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Improvement in production rate by reducing the defects of die casting process by DMAIC approach

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ABSTRACT

Six Sigma's problem-solving methodology DMAIC has been one of several techniques used to improve quality. The work follows the DMAIC methodology to investigate defects, root causes and provide a solution to reduce/eliminate these defects. The analysis from employing Six Sigma and DMAIC indicated that the metal melting temperature, die temperature and die holding time influenced the number of defective items produced. In particular, the design of experiments (DOE) and two-way analysis of variance (ANOVA) techniques were combined to statistically determine the correlation of the metal melting temperature, die temperature and die holding time with defects as well as to define their optimum values needed to reduce/eliminate the defects. As a result, a reduction of 16.93 % to 10.04 % in the terminal cover and 16.62 % to 8.97 % in the din based cover was achieved, which helped the organisation studied to reduce its defects per million opportunities (DPMO) and thus improve its Sigma level from 2.53 to 2.79 for the terminal cover and 2.55 to 2.85 for the din based cover.

Keywords: *Defects, Productivity, Quality, DMAIC approach, Cause and effect analysis*

1. INTRODUCTION

The DMAIC is both a philosophy and a methodology that improves quality by analyzing data to find the root cause of quality problems and to implement controls. Although DMAIC implemented to improve manufacturing and business, processes such as product design and supply chain management. It is a business improvement strategy used to improve profitability to drive out waste in the business process and to improve the efficiency of all operation that meets customer's needs and expectation. DMAIC is a customer-focused program where cross-functional teams work on a project aimed at improving customer satisfaction. It is a scientific method to improve any aspect of a business, organization process.

DMAIC is a methodology to
1. Identify improvement opportunities.
2. Define and solve problems
3. Establish measures to sustain the improvement.

Six- Sigma is a statistical measurement of only 3.4 defects per million. Six-Sigma is a management philosophy focused on eliminating mistakes, waste and rework. It establishes a measurable status to achieve and embodies a strategic problem-solving method to increase customer. Satisfaction and dramatically reduce cost and increase profits. Six-Sigma gives discipline, structure, and a foundation for solid decision making based on simple statistics. The real power of Six Sigma is simple because it combines people power with process power. The Six Sigma is a financial improvement strategy for an organization and now a day it is being used in many industries. Basically it is a quality improving process of final product by reducing the defects; minimize the variation and improve capability in the manufacturing process. The objective of Six Sigma is to increase the profit margin, improve financial condition through minimizing the defects rate of product. It increases the customer satisfaction, retention and produces the best class product from the best process performance.

2. LITERATURE REVIEW

Mohit Chhikara (2017) presented the literature-assessment of the works already carried out inside the discipline of Six Sigma Implementation by using the various authors till now. The findings of this paper might be the premise of my similarly research in this field with the aid of developing suitable research technique needed to achieve the targets set via me for my research work. Rajat Ajmera and Valase K.G. (2017) explore using DMAIC methodology of six sigma to decrease the defect in a specific textile industry. That is a scientific technique in the direction of defects minimization thru 5 stages of DMAIC technique named define, measure, analyze, improve and control. Special six sigma equipment were utilized in different levels. Pareto analysis was done to identify the predominant kinds of defects. Root causes of those defects were detected via cause and effect analysis. In the end a few ability answers are counselled to conquer those causes. The result determined after implementation of the solutions is very large. Enhancements within the satisfactory of strategies result in cost reductions in addition to service upgrades. The defect percent has been reduced from 7.4 to 5.08 % and therefore the Sigma stage has been progressed from 2.9 to a 3.2. Jitendra A Panchiwala (2015) carried out the research work made by using several researchers and an try to get technical solution for minimizing numerous casting defects and to enhance the entire process of casting production. C. Manohar and A. Bala Krishna (2015) discusses the quality and productivity development in a manufacturing industry through defect analysis and offers with an application of Six Sigma DMAIC (define–degree-analyse-improve-manipulate) method in wheel production plant which offers a framework to become aware of, quantify and remove assets of variant in an operational system in question, to optimize the operation variables, enhance and maintain performance viz. process yield with well completed control plans to reduce defects occurring in cast wheel manufacturing. Ghazi Abu Taher & Md. Jahangir Alam (2014) reveals out the effective manner of enhancing the great and productivity of a manufacturing line in production enterprise. The goal is to perceive the disorder of the company and create a higher answer to enhance the manufacturing line performance. Various commercial engineering technique and gear is implementing on this examine so as to research and solve the trouble that happens inside the production. But, 7 excellent manipulate equipment are the primary tools in an effort to be carried out to this observe. Records for the chosen assembly line manufacturing facility are amassed, studied and analysed. The illness with the very best frequency will be the primary goal to be stepped forward. Various reasons of the defect can be analysed and various solving technique might be present. The high-quality fixing approach can be chosen and recommend to the agency and examine to the preceding result or production. But, the implementation of the solving techniques is depending at the employer whether or not they wanted to apply or not.

3.1 SIX-SIGMA METHODOLOGY (DMAIC)

The DMAIC methodology has a core process: Define-Measure-Analyse-Improve- Control (DMAIC) methodology. The five steps to DMAIC approach are:

3.1.1 DEFINE PHASE

The first stage of the Six Sigma and DMAIC's methodology is "define". This stage aims at defining the project's scope and boundary, identifying the voice of the customer (i.e. customer requirements) and goals of the project. However, before defining these elements within the project, the Six Sigma team has to be set up.

Finally, a project charter which is a tool used to document the targets of the project and other parameters at the outset were employed to state and present the project's information structure. The project charter, in other words, summarised the project's scope, boundary, goal and the team's role in this research project. The project charter is presented in Table 1.

Table 1: Project charter

Project Title: Defects reduction in terminal cover and din based cover	
Background and reasons for selecting the project: A large amount of terminal cover and din based cover has been rejected by customers due to they were defective. This problem causes several types of losses to the company, for example time, materials, capital as well as it creates customers' dissatisfaction, which negatively affects the organization's image.	
Project Goal: To reduce the defects by 50% after applying Six Sigma into the terminal cover and din based cover manufacturing process	
Project Boundary:	Focusing solely on terminal cover and din based cover
Expected Financial Benefits:	A considerable cost saving due to the defects reduction
Expected Customer Benefits:	Receiving the product with the expected quality

3.1.2 MEASURE

Particularly, in this project, the "measure" phase meant the definition and selection of effective metrics in order to clarify the major defects which needed to be reduced [2]. Also, a collection plan was adopted for the data to be gathered efficiently. One of the metrics defined was simply a number of defects per type. After defining the total number of defects, the DPMO and Sigma level of the terminal cover and din based cover manufacturing process were calculated. According to the company's records, there was one major type of defects which had contributed to the terminal cover and din based cover to be rejected by the customers. These one major defects were blown holes. The defects data was collected for ten days. The results are shown in fig. 1 and summarised in Table 2.

Table 2: Rejection % with no. of defected items before study for terminal cover and din based cover

No. of Batches	Rejection % (for terminal cover)	Defected items (for terminal cover)	Rejection % (for din based cover)	Defected items (for din based cover)
1	16.4	82	17.37	78
2	15.2	76	22.25	74
3	16.8	84	19.33	82
4	17.6	88	20.77	88
5	15.8	79	17.65	77
6	16.8	84	19.62	91
7	18.4	92	21.07	92
8	17.6	88	17.92	89
9	17.8	89	23.76	77
	Defect % = 16.93	**762**	**Defect % = 16.62**	**748**

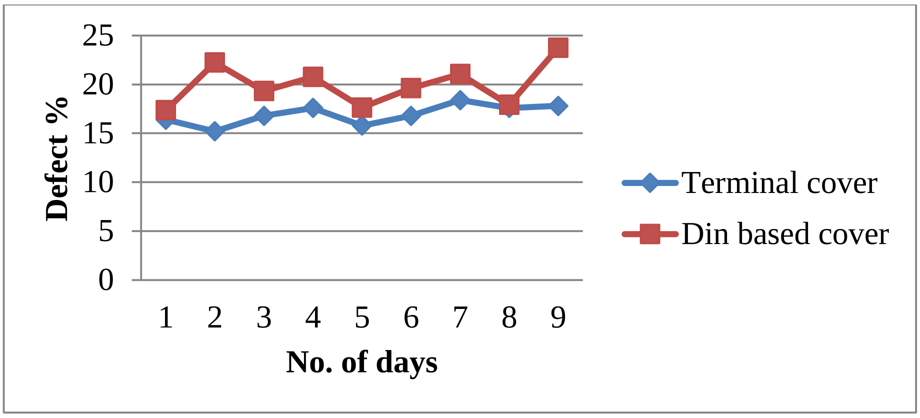

Fig. 1: Defects per day for terminal cover and din based cover

Table 3: Defects summary (before the improvement) for terminal cover and din based cover

Type of defects	Type of product	Production per day	Total production for 9 days	Total no. of defects	Percentage of defects
Blow hole	Terminal cover	500	4500	762	16.93 %
Blow hole	Din based cover	500	4500	748	16.62 %

Table 4: Sigma quality level of batches before study for terminal cover

Batch	Rejection %	DPU	DPMO	sigma level	Range
1	16.4	0.164	164000	2.48	
2	15.2	0.152	152000	2.53	**Max**
3	16.8	0.168	168000	2.47	
4	17.6	0.176	176000	2.44	
5	15.8	0.158	158000	2.51	
6	16.8	0.168	168000	2.47	
7	18.4	0.184	184000	2.40	**Min**
8	17.6	0.176	176000	2.44	
9	17.8	0.178	178000	2.43	

Table 5: Sigma quality level of batches before study for din based cover

Batch	Rejection %	DPU	DPMO	sigma level	Range
1	14.8	0.148	148000	2.55	**Max**
2	18.2	0.182	182000	2.40	
3	16.2	0.162	162000	2.49	
4	17.2	0.172	172000	2.45	
5	15	0.15	150000	2.54	
6	16.4	0.164	164000	2.48	
7	17.4	0.174	174000	2.44	
8	15.2	0.152	152000	2.53	
9	19.2	0.192	192000	2.37	**Min**

3.1.3 ANALYSE PHASE

This phase in the DMAIC improvement methodology involves the analysis of the system, in this case the manufacturing process that produces the terminal cover and din based cover, in order to identify ways to reduce the gap between the current performance and the desired goals. To do this, an analysis of the data is performed in this phase, followed by an investigation to determine and understand the root cause of the problem (defects). Several brainstorming sessions were conducted to identify based on the improvement team members' experience, possible causes as to why the blow holes problem occurred

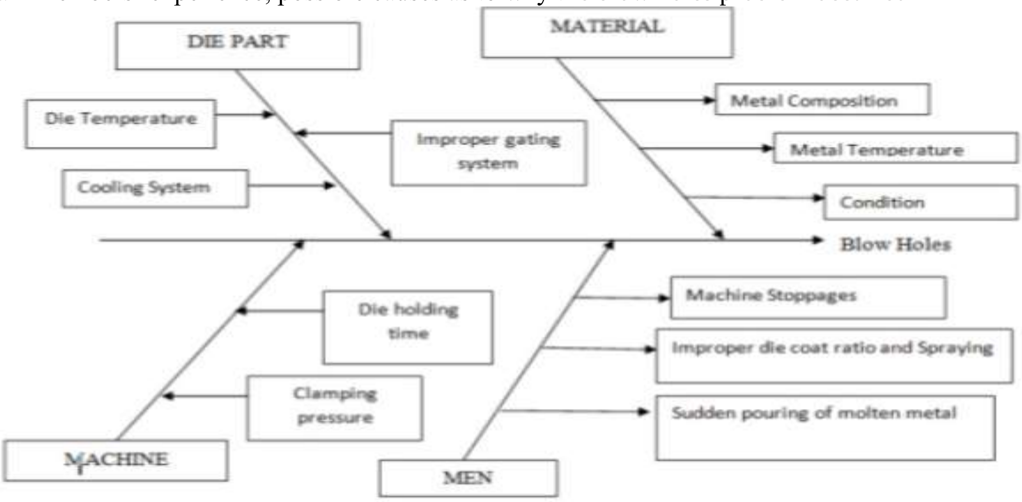

Fig. 2: Cause and effect diagram

3.1.4 IMPROVE PHASE

In this phase, Taguchi DOE is conducted with the three process parameters identified from the analysis phase.
Since the relationship between these parameters was not known, it was decided to experiment all these parameters at three levels. The parameters and levels selected for experimentation are presented in Table 6.

Table 6: Parameter and level selection for experiment

Factor	**1**	**2**	**3**
Metal melting temperature	650 °C	675 °C	700°C
Die temperature	250 °C	275 °C	300°C
Die holding time	65 sec	75 sec	85 sec

It was possible to estimate the effect of these selected parameters and interactions using the 9 experiments with the help of Orthogonal Array (OA). Hence for conducting an experiment with three parameters and three interactions, the L9 orthogonal array was selected.
As per the design layout is given in Table 7, the experiments were conducted after randomizing the sequence of experiments, and the data were collected. The experimental data were analyzed by Taguchi's Signal-to-Noise (S/N) ratio method. The S/N ratio is advocated in the Taguchi method to minimize the number of the defect.

Table 7: L9 orthogonal array sequence for an experiment for terminal cover

SN	**Metal melting temperature (°C)**	**Die temperature (°C)**	**Die holding time (s)**	**No of defects**	**S/N ratio**
1	650	250	65	48	-33.62
2	650	275	75	46	-33.26
3	650	300	85	52	-34.32
4	675	250	75	57	-35.12
5	675	275	85	58	-35.27
6	675	300	65	49	-33.80
7	700	250	85	47	-33.44
8	700	275	65	52	-34.32
9	700	300	75	43	-32.67

Table 8: L9 orthogonal array sequence for experiment for din based cover

SN	Metal melting temperature (°C)	Die temperature (°C)	Die holding time (s)	No of defects	S/N ratio
1	650	250	65	47	-33.44
2	650	275	75	54	-34.65
3	650	300	85	43	-32.67
4	675	250	75	55	-34.81
5	675	275	85	51	-34.15
6	675	300	65	56	-34.96
7	700	250	85	42	-32.46
8	700	275	65	58	-35.27
9	700	300	75	48	-33.62

The experiment is carried out as per the factor settings in each test condition and 5000 components are produced in 10 batches. The number of defected components is recorded as a response for each test. Since the experiment response is a number of defected components, 'Smaller the better' S/N ratio characteristic selected and calculated using the below equation and recorded as shown in Table 7-8.

$$\frac{S}{N_{smaller)}} = -10 \log\left(\frac{\sum(y_i^2)}{n}\right)$$

3.1.5 Control phase

The real challenge of the Six Sigma implementation is the sustainability of the achieved results. Due to a variety of reasons, which includes people changing the job, promotion/ transfer of people operating on the process, converting awareness of the individual to different manner-related problems some other place within the organization and lack of possession of new humans within the method, pretty often keeping the consequences are extraordinarily hard. Sustainability of the results requires standardization of the advanced methods and introduction of monitoring mechanisms for the key consequences executed.

4. RESULTS AND DISCUSSION

4.1 Main effect plots for blow hole defect for terminal cover and din based cover

Main effect plots for patches are shown in figure 3. Main effect plot shows the variation of no. of the defected item with respect to parameter considered. X-axis represents a change in the level of the variable and y-axis represents the change in the resultant response.

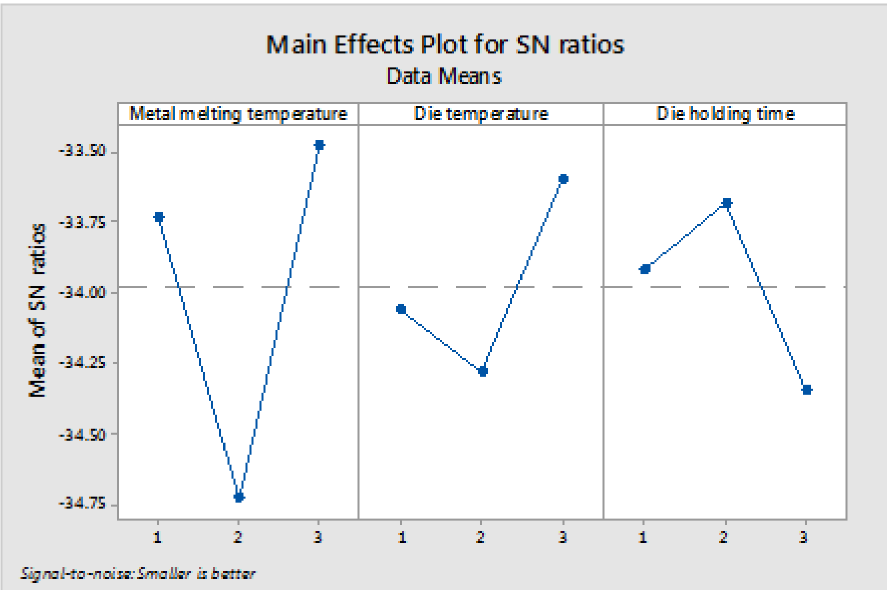

Fig. 3: Main effects plot of S/N ratios for blow holes for terminal cover

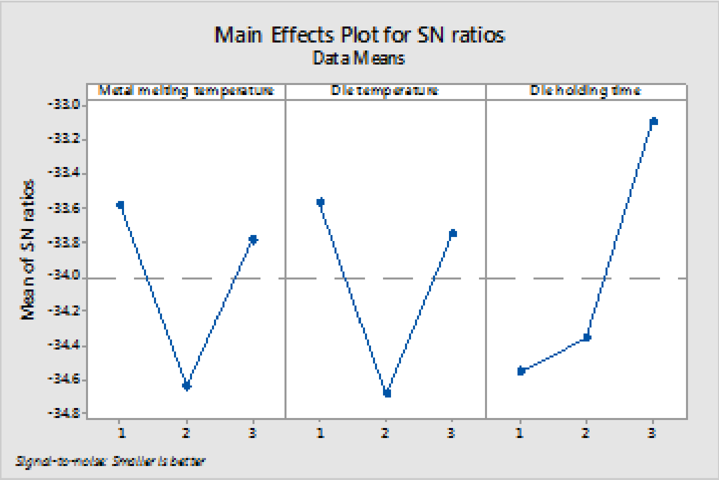

Fig. 4: Main effects plot of S/N ratios for blow holes for din based cover

4.2 Determination of optimum solution for blow hole defect for terminal cover and din based cover

From figure 3-4, optimum factor levels for patches are identified based on the 'Bigger the Better' S/N ratio characteristic and listed in Table 9-10. The optimal result has been verified through confirmatory test showed the satisfactory result.

Table 9: Optimum levels for blow hole defect for terminal cover

Parameter designation	Process parameters	Optimal levels
A	Metal Melting temperature (°C)	675
B	Die temperature (°C)	275
C	Die holding time (sec)	85

Table 10: Optimum levels for blow hole defect for din based cover

Parameter designation	Process parameters	Optimal levels
A	Metal Melting temperature (°C)	675
B	Die temperature (°C)	275
C	Die holding time (sec)	65

4.3 Confirmation test for blow hole defect for terminal cover and din based cover

The last step of Taguchi parameter design is to verify and predict the improvement in a number of defect (response) using optimum combination of parameters.

A confirmation test is conducted with the batch volume of 5000 product at the optimum factor settings. Out of 500 components produced in 10 batches. The confirmation experiment results inferred that the rejection rate is brought to 9.92 % and 8.14 %.

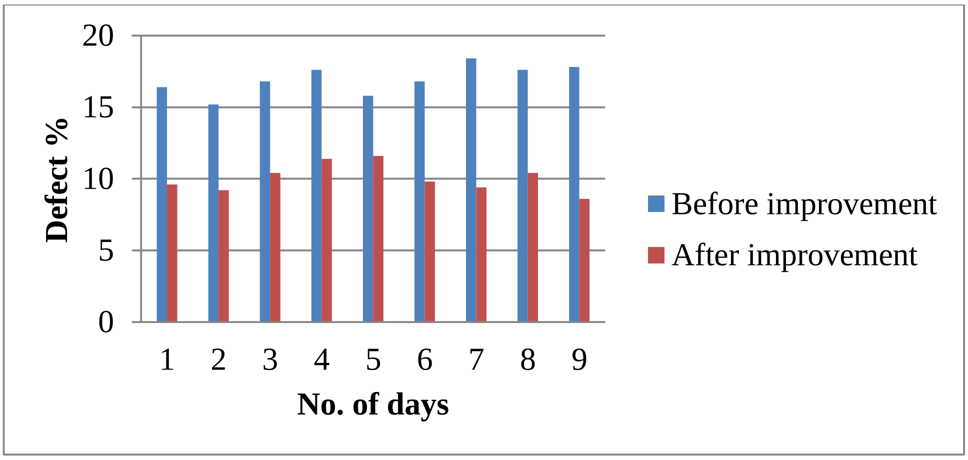

Fig. 5: Rejection trend after implementation for terminal cover

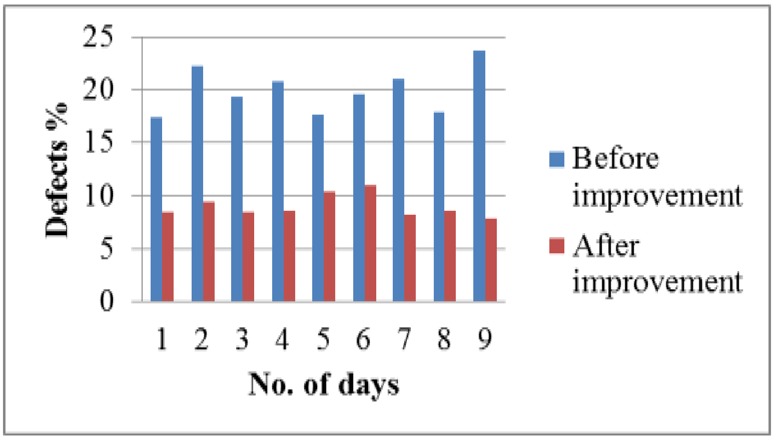

Fig. 6: Rejection trend after implementation for din based cover

4.4 Calculation of sigma level after study for blow hole defect for terminal cover and din based cover

FOR TERMINAL COVER:

The defects per unit (DPU) are:

DPU = Total number of defects observed in the batch /Total number of units produced in the batch

=496/5000 = 0.0992

Defects per opportunities (DPO) is: one

DPO= DPU/1 = 0.0992

Defects per million opportunities (DPMO) are:

DPMO = DPO×1,000,000= 0.0992 x 1000000= 99200

Sigma quality level = $0.8406 + [29.37 - 2.221 \times \ln(99200)]^{1/2} = 2.79$

FOR DIN BASED COVER:

The defects per unit (DPU) are:

DPU = Total number of defects observed in the batch /Total number of units produced in the batch

= 446/5000 = 0.0892

Defects per opportunities (DPO) is: one

DPO= DPU/1 = 0.0892

Defects per million opportunities (DPMO) are:

DPMO = DPO×1,000,000= 0.0892 x 1000000= 89200

Sigma quality level = $0.8406 + [29.37 - 2.221 \times \ln(89200)]^{1/2} = 2.85$

5. CONCLUSION

5.1 conclusions for blow holes defect for terminal cover

From the experiment following results were obtained.

- It has been found that metal melting temperature is found to be the most significant factor. The best results (small is better) would be achieved with optimum parameter= metal melting temperature = 650 °C, die temperature = 275 °C and die holding time = 85 sec. With 95% confidence interval, the metal melting temperature effect the blow holes defect most significantly.
- The blow holes defect is mainly affected by metal melting temperature, die temperature and die holding time. With the increase in metal melting temperature and die temperature the blow holes defect first decrease and then increases and as the die holding time increase blow holes defect first increases and then decreases.
- From ANOVA analysis, parameters making a significant effect on blow holes defect are metal melting temperature.
- Using experiment conducted optimum parameters were determined i.e. metal melting temperature = 650 °C, die temperature = 275 °C and die holding time = 85 sec.
- The percentage of rejection decreases from 16.93 % to 10.04 % as shown below.
- Sigma Level improves after study from 2.53 to 2.79.
- The number of defective items also decreased from 762 to 452.
- The number of good items also increased from 3738 to 4048.
- Productivity increases from 82.9 % to 90.08 %.
- Rejection trend after study decreases.

Table 11: Findings of study for terminal cover

	Rejection	**Total Item produced**	**Defective item**	**Good item**	**Productivity**
Before	16.93 %	4500	853	3738	83.06 %
After	10.04 %		452	4048	89.95 %

5.2 Conclusions for blow holes defect for din based cover

From the experiment following results were obtained.

- It has been found that die holding time is found to be the most significant factor. The best results (small is better) would be achieved with optimum parameter= metal melting temperature = 650 °C, die temperature = 275 °C and die holding time = 65 sec. With 95% confidence interval, the die holding time effect the blow holes defect most significantly.
- The blow holes defect is mainly affected by metal melting temperature, die temperature and die holding time. With the increase in metal melting temperature and die temperature the blow holes defect first increases and then decreases and as the die holding time increase blow holes defect increases.
- From ANOVA analysis, parameters making a significant effect on blow holes defect are die holding time.
- Using experiment conducted optimum parameters were determined i.e. metal melting temperature = 650 °C, die temperature = 275 °C and die holding time = 65 sec.
- The percentage of rejection decreases from 16.62 % to 8.97 %
- Sigma Level improves after study from 2.55 to 2.85.
- The number of defective items also decreased from 748 to 404.
- The number of good items also increased from 3752 to 4096.
- Productivity increases from 82.9 % to 90.08 %.
- Rejection trend after study decreases.

Table 12: Findings of study for din based cover

	Rejection	**Total Item produced**	**Defective item**	**Good item**	**Productivity**
Before	16.62 %	4500	748	3752	83.77 %
After	8.97 %		404	4096	91.02 %

6. REFERENCES

[1] Mohit Chhikara, NS Narwal, Pradeep Dahiya (2017), "Implementation of Six Sigma in Indian Manufacturing Industries", International Journal of Advance research, Ideas and Innovations in Technology, Vol. 3, issue 1, PP: 22-31.

[2] Rajat Ajmera and Valase K.G. (2017), "Applying Six Sigma Methodology Based on "DMAIC" Tools to Reduce Defects in Textile Industry", International Journal of Informative & Futuristic Research, Vol. 4, Issue 7, PP: 6732-6741.

[3] Jitendra A Panchiwala, Darshak A Desai, Paresh Shah (2015), "Review on Quality and Productivity Improvement in Small Scale Foundry Industry", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4 Issue 12, PP: 11859-11867.

[4] C. Manohar, A. Bala Krishna (2015), "Defect Analysis on Cast Wheel by Six Sigma Methodology to reduce defects and Improve the Productivity in Wheel Production Plant" International Research Journal of Engineering and Technology, Vol. 2 Issue 3, PP: 1659-1663.

[5] Ghazi Abu Taher, Md. Jahangir Alam (2014), "Improving Quality and Productivity in Manufacturing Process by using Quality Control Chart and Statistical Process Control Including Sampling and Six Sigma", Global Journal of Researches in Engineering, Vol. 14 Issue 3, PP: 201-210.

[6] Darshan D. Patel, K.R.Gawande (2014), "Productivity improvement through six sigma methodology in bearing manufacturing", International Journal for Research in Applied Science and Engineering Technology, Vol. 2, Issue 3, PP: 233-239.

[7] S. Chandra, B. Doloi, B.K. Bhattacharya (2014), "Implementation of Six- Sigma Methodology for Improvement of Process Yield by Reduction of Rejection (For %) in a Manufacturing Process", All India Manufacturing Technology, Design, and Research Conference, PP: 644-670.

[8] Pramod A. Deshmukh, A. B. Humbe (2014), "Productivity Improvement-A Case Study", International Journal of Research in Engineering & Technology, Vol.2, Issue 2, PP: 287-294.

[9] S. Arun Vijay (2014), "Reducing and Optimizing the Cycle Time of Patients Discharge Process in a Hospital Using Six Sigma DMAIC Approach", International Journal for Quality Research, Vol. 8 Issue 2, PP: 169–182.

[10] Mohit Taneja, Arpan Manchanda (2013), "Six Sigma an Approach to Improve Productivity in Manufacturing Industry", International Journal of Engineering Trends and Technology, Volume 5 Issue 6, PP: 281-286.

[11] Hemendra Nath Roy, Sudipta Saha, Tarapada Bhowmick, Sufal Chandra Goldar (2013), "Productivity Improvement of a Fan Manufacturing Company by using DMAIC Approach: A Six-Sigma Practice", Global Journal of Researches in Engineering Industrial Engineering, Volume 13, Issue 4, PP: 115-120.

[12] Faisal Talib (2013), "An Overview of Total Quality Management: Understanding the Fundamentals in Service Organization", International Journal of Advanced Quality Management, Volume 1, Issue 1, PP: 1-20.

