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## Case Study

## APPLICATION OF SIX SIGMA IN INJECTION MOULDING PROCESS

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### ABSTRACT

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Six Sigma is a collective approach, which uses various techniques and tools for quality improvement. Here, Six Sigma methodology was applied to a small injection moulding unit (which can be taken as representative of small and medium size industries) manufacturing Latch. The DMAIC (Define, Measure, Analyze, Improve and Control) approach of Six Sigma was applied to reduce rejection rate of Latch (child part of automobile door lock system) by changing two parameters (injection moulding pressure and pre-drying temperature) in the moulding process. The statistical techniques such as process capability analysis and two sample t-test were done to found the process capability before and after the Six Sigma implementation. After implementing Six Sigma DMAIC approach it was found that the injection moulding firm can increase its profit by controlling rejection rate of Latch. Six Sigma implementation increase the process sigma level from 1.80 to 5.46 by reduction in Latch hole diameter variation. This increase in sigma level will give saving of Rs. 0.708 million per annum to the industry which is a good figure for such industry.

Keywords – Six Sigma, Injection moulding, DMAIC, DPMO.

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### 1. Introduction

Six Sigma is a way to implement better quality standards. It is both a philosophy and a methodology that improves quality by analyzing data with statistics to find the root cause of quality problems and to implement controls. Primarily six sigma implies three things: measure of quality, process for continuous improvement and enabler for culture change. Statistically, Six Sigma refers to a process in which the range between the mean of a process quality measurement and the nearest specification limit is at least six times the standard deviation of the process [1]. According to Mohammad Aazadnia & Mehdi Fasanghari, Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects and minimising variability in manufacturing and business process [2]. The numerical goal of Six Sigma is in reducing defects to less than 3.4 parts per million (PPM) also known as 'Defects Per Million Opportunities' (DPMO), reducing cycle time and reducing costs dramatically which impact the bottom line [3]. Although Six Sigma has been implemented with success in many large corporations, there is still less documented evidence of its implementation in smaller organizations [4].

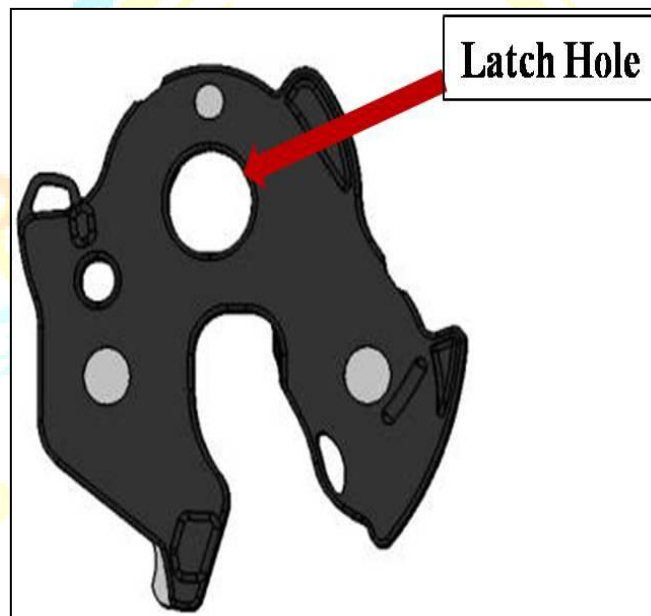
In the present work six sigma methodology was applied over the Injection moulding unit ,to provide a way to small and medium sized enterprises(SME's) , on how to reduce the rejection rate of their products to get high quality commodities and increase profit. Modern quality management techniques like Six Sigma which was

normally supposed to be a key player of quality management for larger industries also shown to be effective for SME's.

Here we have applied the Six Sigma methodology to a small injection moulding unit manufacturing Latch (child part of automobile door lock system). The DMAIC (Define, Measure, Analyze, Improve and Control) approach of Six Sigma was applied to reduce rejection rate of Latch. The statistical techniques such as process capability analysis and two sample t-test, was performed to found the process capability before and after the Six Sigma implementation.

## 2. Case study product

Present study was carried out on a injection moulding unit which manufacture latch i.e. child part of automobile door lock system. It's a small firm representative of SMEs. The firm covers the metal latch with a plastic material by injection moulding in the unit. The Latch with its key hole is shown in Fig. 1. The latch manufacturing process was showing high rejection rate, which was 3.5 percent causing huge annual losses to firm. As the rate of rejection was high so the firm was interested to reduce it. The study was taken to identify the key factors of rejection using the six sigma approach and how the process can be improved.



*Fig. 1. Latch :child part of automobile door lock system*

## 3. Application of DMAIC Methodology

The five phase DMAIC approach (Fig. 2) was chosen to study the key factors for latch rejection and was applied to eliminate or improve these factors to reduce rejection. The tolerance limit of the key hole diameter of latch was in the range of 7.1mm-7.3 mm. The high rejection rate of 3.5 percent was noticed in initial study, which was due to variation in latch hole diameter. So, there was a great need to reduce rejection rate by reducing defects in different processes. Six Sigma DMAIC methodology was used to solve latch rejection problem to achieve the quality level of 3.4 PPM from the present level of 3.5 percent.

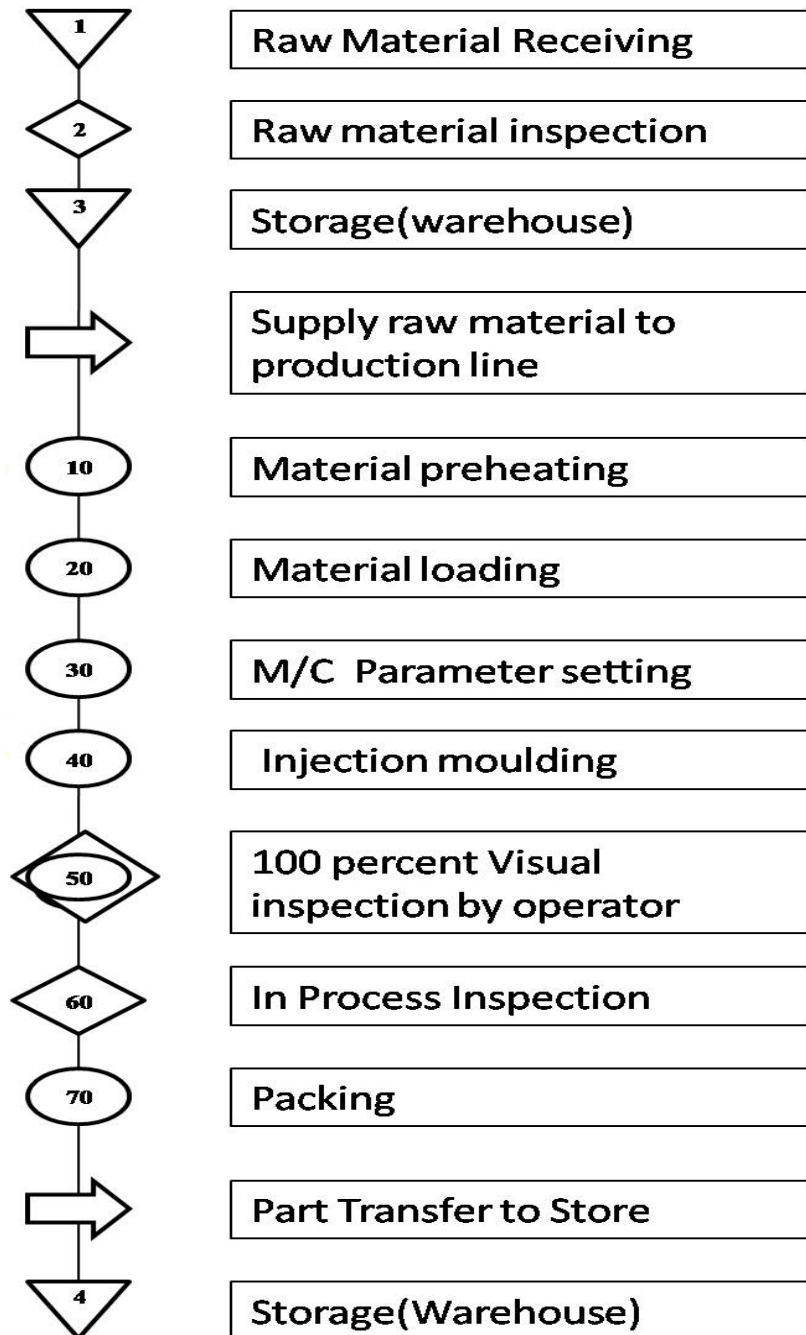
The project registration was the first activity, which showed formal approval from the management to initiate the project, without their backing it was never possible to involve people and implement suggestions. The methodology of implementation is as follow:



*Fig. 2. DMAIC methodology*

### 3.1 Define

Define phase is an initial setup where the cause of problem is addressed for process that need to be improved. So Process Map and High Level Process Map- a SIPOC (Supplier, Input, Process, Output, Customer) diagram were drawn for Latch and studied (Fig. 3, Fig. 4).



*Fig. 3. Process Flow Diagram*

## HIGH LEVEL PROCESS MAP

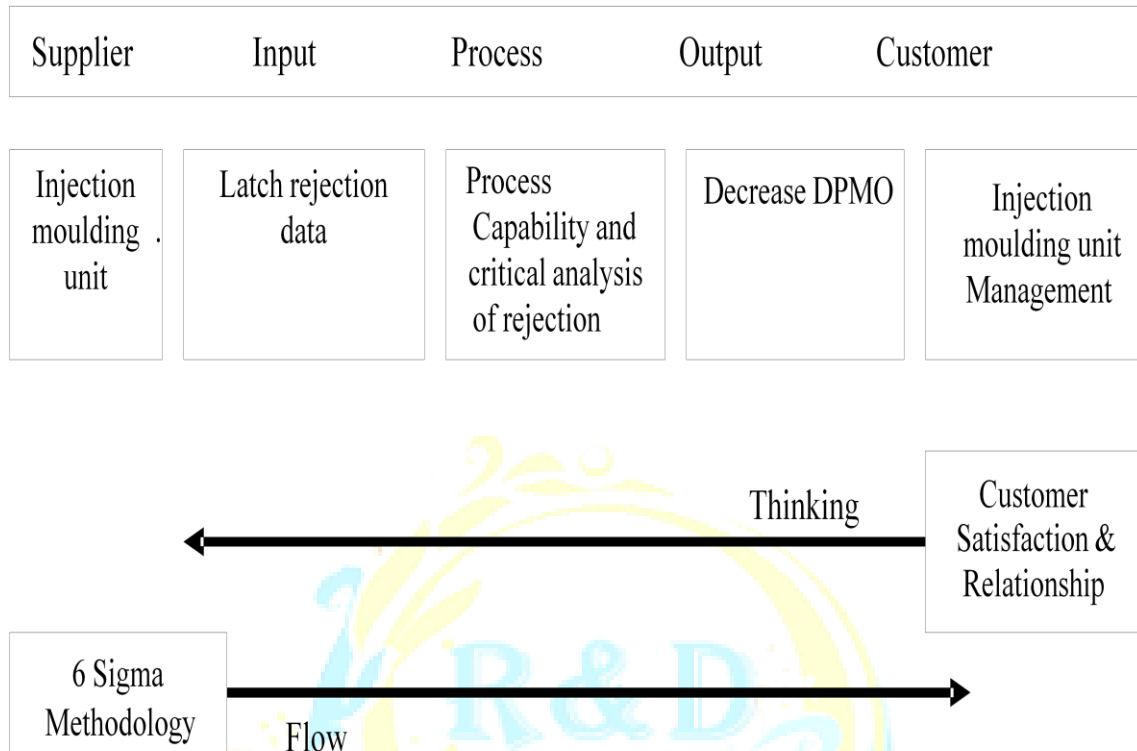


Fig. 4. SIPOC Diagram

### 3.2 Measure

Measurement systems play a crucial role in the finding the quality of the product. As it gives indication whether product is under the desired specification limits or not. Repeatability and reproducibility are the two key factors in judging the measurement system accuracy and efficiency. Repeatability is the measurement variability found when the same item is measured repeatedly with a specific gauge by the same operator. While Reproducibility is the additional measurement variability found when the same item is measured repeatedly with a specific gauge by different operators. Gauge R&R (Gauge repeatability and reproducibility) studies were performed for ensuring the measurement system accuracy. The experiment was performed jointly by operator and investigator. The sample size of 10 was considered and two reading were taken for each sample. Making the collective reading count of forty. Vernier calliper was used for measurement. The repeatability comes out to be 28.18 percent and reproducibility was 0.00 percent. As the percentage study variation (28.18 percent) was less than 30 percent indicating that measurement system was correct

### 3.3 Analysis

The analysis phase uses various statistical methods to find out variations contributing significantly towards the problem [5]. Many statistical tools were used to carry out the analysis are described below.

#### 3.3.1 Process capability analysis

Process capability analysis can be defined as the inherent variability of a process in the absence of any undesirable

special causes. To determine the process state, process capability analysis was done using Minitab software. For process capability curve 100 samples were taken and were sub-grouped into group of five consisting of twenty samples each. From the curve the Z-Bench value of 1.80 and DPMO of 35765.14 was obtained (Fig. 5). As DPMO was found to be high, there was the need to improve the process.

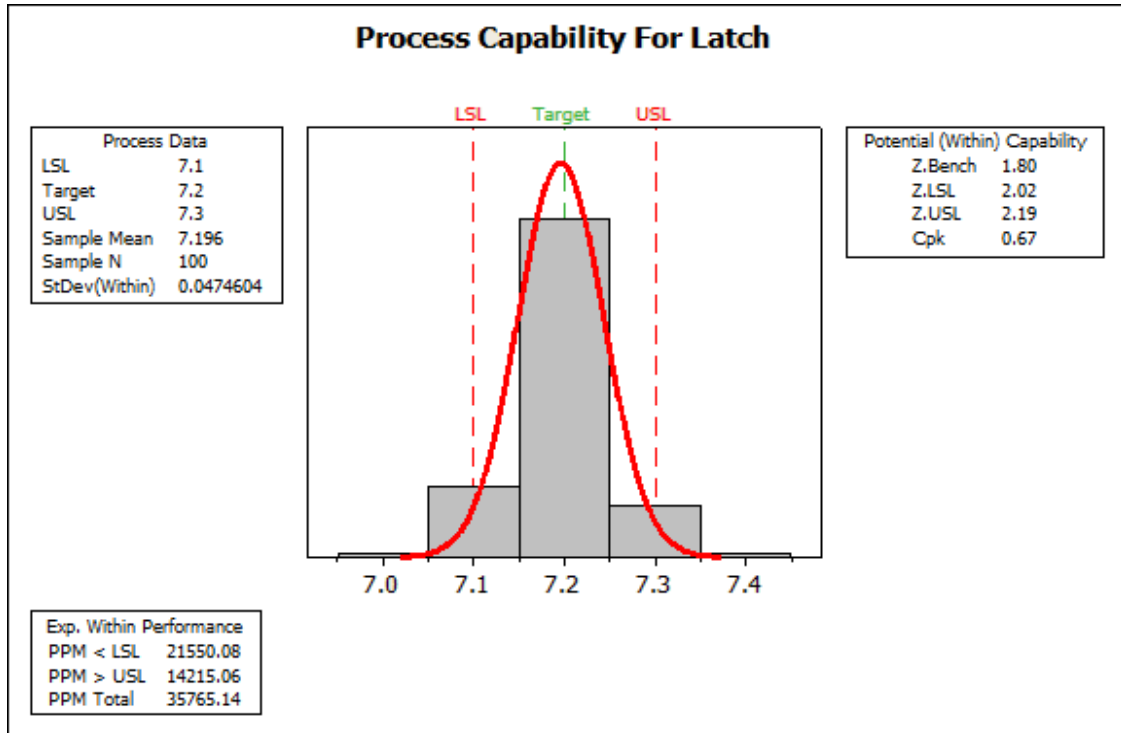


Fig. 5. - Process Capability Analysis of Latch Rejection Data before Implementing DMAIC Methodology

### 3.3.2 Ishikawa diagram (Cause and Effect Diagram)

Ishikawa diagrams also known as cause-and-effect diagrams are causal diagrams created by Kaoru Ishikawa (1968) that show the causes of a specific event.[6,7]. Ishikawa diagram are used in product design and quality defect prevention studies in order to detect causes of variations in process. Due to high rejection rate of latch, Ishikawa diagram was drawn to find out the cause of variation in the latch hole diameter (Fig. 6). In Ishikawa diagram all the factors was shown which can be a cause for the latch rejection and after that most effective factors for latch rejection were determined. Two sample T- test was performed to find out the main factor which could be a rejection factor.

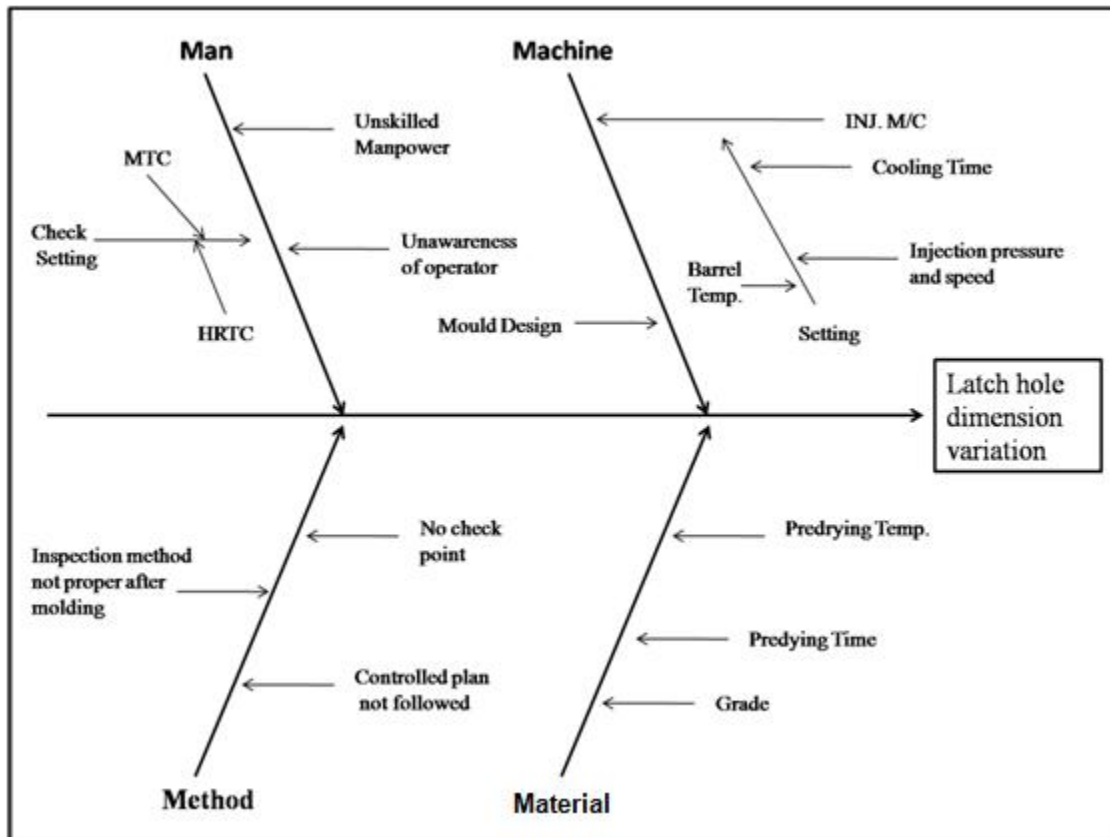
### 3.3.3 Two Sample T- Test

From the Ishikawa diagram three factors were identified that may be the cause of variation in the Latch hole Diameter i.e. a) operator skill, b) injection moulding pressure and c) pre-drying temperature. These factors were then analyzed by using two sample t-test.

Factors

- Operator Skill were studied by taking the sample size of 50 for unskilled and skilled operators

- Injection moulding pressure was studied at two points of 125MPa(Old) and 140MPa (new) by taking the sample size of 50 at each pressure level.
- Pre-drying temperature was studied at 80°C (old) and 90°C (new) by taking the sample size of 50 at each temperature.



*Fig. 6. Ishikawa Diagram*

The results of two sample t-test performed using Minitab software are shown in Table 1. The P-value of 0.686, 0.038 and 0.027 were obtained from the two sample t-test analysis for operator skill, injection moulding pressure and pre-drying temperature respectively. A p-value greater than 0.05 shows the factor not be a cause for rejection while a value less than 0.05 shows that factor might be a cause for rejection. Analysis reveal that operator skill was not the cause of rejection, here injection pressure and pre-drying temperature might be a factor of rejection.

### **3.4 Improve**

Improve phase includes the identification, testing and implementation of a solution to the problem. Here investigator tries to identify creative solutions to remove rejection factors.

A 2×2 experiment was designed consisting of two factors at each level. Design of Experiments was such to find out the optimum conditions for the key vital factors found out after the two sample t-test. These experiments were conducted to optimize the value of the parameters [8] i.e. injection pressure and pre-drying temperature. Table 2 shows the significant vital factors for Lath hole diameter variation. Table 3 shows the readings of significant factors at various levels suggest that injection pressure and pre-drying temperature are major factors.

**Table 1. Showing results from two sample t-test for rejection factor: Operator Skill, Injection Pressure, Pre-drying Temperature.**

Factor/ properties	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
	Operator A	Operator B	New Injection pressure (140MPa)	Old Injection pressure (125 MPa)	New Pre- Drying temp (90°C)	Old Pre- Drying temp 80°C
Sample Size	50	50	50	50	50	50
Mean	7.202	7.206	7.204	7.232	7.204	7.234
StdDev	0.0319	0.062	0.0348	0.0868	0.0348	0.0872
SE Mean	0.0045	0.0088	0.0049	0.012	0.0049	0.012
Estimate for difference	-0.004		-0.028		-0.03	
P-Value	0.686		0.038		0.027	

**Table 2. Significant vital factors for Latch Hole Diameter variation**

Vital Factors	Low Level	High Level
Injection pressure	125 MPa	140 MPa
Pre-drying temperature	80°C	90°C

**Table 3. Readings of Significant Factors at Various Levels.**

Sr. No.	Injection pressure	Predrying temperature	Readings(Latch Hole Diameter mm)
1	125 MPa	80°C	7.1
2	140 MPa	80°C	7.3
3	125 MPa	90°C	7.1
4	140 MPa	90°C	7.2

### 3.5 Control

The control step is generally performed to carry on the gains achieved in previous steps. Here improvements in the process are monitored to make sure that changes made in the essential parameters are hereditary.  $\bar{X}$  / R control chart forms a better visualization mechanism for the assignable cause of variations after implementation of the changes in factors as proposed by DOE to ensure the process improvement. Sample size of 100 was taken for making the chart in Minitab software (Fig. 7).

## 4. Result Appraisal:

After the application of DMAIC approach of six sigma, an improvement in the process can be viewed. So we again draw the process capability curve using Minitab software to validate the changes made in vital parameters

of injection pressure and pre-drying temperature. It shows an increase in sigma level from 1.80 to 5.46 and decrease in ppm level from 35765.14 to 0.02 (Fig. 8). This huge decrease in rejection rate of latch will give financial saving of Rs. 0.708 million annually to the firm (Appendix A)

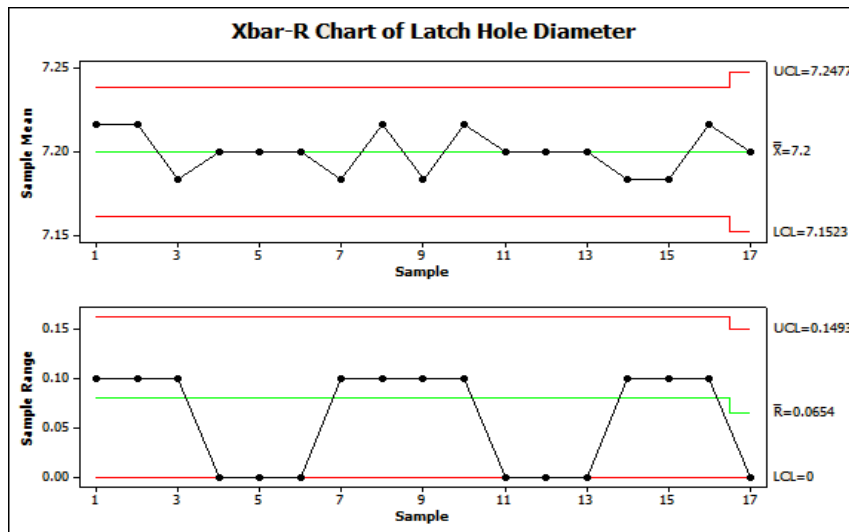


Fig.7. X bar/R Chart for Latch Hole Diameter after Improvement

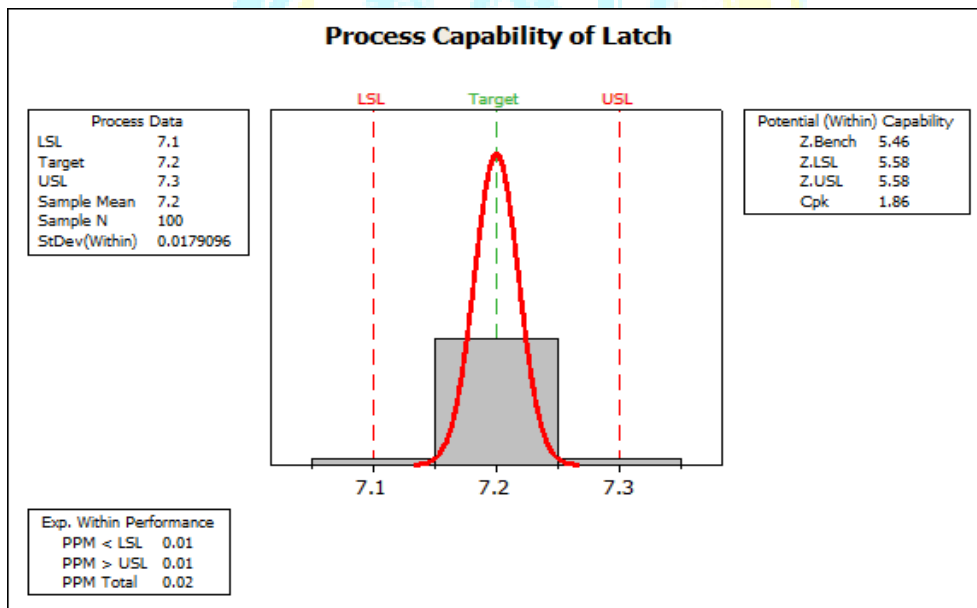


Fig. 8. Process Capability Analysis of Latch Rejection Data after Improvement

### 5. Conclusion

After implementing Six Sigma DMAIC approach it was found that the injection moulding firm can increase its profit by controlling rejection rate of Latch. Six Sigma implementation increase the process sigma level from 1.80 to 5.46 by reduction in Latch hole diameter variation. This increase in sigma level will give saving of Rs. 0.708 million per annum to the industry which is a good figure for such industry. This paper gives information about Six Sigma implementation in a injection moulding unit. As this study is representative for SME's it will help to small and medium sized enterprises (SME's).



**Appendix – A****Cost saving calculation on account of reduction in Latch rejection rate**

Current PPM = 35765.14

Achieved PPM = 0.02

Cost / pc = Rs. 11.00

PPM reduction = 35765.12 PPM

Monthly Production = 150000 pcs

$$\text{Saving / Month} = 35765.12 \times 150000 / 10^6$$

$$= 5364.77 \text{ pcs}$$

$$\text{Cost saving / annum} = 5364.77 \times 11.00 \times 12$$

$$= 708149.64$$

$$= 7.08 \text{ lacs}$$

=0.708 million

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