Original Article

Application of Six Sigma for Process Improvement and Variation Reduction of Automotive Batteries

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Abstract

This paper mainly emphasizes on process improvement and variation reduction with the application of DMAIC, which is a sub methodology of Six Sigma. It shows the application of Six Sigma in AMARA RAJA BATTERIES manufacturing to reduce the production defects like paste rejection. Six sigma at many organizations simply means a measure of quality that strives for near perfection. Six sigma is a disciplined data driven approach and methodology for eliminating defects in any process from manufacturing to transaction and from product to service. It is a known fact that Battery is an inevitable accessory for all automobiles, as it is the source of power for ignition, lighting and other external accessories. It is a practical work done at AMARA RAJA BATTERIES, Tirupati where initially the percentage of paste rejection was nearly 3.09%, which drastically got reduced to about 2.26% within two months by applying the six sigma. Proposals have been made at the firm to install the sensors like paste sensor, jam detecting, door sensors to reduce the scrap further.

Keywords: DMAIC, Jam Detector, Paste sensor, Six Sigma.

1. Introduction

Six Sigma is essentially a comprehensive yet flexible system for achieving, supporting, and maximizing business profits. It is a methodology driven by understanding customer needs, and the disciplined use of data, facts, and statistical analysis to improve and reinvent organizational processes.

It is a methodology for improving key processes, and a “tool box” of quality and management tools for problem resolution, which can continuously focus on business improvement.

Defects are defined as units that are not members of the intended population. Since it was originally developed, Six Sigma has become an element of many Total Quality Management initiatives.

Six sigma has two key methodologies: DMAIC and DMADV. DMAIC is used to improve an existing business process. DMADV is used to create new product designs or process designs in such a way that it results in a more predictable, mature and defect free performance.

1.1. Automotive (SLI) Batteries

These are used for starting, lighting and ignition purposes. It comes with the brand name AMARON. Amaron offers long life, involves high technology and is totally maintenance free. Batteries are made to the specific standards of ISO 9001, QS 9000. TS 16949 and ISO 14001 certificates using world-class technology, and quality-controlled parameters.

1.2. Amaron Design Features and Batteries

- Long-life Reformulated, premium silver alloys.
- Zero maintenance on top-ups, high heat technology, and premium silver alloy for low corrosion.
- Fully sealed and tested-factory charged, wet shipped.
2. The Six Sigma Quality Philosophy

2.1. DMAIC in Six Sigma:
DMAIC or Define-Measure-Analyze-Improve-Control, principle is used to execute six sigma projects in an organization.

2.1.1. Define Phase and Tool:
Define (D) is the first step of the Six Sigma methodology where leaders are expected to select projects, set initial goals or targets, and develop a project charter or statement of work (SOW). Costs of poor quality associated with the new or existing process being analyzed are estimated. Improvement targets are set often in terms of sigma and cost. The team then determines more precisely the criteria that are critical to the customer. Run charts, interviews, or surveys, for example, are utilized to obtain leads and useable figures. A high-level process map of the existing process is to be developed with start and end-points clearly illustrated. Strategic deliverables are a process map, a working project charter, a team roster, and the costs of poor quality.

2.1.2. Measure Phase and Tool:
Measure is the second step of the Six Sigma methodology and is denoted by the capital letter M. The goals of Measure appear to activate only in the mode of data management, which includes both collection and organization of the data for the purpose of observation. FMEA, MSA and particularly Gage R&R are tools that serve largely in a verification capacity, which fall into the problem identification and data management stages.

2.1.3. Analyze Phase and Tool
The third step, A, is analyze. Here teams identify several possible causes (X’s) of variation or defects that are affecting the outputs (Y’s) of the process. One of the most frequently used tools in the analyze step is the cause and effect diagram. A Six Sigma team explores possible causes that might originate from sources, such as people, machinery and equipment, environment, materials, and methods. Team member suggestions may need clarified before proceeding further, so each and every team member has a clear understanding of the cause being presented. The resulting list should be reduced to the most probable root causes. Causes can be validated using new or existing data and applicable statistical tools, such as scatter plots, hypothesis testing, ANOVA, regression, or design of experiments (DOE). Experts warn not to assume causation or causal relationships unless there is clear proof. Furthermore, validating root causes can help teams avoid implementing ineffective improvements and wasting valuable resources.

2.1.4. Improve Phase and Tool
The team then enters the improve (I) step. Here a team would brainstorm to come up with counter measures and lasting process improvements that address validated root causes. The tool most preferred for this process is the affinity diagram, which is a brainstorming technique where a topic or issue is presented to a small team who then quickly list ideas or solutions. The team should narrow the list to one or two potential improvements that are step deliverables for small-should be selected based on probability of success, time to execute, impact on resources, and cost. If newly gathered data indicates the small-scale implementation is a legitimate success, teams should proceed to full-scale implementation.

2.1.5. Control Phase and Tool
The final step for at least the black belt and many of the team members is control, which is signified by the capital letter C. At this point devices should be put in place to give early signals when a process is heading out of control. Teams may develop poka-yoke or mistake proof devices that utilize light, sound, logic programming, or no-go design to help control a process. The ultimate goal for this step is to reduce variation by controlling X’s (i.e., the inputs) and monitoring the Y or Y’s (i.e., the outputs).

3. DMAIC Applied in the Work

3.1. Define:
The existing data of the process is calculated for the future comparison by the following charts

3.1.1 Waste Management
ABD-Pasting Line one/two
Shift------------- Date---------

3.1.2 Scrap analysis report for pasting process

PASTE SCRAP
Type :
Production quantity:

A. Mixer designer scrap
1. --------------------------KG
Any abnormality --------------------------
Operator cleaning/not cleaning the mixture every time after dumping the mixture
Mixing operator name:
Paster operator name:

B. Process scrap: --------------------------KG
C. Paster design scrap--------------------------KG

The above chart gives the amount of paste input to the process. Any abnormalities such as machinery problems are also defined. At last the process scrap is entered.
For every half an hour, the data is collected in every shift for studying purpose (table 1).

### 3.1.3 Feeder Rejection (Grids)

Data about grid rejections for every half an hour

<table>
<thead>
<tr>
<th>Grid feeder rejection</th>
<th>KG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid jamming</td>
<td></td>
</tr>
<tr>
<td>Lifting problems</td>
<td></td>
</tr>
<tr>
<td>Driver roller problem</td>
<td></td>
</tr>
<tr>
<td>Accelerating roller problem</td>
<td></td>
</tr>
</tbody>
</table>

### 3.1.4 Input Material Problem (30min Once) / Grid Defects:

**Other Major Causes for Rejection:**

- Man power
- Material
- M/C
- Process ADJ
- Spares wear and tear
- Leakages observed:
  - Air
  - Water
  - Hyd Oil
- Checked By
- Supervisor
- Filled By

### 3.1.5 Formulae To Calculate %Plate, %Paste, %Grid Scrap:

1. **PASTE SCRAP** = No of plates scrapped * (plate mean wt-grid mean weight)
   
   \[
   \text{% of paste scrap} = \frac{\text{paste scrap} \times (100)}{\text{total paste produced}}
   \]

2. **PLATES SCRAP** = Total plates scrap which is available near porter.

   \[
   \text{% of plates scrap} = \frac{\text{plates scrap} \times (100)}{\text{total plates produced}}
   \]

### 3. GRIDS SCRAP = Feeder rejection (no of grids rejected in feeder)

<table>
<thead>
<tr>
<th>Feeder Rejection</th>
<th>feeder rejection (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Grid mean wt. (gr.) * (1000)</td>
</tr>
<tr>
<td>Feeder rejection numbers</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{% of Grid Scrap} = \frac{\text{feeder rejection numbers}}{\text{total grids consumed}}
\]

**Total grids consumed** = total plates produced + total feeder rejection.

a. Major contribution of input material defect (half hour once)
b. output (plate) defect (half hour once)
c. mixer scrap (while going to m/c cleaning (-ve to +ve)

### 3.2 Measure:

The data collected in the defining section is used in the measuring phase to identify the type of defects. The data collected is plotted pictorially on a graph for better understanding purpose.

#### 3.2.1 Pareto Analysis

**Figure 1: Pareto on grid rejection**

Figure 1 shows the defect wise grid rejection in the manufacturing of grids.
Analyzing Grid Bends:
The analysis of Pareto chart of defect wise grid rejects gives us the following information:

Table 2: Analysis of grid bends

<table>
<thead>
<tr>
<th>CAUSE</th>
<th>REJECTION IN Kgs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grind bend</td>
<td>31699</td>
</tr>
<tr>
<td>Improper aging</td>
<td>11575</td>
</tr>
<tr>
<td>Lumps on grids</td>
<td>5819</td>
</tr>
<tr>
<td>Crack</td>
<td>4352</td>
</tr>
<tr>
<td>Wire missing</td>
<td>3085</td>
</tr>
<tr>
<td>Lug bend</td>
<td>2297</td>
</tr>
<tr>
<td>Damage while transferring</td>
<td>2000</td>
</tr>
<tr>
<td>Flashes</td>
<td>1927</td>
</tr>
<tr>
<td>Thickness variations</td>
<td>1850</td>
</tr>
<tr>
<td>Cross cut</td>
<td>1094</td>
</tr>
<tr>
<td>Lug blow hole shrinkage</td>
<td>933</td>
</tr>
</tbody>
</table>

Table 2 gives the total rejections due to grid rejections figures as 31699, and this share up to 48%. Reducing the rejections due to grid bends, most of problem is solved. This is the reason why analysis of Grid bends has been done.

Pareto on plate rejection:

Pareto on plate rejection:

![Pareto chart for defect wise plates rejection]

Figure 2: plate rejection

Figure 2 shows the various causes and quantity of paste rejection accordingly.

Analyzing Half Pasted Plates:
The Pareto chart shows the rejections as follows. As the rejection of half pasted accounts for 27% the concentration is mainly done on half pasted plates.

From the table 3, it is clear that, the plate rejections due to HALF PASTED PLATES are 11809. And this contributes to 27% of the total rejections. This is the major contribution for the plate rejections.

Table 3: Analysis of half pasted plates

<table>
<thead>
<tr>
<th>CAUSE</th>
<th>REJECTION IN Kgs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half pasted</td>
<td>11809</td>
</tr>
<tr>
<td>Pallets down</td>
<td>10988</td>
</tr>
<tr>
<td>Cross cutting</td>
<td>10660</td>
</tr>
<tr>
<td>Jamming</td>
<td>4910</td>
</tr>
<tr>
<td>Cutter adjustment</td>
<td>3497</td>
</tr>
<tr>
<td>Without paste</td>
<td>1209</td>
</tr>
<tr>
<td>Operator</td>
<td>61</td>
</tr>
</tbody>
</table>

3.3. Analyze:
After measuring the current process, relevant data is collected from Define stage for future comparison. By conducting brain storming sessions it is ensured that all possible factors have been considered for half pasted, pellet down, cross cutting pellet and grid bend.

3.3.1 Fishbone Diagram
Dr. Kaoru Ishikawa, a Japanese quality control statistician, invented the fishbone diagram. Therefore, it may be referred to as the Ishikawa diagram. The fishbone diagram is an analysis tool that provides a systematic way of looking at effects and the causes that create or contribute to those effects. Due to its function, the fishbone diagram, it may be referred to as a cause-and-effect diagram. The design of the diagram looks much like the skeleton of a fish. Therefore, it is often referred to as the fishbone diagram.

![Fishbone diagram on grid bend]

Figure 3: Fish bone diagram on grid bend

Does the team...
- Need to study a problem/issue to determine the root cause?
Figure 4: Fish bone diagram on Half pasted plates

Figure 5: Fish Bone Diagram for Cross Cut

Figure 6: Fish Bone Diagram for Pellet Down
• Want to study all the possible reasons why a process is beginning to have difficulties, problems, or breakdowns?
• Need to identify areas for data collection?
• Want to study why a process is not performing properly or producing the desired results?

All the possible factors contributing for paste scrap collected from brainstorming sessions are presented through Ishikawa’s cause and effect diagrams (Fish Bone Diagram) given in figures 3, 4, 5 and 6.

3.4. Improve:
From all the possible causes, implementable causes are selected and action plan is executed to correct these causes.

Perhaps the most difficult part of the Six Sigma process is the Improve stage. There are only a few tools that can point out the obvious way forward and it relies on the knowledge and creativity of the team.

The following Action Plan has been made on the basis of problems obtained during the Measure and Improve stages to correct the present problems and reduce the Paste Rejection.

3.5. Control:
To ensure that any variances are corrected before they result in defect, this is probably the most important part of DMAIC process. By taking corrective actions, paste rejection is reduced beyond the target percentage. In order to maintain the same results the following sensors are used,

• paste sensor
• Jam detecting sensor
• Motor drive sensor
• Hopper up and down sensor
• Synchronization speed sensor
• Cross cutting detecting sensor.

4. Result:
Table 4: Improvements after DMAIC Application

<table>
<thead>
<tr>
<th>s.no</th>
<th>Month</th>
<th>Paste produced (Kg)</th>
<th>Paste rejected (Kg)</th>
<th>% paste rejected</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OCT</td>
<td>1551658</td>
<td>48092</td>
<td>3.09</td>
<td>3.00</td>
</tr>
<tr>
<td>2</td>
<td>NOV</td>
<td>1513158</td>
<td>40187</td>
<td>2.65</td>
<td>2.75</td>
</tr>
<tr>
<td>3</td>
<td>DEC</td>
<td>1217252</td>
<td>27237</td>
<td>2.26</td>
<td>2.50</td>
</tr>
</tbody>
</table>

Table 4 shows the improvements obtained after implementing corrective action plans. By applying Six Sigma (DMAIC), by December, paste rejection has been drastically reduced from 3.09% to 2.26%.

5. Conclusions:
• Before the application of DMAIC the paste rejection cost an amount of Rs 80,000/-, but on the application of DMAIC process Rs 22,000/- is saved per day.
• The gist six sigma is effective at what it is intended to do, but it is “narrowly designed to fix an existing process” and does not help in “coming up with new products or disruptive technologies”.

By taking the corrective actions for the causes the paste rejection percentage is reduced beyond the target percentage.

References
[7] Subodh K. Das and Margaret Hughes, Improving Aluminum can recycle Rates: A Six Sigma Study in Kentucky, JOM web site (www.tms.org/JOMPT)

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