

Strategic Enhancement of Quality through 6σ : A Case Study

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Abstract— The business objectives are to provide a high quality product to the customer at lower cost and earliest delivery. Six Sigma is a main tool that helps to achieve these objectives. The aim of Six Sigma methodology is to improve the quality by reducing the number of defects as much as possible. This paper describes the application of Statistical methods in quality improvement after application of Six Sigma. This case study was conducted at Caparo Maruti Ltd, BAWAL which mainly manufactures various sheet metal parts and components associated with automobiles. In this, our focus is mainly on manufacturing of one of these sheet metal parts i.e. Panel component wheel housing inner left hand (LH) & right hand (RH) sheet metal part for G model (Maruti Suzuki SWIFT). Pareto Diagram was used to analyze various defects which occur in this sheet metal part and Fishbone diagram is used to explain the causes for defects. The case study recommended measures for Quality Improvement.

Keywords—Panel component wheel housing inner (LH) & (RH) sheet metal part, Define, Measure, Analyze, Improve and Control (DMAIC), Defects per Million Opportunities (DPMO), Six Sigma.

I. INTRODUCTION

The Six Sigma approach was first introduced and developed at Motorola in early 1990s. Six Sigma has been launched all over the world. Later many companies testified its pivotal role in their success [1]. Well-known examples of Six Sigma companies include Motorola, General Electric, Allied Signal (now Honeywell), ABB, Lockheed Martin, Polaroid, Sony, Honda, American Express, Ford, Lear Corporation and Solectron.

Six Sigma is a business improvement approach that seeks to identify and eliminate causes of errors or defects or failures in business processes by focusing on outputs that are critical importance to customers [2]. It is a quality management philosophy and system to reduce the variations, defects and keep the defects out of customer specifications by changing the culture of the organization. The traditional

quality management approaches, including Statistical Quality Control (SQC), Zero Defects and Total Quality Management (TQM), have been key players for many years, while Six Sigma is one of the more recent quality improvement initiatives to gain popularity and acceptance in many industries across the globe. Six Sigma differs from other quality programs in its top-down drive in its rigorous methodology that demands detailed analysis, fact-based decisions, and a control plan to ensure ongoing quality control of a process.

Six Sigma enables organizations to become more ambidextrous by switching structure, act organically when being challenged by new ideas and operate mechanically in focusing on efficiency [3], [7]. Six Sigma is one of the important driving force for the organizations to improve their quest for business improvement philosophy. Six Sigma has proved to be a popular approach in driving out variability from processes through the use of statistical tools.

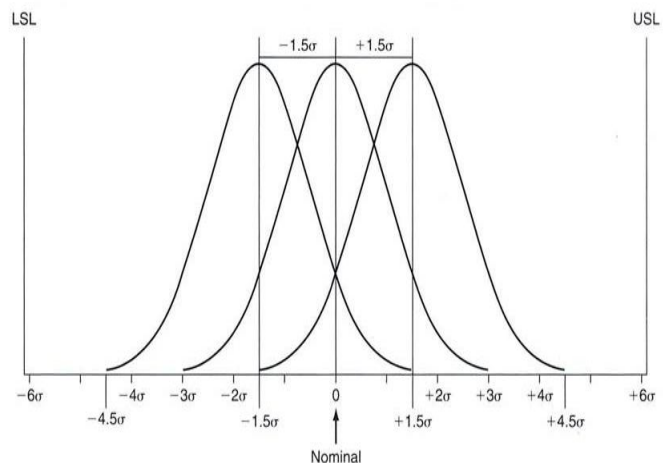


Fig. 1 Normal distribution curve for both when process is centered and when process is off-center $\pm 1.5\sigma$

Six Sigma allows almost zero defects in all situations. The critical success factors are top management commitment, availability of resources, well designed education and training programs for appropriate tools and techniques. Sigma, σ , is the Greek symbol for the statistical measurement of dispersion called standard deviation [4], [8]. It is the best measurement of process variability, because the smaller the deviation values, the less variability in the process. Fig.1 shows a process that is normally distributed and centered with the upper and lower specification limits established at $\pm 6\sigma$. For this situation, 99.999998 % of the product or service will be between specifications, and the nonconformance rate will be 0.002 per million, shown below in table I [4].

TABLE I
NONCONFORMANCE RATE WHEN PROCESS IS CENTERED

Specification Limit(Sigma Level)	Percent Conformance	Nonconformance Rate(Parts per million)
$\pm 1\sigma$	68.7	313000
$\pm 2\sigma$	95.45	45500
$\pm 3\sigma$	99.73	2700
$\pm 4\sigma$	99.9937	63
$\pm 5\sigma$	99.999943	0.57
$\pm 6\sigma$	99.999998	0.002

According to Six-sigma philosophy, processes rarely stay centered; the center tends to shift above and below the nominal target, O. Fig. 1 also shows a process that is normally distributed, but has shifted with in a range of 1.5σ above and 1.5σ below the target. For the diagrammed situation 99.99966 % of the product or service will be between specifications and the nonconformance rate will be 3.4 ppm (Parts per million), shown below in table II [4].

TABLE II
NONCONFORMANCE RATE WHEN PROCESS IS OFF- CENTERED
 $\pm 1.5\sigma$

Specification Limit(Sigma Level)	Percent Conformance	Nonconformance Rate(Parts per million)
$\pm 1\sigma$	30.23	697700
$\pm 2\sigma$	69.13	308700
$\pm 3\sigma$	93.32	66810
$\pm 4\sigma$	99.379	6210
$\pm 5\sigma$	99.9767	230
$\pm 6\sigma$	99.99966	3.4

Whenever process achieves a level not more than 3.4 defects per million opportunities (DPMO), the process has achieved Six-Sigma level [4].

II. SIX SIGMA METHODOLOGY

One of the most common methodologies used in Six Sigma is DMAIC methodology: Define, Measure, Analyze, Improve and Control. This is briefly described below [5], [6].

Define: The problem is stated in this phase. The product or process to be improved is identified. Customer needs are identified and translated into Critical to Quality Characteristics (CTQs). The problem/goal statement, the project scope, team roles and milestones are developed. A high-level process is mapped for the existing process.

Measure: The process performance is estimated in this phase to find the present Sigma level. The key internal processes that influence the CTQs are identified and the defects generated relative to the identified CTQs are measured.

Analyze: This phase is used to find the reasons for poor performance. The objective of this phase is to understand why defects are generated. Brainstorming and statistical tools are used to identify key variables that cause defects. The output of this phase is the explanation of the variables that are most likely to affect process variation. Finally the recommended solutions are implemented in the next phase - Improve.

Improve: The objective of this phase is to confirm the key variables and quantify the effect of these variables on the CTQs. It also includes identifying the maximum acceptable ranges of the key variables, validating the measurement systems and modifying the existing process to stay within these ranges.

Control: The objective of this phase is to ensure that the modified process now enables the key variables to stay within the maximum acceptable ranges, using tools like Statistical Process Control (SPC), simple checklists or we can say this phase is used to find the deviations from the recommended method to the actual progress and reasons for deviations will be analyzed.

A. Define Phase

This project was carried at Caparo Maruti Limited BAWAL, which mainly manufactures various sheet metal parts and components associated with automobiles. One of these automobile parts which are manufactured in this company is Panel component wheel housing inner (LH) & (RH) sheet metal part for model G (Maruti Suzuki SWIFT). The main material used in manufacturing the inner wheel housing part is cold rolled continuous annealed steel material in the form of metal sheet. These metal sheets are bought from their vendor companies mainly from Tata Steel, Bhushan Steel and Essar etc. Major steps for making the inner wheel housing part, we have to do various operations on the metal sheets in different compartments or shops i.e. press shop and weld shop. Drawing, Trimming & piercing, Trimming & Cam piercing and Restrike & parting operations are done in press shop.

Projection and Spot welding are done in weld shop. The process flow diagram (PFD) is shown in Fig. 2.

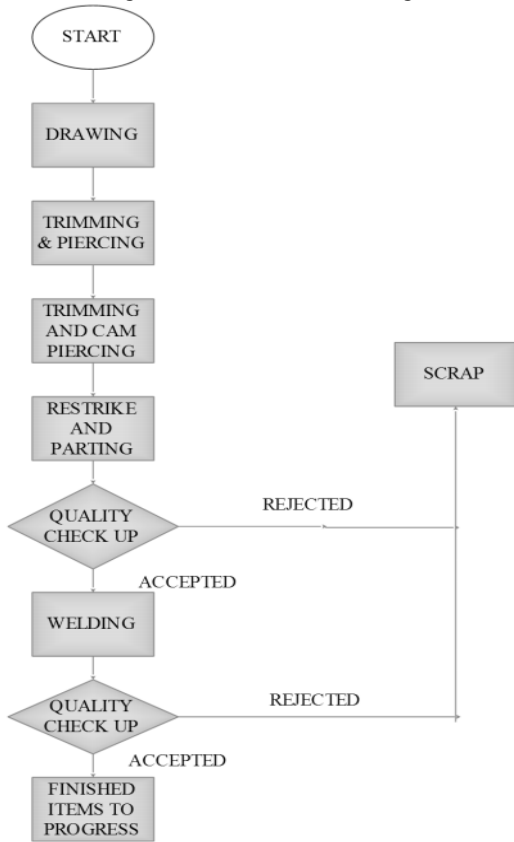


Fig. 2 Process flow diagram of inner wheel housing

In this project the management wants to improve the process quality. Even though there are lot of checks at various stages the nonconformance rate is 0.0582%. Management desires to estimate the Sigma level and improve the process from present level.

B. Measure Phase

All the finished inner wheel housing parts were tested for quality by using visual inspections. Mainly three types of inspections are conducted on all the parts before dispatching to customers. These three types of inspections are (a) on processing visual inspection (b) fitment inspection by manually checking fixture (c) pre- dispatch visual inspection. Data on the basis of these inspections was collected for 10 months. Out of the 283470 units tested, 283305 units passed all the tests and 165 failed in tests. This detail is shown in Table III. Inner wheel housing parts tested for 3 inspections out of which there are some major defects come mainly due to poor environmental condition regarding to sheet metal

parts, press & welding failure are in (a) Red rust, (b) Nut out, (c) Part bend or damage, (d) Spot Dent, (e) Part mismatch, (f) Spot Burn (g) Cracking & Necking (h) Welding offset.

TABLE III
CROSS MEMBER FRONT LOWER FAILURE DATA

Period	01-04-2012 to 31-01-2013	
Total Units Tested	283470	% Failed in
Units Passed	283305	
Units Failed	165 (0.0582%)	
Units Failed in Red rust	96	58.18
Units Failed in Nut out	27	16.36
Units Failed in Part bend or damage	21	12.72
Units Failed in Spot Burn	9	5.45
Units Failed in Part mismatch	5	3.03
Units Failed in Spot Dent	4	2.42
Units Failed in Cracking & Necking	2	1.21
Units Failed in Welding offset	1	0.60

Defects per Million opportunities

$$DPMO = \frac{165 \times 1000000}{283470 \times 8} = 73$$

i.e Sigma Level of Approximately 5.393 (From Table IV)

TABLE IV
LEVEL OF SIGMA PERFORMANCE

S. No.	Conformance Level (%)	DPMO (Defects per million opportunities)	Sigma Level
1	30.85	691500	1
2	69.15	308500	2
3	93.3	66800	3
4	97.73	22700	3.5
5	99.38	6200	4
6	99.795	2050	4.375
7	99.87	1300	4.5
8	99.94	600	4.75
9	99.977	230	5
10	99.997	30	5.5
11	99.99966	3.4	6

C. Analyze Phase

The Pareto diagram and Line diagram reveals major defect is red rust appearance on sheet metal part as shown in Fig. 3(a) & Fig. 3(b) respectively. This defect occurs on metal sheets mainly due to a long contact with moisture air. This type of defect comes under appearance related category. This defect may be produced on both raw material sheets and manufactured parts which may be easily known only by visual inspection. The potential failure mode

of inner wheel housing parts due to red rust is (a) rusty sheet metal part gives a red appearance which indicates that corrosion must be produced on parts throughout the life. Some of potential effects due to corrosion are (a) part will become functionally weak in strength after some time (b) part life will become small as compare to others (c) other defects may be occurred like cracks in part (d) painting defects will be occurred.

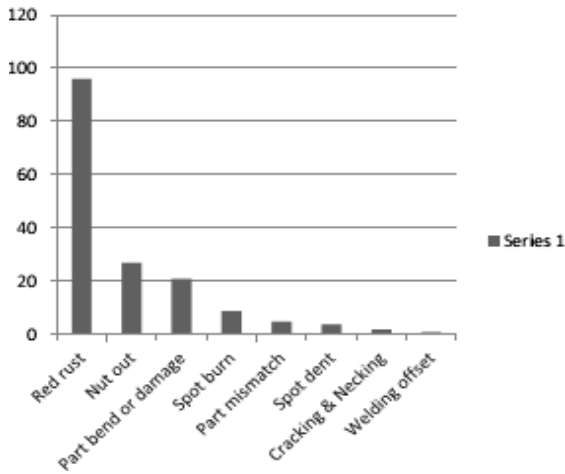


Fig. 3(a) Pareto diagram

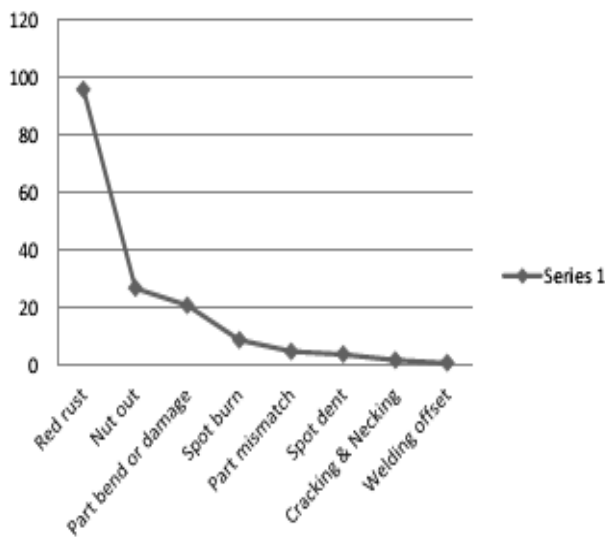


Fig. 3(b) Line diagram

These potential effects of failures occurs on the surface of inner wheel housing parts which is very critical mainly for maintenance, accidental & safety purposes throughout the life. These potential effects of failures may not be avoided as per customer satisfactions. If we are able to eliminate the major failure which may be occurred due to red rust, the

defective level can be brought down to 0.0243 % from the present level of 0.0582 %. The principle of Pareto diagram also states that investment in improvement of vital few yields better than compared to investment in trivial many. Hence inner wheel housing defect, red rust appearance on sheet metal surface was taken up for investigation.

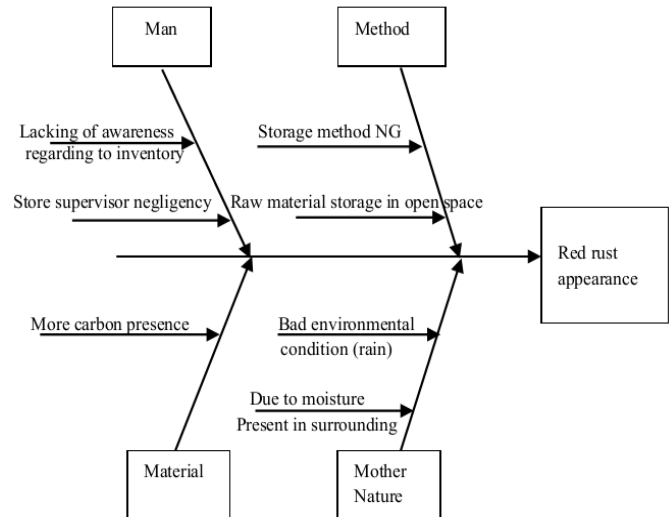


Fig. 4 Fishbone diagram

The major causes for red rust appearance was (1) Lacking of awareness regarding to inventory stock, (2) Store supervisor negligency or improper arrangement of raw material sheets in inventory stock, (3) Raw material storage in open space, (4) Due to bad environmental condition like rain, (5) Due to moisture presence in surrounding of raw material, (6) Storage method not good, (7) More carbon presence in component . Fishbone diagram reveals all the major causes of red rust appearance as shown in Fig. 4. Defected parts due to red rust appearance account 0.0339 %.

D. Improve Phase

The causes for red rust were analyzed and found that it is due to the bad environmental conditions like due to rain and moisture air only. The material used is high quality cold rolled continuous annealed steel sheets as a raw material bought from their reputed vendor companies, mainly from Tata Steel Ltd. and others. Firstly, this raw material must be deeply examined before it is introduced in the manufacturing process. Hence defects due to material will be ruled out. The improvement can be brought into the product by using anti rust oil spray techniques on raw material if necessary before introducing in manufacturing process by which we can improve quality of our product. The same thing was recommended to the management. If only the red rust appearance failure in inner

wheel housing parts were eliminated, the improvement in Sigma level will be from 5.393 to 5.5.

Defects per Million opportunities,

$$DPMO = \frac{69 \times 1000000}{283470 \times 8} = 30$$

i.e. Sigma level of Approximately 5.5 (From table IV) Defective level can also be brought down to 0.0243% (From 0.0582 %).

E. Control Phase

Once the solution is implemented, the next step is to place the necessary control to assure that the improvements are maintained long-term. This involves monitoring the key process metrics to promote continuous improvement.

III. CONCLUSIONS

Pareto diagram revealed major failures in red rust appearance test. 58.18% inner wheel housing parts failed in red rust appearance test. Hence substantial improvement in the process can be achieved through the elimination of red rust appearance failures. The reasons for red rust appearance failures were identified and solutions were recommended to the management for improvement. This may improve the process from Sigma level of 5.393 to 5.5.

IV. SCOPE FOR FUTURE WORK

It can also be referred as future scope. Application of Six Sigma in Indian Small scale Industries has large scope, but due to lack of knowledge and awareness on latest quality tools and statistical techniques among the management, its implementation is very limited. In this context, application of Six Sigma methodology on one of the chronic problems uncovered the scope of following further study and research in Indian industries.

- Six Sigma can also be implemented over other SME industries such as foundries, power looms, rolling mills etc. to improve the productivity level.
- Application of DMAIC methodology at other areas such as, accounts receivable, shortening development time of the new products, reducing customer complaints etc. and ultimately deploying Six Sigma company-wide.
- Six Sigma implications can be studied and explored over different service organizations like healthcare, safety care, transportation, traffic management etc.

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