Optimization of Process Parameters In Cold Chamber Die Casting Process Using Taguchi Method

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Abstract- *Die casting is an easy and simplest form of producing large quantity product. High Pressure die casting process is a process ideally suited to manufacture mass produced metallic parts of complex shapes requiring precise dimensions. In this process, molten metal is forced in to empty cavity of desired shape and is allowed to solidify under high holding pressure. Die casting is a complex process which is controlled by many parameters such as die related parameters, machine related parameters, which has direct impact on casting quality. Improper settings of these parameters end up in producing quality related issues in the casting. One such issue is blow holes and porosity which is caused by improper setting of process parameters. In this paper an industrial component having blow hole problem has been taken. This study proposes application of Taguchi methodology in identifying the optimum process parameters in order to improve the casting quality. Process parameters such as holding furnace temperature, slow shot, Fast shot, Die holding time, Intensification pressure has been selected for optimization. The response factor (quality characteristic) chosen is density of the casting. Density of the casting is chosen as a quality characteristic since it has direct relationship with casting defects. Generally denser the casting lesser the internal defects such as porosity, blow holes etc. Besides all this, final results were validated by both experimental and casting simulation.*

Keywords- Cold Chamber, Die casting, Foundry,Density of the material, Taguchi and ANOVA.

I. INTRODUCTION

In manufacturing processes, there are various parameters with different adjustment levels, which may influence the final characteristics of the product. To optimize a manufacturing process, the trial and error method is used to identify the best parameters to manufacture a quality product. However, this method demands extensive experimental work and results in a great waste of time and money. Thus, optimization methods appear to be an important tool for continuous and rapid improvements. These experimental methods may be employed to solve problems related to a manufacturing process, and understand the influence of various factors on the final quality of a given product.

Die casting is a moulding process in which the molten metal is injected under high pressure and velocity into a split mould die. It is also called pressure die casting. The split mould used under this type of casting is reusable. Die casting is categorized two types namely- hot chamber and cold chamber as shown in Fig.1. Metals like Zinc, tin and lead alloys are casted in hot chamber die casting having melting point below 3900℃ whereas aluminum alloys are casted in cold chamber die casting machine. Aluminum dissolves ferrous parts in the die chamber and hence preferred to be used in cold chamber die casting. Continuous contact of molten metal is avoided by using a ladle for introducing molten metal directly to the machine.

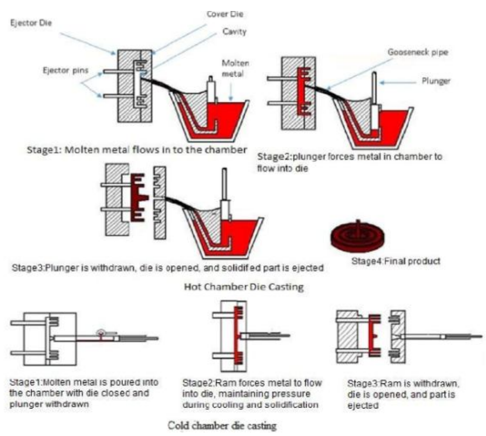

FIG.1. Outline of production steps in a typical cold chamber die casting operation

II. COLD CHAMBER DIE CASTING OPERATIONAL PARAMETER

The die casting process is controlled by several parameters. When properly determined and adjusted, they result in an improvement in quality of the die casting parts. Usually, the main controlled variables are metal temperature, slow shot, and fast shot, intensification pressure, die holding time, chemical composition of metal. G.O. Verran et al. (2008) has analysed the effects of slow shot, Fast shot, and Intensification pressure on casting density. The results indicate that the injection parameters affect the casting density to a greater extent. Similarly V.D. Tsoukalas (2008) has analysed effects of die casting process parameters on porosity formation using genetic algorithm. The results reveal that under optimized conditions porosity formation is very less. P. Vijian et al. (2006) has applied Taguchi method for optimizing the parameters in squeeze casting in order to minimize surface roughness.

In this study optimization of die casting parameters using Taguchi methodology was carried out to solve the blow hole problem in an aluminium component named 'Front Wheel Hub I'. The material is AlSi9MnMg alloy.

The component has high rejection rate due to the occurrence of blow hole problem. Especially the critical area of the casting shown in Fig.2 has more number of blow hole occurrence compared to the other areas of the casting.[4]

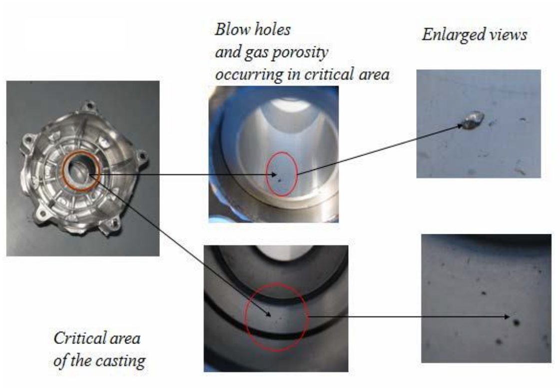

Fig.2 Blow holes in 'Front Wheel Hub I casting'

III. TAGUCHI PARAMETER DESIGN

Taguchi parameter design provides a means of both reducing cost and improving quality by making effective use of experimental design methods. This involves the determination of parameter values that are least sensitive to noise .When the goal is to design a process or product with high stability and reliability, parameter design is the most important step in which the functional non linearity is used to best advantage. Initially parameters that are to be optimized are chosen carefully. A cause and effect diagram can be used for identifying the parameters that affects the response. In this study, casting density has been chosen as a response, since if the casting density is higher, lower the internal defects such as blow holes and porosity. A cause and effect diagram drawn for blow holes in casting is shown in figure 3.

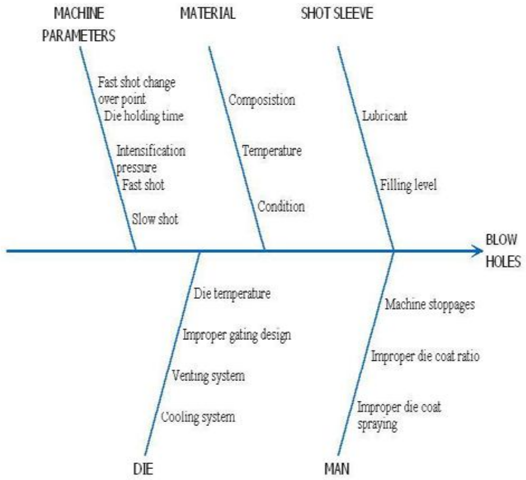

Figure.3. Cause and effect diagram for blow holes

After analyzing the cause and effect diagram, and checking the various parameters, die casting machine parameters such as Metal temperature (A), Slow shot(B), Fast shot(C),Intensification pressure(D), Die holding time(E), have been selected for the analysis of the blow hole problem in casting. Interactions were also considered between parameters Metal temperature, slow shot, Fast Shot. The ranges for the chosen factors were selected based upon preliminary trials conducted during process validation. The ranges for the selected factors are shown in Table 1.

Table.1. Selected Taguchi design parameters and their ranges

S.No	Parameters Destination	Parameters	Range	Level 1	Level 2	Level 3
1	A	Metal temperature (°C)	640-680	640	660	680
2	B	Slow Shot (m/s)	0.12-0.22	0.12	0.17	0.22
3	C	Fast shot (m/s)	1.92-2.42	1.92	2.17	2.42
4	D	Die holding time (seconds)	8-10	8	9	10
5	E	Intensification pressure (kg/cm^2)	270-290	270	280	290

The selection of orthogonal array depends upon the degrees of freedom of the factors and the three interactions that have been considered. An orthogonal array is selected with 9 experimental runs and five columns. Taguchi has provided in the assignment of factors and interaction to arrays. The assigned L9 orthogonal array is shown in Table 2 and the experimental orthogonal array having their levels are assigned to columns is shown in Table 3.

Table.2. L_9 Orthogonal array

Trail No.	A	B	C	D	E
1	1	1	1	1	1
2	1	3	1	1	2
3	1	2	1	1	3
4	2	1	2	3	1
5	2	3	2	3	2
6	2	2	2	3	3
7	3	1	3	2	1
8	3	3	3	2	2
9	3	2	3	2	3

IV. EXPERIMENTAL ORTHOGONAL ARRAY

Formation of an orthogonal array depends upon the number of control factors and interaction of interest. It also depends upon number of levels for the control factors of interest. Therefore with one control factor Metal temperature (°C) of two levels and other control factors Slow Shot (m/s), Fast shot (m/s) , Die holding time (seconds) and orthogonal array is selected with 9 experimental runs and five columns. Taguchi has provided in the assignment of factors and interaction to arrays. The assigned L9 orthogonal array is shown in Table 2 and the experimental orthogonal array having their levels are assigned to columns is shown in Table 3.

Table -3 EXPERIMENTAL ORTHOGONAL ARRAY L9

Trial No.	A Metal temperature (°C)	B Slow Shot (m/s)	C Fast shot (m/s)	D Die holding time (seconds)	E Intensification pressure (kg/cm^2)
1	640	0.12	1.92	8	270
2	640	0.22	1.92	8	280
3	640	0.17	1.92	8	290
4	660	0.12	2.17	10	270
5	660	0.22	2.17	10	280
6	660	0.17	2.17	10	290
7	680	0.12	2.42	9	270
8	680	0.22	2.42	9	280
9	680	0.17	2.42	9	290

The density of the castings were measured based upon the Archimedes principle. Before measuring the density of the casting, care was taken that casting is completely free from the burr or any dust in order to avoid errors in the measurement. Belavendram(10). Belavendram The castings were first weighed in air and then weighed when completely immersed in water. All the weighings were done by using electronic weighing machine having accuracy up to 100 mg. Ko Ta Chiang et al.(2009). The density measurement of each casting was measuredthrice in order to avoid any errors. The density of the casting were calculated based upon the formula

$$\rho = \{w_1 / (w_1 - w_2)\} \times \rho_{water}$$

Where ρ = density of the casting (gm/cm^3)
w_1= weight of the casting in air (grams)
w_2= weight of the casting in water (grams)
ρ_{water} = density of water (1 gm/cm^3)

V. MATERIAL AND METHODOLOGY

Mild steel or low carbon steel is mostly used alloy steels for making most of the industrial products.The main components involved in mild steels are as follows: Carbo,Silicon,Manganese,Sulphur,Phosphorus,Nickle,Chromium,Molebdenum,Tungsten and Vanadium as alloying elements.

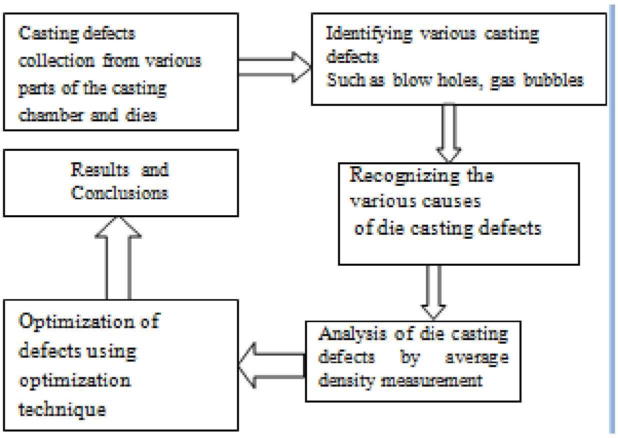

Fig. 4 METHODOLOGY

VI. OPTIMIZATION OF PROCESS PARAMETERS IN COLD CHAMBER DIE CASTING

The density of the casting was measured by Archimedes principle and the results are shown below. Minitab 14 software has been used to carry out Taguchi optimization .The response value is taken as average density of the three sample castings that were cast under each trail condition. Then S/N ratio were computed based upon the formula S/N ratio for

larger the better characteristics =**-10 log (1/r Σ (1/y_i^2))**

where r -number of observations, yi -Response value for each trail. The experimental results are shown in table 4.

VII. RESULTS OF EXPERIMENT & S/N RATIO

The result of this experiments is obtained by conducting thrice for the same set of parameters using a single-repetition randomization technique .The density that occur in each trial conditions were found and recorded. The average of the material density was also determined for each trial condition as shown in Table 4. The average density are “larger the better” type of quality characteristics. Larger the better S/N ratios were computed for each of the 9 trials and the values are given in Table 4:

Table -4 Experimental results with S/N Ratio

Trial No.	Density (g/cm³)			Average Density	S/N Ratio
	1	2	3		
1	2.578	2.583	2.584	2.581	8.236
2	2.581	2.587	2.587	2.585	8.249
3	2.591	2.592	2.592	2.592	8.273
4	2.584	2.589	2.590	2.587	8.256
5	2.588	2.592	2.594	2.592	8.273
6	2.578	2.582	2.584	2.581	8.236
7	2.588	2.593	2.595	2.592	8.273
8	2.577	2.584	2.584	2.582	8.239
9	2.582	2.588	2.589	2.586	8.253

VIII. MEAN EFFECT PLOTS TABLE FOR S/N RATIO

Table-5 for the mean effects plots for S/N Ratio is as Follows:

Level No.	Metal temperature (°C)	Mean S/N Ratio	Slow Shot (m/s)	Mean S/N Ratio
1	640	8.252	0.12	8.255
2	660	8.255	0.17	8.254
3	680	8.255	0.22	8.253
Level No.	Fast shot (m/s)	Mean S/N Ratio	Die holding time (seconds)	Mean S/N Ratio
1	1.92	8.252	8	8.252
2	2.17	8.255	9	8.255
3	2.42	8.255	10	8.255

Table-5 Values of mean S/N Ratio for different parameters

Level No.	Intensification pressure (kg/cm²)	Mean S/N Ratio
1	270	8.255
2	280	8.253
3	290	8.254

IX. MEAN EFFECT GRAPHS FOR S/N RATIO

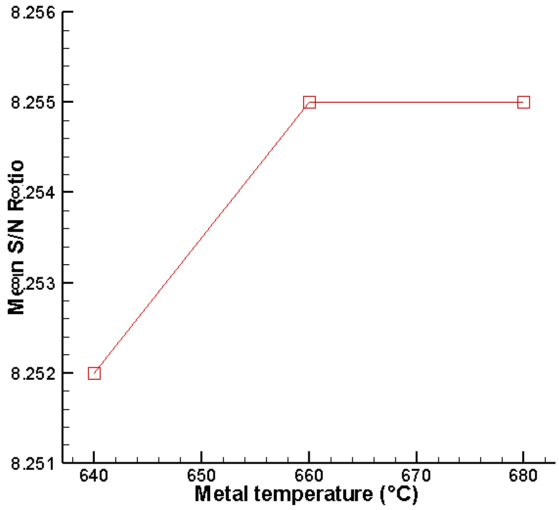

Fig .5 Metal temperature (°C) vs Mean S/N Ratio

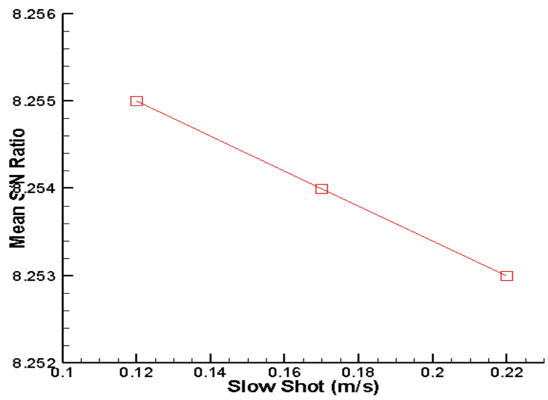

Fig .6 Metal temperature (°C) vs Mean S/N Ratio

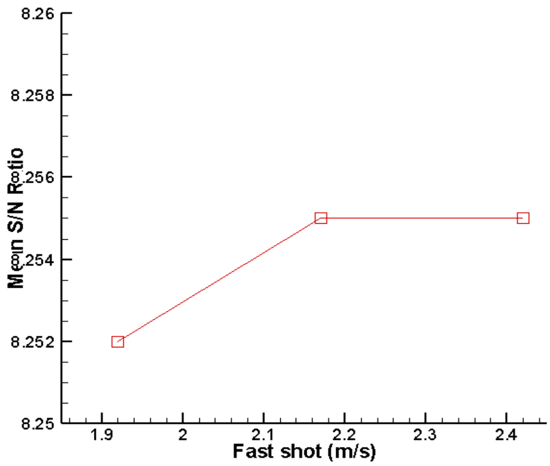

Fig .7 Metal temperature (°C) vs Mean S/N Ratio

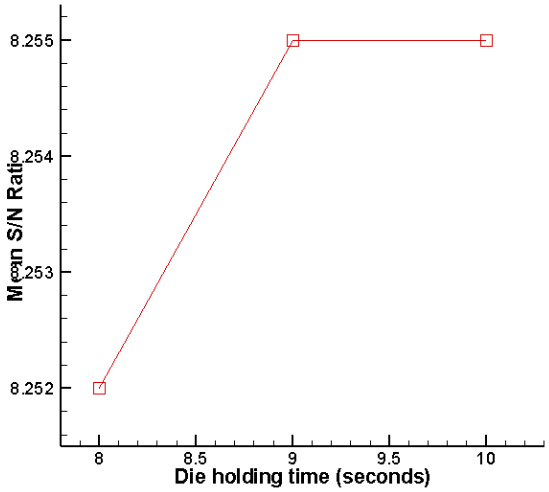

Fig .8 Metal temperature (°C) vs Mean S/N Ratio

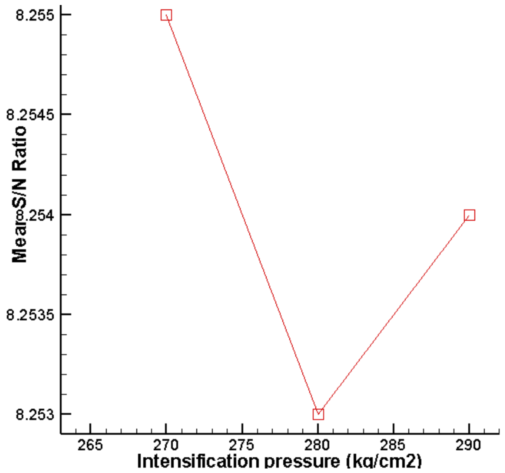

Fig .9 Metal temperature (°C) vs Mean S/N Ratio

X. CONCLUSION

The optimum conditions for the parameter computed for the cold chamber die casting process by the help of graphs and experiment are found in trail no.4 which values are given as-

Metal temperature (°C) – level 2 – 660
Slow Shot (m/s) – level 1 – 0.12
Fast shot (m/s)– level 2 – 2.17
Die holding time (seconds)– level 3 – 10
Intensification pressure (kg/cm2)– level 1 – 270

The improvement expected in minimizing the variation is 18 % which means reduction of casting defects from the present of 61% to 43% of the total casting product in the foundry. This also reflect that by using Taguchi method the factor levels when optimized will result in reduction of casting defects and increase the yield percentage of the accepted casting without any additional investment. A usage of quality tools like pareto chart is useful for finding the major defects in the daily operations of foundry. Quality of casting can be improved by aesthetic look, dimensional accuracy, better understanding of noise factor and interaction between variables, quality cost system based on individual product, scrap reduction, reworking of casting and process control.

XI. FUTURE SCOPE

The present method adopted to solve the optimization problem of Casting process is simple enough and is flexible in selection of objective functions for such manufacturing processes. During the solution of the problem, it has been found that the results obtained by the Taguchi method towards the exact solutions. This approach may be coupled to other optimization algorithms to get multistage multi-criterion optimization by Taguchi approach. Then this method will be able to show its importance in real life complex manufacturing problem solution.

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