REDUCTION OF PASTING DEFECTS BY USING SIX SIGMA TECHNIQUES: A CASE STUDY IN BATTERY MANUFACTURER COMPANY

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ABSTRACT

Highly diverse customer demand had changed the way of doing business. Modern business model are working with new economy. Six sigma is most widely accepted method for quality improvement among others program. In this paper six sigma approach has been used to reduce defects of pasting process in battery manufacturer organization. This study follows the DMAIC methodology to investigate defects, root causes and provide improvement plans for reducing these defects. Different quality tools such as Pareto analysis, cause and effect diagram, histograms are used in different phases of DMAIC model. The ultimate aim of this study is to reduce the defects and increase the level of six sigma in pasting process.

Keywords: Battery Industry, DMAIC Model, Defects Reduction, Six Sigma.

I. INTRODUCTION

Customer satisfaction is important key to survival of manufacturing organizations. In the way of this survival companies have been forced to improve the quality of their processes and products (Efstratiadis et al., 2000). To compete turbulent environments companies are adopting six sigma philosophy to achieve expected goals. Six sigma is well structured methodology to continuous improvements and reduction of cost associated with quality issues. High sigma level means process has lowest defect rate and low sigma level indicates high defect rate. Battery organization that has studied in this paper has aim to maintain the quality of its products, so as to able to delight its customer. Six sigma philosophy has been implemented in early 1980s. Six sigma is an integrated approach to reduce variability, waste, rework and defects. Six sigma techniques are used to focus on quality rather than speed. Six- Sigma is a statistical measurement of only 3.4 defects per million. Six sigma has become the financial improvement strategy for the organizations. This increases the customer satisfaction and produces high class products from the best process performances. Six sigma is a power full tool for achieving expected goals and improving the company's value by following:

- Customer focused
- Project based
- Data driven
- Disciplined and systematic

The purpose of this paper is to find out main possible reasons responsible for rejection of pasted plates and give suggestion for improvements by using six sigma DMAIC methodology.

II. LITERATURE REVIEW

For the last one decade a dozens of research paper has been published in this methodology. Bill Smith who is vice president of Motorola corporation is considered as father of six sigma. Fredrick Taylor, Walter Shewhart and Henry Ford played a great role in the evolution of six-sigma in the early twentieth century. Sigma traditionally used for measurement of variation with in a process. Six sigma level refers to 3.4 defects per million opportunities [1].The organization working daily with six sigma practices and concepts with notable improvements in customer satisfaction and process performance is considered to a six sigma organization [2]. Many authors found benefits of six sigma methodology in reducing cycle time, cost reduction, defects elimination and customer satisfaction [1, 3]. Brue and Howes [2005] mentioned six sigma as a strategy for improvement and problem solving methodology that can eliminate root cause of effects. O' Nail and Duvall [2003] discussed applications of six sigma quality frameworks. They have used quality tools and post occupancy evaluation research method to create and manage optimal space for office workers. Some of six sigma program has been failed in manufacturing industry due to lack of knowledge of six sigma methodology. Kwak and Anbari [2006] discussed the obstacles and benefits of six sigma. They also identified future of six sigma approaches. Snee [2004] focused on process outputs that are of critical important to customer. Six sigma was described as business improvement approach that finds and eliminate defects or causes of mistake in processes. Mike Harry [2000] indicated that six sigma is a new paradigm of management innovation for companies survival in modern period, which is based on three things: Quality Culture, Management Strategy and statistical Measurement. Gijo and Rao [2005] suggested that selection of suitable belt projects plays an important role in six sigma implementation and six sigma projects should be selected on the bases of organization goal and objectives. Macmanus [2007] analyzed that there would be team work in every organization for process improvement. This kind of team approach is important for sustained progress toward process excellence to improve the sigma level.

DMAIC is one of six sigma approach for process and quality improvement. This modal has five phases: Define Measurement, Analyze, Improve and Control. This DMAIC modal systematically helps organizations to solve problems and improve their processes. Dale et al. [2007] described the DMAIC phases as follow:

- **Define:** This phase define scope of project, team role, objectives, voice of customer and the goal of project.
- **Measure:** This phase measure the current process or performance and presents the detailed process mapping, data collection chat.
- **Analyze:** This phase of DMAIC identify the main causes responsible for defects by using quality tools such as cause and effect diagram, Pareto chart, why analysis and FMEA analysis etc.
- **Improve:** This phase generate possible improvement to the problems find out in last phase with help of statistical tools.
- **Control:** The last phase of this methodology is control that ensures that improvements are sustained. This is done by regular audits of the processes.

Chakravorty [2009] proposed a model for successful implementation of six sigma so that it can reduce the variation or waste from the operation. S. Soni et al. (2013) discussed the quality and productivity improvement in a manufacturing enterprise. This study deals with an application of Six Sigma DMAIC (Define-Measure-

Analyze-Improve-Control) methodology in an industry. H.C Hung and M.H. Sung (2011) explored how a food company in Taiwan can use a systematic and disciplined approach to move towards the goal of Six Sigma quality level. The DMAIC phases were utilized to decrease the defect rate of small custard buns by 70% from the baseline to its entitlement.

III. THE DMAIC SIX SIGMA METHODOLOGY

The primary objective of six sigma project is customer satisfaction. Six sigma is quality improvement strategy as results satisfaction of its customer. The DMAIC is basic component of six sigma methodology. The other important aspect of sig sigma methodology is training, involvement and rewards of employees. For implementation of six sigma program it is necessary to establishment of six sigma team. DMAIC methodology has five phases for quality improvement: Define Measure, Analyze, Improve and Control.

3.1 Define phase

The first step of DMAIC methodology is "Define" phase. The define phase is for defining the goal, scope, identifying the voice of customer [4]. Six sigma team is set before the starting the DMAIC methodology. This six sigma team includes three members which are manager, operator and team leader. The project reducing pasting defects has chosen for significant and positive impact on customer as well as cost saving. Six sigma project should be selected on the company issues related [5].The project is should define customer voice (customer requirements), because listening to customer is critical to business to be successful [6]. VOC is collected by conducting brain storming sessions among the customers. A project charter is a tool used to the document the targets of the project and other parameter. The project charter is presented below:

a. **Project title:** Defects reduction in pasting plates.

b. **Background and reason for selecting the project:** pasting plates are rejected in the pasting section. This problem causes several types of losses in the company, such as time, material, capital and also customer dissatisfaction.

c. **Project goal:** To reduce defects up to six sigma level.

d. **Voice of customer:** quality of product.

e. **Project boundary:** Focusing on DCLA (-ve) plates.

f. **Expected beneficial benefits:** A considerable cost saving due to defects reduction.

g. **Expected customer benefits:** receiving the product with high quality.

Process mapping is a key step in understanding the process used in the organization. SIPOC process map starts with raw material and end with benefit received by customer. SIPOC is created for the pasting process. This is presented in table 1.

Table1. SIPOC Diagram

Supplier	Input	Process	Output	Customer
Casting section	Paste and grid	Pasting process	Pasted plates	Next machine with curing process.

Casted grid plates are supplied to pasting machine. Pasting machine prepares mixture of paste and this mixture is pasted on grid frame work. After water and acid spray passed through oven and collected at other end with help of conveyor. The pasted plates out of specified standard are rejected at this point. The customer of these pasted plates is next machine with curing process.

3.2 Measure Phase

The second phase of DMAIC methodology is measure phase, which consist of establishing reliable metrics to monitor progress towards the goal [7]. In this project the goal is reducing the number of quality defects in pasted manufacturing process. This phase measures how frequently each and every defects occur. Collected data shows that whether the production process is going out of control or not. This step is basically depends on data collection so for gathering data efficient plans should adopted. In this project to clarify major defects a simply metric is prepared showing number of defects per type. Three defects are found in pasting process which is responsible for rejection. These three defects are missing pallet, distortion and lumps. For this research the missing pallet defect defined as those plates which are missing paste on the grid at some area. Distortion defect is defined as those plates having distortion more than 1mm difference from the base line from any side. The last defect is lump due to which pasted plates are rejected. The defect data on pasted plates is collected for a month. The results for defects are given in table2.

Table2. Defects summary (Before the improvement)

Type of defect	Number of defects
Missing pallet	6711
Distortion	2943
Lump	291
Total	9945

The Pareto analysis is carried out in next step to prioritize the most critical problems and identify the most utmost occurring defect [8]. Pareto chart shown in figure1.indicates that the highest rate of defects is caused by missing pallet. Missing pallet contributed 66% of total amount of defects. Therefore it was decided to initially focus on the reduction of missing pallet defect.

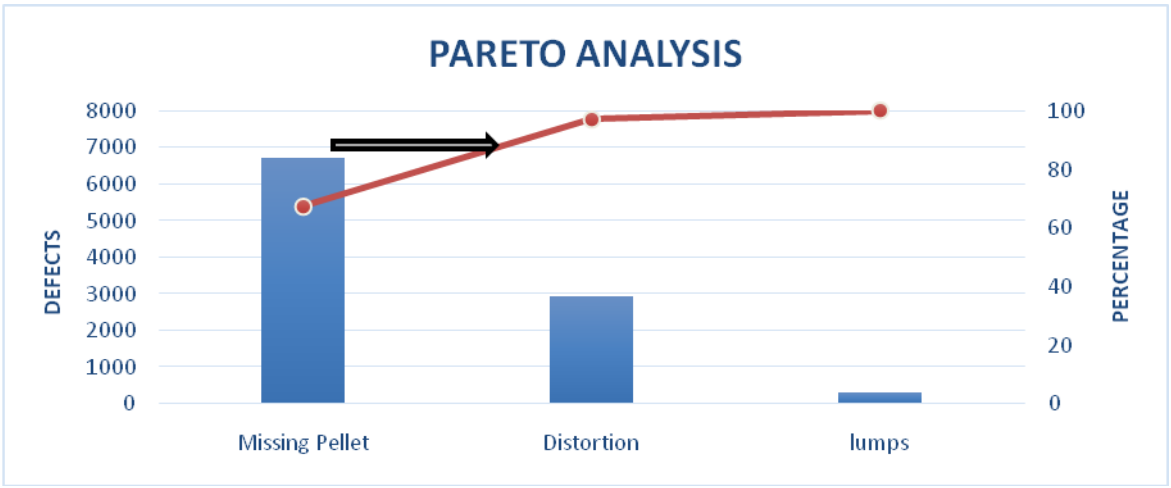

Figure1. Pasting defects Pareto chart

3.3 Analyze Phase

The analyze phase of DMAIC methodology is to analyze the manufacturing process and identify the ways to reduce gap between the current performance and desired performance [9].This phase shows the input and out variables which effect each critical to customer. The data measure in the last step is analyze and followed by an investigation to understand the root causes of the problem. The understanding of pasting manufacturing process is main requirement of improvement. In order to understand this manufacturing process in analyze phase a flow chart is given in figure3. This flow chart of pasting manufacturing process gives details of different stages involved in this process. Once the manufacturing process is understood, an analysis is carried out to identify the root causes. In this research work critical analysis is carried out with the help of cause and effect diagram. Cause and effect diagram are used to identify and systematically list the different causes, which are responsible to a problem. So, this diagram help to determine which of several causes has greatest effect. Once this diagram is completed provide the ideas for further improvement. The five main categories used in cause and effect diagram are: Method, Material, Machine, Manpower, and Environment.

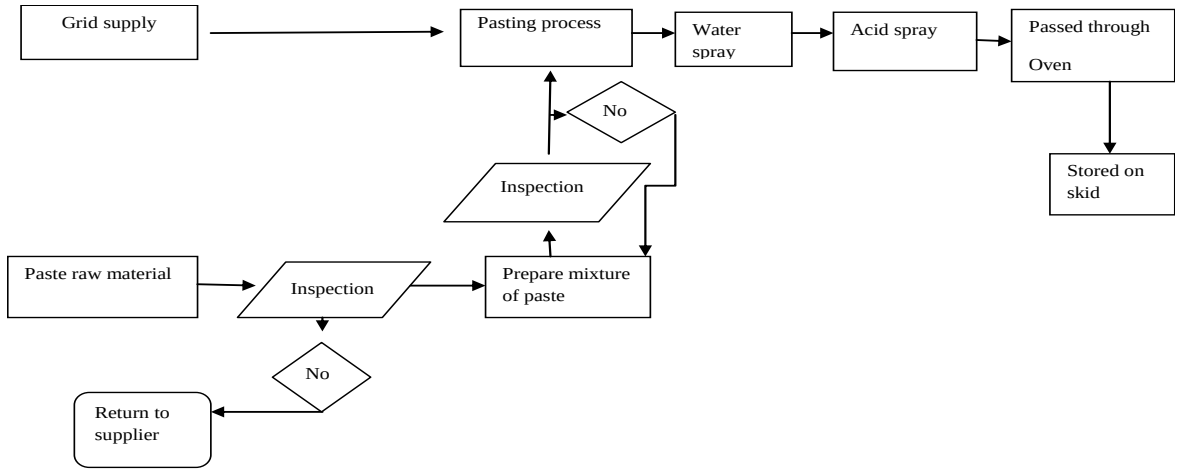

Figure2. Pasted Manufacturing Process Flowchart

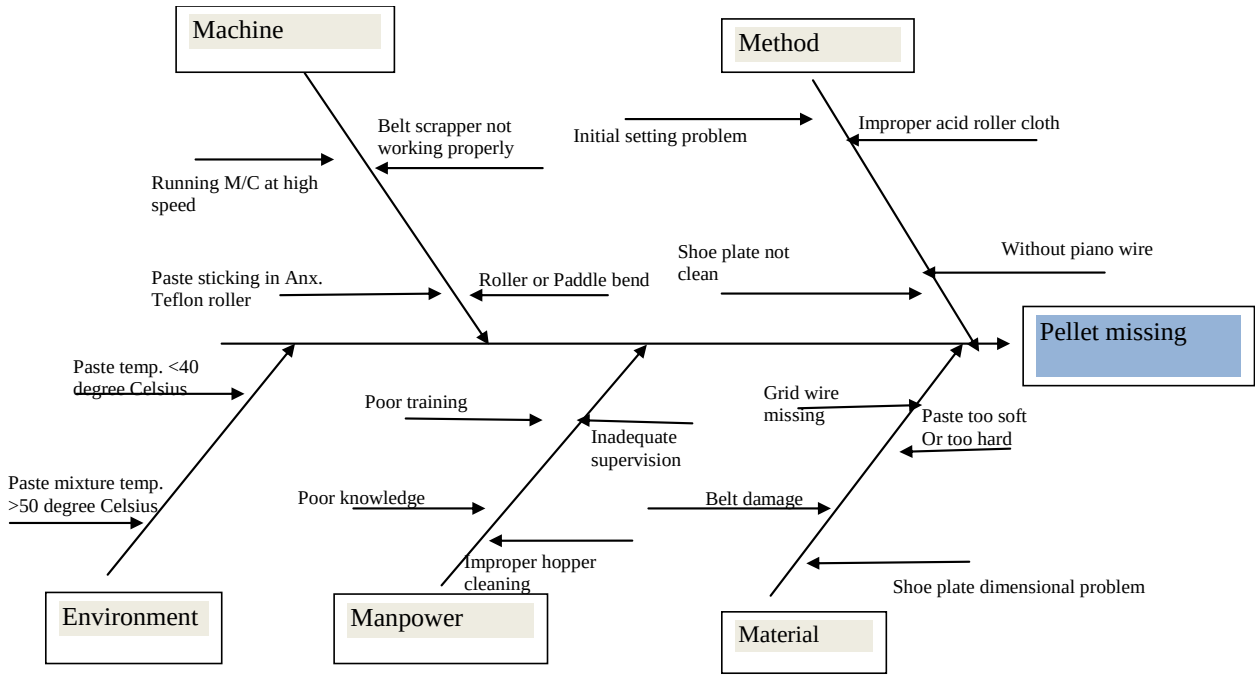

Figure3. Cause and Effect Diagram Related to Missing Pellet Defects.

3.4 Improve Phase

Improvement of DMAIC deals with solution and activities that are responsible for improvement [10]. The improvement phase designs the appropriate experiments so that defects can reduce. In this project FMEA is used to identify all possible types of failure. The objective of conducting FMEA is to anticipate all possible types of failures that could occur. FMEA includes the parameters such as failure mode, failure effects, failure causes, occurrence, detection, severity, RPN and improvements plans.

Table3. Evaluation of Improvements with FMEA

Process Function	Failure Mode	Failure Effects	Failure Causes	(S)	(O)	(D)	R.P.N.	Action to reduce failure
Pasting of plates	• Hopper paddle rpm	• Missing of pellet so mostly decrease in weight of pasted plate (Improper pasting).	• Hopper paddle rpm high or low	8	8	5	320	• Set hopper paddle speed between 25-28 rpm.
	• Knurling problem		• Knurling not proper after some time		9	6	432	• Change after 3 months and weekly inspection.
	• Zero setting of hopper		• Careless of operator		8	4	256	• Skilled operator
	• High density and low density		• High and low temperature of mixture		6	6	288	• Set the mixture temp. between 40 to 50 degree Celsius and use chiller
	• Belt condition		• Thickness decrease with time		7	4	224	• Change belt after 40000 pannel
	• Improper masking		• Mask hole size over due to wear and tear		6	6	288	• Weekly audits
	• Squeeze roller		• Not proper maintenance		6	5	240	• Weekly changing of squeeze roller
	• Squeeze pressure		• Improper maintenance		5	7	280	• For proper pressure maintenance weekly

All possible failure mode of pasting process are considered and also failure causes responsible for them.RPN is calculated for pasting process by discussing every failure mode with engineer and operator of the machine. FMEA considered 8 failure modes for rejection of pasting process and improvement plans are given respectively.

The process of pasting is not in control before the improvements given by FMEA at every failure mode.UCL and LCL for DCLA (-ve) plate are 447 and 431 gram. Average class limit is 439 gram. Data is collected from operators for 16 days regularly. Mean weight is calculated for day and drawn with help of P chart. P type chart is used to measure the data which are out of control.

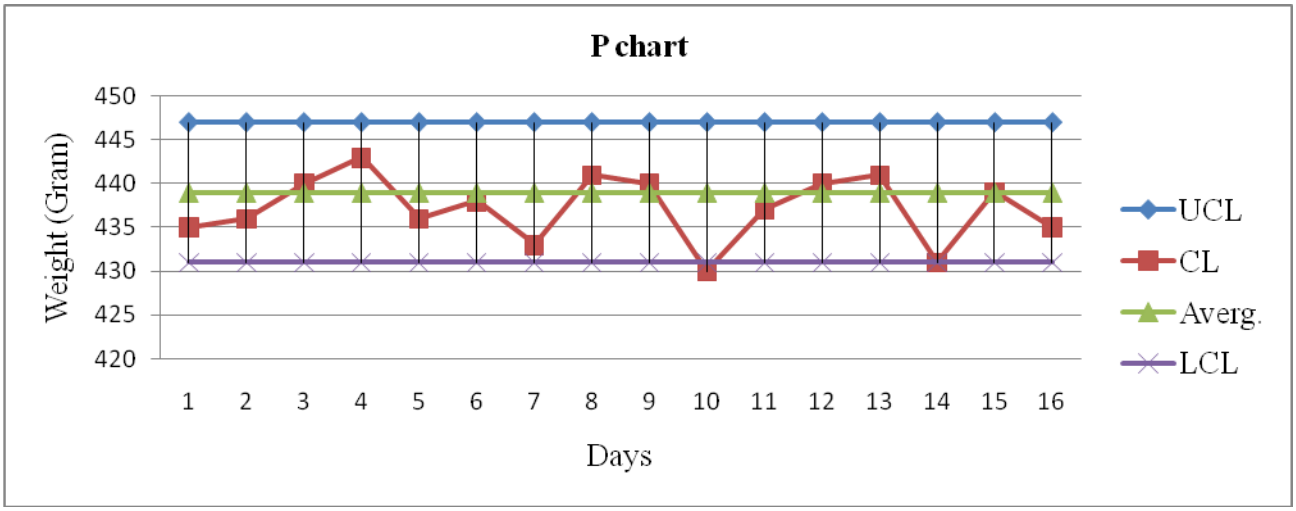

Figure4. P chart Before improvement

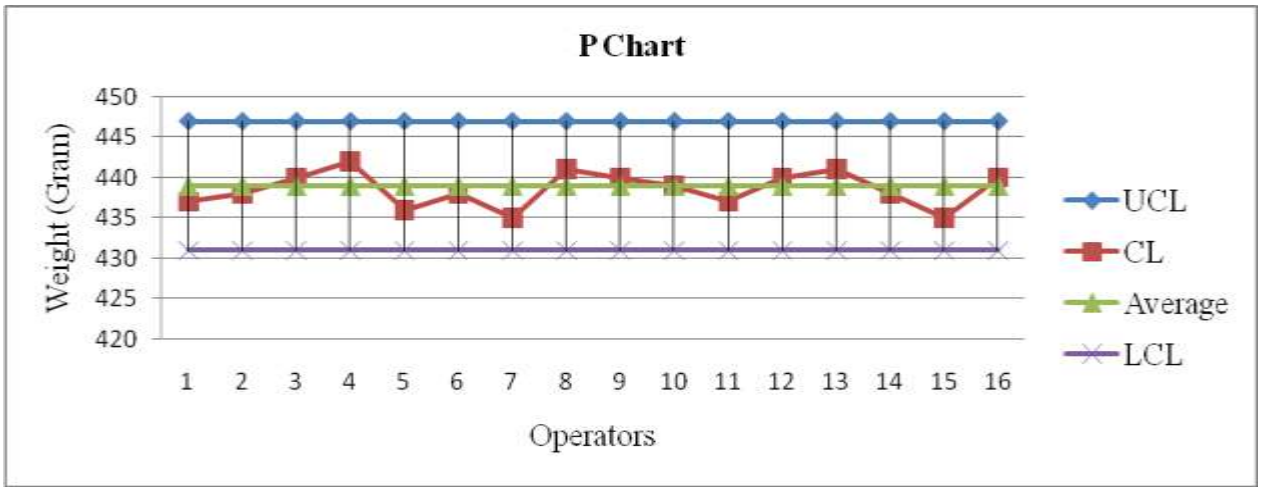

Figure5. P chart After improvement

P chart after the improvements given by FMEA showed the successful implementation of six sigma program.

3.5 Control Phase

Control phase is for sustaine the improvement gained from the improvement phase. All the actions are implemented in the pasting process and results are monitors. For monitoring improvements plans tools such as revised FMEA , Statistical Process Control, Poke-Yoke and trainings plans are used.

IV. CONCLUTIONS

Six sigma is a power ful tool for customer satisfaction by quality improvement in the process. A successful case study of defects reduction in pasting process of battery manufacturing company is done by six sigma methodology. At before of the project the company sigma level was between 3 and 4 sigma. Analysis and improvement phase identify all possible causes for rejection and then improvemenmts for every failure

mode.Three kinds of defects were described for pasting rejections and these were Missing Pellet, Distortion and Lumps. Missing Pellet foung major cause for rejection at pasting section. Improvement plans are given to every failure mode.The implementation of project decearses the rejection level, but still not able to take six sigma level.The defects are reduced 6711 to 2505.This projects showed that organisation can achieve continous improvement throgh six sigma program. Six sigma means culture of continous improvement and also benefits in cost saving, reducing time, satisfaction of customer and enhancing quality. This case study assured that success ful implementation of six sigma brin gs huge profit to the organisation.

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