Casting Defects Analysis and Parameter Optimisation through ANOVA

[1]Amol S. Karape, [2] K.H. Inamdar,
[1]PG-Student, [2]Associate professor
Department of Mechanical Engineering,
Walchand College of engineering, Sangli, India.

Abstract— In casting production various defects is occurring during the casting process. Because of uncertainty of the process variation, methoding of the casting feeding system and material of the casting. This factors directly affected on the casting. In this paper taguchi method is used to obtain optimal setting of process parameter of green sand casting process. The selected parameter are moisture content, pouring temperature, and green compressive strength and mould hardness. The attempt has been made to obtain optimal setting of process parameter in order to improve quality and reduction of casting rejection. The DoE, Signal to noise ratio and analysis of variance are used to find out the effect of selected process parameter and their level on the casting rejection. The selected process parameter significantly affected the defect of the green sand casting process. As per DoE, experiment has been done and verify the results. Which is shows, the taguchi method is efficient to determine the optimal value of process parameter.

Index Terms— Green sand casting process, DoE, Analysis of variance, rejection, Signal to Noise ratio.

I. INTRODUCTION

In the casting process a pattern is made in the shape of the desired part. This pattern is made out of wood, plastic or metal. Simple designs can be made in a single piece or solid pattern. More complex designs are made in two parts, called split patterns. A split pattern has a top or upper section, called a cope, and a bottom or lower section called a drag. Both solid and split patterns can have cores inserted to complete the final part shape. Where the cope and drag separates is called the parting line. When making a pattern it is best to taper the edges so that the pattern can be removed without breaking the mould.

The patterns are then packed in sand with a binder, which helps to harden the sand into a semi-permanent shape. Once the sand mould is cured, the pattern is removed leaving a hollow space in the sand in the shape of the desired part. The pattern is intentionally made larger than the cast part to allow for shrinkage during cooling. Sand cores can then be inserted in the mould to create holes and improve the casting's net shape. Simple patterns are normally open on top and melted metal poured into them. Two piece moulds are clamped together and melted metal is then poured in to an opening, called a gate. If necessary, vent holes will be created to allow hot gases to escape during the pour. The pouring temperature of the metal should be a few hundred degrees higher than the melting point to assure good fluidity, thereby avoiding prematurely cooling, which will cause voids and porosity. When the metal cools, the sand mould is removed and the metal part is ready for secondary operations, such as machining and plating. Sand casting is the least expensive of all of the casting processes.

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/cm2, permeability number: 140 and mould hardness number: 85.

Haq et al. [5] made an attempt to obtain optimal settings of CO2 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-ata-time traditional experimental methods, because it allows a judgment on the significance of not only input variables orfactors 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 "2nd 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. Design of Experiment

The design of experiment is the simultaneous evaluation of two or more factors for their ability to affect the resultant average of particular process characteristics. The design of experiment process is divided into three main phases are given as:

• Planning phase
• Conducting phase
• Analysis phase

The planning phase is the most important phase for the experiment to provide the expected information about the process. Sensible and measurable parameters that affect the quality of the product are identified in this phase. The second most important phase is the conducting phase, in this phase all experiments are well planned and conducted when test results are actually collected. This phase gives either positive or negative information about the process and parameter level. The third phase is analysis phase, in this phase the experiment results are compared with conformation experiment results. This phase is the most statistical in nature of the three phases of the design of experiment by a wide margin. [14].

The focus of this paper is on the robustness of the green sand casting process. The basic steps for achieving the above target are summarized below [3]:

1. Casting defects have been selected as the most representative quality characteristics in the green sand casting process, as it is related to many internal defects (shifts, warpage, blow holes, drop etc.). The target of the green sand casting process is to achieve "lower casting defects" while minimizing the effect of uncontrollable parameters.
2. To select the most significant parameters that cause variation of the quality characteristics.
3. Make the green sand casting process under the experimental conditions dictated by the chosen orthogonal array (OA) and parameter levels. Based on the experimental conditions, collect the data.
4. Analyse the data. An analysis of variance (ANOVA) table can be generated to determine the statistical significance of the parameters. Response graphs are plotted to determine the preferred levels for each parameter.
5. Make decisions regarding optimum settings of the control parameters and predict the results of each of the parameters at their new optimum levels.
6. Verify the optimum settings result in the predicted reduction in the casting defects.

Process parameter of green sand casting

An ishikawa diagram (cause and effect diagram) was constructed as shown in Figure 1 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

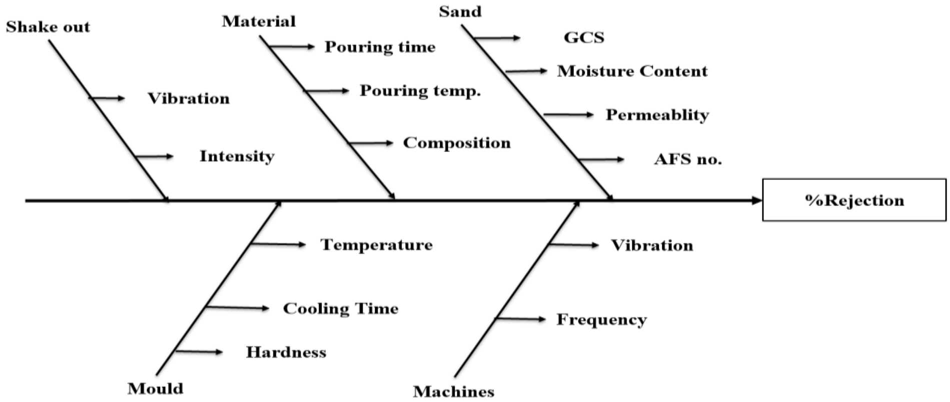

Figure 1. Cause effect diagram for casting defect

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

1) Moisture Content (%)
2) Pouring Temperature
3) Mould Hardness (No)

The range of moisture content selected as 3.0%–3.5%, Pouring Temperature selected as 1320-1425 °C and the mould hardness number selected as 70–90. The selected green sand casting process parameters, along with their ranges, are given in Table 1.

Table 1 Process Parameter with Their Ranges and Values at Three Levels

Parameter designation	**Process Parameter**	**Range**	**Level 1**	**Level 2**	**Level 3**
A	Moisture Content (%)	3-3.5	3.0	3.3	3.5
B	Pouring Temperature	1320-1425	1320	1380	1425
C	Mould Hardness (No)	70-90	70	80	90

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, Pouring Temperature 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 2.

Table 2 L9 Orthogonal array (control factors assigned)

Sr. No.	Moisture Content	Pouring temperature	Mould Hardness
1	3	1320	70
2	3	1380	80
3	3	1425	90
4	3.3	1320	80
5	3.3	1380	90
6	3.3	1425	70
7	3.5	1320	90
8	3.5	1380	70
9	3.5	1425	80

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 2.

Table 3 Experimental % rejection and S/N Ratio value.

Sr. No.	Moisture Content	Pouring temperature	Mould Hardness	% Rejection	SNRA
1	3	1320	70	8.91	-18.99755
2	3	1380	80	3.41	-10.65509
3	3	1425	90	7.65	-17.67323
4	3.3	1320	80	4.02	-12.08452
5	3.3	1380	90	3.1	-9.827234
6	3.3	1425	70	4.01	-12.06289
7	3.5	1320	90	7.75	-17.78603
8	3.5	1380	70	3.65	-11.24586
9	3.5	1425	80	4.89	-13.78618

The experiments were conducted on set of parameters using a single-repetition randomization technique. The Percentage rejection that occur in each trial conditions were measured. In this work, the rejection that occur during the process 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].

$$\text{Percentage of Rejection} = \frac{\text{Total wt. of rejection Qty.}}{\text{Total wt. of production Qty.}}$$

The percentage rejection 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 4:
S/N ratio (η) = −10 log10 [(∑y^2_i)/n]

A. Analysis of Variance

Analyses of experimental results were performed using Minitab 17 software and ANOVA and AOM plots are obtained given in Table 4 and Figure 2 respectively. ANOVA in TABLE V indicates that moisture content, Pouring Temperature, green compression strength and mould hardness parameters significantly influence the % rejection at 90% confidence level.
Another analysis of variance has been done using parameter moisture content, Pouring temperature and Mould Hardness. Analysis shown in table 4. Result shows P value of Pouring temperature is 0.016 and % contribution is 53.38. the pouring temperature is most significant parameter influence the %rejection.

Table 4 ANOVA for %Rejection

Source	DF	Seq SS	Adj SS	Adj MS	F	P	%C
Moisture content	2	30.7535	30.7535	15.3768	38.06	0.026	32.01
Pouring Temp. (^{0}C)	2	51.2729	51.2729	25.6365	63.45	0.016	53.38
Mould Hardness	2	13.2273	13.2273	6.613	16.37	0.058	13.76
Residual Error	2	0.8081	0.8081	0.4040			
Total	8	96.0618					
S = 0.6356 R-Sq = 99.2% R-Sq(adj) = 96.6%							

Analysis mean plot shown in figure 1.2. From graph Percentage rejection minimize at moisture content A2, Pouring temperature B2, Mould hardness C2.

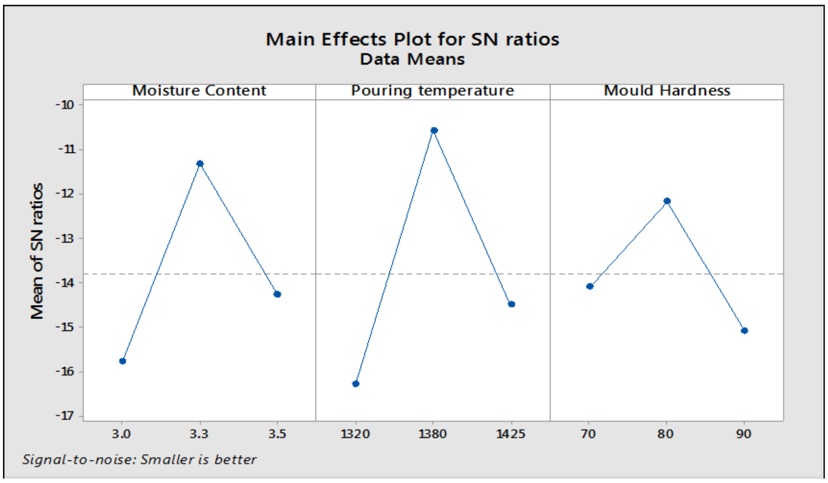

Figure.2 Main effects plot for S/N Ratio of %Rejection

V. Conclusion

Application of taguchi method for sand casting process, it's improve productivity and quality of the casting and stable the casting process. Analysis of variance result shows moisture content and pouring temperature is most significant parameter influence the % rejection. From design of experimentation, the optimal setting for given case study were moisture content 3.3%, pouring temperature 1380^{0}C, green compressive strength 1320 and mould hardness 80.

VI. Acknowledgment

The authors would like to thank the company Gnat Foundry Private Limited, Kolhapur and Vinyak S. Patil Manager and production department for their involvement in the study. The authors also gratefully acknowledge supported by the company Gnat Foundry Private Limited.

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.

[14] Taguchi, G.: Introduction to Quality Engineering. Asian Productivity Organization, Tokyo, Japan, 1986.