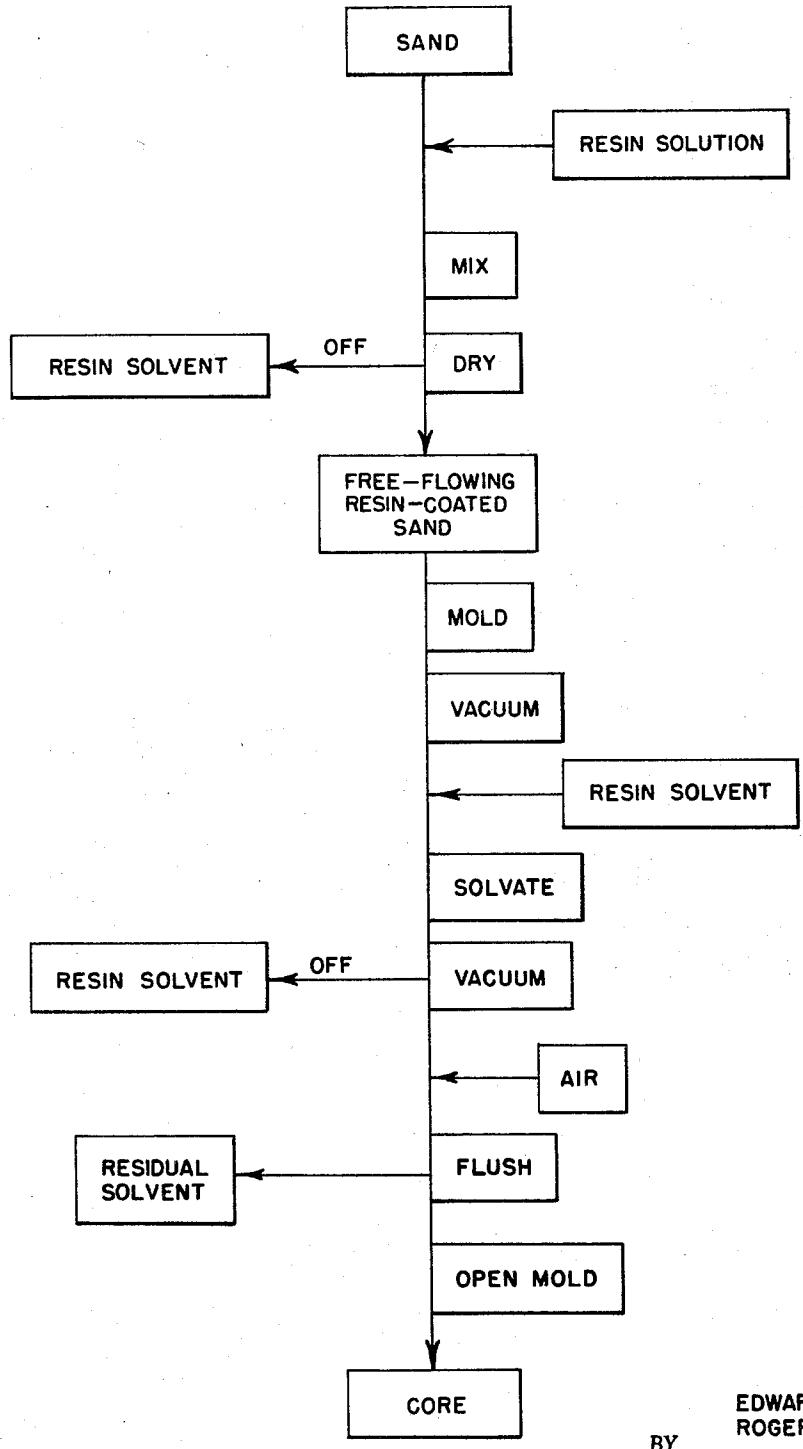
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FOUNDRY CORE FABRICATION PROCESS

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# FOUNDRY CORE FABRICATION PROCESS

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This invention relates to the production of foundry cores and molds.

Many types of binders have been proposed for foundry cores and molds. The use of numerous organic binders is well known. For many years, linseed oil and its derivatives were the most popular foundry core binders. More recently, synthetic binders have been developed which have advantages in speed of cure and greater tensile strength. Normally, the organic resins used for binding foundry cores and molds are thermosetting resins. Thermoplastic resins have been suggested but are normally not used because of the difficulty in obtaining reproducible dimensional accuracy in the core. A thermoplastic binder allows the core to sag during curing or in removing a hot core from its mold.

The foundry trade is constantly striving to improve the quality and dimensional accuracy of their castings. The accuracy and precision with which a casting is made is dependent on the accuracy obtained in the core. The best accuracy is obtained by curing or hardening the core while it is still in the mold. Several methods have been suggested for hardening the sand while still in the mold. One method is to gas an alkali silicate with carbon dioxide, another method is to cure in a heated mold, and a further method is to cure the resin catalytically while in the mold.

Each of these methods have their advantages and disadvantages. The alkali silicate binders produce good dimensional accuracy; but because they are inorganic, cores formed using these binders do not have the desired breakdown characteristics that are necessary to promote an efficient foundry operation. The curing of cores in a heated mold is a rapid operation but requires somewhat of a sacrifice in dimensional accuracy. Since the mold is normally heated to about 450° F., the sand is in an expanded state while in the pattern; and on cooling, because of contraction, the core is not an exact replica of the mold. Dimensional accuracy of the catalytically cured cores is good and the breakdown is also good since the binder is normally an organic material. Such binders, however, have disadvantages in that the prepared sand composition must be used immediately. This means that sand mixes must be prepared individually for each molding operation.

It is therefore an object of this invention to provide a novel method of improving the dimensional accuracy of foundry cores and molds by a novel in situ hardening process. Another object of this invention is to provide a method of forming hard foundry cores and molds from sand precoated with a thermosetting resin without thermosetting the resin. A further object of this invention is to provide a means for forming foundry cores and molds from free-flowing synthetic resin-coated sand without the use of heat.

The objects of this invention are accomplished by a process which comprises precoating sand with a synthetic organic resin, drying the precoated sand to a free-flowing state, forming the prepared sand in a mold, solvating the resin with a solvent, and thereafter removing the solvent.

This process overcomes many of the disadvantages of the prior art. Dimensional accuracy is of the highest order since the core is cured at room temperatures while in the mold. The binder is organic and therefore provides rapid breakdown at casting temperatures. In addition, the prepared sand is in a dry free-flowing state and can be stored for indefinite periods. Thus, the more desirable characteristics of foundry binders and molding operations are incorporated into a single system which greatly facilitates the production of metal castings of high dimensional accuracy.



The process of this invention provides two methods of accomplishing the bonding of the core sand. One method is to shape the core by placing a dry synthetic resin-coated sand into a cavity, pressurizing with a gaseous solvent and establishing liquid-vapor equilibrium to partially dissolve the resin coating allowing it to unite at the points of contact, releasing the pressure to flash off the solvent, and subsequently removing the bonded core shape from the cavity. The second method is to shape the core by placing a dry synthetic resin-coated sand, into a cavity, solvating the resin coating with a volatile liquid solvent, flashing off the solvent under reduced pressure, and subsequently removing the bonded core shape from the cavity.

The accompanying single figure of the drawing illustrates this invention.

The term foundry "core" when used means both cores and molds, the differentiation being that cores are normally internal structures and the molds are external structures. The term "solvent" means both normally liquid and normally gaseous solvents which are capable of plasticizing a resin. The term "solvating" means the process of dissolving, plasticizing, or softening a resin with a solvent. Solvating to a liquid state means plasticizing sufficiently to cause flow.

The synthetic resins useful in the process of this invention are those resins which are capable of curing to a rigid state. In addition, the useful resins are those resins which are normally solids when not plasticized and have softening points above 100° F.

The term "synthetic resin" includes both thermosetting and thermoplastic resins. The preferred resins, however, are thermosetting resins. Resins used in the process of this invention are plasticized with sufficient volatile solvent to obtain a free-flowing liquid having a viscosity of less than about 30 stokes. This is accomplished by adding various amounts of solvent, depending on the polymerized state of the resin.

The term "thermosetting resin" is used herein to distinguish the characteristics of these resins from those of the thermoplastic resins. The distinguishing characteristic of thermosetting resin is not the curing with heat but the curing to an infusible state by the crosslinking of a polymer. After a polymer is crosslinked, it is very resistant to solvent and heat. Thermosetting resins are often cured at room temperatures by the addition of a catalyst.

In carrying out the processes of this invention the aggregate material is first coated with a synthetic resin having a softening point above 100° F. The aggregate material is normally a lake sand or a silica sand but may also be any other inexpensive heat-resistant aggregate material.

The preferred resins are thermosetting resins such as hydrocarbon resins, alkyd resins, rosin ester resins, rosin ester modified resins, novolak resins, and acrylic resins. In addition to the thermosetting resins, thermoplastic resins having softening points above 100° F. can be utilized because the molding process is conducted without the use of heat which would normally cause distortion in removing from a heated pattern or an oven. During the casting operation, sagging is eliminated because of the high metal temperature which carbonizes the resin binder to a rigid state faster than the sand can flow.

The hydrocarbon resins useful with this invention are the polymerizable resins obtained from petroleum fractions. These resins are both aliphatic and aromatic in

structure and are distinguished by their capability of polymerizing under heat, pressure, or by catalytic reagents such as Friedel-Crafts catalysts or strong acids. The useful hydrocarbon resins are polymerized to a normally solid state having a softening point above 100° F. By further heating, these resins will polymerize to higher polymers.

The alkyd resins useful with this invention are of the medium oil and short oil alkyd type. Such resins are the reaction product of a fatty ester and a dibasic acid such as maleic and phthalic. These resins may also be modified with hydrocarbon resins by blending with polymerized hydrocarbon resins or by copolymerizing with unsaturated hydrocarbon monomers such as cyclopentadiene and dicyclopentadiene.

The fatty esters used in alkyd resins are normally derived from natural oils. Synthetic fatty esters are also useful. They are reaction products of polyhydroxyl alcohols such as pentaerythritol glycerine and sorbitol and carboxylic acids of 8 to 26 carbon atoms. The desirable fatty esters, also known as fatty oils, are characterized by ethylenic unsaturation in a hydrocarbon chain of 8 to 26 carbon atoms. Such oils are derived from animal, vegetable, and marine sources.

The rosin ester resins which are useful with this invention are esters obtained by esterifying tall oil rosin, gum rosin, or wood rosin with a polyhydroxy alcohol to form a resin which has a softening point above 100° F. Polyhydroxyl alcohols used include pentaerthyritol, glycerine, and sorbitol and the like. Included with these rosin esters are the modified rosin resins such as those modified with 1% to about 40% phenol, 1% to 70% fatty ester, or various dibasic acids such as maleic and phthalic.

The phenolic resins useful in this invention are of the novolak type. Novolak resins are the condensation product of phenol and formaldehyde under acidic conditions. Such resins are phenol-rich in that a further addition of formaldehyde causes cross-linking. The novolak type resins useful are those which have been polymerized to a softening point above 100° F. In the operation of this invention, using a novolak resin, an additional amount of formaldehyde is added to the sand-resin mix during the coating of the sand. The formaldehyde is normally added in the form of hexamethylenetetramine which on heating provides free formaldehyde for further polymerization and crosslinking of the phenolic resin.

Acrylic resins are also useful in this invention. The resins useful are preferably thermosetting compositions. Such compositions are composed of linear polymers and crosslinking monomers which have functionality in an amino group, an amido group, a hydroxyl group, a carboxyl group or a glycidyl group. Typical of this type of polymer is a linear thermoplastic copolymer which is crosslinked by an epoxy oil to a thermosetting composition. A typical linear polymer is a copolymer of an aromatic vinyl monomer, a lower alkyl ester of acrylic acid, and acrylic acid. The copolymer is diluted with an inert solvent in admixture with an epoxy oil. Curing is initiated by a free radical catalyst or heat. Numerous other systems are well known deriving their functionality through the functional groups named.

The resins described are soluble in aromatic and aliphatic solvents. Depending on the structure of the resin, volatile solvents such as methanol, ethanol, isopropanol, diethyl ether, petroleum naphtha, petroleum ether, benzene, xylene, toluene, acetone, chloroform, methylene chloride, chlorinated hydrocarbon solvents, ketones, esters, ethers, and the like and combinations thereof are used to reduce the viscosity of the resin prior to the coating operation. The solvent is removed during the coating operation to yield a dried but uncured resin.

As has been stated, the thermosetting resins are the preferred polymers. During the process of coating the foundry sand, the coating resin is not cured to an infusible state. The coating is merely dried on the sand granular by evaporation of a volatile solvent. This procedure allows subsequent solubilizing and plasticizing of the coating.



The amount of resin used for coating the sand is from 1% to about 8% by weight based on the weight of sand. The preferred range is about 1% to about 4% resin. With thermosetting resins, a polymerizing agent is preferably added during the resin coating operation. Subsequent heating either prior to casting or curing during the metal pouring operation will cure the thermosetting resin to an infusible state.

Both liquid and gaseous solvents are utilized to resolvate the resin-coated sand. Solvents which are normally liquid are preferred. The liquid solvents preferred are solvents capable of solubilizing the resin coating and which readily volatilize in vacuums of 20 to 30 inches of mercury at temperatures of about 20° C. to 50° C. Preferably solvents such as chloroform, petroleum ether, petroleum naphtha, acetone methylene chloride, diethyl ether, ketones, esters, and chlorinated hydrocarbons are used to solvate the resin coating. Solvents which are normally gases may also be used but are not preferred.

In forming cores using normally gaseous solvents, the operation is carried under sufficient pressure to produce a liquid-vapor equilibrium within the core shape. Absolute pressures of about 10 to about 5,000 pounds per square inch are used. The solvent is then released under atmospheric pressure. The preferred method is to solubilize the resin with a normally liquid solvent and subsequently remove the solvent under 20 to 30 inches of mercury vacuum.

The amount of solvent required for the solvation procedure of this invention is dependent on the type of resin, the amount of resin coated on the sand and the solvating power of the solvent. The amount of solvent used is of little economical concern since more than 98% to 99% of the solvent can be recovered and reused. The solvent required for solvation is normally between a weight ratio of 1:200 to 1:10 solvent to resin-coated sand. The requirement is that sufficient solvent be used to solvate the resin coating sufficiently to cause resin flow at the points of sand contact but not enough solvent to cause removal of the resin is used. Extraction of the resin has not caused difficulties.

During the operations of this process the evaporation or volatilization of the solvent causes a temperature change which in some situations slows down the processing time. Low temperatures inhibit resin flow and require larger quantities of solvent to accomplish the solvation. Therefore, it is desirable to maintain a relatively constant temperature of about 20° C. to about 50° C. in the pattern during the molding operation. This is readily accomplished by means of a water jacket or other heat stabilizing means.

The invention will be better understood with reference to the following examples which are illustrations of certain preferred embodiments of the present invention. Unless otherwise indicated, all parts and percentages used herein are by weight.

*Example I*

A resin-coated sand was prepared by coating American Foundry Society (AFS) Standard Sand with a phenol formaldehyde resin of the novolak type having a melting point of 107° C. This resin was diluted to 50% solids with ethanol. The sand was coated by mixing 120 parts of resin solution and 9 parts of hexamethylenetetramine with 2000 parts of sand. The solvent was evaporated during the mixing resulting in a free-flowing sand coated with 3% resin solids.

The prepared sand was placed in a mold which was permeable to gases and liquids. The mold was filled with the resin-coated sand and placed in a chamber which was evacuated to 29 inches of mercury vacuum. Methylene chloride was added to the evacuated chamber. This

addition increased the pressure to atmospheric pressure. The chamber temperature was maintained at 30° C. during the solvation procedure. The chamber was then re-evacuated to 29 inches of mercury vacuum and flushed with air back to atmospheric pressure. For a core weighing 190 grams, 40 milliliters of solvent was used. More than 98% of the solvent was recovered and recycled in subsequent solvating procedures.

Cores formed in this manner were ready for immediate use in the casting operation. The high temperatures of molten metal instantaneously thermosets or carbonizes the resin binder eliminating sand movement or flow. Castings formed using cores made by the process of this invention had high dimensional accuracy.

*Example II*

Resin-coated sand prepared as in Example I was blown into a mold which was maintained under reduced pressure of about 27 inches of mercury vacuum. The sand contained in the pattern was then gased with methylene chloride by injecting liquid methylene chloride into the mold chamber. The liquid methylene chloride vaporized under the reduced pressure causing the pressure to increase from about 27 inches of mercury vacuum to atmospheric pressure. Reduced pressure was again applied drawing the vaporized methylene chloride through the sand-filled cavity. The methylene chloride in a liquid-vapor equilibrium, solvated the resin which coated the sand sufficiently to allow the resin to flow and bond at the points of contact. The solvent was drawn off under vacuum and recovered for subsequent solvations. The mold chamber was then flushed with air by increasing the pressure to atmospheric.

Cores formed in this manner were ready for immediate use in casting operations.

*Example III*

Resin-coated sand prepared as in Example I was rammed into a mold permeable to gases and liquids. The pattern was constructed so that a vacuum could be drawn on the contents of the mold. The resin-coated sand in the mold was hardened by drawing a vacuum of about 29 inches of mercury and injecting sufficient chloroform into the pattern so that the vacuum was reduced from 29 inches of mercury to about atmospheric pressure. The temperature of the mold was controlled by a water jacket at 30° C. to 35° C. so that the volatilizing chloroform would not reduce the temperature and thus retard volatilization and solvation. The vacuum within the mold was again increased to about 29 inches of mercury to remove the chloroform. The chloroform removed was condensed and retained for recycling.

With the vacuum again at about 29 inches of mercury, chloroform was again introduced allowing the pressure to return to atmospheric. The chloroform was again removed from the mold by increasing the vacuum to about 29 inches of mercury. The mold was then flushed with air allowing it to return to atmospheric pressure. The resin coated sand within the mold was found to have been reduced to a hardened state. Cores formed in this manner could be used immediately without further curing or in the alternative could be subjected to a heat cure to increase the hardness.

*Example IV*

The process of Example III was again repeated using diethyl ether as the solvent. Cores formed in this manner were suitable for immediate use in casting operations.

*Example V*

An acrylic resin was made by charging 65 parts xylene and 16 parts butyl alcohol to a flask equipped with an agitator, thermometer, reflux condenser and a metering tank. The metering tank contained 50 parts vinyl toluene, 10.2 parts methylmethacrylate, 6 parts 2-ethylhexyl acrylate, 12.9 parts of methacrylic acid and 2.4 parts cumene hydroperoxide. The xylene and butanol were heated to 240° F. The monomer mixture in the metering tank was then added slowly over a 3-hour period while the reaction mixture was maintained at 240° F. The reaction mixture was kept at about 240° F. for 3 hours after completion of the monomer addition. At this time the percent nonvolatile of the mixture was determined to be 50%, indicating the copolymerization reaction was complete. To form the thermosetting resin, 15 parts epoxidized soybean oil having an oxirane value of 6.3% was added to 100 parts of the copolymer.

A resin-coated sand was prepared by coating Nugent Lake sand with the prepared thermosetting acrylic resin. The acrylic resin had a solid content of about 57.5% which was reduced by an addition of xylene to 50% solids. The sand was coated by mixing 4 parts of resin solution with 100 parts of sand. The solvent was evaporated during the mixing resulting in a free-flowing sand coated with 2% resin solids which was dried unto the sand granules.

The prepared sand was placed in a mold which was permeable to gases and liquids and in which a reduced pressure could be applied. The mold was evacuated to about 29 inches of mercury vacuum and methylene chloride was added to the evacuated mold. The temperature of the mold was regulated with a water jacket so as to maintain a temperature between 30° and 40° C. The evaporation of the methylene chloride increased the pressure within the mold to atmospheric pressure. The mold was then re-evacuated to about 29 inches of mercury. The methylene chloride was condensed and retained for subsequent solvation. The evacuated chamber was then flushed with air to return to atmospheric pressure.

The cores formed in this manner were ready for immediate use in the casting operation. Since the resin had not been polymerized to an infusible state, a subsequent baking period could be used if desired to increase the strength of the core. It, however, has been found that this is not necessary since the high temperatures of molten metal instantaneously carbonizes the binder to higher strengths.

*Example VI*

Utilizing the resin-coated sand and procedure of Example V, foundry cores were prepared using diethyl ether as the solvent. Cores produced in this manner were ready for immediate use in casting operations.

*Example VII*

Using the resin-coated sand and procedure of Example V, cores were again made utilizing chloroform as the solvent. Cores prepared in this manner could also be used immediately without further treatment in casting operations.

The procedures of this invention are useful in the formation of foundry cores. In addition, these procedures can be utilized wherever it is desirable to bind particles together provided there is sufficient permeability to allow solvent contact with the resin and subsequent volatilization.

The specific embodiments in which an exclusive property or privilege is claimed are defined as follows:

1. The process for the formation of foundry cores or molds, which comprises mixing aggregate with a resin, placing the resultant mixture in a mold and compressing said mixture therein, introducing a solvent into said mold and solvating said resin, removing said solvent from said mold, and removing the resultant molded article from said mold.

2. The process for the formation of foundry cores, which comprises coating sand with a resin, drying the resultant mixture to a free-flowing state, placing the resultant free-flowing, resin-coated sand in a mold and compressing the coated sand therein to form a core, pressurizing said mold with a solvent to solvate said resin, reducing the pressure on said mold to remove said

solvent, and removing the resultant core from said mold.

3. The process for the formation of foundry cores, which comprises mixing sand with a resin solution, drying the resultant mixture to form free-flowing, resin-coated sand, placing said coated sand in a mold and compressing said coated sand therein to form a core, pressurizing said mold with a solvent to solvate said resin while maintaining said core under compression in said mold and subsequently reducing the pressure in said mold to remove said solvent, and removing the resultant core from said mold.

4. The process according to claim 3, wherein said resin is a synthetic resin which is solvated in said mold to a liquid state with a volatile liquid or gaseous solvent which is thereafter removed under vacuum from said mold.

5. The process according to claim 3, wherein the resin-coated sand comprises 1 to 8 weight percent by weight of the sand of a normally solid thermosetting resin selected from the group consisting of hydrocarbon resins, alkyd resins, rosin ester resins, novolak resins, and acrylic resins, and said resin is solvated in said mold with a solvent which is volatile under a vacuum of 20 to 30 inches of mercury at 60 to 100° F., which solvent is thereafter volatilized and removed from said mold.

6. The process according to claim 5, wherein said solvent is selected from the group consisting of chloroform, methylene chloride, acetone, petroleum ether, petroleum naphtha, and diethyl ether.



7. The process according to claim 5, wherein said resin is a phenol-formaldehyde novolak resin and said solvent is methylene chloride.

8. The process according to claim 5, wherein said resin is a phenol-formaldehyde novolak resin and said solvent is chloroform.

9. The process according to claim 5, wherein said resin is a phenol-formaldehyde novolak resin and said solvent is diethyl ether.

10. The process according to claim 5, wherein said resin is an acrylic resin and said solvent is methylene chloride.

11. The process according to claim 5, wherein said resin is an acrylic resin and said solvent is diethyl ether.

12. The process according to claim 5, wherein said resin is an acrylic resin and said solvent is chloroform.

**References Cited by the Examiner**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 2,154,185 | 4/1939 | Robie | 264—123 |
| 2,517,815 | 8/1950 | Weston | 22—193 |
| 2,583,036 | 1/1952 | Wolf | 22—194 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 321,967 | 7/1957 | Switzerland. |

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