Analysis of Foundry defects and Quality improvement of Sand casting

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Abstract - *Sand casting is an indispensable manufacturing process which is used widely around the globe. It involves pouring molten metal into moulds having cavities, so as to cast metal into the desired shape of the cavity. Sand casting is a study in itself, and is a blend of fluid mechanics and heat transfer. Common parameters that are varied include- flowing velocity, filling time, porosity of mould material etc. The process of sand casting presents with its own set of challenges, one of them being casting defects. Casting defects compromise the quality of the castings, and make them weaker. The study of casting helps us predict the casting quality and defects without doing actual castings, and hence, save time, money and resources. The main aim behind this is to maximize the sand quality with the help of different methods and also work upon the casting defects therefore improving the overall casting.*

Key Words: **Taguchi Analysis, ANOVA, Orthogonal arrays, Ishikawa Diagram, Quality Improvement, Sand casting**

1.INTRODUCTION

Sand casting is an indispensable manufacturing process which is used widely around the globe. It involves pouring molten metal into moulds having cavities, so as to cast metal into the desired shape of the cavity. Sand casting is a study in itself, and is a blend of fluid mechanics and heat transfer. Common parameters that are varied include- flowing velocity, filling time, porosity of mould material etc. The process of sand casting presents with its own set of challenges, one of them being casting defects. Casting defects compromise the quality of the castings, and make them weaker. The study of casting helps us predict the casting quality and defects without doing actual castings, and hence, save time, money and resources. The main aim behind this is to maximize the sand quality with the help of different methods and also work upon the casting defects therefore improving the overall casting.

2. METHODOLOGY

A process which has to be optimized has many process parameters which affects the expected target value directly or indirectly. Optimization involves choosing the right levels of the parameter values to obtain the desired value. This is known as the Static Problem. The noise remains in the whole process but this should not affect the output which is actually the primary aim of Taguchi's method.

The purpose of this article is to optimize the parameters of the sand-casting process, including optimal levels. The Taguchi method can be implemented using the following steps:

1. To determine the most important variables that influence quality qualities.

2. Casting defects have been chosen as the most representative quality parameters in the green sand-casting process (cold shut hot tear etc.). The goal of the green sand-casting method is to obtain "reduced casting faults" while reducing the influence of uncontrollable variables.

3. Make the green sand-casting procedure according to the experimental conditions indicated by the orthogonal array and parameter values you have chosen.

4. To establish the statistical significance of the parameters, an analysis of variance (ANOVA) table is created. To find the preferred level for each parameter, response graphs are plotted.

5. Predict the results of each of the parameters at their new optimum values, in addition to the ideal settings of the control parameters.

Data is collected from the foundries of small scale or medium scale levels. It is collected for a longer period of time and are observed by plotting the graph between the production rate and rejection rate and suitable components are chosen which have higher rejection rates comparatively. It is found that these rejections are mainly due to the sand related defects. Pareto Analysis is used to identify the defects which affects the final casting quality on a larger scale. Based on this testing made, approximately 78% castings were rejected because of cold shut defect and hot tear. Ishikawa Diagram is used to identify the major causes behind the cold shut defect and hot tear. Less fluidity of molten metal, high moisture content in moulding sand, improper gating system, slow and medium pouring, residual stresses in the material and improper mould design were responsible majorly to cause the cold shut defect and hot tear.

Three parameters are chosen for experimentation.

1. Pouring temperature

2. Gating system

3. Pouring time

Table -1: First set of Process parameters

Sl. No.	Parameter	Level 1	Level 2
1	Pouring Temperature (°C)	1320-1390	1390-1420
2	Gating System	No change	Change
3	Pouring Time (Second)	15	13

Two levels are assigned to the parameters with some changes in the values of the parameters (some parameters remain constant for all levels).

L4 orthogonal array is used for 3 parameters and 2 levels. It gives us the permutation for the sand casting to be done for various levels.

Process parameters were changed and the same process was followed. The second set of parameters chosen are: -

1. Compression Strength
2. Moisture content
3. Permeability
4. Mould Hardness Number

Table – 2: Second set of Process parameters

Parameter	Range	Level 1	Level 2	Level 3
Compression Strength (g/cm^2)	1000-1300	1000	1260	1300
Moisture Content (%)	3.2-4	3.2	3.5	4
Permeability No	140-190	140	163	190
Mould Hardness Number	85-95	85	90	95

Three levels are chosen with L9 orthogonal array.

2.1 Standard Attributes

The quality characteristic to be measured was casting flaws. The most prevalent problems in the foundry were tracked and documented. The lower the amount of casting flaws, the higher the process performance. The objective function to be maximised in this case is:

S/N (Signal to Noise) Ratio = $-10 \log(\sum(1/Y^2)/n)$

n = Number of experiments

Y = Percentage of approved casting

The lesser the S/N value, the better the quality.

S/N ratios are calculated to assess the best experimental process with respect to the levels assigned to each parameter. Signal represents the desired value (Percentage of Approval) and Noise represents undesirable value.

2.3 Selection of Orthogonal array

The number of control parameters and the interaction of interest influence the choice of an orthogonal array. The number of levels for the control parameters of interest is also a consideration. The standard Taguchi L9 Orthogonal Array (OA) format is chosen from preliminary work with three parameters namely the mould temperature, pouring temperature and as important casting process variables which affect the mechanical properties. The criteria used for choosing the three parameter levels are to explore a maximum range of experimental variables. The assigned levels of parameters are shown in Table 1 and Table 2. The experimental orthogonal array along with their levels are shown in the Table 5.

Table – 3: Signal levels

Parameter	Range	Level 1	Level 2	Level 3
Pouring Temperature (°C)	1300-1500	1300	1320	1350
Permeability (No)	130-180	130	150	180
Sand Particle size (AFS)	50-55	50	52	54
Mould Hardness (Nu)	50-80	50	60	75

Table – 4: Consolidated Process parameters

Parameter	Level 1	Level 2	Level 3
Moisture Content (%)	3.2	3.8	4.3
Green Strength (g/cm^2)	1200	1400	1800

Sand Particle size (AFS)	50	52	54
Mould Hardness (nu)	50	60	75

Table – 5: Experimental Orthogonal array

Trial No.	A	B	C	D	E	F
	Pouring Temperature (°C)	**Permeability (No)**	**Moisture Content (%)**	**Green Strength (g/cm²)**	**Sand Particle size (AFS)**	**Mould Hardness Number**
1	1300	130	3.5	1200	50	50
2	1300	150	3.5	1500	52	60
3	1300	180	3.5	1700	54	75
4	1320	150	3.5	1200	52	75
5	1320	180	3.5	1500	54	50
6	1320	130	3.5	1700	50	60
7	1350	180	3.5	1200	54	60
8	1350	130	3.5	1500	50	75
9	1350	150	3.5	1700	52	50

3. EXPERIMENTATION RESULTS

The experiments were conducted twice for two same set of parameters. The casting defects that occur in each trial conditions were found and recorded for optimization. It is done with the help of Minitab 16 software by Taguchi Design of Experiment (DOE) technique. Only single defect – Cold shut is considered for the inspection. The average of the casting defects was determined for each trial condition as shown in Table 9. The casting defects are the "lower the better" type of quality characteristics. Lower the better S/N ratios were computed for each of the 9 trials and the values are given in Table 9:

For example, for trial number 1:

η = -10 log [(Σy^2i)/3]

S/N Ratio = - 10 log [(6.50^2) +(5.30^2) +(6.90^2)/3]

= -10 log [(42.25+28.09+47.61)/3]

= -10 log [(117.95)/3]

= -10 log [39.31]

= -15.945

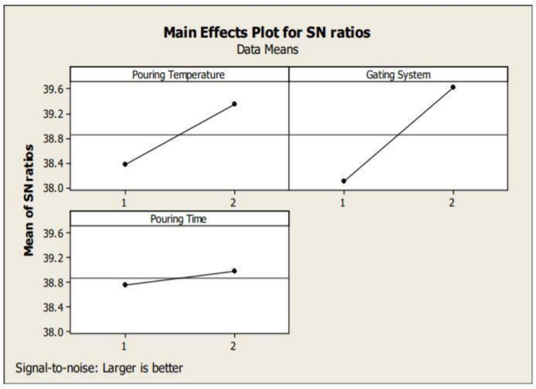

Figure – 1: S/N Ratios with corresponding levels

Table – 6: Experimentation Results

Experiment Number	Signal Level for parameters			Total Casting Poured	Number of Castings approved	Percentage of Castings approved
	Pouring Temperature	**Gating System**	**Pouring Time**			
1	1	1	1	36	27	75%
2	1	2	2	36	33	91.67%
3	2	1	2	36	31	86.11%
4	2	2	1	32	32	100%

Table – 7: S/N Ratios of the experiments performed

Experiment Number	Percentage of approved Casting	Signal to Noise Ratio	Mean
1	75%	37.5012	75
2	91.67%	39.2445	91.67
3	86.11%	38.7011	86.11
4	100%	40.0000	100

Table – 8: Optimum parameter values

Parameters	Level	S/N	Mean	Optimum Value
Pouring Temperature (°C)	2	39.35	93.06	1390-1420
Gating System	2	39.62	95.84	Change
Pouring Time (Second)	2	38.97	88.89	13

3.1 Analysis of the results and its effects

The analysis of variance technique (ANOVA) is used to examine the outcomes of the experiments after they have been completed. For several trial settings and parameters that significantly influence casting defects, important factors and/or their interactions are discovered. However, more information is required to arrive at an optimal parameter setting.

Table – 9: Defects percentage and S/N ratios compared with the respective experiment trials

Trial No.	% Defects in Experiment				S/N Ratio	Average
	1	2	3	Total		
1	6.50	5.30	6.90	18.70	-15.9450	6.23
2	5.50	3.80	5.30	14.6	-13.7506	4.87
3	7.34	5.60	7.56	20.5	-16.6884	6.83
4	3.50	4.20	4.01	11.71	-11.8213	3.90
5	6.32	4.90	7.14	18.36	-15.7350	6.12
6	7.43	6.67	6.00	20.1	-16.5215	6.70
7	7.12	5.00	5.75	17.87	-15.5049	5.96
8	3.33	7.32	4.50	15.15	-14.0658	5.05
9	3.50	5.60	1.53	10.63	-11.1501	3.61

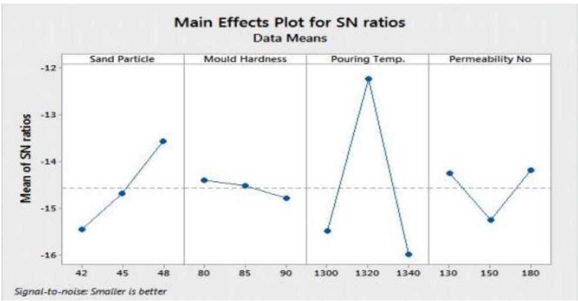

Figure 2: Graph depicting S/N ratios across the parameters

4. CONCLUSIONS

- It was observed that all the first set of parameters provide better results with respect to the cast quality when worked in Level 2. Pouring temperature showed 92-96% of approval, Gating system showed 96% approval and Pouring time of about 84-86% approval.

- It is observed that Moisture content and Permeability provide better results at Level 2 whereas, Compression Strength and Mould Hardness Number at Level 3. 20-30% reduction in defects variation could be seen and also the regression value was 85%. Rejection of the final cast products came down to 3.4% which is a good improvement.

- The outcome of conducting the Taguchi Analysis with the help of Ishikawa Diagram and Pareto Analysis, has been satisfying. This method is efficient in both ways, i.e. when a single defect is identified and Taguchi method is applied to remove or reduce that particular defect and also when this method is used to reduce the defects which are generally seen in the final cast.

- This method not only contributes as one of the efficient and feasible solutions to reduce cast defects directly, but this method has also become an important foundation for many other solutions which were inspired from this technique that were proposed later on too.

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BIOGRAPHIES

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