

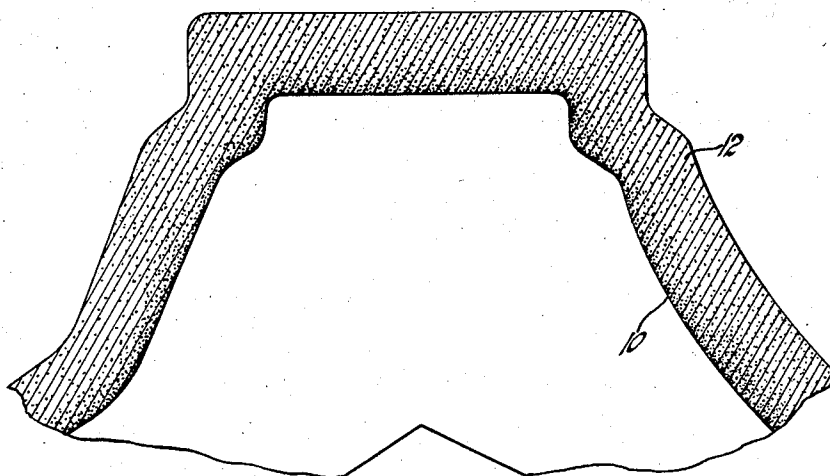
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SHELL MOLDS

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SHELL MOLDS

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This invention relates to shell molding and particularly to an improved shell molding mix and shell mold formed therefrom for use in the precision casting of metals. This patent application is a continuation-in-part of my co-pending application Serial No. 320,910, filed November 17, 1952, now abandoned.

Recently developed techniques in foundry practice employ thin-walled dispensable molds and cores composed of sand and thermosetting binders. These procedures, generally referred to as "shell molding" processes, are particularly suited for the production of precision castings in a wide variety of metals. Essentially the shell molding process consists of using thermosetting plastic or resin as a binder for the sand grains to form rigid molds having high gas permeability, good surface smoothness and dimensional stability. The molding material, which is generally a dry mixture of a major proportion of silica sand and a minor proportion of a thermosetting binder, is used in a powdered form with no water being added. Phenol formaldehyde and melamine formaldehyde resins are typical examples of the type of thermosetting binders preferably used. It is desirable that the sand employed be free of metal oxides, clay, moisture and organic matter.

These sand-resin molds are prepared by allowing the dry mixture of sand and resin powder to come into contact with a hot metal pattern for a short period of time. A layer of the mix adheres to the metal surfaces due to the heating of the resin which entraps the sand with which it is intimately mixed, thereby accurately reproducing pattern details. The half patterns, gates and runners are usually all permanently fixed on metal plates. Metal patterns must be used because they are subjected to elevated temperatures. Pattern temperatures in the range between 250° F. and 500° F. are typical, but temperatures up to 700° or even higher may be advantageously employed under particular conditions. The pattern temperatures and the length of time the molding material is allowed to remain in contact with the hot pattern surfaces determine the resulting thickness of the mold. Mold build-up times ranging from a few seconds to approximately one minute are appropriate for various applications.

After this short time interval, any excess or unbounded sand and resin are removed, and the closely adhering sand-resin layer is preferably cured while in contact with the pattern by subjecting it to a temperature within the range of approximately 300° F. to 1500° F. a short period of time, usually from a few seconds to five minutes. This baking operation results in the conversion of the resinous material to a hard insoluble binder which securely bonds the sand grains together. After the removal of the pattern and the mold from the curing oven, the mold is stripped from the pattern. The formed molds are, in effect, thin shells which possess sufficient strength and stiffness to make them suitable for many casting operations.

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One of the primary reasons for the relatively restricted use of the shell molding process up to the present time has been the comparatively high cost of the thermosetting resin binder. Inasmuch as the sand-resin mix normally contains between 6% and 15% by weight of binder, the cost of the binder has been a substantial item of expense when this process is employed. This is particularly true in applications requiring the inclusion of a finely comminuted refractory facing material, such as silica flour, in the molding mix since such a mixture necessitates the use of an exceptionally high binder content. The use of a mix containing a fine refractory filler material is especially desirable in satisfactorily casting steel or other high melting metals by the shell molding process, a procedure which previously has been impracticable. Moreover, shell molds heretofore have proved to be somewhat brittle and not sufficiently strong or resilient to provide optimum results in all instances.

Accordingly, a principal object of the present invention is to provide a new and improved shell mold which is appreciably less expensive than those heretofore used. A further object of this invention is to provide a process for forming shell molds of this type in which the amount of the relatively costly thermosetting resin binder necessary may be substantially reduced, amounts in the order of approximately 1% by weight being all that is necessary for many applications.

The above objects are obtained in accordance with my invention by forming an inexpensive shell mold of a mixture of sand or other suitable refractory material, a thermosetting binder material and a thermoplastic binder. The thermosetting binder provides the mold with smooth casting-defining surfaces and high strength, while the thermoplastic material is used for additionally bonding the sand particles together as well as contributing further high strength characteristics to the mold.

It will be understood that the term "mold," as used herein, is applied in its generic sense to mean a casting form which includes both molds and cores, this invention in no manner being limited to the former. Similarly, unless otherwise indicated, the word "pattern" is used herein as including both mold patterns and core boxes.

Other objects and advantages of this invention will more fully appear from the following description of a preferred embodiment of the invention in conjunction with the accompanying drawing showing a fragmentary sectional view of a shell mold.

In preparing the binder for my new and improved shell mold, a combination of thermoplastic and thermosetting materials, including any appropriate small amount of accelerator or co-condensating agent, such as hexamethylene tetramine or paraformaldehyde, is mixed with the proper amount of silica sand or other suitable refractory filler material. These constituents can be mixed in any conventional manner. For example, the binder materials may be mixed together and subsequently added to the sand, or they may be successively mixed with the sand.

Conventionally used thermosetting resin binders, such as the phenol formaldehyde or melamine formaldehyde resins, may be employed, the Monsanto Chemical Company resin No. 1128 being an example of such a thermosetting resin binder.

Gulf binder No. K-44, manufactured by the Gulf Research and Development Company, a subsidiary of Gulf Oil Corporation, is typical of the type of reversibly thermoplastic materials suitable for use as the thermoplastic constituent in the binder of the present invention. This type of thermoplastic material is formed by the polymerization of unsaturated hydrocarbons during vacuum distillation or cracking of petroleum. Among the poly-

merized hydrocarbons which I have found to be particularly satisfactory are the high-melting point residue fractions resulting from the distillation process. These thermoplastic materials contain polyaromatic constituents with no functional or chemically reactive groups normally

being present. The Gulf binder referred to above is a solid at room temperature and has a maximum bulk density of approximately 58 pounds per cubic foot and a specific gravity of about 1.1. It has an ASTM ring and ball softening point of approximately 415° F. On analysis this binder is shown to contain about 41% by weight of volatile matter, 58.9% by weight of fixed carbon, and 0.1% by weight of ash. This type of high-melting petroleum pitch is formed when the distillation is continued until the residue is free of all normally desirable petroleum products which contain acidic hydrogens. Hence the pitch residue which is used as the thermoplastic constituent in the binder of the present invention is substantially free of methoxyl and hydroxyl groups.

Mid-continent or asphaltic crude oils, which contain a large proportion of aromatic and polymethylene compounds, may be used in the distillation process. Cracking temperatures ranging from approximately 400° C. to 700° C. are typical. When relatively high vacuums are used, however, lower temperatures may be employed. As the higher temperatures are approached, depending on the amount of vacuum, the residue or pitch is polymerized and is of the type hereinbefore described. The details of particular cracking processes which can be used are not pertinent to the present invention so long as the residue or pitch produced is of the type described above. However, a vacuum flash unit operating at a temperature of about 750° F. to 800° F. and at an absolute pressure of 65 to 75 millimeters of mercury is illustrative of an apparatus for producing a usable asphaltic pitch. A 6.2° API pitch is a typical example of the resultant product.

The residues from petroleum refining may be oxidized to provide a particularly useful thermoplastic binder constituent of this type by transferring the asphaltic residue from vacuum towers to vertical stills which function as batch type or continuous oxidizers. Air is subsequently passed through the still, usually at temperatures of about 450° F. to 500° F. Since the reaction is exothermic it is not necessary to apply additional heat beyond that contained in the hot oil and residue. Although this reaction is not thoroughly understood, it is principally one of dehydrogenation and condensation. Approximately 80% to 90% of the oxygen is recovered as water and a portion of the reacting hydrogen is bound in the asphalt. Small quantities of CO₂ and other reaction products are also formed.

The charge is preferably fed to the bottom of the column when the air is introduced. At the top of the column the liquid overflows into a buffer tank. Thereafter the oxidized asphalt is drawn off from this tank by means of a pump, provision normally being made for recirculation of this residue. Hence an asphaltic residue having an optimum ring and ball softening point may be produced by oxidation, continued distillation or a combination of these two processes. Likewise, a mixture of residues produced by the two processes may be used to obtain the desired softening point. In general, blowing provides the residue with a higher softening point than continued distillation. In order to provide the resultant shell mold with optimum strength properties, it is usually desirable to use a thermoplastic material which will solidify to an ASTM ball point hardness within the range between 350 and 400.

No appreciable amount of polymerization occurs between the thermosetting resin and the thermoplastic binder constituent during the formation of shell molds. As pointed out above, the polymerized unsaturated hydrocarbons used by the applicant are substantially free of hydroxyl and methoxyl groups. These hydrocarbons are not reactive in the para or ortho positions because they

either have long-chain groups, fused ring groups, or groups so large that the para and ortho carbon atoms are blocked from reacting. Hence these hydrocarbons, which otherwise may be considered as being generally linear-type polymers, are chemically unreactive in the polymerization sense. Such thermoplastic materials do not release toxic or other very noxious fumes on contact with the hot metallic patterns.

The unusual efficiency of the binder mixture of the present invention results from the differential flow characteristics of the thermosetting and thermoplastic materials. This differential flow between the thermosetting binder and the thermoplastic binder provides the casting-defining surface of the shell mold with exceptional smoothness and at the same time contributes additional strength to the mold.

More specifically, the metallic pattern is heated to a temperature sufficient to cause a relatively large proportion of the thermosetting material to become concentrated near the mold-engaging surface of the hot pattern while permitting the thermoplastic material to remain more evenly distributed throughout the mold. Such a distribution of the binder constituents increases the strength of the mold while permitting a decrease in the amount of thermosetting plastic material which would otherwise be necessary to provide similar strength and mold surface qualities. This optimum pattern temperature is within the range between 350° F. and 450° F. for most binder mixtures. Inasmuch as the thermosetting binder, such as a phenolic resin, upon heating to such a temperature, flows more readily than the thermoplastic material, the former completely melts at and has a tendency to flow toward the surface of the hot pattern. On the other hand, the thermoplastic constituent of the binder melts only to a sufficient extent to assist in bonding the sand particles together throughout the thickness of the mold, particularly near its back or supporting surface. This distribution of the binder constituents results in the high temperature-resistant thermosetting material being on the high-temperature or pour side of the mold. As indicated above, the less expensive thermoplastic material functions primarily as a binder to provide the entire mold with increased strength.

As can be seen from the drawing, there is a gradation of concentration of the two principal binder constituents, as shown by the thermosetting resin-rich portion, indicated at 10, and the portion 12 which contains a relatively higher proportion of the thermoplastic material in the binder and a lower percentage of thermosetting resin. It will be understood, of course, that the above discussion relative to the differential flow of these binder constituents presupposes the placement of the molding mix on top of the heated pattern so as to permit gravitational forces to distribute these constituents in the foregoing manner.

If the pattern temperature is below approximately 350° F. when the molding mixture contacts it, the thermoplastic material will not melt or flow to a sufficient extent to be of any value in strengthening the mold. On the other hand, if the pattern temperature is above 450° F., the resultant mold will become too homogeneous with respect to the binder constituents. Inasmuch as, under this latter condition, the thermosetting binder and the thermoplastic material would both flow to approximately the same extent, the desired differential distribution of the binder materials is insufficient from a practical standpoint, resulting in no appreciable increase in desirable physical properties as compared with a conventional shell mold.

To obtain the proper differential flow with the above temperature range, the time the molding mixture should remain in contact with the heated metallic pattern should in all instances be at least 10 seconds with a contact time between 20 and 35 seconds at the above pattern temperature usually providing highly satisfactory results. There is generally no maximum pattern-contacting time because the mold build-up on the pattern is sufficiently rapid so

that heat is rather quickly conducted from the pattern and soon results in the lowering of the pattern temperature below 350° F. if no further heat is applied to the mold, thus precluding further flowing of the thermoplastic material. For practical purposes, however, approximately two minutes may be considered to be the maximum period the mold should be allowed to contact the hot pattern before removal of the mold-pattern assembly for curing.

Likewise, it is necessary that the formed mold be subsequently baked for a period of time just sufficient to cure the thermosetting resin binder but not long enough to permit the thermoplastic material to flow to any measurable degree. This curing or baking time should be between 30 and 120 seconds, a 40 to 90 second cure normally providing optimum results. Of course, the baking period depends on the baking temperature, the higher the curing temperature, the shorter the curing time, and vice versa. Curing temperatures between 350° F. and 1400° F. have proved to be satisfactory, although oven temperatures as high as 1800° F. may be employed. Dumping the molding mix upon the hot metallic pattern and the subsequent baking operation cures or hardens the thermosetting resin with the aid of the included small proportion of hexamethylenetetramine or similar curing agent in the binder.

For most applications a total binder content between 2% and 15% by weight is required with the balance of the molding mix being substantially all sand. The thermosetting resin normally should constitute at least 60% of this total binder content in order to provide the formed mold with the desired smooth surface and rigidity.

Thus a molding material comprising about 1% to 15% by weight of a thermosetting resin, a small but effective amount not in excess of 6% by weight of a thermoplastic binder, 3% to 20% by weight of silica flour, and the balance (approximately 65% to 93% by weight) substantially all sand may be used to form an inexpensive, strong, and smooth-surfaced shell mold. A preferred molding mixture composition which may be used in accordance with my invention, however, is one comprising 4% to 9% Monsanto resin No. 1128, 1.5% to 3.5% Gulf binder No. K-44, and the balance substantially all refractory filler materials. Such a mixture provides excellent results when placed into contact with a metal pattern which has been heated to a temperature between 380° F. and 400° F. and permitted to remain on this pattern for approximately 45 seconds.

When the dry molding mixture contains silica flour, as well as a coarser sand, the mold formation occurs in the following manner upon contact with the hot metal pattern. During the initial part of the molding period, the thermosetting resin melts and flows by gravity toward the surface of the pattern plate, carrying with it the fine silica flour with which it is intimately mixed. At the same time the thermoplastic material melts only to a slight extent to assist in binding the sand and silica flour particles together throughout the entire mold. The mold surface or facing thus formed in accordance with this process is extremely smooth, and reproduction of every minute detail of the pattern is thereby obtained. The reinforcing back portion of the mold, on the other hand, is relatively resilient and strong, being bonded by both the thermoplastic binder and a portion of the thermosetting resin. The sand-resin shell-type mold thus produced has excellent permeability, possesses high transverse strength and shows no tendency to cause blowing on the casting when the molten metal is poured.

On pouring the liquid metal into the mold or core cavity in the usual way, the hot metal, on coming into contact with the mold or core, burns the plastic binder to essentially carbon. The gases which are generated readily escape through the highly permeable sand-resin shell. As a result of this plastic breakdown, the shake-out is easily accomplished.

Molds formed in accordance with the above-outlined procedure have proved to be highly satisfactory at casting metals poured at temperatures as high as 2800° F. Such molds are especially adapted for pouring steel and, as indicated above, this is one of the principal reasons why a fine refractory filler is desirable. However, the above method of forming inexpensive high-strength shell molds permits the precision casting of non-ferrous as well as ferrous metals.

Among the numerous advantages of this process and the molds produced thereby is the fact that these molds offer very little resistance to the expansion and contraction of the molten metal subsequent to pouring, thus minimizing the danger of formation of cracks or hot tears. Moreover, the resultant castings have unusually smooth and clean surfaces, true dimensions, and a minimum of fin at the parting line. The surfaces of these castings are free of residual mold material, thereby eliminating the necessity of shot blasting. This process and the molds formed in accordance therewith can be used to provide castings of extremely thin section due to the unusual smoothness and high gas permeability of the molds. Moreover, the cured molds have no affinity for water, are completely stable under atmospheric conditions and may be stored indefinitely. Furthermore, these molds can be produced and processed without dust formation.

As a consequence of the aforementioned desirable qualities, molds formed in accordance with my invention accurately reproduce pattern details, maintain good dimensional tolerance and possess excellent surface qualities. Such molds permit the production of sound castings of a wide variety of metals over a large range of casting temperatures.

While the present invention has been described by means of certain specific examples, it is to be understood that the scope of the invention is not to be limited thereby except as defined in the following claims.

I claim:

1. A sand-resin mold for use in shell molding operations, said mold being formed from a dry mixture comprising approximately 3% to 20% by weight of silica flour, 2% to 15% by weight of a mixture of thermosetting and thermoplastic binders, and the balance substantially all sand, said thermosetting binder constituting at least 60% by weight of the total binder content, said thermoplastic binder being a residue fraction resulting from distillation of petroleum and being substantially free of methoxyl and hydroxyl groups.

2. A dry molding mix for application to a heated metallic pattern to form shell molds, said molding mix comprising, by weight, approximately 65% to 93% sand, 3% to 20% refractory flour, 1% to 15% thermosetting resin and a small but effective amount not in excess of 6% of a thermoplastic binder of polymerized unsaturated high-melting hydrocarbons which are residue fractions resulting from vacuum distillation of petroleum, said thermoplastic binder containing polyaromatic constituents and being substantially free of methoxyl and hydroxyl groups.

3. A sand-resin shell mold for metal casting operations formed from a dry mixture consisting essentially of approximately 1% to 15% by weight of a thermosetting resin binder, a small but effective amount not in excess of 6% by weight of a thermoplastic linear-type polymer binder of polymerized unsaturated hydrocarbons which are residue fractions resulting from vacuum distillation of petroleum and the balance substantially all silica sand, the total binder content in said mixture not exceeding about 15% of the weight of the mixture, said shell mold having a smooth molding surface formed by a facing layer having a high concentration of the thermosetting resin binder, the remainder of said mold being a reinforcing back layer containing a lower concentration of the ther-

mosetting resin binder and a relatively higher proportion of the thermoplastic binder.

4. A method of forming a smooth-surfaced shell mold which comprises placing a mixture of a refractory filler material, a thermosetting binder and a thermoplastic binder of polymerized unsaturated hydrocarbons which are residue fractions resulting from the refining of petroleum into contact with a heated metallic pattern so that a thin smooth-surfaced layer of the mixture having a high concentration of thermosetting binder is formed adjacent said metallic pattern and a reinforcing layer of the mixture having a lower concentration of thermosetting resin and a relatively high proportion of thermoplastic binder forms the back surface of the resultant shell mold, thereafter curing the mold and removing it from the pattern surface.

5. A method of forming a smooth-surfaced sand-resin shell mold which comprises placing a dry molding material consisting essentially of approximately 2% to 15% by weight of a mixture of thermosetting and thermoplastic binder materials and the balance substantially all sand into contact with a hot metallic pattern for a short time interval, said thermoplastic binder material containing polyaromatic constituents and being substantially free of hydroxyl and methoxyl groups, removing any excess of the sand-binder mixture, and thereafter curing the formed mold shell by baking while in contact with the pattern.

6. The process of forming a shell-type sand-resin mold which comprises mixing, by weight, approximately 3% to 20% of a refractory flour, 1% to 15% of a thermosetting resin, a small but effective amount not in excess of 6% of a thermoplastic binder of at least one polymerized unsaturated high-melting hydrocarbon which is substantially free of reactive hydroxyl and methoxyl groups, and the balance substantially all sand, the total binder content in said mixture not exceeding approximately 15% of the total weight of the mixture, placing the mixture on top of a hot metal pattern for an interval sufficient to melt the thermosetting resin binder and to cause a substantial portion thereof to flow to the surface of the hot metallic pattern, the thermoplastic binder melting only to a sufficient extent to assist in bonding the said particles together throughout the thickness of the mold, subsequently removing any excess molding mixture, and thereafter curing the formed mold.

7. A process for forming shell-type sand-resin molds which comprises mixing approximately 65% to 93% by weight of sand, 3% to 20% by weight of silica flour, and 2% to 15% by weight of a binder mixture of thermosetting resin and thermoplastic materials, said thermosetting resin constituting at least 60% of the total binder

content, said thermoplastic material being a residual petroleum asphalt produced during the refining of petroleum, placing the mixture in contact with a metallic pattern heated to a temperature between 350° F. and 450° F. for at least 10 seconds, thereafter curing the formed mold by heating while in contact with said pattern, and cooling said mold so that the thermoplastic material solidifies to an ASTM ball point hardness between approximately 350 and 400.

8. A shell mold for metal casting operations formed from a mixture comprising approximately 4% to 9% by weight of a thermosetting resin binder, 1.5% to 3.5% by weight of a thermoplastic binder of polymerized unsaturated high-melting hydrocarbons which are residue fractions resulting from vacuum distillation of petroleum, 3% to 20% silica flour, and the balance substantially all silica sand, said shell mold having a smooth casting-contacting layer containing a high concentration of a thermosetting resin binder and a reinforcing back layer containing a lower concentration of the thermosetting resin binder and a relatively higher proportion of the thermoplastic binder.

9. A molding mix for application to a heated metallic pattern to form a shell mold, said molding mix consisting essentially of 4% to 9% by weight of thermosetting resin binder, 1.5% to 3.5% by weight of thermoplastic binder of at least one polymerized unsaturated high-melting hydrocarbon which, when heated to a temperature between 350° F. and 450° F., flows to a lesser extent than the thermosetting binder when heated to the same temperature and which, upon subsequent cooling, solidifies to an ASTM ball point hardness between 350 and 440, and the balance substantially all sand.

10. A molding mix for application to a heated metallic pattern to form shell molds, said molding mix comprising, by weight, 4% to 9% thermosetting resin, 1.5% to 3.5% thermoplastic binder of polymerized unsaturated hydrocarbons which are residue fractions resulting from vacuum distillation of petroleum, and the balance substantially all refractory filler material, said unsaturated hydrocarbons containing polyaromatic constituents and being substantially free of hydroxyl and methoxyl groups.

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