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EFFECT OF PROCESS PERAMETERS ON MECHANICAL PROPERTIES OF THE INVESTMENT CASTING PRODUCED BY EXPANDEBLE POLYSTERINE PATTERN

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Abstract

Abstract this paper is concerned with the investigation of mechanical properties of A713 alloy castings produced by investment casting process using expandable polystyrene as the pattern material and the plaster of paris asthe mould material. Experiments were conducted as per Taguchi's L9 orthogonal array. Castings were made under the constraint of different process parameters like mould firing temperature, pouring temperature, firing time and mixing of silica sand of different grain fineness numbers to investigate their effects on the surface hardness, impact strength and tensile strength of the final castings. The variations in the trend of the aforesaid mechanical properties were observed and it was deduced out that high mould firing temperature, higher pouring temperature, maximum firing time and high grain fineness number significantly reduce the mechanical properties of A713 alloy castings produced.

Key Words: *Method of casting process1, Experimental procedure2*

1. INTRODUCTION

Modern investment casting techniques stem from the development in the United Kingdom of shell process utilizing wax patterns known as the Investment X Process. This method resolved the problem of wax removal by enveloping a completed and dried shell in a vapor degreaser. The vapor permeated the shell to dissolve and melt the wax. This process has been evolved over years into the current process of melting out the virgin wax in an autoclave.

The process is suitable for repeatable production of net shape components, from a variety of different metals and high performance alloys. Although generally used for small castings, this process has been used to produce steel castings of up to 300 kg and aluminum castings of up to 30 kg. Compared to other casting processes such as die casting or sand casting it can be an expensive process, however the components that can be produced using investment casting can incorporate intricate contours, and in most cases the components are cast near net shape, so requiring little or no rework once cast.

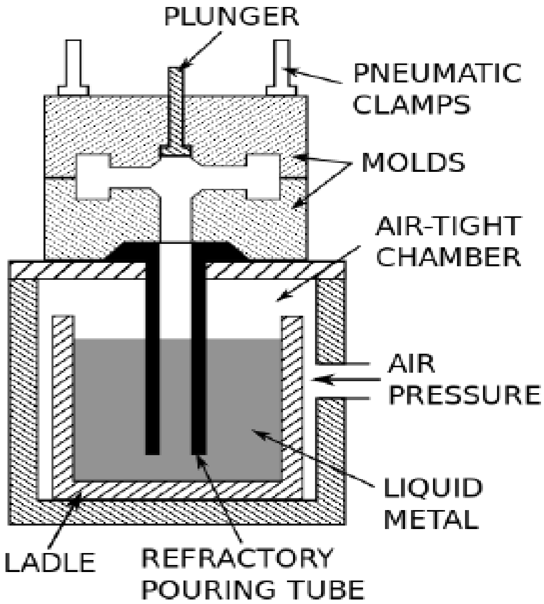
The Investment Casting industry, is one of the principal suppliers of precision net shape components to several markets, including: Aerospace, Automotive, Medical, Commercial

1.1 Different types of casting process

1. Investment casting
2. Permanent mold casting
3. Centrifugal casting
4. Continuous casting
5. Sand casting

Investment casting (known as lost-wax casting in art) is a process that has been practiced for thousands of years, with lost wax process being one of the oldest known metal forming techniques. From 5000 years ago, when bees wax formed the pattern, to today's high technology waxes, refractory materials and specialist alloys, the castings ensure high quality components are produced with the key benefits of accuracy, repeatability, versatility and integrity.

1.2. Permanent mould casting



Permanent mold casting (typically for non-ferrous metals) requires a set-up time on the order of weeks to prepare a steel tool, after which production rates of 5-50 pieces/hr-mold are achieved with an upper mass limit of 9 kg per iron alloy item (cf., up to 135 kg for many nonferrous metal parts) and a lower limit of about 0.1 kg. Steel cavities are coated with a refractory wash of acetylene soot before processing to allow easy removal of the work piece and promote longer tool life. Permanent molds have a limited life before wearing out. Worn molds require either refinishing or replacement. Cast parts from a permanent mold generally show 20% increase in tensile strength and 30% increase in elongation as compared to the products of sand casting.

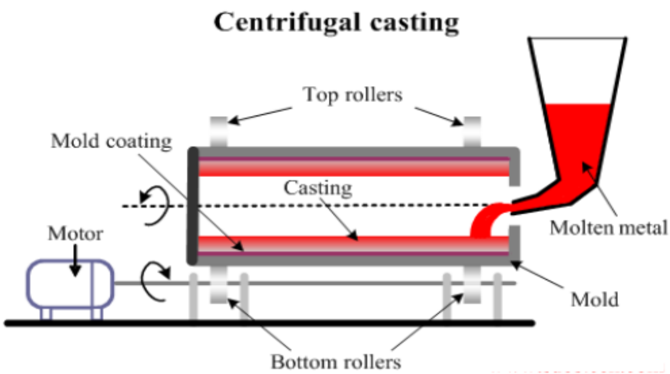
Sub-types of permanent mold casting

1. Gravity Die Casting.
2. Low pressure die casting.(LPDC)
3. High pressure die casting.(PDC)

1.3 Centrifugal die casting

Centrifugal casting is both gravity- and pressure-independent since it creates its own force feed using a temporary sand mold held in a spinning chamber at up to 900 N (90 g). Lead time varies with the application. Semi- and true-centrifugal processing permit 30-50 pieces/hr-mold to be produced, with a practical limit for batch processing of approximately 9000 kg total mass with a typical per-item limit of 2.3-4.5 kg.

Industrially, the centrifugal casting of railway wheels was an early application of the method developed by German industrial company Krupp and this capability enabled the rapid growth of the enterprise.

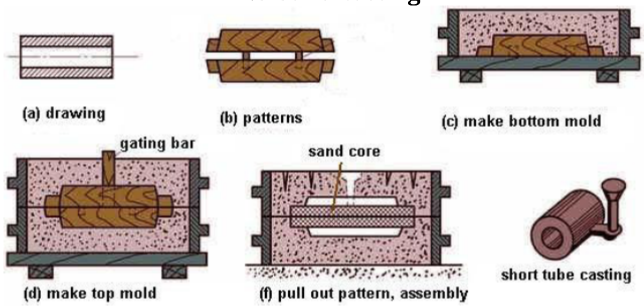


1.4 Continuous casting

Continuous casting is a refinement of the casting process for the continuous, high-volume production of metal sections with a constant cross-section. Molten metal is poured into an open-ended, water-cooled copper mold, which allows a 'skin' of solid metal to form over the still-liquid centre. The strand, as it is now called, is withdrawn from the mold and passed into a chamber of rollers and water sprays; the rollers support the thin skin of the strand while the sprays remove heat from the strand, gradually solidifying the strand from the outside in. After solidification, predetermined lengths of the strand are cut off by either mechanical shears or travelling oxyacetylene torches and transferred to further forming processes, or to a stockpile. Cast sizes can range from strip (a few millimeters thick by about five meters wide) to billets (90 to 160 mm square) to slabs (1.25 m wide by 230 mm thick). Sometimes, the strand may undergo an initial hot rolling process before being cut.

Continuous casting is used due to the lower costs associated with continuous production of a standard product, and also increases the quality of the final product. Metals such as steel, copper and aluminium are continuously cast, with steel being the metal with the greatest tonnages cast using this method.

1.5 Sand casting



Sand casting is one of the most popular and simplest types of casting that has been used for centuries. Sand casting allows for smaller batches to be made compared to permanent mold casting and a very reasonable cost. Not only does this method allow for manufacturers to create products for a good cost there are other benefits to sand casting such as there are very little size operations. From castings that fit in the palm of your hand to train beds (one casting can create the entire bed for one rail car) it can be done with sand casting. Sand casting also allows for most metals to be cast depending in the the type of sand used for the molds.

Sand casting requires a lead time of days for production at high output rates (1-20 pieces/hr-mold), and is unsurpassed for large-part production. Green (moist) sand has almost no part weight limit, whereas dry sand has a practical part mass limit of 2300-2700 kg. Minimum part weight ranges from 0.075-0.1 kg. The sand is bonded together using clays (as in green sand) or chemical binders, or polymerized oils (such as motor oil.) Sand in most operations can be recycled many times and requires little additional input.

2. EXPERIMENTAL PROCEDURES

2.1 Additive materials

From the problem identification phase in conventional investment casting process it is shown that improvement required in coating stage. So we focus on the coating stage and the slurry additives as the slurry or shell properties required, as below

Properties of Shell / Mould materials

a. The material should have refractory properties.
b. It should be thermally stable i.e. dimension changes on heating should be minimal.
c. Chemical compatibility with other mould materials and metal to be cast is important.
d. It should resist hot deformation, i.e. the material should not become soft at molten metal temperatures, and deform.
e. Good bonding properties.
f. Low cost and easy availability of consistent quality material is also important.

As per the required properties of mould following are the materials which can be used as additives in the slurry.

Refractory properties:- Aluminum oxide, Graphite, Chromium carbide, Calcium carbonate, Magnesium oxide, Lanthanum hex boride, Niobium carbide, Tantalum carbide, Vanadium carbide, Yttria-stabilized zirconia.

Bonding properties:- Silica fume, Fly ash, Metakaolin, Rice husk ash, Calcium silicate hydrate, Ground granulated blast furnace slag.

As above mentioned materials, requirement of bonding agent and thermally stable & refractory properties Calcium carbonate(caco3) and Fly-ash are most suitable materials which also cheap and easily available. There properties are as below:-

Properties of Calcium carbonate (Caco3):-

Calcium carbonate is a chemical compound with the formula $CaCO_3$. It is a common substance found in rocks in all parts of the world, and is the main component of shells of marine organisms, snails, coal balls, pearls, and eggshells. Calcium carbonate is the active ingredient in agricultural lime, and is created when Ca ions in hard water react with carbonate ions creating lime scale.

Calcium carbonate is prepared from calcium oxide. Water is added to give calcium hydroxide, and carbon dioxide is passed through this solution to precipitate the desired calcium carbonate, referred to in the industry as precipitated calcium carbonate (PCC)

$$CaCO_3 \rightarrow CaO + CO_2$$
$$CaO + H_2O \rightarrow Ca(OH)_2$$
$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

2.2 Slurry Characterization

The slurry used for producing investment shell molds has a major effect on mould properties. The materials used to make the slurry govern the mould's reaction to temperature changes and its rate of heat transfer from the molten metal. For these experiments, fused silica based materials were selected for both the slurry's binder and solids so that material ratios did not become a variable.

The properties of the slurry have a direct effect on the formation and structure of a mould. The viscosity of the slurry affects the surface tension of the slurry coating the patterns, with higher viscosity slurries producing thicker slurry layers within the mould's structure. By controlling the slurry viscosity, the slurry-stucco layering was replicated nearly uniform through the thickness of all samples.

2.3 Slurry Preparation

The ceramic slurry to build the investment moulds consisted of a mixture of fused silica flour in a colloidal silica binder. The binder used was Dioctyl sodium sulphosuccinate (Aerosol OT) which contained 45wt% amorphous silica and < 1wt% sodium hydroxide in a water solution. The flour and binder were combined in a 2:1 weigh ratio giving a 4.44:1 solids ratio. Initial, high shear mixing of the ingredients was done using a 333rpm1/40HP, DC motor until no clumps of flour were visible. Once all the flour was adequately dispersed into the binder, the bucket was placed onto a plate rotating 15.7RPM with a scraper bar, to maintain a constant low shear rate to keep the solids from settling.

2.4 Slurry Parameter Control.

After preparation, the slurry was left under low shear stirring for a minimum of 12 hours to allow air bubbles, introduced during flour addition, to float out. Once the entrapped air had escaped the slurry and the slurry's viscosity had stabilized, rheological testing was started.

2.5 Steps by Step Procedure

Step 1:- Make a pattern of wax

We make the pattern which is round bar has a length 3"& diameter 0.8" pattern of wax by using injection molding machine. In the machine sate the temperature of wax 126oF and the pressure at 120 Kgf/cm2. We made 8 no. of patterns of same size.

Step 2:- Visual inspection & repairing work of wax pattern

After ejection from injection molding machine the pattern is cooled in water. Then visual inspection is done on pattern and if defects found on the surface of pattern then it is repaired. Also burr cleaning on the pattern for give it smooth surface finish to the pattern.

Step 3:- Making pattern cluster/ Tree

We made pattern cluster of 2 no. of pattern around the Gate system with a pouring cup which is used for flowing the material during pouring. Wax components are assembled by wax welding, using hot iron or spatula which heated by electric heater. Wax at the interface between two components is quickly melted, and the components are pressed together until the wax solidifies 4 no. of pattern cluster generated.

Step 4:- Primary coating

We dipped all pattern cluster in liquid slurry that contains colloidal silica and zircon flour. The wet layer is immediately stuccoed with coarser ceramic particles by ‘raining’ on it the stucco particles. The fine ceramic layer forms the outer face of the mould, and reproduces every detail, including the smooth surface of the pattern. It also contains the bonding agent, which provides strength to the structure.

Step 5:- Drying period

After primary coated the pattern than it kept at controlled temperature at 21oC and relative humidity 52% for the period of two hours.

Step 6:- Secondary coating

After the primary coating is applied secondary coating is applied which is used to provide high strength, and to build up the required thickness with a minimum number of coats. it contains the coarser ceramic slurry and then after stucco coats are applied. As per the company standard of no. of coating layers required based upon the weight of cluster.

Table no 2.1

Part weight	Coat required	Shell thickness required
0.010 to .250 Kg	7 to 8	8 to9 mm
0.251 to 2 Kg	8 to9	10 to 11 mm
2 to 10 Kg	9 to 11	12 to 14 mm
10 to 40 Kg	11 to 13	17 to 18 mm
40 to 100 Kg	14 to 16	20 to 22 mm

Weight of our part is 245gm so as per the company standard 8 no. of layers are required.
For that purpose we gave names to the cluster A, B, C, D.
Where the cluster A refers to 8 no. of layers in conventional slurry
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- The cluster B refers to 8 no. of layers
- The cluster C refers to 7 no. of layers
- The cluster D refers to 6 no. of layers

These 3 layers are immersed in our slurry which contains 10% Caco3 & 3% fly-ash.

Table no: - 2.2

Name of cluster	3080 sand	1630 sand
Cluster A	4	4
Cluster B	4	4
Cluster C	3	4
Cluster D	2	4

Step 7:- Drying period

After secondary coated the shell mold dried to a period of 2 to 212 hours. As coating layers are increases then drying time also increases.

Step 8:- Repeat the secondary coating

One pattern tree of conventional composition slurry is applied 8 subsequent coating layer and shell is created. In other patterns no. of layers are repeated as
Per above table

Step 9:- Hot liquid dewaxing

Hot liquid Dew axing has found minimum capital investment. Hot wax at 185 °C is often used as the medium, while other liquids can also be used. At this temperature wax liquidize and drain out from the shell mold and cavity generated in it. Cycles are longer than for autoclave and flash dewaxing.

Step 10:- Shell sintering

After the Dew axing of mould the shell are kept for preheating in gas fired furnace at 1190^{0}C for 1 hour.

Step 11:- metal pouring

The preheated shells are then poured with CF8 material which melted at 1625^{0}C temperature.

3. CONCLUSION

An additional drawback to traditional method is that require the pattern to be dipped in to a refractory slurry then coated with dry refractory grains, over and over until the desired shell thickness is obtained typically, shells are gradually built up to a thickness of approximately 1/8 inch or more tp attempt to prevent defects form appearing in the final part. Such defects typically result from the shell shrinking, sagging or cracking. It is not uncommon in industry to use seven or more layers per shell. For some application, the coats are applied with conventional manual dipping but for much application including larger volume industrial application, such as manual dipping is prohibitively. As a result costly robotic manipulator may be required for dipping, thus serving as another barrier to those user who could otherwise effectively employ investment casting method. The authors can acknowledge any person/authorities in this section. This is not mandatory.

The improvement shell slurry composition and corresponding method minimizes patterns to pour cycle times and also must be is environmentally friendly.

Following processes are become in conventional method of investment casting the processes and consumed time are given below table.

Table No 3. Name and time required for operation

Sr.No.	Operation name	Consumed time (min.)
1.	Pattern making	5-10
2.	Make cluster(tree)	10-15 (Depend on no. of pattern are join)
3.	Ceramic coating process	1200-1320 (Including drying time)
4.	Dewaxing	10-15
5.	Pre-heating of shell	60
6.	Pouring	60-120 (Depend on size of shell)
7.	Knock-out	5-10
8.	Cut-off	10-15
9.	Finishing operation	15-20
Total time (min.)		1530

From the time required calculation we observed that around 86% of total time conceded in the coating process. So we focused on the phase and believed that if this time is reduced in some layer in coating process than the time, material, manpower, and money can be saved. It will also affect the profit of the industry.

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