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(54) **Title**: DEWAX METHOD FOR INVESTMENT CASTING

(57) **Abstract**: A method for controlling the dewaxing of a ceramic investment casting shell assembly is provided whereby the shells are immersed in a fluid having a relatively low boiling point, e.g., below about 230F. The fluid must be hot enough to transfer heat though the shell assembly so as to melt the wax pattern, but low enough so as to limit steam generation as a result of moisture in the shell. By controlling the rate of immersion of the shell in the hot fluid bath, shell cracking can be greatly reduced.

DEWAX METHOD FOR INVESTMENT CASTING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Utility Application No. 13/269,773 filed on October 10, 2011 and U.S. Provisional Application No. 61/391,159 filed on October 8, 2010. The entire disclosure of which is incorporated herein by reference.

FIELD

[0002] This invention offers and improved method for removing wax from investment casting shells. This invention involves the use of both special heat transfer fluids and inverted directional solidification. Wax is removed with little or no stress on the shell. By using this technique, it is possible to remove several constraints placed on the investment caster that are in place to prevent or reduce shell cracking.

BACKGROUND

[0003] As noted in US Patent No. 7,926,542B2 to Yang, the entire disclosure of which is hereby incorporated by reference, precision investment casting generally involves the construction of a wax pattern assembly that is contained within a ceramic shell mold. The wax pattern assembly is removed from the ceramic shell mold and the resulting shell mold is subsequently filled with molten metal in a further step of the casting process. Removal of the wax pattern assembly from the ceramic shell mold may be effected through the use of heat that causes the wax to melt and thus drain out of the ceramic shell mold. The necessary heat may be obtained through placement of the wax pattern assembly and ceramic shell mold within a high-pressure steam autoclave. As an alternate method of imparting heat to the combination, flash firing may be performed. Although capable of heating and therefore removing the wax, such processes may induce stresses into the ceramic shell mold and cause cracking and other defects. The wax pattern assembly has a higher rate of thermal expansion than the ceramic shell mold in which it is located. Heating of these components thus causes greater thermal expansion in the wax than in the ceramic shell mold. Disproportionate thermal expansion of the wax pattern assembly induces a hoop type pressure and stress on the ceramic shell mold thus causing cracks during the dewaxing process that can ultimately lead to metal casting run-outs, metal finning or dimensional scrap.

[0004] Precision investment casting parts sometimes include ceramic cores located inside of the wax pattern assembly that often have a complex, nonsymmetrical shape. The thickness of the wax pattern between the ceramic core and the ceramic shell mold is different at different locations. Dewaxing of the wax pattern assembly through the use of an autoclave or by flash firing causes the entire wax pattern surface to heat at the same time. The ceramic core is thus subjected to different pressures at different locations thereon. Pressure differentials on the ceramic core may cause it to shift or break during the dewaxing process. Further, a pressure differential is realized between the portions of the wax pattern assembly near the pour cup and those located farthest from the pour cup. The presence of the pour cup allows pressure to be relieved at those portions of the wax pattern assembly near the pour cup while a greater pressure is imparted to the wax pattern assembly remote from the pour cup. This pressure differential may cause the ceramic core to become dislodged. In order to reduce defects caused by thermal expansion of the wax pattern assembly, the ceramic shell mold may be made of additional layers so that it is higher in strength and thus resistant to stresses imparted by the thermally expanded wax. However, the use of thicker ceramic shell molds may cause still further casting defects and scrap than if thinner ceramic shell molds were employed. In addition, the use of thicker ceramic shell molds may make certain parts difficult or impossible to cast and may increase the cost of the casting process as additional material and time is needed.

[0005] While each of the foregoing methods suffers from unique drawbacks, they all have one thing in common. Energy to melt the wax is applied in a relatively uniform manner at one time to the entire shell. This uniformity of applied energy has long been recognized as a problem leading to shell cracking. A method used to overcome the cracking caused by the uniform application of heat is the common use of two different waxes for patterns and gating. The gating wax typically is required to have a melt point 10° degrees Fahrenheit below that of the pattern wax to help reduce cracking of the shell from internal wax pressure. In addition to added costs, the use of two different waxes in the shell assembly also has the disadvantage of making wax reclaim and recycling more difficult.

[0006] In an effort to address some of the foregoing issues regarding the stresses caused by dewaxing, in his '542 patent, Yang proposed using a hot oil bath in a localized manner. More precisely, Yang describes a method which involves wetting the shell mold with water then immersing the saturated shell in a hot oil bath wherein the hot oil is above the boiling point of water and preferably well above the boiling point of water, e.g., between 300°F - 500°F. This in turn causes moisture in the shell to turn to steam and the steam is transferred to other portions of the shell causing hot zones of the shell. The heat occurring along the hot zones of the shell are transferred through the shell wall to the wax pattern causing it to melt. The steam generated under the Yang method moves inward from the shell wall thereby washing out the wax pattern to the center of the shell mold and out the pore cup. The use of steam is presented as a means of precluding the accumulation of wax on the shell walls.

[0007] While Yang has recognized an improvement upon other known methods of localized heating of ceramic shells, as will be described in further detail below, the Yang method requires significantly more energy transfer than the method of the present invention to accomplish similar results.

SUMMARY

[0008] The method described under the present invention removes the wax much differently than past methods of removing wax. Instead of applying energy uniformly to the entire shell at once, energy is applied to a well defined small horizontal band around the shell. The band is then progressively moved up the shell. This directional wax removal applies less stress to the ceramic shell because the entire wax is not being heated. Only a small portion of the wax is heated at one time and liquid wax merely runs out without building pressure.

[0009] If the internal wax stress is significantly lowered, shell cracking can be reduced, if not eliminated. Additionally, the constraints used to make the autoclave or flash fire dewax process work acceptably, could be removed. That is to say, an engineer is no longer bound by the past ways of constructing a shell or by using normal methods for dewax crack prevention. Some of the advantages of employing the methods disclosed herein include reducing or eliminating the need for:

[0010] High number of dips and/or extreme shell thickness.

[0011] Different melting point waxes.

[0012] Improved wax reclamation.

[0013] Shell reinforcement using wax, wire, ceramic string, ceramic rods, for example.

[0014] Dewax vents.

[0015] Patching of cracks in the shell.

[0016] Inclusions in the casting due to shell cracks and patching.

[0017] Furthermore, it may be possible to use completely different waxes than are currently used. For example, waxes that have high thermal conductivity are desirable for quick set up time after wax injection, but they are not used because they do poorly in the currently employed dewax processes. This constraint is removed and the investment casting engineer has greater freedom to select more advantageous waxes for use employing the currently presented method.

[0018] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0019] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0020] Fig 1 is a side schematic view of a prior art method of dewaxing a ceramic shell mold; and

[0021] Fig. 2 is a side schematic view of the process and apparatus of ceramic shell dewaxing according to the present invention.

[0022] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0023] The present invention related to an improved method of dewaxing ceramic shell molds to reduce, if not eliminate, mold cracking. While it is believed that shell molds of various shapes, sizes and compositions would be useful according to methods of the present invention, those having refractory compositions inclusive of one or more of the following materials should benefit patentably: zircon, zirconia, yttria, alumina, alumina silicates, and fused silica and combinations thereof. Useful shell binders include colloidal silica, ethyl silicate, ammonium zirconium carbonate, zirconium acetate, colloidal alumina, colloidal zirconia, colloidal yttria, sodium and potassium silicate, and alumina coated colloidal silica, by way of non-limiting example.

[0024] In order to fully demonstrate the feasibility of the dewax method according to the teachings of the present invention, a prototype machine was designed and built for directional wax removal. Initial data was generated employing a hot oil bath such as that taught by Yang. The temperature of the oil and the speed of lowering the shell into the oil were variable. A method of keeping the wax separate from the oil was also evaluated in this work.

[0025] Dewax test pieces were prepared to shell and run in the prototype equipment of the present invention and in standard dewax processes for comparison. A suitable test piece would need to crack in the standard process and not in the directional dewax process. Thus, dewax test pieces were constructed employing a specific wax pattern with different samples having varying shell thickness and shell types. Again, it was thought that shells would crack in either autoclave or flash fire dewax, but not in the directional melting process employing hot oil. Note that both the cone and gating were formed to have sharp edges to intentionally promote cracking. The wax in the cone must travel through a restriction to flow out of the shell.

[0026] Waxes were injected and assembled at IMDS Cencast in Molalla, Oregon. Some waxes were shelled at Cencast and some at Calcagno Foundry in Boring, Oregon. Those shells to be autoclaved were processed at Ti-Squared Technologies in Sweet Home, Oregon. The directional hot oil dewax was done using the prototype equipment at Buntrock Technology Lab in Portland, Oregon.

[0027] All wax assemblies had double prime dips at Cencast. Those receiving Fibercoat 1109 backup were dipped also at Cencast. Dip sequences were 2 primes + 2 or 3 Backups + seal. Thinner shells were made with one less backup. Standard fused silica backup shell was applied in a similar fashion at Calcagno Foundry. All backup stucco was 30x50 fused silica.

[0028] After the waxes were dipped and de-waxed, they were burned out to remove residual wax, oil, and carbon. They were then inspected visually with a magnifying glass for through wall cracks and also each cone was removed and sectioned. Interior cracks of the cone were counted. Observations were also made regarding cracking on the gating.

[0029] **<u>Results</u>**

Backup Shell	Number BU Dips	Avg. Shell Thickness	Type of Dewax	Outside Cracks	Inside Cracks	Gating Cracks
FC1109	2	0.25	Flash Fire	0	7	N/A
	2	0.25	Autoclave	0	0	N/A
	2	0.25	Directional	0	0	N/A
Fused Silica	3	0.25	Flashfire	13	32	N/A
	3	0.25	Autoclave	0	0	2
	3	0.25	Directional	0	0	3

[0030] Both autoclave and directional melting proved to be better than flash fire dewax and Fibercoat 1109 was much better than the fused silica shell system when flash fire dewaxing was carried out. It is clear that this test wax assembly did not discriminate between autoclave and directional dewax.

[0031] Two more shells were made but only in the fused silica shell. One less dip was applied making the shell thinner. In addition, the wax gate was restricted in size by about 50%. One shell was dewaxed in the autoclave and one in the directional melting equipment employing hot oil as the heat transfer fluid.

[0032] The results of these two trial molds are presented below.

Backup Shell	Number BU Dips	Avg. Shell Thickness	Type of Dewax	Outside Cracks	Inside Cracks	Gating Cracks
Fused Silica	2	0.17	Autoclave	2	2	12
	2	0.17	Directional	0	7	2

[0033] The autoclaved fused silica shell had one cone that was severely cracked across and around the top. All of the restricted gates of the autoclaved shell were cracked while two cracked in the directional melting dewax method employing hot oil. Thus, while directional heating employing hot oil demonstrated an improvement over other known methods, the method has its own perceived drawbacks. For example, hot oil does not offer highly efficient heat transfer and thus must be run at high temperatures. This in turn leads to higher energy consumption. Additionally, by intentionally generating steam above the immersion lever of the hot oil as depicted in Fig. 1 and described by Yang, true localized heating of the shell is compromised. It is clear that an improvement was still needed.

[0034] It was mentioned earlier that these experiments also evaluated a method to keep the wax and hot oil separate in order to facilitate easier reclamation of the wax. The wax assemblies were clamped securely onto the platform to be lowered into the hot fluid. As part of the equipment design there was a hole in the platform directly below the cup area of the assembly. A tube was secured to the hole such that the melted out wax would flow through the tube and out the exit end into a bucket or tray for collecting the wax. It was observed that at the start of the cycle, very good quality wax was coming over and being collected in the bucket. However, as the cycle proceeded and more wax was evacuated from the shell assemblies, some of the hot oil was penetrating through the permeable shell walls and was coming over with the wax into the bucket. Since the hot oil had a different composition from the wax, this was very undesirable, as the mix of the hot oil with the wax would make the wax reclamation much more difficult.

[0035] With all of this data at hand which proved the inventors' theory that directional heating could be utilized more efficiently than other known methods, the method of the present invention was evaluated.

[0036] A system and assembly as shown in Fig. 2, including an aqueous bath 10, a pour cup 12 and a collection area (not shown) for the reclaimed wax pattern material is employed. The system further includes a ceramic shell mold 20 having a selectively disposable wax pattern 30 contained therein. The aqueous bath is filled with a sufficient amount of hot water to selectively submerge the shell mold and wax pattern as the bath is advanced over the shell. Through experimentation, it was found that an average advancement rate of about one inch per minute proved suitable based on the wax pattern compositions utilized. The rate at which the shell can be immersed in the hot fluid generally ranges from about 0.2 inches/minute to about 5.0 inches/minute depending on investment shell casting composition and shell thickness, the wax pattern material thickness and the overall shape of the shell design.

[0037] Hot water was used and evaluated at 190°F, 195°F, and 200°F, respectively. The objective was to use a high enough temperature to transfer enough heat to the shell, but to avoid the generation of steam. All of these trials were successful when the shell assemblies were gradually lowered at an average rate of about one inch per minute. With this additional methodology, the wax could be readily reclaimed and recycled. An additional enhancement is to add a soluble salt to the water such as calcium chloride, sodium chloride, potassium nitrate, ferric chloride, etc. Dissolution of the soluble salt into the water raises the boiling point of the fluid such that higher temperatures can be utilized, e.g., up to about 230°F. At temperatures over 230°F and the risk of steam being generated occurs. All of the above-mentioned salts are readily available and fairly low in cost; and the wax can be readily separated for reclaim and recycling.

[0038] One additional technique was evaluated to further enhance the directional dewax method of the present invention. Shells were first moistened by dipping in a bucket of water prior to mounting in the aqueous bath apparatus. A large fan (not shown) was installed over the top of the hot fluid bath. This served to keep the upper portion of the shell assembly cool and the evaporation of the water from the shell assembly limited. Additional techniques such as shielding the upper part of the shell assemblies from the radiant heat could also be employed. However, the technique of first moistening the shells with water and using the fan was quite sufficient to keep the upper part of the shell assemblies cool and prevent shell cracking.

[0039] Gradual lowering of the shell assemblies into the hot fluid, can be accomplished by placing the shell assemblies in the apparatus on a fixed platform and gradually filling the tank with the hot fluid. This can easily be achieved by either a valve and/or a restricted pipe connection enabling the gradual filling of the tank with the hot fluid.

[0040] While water, optionally treated with a soluble salt, heated and maintained at a temperature below its boiling point has been identified as a preferred solution to carry out gradual shell heating under the present invention, still other solutions such as hot wax similar to that used for the was pattern or dimethyl silicone may also be employed.

[0041] In additional to a cost advantage, the use of hot water instead of hot oil as taught by Yang, offers an additional advantage because of its higher heat capacity. The specific heat of hot oil or hot wax is around 0.5; this means that for each pound of fluid (hot oil) which loses one degree Fahrenheit of temperature, only 0.5 BTU's of energy are available to heat the shell and melt out the wax. Water, on the other hand, has a specific heat of 1.0; this means that for each pound of hot water which loses one degree Fahrenheit of temperature, a full BTU of energy is available to heat the shell and melt out the wax. Thus, the water facilitates a more efficient transfer of energy and this helps account for its successful use at lower temperatures than either hot oil or hot wax.

[0042] A further advantage of using the hot water bath is that the heating is more controlled and more localized. This more controlled and more localized heating from the hot water creates less stress on the shell as the wax is being melted out at a more controlled interface, essentially only at or below the level of the hot water immersion. Since the hot oil method as taught by Yang generates steam from the moisture in the shell, its heating zone encompasses an area well above the immersion level.

[0043] Note that the hot zone where the wax is melting (as indicated by D) is more directional and more confined with the hot water system of the present invention as compared to Yang which has a broader hot zone. Since the wax is expanding when melting out, there is less stress being applied to the shell in the hot water bath due to D being shorter in length as depicted in Fig. 2 (the present invention) as compared to Fig. 1 (prior art).

[0044] The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

CLAIMS

What is claimed is:

1. A method for dewaxing a casting shell assembly including a wax pattern, said method comprising the steps of:
   a) providing a bath containing a fluid heated above the melting point of the wax pattern but below a boiling point temperature of about 230°; and
   b) means for immersing the casting shell assembly into the hot fluid at a controlled rate of speed to melt away the wax pattern.

2. The method of claim 1 in which the hot fluid is water.

3. The method of claim 2 wherein the hot water is heated to a temperature of between about 190°F and 230°F.

4. The method of claim 3 wherein the hot water is heated to a temperature of between about 190°F and 210°F.

5. The method of claim 2 in which a soluble salt is added to the water to enable higher operating temperatures.

6. The method of claim 1 in which the shell is moistened with water prior to immersion in the hot fluid.

7. The method of claim 6 in which a fan is added to the apparatus to further cool the non-immersed portion of the shell assembly.

8. The method of claim 1 in which the hot fluid is di methyl silicone.

9. The method of claim 1 in which the hot fluid is a wax having the same composition as that of the wax pattern.

10. The method of claim 1 wherein the rate of immersion of the shell assemblies into the hot fluid is between about 0.2 inches/minute and about 5.0 inches/minute.

11. A system for dewaxing comprising:

a ceramic shell mold;

a wax pattern located within the ceramic shell mold;

a hot fluid bath maintained at a temperature below about 230°F but above the melting point temperature of the wax pattern, and configured to receive the ceramic shell mold therein;

a pour cup engaging the ceramic shell mold and arranged such that melted wax of the wax pattern flows out of the ceramic shell mold and through the pour cup, and

means for immersing the ceramic shell mold within the hot fluid bath at a controlled rate of speed.

12. The system of claim 11 in which the hot fluid is water.

13. The system of claim 12 wherein the hot water is heated to a temperature of between about 190°F and 230°F.

14. The system of claim 13 wherein the hot water is heated to a temperature of between about 190°F and 210°F.

15. The system of claim 12 in which a soluble salt is added to the water to enable higher operating temperatures.

16. The system of claim 11 in which the shell is moistened with water prior to immersion in the hot fluid.

17. The system of claim 16 in which a fan is added to the apparatus to further cool the non-immersed portion of the shell assembly.

18. The system of claim 11 in which the hot fluid is di methyl silicone.

19. The system of claim 11 in which the hot fluid is a wax having the same composition as that of the wax pattern.

20. The system of claim 11 wherein the rate of immersion of the shell assemblies into the hot fluid is between about 0.2 inches/minute and about 5.0 inches/minute.

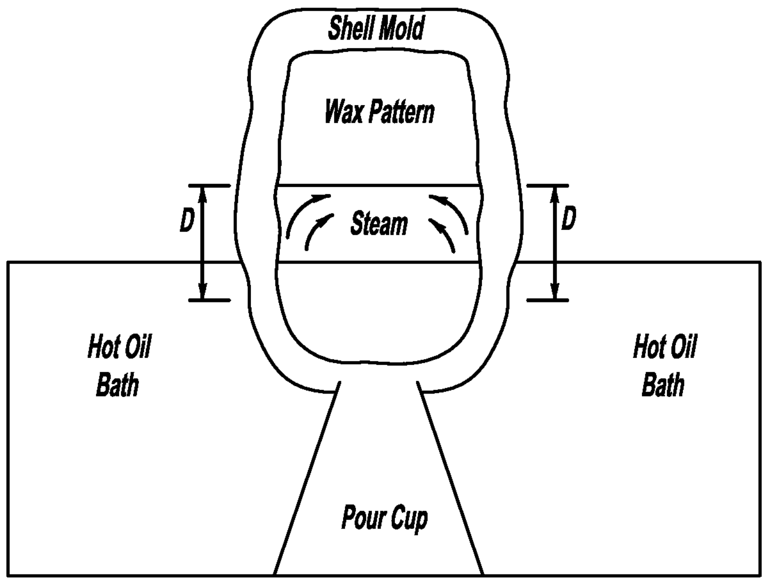

FIG - 1
Prior Art

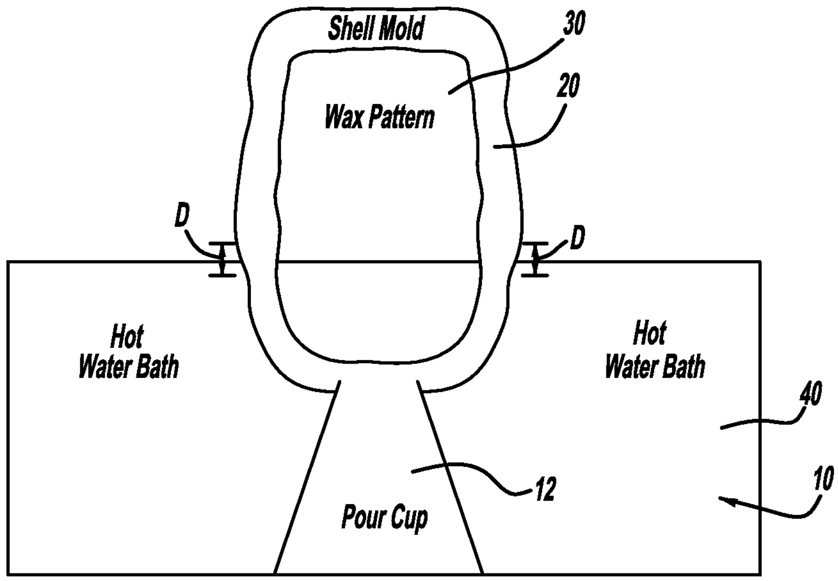

FIG - 2