

United States Patent

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[54] **PRECISION METAL CASTING MOLDS**
 6 Claims, No Drawings

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 B22c 9/12
[50] Field of Search..... **164/8, 23,**
 24, 25, 26

[56] **References Cited**
 UNITED STATES PATENTS
2,912,729 11/1959 Webb..... 164/25 X
3,512,571 5/1970 Phelps..... 164/8 X
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ABSTRACT: A process for producing ceramic shell molds for use in the casting of metals which involves the steps of building up a ceramic shell mold by freezing a plurality of superimposed stuccoed layers onto an expandable pattern and removing the pattern by the application of heat.

PRECISION METAL CASTING MOLDS

INTRODUCTION

The precision casting of metals may be defined as a process whereby a molten metal is poured into a mold, wherein it solidifies to produce a cast metal object which is characterized as having close specifications as to tolerance, detail and surface quality. One of the most common methods of precision casting is precision investment casting, which is sometimes referred to as the lost wax process.

A specific form of investment casting, which embodies the most modern form of the process, is the shell mold investment casting process. This process utilizes an expendable pattern which is a replica of the article to be produced. The pattern is coated with a ceramic slip which is made up of a granular refractory in a liquid binder vehicle. The coated pattern is stuccoed with granular refractory material and the stuccoed coat is allowed to dry. The process of coating and stuccoing is repeated to build up successive layers which form a ceramic shell around the expendable pattern. The ceramic shell thus formed is treated to remove the expendable pattern, leaving a thin mold capable of having many types of molten metals poured directly into its cavity to produce precision castings of high quality. One embodiment of the shell mold investment casting process is disclosed and explained in detail in U.S. Pat. No. 2,948,032.

The combination of the use of slip coating and stuccoing a pattern results in extremely good reproduction of the pattern face by the mold. It can be readily seen that this process of coating a pattern is not limited to use in conjunction with expendable patterns or to the lost wax process. Precision molds can also be made wherein a shell mold as described above is reinforced by investment in a backup material such as granular refractory, insulating material or a castable. Another method would be to produce mold sections by coating and stuccoing patterns and using the mold sections independently. More preferably, the sections could be used in conjunction with a backup material such as sand, plaster, a granular refractory or a suitable castable.

It is essential to the production of a high quality precision metal casting that the mold surface be dimensionally correct. The mold surface must also be smooth, impermeable to the metal, and of such a chemical nature that it does not react with the metal. For these purposes, various refractory materials may be used depending upon the chemical nature of the metal which is being poured.

The problems of control of mold dimensions and mold surface, as well as the problems of providing a mold which is chemically unreactive with the metal which is being cast, have been dealt with by the prior art. The mechanics of proper grain sizing, control of viscosity of slips and other techniques in the physical making of a mold have been developed to a high degree by the prior art and are not essential to the subject invention.

Although the shell mold investment casting process has been developed to a high degree by the prior art and is extremely useful in the making of precision metal castings, the process does have some shortcomings. Perhaps, the greatest shortcoming is involved in the time and effort necessary to build up a composite shell mold by coating, stuccoing and drying.

Before successive layers can be added to a pattern to build up a shell mold by the prior art method of investment casting mold making, each earlier layer must be dried thoroughly. The drying of successive layers involves the expenditure of a good deal of time in the making of a mold. For instance, a five-layer shell mold, wherein 1 hour is allowed for each layer to dry before applying the next coating and stucco layer, would take a minimum of 5 hours for its manufacture. This 5-hour span involves not only the use of a period of time but also the use of the quantity of space which is necessary to store the molds at a controlled temperature and humidity, so that they may be dried properly.

OBJECTS

It is an object of the subject invention to provide an improved process for producing a ceramic shell mold for use in the investment casting of metals whereby stuccoed layers can be added to each other to form the finished shell mold without waiting for each preceding layer to dry.

Another object of the subject invention is to provide a process for producing a ceramic shell mold whereby a succession of coated and stuccoed layers are built up upon an expendable pattern with each layer being frozen prior to the application of each successive layer.

Other objects will appear hereinafter.

THE INVENTION

In accordance with the objects of the subject invention, an improved process for producing a ceramic shell mold for use in investment casting of metals has been discovered. The process of the subject invention is one whereby a ceramic shell mold which is comprised of a composite of successive stuccoed layers is made in a small fraction of the time which is necessary for the making of a similar ceramic shell mold by prior art processes.

The process of the subject invention involves forming a ceramic shell by the steps of:

1. Coating an expendable pattern with a ceramic slip which comprises an aqueous colloidal silica sol or an aqueous alumina coated colloidal silica sol vehicle having a granular refractory material suspended therein,
2. Stuccoing the coated pattern with a granular refractory material,
3. Freezing the stuccoed coat at a temperature below about +5° F.,
4. Forming a plurality of superimposed similar coatings on the pattern, and
5. Removing the pattern from the ceramic shell.

Aqueous colloidal silica sols of the type used as binders in the practice of the subject invention are available commercially from several sources and have been described in detail in the prior art. A thorough description of these colloidal silica sols is set forth in the aforementioned U.S. Pat. No. 2,948,032.

The sols are most usually prepared using the techniques in accordance with the teachings of Bird, U.S. Pat. No. 2,244,325. Bird teaches that aqueous colloidal silica sols of high purity may be prepared by passing a dilute solution of an aqueous alkali metal silicate solution in contact with a cationic exchange resin in the hydrogen form.

The sols produced by the Bird patent are relatively dilute, but may be concentrated using evaporation techniques such as, for example, those described in Bechtold, et al., U.S. Pat. No. 2,574,902 and Alexander, U.S. Pat. No. 2,601,235.

The particular method of preparation of the colloidal silica sols which are useful in the subject invention is not essential to the invention. Since preparation of these sols is well known to the prior art and has been described in detail in the patents cited, as well as in numerous other publications, the specific preparation procedures will not be further discussed here.

The colloidal silica sol binders which are most useful in the practice of the invention contain relatively large amounts of silica, so that the SiO₂ content is between about 12 percent and about 60 percent by weight, with excellent results being obtained with silica sol binders containing between about 20 percent and about 60 percent by weight of silica.

The alumina coated sols which are useful in the practice of the subject invention as alternate binders to the colloidal silica sols are defined as those in which all of the silica particles are coated with at least a continuous monolayer of alumina. The sols are further characterized as comprising dense spherical particles of an average particle size of from 10—30 millimicrons and an alumina-to-silica ratio of from 0.10 to 0.50. More preferably, the sols are of a particle size of from 15—20 millimicrons and have an alumina-to-silica ratio of from 0.10 to 0.30. An ideal sol, as shown below in Table 1, has an

average particle size of 20 millimicrons and an alumina-to-silica ratio of 0.20.

Table 1

ALUMINA COATED SOL	
Solids	20%
pH	5.5
Al ₂ O ₃ /SiO ₂ Ratio	0.20
Viscosity at 77° F.	5 c.p.s.
Specific Gravity at 68° F.	1.14
Specific Surface Area	150 m. ² /gm.
Average Particle Size	20 millimicron
Particle Charge	Positive
Density of Sol at 68° F.	9.5 lbs./gal.
Freezing Point	32° F.
Na ₂ O Content	Less than 0.01%
Chloride Content	0.3

A method of producing the alumina coated sols has been described by Mindick, et al., in U.S. Pat. No. 3,139,406. However, it must be understood that the method of making alumina coated sols is not essential to the subject invention. It is only necessary that the finished sol be one in which all of the silica particles are covered with at least a continuous monolayer of alumina.

The preferred alumina coated sols for use in the subject invention have a total solids content of from 5 percent—40 percent by weight. More preferably, the sols should have a solids content of from 15 percent—35 percent by weight and most preferably, about 20 percent by weight. The sols should further have a pH range of from 0.5—6.5 and more preferably, a pH range of from about 5.0 to about 6.0.

The alumina coated sols which are most useful in the subject invention and their manner of use in the prior art method of manufacturing ceramic shell molds for use in investment casting is described in detail in copending application U.S. Ser. No. 619,143, now Pat. No. 3,445,250, filed Feb. 28, 1967. The improvement in this application over the copending application lies in the use of the freezing step and not in the use of the binder or refractory.

The refractories which are useful both in the ceramic slip of the subject invention and as a stucco material which is used in the process of the subject invention are of a variety of granular refractory materials. The particular refractory material to be used is chosen on the basis of economic availability, ease of handling, chemical reactivity with the metal to be poured and other considerations which are not essential to the subject invention.

As has been pointed out above, it is not the particular colloidal silica sol nor is it the particular refractory material which is used which is essential to the subject invention. The novelty of the subject invention lies in the freezing of each layer and the immediate application of additional layers to the previously frozen layers to provide a fast method of making a ceramic shell. Aside from the freezing steps which are replacements for the prior art drying steps in the process of manufacturing a ceramic shell mold, the ceramic slips and granular refractory materials which are used in the subject invention are essentially the same as those taught by the prior art.

The only variation which is provided by the subject invention is that refractory materials which would not be used in the prior art process because of their tendency to react with a colloidal silica or alumina coated sol to form an unstable slip, might be used in the practice of the subject invention, because a slip might not have to be held in a stable condition for as long a period of time. For instance, a magnesium silicate stucco material which might tend to gel a prior art coating slip and thus prevent it from drying properly might be used in the prac-

tice of the subject invention, because the fast freezing step would not allow the magnesium silicate sufficient time to have a deleterious effect upon the slip.

Typical granular refractory materials which are useful in the subject invention are those selected from the group consisting of fused silica, crystalline silica, zircon, mullite, alumina, calcined aluminosilicates, magnesia, chromia and magnesium silicate. For use in the ceramic slips of the subject invention, the grain size of the granular refractory should, most desirably, not exceed 100 microns nor should it be less than 0.1 micron.

The amount of aqueous colloidal silica sol or alumina coated sol used in relationship to the granular refractory may be varied over a relatively wide range. Usually, from about 20 percent to about 50 percent by weight of the aqueous silica sol material may be used and from about 50 percent to about 80 percent by weight of the granular refractory material. The weight ratio of sol vehicle to ceramic material usually should be maintained within the range of about 1 to 1 to about 1 to 3. It must be understood, however, that the weight ratio may vary depending upon a particular granular refractory which is used, as, obviously, some of the refractory materials named above are considerably more dense than others.

The ceramic slips which are useful in the subject invention are essentially the same as the ceramic slips which are used in the prior art method of ceramic shell manufacture, such as that described in U.S. Pat. No. 2,948,032 and such as are well-known to the prior art. The particular slip which is used is identical with that used in the prior art process. The novelty of the process of the subject invention lies in the freezing of the stuccoed slip and not in any variation of the slip itself.

The granular refractory material which is used in stuccoing the coated expendable pattern and in building up successive stuccoed layers should have a particle size within the range from about 50 to about 2000 microns and should be of a material which is compatible with the granular refractory material which is used in any particular slip which is being stuccoed.

Other ingredients, which are known to the prior art, such as compatible wetting agents, may be added to the ceramic slip to achieve better wetting of patterns and the resultant better surface of the finished shell mold.

Other materials, such as dyes, can be added to color the molds or to serve as indicators in the treatment of the molds. The addition of these auxiliary materials does not change the character of the slip or the stucco material in its ability to be frozen to build up the shell mold by the process of the subject invention. Therefore, these materials need not be described further.

After a sufficient number of refractory coats have been built up upon the expendable pattern material and have been frozen, the expendable pattern must be removed from the resultant ceramic shell. In the practice of the subject invention the expendable pattern is removed by heating the shell mold and the pattern to a temperature ranging from about 700° F. to about 2000° F. Where suitable equipment is available, it is preferred to conduct the pattern removal operation at a temperature ranging from about 1400° F. to about 1700° F. This removal of the pattern by the application of heat can be performed in a suitable furnace or in some other apparatus such as an infrared heating oven. Furnaces which can be used are of types which are typically used in foundries practicing the prior art method of shell mold investment casting and are well-known to the art. The particular apparatus which is used is not essential to the subject invention.

The invention will be better understood with reference to the following examples.

EXAMPLE I

A typical shell mold is made by the process of the subject invention as follows: 2500 milliliters of an aqueous colloidal silica sol having 30 percent SiO₂ by weight is placed in a 6 liter

steel beaker. 13.5 pounds of a granular fused silica having an SiO_2 content of 97.3 percent by weight and a thermal coefficient of expansion of about 5×10^{-7} cm./cm./°C., ground so that the largest particle present is no greater than 75 microns, is added using good mechanical stirring.

After the addition of the fused silica powder to the colloidal silica sol, the total volume of the slip is about 5 liters.

A clean wax pattern is dipped into the prepared slip and stuccoed with a fused silica grain having the same characteristics as the fused silica used in making the slip and having a particle size such that the smallest particle size of the granular fused silica is no smaller than 95 microns. The wax pattern, so treated, is immersed into a freezing chamber at -30°F . The coated pattern is held in the freezing chamber for a period of 10 minutes, removed, recoated with the slip and stucco and returned to the freezing chamber. The process is repeated until a total of five coats are deposited upon the wax pattern to form a frozen ceramic shell mold.

The coated pattern is placed in a melt-out oven, the temperature of which is approximately 1900°F . The wax is melted out of the shell mold within a period of a few minutes. The mold is held in the oven at temperature for approximately 15 minutes to decarburize the mold and remove any remaining residue from the wax. The mold is then removed from the oven and is ready to be used for the casting of metal.

EXAMPLE II

Another example of the preparation of a ceramic shell mold by the process of the subject invention is as follows:

A slip is made up using $2\frac{1}{2}$ gallons of an alumina coated silica sol having the physical characteristics given in Table I above and 50 pounds of -325 mesh tabular alumina.

The viscosity of the slip is adjusted by adding tabular alumina until a number five Zahn cup viscosity of 10 seconds is obtained. The slip is allowed to stand overnight with continuous agitation in order to reduce the number of air bubbles contained therein.

Wax patterns are dipped in the slip and stuccoed with $+70$ mesh tabular alumina. The stuccoed coatings are placed into a freezing chamber at a temperature of -10°F . and held for a period sufficient to completely freeze the coating, approximately 7 minutes. An additional stuccoed coat is added and frozen in place in the same manner and three backup coats are applied in the same manner, except that a $+100$ mesh calcined alumina silicate grog is used as a stucco material. The frozen stuccoed patterns are placed into a burnout oven where the wax patterns are removed completely from the ceramic shell mold. The shell mold is now ready to receive the molten metal to form a casting.

EXAMPLE III

Other ceramic shell molds, for use with various metals and utilizing various colloidal silica sols and alumina coated sols as binders and various granular refractory materials as replacements for the fused silica and tabular alumina of Examples I and II, are made in a manner similar to that described in Examples I and II. Lower freezing temperatures can be used to cut down the time necessary to freeze each stuccoed layer.

Freezing temperatures which are very much in excess of approximately -20°F . should not be used, as the time for freezing

will be lengthened to an excessive degree and the resultant frozen layers will not be as strong, as when the layers are frozen in a shorter period of time. Temperatures in excess of $+5^\circ\text{F}$. are impractical for use.

CONCLUSION

It can be seen by the foregoing Examples that the objects of the invention have been substantially realized. An improved process for making ceramic shell molds has been discovered whereby a composite mold can be made in much less time than was needed for the prior art process. A process has been discovered whereby stuccoed layers can be frozen on top of each other to form a composite ceramic shell mold in a short period of time.

The invention is hereby claimed as follows:

1. The process of producing a ceramic shell mold which comprises forming a ceramic shell by the steps of:

a. Coating an expendable pattern with a ceramic slip comprising an aqueous colloidal silica sol vehicle having a granular refractory material suspended therein,

b. Stuccoing the coated pattern with a dry portion of said granular refractory material to form a stuccoed layer,

c. Freezing the stuccoed layer at a temperature below $+5^\circ\text{F}$.,

d. Forming a plurality of superimposed similar layers on the pattern to form a frozen ceramic shell, and

e. Removing the pattern from the ceramic shell by heating the pattern to a temperature of at least 700°F . for a period of time sufficient to remove the pattern from the ceramic shell.

2. The process of claim 1 in which the granular refractory material is at least one member of the group consisting of fused silica, crystalline silica, zircon, mullite, alumina, calcined alumino-silicate, magnesia, chromia and magnesium silicate.

3. The process of claim 2 in which the refractory material is fused silica.

4. The process of producing a ceramic shell mold which comprises forming a ceramic shell by the steps of:

a. Coating an expendable pattern with a ceramic slip comprising an aqueous alumina coated colloidal silica sol vehicle having a granular refractory material suspended therein,

b. Stuccoing the coated pattern with a dry portion of said granular refractory material to form a stuccoed layer,

c. Freezing the stuccoed layer at a temperature below $+5^\circ\text{F}$.,

d. Forming a plurality of superimposed similar layers on the pattern to form a frozen ceramic shell, and

e. Removing the pattern from the ceramic shell by heating the pattern to a temperature of at least 700°F . for a period of time sufficient to remove the pattern from the ceramic shell.

5. The process of claim 4 in which the granular refractory material is at least one member of the group consisting of fused silica, crystalline silica, zircon, mullite, alumina, calcined alumino-silicate, magnesia, chromia and magnesium silicate.

6. The process of claim 5 in which the refractory material is alumina.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,583,468

Dated June 8, 1971

Inventor(s) Alan K. Cutler

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, Table I, underneath "pH", --Al₂O₃/SiO₂ Ratio--
should appear in first column of table

Signed and sealed this 2nd day of November 1971.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents