QUALITY IMPROVEMENT THROUGH SIX SIGMA

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Abstract

Six Sigma is a powerful approach to achieve breakthrough improvements in manufacturing, engineering and business processes. This approach relies heavily on advanced statistical methods that complement the process and product knowledge to reduce variation in processes. It is a new way of doing business that would eliminate the existing defects efficiently and would prevent defects from occurring. A case study is analyzed in the injection cell of rubber moulding process in a rubber product manufacturing company. The defect level is reduced using Six Sigma DMAIC approach.

Keywords: *Six Sigma, Quality improvement, Defect reduction*

1. Introduction

Six Sigma is a quality improvement program that aims to reduce the number of defects to as low as 3.4 parts per million. It uses the normal distribution and strong relationship between product nonconformities, or defects, and product yield, reliability, cycle time, inventory, schedule, etc.. Six Sigma emphasizes an intelligent blending of the wisdom of an organization with proven statistical tools to improve both the efficiency and effectiveness of the organization when it comes to meeting customer needs. The ultimate goal is not simply improvement for improvement's sake, but rather the creation of economic wealth for the customer and provider alike. This does, not imply that Six Sigma replaces existing and ongoing quality initiatives in an organization, rather that senior management focuses on those processes identified as critical-to-quality in the eyes of customers. Those critical systems are then the subject of intense scrutiny and improvement efforts, using the most powerful soft and hard skills the organization can bring to bear. A very powerful feature of Six Sigma is the creation of an infrastructure to assure that performance improvement activities have the necessary resources. Creating a successful Six Sigma infrastructure is an ongoing process whose aim is to infuse an awareness of quality into the way all employees approach they everyday work. Six Sigma projects of continuous process improvement are led, from concept to completion, through five project management steps or phases named DMAIC (define measure, analyze, improve, control).

2. Problem for Analysis

In this paper, it is proposed to analyze a case study in a rubber product manufacturing company. The product taken into consideration for analysis is pin boot. It has a high rejection percentage in the Injection Cell. The following are the problems with this product.

- Internal quality failure cost is high.

- High scrap value in Injection Cell.
- Wall thickness variation of the component is high.
- Rubber leak in the Injection Ramp.
- Maximum flow and tearing rejections occurring exactly to opposite of the Injection Point.
- Lack of Defect Location Analysis

3. Description of Pin Boot

Part No	: 29320122
Product Name	: Pin Boot
Customer	: M/s. Brakes India Ltd.,
Base polymer	: EPDM
Selling price/unit	: Rs 3.32
Production rate	: 100000 parts per month.

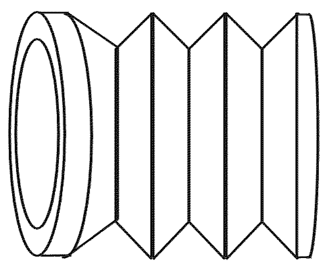

Figure – 1: Pin Boot

4. Process Parameters For Injection Moulding Machine

Type of Moulding	: Injection Mould
Cure Temperature	: 200 °c
Curing Time	: 120 sec
Injection Time	: 10 sec
Extrusion Time	: 20 sec
Injection Pressure	: 2000 PSI
No of Bumping	: 3
Type of press	: Injection Press
No of moulds available	: 2 Moulds
Total No. of Cavity Available	: 16

4.1 Define Phase

The three specific tasks that are completed during define phase of work are customer focus, team charting and process map.

4.1.1 Identify Project CTQs

The customer for this project is Pin Boot manufacturing cell in the Rubber Moulding process. The rubber product taken into consideration is Pin Boot produced in the Injection Cell.

4.1.2 Develop Team Charter

A charter clarifies what is expected of the team, keeps the team focused, keeps the team aligned with organizational priorities. The five major elements of a charter are:

a) Business case

This project aims to decrease defects and to reduce the internal quality failure. The rejection value in this product is more than Rs. 6 Lakhs per annum operating at 2.6 sigma level. Increase in sigma level of this product will lead to increase in productivity, and business improvement.

b) Problem Statement

The internal quality failure has increased steadily in the Injection Cell, over the past six months. The rejection percentage accounts to 13.99%. The impacts of the problem are high internal rejections and high wall thickness variation.

c) Goal Statement

The goal statement of the project is to reduce the rejection of Pin Boot from 13.99% to 0%.

d) Project Scope

The scope is one of the most important elements in the charter because it sets the boundary of what is included and what is excluded. The scope of this project includes the entire process, right from milling to inspection.

e) Define Process Map

Process mapping goal is to connect the customer to the process and identify inputs and requirements.

Product Name: Pin Boot **Process Start:** Mixing **Process End:** Inspection

Table – 1: SIPOC Worksheet

CTQs	Supplier	Input(s)	High level Process Steps	Output(s)	Customer(s)
	S	**I**	**P**	**O**	**C**
Reduce the rejection in Pin Boot	Raw material stores	Raw material	Mixing	Mix Rubber Sheet	Injection Cell
		Mix Rubber Sheets	Moulding	Semi finished goods	
		Semi finished goods	Deflashing	Deflashed goods	
		Deflashed goods	Inspection	Good & Rejection of Pin Boot	

4.2 Measure Phase

In the measure phase, select one or more product/process characteristics to address and map their respective process, to show what it actually looks like and validate measurement system. The three specific tasks that have been completed during this phase are selection of the CTQ to improve, determining performance standards and ensuring adequate measurement system.

4.2.1 Select CTQ Characteristics

The Big Y is the CTQ of this project. The Big Y refers to the defect prevention in the Pin Boot. Any product non conforming to visual / dimensional standards is termed as defects.

4.2.2 Define Performance Standards

Performance standard is the requirements or specifications imposed by the customer on a specific CTQ. The goal of a performance standard is to translate the customer need into measurable characteristics.

4.2.3 Measurement System Analysis

Measurement system analysis identifies how much variation is present in the measurement process. Understanding measurement variation is necessary for identifying true process variation and maximizing true Y improvements. Measurement system analysis helps in directing efforts towards decreasing measurement variation.

(a) Accuracy

The first and foremost factor is the accuracy of measurement. It is the difference between observed average measurement and a standard. All gauges and sensors should be accurate and sensitive enough to read the measurable. One has to question the resolution of the measuring equipment. If the resolution is not adequate, higher resolution tools and equipments have to be procured. It is the management's responsibility to provide for accurate tools.

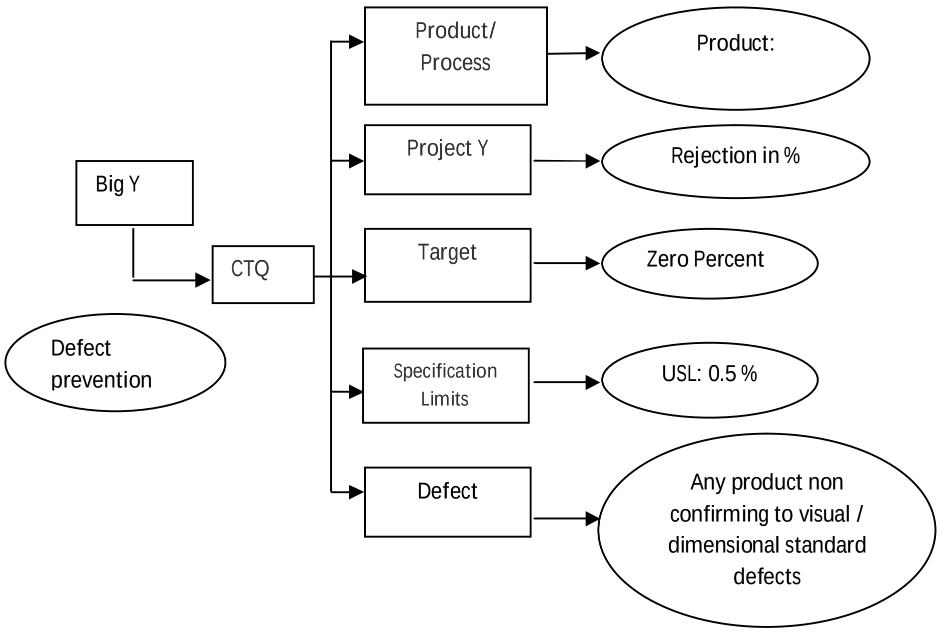

Figure – 2: CTQ Characteristics

(b) Repeatability

Variation noticed when one person repeatedly measures the same unit with the same measuring equipment. The Black Belt who oversees the measurements must ensure repeatability**.**

(c) Reproducibility

Variation noticed when two or more people measure the same unit with same measuring equipment

Table – 2: Results and plan for attribute R&R

	Thumb Rule	**Achieved**	**Comment**
1)	% Repeatability [>= 90%]	97.5 %	Ok
2)	% Reproducibility [>= 90 %]	60 %	Need to improve
3)	% Accuracy [>=90%]	60 %	Need to Improve

Plan for improvement

It is proposed to work on repeatability problem by conducting a team meeting with two inspectors and discuss the difference in their measurements. Suggesting additional training for less experienced inspectors (because the data shows less experienced inspectors answering differently). Also to investigate whether any unique solution could be suggested for reproducibility issue.

4.2.4 Process Capability Measurement

Process capability may be defined as the "minimum spread of a specific measurement variation which includes 99.7% of the measurements from the given process". It is customary to take the six – sigma spread in the distribution of the product quality characteristic as a measure of process capability.

Specification Limit: 0.6 – 0.8mm

$Cp = (USL-LSL)/6\sigma = 0.51$

$Cpk = Min ((USL-X)/3\sigma, (X – LSL)/ 3\sigma) = Min (0.7, 0.26)$

$Cpk = 0.26$

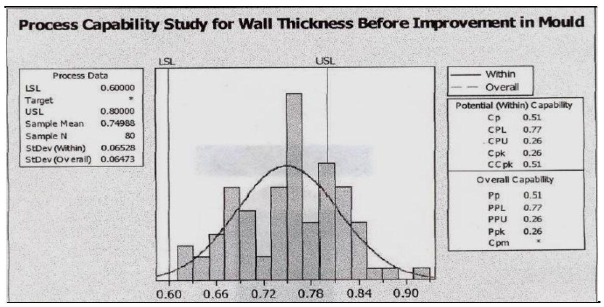

Figure 3- Process capability study for wall thickness before improvement in mould

4.3 Analyze Phase

The objective of this phase is to understand why defects occur. Brainstorming and Statistical tools are used to identify the key variables (X's) that cause defects. The output of this phase is to explain the variables, that are most likely to affect the process variation.

4.3.1 Base Line

a) Defects per Unit

DPU = No.of Defects / Total No. Inspected = 10414 / 74386 = 0.1399

Current PPM = 0.1399×10^6 = 139900

Target = less than 500 PPM

Project goal: Reduce variation (span) and shift central tendency (medium).

4.3.2 Pareto Analysis

It is a commonly used tool for analyzing attribute data. It is based on the principle that 80% of defects are generated by 20% of causes. Pareto prioritizes the problem to be addressed first. It is also called as 80-20 rules. Variation sources are identified through analysis of historical data. With the help of historical and Pareto chart, factors that influence the rejection most can be identified.

4.3.3 Brainstorming

Brainstorming has been conducted in the quality circle with the invited members from various cross–sections like, cell manager, production head, technical head, product development, quality assurance etc. also have participated in the brainstorming session along with the quality circle members. From the brainstorming, the various causes are identified, and classified as follows for the cause and effect diagram. The various causes were identified from the brainstorming are grouped into five categories man, machine, method, mould and materials.

4.3.4 Potential X's Identifications

List of Process Parameters were identified through the brainstorming sessions like Temperature, Cure Time, Pumping, Air Pressure, Cure Weight. Operator and Compound are considered as a noise factors. It has been analyzed whether factors influences the process or not by using single factor experiment.

Table – 3: Data for Releasing Air Pressure

Treatments	**Releasing Air Pressure (in bar)**		
	2	**2.5**	**3**
1	2	8	10
2	3	7	8
3	2	8	12
4	2	7	14

Null Hypothesis (H_o) : Air Pressure is not significant

Alternate Hypothesis (H_a): Air Pressure is significant

Table – 4: ANOVA for Releasing Air Pressure

Sources of Variations	**DF**	**SS**	**MS**	**F**	**P**
Air Pressure	2	155.17	77.58	32.10	0.00
Error	9	21.75	2.42		
Total	11	176.92			

- Inference releasing air pressure is significant

Table – 5: Data for Temperature

Treatments	**Releasing Temperature (^{0}C)**		
	195	**200**	**205**
1	8	3	5
2	7	4	3
3	10	4	3
4	8	7	5

Null Hypothesis (H_o): Temperature is not significant

Alternate Hypothesis (H_a) : Temperature is significant

Table – 6: ANOVA for Temperature

Sources of Variations	DF	SS	MS	F	P
Temperature	2	43.17	21.58	10.94	0.004
Error	9	17.75	1.97		
Total	11	60.92			

- Inference: Temperature is significant

Table – 7: Data for Cure Time

Treatments	Cure Time (in sec)	
	110	**120**
1	6	13
2	5	14
3	8	11
4	6	10

Null Hypothesis (H_o): Cure time is not significant

Alternate Hypothesis (H_a): Cure time is *significant*

Table – 8: ANOVA for Cure Time

Sources of Variations	DF	SS	MS	F	P
Cure Time	1	66.13	66.13	26.90	0.002
Error	6	14.75	2.46		
Total	7	80.88			

Inference: Cure Time is significant

4.4 Improve Phase

4.4.1 Improved Gage R & R

The inspectors have been trained to identify the type of defect using detection analysis and as a result it was found the repeatability and reproducibility has been increased.

Table – 9: Improved Gage R&R

Sl. No.	Thumb Rule	Achieved	Comment
1)	% Repeatability [>= 90%]	95 %	Ok
2)	% Reproducibility [>= 90 %]	95%	Ok
3)	% Accuracy [>=90%]	93%	Ok

4.4.2 Improvement in the Mould

- The 16 cavity mould is replaced with 20 Cavity Mould and all core pins and sleeves were replaced. After replacement of the core pin and sleeves the wall thickness variation has been reduced.
- Releasing agent monocoat/lube oil is provided as a releasing agent.

4.4.3 Improvement in the Mould Life

- 20 bin wooden cupboard is provided to increase the life of the core pin and sleeves.
- Instead of shot blasting the salpha cleaning provided.
- Proper nozzle is provided for releasing the Component from the Core Pin.

4.4.4 Design of Experiments

Design of experiment is a useful tool that is applied in industry for product and process design optimization. Its application leads to an understanding of the often complex relationship between the input parameters (X) and the output parameters (Y). Design of experiments has the potential to provide significant benefits in a complex service environment, where there are many critical X's influencing the critical Y's. Additionally different levels of the X's can be tested interactively and individually to determine the impact on the input on the response.

4.4.5 Noise Factors

Through the brainstorming the following parameters were identified noise Operator and Compound.

Table – 10: Process Parameter and levels

Symbol	Parameter	Unit	Level 1	Level 2
A	Temperature	^{0}C	200	205
B	Cure Time	Sec	110	120
C	Pumping	-	2	3
D	Cure Weight	gms	120	130
E	Air Pressure	Bar	2	3

4.4.11 Improvement in Yield

The yield has been improved after the corrective action implementation

Yield $(\Psi) = P(x = 0) = e^{-DPU} = e^{-0.035} = 0.9657$

4.4.12 Process Capability Measurement after Improvement in the Mould

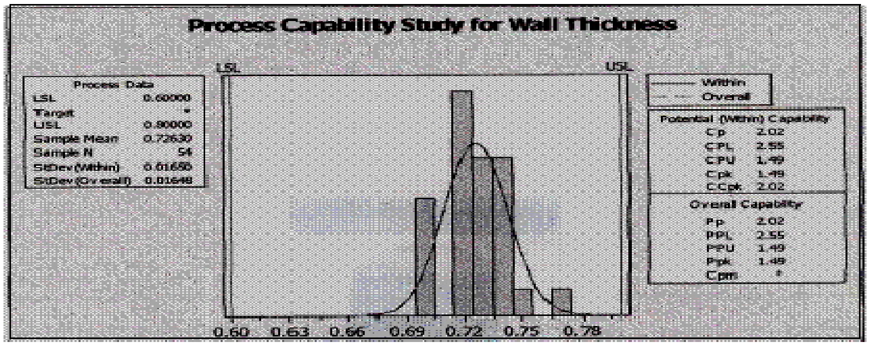

Figure 6: Process capability study for wall thickness

Specification Limit: 0.6 – 0.8mm

Cp = (USL-LSL)/6σ = (0.8-0.6)/6(0.014) = 2.02

Cpk = Min ((USL-X)/3σ, (X– LSL)/ 3σ) = Min (2.55, 1.49)

Cpk = 1.49

4.5 Control Phase

The main objective of the control phase is to make sure that the process stays in control after the solution has been implemented and to quickly detect the out of control state and determine the associated special causes so that actions can be taken to correct the problem before non conformities are produced.

5. Conclusion

In this project a case study is analyzed in the injection rubber moulding process. The rubber product pin boot whose rejection percentage is high in the injection cell is taken as project CTQ. Six Sigma DMAIC methodology is used to reduce the rejection percentage. In the define phase, project CTQ is identified. Also problem statement, goal statement, project scope and project milestone are identified in this phase. In the measure phase, CTQ characteristics is selected, calculate the process capability of existing process and measurement system analysis is done. In the measurement system analysis attribute repeatability, reproducibility and accuracy were measured and obtained results are found to be 97.5%, 60% and 60% respectively. Process capability of existing process was measured. After providing proper training to workers and inspectors, the repeatability, reproducibility, and accuracy has been increased 95 %, 95% and 93% respectively.

In the analyze phase base line of process, statistical goal of the project is established and variation of sources were identified through the brainstorming session. Pareto analysis has been conducted using historical data, from the Pareto chart identified tearing and flow rejection address first. Root causes are classified in the five categories man, machine, method, mould and material identified through the brainstorming have been analyzed and necessary corrective action is implemented.

In the improve phase, it has been analyzed various factors influencing the Injection Moulding Process and L_8 (2^7) Orthogonal Designs used to predict the most robust deign parameter levels of the process. A Main

Effect and Interaction Effect plot was drawn. From the graphs and S/N ratio the most robust design parameter setting is as given below in Table 17.

Table 11: Robust Design Parameter setting

Symbol	Factors	Existing	New Setting
A	Temperature	200^0 C	205 ^{0}C
B	Cure Time	120 Sec	110 Sec
C	Air Pressure	2 bar	3 Bar
D	Cure Weight	120 gms	130 gms
E	Pumping	3	2

An experiment was conducted after setting levels of factors as described above for 5 replication and process was closely monitored. The result from this experiment was that there were no flow rejection and simultaneously no other rejects were reported.

6. Future Scope

The scope of the project in future for continual improvement

- To improve the releasing system (Ejection System for sleeves)
- Manual operation to be stopped.
- To provide Temperature Indication System.
- To standardize the operator working in three shift

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