



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 10, October 2023

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

 9940 572 462

 6381 907 438

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# Analysis of Shrinkage Defect in Sand Casting by Using Design of Experiment (DoE)

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**ABSTRACT:** Casting industries are the one, which plays a significant role in the manufacturing of complex shapes and size from the raw material into a product in a single process, but which cannot be produced in the other process in a single technique as other processes need more than one technique to make a raw material into a product. So, casting industries are essential in the manufacturing of products. The casting quality should be maintained without defects when producing the casting, but this is not possible as we cannot produce a cent percentage of accuracy. However, the percentage of defects can be reduced with the help of specific quality control tools and techniques. Here, we have applied the Six Sigma (DMAIC) technique to reduce the casting defects in Coimbatore's leading ductile cast iron manufacturing industry. We have collected data from the industry for the past six months and identified the defects with the help of the Six Sigma (DMAIC) technique. Also, we applied the quality control tools in different stages of the DMAIC technique for identifying and controlling the defects. Then, we applied the Taguchi technique for creating the L9 arrays from the Minitab software. Finally, we got the best possible solution from it and suggested the industry for defects reduction in the upcoming days.

**KEYWORDS:** Casting defects, DoE, Six Sigma, DMAIC process.

## I. INTRODUCTION

Six Sigma is a set of techniques and tools for process improvement. It was introduced by engineer Bill Smith while working at Motorola in 1980. Jack Walch made it central to his business strategy at General Electric in 1995. Six Sigma helps improve the quality of casting products by identifying and removing the causes of defects and minimizing the variability in manufacturing and the business sector. It uses a set of quality management methods and statistical methods. It creates a better way for people within the organization who are the experts in these methods. Each Six Sigma method project within an organization follows a sequence of steps and has a specific value target to gain mass production. For example, it may reduce process cycle time, reduce pollution, reduce cost, increase customer stratification and increase profits.

### Scales of Sigma defects

Defects rate (PPM) cost of poor quality (% Sales) Competitive Level  $6\sigma$  -  $3.4 < 10\%$  World Class,

- $5\sigma$  - 233, 10%-15%
- $4\sigma$  - 6, 21015%-20% High Quality
- $3\sigma$  - 66, 80720%-30% Industry Average
- $2\sigma$  - 3, 08, 53730%-40%
- $1\sigma$  - 6, 90,000 > 40% Non-Competitive

**COMPONENTS OF MOULD**

Mould components make the mould work and the mechanisms to deliver a quality end product.

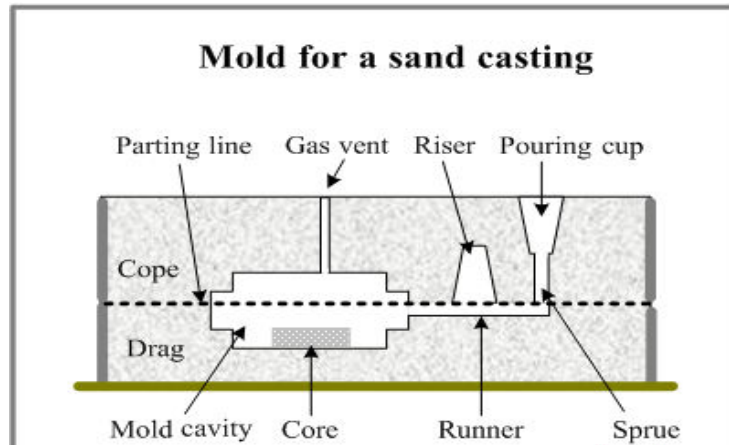


Fig 1. Mould for Sand Casting

**II. METHODS**

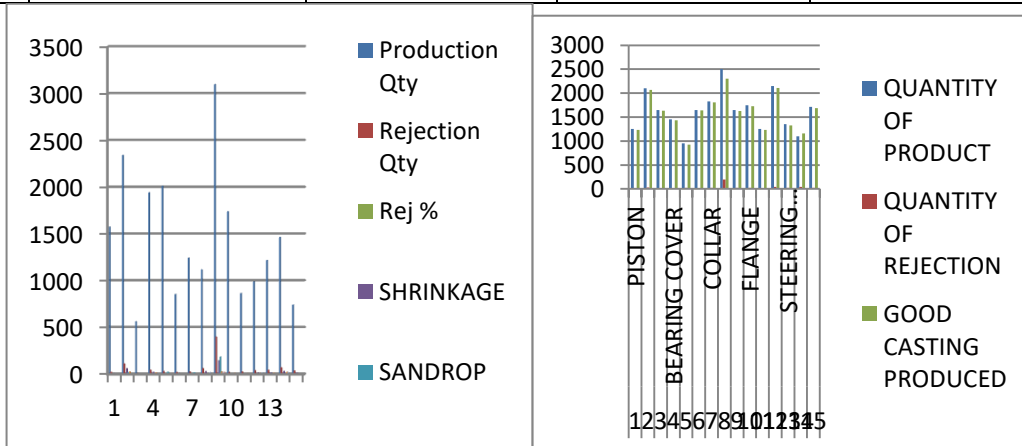
**DEFINE STAGE**

**Table 1: Experimental setup**

S.No.	PRODUCT NAME	QUANTITY OF PRODUCT	QUANTITY OF REJECTION	GOOD CASTING PRODUCED
1	PISTON	1250	15	1235
2	FAN HUB	2100	30	2070
3	SUSPENSION	1650	15	1635
4	BEARING COVER	1450	16	1434
5	RETAINING RING	950	25	925
6	HUB	1650	12	1638
7	COLLAR	1825	20	1805
8	SUSPENSION LEG FOR CYLINDER	2500	200	2300



9	VALVE	1650	26	1624
10	FLANGE	1750	25	1725
11	BASE TRUNNION	1250	15	1235
12	CLAW BEAM ASSY	2150	45	2105
13	STEERING BRACKET	1350	26	1324
14	PLANETARY FIN	1100	40	1160
15	BUSH	1715	25	1690



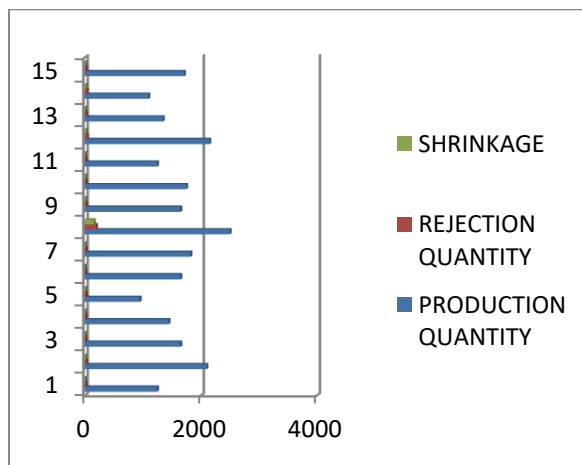
MEASURE STAGE

Table 2. Measure stage

S. NO	PRODUCTS	REJECTION QUALITY	DEFECTS				
			SHRINKAGE	SANDROP	PIN HOLE	SAND INCLUSION	DROP
1	1250	15	6	0	2	0	7
2	2100	30	15	6	0	4	5
3	1650	15	7	1	4	3	0
4	1450	16	10	3	2	1	1
5	950	25	15	4	2	0	3



6	1650	12	5	2	4	1	0
7	1825	20	10	5	0	5	0
8	2500	200	160	20	5	6	9
9	1650	26	15	6	5	0	5
10	1750	25	12	7	0	1	5
11	1250	15	9	3	1	0	2
12	2150	45	23	7	4	11	0
13	1350	26	12	3	1	0	10
14	1100	40	24	8	6	1	1
15	1715	25	13	7	4	0	1



ANALYZE STAGE

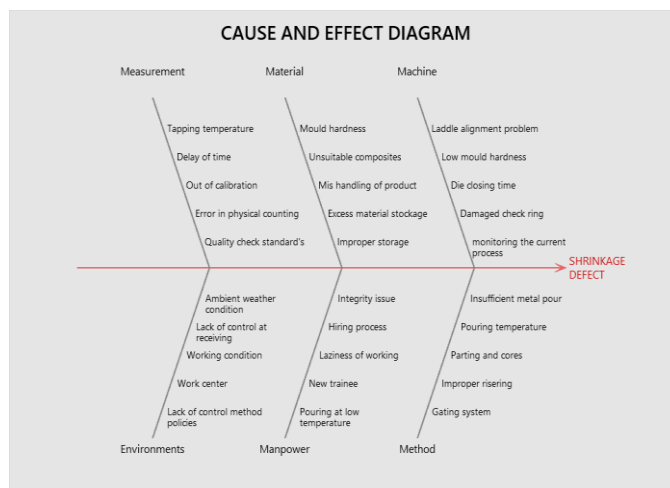


Fig 2. Cause and effect diagram



From this, we identified three parameters which affect the product quality

1. Tapping temperature
2. Pouring temperature
3. Mould hardness

**IMPROVE STAGE**

**Table 3. Improve stage**

FAC TOR DES TIN ATION	PAR AME TER	RANG E	LEVE L 1	LEVE L 2	LEVE L 3
A	Tappi ng tempe rature (degc )	1570°c – 1560	1570	1565	1560
B	Pouri ng tempe rature (degc )	1380°c- 1440°c	1375	1400	1430
C	Moul d hardn ess (nu)	50-80	55	65	75

Taguchi Design  
 Design Summary  
 Taguchi L9(3^3)  
 Array

Factors: 3

Runs: 9

Columns of L9 (3^4) array: 1 2 3

**Table 4.Taguchi Array**

Trial No	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3





4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Taguchi Orthogonal Array (OA) design is a general fractional factorial design type. It is a highly fractional orthogonal design based on a design matrix proposed by Dr. Genichi Taguchi. It allows you to consider a subset of combinations of multiple factors at multiple levels. Taguchi Orthogonal arrays are balanced to ensure that all levels of all factors are considered equally. For this reason, the factors can be evaluated independently of each other despite the fractionality of the design.

In the Taguchi OA design, only the main effects and two-factor interactions are considered, and higher-order interactions are assumed to be nonexistent. In addition, designers are asked to identify (based on their knowledge of the subject matter) which interactions might be significant before conducting the design.

Table 5. Stages of Taguchi array

Trials No	Tapping temperature	Pouring temperature	Mould hardness	Range
1	1570	1375	55	25.09
2	1570	1400	65	21.53
3	1570	1430	75	19.00
4	1565	1375	65	21.23
5	1565	1400	75	18.66
6	1565	1430	55	26.00
7	1560	1375	75	18.40



8	1560	1400	55	25.45
9	1560	1430	65	22.00

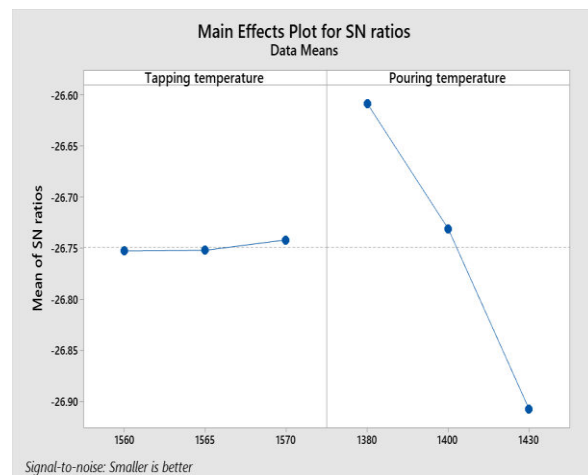
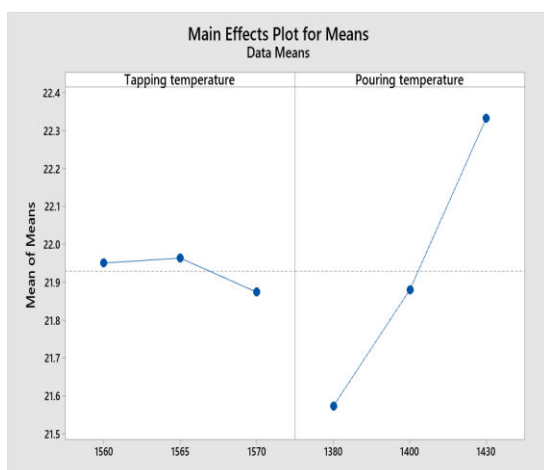
Smaller is better

Level	Tapping	Pouring
	temperature	Temperature
1	-26.75	-26.61
2	-26.75	-26.73
3	-26.74	-26.91
Delta	0.01	0.3
Rank	2	1

Table 6. Overall Improve Stage

S. No	Tapping temperature (Deg C)	Pouring temperature (Deg C)	Mould hardness	Range	SNR A1	MEAN 1
1	1560	1380	75	18.40	-25.2964	18.40

III. RESULTS AND DISCUSSION







**CONTROL STAGE**

**Table 7. Control stage**

S. No	Tapping temperature(Deg C)	Pouring temperature(Deg C)	Mould hardness	Range	SNRA 1	MEAN 1
1	1560	1380	75	18.40	- 25.296 4	18.40

- Hence, the problem is defined in the defined stage.
- We measured a shrinkage defect in the measure stage by comparing the flow chart.
- Then, the particular defect was focused on the analysis stage for choosing the parameters, and hence, the chosen parameters were implemented with the help of Minitab software.
- Those three parameters were implemented in the improved stage of Taguchi design, thereby finding that the above data is best for reducing shrinkage defects.
- The data mentioned above have been taken to the foundry industry; hence, we tapped it at a temperature of 1560 degrees c and poured it at a temperature of 1380 with a mould hardness of 75.
- From this, improving the mould hardness may reduce the shrinkage defect; hence, we controlled the control stage.

**IV. CONCLUSION**

Six Sigma methodologies are not only helpful in reducing casting defects but also help in improving the quality of the product at an industrial level.

- To obtain better quality product components one should adopt a Six Sigma methodology in industries.
- It helps the designer and manufacturer to do their process efficiently in a particular period with good quality.
- In the sand casting process, significant defects like blow holes, pinholes, shrinkage cavities, etc., and those defects affect the product quality. We should adopt a six-sigma methodology to overcome these defects to obtain defect-free casting components.

**V. FUTURE SCOPE**

- Many researchers have conducted experiments to find the sand process parameters to get better quality castings. They have successfully reduced the casting defects considerably up to 6% by properly selecting sand parameters. *DoE* is a technique which can be implemented in any processing industry. In India, several small-scale industries can implement such techniques to improve the yield, give standard process parameters and increase the adequate capacity of the unit. From the research papers' study, we conclude that Six Sigma is a breakthrough improvement methodology. With the use of Six Sigma, it is confirmed that we get a min.50% improvement if we work hard and top management involvement is good. It can also be concluded that the industries mainly use the DMAIC methodology to improve performance.
- This study will help small-scale foundries to initiate Six Sigma projects in their organizations and improve their performance in terms of customer satisfaction as well as financial benefits with an increase in competitiveness in the worldwide market of the foundry.

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