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SIX SIGMA APPLICATION FOR PROCESS IMPROVEMENT – A CASE STUDY

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Abstract: *In a fast changing world, competitive advantage comes through operational efficiency. Operational efficiency drives profit, return on investment, and ultimately, shareholder value. It is companies that can bring well-designed new products to market quickly, operate efficiently with minimal overhead, and produce high-quality products with minimal scrap or rework that will succeed and grow. A critical factor in operational efficiency is the ability to design and build high-quality products. Six Sigma has been recognized globally as a structured statistical quality improvement process leading to operational and performance excellence through error free and robust process. This paper discusses six sigma fundamentals as well as various success stories of its implementation in companies like GE, Motorola etc. There are several approaches and strategies suggested for adopting six sigma The strategies and their effect depends on operational characteristics as well as cultural settings of an organization. Similarly, there are number of tools and techniques that can be effectively employed in various situations for getting optimum results. The paper attempts to develop an approach/strategy for implementing six sigma in Indian industrie[7]. The application through a case study is finally reported with its detailed findings.*

Keywords: *DFSS, SQC, TQM, QC, Six Sigma, Quality management, Process improvement*

1. INTRODUCTION

With the growing production and increasing complexity in the process of the manufactured items it's getting more and more difficult to process and analyze the data obtained from various industrial activities manually and this leads to the aid of software for processing and analyzing data.

In every kind of the industrial processes, the data collected from an exhaustive investigation, inspection or survey method need to handle for appropriate interpretation. As statistical methods, when properly used, make for more efficient analysis; it is necessary that all quality control engineers become very familiar with the basic concept and techniques of statistical software. Statistical methods can be considered as a kit of tools that can be extremely useful in various industrial applications like quality control and process capability etc. The science of statistics has much to offer the engineers in QC, analyzing and interpretation of the results of his investigation.

2. WHAT IS SIX SIGMA?

Sigma is a letter in the Greek alphabet that has become the statistical symbol and metric of process variation. The sigma scale of measure is perfectly correlated to such characteristics as defects-per-unit, parts-per-million defectives, and the probability of a failure. Six is the number of sigma measured in a process, when the variation around the target is such that only 3.4 outputs out of one million are defects under the assumption that the process average may drift over the long term by as much as 1.5 standard deviations.

Six Sigma was launched by Motorola in 1987. It was the result of a series of changes in the quality area starting in the late 1970s, with ambitious ten-fold improvement drives. The top-level management along with CEO Robert Galvin developed a concept called Six Sigma. After some internal pilot implementations, Galvin, in 1987, formulated the goal of "Achieving Six-Sigma capability by 1992" in a memo to all Motorola employees. The results in terms of reduction in process variation were on-track and cost savings totaled US$13 billion and improvement in labor productivity achieved 20% increase over the period 1987–1997.(Pande,2003)

In the wake of successes at Motorola, some leading electronic companies such as IBM, DEC, and Texas Instruments launched Six Sigma initiatives in early 1990s. However, it was not until 1995 when GE and Allied Signal launched Six Sigma as strategic initiatives that a rapid dissemination took place in non-electronic industries all over the world. In early 1997, the Samsung and LG Groups in Korea began to introduce Six Sigma within their companies. The results were amazingly good in those companies. For instance, Samsung SDI, which is a company under the Samsung Group, reported that the cost savings by Six Sigma projects totaled US$150 million (Lakshmi kantan,2000). At the present time, the number of large companies applying Six Sigma is growing exponentially, with a strong vertical deployment into many small and medium-size enterprises. Six Sigma is a "New strategic paradigm of management innovation for company survival in this 21st century, which implies three things: statistical measurement, management strategy and quality culture." It tells us how good our products; services and processes really are through statistical measurement of quality level. It is a new management strategy under leadership of top-level management to create quality innovation and total customer satisfaction. It is also a quality culture. It provides a means of doing things right the first time and to work smarter by using data. CTQ could be a critical process/product result characteristic to quality, or a critical reason to quality characteristic. The former is termed as CTQy, and the latter CTQx.(Goh,2002)

3. DMAIC PROCESS & SIX SIGMA TOOLS

3.1 Define (D)

The purpose of the Define phase is to clearly identify the problem, the requirements of the project and the objectives of the project. The objectives of the project should focus on critical issues, which are aligned with the company's business strategy and the customer's requirements. The Define phase includes:

The most applicable tools at this phase are the following:

Project Charter -his document is intended to clearly describe problems, defect definitions, team information and deliverables for a proposed project and to obtain agreement from key stakeholders.

Trend Chart - To see (visually) the trend of defect occurrence over a period of time.

Pareto Chart -To see (visually) how critical each input is in contributing negatively or positively to total output or defects.

Process Flow Chart - To understand how the current process functions and the flow of steps in current process.

3.2 Measure (M)

The purpose of the Measure phase is to fully understand the current performance by identifying how to best measure current performance and to start measuring it. The measurements used should be useful and relevant to identifying and measuring the source of variation. This phase includes:

The most applicable tools at this phase include the following:

o Fishbone Diagram – To demonstrate the relationships between inputs and outputs

o Process Mapping - To understand the current processes and enable the team to define the hidden causes of waste.

o Cause & Effect Matrix - To quantify how significant each input is for causing variation of outputs.

o Preliminary Failure Mode & Effect Analysis (FMEA*)* - Using this in the Measure phase helps to identify and implement obvious fixes in order to reduce defects and save costs as soon as possible.

o Gauge Repeatability & Reproducibility (GR&R) - Used to analyze the variation of components of measurement systems so minimize any unreliability in the measurement systems.

3.3 Analyze (A)

In the Analyze phase, the measurements collected in the Measure phase are analyzed so that hypotheses about the root causes of variations in the measurements can be generated and the hypothesis subsequently validated. It is at this stage that practical business problems are turned into statistical problems and analyzed as statistical problems. This includes:

- Generate hypotheses about possible root causes of variation and potential critical Inputs (X's)
- Identify the vital few root causes and critical inputs that have the most significant impact

The Analyze phase offers specific statistical methods and tools to isolate the key factors that are critical for a comprehensive understanding of the causes of defects

Five Why's - Use this tool to understand the root causes of defects in a process or product, and to penetrate through incorrect assumptions about causes.

Tests for normality (Descriptive Statistics, Histograms) – This is used to determine if the collected data is normal or abnormal so as to be properly analyzed by other tools.

Correlation/Regression Analysis - To identify the relationship between process inputs and outputs or the correlation between two different sets of variables.

Analysis of Variances (ANOVA) - This is an inferential statistical technique designed to test for significance of the differences among two or more sample means.

FMEA (Failure Mode and Effect Analysis) - Applying this tool on current processes enables identification of sufficient improvement actions to prevent defects from occurring.

Hypothesis testing methods - These are series of tests in order to identify sources of variability using historical or current data and to provide objective solutions to questions which are traditionally answered subjectively.

3.4 Improve (I)

The Improve phase focuses on developing ideas to remove root causes of variation, testing and standardizing those solutions. This involves:

- Identify ways to remove causes of variation;
- Verify critical Inputs;
- Discover relationships between variables;
- Establish operating tolerances which are the upper and lower specification limits (the engineering or customer requirement) of a process for judging acceptability of a particular characteristic, and if strictly followed will result in defect free products or services.
- Optimize critical Inputs or reconfigure the relevant process.

The most applicable tools at this phase are:

Process Mapping -This tool helps to represent the new process subsequent to the improvements.

Process Capability Analysis (CP_K) - In order to test the capability of process after improvement actions have been implemented to ensure we have obtained a real improvement in preventing defects.

DOE (Design of Experiment*)* - This is a planned set of tests to define the optimum settings to obtain the desired output and validate improvements.

3.5 Control (C)

The Control phase aims to establish standard measures to maintain performance and to correct problems as needed, including problems with the measurement system. This includes:

- Validate measurement systems;
- Verify process long-term capability;
- Implement process control with control plan to ensure that the same problems don't reoccur by continually monitoring the processes that create the products or services.

Most applicable tools at the Control phase include:

Control Plans -This is a single document or set of documents that documents the actions, including schedules and responsibilities, that are needed to control the key process inputs variables at the optimal settings.

Operating Flow Chart(s) with Control Points - This is a single chart or series of charts that visually display the new operating processes.

Statistical Process Control (SPC) charts - These are charts that help to track processes by plotting data over time between lower and upper specification limits with a center line.

Check Sheets - This tool enables systematic recording and compilation of data from historical sources, or observations as they happen, so that patterns and trends can be clearly detected and shown.(Park,2003)

4. CASE STUDY

This case study was carried out in an automobile industry, which has shown an early interest for investigating how Six Sigma could be implemented in the manufacturing division.

There has been increase of complaints in engine assembly. Most of these complaints can be driven from valve leakage problem. This problems appears between valve seat and poppet valve as shown in picture. These are both esthetical and capability problem. There are also efficiency losses, in the form of down time connected to this problem.

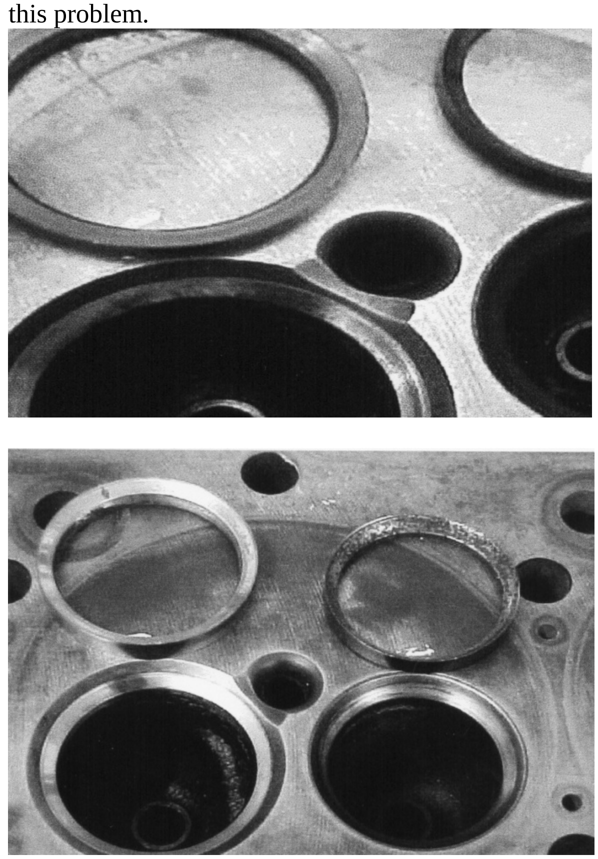

Fig. 1 Valve Seat

This particular problem provides an opportunity to further investigate if and how the Six Sigma methodology (DMAIC) and tools can be used successfully to solve it.

4.1 Valve leakage problem can be defined as:

The rejection of cylinder head sub assembly at Valve leak checking machine (Saturn Make) for valve leak reason against the SOP criterion. (=620 mm of Hg test pressure(vacuum), max 20 mm drop in pressure within set time in PLC- 2 to 3.9 sec normally over the yearconfirmed by Master Leak. This is equivalent to the 70 cc/min at 200bar positive test pressure at 20 deg C ambient as per PS-655).

4.2 Objectives

Sigma performance level:-

Present PPM = 6392	Targeted PPM = 500
Present Sigma level =4	Targeted Sigma level = 4.8

4.3 The Define Phase

The Define Phase is the first step in the DMAIC improvement cycle. This section Describes how the DMAIC project was generated, results of the used tools and the goals for the project.

The Project Charter

Team Charter Project - Reduction in Valve leakage of AVL cylinder head-

Business case:

Aligning with following business strategies

- World class organization
- Schedule adherence 100%
  Cost Leadership
- Our approach toward zero defect

Goal statement:

To reduce r/w & rejection due to valve leakage in cylinder head from 6392 ppm to 500 ppm by 28-02-2006

Opportunity statement:

- Loss of working time in engine (EWT):- 791mins
- Contribution of rejection due to valve leakage problem 6392 ppm
- Scrap cost generated due to valve leakage problem is appox. Rs.7500 per annum
- Considerable labour and overhead costs lost in this rejection.

Project scope:

- All Regular (AVL) cylinder heads, finished machined in plant.
- All processes pertaining to CH from Receipt Inspection to Engine testing.
- 235 & 245 DI engine cyl. heads are Not in scope.

Project plan:

Define - 21-10-05 To 30-11-05
Measure - 1-12-05 To 30-12-05
Analyze - 15-12-05 To 30-01-06
Improve - 15-01-06 To 10-02-06
Control - 10-02-06 To 28-02-06

Team selection:

Champion
Team Leader
Members

Process Mapping - SIPOC
(SIPOC: Supplier - Input - Process - Output - Customer)

CYLINDER HEAD READ FOR ASSEMBLY				
SUPPLIERS	INPUTS	PROCESS	OUTPUT	CUSTOMERS
NSSL,Nagpur	Semi finished Casting	Mfger. proces s	AssembledCH.	Engine Assemly
Rane Engine Valves,Banglore	Valve			
Sundarram Fastner Ltd.,Hosur	valve Seat			
Friends Auto,Phillour	Valve Guide			
Friends Industrial work,Mumbai	Wetch plug			
BCL spring Aurangabad	Spring			
Finner Seals	Oil seal			
	Machines			
	Operator			
	Tools			

Fig. 2 SIPOC

CTQ's & CTP's (Critical to Quality and Critical To Process:

Effective process improvement means that the measure we use in our business is directly tied our customers.

- Develop a customer focused business strategy
- Listening to the Voice of customer
- Translating Voice of Customer (VOC) into Critical Customer Requirements(CCR's)
- Developing Measures and Indictors

With the help of process study, CTQ's & CTP's was found out.

Top Down Chart:

A Top down chart was done to create a simple picture of the process, using two levels of details. The first level captured the major steps in the process, while the second level listed the sub-processes that fall under each major step.

Functional Process Mapping :

Like the Top down chart, a Functional deployment process map displayed the steps depicted in the process in sequential order. The Functional deployment process map also illustrated where each step is performed and who was involved.

Steps performed while creating Functional deployment Map :

- Starting and ending boundaries was established.
- Each of the process steps were listed in the sequential order.
- Horizontal axis was used to show the location for step performed.
- Each process was labeled down the column.
- Activities and decisions were listed which helped to get everyone thinking on the same level.

4.4 The Measure Phase:

This Section describes the formulation of the improvement group, measurement of the existing process and the results of a Cause-and-Effect Diagram. The improvement group their competence lies in the area of Six Sigma, DMIAC methodology and its tools. To be able to measure, analyze and improve the current situation in the valve leakage problem, there is a need for process knowledge. Thus, they decided to form an improvement group containing a variety of competences. The improvement group consists of Manager, Dy.Manager, two WST's and a quality engineer, besides them.

Input & Process Indicators:

Input indictors measures that value the degree to which the input to a process, provided by supplier are consistent with what the process needs to effectively and efficiently convert into customer satisfying output. Process indictor's measures that evaluates the effectiveness, efficiency, and quality of the transformation process. Output indictor's measures that evaluate dimension of the output.

Table1
The Development Of Defects Due To Valve Leakage Problem In The Different Months From And Onwards.

MONTH	3DI REJECTION	4DI REJECTION
May'05	57	24
June'05	21	25
July'05	1	8
Aug'05	6	14
Sept'05	10	3
TOTAL	95	74

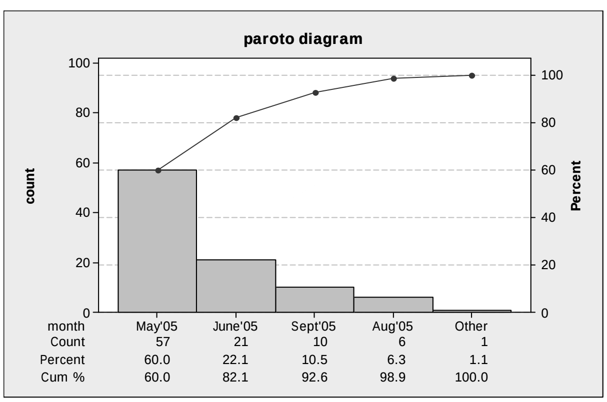

Fig. 3 Pareto Chart Illustrating The Different Month Ordered By How Many Defects They Have Produced During Last Five Months. The Historical Development In Defect Due To Valve Leakage, Presented In Figure Shows That The Cylinder Heads Rejected

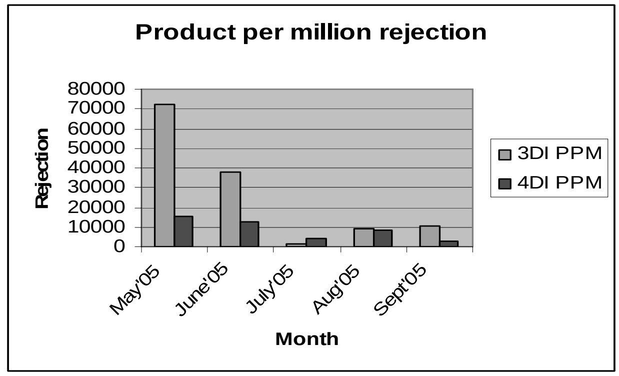

Fig. 4 Historical Developments In Defect Due To Valve Leakage In Cylinder Heads

Table 2
Loss Of Effective Working Time

MONTH	NO.OF CH. Rejected	TIME IN MINS.
July'05	4	28
Aug'05	37	259
Sept'05	36	252
Oct'05	3	21
Nov05	63	441
Dec'05	11	77
TOTAL	113	791

NOTE:- Cyl Time per Ch subassembly = 7 min/ cyl hd.

Loss of effective working time = CH rejected * Cyl time / Cyl Head.

Measurement system analysis (MSA):-

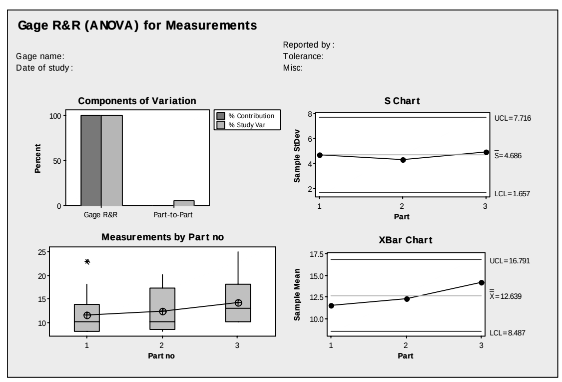

Fig. 5 Gage R&R Study - ANOVA Method

* NOTE * No or identical values for Operator - will analyze data without Operator factor.

One-Way ANOVA Table

Source	DF	SS	MS	F	P
Part no	2	45.389	22.6944	1.03026	0.368
Repeatability	33	726.917	22.0278		
Total	35	772.306			

Alpha to remove interaction term = 0.25

Gage R&R Source	VarComp	Contribution (of VarComp)
Total Gage R&R	22.0278	99.75
Repeatability	22.0278	99.75
Part-To-Part	0.0556	0.25

Total Variation 22.0833 100.00

Source	StdDev (SD)	Study Var (6 * SD)	%Study Var (%SV)
Total Gage R&R	4.69338	28.1603	99.87
Repeatability	4.69338	28.1603	99.87
Part-To-Part	0.23570	1.4142	5.02
Total Variation	4.69929	28.1957	100.00

Number of Distinct Categories = 1

4.5 The Analysis Phase:

The Analyze Phase is the third step in the DMAIC improvement cycle. This section describes the work and results of the cause and effect diagram to identify probable causes, Specific data collection on probable causes to prioritize root causes.

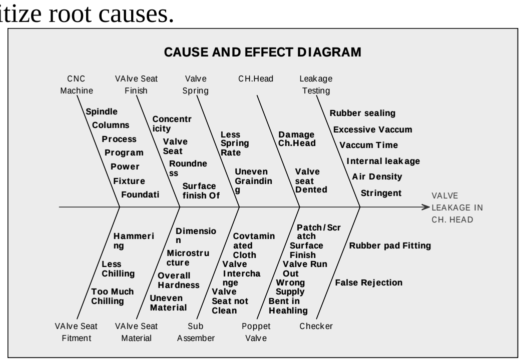

Fig. 6 Cause and effect Diagram.

Control chart:

The Statistical software was used to monitor different important parameters of the valve seat. Two of these parameters were directly affected by the valve leakage. In consultation with supervisor coded the parameters has been selected for the further study i.e. Concentricity and Circularity of Valve Seat. The idea is that the operator makes continuous measurements during production. The existing sample size was one cylinder head and all parameters were measured for all cylinder heads. These two parameters were analyzed for the different cylinder heads that passed through the frequency study of the valve leakage process.

X bar chart for Concentricity Inlet Valve:

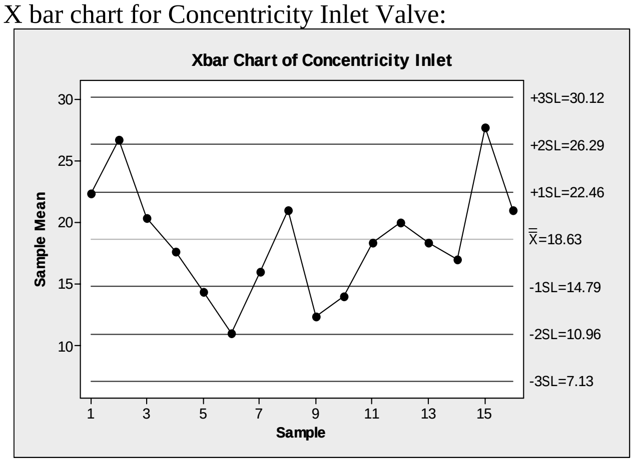

Fig. 7 Xbar Chart

Test Results for Xbar Chart of Concentricity Inlet

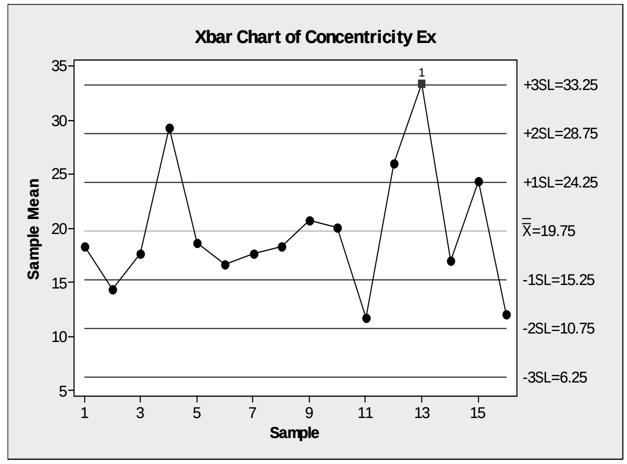

Fig. 8 TEST 1. One point more than 3.00 standard deviations from center line. Test Failed at points: 13

4.6 The Improve Phase

The Improve Phase is the fourth step in the DMAIC improvement cycle and aim to find and implement measures that would solve the problems. The main problem was formulated:

"How could the complaints in Valve leakage be eliminated?"

The critical study was conducted with the Champion, Team members and WST, the brain storming section was conducted. Based on this the group suggests that the following measures are implemented in the industry. As soon as possible.

- More frequent review of cutting tool
- Design of Experiment on Cutting data
- Insert Mounting (Investigate and implement)
- Press fitment of the Valve seat should be done instead of Hammering
- Vibration measurement of CNC can be done.
- SOP should be followed by WST
- Proper cleaning of components of valve assembly
- More strict demands on ingoing material with respect to valve leakage problems
  (Discuss with the suppliers if possible)
  - Clearer instructions
  - Common storage of NC-Program (for machining operation)

The following measures were also considered as important, but an implementation

Isn't urgent:

- Mapping of spare parts
- Reconsider valve seat, valve design with respect to the cylinder head parent bore
- Better planning of planned stops, so shortages can be reported in advance
- Training in MCSS (Scrap reporting)
- Visit customers

These suggestions will have to be implemented.

4.6 The Control Phase

The recommendations for how this phase could be implemented will be given. The development of customer complaints related to the valve leakage problem should be followed continuously and after implementing the recommended measures a decreasing trend of customer complaints (Assembly line of Engine) will hopefully appear. The downtime due to the valve leakage problem in Engine Assembly line can be evaluated from the Production register and it has been convinced that many of the measures aiming to decrease customer complaints (Engine Assembly) will also be efficient to reduce the downtime. It has been recommended that the company try to make it easier to more accurately be able to decide which operation is responsible for causing a valve leakage. If this is done it will be easier to use the reports as a basis for the performance of the process (Probably for the other activities in the Production line). Statistical Process Control is a frequently used tool in the Control Phase of a DMAIC project. However, it has been recommended that besides increasing the number of measurements, the company should further investigate if the current sampling procedure and sample size is optimal. It has been suggested that the FMEA could work as a tool for following up on implemented measures and developing further measures.

5. CONCLUSION

The present case study showed that there has been an improvement @ 20% which is much less than the target set. The process need be further improved using more advanced techniques such as Design for Six Sigma (DFSS). For global competitiveness industries need overall operational excellence by implementing the proven breakthrough strategy, such as Six Sigma. It is one of the most effective breaks – through improvement strategies having direst impact on bottom – line of the organization. From researches and surveys conducted and published so far, it appears that Six Sigma and it's statistical tools is not being explored by industries to its full potential.

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