Analysis of Six Sigma—Implementation of DIMAC Methodology in Foundry Industry

P. Nethaji, P. Kaliyappan, R. Sathya, S. R. Hariprakash, and K. Prakash

Abstract This paper work has the objective of suggesting improvements in the quality of a compressor housing work cell using SIX SIGMA concepts. Customers expect good quality products at the right time. Competition in the market is increasing day by day, to overcome this situation; Industries are compelled to develop their manufacturing processes to fulfil customer needs. Many defects occur during the casting process, resulting in poor quality of products there is, therefore need to find a compelling problem that makes the product in-to Critical to Quality (CTQ). A perusal of the relevant literature shows that SIX SIGMA provides a defined paradigm for large scale industries. The goal of this paper is to investigate how SIX SIGMA tool can be adapted to the manufacturing environment. With a reference to taking a leading foundry industry as a case study, the main objective of this project is to reduce the rework/rejection in gravity die casting process and to optimize the parameters using the application of SIX SIGMA methodology; Define-Measure-Analysis-improve-Control (DMAIC).

Keywords Casting defect · CTQ · Six sigma · Gravity dies casting process · DIMAIC

1 Introduction

Quality is based on the established utility of the product. When a product manufactured is free of defects, it is a good quality product. Six Sigma provides continuous improvement in an organization and helps to achieve customer satisfaction. Use of the Six Sigma approach in the organization helps boosting on an on-going basis the

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financial status of the industry. It is used mainly for quality improvement process by reducing the rejection/rework and also the production cost.

Joshi [1], has made an analysis of the various defects in the casting process with Pareto and cause and effect diagrams to locate the exact causes and the remedial factors to improve quality level and productivity of the organization [1]. Chintan [2], discusses various tools and techniques used in Six Sigma methodology and performance measurement of the organization DPMO, maintained at Six Sigma level [2]. Manohar and Balakrishna (2013), there is an analysis of various defects seen on the casting wheel and shows how Six Sigma methodology can be adapt in the casting wheel production process [3]. Sandhya and Ramakrishna [4], discuss Six Sigma DIMAIC methodology tools for reducing defects and optimizing the parameters. Their paper demonstrates their findings of various causes using a cause and effect diagram [4]. Sanjiv Kumar Tiwari [5], has taken up the study of a small scale foundry industry in India, for reducing rejections in a green sand casting using Six Sigma tools, response surface methodology using ANOVA and control chart [5].

Execution for this schema implies that the consolidation from claiming MCDM in six sigma prompt. An noteworthy change in the sigma level of the firm Regardless of unapproved unlucky deficiency for addition assets. This examines could help scientists Furthermore professionals will completely see all the Furthermore profit starting with BDA abilities Also change activities for example, such that LSS What's more GM same time overseeing Ecological issues [6–8]. Those later acquaintance of the six sigma methodology likewise helped large portions firm for effectively upgrading their generation capacities, lessening waste, What's more expanding effectiveness, also usage of the recommended six sigma approach might diminish the dismissal rate significantly [9–11].

Execution of a six sigma nature change one task clinched alongside Indian MSME association included in the creation about transportable enhancer frameworks with a point to decrease the repairs Furthermore rejections Also likewise discriminating survey with respect to detail cutoff points Also control cutoff points may be produced starting with the point of view for six sigma nature and the require to An solid security between the two will be pushed [12–15]. Incline manufacturing by and large used to dispense with waste What's more six sigma methodology utilized to decreasing the defects clinched alongside manufacturing procedure Toward eliminating the methodology variety for assistance for Factual instruments Furthermore systems Also Additionally it could tackle the issue from claiming insufficient specimens in the industry, Furthermore there will be an effective assessment transform accessible to applications [16, 17].

There are many types seen in the casting process to suit mass production. Defect creeping during the gravity die casting process, these deteriorate the quality of the product. The aim of this paper is to find methods for reducing defects in the gravity die casting process and to maintain at Six Sigma level (zero defects).

2 Methodology

This study was done in leading foundry industry, with an in-depth study of the gravity die casting process and controls the defect using Six Sigma methodology and concepts. Figure 1 shows the methodology used for this study.

2.1 *Define Phase*

The first phase shows the existing gravity die casting process and problem definition, with analysis of the internal and external customer voice. This phase provides the objective of the paper and goal statement as well as the relevant data collected.

$$Y = f(x) \tag{1}$$

where

Y Response (problem in the process), and
f(x) Suspected source of variance (cause for the problem).

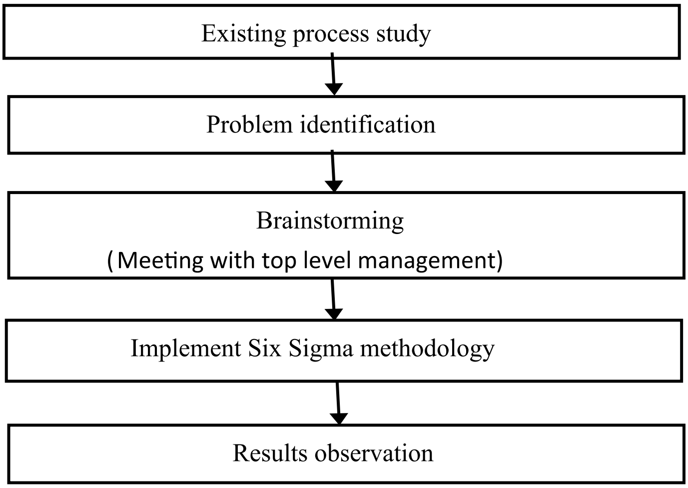

Fig. 1 Methodology six sigma implementation

2.2 Case Study

Six Sigma tools were planned for improvement in foundry industry. This manufacturing process is gravity die casting process; compressor housing products are manufactured here.

3 Measure Phase

A measure phase was used for gathering the current data for quality and cost of the rework, rejection rate, and locating critical defects. Pareto diagram (Fig. 2) shows the number of defects in y axis and the nature of the defects in x axis. It shows "Metal Not Filling defect" (MNF) accounts for bigger quality loss by the rule of 80–20. MNF defect contributes 13.3% of quality loss (Table 1).

3.1 Statement

Molten metal is not filling (MNF Defect) properly in the diffuser area resulting in gaps in the finished product, thereby increasing defects and reducing quality. This problem was identified only in final inspection (Fig. 3).

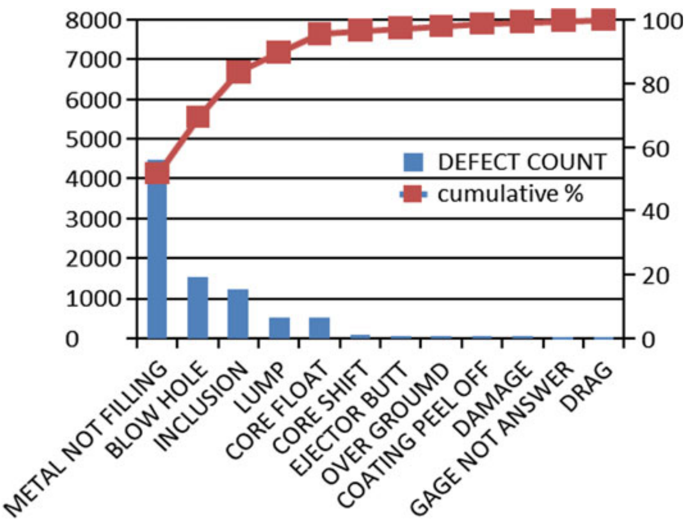

Fig. 2 Pareto diagram

Table 1 Table for Pareto diagram

Defects	Count	Cumulative count	Cumulative %
Metal Not Filling	4470	4470	51.73012383
Blow Hole	1534	6004	69.48269876
Inclusion	1226	7230	83.67087143
Lump	532	7762	89.82756625
Core Float	508	8270	95.70651545
Core Shift	79	8349	96.62076149
Ejector Butt	65	8414	97.37298924
Over Ground	64	8478	98.11364425
Coating Peel Off	63	8541	98.84272654
Damage	47	8588	99.38664506
Gage Not Answer	28	8616	99.71068163
Drag	25	8641	100

Fig. 3 MNF defect in diffuser area Problem

4 Analysis Phase

This phase helps to identify the critical cause for the MNF defect, suspected source of variance and find the root cause (X) for the CTQ and decide which vital cause requires controls (Y). Figure 4 shows the cause of the problem. Data was collected with the help of the production engineer and quality manager.

4.1 Improve Phase

The aim of the improvement phase is to improve quality and provide a solution for critical defects.

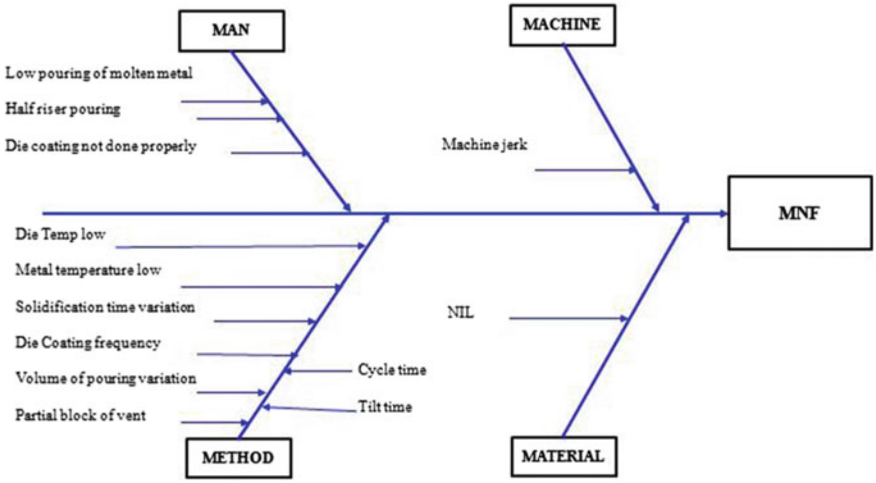

Fig. 4 Cause and effect diagram

5 Metal not Filling (MNF)-The Step

(1) Ensure that molten metal is not returned to the holding furnace.
(2) Avoid half raiser pouring
(3) Increase the vent hole size. This increases the rate of core gas escapes from the die during solidification.
(4) Decrease the tilt time. This helps to increase the filling effect of molten metal in the die.
(5) Ensure that die is clean.
(6) Standardize the pouring cup angle.

5.1 Full Factorial DOE Analysis

Full Factorial gives all possible combinations of factors and levels and these were all tested. Two factors were selected for the test (Tilt Time and Vent hole size). The following equation shows the relationship between Y(response) and Xs(factors).

$$Y = a_0 + a_1X_1 + a_2X_2 + \cdots \in +a_pX_1X_2 \ldots\ldots X_N + \varepsilon \quad (2)$$

where

Y	is the response and X_1, X2.... X_k are the factors.
a_0- a_1,a_2.....a_p	Intercept coefficients of the factors and interaction.
ε	Error of the model.

$2^k = 2^2$ = 4 treatment;
K Factor (Figs. 5 and 6: Tables 2, 3 and 4).

In the control phase, the result should be palpable control and sustain the new result and monitor it to ensure that problem seen earlier does not crop up. The following action was implemented by the production and quality department to sustain the new result.

- New design for the die should not be getting back into older design.

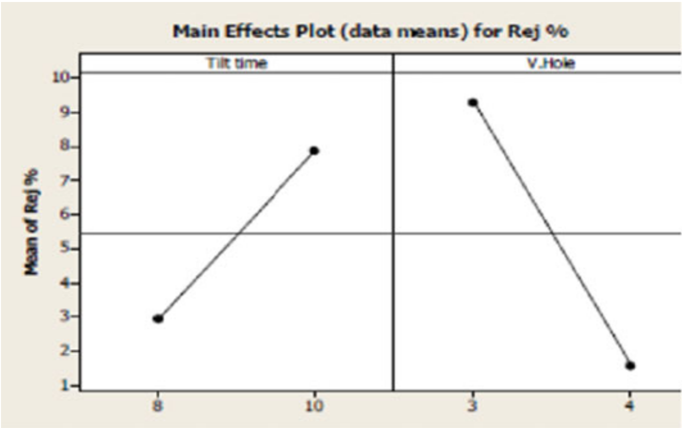

Fig. 5 Main effect plot

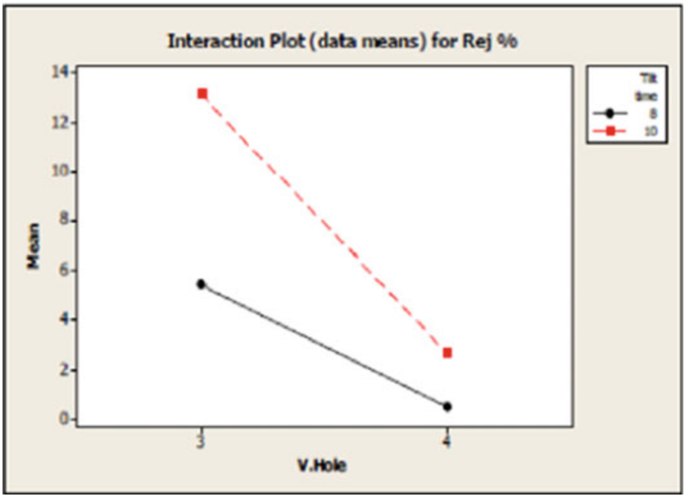

Fig. 6 Interaction plot control phase

- Tilt time for the machine should be monitor regularly. Proper training to be provided to the operator.

6 Concluding the Results

This paper shows how SIX SIGMA DMAIC methodology can be used for reducing critical defects in a foundry industry. Quality level of the compressor housing part is increased by the use of the six sigma approach and it helps to meet the customer demand quickly. After using the Six Sigma methodology, the rejection rate of MNF defect came down to 0.45% from 13.3% (Fig. 7).

Fig. 7 Defect-free job

Table 2 Factors and levels

Sl. No	Suspected source of variance	unit	Current setting (−)	New setting (+)
1	Tilt Time	seconds	10(−)	8(+)
2	Vent hole size	Millimetre	3(−)	4(+)

Table 3 Two factors, two leave full factorial

Run	Treatment	Factors	
		Tilt Time (A)	Vent size (B)
1	L	−1	−1
2	A	+1	−1
3	B	−1	+1
4	Ab	+1	+1
Trail 1 tilt time =10, vent size=3		**Trail 2 tilt time =8, vent size=3**	
Test	MNF rejection %	Test	MNF rejection %
1st	8.22	1st	5.24
2nd	13.20	2nd	6.28
3rd	13.16	3rd	5.42
Median	13.16	Median	5.42
Trail 3 tilt time =10, vent size=4		**Trail 4 tilt time =8, vent size=4**	
Test	MNF rejection %	Test	MNF rejection %
1st	2.63	1st	0.64
2nd	2.42	2nd	0.48
3rd	2.82	3rd	0.46
Median	2.63	Median	0.48

Table 4 Result of the trails

Trail no	Tilt time	Vent hole size	Treatment	Response (median of rejection %)
1	(−1) 10	(−1) 3	L	13.16
2	(+1) 8	(−1) 3	A	5.42
3	(−1) 10	(+1) 4	B	2.63
4	(+1) 8	(+1) 4	Ab	0.48

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