Parameter Optimization of Sand Casting Process by using Taguchi Method

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***Abstract* - In this paper taguchi method is used for the optimisation of significant parameters of Spheroidal Graphite sand casting process. The parameter considered are moulding sand, mould and molten metal related parameter like moisture content, green compression strength, mould hardness, AFS No. of sand. The attempt has been made to obtain optimal setting of the process parameter in order to improve quality of the process. The DoE, signal-to-noise (S/N) ratio and analysis of mean are used to investigate the effect of the selected process parameter and their level on the casting defects. The selected process parameter significantly affect the defects of the spheroidal graphite sand casting process. As per DoE, experiment is done and verify the results, which shows the taguchi method is efficient to determine the optimal value of process parameter.**

Index Terms - Taguchi method, spheroidal graphite, sand casting process, casting defects.

I. Introduction

Sand casting is one of the oldest and mostly used casting process. It is also easiest casting process. In sand casting large weight of casting can produce. The sand casting processes divided in the four stages pattern making, mould making, melting metal. Pattern which is replica of the end product is created with help of machining. Mould is made from using mixture of sand, water, clay and binder. Pattern is placed in moulding box and mixture of sand fill into box and rammed with help of jolting and squeezing machine after pattern is removed and molten metal is poured into the mould cavity and allowed for the solidify. After solidified box is breaking and unwanted material removed from end product. It passes to shot blasting process to remove the stacked sand.

In sand casting process, casting suffers from poor quality and productivity due to the large number of process parameters, combined with lower penetration of manufacturing automation and shortage of skilled workers compared to other industries and also even in a completely controlled process, defects in casting are observed and hence casting process is also known as process of uncertainty which challenges explanation about the cause of casting defects.

Casting defects analysis is process of finding the root cause of occurrence of defects in the rejection of casting and taking necessary steps to reduce the defects and to improve the casting yield. Taguchi method is used for analysis casting defects like sand and mould related defects such as sand drop, bad mould, blow holes, cuts and washes [1].

II. Literature review

Kumar et al. [2] this work presents a study on various sand casting parameters which affect the casting qualities. The following parameters affect the quality Moisture, Green strength, Pouring temperature, Mould hardness vertical, Mould hardness horizontal. all this parameters affect both the mean and variance of the casting defects, and also shows the optimal settings of each parameter to reduce the casting defects and improves the quality of castings at low cost. Guharaja et al.[3] improving the quality by Taguchi's method of parameter design at the lowest possible cost, it is possible to identify the optimum levels of signal factors at which the noise factors' effect on the response parameters is less. The outcome of this paper is the optimised process parameters of the green sand castings process which leads to minimum casting defects.

Rahul C. Bhedasgaonkar and Uday dabade [4] studied that, the green sand related process parameters considered are, moisture content, green compression strength, and permeability of moulding sand and mould hardness. Optimized levels of selected process parameters obtained by Taguchi method are: moisture content: 4.7%, green compression strength: 1400gm/cm^2, permeability number: 140 and mould hardness number: 85. Haq et al. [5] made an attempt to obtain optimal settings of CO_2 casting process parameters using taguchi method. P.Vijian and V.P.Arunachalam [6] made an attempt to obtain optimal settings of squeeze casting process parameters using taguchi method.

A. Reddy et al. [7] studied taguchi method optimisation of deep drawing process parameter. Optimisation of parameter were taken as punch radius, blank holding force, and die radius. The Taguchi method can be used to identify the most significant forming parameter affecting deep drawing. A.

Bharatish et al. [8] studied that, circularity of drilled hole at the entry and exit, heat affected zone in alumina ceramics material. Based on ANOVA (taguchi method), both entrance and exit circularities were significantly influenced by laser power and hole diameter. Gunasegaram et al. [9] studied and concluded that, DoE is a powerful tool for identifying a set of process factors (parameters) which are most important to the process and then determine at what levels these factors must be kept to optimize the response (or quality characteristic) of interest.it also provides more information than one-change-at-a-time traditional experimental methods, because it allows a judgment on the significance of not only input variables or factors acting alone (main effect), but also factors acting in combination with one another (interactions). This is because, when the factors are changed simultaneously, any influence that one factor has on the other becomes apparent in the resulting response. Any such interaction involving two- or three-factor is called a "2^{nd} order" or "3rd order" effect respectively, and so on. The process parameter taken for DoE tilt time (7-11.5-16), inlet temperature (650-710), mould coat/heat transfer coefficient, in gate geometry mould flame temperature.

Ziaulhaq et al. [10] studied that, process parameter effected on surface of al-alloy sand casting process. Parameter were, Pouring temperature (670-750), moisture content (3-5%), mould hardness (70-90), mould pre-heat temp. (100-200) based on taguchi method, sand parameter process was optimised. Lakshamanan Singaram [11] studied different optimisation techniques like taguchi method and artificial neural network. Based on this optimisation techniques, moisture content (2-4) % GCS (700-1200) g/cm2 mould hardness (60-100) this parameter were optimised. Kanthavel et al. [12] investigated chill performance on steel casting (steel ball valve). For investigation of chill performance, the experiments were performed using DoE and response surface method. The parameters were taken chill distance, chill thickness, pouring temperature, pouring time.

Singh et al. [13] concluded that, it is discovered that the pouring temperatures and the permeability of moulding sand significantly affect the mechanical properties of sand casted aluminium alloy. With the increasing the pouring temperature and permeability of sand, the hardness was increased due to increasing the cooling rate of molten metal resulting in formation of fine grain structure of aluminium alloy cast. When the pouring temperature increased, the ASTM number is increased, so the fine grain of aluminium alloy cast was formed. When the permeability of sand increased, the ASTM number of microstructure was increased. So the fine grain was formed.

III. TAGUCHI METHOD

Taguchi recommends the achievement of a robust process or product design. A robust process or product is one whose response is least sensitive to all noise factors. The aim is fulfilled by considering the "signal-to-noise" ratio (S/N ratio) as the measure of performance. Of course, a mathematical analysis is available to support the above. However according to it, each product or process performance characteristic would have a target or nominal value. The parameter design of the Taguchi method involves determining the design parameter's settings for a product or a process so that the product's response has the minimum variation and its mean is close to the target. Experimental design is used in this method to arrange the design parameters and noise factors in the orthogonal arrays. The signal-to-noise (SN) ratio is computed for each experimental combination. Next, SN ratios are analysed to determine the optimal settings (i.e. control factors and their levels) of the design parameters. However, a large number of different S/N ratios have been defined for a variety of problems, with the problem under study for minimizing casting defects.

S/N ratio $(\eta) = -10 \log10 [(\sum y^2_i)/n]$
where n=number of replications

This is termed a smaller-the-better type problem where minimization of the characteristic is intended.

The methodology used to achieve optimized process parameters using DoE is as given below:

1) Select any defect observed due to sand and mould. Set to target to achieve, "Lower Casting defects" by the adjusting the process parameters.
2) Select the most significant parameters influencing defects in casting by cause effect diagram.

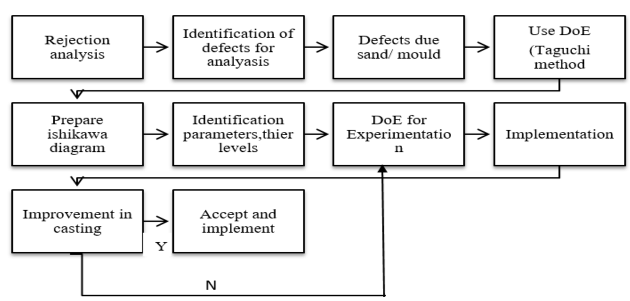

Fig.1 Flow chart of analysis of casting defects using DoE method.

3) Select the parameters and their levels. Perform the experiments (trial castings) as per DoE (Taguchi method) and collect the data.

4) Analyse the data using statistical tools. An analysis of variance (ANOVA) can be obtained to determine the statistical significance of the parameters. Means plots can be plotted to determine the preferred levels of parameters considered for experimentation.
5) Select optimum levels of control parameters, perform confirmation experiments and implement the process [4].

A. Process parameter of green sand casting

An ishikawa diagram (cause and effect diagram) was constructed as shown in Fig.2 to identify the casting process parameters that may influence green sand casting defects. The process parameters can be listed in five categories as follows [2]:

1) Mould-machine-related parameters
2) Cast-metal-related parameters.
3) Green-sand-related parameters
4) Mould-related parameters
5) Shake-out-related parameters

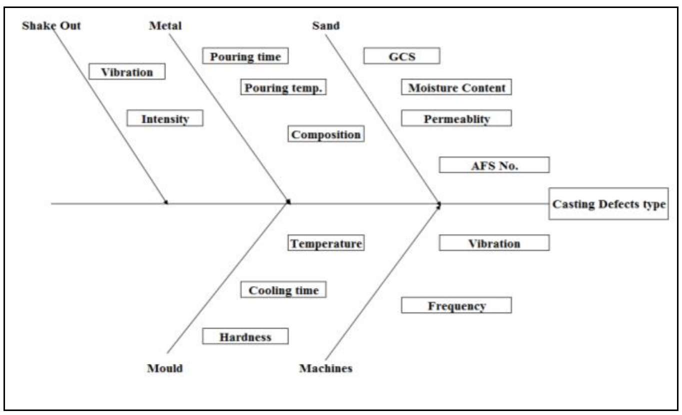

Fig. 2 Cause and effect diagram.

To visualize the effect of process parameters on the casting defects of SG iron casting, following parameters are selected:

1) Moisture Content (%)
2) Green Compression Strength (g/cm2)
3) AFS No.
4) Mould Hardness (No)

The range of moisture content selected as 3.0%–3.5%, the green compression strength selected as 1250gm/cm^2-1320gm/cm^2, AFS No. selected as 55-65 and the mould hardness number selected as 70–90. The selected green sand casting process parameters, along with their ranges, are given in TABLE I.

TABLE I
PROCESS PARAMETER WITH THEIR RANGES AND VALUES AT THREE LEVELS

Parameter designation	Process Parameter	Range	Level 1	Leve l 2	Level 3
A	Moisture Content (%)	3-3.5	3.0	3.3	3.5
B	Green Compression Strength (g/cm^2)	1250-1320	1250	1285	1320
C	AFS No.	55-65	55	60	65
D	Mould Hardness (No)	70-90	70	80	90

B. Selection of Orthogonal Array

Before selecting a particular orthogonal array to be used for conducting the experiments, two points must be considered-

1) The number of parameters and interaction of interest.
2) The number of levels for the parameters of interest [2].

Therefore four control factors, moisture percentage, AFS No., green compression strength (GCS) and mould hardness number with three levels were taken and L9 orthogonal array is selected for experimental runs. Taguchi has provided in the assignment of factors and interaction to arrays. The assigned L9orthogonal array is shown in TABLE II.

TABLE II
L9 ORTHOGONAL ARRAY (CONTROL FACTORS ASSIGNED)

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

IV. CASE STUDY

Once the parameters and parameter interactions are assigned to an exact column of the selected orthogonal array, the factors at different levels are assigned for each trial. The experimental array is shown in Table III.

TABLE III
EXPERIMENTAL L9 ARRAY

Trail No. 1	A Moisture Content (%)	B Green Compression Strength (gm/cm^2)	C AFS no.	D Mould Hardness (No.)
1	3	1250	55	70
2	3	1285	60	80
3	3	1320	65	90
4	3.3	1250	60	90
5	3.3	1285	65	70
6	3.3	1320	55	80
7	3.5	1250	65	80
8	3.5	1285	55	90
9	3.5	1320	60	70

The experiments were conducted thrice for the same set of parameters using a single-repetition randomization technique. The casting defects that occur in each trial conditions were measured. In this work, the casting defects that occur during the moulding process alone is considered. The percentage of defects for each repetition was calculated by using the given formula, and then the average of the casting defects were determined for each trial condition [3].

$$\text{Percentage of defects} = \frac{\text{No: of defects occurring due to moulding process}}{\text{Total no: of defects occurring in the process}}$$

The percentage casting defects are "lower the better" type of quality characteristics. Lower the better S/N ratios were computed for each trials and the values are given in TABLE IV:

For example, for trial no. 1, the S/N ratio is:

$$\text{S/N ratio } (\eta) = -10 \log 10 \, [(\sum y^2_i)/n]$$
$$= -10 \log 10 \, [(5^2+5.7^2+7^2)/3]$$
$$= -15.509$$

The mean effect graph is refer using average value and S/N ratio.

TABLE IV
CASTING DEFECTS IN TRIAL AND THEIR S/N VALUE

Trial No.	% Defects in experiment					
	1	2	3	sum	Avg.	S/N ratio
1	5	5.7	7	17.7	5.90	-15.50
2	4	4.3	4.5	12.8	4.27	-12.61
3	6.25	6.7	7	20.0	6.65	-16.47
4	3.8	3.9	3.5	11.2	3.73	-11.45
5	6.66	6.78	7.2	20.6	6.88	-16.76
6	3.1	3.33	3.1	9.5	3.18	-10.05
7	7.2	6.72	7.1	21.0	7.01	-16.92
8	6.67	6.2	5.7	18.6	6.19	-15.85
9	7.5	7.2	6.7	21.4	7.13	-17.08

From TABLE IV S/N value taken to plot mean effect diagram to find out optimal value of parameter, the main effect plot diagram shown in Fig. 3.

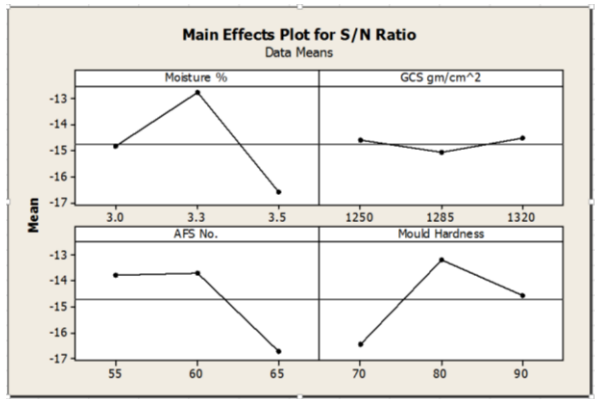

Fig. 3 Main effect plot for S/N ratio.

V. CONCLUSIONS

The optimized levels for the selected parameter is obtained by Taguchi method is Moisture 3.3%, Green compression strength is 1320, AFS no.60, and Mould hardness 80. From the result of the experiment the application of the taguchi method to sand casting process improve the productivity of the casting and stable the casting process. Before application of taguchi method defect of casting were 6.79% and after application of taguchi method casting defects are reduced up to 3.36%.

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REFERENCES

[1] Vivek S.Gondkar and K .H. Inamdar, "Optimization of Casting Process Parameters through Simulation," IJAIEM, vol.3, pp. 2319-4847, June 2014.

[2] Sushil Kumar, P. S. Satsangi and D. R. Prajapat,"Optimization of green sand casting process parameters of a foundry by using Taguchi method," International Journal of Advance Manufacturing Technology, vol. 55, pp.23-34, 2011.
[3] S. Guharaja, A. Noorul Haq and K. M. Karuppannan, "Optimization of green sand casting process parameters by using Taguchi's method," International Journal of Advance Manufacturing Technology, vol. 30, pp.1040–1048,2006.
[4] Uday A. Dabade and Rahul C. Bhedasgaonkar, "Casting Defect Analysis using Design of Experiments (DoE) and Computer Aided Casting Simulation Technique," Procedia CIRP, vol.7, pp.616 – 621, 2013.
[5] A. Noorul Haq, S. Guharaja and K. M. Karuppannan, "Parameter optimization of CO2 casting process by using Taguchi method," International Journal of Advance Manufacturing Technology, vol.3, pp.41-50, 2009.
[6] P. Vijian and V. P. Arunachalam, "Optimization of squeeze casting process parameters using Taguchi analysis," International Journal of Advance Manufacturing Technology, vol.33, pp. 1122–1127, 2007.
[7] A. C. S. Reddy, S. Rajesham, P. R. Reddy, T. P. Kumar and J. Goverdhan, "An experimental study on effect of process parameters in deep drawing using Taguchi technique," International Journal of Engineering, Science and Technology, Vol.7, pp. 21-32, 2015.
[8] A. Bharatish , H.N. Narasimha Murthy, B. Anand, C.D. Madhusoodana, G.S. Praveena and M. Krishna, "Characterization of hole circularity and heat affected zone in pulsed CO2 laser drilling of alumina ceramics," Optics & Laser Technology, vol.53, pp.22–32, 2013.
[9] D.R. Gunasegaram, D.J. Farnsworth and T.T. Nguyen, "Identification of critical factors affecting shrinkage porosity in permanent mold casting using numerical simulations based on design of experiments," journal of materials processing technology, vol.209, pp.1209–1219, 2009.
[10] Mohd. Ziaulhaq, Dr. Shahnwaz alam and M. T. Jamali, "Study of Process Parameters Effect on Surface Finish in Al-Alloy Sand Casting by Using Taguchi Method," IJERT, vol.2, pp.1521-1526, 2013.
[11] Lakshamanan Singaram, "Improving Quality of Sand Casting using taguchi And ANN Analysis," International journal on design and manufacturing technologies, vol.4, pp.1-5, 2010.
[12] K.Kanthavel, K. Arunkumar and S.Vivek, "Investigation of chill performance in steel casting process using Response Surface Methodology," Procedia Engineering, vol. 97, pp. 329 – 337, 2014.
[13] Mahipal Singh, Manjinder Bajwa, Rohit Sharma and Hitesh Arora, "Behaviour of Aluminium Alloy Casting with the variation of Pouring Temperature and Permeability of Sand," International Journal of Scientific & Engineering Research, vol.6, pp. 1497-1503, 2013.