Study of Prevention Mechanism in Process Control

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Abstract—The product is built by manufacturing process or working process. In order to get the maximum output with best quality by minimum input and lowest operating costs, the prevention mechanism is proposed to be set up in production. The quality is often studied, however, the prevention mechanism is seldom mentioned or studied further till the issues are found. This paper reports the prevention mechanism with Six Sigma Methodology from the quality management perspective. The key techniques including DMAIC, SPC and MSA are utilized to prevent the unexpected occurrences in the final product. According to the statistical principle, the process capability is checked and the process reliability is evaluated to verify the prevention mechanism. The demonstration on power meter production shows the average failure on line has been decreased 33% and the remedy costs are saved completely after the prevention mechanism in process control is set up.

Index Terms—Six sigma methodology, DMAIC, statistical process control, control chart, measurement system analysis, gauge repeatability and reproducibility.

I. INTRODUCTION

The working process exists in kinds of job. When the firm seeks for the customer satisfaction and the maximum profit, it is most important to manufacture the reliable output in best quality. The output is usually produced through many steps in the working process; any variation from the first step to the final one will cause the unacceptable output. If the variation can be detected and removed, then the unacceptable output will be prevented and the remedy costs will be saved. So it is important to set up the effective preventive measures, not waiting for mending till the unexpected occurrence. However, the prevention is often neglected and not emphasized enough. In this paper, the prevention mechanism in the statistical process control is proposed and studied to set up from the view of the quality management.

The details of prevention mechanism in the manufacturing process are presented in section III.

II. SIX SIGMA METHODOLOGY

It is expected to reproduce products which are identical to each other in every characteristic in production. However, there are uncontrolled variations in instruments, materials, method and environment, which make each output slight different from each other.

The unit to unit differences are usually illustrated by the Standard Deviation with a normal distribution by a bell-shaped curve. The narrower the shape is, the less the variance is. The Standard Deviation is also called as Sigma. When the process reaches the 6 Sigma according to the quality management, there are 3.4 Defects per Million Opportunities [1]–[2]. Motorola has got the great success of reducing costs on defects after initiating its own innovative quality program called Six Sigma [2], now the objective of Six Sigma Methodology is to reduce variation through continuous process improvement, this leads to customer satisfaction [1].

There are many statistical techniques in Six Sigma Methodology, those utilized in prevention mechanism set up is in the following.

A. DMAIC

DMAIC is an acronym for Define, Measure, Analyze, Improve and Control [1], which is the roadmap of Continuous Improvement in Six Sigma Methodology. It outlines a clear sequence of steps that focuses on improving existing processes and performance [1]. DMAIC is the methodology on business or process improvement.

B. SPC

Only one representative process parameter is considered at a sampling time. During one sampling, it is impossible to control 100% of quality data. SPC focuses on controlling the process rather than the product [3].

SPC studies the Process Stability and Process Capability. The Process Stability in SPC means that distribution characteristics remain constant over time in control chart. If a process has more than 99% of the summarized quality characteristics distributed within the ±3σ of average value, then it is in quality control. The ±3σ of average value is the statistical calculation based on data and called as the Upper-Control-Limit (UCL) and the Lower-Control-Limit (LCL) [4]. It is shown in Fig.1. μ is the mean or the average value of the data.
Process Capability Indices (PCI) includes Process Potential Index denoted by \( C_p \) and Process Performance Index denoted by \( C_{pk} \) [5]. The equation of double-sided distribution is in Eq.1 [5].

\[
C_p = \frac{USL - LSL}{6\sigma}
\]

\[
C_{pk} = \min \left( \frac{USL - \mu}{3\sigma}, \frac{\mu - LSL}{3\sigma} \right).
\]  

The process potential ability is sufficient when \( C_p > 1.33 \) and the process performance ability is sufficient when \( C_{pk} > 1 \) [5]. The \( C_p \) and \( C_{pk} \) must be checked together for the process capability evaluation.

C. MSA

The Measurement System Analysis (MSA) is the process to assess the measurement system to determine meaningful differences in process variations [6]. The repeatability and the reproducibility are the objectives of MSA study. The Gauge Repeatability and Reproducibility (GR&R) and Number of Distinct Categories (NDC) determine how much of the observed process variation is due to measurement system variation. GR&R illustrates the system with \( %R&R \) or \( %P/T \) in Eq.2 [7]. The \( \sigma_{MSE} \) is the standard deviation of the measurement system and the \( \sigma_{Total} \) includes the standard deviation of both the measurement system and the interaction influence [7].

\[
%R&R = \frac{6\sigma_{MSE}}{6\sigma_{Total}} \times 100\%
\]

\[
%P/T = \frac{6\sigma_{MSE}}{USL - LSL} \times 100\%.
\]  

The system is in best status when the value of \( %R&R \) or \( %P/T \) is less than 10%, the system is acceptable when the value of \( %R&R \) or \( %P/T \) is more than 10% but less than 30%, the system must be improved if the value of \( %R&R \) or \( %P/T \) is more than 30%. There are nested GR&R and crossed GR&R for MSA, but the reproducibility will not be estimated in nested GR&R, while the repeatability and reproducibility can be estimated based on the assumption that the same batch of parts is homogeneous in the crossed GR&R [7].

III. PREVENTION MECHANISM IN POWER METER PRODUCTION

The manufacturing process for the power meter production shown in Fig.2 includes the Printed Circuits Board assembly, PCBA testing, Housing assembly, Function test, Packing, Quality Checking and then Ship out to customer. The failures per half hour in each step of the manufacturing flow are calculated and sent to the Repair Center. The DMAIC and statistical tools are utilized to study the prevention mechanism in process control.

A. Define

The failures are analyzed and reported to the management team. It is found most failures come from the Function test station. The quantity of the failures is increasing very quickly. It is very urgent to set up the prevention mechanism on Function test station to avoid the failures increasing to impact the production capacity.

B. Measure

The quantity of the nonconforming may be covered by Attribute Control Chart, which is also the np chart. After checking the failure quantity on Function test station is not autocorrelation according to the SPC principle, the np chart is generated based on the target of zero defect and the 6 sigma, the np chart shown in Fig.3 indicates the current data is still within statistical control limit but it shows the trend to the out-of-control, also the current failure quantity is far more than the quality expectation.

C. Analysis

The failures analysis could not found the issues on the board. Since the machine, the operator, the fixture, the product and the method set up the Measurement System, the MSA is
conducted to check this system. The testing unit, the test station and the operator are the influence factors in the function test station.

The data model for crossed GR&R is shown in Fig.4 [7]. The operator A tests 8 units on No.1, No.2 and No.3 test station with the same working instruction and gets 24 pieces of reading data. The operator B tests these 8 units on the same 3 test stations to get another 24 pieces data. The operator C tested these 8 units on the same 3 test station.

As shown in table 2, there are %R&R = 22.8%, %P/T = 13.77% and NDC = 6. These metrics show the measurement system is valid and is reliable and stable for the quality control in power meter production.

Table II. GR&R STUDY

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Source</th>
<th>% of Var</th>
<th>Std Dev</th>
<th>6*Sig ma</th>
<th>%R&amp;R</th>
<th>%P/T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total GR&amp;R</td>
<td>0.0005</td>
<td>0.0</td>
<td>0.02295</td>
<td>0.13</td>
<td>22.8</td>
<td>13.77</td>
</tr>
<tr>
<td>Repeatability</td>
<td>0.0005</td>
<td>0.0</td>
<td>0.02295</td>
<td>0.13</td>
<td>22.8</td>
<td>13.77</td>
</tr>
<tr>
<td>Reproducibility</td>
<td>0.0000</td>
<td>0.0</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Operator</td>
<td>0.0000</td>
<td>0.0</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Unit-to-Unit</td>
<td>0.0096</td>
<td>94.8</td>
<td>0.09799</td>
<td>0.58</td>
<td>97.3</td>
<td>58.8</td>
</tr>
<tr>
<td>Total Variance</td>
<td>0.0101</td>
<td>100.0</td>
<td>0.10064</td>
<td>0.60</td>
<td>100.0</td>
<td>60.39</td>
</tr>
</tbody>
</table>

The unit-to-unit variance is the major variation. So the testing units are checked in the working flow. The material and the working instruction on the Housing Assembly station were verified. At last it is found the cushion around the housing has different thickness and caused the housing is not screwed tightly with printed circuits board, which causes the failures in Function test station.

**D. Improve**

Since the root cause is found, the corrective action plan need be generated accordingly. Firstly these failures are fed-back to the design team. The technical requirements for the housing and cushion are checked by the design team to update. Secondly the action of sorting material must be conducted and the material vendor must be informed to change and improve the material. Thirdly the np control chart of failure quantity every half hour for Function test station must be set up to prevent the failures happened again.

The corrective actions need be verified. The total quantity of the failures in production line is collected in new build. The np chart is generated again in Fig.6 and the average failures in line decrease 33% compared to the Fig.3. And the Process Capability is sufficient shown in Fig.7 with Cp>1.33 and Cpk>1. The corrective action plan is effective.

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E. Control

The failures of the Function test station are effectively eliminated and the performance of the Function test station is improved greatly by preventive mechanism. In this way, if the prevention mechanism in good process control is set up in every step of the manufacturing process as shown in Fig.8, then the quality goal will be met very easily to reduce the remedy costs and gain the maximum output.

IV. CONCLUSION

The data are the foundation of the decision making and the statistics is the science of turning data into information. The prevention mechanism in process control is based on the statistical Six Sigma Methodology for production management. It has been verified by the power meter production, which indicates that the prevention mechanism is in the efficient and economical manner to reach the customer satisfaction and the maximum profit.

In the future the study will be expanded to the prevention mechanism on the new process design.

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