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A DEVELOPMENT OF QUALITY IN CASTING BY MINIMIZING DEFECTS

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Abstract: **In this paper design of experiment and FMEA techniques are combined to analyze casting defects. Attempt has been made to get optimal parameter setting for defects like cold shut and blow hole. Producing defect free casting is impossible. Defect analysis is carried using FMEA tool and Pareto analysis to know potential causes of failure and their effects along with correct actions to improve quality strength and productivity. The main objective of this paper is to optimize sand casting process parameter using DOE method through Taguchi method. Taguchi based L9 orthogonal array was used for experimental purpose and analysis was carried out using Minitab software for analysis of mean (ANOM) plot. In this paper the data collected is taken from one foundry.**

Keywords: **Casting, FMEA, DOE, Taguchi methodology, Pareto analysis.**

1. INTRODUCTION

Casting is simply melting the metal and pouring molten metal into mold cavity, allowing the metal to solidify and then breaking up mold to remove casting. Casting as an old technique is the quickest link between engineering drawings 2nd manufacturing. It provides us with the possibility of forming wide range of shapes with wide range of materials. Casting process involves number of process parameters so it is difficult to produce defect free casting even in a controlled process, defects in casting are observed which challenges explanation about the cause of casting defects [1]. Casting defects analysis is the process of finding the potential failure cause of Occurrence of defects in the rejection of casting and taking necessary steps to reduce the defects and to improve the casting yield. [1-2]

In this paper, for casting defects analysis techniques like Pareto-chart, FMEA and DOE (Taguchi Method) are conversed in following section.

2. LITERATURE REVIEW

Now days in order to sustain in any variety of manufacturing industry we need to be competitive enough as rivals. The main thing we should concentrate on how we are going to minimize defects that occur in industry so necessary preventive actions should be taken.

Wilson et al. (1993) have defined the Root Cause Analysis as an analytical tool that can be used to perform a corrective and comprehensive, system based review of critical defects. Uday A. Dabade and Rahul C. Bhedasgaonkar [2] have put their emphasis on casting defect analysis using Design of Experiments and Computer Aided Casting Simulation Techniques. They work to analyze the sand related and method related defects in green sand casting. They applied Taguchi based orthogonal array for Experimental purpose and analysis was carried out using Minitab Software for analysis of variance and analysis of mean plot.

From literature review we came to know that application of Pareto analysis, failure mode effect analysis and design of experiment can significantly minimize the defects of manual casting operation.

3. METHODOLOGY

The study conducted in engine casing component manufacturing foundry where cold shut, blow hole, shrinkage, rib cut and sand inclusion are most important defects observed, and DOE is used for analysis of above mentioned casting defects. FMEA determines the potential failure cause of occurrence of defects in casting rejection.

FMEA is set of guidelines for identifying and prioritizing the potential failure or defects. Prioritizing the defects by finding the RPN (risk priority number).

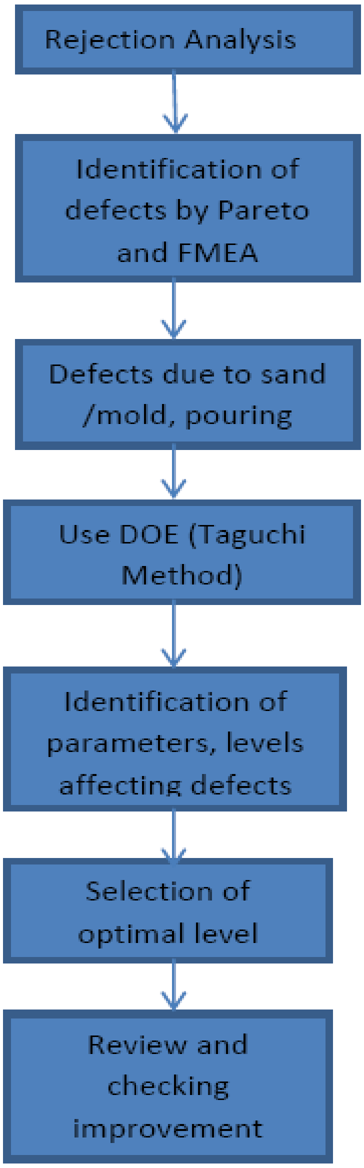

Figure 1: Research Methodology

4. PROBLEM STATEMENT

To achieve or develop quality in casting by minimizing defects

- Every 10 casting 4-6 castings are rejected.
- Affecting defects are cold shut, blowhole and sand inclusion.

4.1 Objective

- Identification of defects in engine casing (EICHER 298) and analysis
- Identification of potential failure and causes through FMEA
- Quality improvement, including reduction of variability and improved process and product performance

5. DATA COLLECTION

Simplified data from the total rejection sheet is represented in the following table. Data shows the total production per month and the data is of three months. Rejection of total Eicher-298 is given in the following Table-1.

Table-1 Rejection data sheet

Month	Production	Total rejection	Cold metal	Blow hole	Sand inclusion	Others
February	4210	508	202	138	96	72
March	3975	318	119	92	63	44
April	3508	186	97	30	42	17
Total	11693	1012	418	260	201	133

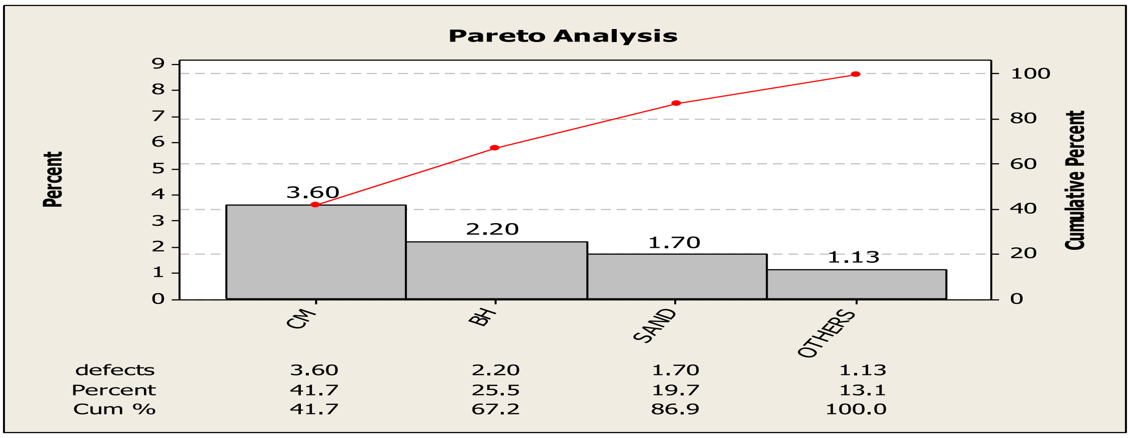

Figure 2: Pareto graph

With the help of Pareto chart, factors that influenced the rejection most are identified. The above graph shows the percentage rejection of defects and also cumulative percentage of defects. From the above Pareto graph 3.6% cold metal defects, 2.2% blowhole defects occur and it came it out as major defects and sand inclusion also effects.

5.1 FMEA Implementation

Table-2 FMEA for EICHER 298 casting

Defects	Potential failure mode	Potential cause for failure	S	O	D	RPN
Blowhole	Internal voids with depression	Moisture left in mold and core	7	6	6	252
Cold shut	Small shot like sphere	Due to rapid solidification before filling up of mold	8	8	5	320
shrinkage	Reduction in volume	Due to lack of riser system	4	4	4	64
Sand inclusion	Inclusion of sand on the edges of casted surface	Improper ramming of sand	7	5	5	175

The Risk Priority Number (RPN) is determined by three risk parameters which include Severity Rating (S), Occurrence Rating (O), and Detection Rating (D). FMEA can be divided into two phases. The first phase (Measure) is to identify the potential failure modes and to decide the value of Severity, Occurrence and Detection, as given in Table in the second phase (Improve), the manager should make recommendations for correct actions.

With the help of the FMEA domains of possible improvement are clearly identified and recommended for further action.

6. EXPERIMENT DETAILS

Experiments were carried out in foundry industry producing CI components. The analysis of casting defects involves selecting parameters and their levels. Performing experiments as per DOE (Taguchi method) and collect data.

As per rejection analysis it was found that the component EICHER-298 rejection was maximum due to sand inclusion, blowhole and cold shut. So this component is selected for analysis by DOE method.

Proper selection of the casting parameters can results in minimum casting defects. Optimization of these casting parameters based on 3 levels and 4 factors is adopted in this paper to minimize the casting defects. L9 orthogonal array was used the design factor and their levels are shown in Table-3

Table-3 Factors and their level

Sl. no	code	Factors(units)	Levels		
			1	2	3
1	A	Pouring temperature	1380	1410	1440
2	B	Inoculant	0.1	0.2	0.3
3	C	Moisture content	3	3.3	3.6
4	D	Sand binder ratio	60:0.9	60:1	60:1.2

Experimental layout for L9 Taguchi orthogonal array-Total 9 experiments were carried out and response were recorded out of 10 products in %. The S/N ratio for minimum defects coming under smaller-is–better type characteristic.

7. RESULT AND DISCUSSION

Analysis of experimental results was performed using Minitab software and ANOM plots obtained are given in Table and Figure respectively.

Table-4 Results of ANOM

Factors	Levels (dB)			Optimum level
	L_1	**L_2**	**L_3**	
A	- 31.21	-35.48	-31.21	1&3
B	-33.66	-32.38	-31.85	3
C	-32.69	-32	-33.22	2
D	-32.38	-31.85	-33.66	2
Optimum mean =-29.02				

ANOM plot in Figure 3 indicates that %rejection is minimum at first level and third level of pouring temperature (A1&A3), third level of inoculant (B3), moisture content (C2) and sand binder ratio (C2)

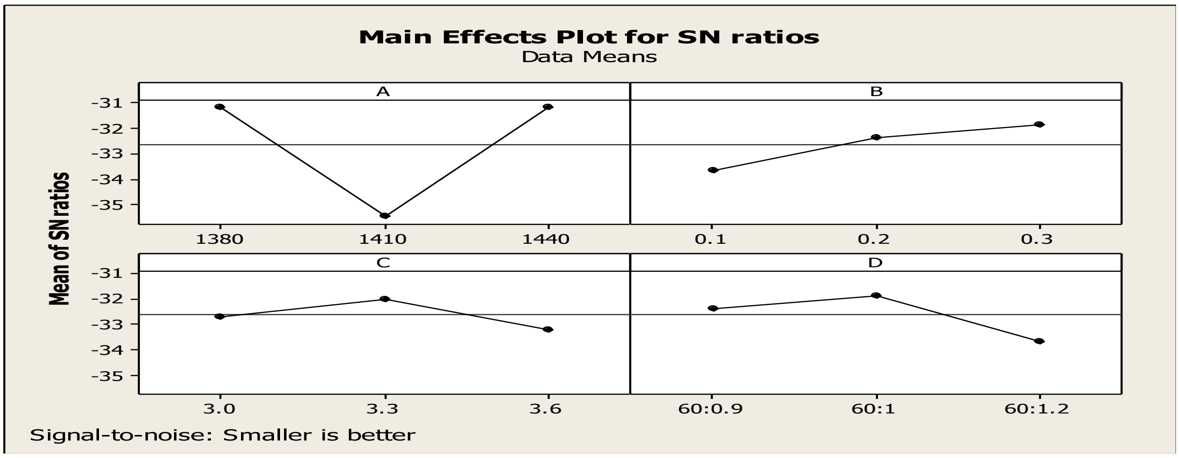

Figure 3-Response graph

7.1 Analysis of Experiment Result

Table-5 Summary of ANOVA

Factors	Degrees of Freedom	Sum of Squares	Mean Squares	Contribution %
A	2	36.46	18.23	74.27
B	2	5.19	2.59	10.57
C	2	2.24	1.12	4.56
D	2	5.19	2.59	10.57
Error	0	0	-	-
Total	8	49.09	6.45	99.97

From the results of ANOVA as shown in Table-5 it is observed that pouring temperature and inoculant have major contributions in controlling the defects. On the other hand, Sand-Binder ratio has moderate effect and the moisture content has least effect on defects.

Since the ANOVA has resulted in zero degree of freedom for error term, it is necessary to pool the factor having less influence for correct interpretation of results. After selecting the optimal level of process parameters, the final step is to predict and verify the adequacy of the model.

Experiments were conducted with optimal levels of factors obtained by Taguchi optimization. The measured values of defects under the optimal process conditions were used to determine the observed values of signal to noise ratio (η_{obs}).

Confirmation experiments were performed at the optimized setting of process parameters, results of which are shown in below Table-6.

In order to judge the closeness of observed value of signal to noise ratio with that of the predicted value, the variance of prediction error (σ^2_{pred}) is determined and the corresponding two-standard deviation confidence limits for the prediction error of the signal to noise ratio is calculated. From the results of conformity tests, summarized in Table7 and the Calculation is done.

It can be observed that the calculated value of prediction error is close to confidence limit, which indicates that the additive model of defects is adequate.

Table-6 Results of Confirmation experiment

Sl.no	Pouring temperature	inoculant	Moisture content	Sand- Binder Ratio	Defects In %	S/N Ratio
1.	1380	0.3	3.3	60-0.1	20	-26.02
2.	1440	0.3	3.3	60: 0.1	20	-26.02
Average signal to noise ratio= -26.02						

Table-7 Confirmatory Test Result

Levels (A, B, C, D)	1-3-2-2
Signal to noise ratio observed (η_{obs}), dB	-26.02
Predicted Signal to noise ratio (η_{pred}), dB	-29.65
Prediction error, dB	3.63
Confidence limit (2σ), dB	±2.39

8. CONCLUSION

The following conclusions were drawn from the present investigation.

- Pareto principle is used to identify and evaluate different defects and causes for these defects responsible for rejection of components at different stages of manual metal casting operations. The correct identification of the casting defect at initial stage is very useful for taking remedial actions.
- By FMEA method, we find the potential failure mode and potential cause for failure of defect.
- Defects in casting are minimized with optimal level settings of process parameters.
- All factors considered contribute to the quality of performance.
- The optimized levels of selected process parameters obtained by Taguchi method pouringtemperature(1380&1440),inoculant(0.3),moisture-content(3.3),sand-binder ratio(60:1)
- The percentage contribution of error is within 10%, which indicates that, no important factors are left out from analysis.

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