined in claim 1, wherein said magnetizable particles, respectively, are covered with an insulating coating.

26. A method as defined in claim 1, wherein an adhesive is applied to said pattern prior to introduction of the latter into said particulate mass of mold-forming material, said adhesive

upon contacting said particulate mold-forming material causing at least partial adherence of particles located adjacent said pattern to each other.

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