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OPTIMIZATION OF IN PROCESS PARAMETERS OF INVESTMENT CASTING

Mr. Abhishek Chandrakar[1], Mr. Avnish Panigrahi[2].

[1]*Department of Production Engg., GDRCET , Bhilai, Chhattisgarh Swami Vivekanand Technical University, India.*
[2]*Assistant Professor, GDRCET , Bhilai, Chhattisgarh Swami Vivekanand Technical University, India.*
[1]abhishek_15october@yahoo.com [2]avnish111@gmail.com

***Abstract*— Investment casting process, also known as lost wax process, is utilized when complex detail, undercuts or non-machinable features and accurate parts are desired. It begins with a wax pattern which is an exact replica of the as cast part. So the properties of the wax patterns are ultimately passed on to the castings. The confirmation tests with optimal levels of process parameters are carried out to illustrate the efficacy of the proposed method. The optimization results revealed that a overall improvement in the quality of the castings. It has also been established that there is some quality loss in terms of surface finish of the wax patterns in multi response optimization as compared to single response optimization, though an overall improvement in the process is being observed.**

***Keywords*— "Investment Castings, Injection Temperature, Wax Preparation, Slurry Viscosity."**

I. INTRODUCTION

Investment casting is also known as the "lost-wax" process, is regarded as a precision casting process to fabricate near-net-shaped metal parts from almost any alloy. The process begins with preparation of the wax patterns for every casting made. Wax is injected into an aluminium or steel die to produce a pattern that is an exact replica of the part to be produced. The patterns are clustered around a sprue. The cluster is dipped into a ceramic slurry made by suspending fine ceramic materials in silica-sol. The excess liquid is allowed to drain off from patterns, and then fine zircon sands are stuccoed on this ceramic coating. Thus a small shell is formed around the wax patterns. After drying, this process of dipping and stuccoing is repeated again and again, using progressively coarser grades of ceramic material, until a self-supporting shell has been formed. It takes approximately 5 to10 days to make the mould. When a shell thickness of approximately 6 to 10mm has been built, the moulds are dewaxed by autoclaving (pressure and steam). This leaves a ceramic shell containing cavities of the casting shape desired with passages leading to them. The hollow shells are then preheated to 900-1200^0 C, depending on the alloy to be poured and the molten metal cast immediately into the hot shell. After cooling, the ceramic is vibrated and blasted off the metal parts and discarded. The balance of the cleaning operations (cut off, grind, heat treat, straightening, blast) are straight forward and quite similar to the other casting processes.

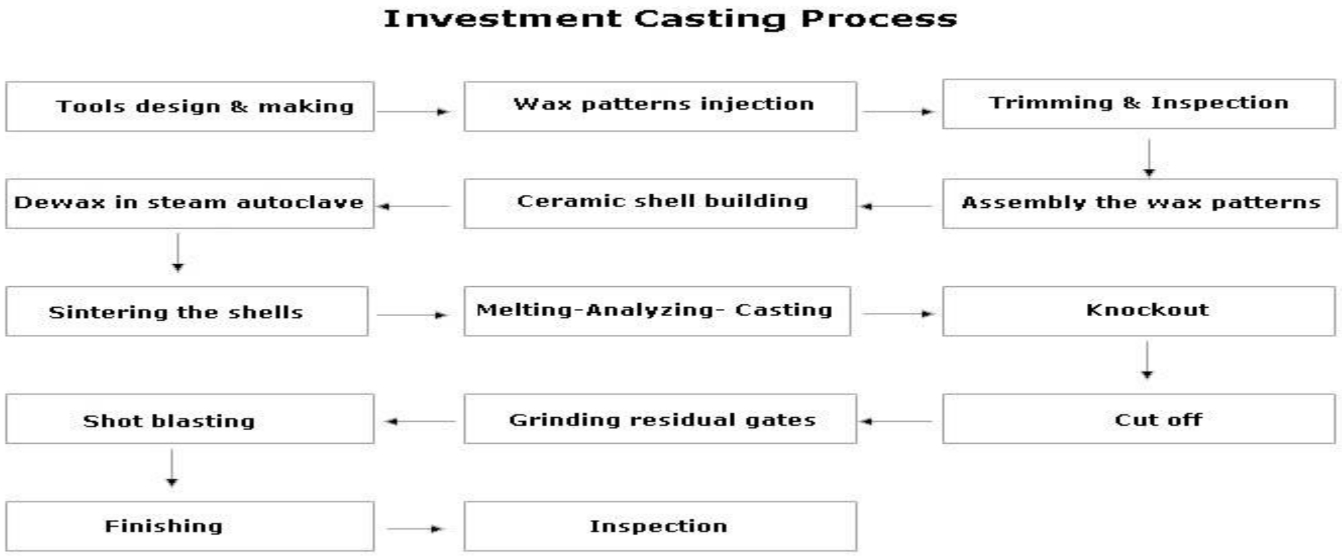

FIG 1

II. PROBLEM STATEMENT

Investment casting industry is one of the foremost suppliers of castings to the steel making pumps and railways product development industry. The manufacturer of sand castings is required to meet the quality requirements set forth by the engineering product development industry, failing which defective castings impose a financial burden on the manufacturer due to rejections. Hence this research proposes an effective methodology aimed at validating the results of investment castings process with these suitable experimentation. The effective implementation of the proposed methodology in the alloy steel casting industry would reduce the cost, save time, and enhance the manufacturers reputation in respect of quality.

III. METHODOLOGY

THERMAL ANALYSIS OF WAXES : The thermal analysis techniques used for measuring the effect of temperature on the blend sample are Thermo- Gravimetric Analysis (TGA), Differential Thermo- Gravimetric (DTG) and Differential Thermal Analysis (DTA). DTA is a technique which measures the difference in heat gained or lost by the sample, in comparison to a reference temperature during a temperature ramp. Temperature changes in the sample are due to endothermic or exothermic enthalpy transition or reaction such as those caused by phase changes, fusion, sublimation etc. DTG measures the loss in weight of a sample as it is heated. TGA is widely used to separate and quantify the components in a mixture.

Table No. 01: Differential Thermal Analysis results.

Wax type	Heating rate ^{0}C	Loss of material (%)	Melting temperature ^{0}C
Pattern Wax	5	0	65
Paraffin Wax	5	0.2	64
Riser Wax	5	0.3	66

The thermal technique provides information concerning the thermal stability and composition of the sample and of any intermediate compound. The results obtained from DTA are summarized in Table no. 01.

PATTERN PRODUCTION:

The four types of waxes are mixed together to produce different wax blends. The molten wax is then injected into the die. The die is heated up to 48^{0}C before injecting the wax and the wax injection temperature was raised up to 70^{0}C. After injecting the wax into the die, it is cooled down to the room temperature. Then the pattern is removed from the die.

Table No. 02: Range of process parameters

Process Parameters	Range
Injection temperature	60-70 ^{0}C
Die temperature	44-48 ^{0}C
Injection Force	440N-540N
Holding Time	7min – 11 min

The parameters customarily controlled include wax temperature, injection temperature and injection pressure, die temperature, holding time. The selected range of the process parameters is shown in the Table no. 02.

THE PROCESS PARAMETER :

In process parameters of investment castings process are
1. Wax injection temperature.
2. Wax Proportion.
3. Slurry Viscosity.
4. Boiler Pressure & Temperature.
5. Preheating Furnace Temperature & Duration.

The typical system made by industry found typical casting defects which has increased percentage of rejection and which has affected productivity. In order to reduce percentage of rejection it was decided to follow standard gating ratio as per ISO in foundry technology.

The rate of flow of molten metal through the sprue is a function of the cross sectional areas of the sprue, runners and in gates. Gating ratios recommended by various theoreticians in the literature vary over a wide range. The process parameters characteristics area for existing process parameters at industry from where data has been taken.

Table No. 03: Existing process parameters

SL. No.	Parameters	Existing System
1	Wax Temperature	75^0 C
2	Viscosity	12 PA-S
3	Boiler Pressure	10 BAR

Experiments were conducted with different types of waxes namely Paraffin wax, Pattern wax and Riser wax, varying their proportions and stirring time. In each case properties of wax pattern like surface roughness and percentage shrinkage (linear/volumetric) were determined. Using the data obtained from the experiments an attempt is made to find out the set of input parameters, which could offer a set of ideal properties of the wax blend. Taguchi method was used to optimize the process parameters.

Table No. 04: Gives the properties of the waxes used in the present study.

S.No	Name of Wax	Density(gm/cc)	Melting point ^{0}C	Volumetric shrinkage (%)
1	Pattern Wax	0.97	65	7.25
2	Paraffin Wax	0.78	64	6.3
3	Riser Wax	1.02	82	4.2

There are two main shrinkage allowances to be considered: the die-to-wax shrinkage and the casting solidification shrinkage. If these allowances are not correct and the final cast-part tolerances are not met, then additional cost and time are incurred because the tooling must be reworked. It is, therefore, very important to ensure that all the appropriate factors are considered when applying the shrinkage allowances. Wax patterns are generally injected at relatively low temperatures and pressures in split dies, using equipment specifically designed for this purpose.

Measurement of properties: After the pattern production the following properties are measured.
a] Linear shrinkage
Linear shrinkage can be calculated by measuring the difference between die dimensions and pattern dimensions produced.
b] Volumetric shrinkage
The Volumetric shrinkage is calculated as follows:
Apply a coating of grease on two halves of die to make it leak-proof from water and align the two- halves of die together.
Fill the die cavity with water and measure its volume with the help of a measuring flask. (V_D)
Fill water in a measuring flask and note the initial reading. (V_i)
Place the wax patterns made inside the measuring flask, volume rises and take the final reading. (V_f)

The difference between the two readings ($V_f - V_i$) gives the volume pattern.
The percentage of volumetric contraction of the pattern is given by

$$\{V_D - (V_f - V_i)\} / V_D \times 100$$

Volumetric coefficient of thermal expansion is calculated by the relationship as shown.

$$\Delta V = \beta . V_i (T_i - T_f)$$

Where, ΔV = change in volume
β = volumetric coefficient of thermal expansion
V_i= initial volume,
T_i = initial temperature.
T_f = final temperature.

IV. RESULTS & DISCUSSION

From the experiments conducted, each wax blend under different set of process parameters exhibited different properties. Yet, there exists a set of process parameters which could offer a set of ideal properties. Hence, an attempt is made to determine the optimum set of process parameters using Taguchi method. It is one of the most important tool for studying the effect of various input process parameters. For a particular defect in a wax pattern production, the number of causes contributing to the defect.
In such a case the traditional experimental design methods are too complex and difficult to use. Moreover, a large number of experiments are to be conducted that are too time consuming and expensive.

Table No. 03: Range and levels of input process parameters

Factors	LEVEL 1 (L1)	LEVEL 2 (L2)	LEVEL 3 (L3)
Injection temperature (A)	66	68	70
Die temperature (B)	44	46	48
Injection force (C)	440	490	540
Holding time (D)	09	10	11

After conducting the experiments it is observed that wax blend having combination 2,2,3,3 is giving minimum shrinkage and better surface roughness. Taguchi optimization technique was applied to wax blend and the analysis of result was carried on Minitab version 16. This software helps to draw graphs and counter plots for different input parameters and response variables.

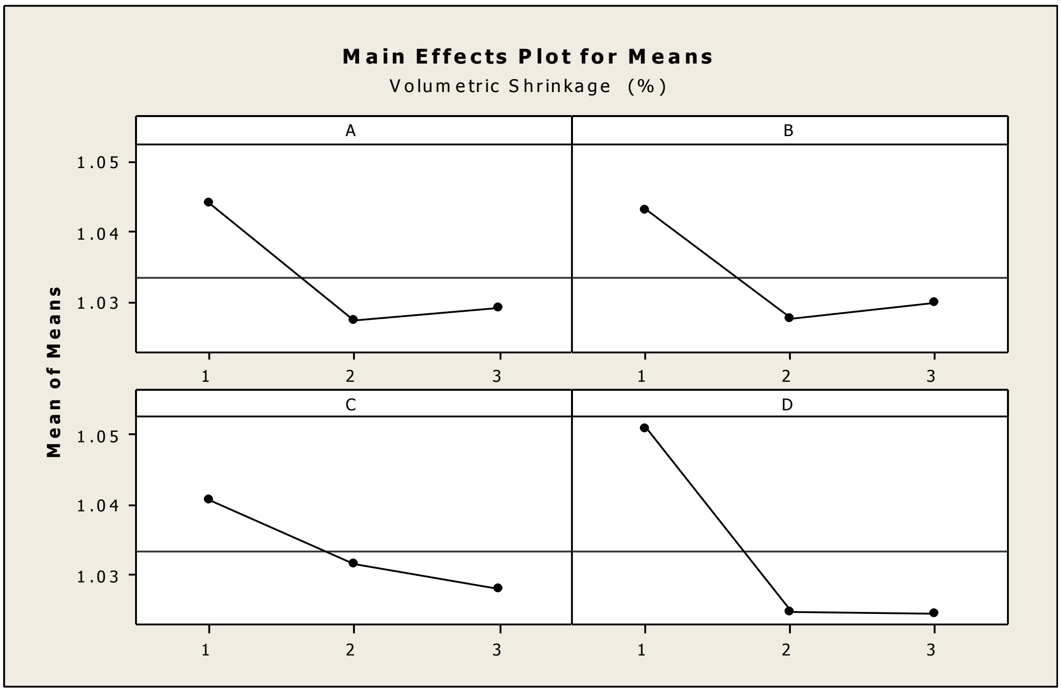

Fig 2

From the graph of injection temperature

(A), it is observed that, as injection temperature increases at 68^{0}C it gives better results but further increase in injection temperature increases the linear shrinkage, volumetric shrinkage and surface roughness. For graph of die temperature (B), it is observed that at 46^{0}C it is giving better results. Similarly for graph of injection force (C) and holding time (D), it is observed that these graphs give better results at 540 N and 11 minutes respectively.

V. CONCLUSIONS

The wax blend 2 with proportion of 50% pattern wax, 30% paraffin wax, 20% Riser wax and 0% carnauba wax gives the better results of linear shrinkage, volumetric shrinkage and surface roughness.

The optimized process parameters (using Taguchi method) are: 68^{0}C (injection temperature), 46^{0}C (die temperature), 540 N (injection force) and 11 minutes (holding time).

If the conventional method is used to carry out the experiments then for the selected process parameter we have to do the experiment for their selected ranges. Thus, we need to conduct more experiments which are time consuming. So, it better to use the technique which reduces the number of experiments to be carried out and optimizes the process parameters.

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