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METHOD OF MAKING A MOLD BY THE LOST-WAX PROCESS

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This invention relates to precision casting by the so-called "lost-wax" process. In carrying out this process it is customary to proceed in the following manner:

After making a wax pattern of the object to be cast, the pattern is provided with an initial coating applied by spraying or dipping, or both, with a refractory slurry comprising a fine refractory material suspended in a liquid bonding medium and then with a stucco or refractory grit such as silica sand or grog. From this coated pattern a mould is formed by placing the pattern on a metal foundation around which is built a steel or other heat-resistant box, and filling the space between the pattern and the walls of the box with a self-bonding slurry containing solids such as silica sand or flour, grog and sillimanite, as well as a bonding liquid such as ethyl silicate, sodium silicate cement and water, plaster of Paris and water. When the thus formed mould has set it is carefully dried out and then heated to a temperature of 110° C. whereupon the wax is run out. The mould is then fired, its temperature being ultimately raised to 1000° C. and maintained thereat until all residual carbon has been removed. The mould is then ready to receive the molten casting metal; after the metal has been cast in the mould the latter is broken down to allow removal of the casting.

Amongst the disadvantages of this procedure is that trial and error methods are necessary for adequately determining in any particular case if the mould has been fired sufficiently to give the appropriate condition of mould porosity having regard to the fact that this is dependent upon such variable factors as the bulk of the mould, the extent to which de-waxing is carried out, the characteristics of the furnace atmosphere and the length of time during which the mould is allowed to remain in the furnace; moreover, restrictions imposed in the choice of mould materials operate against flexibility of control of the rate of solidification of the casting metal; furthermore, the existing methods of de-waxing by the application of heat involve appreciable liability for the formation of cracks and fissures in the mould.

According to the present invention a wax pattern of the object to be cast is provided with a multiplicity of superimposed dip coatings such as to result in the pattern being invested with a shell of refractory material of substantial thickness. After formation of the shell it is contemplated to remove the wax pattern, preferably by the use of a suitable solvent and to complete the forming of the mould by surrounding the shell with a supporting mass of dry refractory material, the thickness of the shell being such that the use of a plastic packing to form the mould is unnecessary. The shell thickness may thus be of the order of from 1/4" to 1/2" thick (according to the size and shape of the wax pattern).

As above stated the wax pattern is conveniently removed from the shell by the application of a solvent to the pattern. Various waxes may be employed, it being desirable that the wax should be substantially pure, have an ash content of less than .05% and possess a suitable solvent. In a preferred method, the shell and pattern may be suspended in a hot vapour of the solvent, for example tri-

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chloroethylene vapour, it being envisaged that this vapour will penetrate the permeable shell, melt and dissolve the wax and leave the shell interior free from residue. Alternatively a water soluble wax such as polyethylene glycol may be used with steam as the solvent. If desired, the wax may be recovered from the solvent, as by distillation, ready for subsequent use. Prior to the application of the coatings above referred to, the pattern may receive an initial coating, such as by dipping or spraying, or both, of a fine refractory to produce a desired surface finish of the casting.

Following removal of the wax pattern from the shell investment, the shell is preferably closed against ingress of contaminating particles as by sealing the mouth of the shell with a wax cover. Thereafter the shell may be placed in a mould box and invested with dry sand or other dry refractory, the packing of the sand all around the shell being facilitated, if desired, by vibrating the mould box, although such vibration will not normally be necessary; the mould box may then be introduced into a furnace and treated at the required temperature to consolidate the mould.

By this procedure many of the difficulties encountered in the practice hitherto followed are obviated. Thus the use of a shell investment from which all trace of wax and thus of residual carbon has been removed as described before the mould is completed by application of the packing of supporting materials around the shell provides improved control of mould porosity, which enables improved surface finish of the coating to be obtained and facilitating the casting of thin sections; moreover, by arranging that the porosity of the loose supporting materials with which the shell is surrounded is sufficiently great, it is possible to attain a condition in which the mould porosity is dependent only upon the grit size and thickness of the investment shell.

In some applications of the lost-wax process it is frequently desirable, when solidification of the casting metal is to be progressive, that such solidification should take place at a slow rate. By applying the procedure according to the invention, control of the rate of solidification can be established by suitable variation of the density of the packing materials to promote or restrict heat flow. In the hitherto known practice the selection of mould materials is largely governed by the expansion/contraction characteristic of the mould as well as by its strength.

As regards removal of the wax from the mould, whereas the treatment in ovens by circulation of hot air according to the hitherto known technique involves appreciable risk of cracks being formed in the mould, such risk is substantially, if not wholly, eliminated by the use of a solvent according to this invention.

A further advantage of the procedure according to this invention is that it results in there being less scrap than is possible with the hitherto known practice, in that

(a) The simpler methods of investment lead to reduced breakage,

(b) The more efficient de-waxing and control of mould porosity involved less risk of casting failure,

(c) The reduced thermal capacity of the shell in relation to that of moulds obtainable hitherto reduces the liability for the production of short-run castings,

(d) The formation of undesirable refractory solids due to investment liquid attacking the wax or filling the space between the wax and the primary refractory coating is avoided,

(e) The use of vibrating tables, with consequent risk of wax breakage, can be obviated,

(f) The possibility of refractory inclusions in the metal castings is reduced due to the freedom from mould cracking.

Finally, the procedure according to the invention results in beneficial advantages as regards cost, in that

(a) Less costly investment material can be used, and the packing material for one mould can be re-used in another mould,

(b) The simpler methods of investment tend to reduce labour costs,

(c) With the removal of carbon in the manner described, and the avoidance of wet mould packing which must subsequently be dried, the use of the furnace for these purposes and attendant risk of explosion is obviated and furnace running costs are reduced,

(d) With the reduced weights of moulds, handling costs can be reduced.

The invention is universally applicable, whether for use in respect of the precision casting of steels, bronzes, aluminium, or any other liquid materials.

A process embodying the features of the invention will now be described by way of example.

The wax pattern is provided with an initial coating sprayed or dipped thereon and comprising a bonding agent consisting of:

34.2% by volume of ethyl silicate
58.2% by volume of methylated spirits
0.4% by volume of hydrochloric acid (10%)
7.2% by volume of water

and, for spraying, zirconium silicate powder used in the proportion of 7 ozs. of the powder to 100 cc. of the bonding agent, and, for dipping, silica flour used in the proportion of 13½ ozs. thereof to 100 cc. of the bonding agent. For the dipping or spraying, other fine refractory materials may be employed such as sillimanite or alumina and other bonding agents such as sodium silicate, cement, or plaster of Paris. The composition of the initial coat will be chosen in accordance with the surface finish required of the casting and the metal to be cast.

The initial coat is allowed thoroughly to dry and the shell is then produced by a multiplicity of dippings in a refractory slurry, excess of slurry being allowed to drain away after each dipping and a stucco of a coarse grained refractory being applied after each dipping. The stucco may, for example, comprise crushed fire brick. By this means a coating of the desired thickness is built up, the thickness depending on the size and shape of the wax pattern and the casting stress.

The coating obtained after each dipping is permitted to gel before the next coat is applied. The time required for the coatings to gel may be reduced by the use of an accelerator such as ammonia vapour, magnesium oxide or any suitable alkali, or by placing the pattern after each coating in a high velocity air stream whereby to remove the volatile constituents of the slurry and to cause a gel. In practice the latter method is generally preferred and may be achieved in a suitably designed wind tunnel adapted to contain a suitable number of patterns simultaneously, for example 15 patterns.

The coating material may comprise a dry mixture of 30% by weight of silica sand and 60% by weight of silica flour added in the proportion of 12¼ ozs. of the mixture to 100 cc. of the bonding agent hereinbefore set forth. The grain size of the various materials referred to above is important and should show the following sieve analyses:

Silica sand

Sieve size:	Percentage retained by weight
—40+60	30
—60+100	55
—100+150	15

Silica flour

Sieve size:	
—100+150	15
—150+200	10
—200	75

Stucco

(a) Sieve size:	
—30+40	10
—40+60	25
—60+90	20
—90+150	25
—150	20

(b) Sieve size:	
—10+20	40
—20+30	45
—30+60	15

It is important that the refractory materials should be dry before use.

In place of the particular materials referred to above, other suitable refractory materials such as zirconium silicate, sillimanite, alumina, malachite, or ethyl silicate, may be employed, having if desired different grain size and different proportions from those set out above. The materials employed in any particular application will be selected according to the form of the casting, the metal being cast and the surface finish required. Similarly other bonding agents may be used such as sodium silicate, cement, plaster of Paris, and the like.

When the shell has been built up to the required thickness, such as of the order of ¼ inch to ½ inch, it is necessary to remove the wax pattern without damage to the shell. For this purpose the shell-coated pattern is suspended in trichlorethylene vapour in such an altitude that the dissolved wax can flow out from all sections of the shell. Trichlorethylene degreasing plant of the common type, and operated at 120° C., is well adapted for this part of the process. The trichlorethylene vapour will penetrate the permeable shell to dissolve out the bulk of the pattern and will also rinse out the shell leaving no trace of wax, consequently maximum porosity is obtained for any particular shell structure. The invention thus provides for the rapid de-waxing of the shell. The mixture of wax and trichlorethylene falling into the bottom of the degreasing plant can be separated and used again. The separation may be readily performed in a second degreasing plant modified to distil off the bulk of the trichlorethylene at 120° C., whilst the remaining traces of trichlorethylene in the wax are removed by bubbling air through the mixture.

The shell is then placed in a mould box of heat-resisting steel and invested with a dry refractory material packed round the shell; said material may comprise sand or firebrick grog, or any other such material adapted to provide sufficient support to the shell and capable of withstanding the temperature to which the mould is raised, and which, furthermore, will not expand to such extent as to exert on the shell sufficient pressure to cause fracture thereof. A mixture of sand and ¼-inch firebrick grog has been found to give excellent results, satisfying not only the conditions set forth above, but also having the further advantage that when the temperature of the mould is raised the mix has a slight "fritting" effect, giving firmer support to the shell and so permitting casting to be carried out under pressure. Where necessary, "fritting" agents can be added to the mix to give a firmer bond. The grain size of the mixture may be varied from mould to mould to give the correct rate of cooling for the product being cast, and may also be varied through the mould to obtain progressive solidification. With previous methods of lost-wax casting, this progressive solidification has not been possible, since the selection of mould materials has necessarily been governed by the expansion and contraction characteristics of the mould and by the mechanical strength of the mould.

The shell and the investment thereof, is then raised in temperature, stabilised, and the metal cast.

After cooling of the mould, the casting may be readily removed therefrom by pouring out the investment, which is then ready for re-use, and the shell stripped from the

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casting by hammering or vibrating the runner. The particles of shell removed from the casting can be broken down and reused, either as stucco in the shell moulding or as filler for the investment.

What we claim is:

1. In the method of making a shell mold suitable for use in precision casting; the steps comprising coating a pattern of an object to be cast with a porous refractory shell having sufficient wall thickness to provide a self-supporting structure and sufficient porosity to allow a vapor to readily permeate therethrough to substantially all surfaces of the pattern; substantially completely surrounding said coated pattern with a vapor atmosphere which is a solvent to the pattern for a sufficient time to allow the vapor to permeate the shell wall to all surfaces of the pattern and dissolve the pattern which is drained from the shell leaving the interior thereof free from pattern residue.

2. The method of claim 1 wherein the pattern is made of a wax soluble in steam; said vapor atmosphere comprising essentially steam.

3. The method of claim 1 wherein the pattern is made of a wax soluble in trichlorethylene vapor; said vapor atmosphere comprising essentially trichlorethylene.

4. In the method of making a shell mold suitable for use in precision casting; the steps comprising coating a wax pattern of an object to be cast with a porous refractory shell having sufficient wall thickness to provide a self-supporting structure and sufficient porosity to allow a vapor to readily permeate therethrough to substantially all surfaces of the pattern; said coating step being accomplished by dipping the pattern in a refractory slurry a plurality of times and allowing the slurry coating picked up during each dip to gel before the next dip; and substantially completely surrounding said coated pattern with a vapor atmosphere which is a solvent to the pattern wax for a sufficient time to allow the vapor to permeate the shell wall to all surfaces of the pattern and dissolve the pattern which is drained from the shell leaving the interior thereof free from wax residue.

5. The method of claim 4 wherein the coated pattern is placed in a high velocity air stream between dips to accelerate gelling of the coating.

6. The method of claim 4 wherein a gel accelerating agent is applied to the coated pattern between dips.

7. The method of claim 4 wherein a stucco comprising a coarse grained refractory material is applied to the coated pattern between dips.

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8. In the method of making a shell mold suitable for use in precision casting; the steps comprising coating a wax pattern of an object to be cast with a porous refractory shell having a thickness of substantially from 0.25 to 0.5 inch to provide a self-supporting structure having sufficient porosity to allow a vapor to readily permeate therethrough to substantially all surfaces of the pattern; said coating step being accomplished by dipping the pattern in a refractory slurry a plurality of times and allowing the slurry coating picked up during each dip to gel before the next dip; said refractory slurry containing at least one refractory material selected from the group consisting of zirconium silicate, silica, sillimanite, alumina, and malachite, and at least one bonding agent material selected from the group consisting of ethyl silicate, and sodium silicate; and substantially completely surrounding said coated pattern with a vapor atmosphere which is a solvent to the pattern wax for a sufficient time to allow the vapor to permeate the shell to all surfaces of the pattern and dissolve the pattern which is drained from the shell leaving the interior thereof free from wax residue.

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