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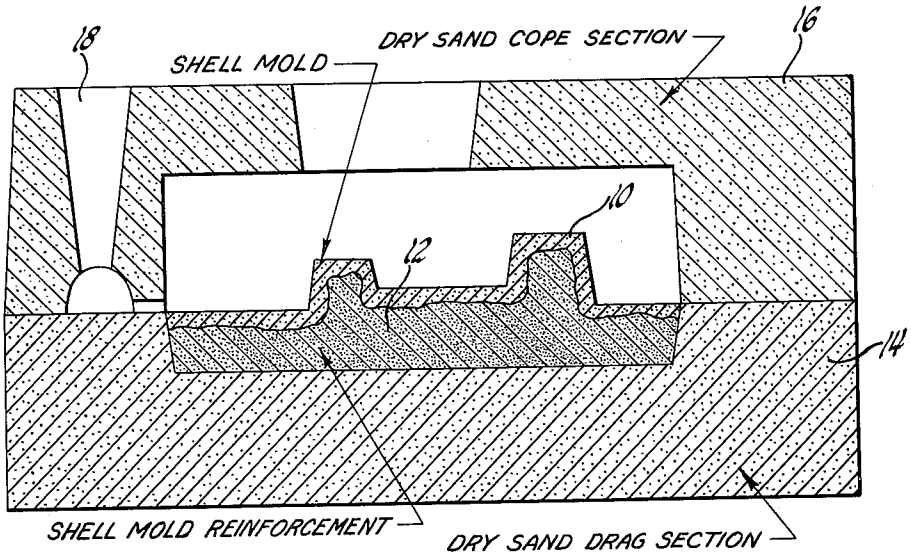

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SHELL MOLD AND METHOD OF MANUFACTURE

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This invention relates to shell molds suitable for processing relatively large heavy castings with a high degree of dimensional accuracy and surface finish.

Foundry practice techniques developed in recent years incorporated the use of thin-walled dispensible molds composed of sand and a plastic binder. These techniques, frequently referred to as "shell molding" processes, are particularly suited for the production of precision castings of a wide variety of metals.

Essentially the shell molding process consists of using a thermosetting plastic or resin as a binder for the sand grains to form thin-walled molds. The molding material, which is generally a dry mixture of a major proportion of silica sand and a minor portion of the thermo-setting binder, is used in powdered form with no water being added. Phenol-formaldehyde and melamine-formaldehyde resins are typical examples of suitable thermosetting resin binders which may be used. The sand employed is preferably free of metal oxides, clay, moisture and organic matter.

These sand resin molds are prepared by permitting 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 producing pattern details. Metal patterns must be employed because they are necessarily subjected to elevated temperatures. Pattern temperatures in the range between 250° F. and 450° F. are typical but in some instances, temperatures up to 800° F. may be advantageously employed. The pattern temperatures and the length of time that the molding material is allowed to remain in contact with the hot metal surfaces determine the resulting thickness of the mold. Mold buildup time ranging from a few seconds to approximately one minute are appropriate for various applications.

After this short time interval, any excess dry sand and resin are removed, and the closely adhering sand-resin layer is preferably cured by heating to a furnace temperature of about 300° F. to 1300° F. for a relatively short period of time, usually from a few seconds to about five minutes, while in contact with the metal pattern. This baking operation results in the conversion of the resinous material to a hard, insoluble binder which securely binds the sand grains together. After the removal of the pattern and mold from the curing oven, the mold is stripped from the pattern. The formed molds are in effect thin shells on which the patterned details are accurately reproduced and which have sufficient strength and stiffness to make them suitable for many casting operations, particularly casting operations involving relatively small parts.

The conventional shell molds above described are unsatisfactory for the production of relatively large castings which must be cast to precise dimensional tolerances, such as dies for use in operation such as forging, die casting and the like, because during the pouring and

solidification of the metal, the thin shell molds tend to bulge, warp, buckle, crack or otherwise deform due to the force of the static head of the metal. Conventional dry sand and green sand molds are also unsatisfactory because of their inherent inability to produce castings of high dimensional accuracy and high surface finish.

It is the basic object of this invention to provide a mold suitable for use in the production of relatively large castings which require a high degree of dimensional accuracy and a smooth surface finish. The mold of the present invention involves a composite structure including a relatively thin shell type mold face layer capable of reproducing surfaces with a high degree of dimensional accuracy and surface finish against which is molded and integrally formed a second relatively thick resin bonded sand layer rendering the mold essentially resistant to the thermal and mechanical effects tending to produce deformation or cracking of the mold. Preferably the composite structure is employed only in the portions of the mold in which are cast portions of the casting requiring a high degree of dimensional accuracy and surface finish. In a preferred embodiment the composite structure forms an insert within a conventional dry or green sand mold.

The composite mold structure of the invention is particularly applicable for the casting of alloy steel dies used for example in the forging of connecting rods and aluminum die casting and the like. The invention provides castings having considerable closer dimensional tolerances and smoother surfaces than those made by methods of the prior art so that a minimum of polishing for service is required and the need for kellering, die sinking and the like is eliminated.

Other objects and advantages of this invention will appear more fully from the following description of the preferred mold and process embodying the invention, reference being made to the accompanying drawing in which a schematic cross sectional elevation view of a mold made in accordance with the present invention is shown.

The invention will now be described with reference to the drawing in terms of a mold suitable for use in casting a die element for use in forging automobile engine connecting rods.

A metal pattern is provided of a suitable material such as a good grade of low alloy steel or a close grain cast iron. The desired design detail is accurately reproduced in the pattern surface by die sinking, kellering or other suitable means capable of meeting the dimensional and surface requirements of the articles to be cast. The dimensions of the pattern impressions are, of course, formed so as to include casting shrinkage, for example, in a range of 0.019 to 0.021 inch per inch for casting hot work tool steel. The dimensional stability of the metal pattern may be improved by stress-relief heat treatments during the process of machining the pattern impressions. Suitable heat treatments may be made at about 1100° F. in the case of cast iron and about 1250° F. in the case of steel.

A substantially uncured layer of sand-resin shell mold mix of suitable thickness is next formed over the pattern impressions by any suitable process such as by dumping or blowing. In a suitable method for this purpose a turnover box is partially filled with a sand-resin mix. This mix is preferably a relatively pure, washed sand such as silica sand, free of metal oxides, clay, moisture, and organic matter having a fineness of about 90 AFS to about 125 AFS, admixed with a suitable curable thermo-setting resin such as phenol-formaldehyde resin in quantities in the range of about 3% to 10% of the sand-resin mix and preferably about 8% to 10%. The resin may be mixed in powdered form with the sand, or the sand particles may be coated with liquid resin or resin dissolved in a suitable solvent, as is well known in

the art. Another sand which may suitably be used is zirconite, in which case the resin content may suitably be reduced to about 1% to 5% and preferably 4% to 5%.

The metal pattern is heated to a suitable temperature such as 400° F., inverted and fastened upon the turnover box. The box and attached pattern are then inverted to permit the sand-resin mix to fall upon the heated metal surface of the pattern and remain on the pattern surface for a time sufficient to permit a first layer or shell of the mix of suitable thickness to build up. In the specific illustration disclosed herein, the sand-resin mix is permitted to dwell on the hot pattern for about 20 seconds whereby a shell having a thickness of about ¼ inch is permitted to build up. The box is then righted to remove the excess sand-resin mix and the pattern with the sand-resin mix layer is removed from the box. In this step, the resin of the mix melts sufficiently to entrap the sand particles and causes them to adhere closely to each other and to the pattern surface to faithfully conform to the dimensions of the pattern impressions, but the resin is in a substantially uncured state. The sand-resin layer described will eventually form the initial or facing shell layer **10** shown in the drawing. The fine, closely packed sand mold facing will, in subsequent casting operations, produce a very smooth casting finish.

A mold frame of suitable configuration and height is next immediately disposed on and about the pattern so as to surround the relatively soft first sand-resin layer, and a second sand-resin layer is poured over the first layer to the level of the rectangular frame. The frame height determines the mold thickness and is preferably from ¼ to 2 inches higher than the highest portion of the first sand-resin layer. The second sand-resin layer is preferably composed of coarser sand, as for example of a fineness of about 60 AFS to about 90 AFS. However, for some applications sand may be used having a fineness of 20 AFS and in other applications the sand fineness of this second sand-resin layer may be substantially equal to the sand fineness of the first sand-resin layer. In general, however, where the sand of the first sand-resin layer is relatively fine as, for example, of a fineness of 120 to 125 AFS, it is highly desirable that the sand of the second sand-resin layer be sufficiently more coarse so as not to materially interfere with the escape of the gases generated by the burning resin in the first layer during the metal pouring procedure. Further, the second sand-resin layer preferably contains markedly less resin (as low as ½%) where the gas permeability of the sand is maintained at a maximum and the gas evolution due to the resin during casting at a minimum while providing the sand with a sufficiently strong bond at a minimum cost. In the specific example disclosed, the preferred resin content of the second layer is about 2%. The second sand-resin layer will form a shell reinforcing layer **12** as is shown in the drawing.

The entire assembly, including the pattern, the two sand-resin layers and the aforementioned frame, are oven cured at suitable temperatures and times, preferably at about 450° F. to 600° F. for approximately 10 to 30 minutes depending on the thickness of the two sand-resin layers. An important aspect of the invention resides in molding both the facing layer **10** and the reinforcing layer **12** in a substantially uncured state and then curing both layers simultaneously while in contact with the pattern, thus providing for a complete integration of the material of the two layers and at the same time insuring accurate duplication of the pattern detail by curing the layers on the metal pattern.

It is to be understood that various sand-resin mix ratios, sand fineness, shell mold thicknesses, and processing times and temperatures may be used within the scope of the invention. The specific times and temperatures and materials disclosed in the foregoing description illustrate a preferred embodiment. Other sand compositions and other thermo-setting resins such as melamine resins and

combinations of these and other resins well known in the art may be used. Various sand-resin shell molding techniques involving mold layer-forming temperature ranges from 250° to 850° F. and curing temperatures ranging from 300° to 1300° F. with curing times ranging from a few seconds to 30 minutes may be used depending on factors such as specific type of resin used and the thickness of the sand-resin layers to be cured. The initial layer **10** may vary from about 1/32 to 5/8 of an inch and the second layer **12** may vary from ¼ inch over the highest point of the first layer **10** to a thickness preferably on the order of 2 inches over the major portions of the initial layer **10**.

After the layers **10** and **12** are cured, the resulting composite structure is stripped from the pattern. It may then be associated with other mold compositions which may be shells, dry sand, core sand or green sand mold components.

The composite shell mold element may be utilized as a portion or insert in a more or less conventional dry sand or green sand mold as is illustrated in the drawing wherein it forms a composite insert **10** and **12** in a green or dry sand (oil bonded sand) drag **14** over which is disposed a cope **16** having a sprue **18** as is well known in the art, the composite insert being located in an area of the mold cavity where high dimensional accuracy and high surface finish are required in the article to be cast. Preferably the mold assembly is formed by molding a dry sand mix **14** on the back of and around the composite shell mold **10** and **12** and then oven baking or curing the dry sand mold with the composite shell mold portion in place. After curing the dry sand, the resulting drag is associated with a dry sand cope.

More specifically, the mold assembly is made by utilizing a dry sand mix consisting of about 1–2% core oil which may suitably consist of linseed and vegetable oils and about ½ to 1½% cereal flour and the balance core sand. The dry sand mix **14** is packed about composite portion **10** and **13**, and the assembly is then baked in an oven for a period of 4 to 5 hours at about 375° to 450° F. and preferably at 425° F. The baking time is dependent on the thickness of the dry sand mold portion and a baking time of about one hour per inch of the dry sand is satisfactory. This method of associating the composite shell mold with the dry sand mold portion is essential where maximum dimensional accuracy is required since it permits precise positioning of the composite portion **10** and **12** on or within the dry sand portion **14** and prevents any space or irregularity from being formed between the composite portion **10** and **12** and the dry mold portion **14**. In instances where the dry sand portion **14** is unusually thick, requiring an unusually long baking time for the cure thereof, the composite portion may be removed during the baking or curing process so as to avoid subjecting the composite portion to unduly prolonged baking. The relatively heavy cope and/or drag portion **14** and **16** rigidly supports the composite mold portion **10** and **12**, and the assembled portions are preferably firmly clamped together by means or metal straps or the like. The assembled mold thus permits the casting of a relatively heavy mass of metal with a minimum of dimensional distortion.

In some instances where the dimensional accuracy of the casting is less critical, the composite shell mold portion or insert **10** and **12** may be positioned in a green or dry sand mold section such as the drag **14** in which the recess for receiving the insert has been printed or otherwise suitably formed prior to assembly of the mold.

The use of the mold of the present invention has been found to be essential in the production of dies for use in forging automobile engine connecting rods. In specific castings, the cast dies were held to an out-of-flat condition of less than 0.015 inch across the die working surface. Each die block, which contained the three impressions of buster, blocker and finisher, were about 18 x 18

inches in area by 3½ inches in thickness and weighed about 350 pounds. Surface smoothness and dimensional characteristics of the die blocks were such that a minimum of polishing was required for service and all need for kellering and die sinking was eliminated. In contrast, die blocks made by casting in the known molds of the prior art involve serious out-of-flat conditions and other dimensional inaccuracies.

Various modifications in the arrangement and details of the specific embodiment described and shown herein will be applicable to those skilled in the art and are contemplated within the scope of the present invention as defined in the appended claims.

We claim:

1. A mold for use in precision casting relatively heavy articles comprising sand cope and drag members, at least one of said members being molded about an insert forming at least a portion of said mold cavity surface, said insert comprising a composite mold structure having a first facing layer formed of a major proportion of sand and a minor proportion of thermo-setting resin and a second supporting layer formed of a major proportion of sand and a minor proportion of thermo-setting resin, the resin content of said second layer being substantially less than the resin content of said first layer, said first and second layers being simultaneously cured and bonded together while said first layer is in contact with a metal pattern.

2. A mold for use in precision casting relatively heavy articles comprising a dry sand cope member and drag member, one of said members being molded about an insert forming at least a portion of the mold cavity surface, said insert comprising a composite mold structure comprising a first facing layer of a major proportion of sand and a minor proportion of thermo-setting resin, and a second layer of a major proportion of sand and a minor proportion of thermo-setting resin, the resin content of said second layer being substantially less than the resin content of said first layer, said first and second layers being simultaneously cured while said first layer is in contact with a metal pattern.

3. A mold for use in precision casting relatively heavy articles comprising dry sand cope and drag members, one of said members being molded about an insert forming at least a portion of the mold cavity surface, said insert comprising a composite mold structure comprising a first facing layer of a major proportion of sand of a fineness of from about 90 to about 125 AFS and a minor proportion of a thermo-setting resin, a second layer of a major proportion of a sand of a fineness of from about 60 to about 90 AFS and a minor proportion of thermosetting resin, the resin content of said second layer being substantially less than that of said first layer, said first and second layers being simultaneously cured and bonded together while said first layer is in contact with a metal pattern, and means firmly clamping said cope and drag members in abutting positions.

4. A mold for use in precision casting relatively heavy articles comprising sand cope and drag members, at least one of said members being molded about an insert forming at least a portion of said mold cavity surface, said insert comprising a composite structure having a first facing layer formed of a major proportion of relatively fine sand and a minor proportion of thermosetting resin and a second supporting layer formed of a major proportion of a coarser sand and a minor proportion of a thermosetting resin, said first and second layers being simultaneously cured and bonded together while said first layer is in contact with said pattern.

5. A process for making a mold for use in precision casting heavy articles comprising cope and drag members forming a mold cavity, at least one of said cope and drag members including a facing insert, said process comprising the steps of placing a first mixture of a major proportion of sand and a minor proportion of a thermosetting resin in contact with a hot metallic pattern for a time sufficient to melt the resin and cause a substantial portion of said sand particles to adhere to one another whereby a first closely adhering substantially uncured sand-resin layer is formed adjacent the pattern, placing a second mixture of a major proportion of sand and a minor proportion of a thermosetting resin over said first layer to form a second layer of substantial thickness over said first layer, curing the resin of said first and second layers simultaneously while said first layer is in contact with said pattern by subjecting the layers to heat at a temperature and for a time sufficient to cure the resin and bond said layers to form said facing insert as an integral composite structure, stripping said facing insert from the pattern, and molding a sand cope or drag about said facing insert in a manner such that the surface of said insert formed by said pattern forms a surface of the mold cavity.

6. A process for making a mold for use in precision casting heavy articles comprising cope and drag members forming a mold cavity, at least one of said cope and drag members including a facing insert, said process comprising the steps of placing a first mixture of a major proportion of sand and a minor proportion of a thermosetting resin in contact with a hot metallic pattern for a time sufficient to melt the resin and cause a substantial portion of said sand particles to adhere to one another whereby a first closely adhering substantially uncured sand-resin layer is formed adjacent the pattern, placing a second mixture of a major proportion of sand and a minor proportion of a thermosetting resin over said first layer to form a second layer of substantial thickness over said first layer, curing the resin of said first and second layers simultaneously while said first layer is in contact with said pattern by subjecting the layers to heat at a temperature and for a time sufficient to cure the resin and bond said layers to form said facing insert as an integral composite structure, stripping said composite structure from the pattern, molding a dry sand cope or drag about said composite structure in a manner such that the surface of said insert formed by said pattern forms a surface in the mold cavity, and baking said dry sand at a temperature and for a time sufficient to bond the dry sand mix.

7. A process for making a mold for use in precision casting heavy articles comprising cope and drag members forming a mold cavity, at least one of said cope and drag members including a facing insert, said process comprising the steps of placing a first mixture of a major proportion of relatively fine sand and a minor proportion of a thermosetting resin in contact with a hot metallic pattern for a time sufficient to melt the resin and cause a substantial portion of said sand particles to adhere to one another whereby a first closely adhering substantially uncured sand-resin layer is formed adjacent the pattern, placing a second mixture of a major proportion of sand coarser than the sand of said first layer and a minor proportion of a thermosetting resin over said first layer to form a second layer of an average thickness of about two inches over said first layer, curing the resin of said first and second layers simultaneously while said first layer is in contact with said pattern by subjecting the layers to heat at a temperature and for a time sufficient to cure the resin and bond said layers to form said facing insert as an integral composite structure, stripping said composite structure from the pattern, molding a dry sand cope or drag about said composite structure in a manner such that the surface of said insert formed by said pattern forms a surface in the mold cavity, and baking said dry sand at a temperature and for a time sufficient to bond the dry sand mix.

8. A process for making a mold for use in precision casting heavy articles comprising cope and drag members forming a mold cavity, at least one of said cope and drag members including a facing insert, said process compris-

ing the steps of placing a first mixture of a major proportion of sand of a fineness of about 90 AFS to 125 AFS and a minor proportion of a thermosetting resin in contact with a hot metallic pattern for a time sufficient to melt the resin and cause a substantial portion of said sand particles to adhere to one another whereby a first closely adhering substantially uncured sand-resin layer is formed adjacent the pattern, placing a second mixture of a major proportion of a coarser sand of a fineness of about 60 AFS to 90 AFS and a minor proportion of a thermosetting resin over said first layer to form a second layer of an average thickness of about two inches over said first layer, curing the resin of said first and second layers simultaneously while said first layer is in contact with said pattern by subjecting the layers to heat at a temperature and for a time sufficient to cure the resin

and bond said layers to form said facing insert as an integral composite structure, stripping said composite structure from the pattern, molding a dry sand cope or drag about said composite structure in a manner such that the surface of said insert formed by said pattern forms a surface in the mold cavity, and baking said dry sand at a temperature and for a time sufficient to bond the dry sand mix.

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