Six Sigma Methodologies for the Quality Improvement of Oil Pump Binding in H-Series Engine Assembly

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Abstract— Manufacturing performances tend to produce defects due to various reasons which can be improved by identifying and eliminating them using six sigma. The Six Sigma approach has been increasingly adopted worldwide in the manufacturing sector in order to enhance productivity and quality performance and to make the process robust to quality variations. This paper deals with the application of lean Six Sigma in finding out the root cause for Engine block-Oil Pump binding in the six cylinder engine assembly and hence reducing the internal customer complaints and quality improvement. In the present work, DMAIC (Define, Measure, Analyze, Improve and Control) has been used to reduce the engine quality losses and solve the oil pump binding problem. In define phase, baseline data collection of customer complaints from eleven months has shown that 20.7% of internal customer complaints are due to Block-Oil Pump Binding and problem is defined by selecting the core issues concerned using Project Charter, SIPOC, Pareto Diagram and CTQ. In the measure phase, data related to dimensions of engine block was collected to determine the current performance and the process capability following the validation of measurement system by MSA study. During Analyzing phase root causes of Oil pump binding were identified using Shainin tools like component search to reach the root cause. In the improvement phase solutions were arrived for the root-causes and finally in the control phase various tools were implemented for tracking the process and putting it under control. The study reports process quality improvement through reduction in defects, from 8880 ppm to 2966 ppm.

Key words: Six Sigma, DMAIC, Oil Pump Binding, Quality Improvement, ICC

I. INTRODUCTION

Six Sigma is a breakthrough strategy employed to eliminate defects in a process. Six Sigma is aimed at reducing variations at the breakthrough level through practical application of statistical methods. Six Sigma begins by translating a practical problem into a statistical one. Statistics then help in finding the optimal solution which is then implemented as a practical solution in a real life situation. The types of success which can be achieved are broad because the proven benefits of the Six Sigma approach are diverse including Improvement in Productivity, Defect reduction, customer satisfaction, Product/service development and much more. Six Sigma offers a wealth of tangible benefits when skillfully applied. The DMAIC methodology focuses on improving an existing process or product. These are mostly “real-life” problems, which need to be solved. The improvement should be scoped such that it can be completed in approximately three months and be able to sustain this improvement for long period of time. The methodology consists of five phases: a) Define business opportunities, b) Measure performance, c) Analyze opportunity, d) Improve performance, and e) Control performance. This project was carried out at a large automotive engine manufacturing enterprise. The company had several quality issues and internal customer complaints in the engine assembly line leading to customer dissatisfaction. The objective is to significantly reduce the Oil Pump binding problem which is one of the major contributions to quality losses. The study hence is taken as a six sigma improvement project.

II. LITERATURE SURVEY

The literature survey of previous research such as,” Quality Improvement in engine assembly process using Six Sigma” is discussed in this section. The study reported six sigma implementation on engine assembly line resulting into huge savings and other associated benefits leading to improved and robust process. Such improvements are possible with many processes in various application areas in both manufacturing and service sectors. The structured DMAIC process leads to all round improvement in a systematic manner and the evolution of many statistical software’s has made the analysis and application of various tools look simple and easy. The study reports process quality improvement through reduction in defects, from 7243 ppm to 687 ppm. The literature survey of process capability improvements using the DMAIC approach is discussed in this section. Schilling (1994) emphasized how process control is better than the traditional sampling techniques. During the same era, Locke (1994), in his paper titled ‘Statistical measurement control,’ emphasized the importance of process charts, cause-and effect considerations, and control charting. After primitive studies on statistical quality control, Lin (2004) had shed some light on process capability indices for normal distribution. Sharma et al. (2013a), b in their papers adopted the DMAIC approach to solve the bolt hole center distance and crankpin bore honing operations of the connecting rod manufacturing process. Chen et al. (2013) discussed the application of ANOVA methodology to find significant parameters that affect the part's quality indices with respect to plastic injection molding.

A careful study from the above literature reveals that the DMAIC approach is the best methodology for problem solving tools to improve the quality. Hence, this paper focuses on the application of DMAIC approach for quality improvement of the oil pump binding in the engine assembly line.

III. PROBLEM STATEMENT

Block Oil Pump Binding in the Oil Pump fitment stage of H-series Engine Assembly which leads to Engine loss and shortens Engine life and Performance. In this stage the sub
assembly of oil pump is fitted to the engine block with a gasket. If the binding between these two is not compatible, it leads to the quality loss. Oil Pump Binding contributes 20.7% of overall internal customer complaints in the quality loss of engine assembly. The total ppm of Oil Pump Quality issue was 8880 ppm with reference to data of loss analysis from April 2014 to Feb 2015.

IV. RESEARCH METHODOLOGY

A. DMAIC Process

1) Phase-1: Define
2) Phase-2: Measure and Analysis
3) Phase-3: Improve
4) Phase-4: Control

B. DMAIC Cycle:

1) Once the project is selected, the first step is we needed to define the Problem in phase -1.
2) The next step is to use six sigma techniques to pin point the root causes of the problem. This is done in phase-2.
3) When the root causes are pin pointed, we have to plan and implement Process Improvement action. This is done in improvement phase. Root cause is also validated in phase-3.
4) Once the process improvement actions are implemented, we need to ensure that the actions stay permanent in process.

C. Define Phase:

1) Outline of Define Phase:
   - Project charter (Table1)
   - SIPOC (Figure2)
   - CTQ

The preliminary study of the problem has been carried out. Data on customer complaints and quality losses in the engine assembly has been collected for 11 months. From the data we found out, customer complaints are addressing to the problem of Oil Pump Binding and this problem would fall in vital few region of the Pareto chart

D. Project Charter:

<table>
<thead>
<tr>
<th>Problem Statement</th>
<th>Business Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Oil Pump Binding in Oil Pump fitting stage of Engine Assembly which leads to Engine loss and shortens Engine life and Performance</td>
<td>To minimize operational defect and Improve engine deliverables</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metric:</th>
<th>PPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>From:</td>
<td>8880</td>
</tr>
<tr>
<td>Target:</td>
<td>2985</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Sponsor</th>
<th>GB: Mr. K. N. Mahesh</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR: Mr. S. Santaseelan, Mr. S. Govindhan</td>
<td></td>
</tr>
<tr>
<td>Project Leader</td>
<td>Ms. Pooja Maragi</td>
</tr>
<tr>
<td>Project Start Date</td>
<td>09-02-2015</td>
</tr>
<tr>
<td>Project End Date</td>
<td>09-05-2015</td>
</tr>
</tbody>
</table>

Table 1:

E. SIPOC Diagram

F. CTQ ‘Y’ (Critical To Quality)

Here the parameter ‘Y’ which is critical to quality is Oil Pump binding and its increased PPM level. Engine Quality Defect was measured to work out PPM

PPM for engine quality defect = (defects) X 10,00,000

(Production)

= (228) X 10,00,000

(25674)

= 8880 PPM
G. Measurement:
   – Measurement System Analysis (MSA Study)
   – Process capability

1) MSA Study:
In this project system under MSA study is ‘Depth Gauge’ and ‘Bore Dial Gauge’ which is used to measure and inspect various dimensional parameters of oil pump depth and oil pump casing respectively. MSA study has been carried out initially by selecting 3 appraisers to measure 10 different engine blocks repeatedly for 3 times to check with the Reproducibility and Repeatability of the machine, i.e., Gauge-R&R Study.

Appraisers are asked to measure oil pump depth and casing diameter of 10 different engine blocks, one block repeating at 3 times, thus we came up with 90 measured readings. This data is been processed in Minitab-17 Software and GR&R Study has been carried out. Following are the outcomes of the study and GRR values.

![Gage R&R Study for Measurement](image1)

Fig. 3:
Inference: GRR= 6.0% hence Measurement is Acceptable

2) Process Capability:
Capability analysis study has been carried out for the machining processes on engine block for various dimensional parameters like Oil Pump depth and casing diameter. The process found to be in statistical control.

![Process Capability Report for Op depth](image2)

Fig. 4:
Inference: The dimensional parameters of OP depth and OP casing diameter follows normal distribution.

![Process Capability Report for OP casing diameter](image3)

Fig. 5:
Inference: Process Capability of OP depth need to be improved

Measurement Phase is summed as follows:-
   – Process Mapping
   – C & E Diagram
   – C & E matrix
   – FMEA Analysis
H. Analyze:

1) Component Search:
Component search is a method used when problem is from assembly and assembly can be disassembled and reassembled again without damaging the component. It’s a helpful tool in finding out whether the assembly process is causing the problem or the parts involved. It is a test to verify whether good part always behaves good and bad parts always behaves badly.

Oil pump Binding can happen because of
- Bad Block (Dimensional parameters out of spec.)
- Bad oil pumps (OP parameters out of spec.)
- Wrong Assembly procedure.
- Take Oil pump binding assembled block.
- Dismantle & assemble same pump and block & check for binding.
- Repeat the procedure for five times. If binding occurs all five times, we can conclude, as there were no assembly issues.
- Observed all the time bad assembly getting bind.
- Suspected either block or Oil Pump is bad.
- No issue with assembly procedure.

2) Detecting the Bad Cylinder Block:
- Replace oil pump with other 3 to 4 new oil pumps at binded cylinder block & oil pump assembly.
- All times oil pump does not rotate freely we can conclude block has problem.
- We received 4 cylinder blocks from engine assembly & cross checked for binding with other five good oil pump for binding.

Inference: All 5 times assembly result is binding, hence concluded as cylinder block is bad

3) Detecting Bad Oil Pump:
Assemble binded pump with 3 – 4 cylinder block. If all times oil pump does not rotate freely we can conclude oil pump has problem. We received only one oil pump from engine assembly & cross checked for binding with other five cylinder block for binding.

Inference: All 5 times assembly result is binding, hence concluded as pump is bad

6) Summary of Component Search
We received only one bad pump from engine assembly & found there is step on gear, as there were no sufficient bad samples we have not conducted good & bad comparison for OIL PUMP. We received 4Nos of bad cylinder blocks, conducted good & bad comparison

Table 2
<table>
<thead>
<tr>
<th>S No.</th>
<th>Characteristics</th>
<th>Min</th>
<th>Max</th>
<th>Bad</th>
<th>Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shaft C bore dia</td>
<td>49.160</td>
<td>49.240</td>
<td>49.270</td>
<td>49.272</td>
</tr>
<tr>
<td>2</td>
<td>Bush C bore dia</td>
<td>49.160</td>
<td>49.240</td>
<td>49.280</td>
<td>49.277</td>
</tr>
<tr>
<td>3</td>
<td>Oil Pump bore depth</td>
<td>32.027</td>
<td>32.057</td>
<td>31.991</td>
<td>31.975</td>
</tr>
<tr>
<td>4</td>
<td>Dist shaft C bore - bush C bore_R</td>
<td>41.090</td>
<td>41.170</td>
<td>41.159</td>
<td>41.153</td>
</tr>
<tr>
<td>5</td>
<td>Dist shaft bore - bush bore_R</td>
<td>41.090</td>
<td>41.170</td>
<td>41.171</td>
<td>41.173</td>
</tr>
</tbody>
</table>

b) Summary of Good and Bad Comparison:
- No issues with oil pump sub assembly.
- Cylinder block OP depth found at minus side and will leads to oil pump binding at engine assembly.
- Need to study OP depth process capability.

Detection for OP performance / binding need to study & improve the same so that bad block should not go to engine assembly.

c) Summary of Analysis Phase:
- Good bad comparison results show that cylinder block is contributing for Oil pump binding and oil pump sub assembly is not.
– Good bad comparison results shows that OP depth is very critical parameter for OP binding and found poor process capability.
– Dial indicator mounting plate found worn-out (up to 0.020mm flatness).
– Flatness of dial indicator mounting plate is not included in the calibration.
– Cleanliness of cylinder block probing face and measuring probe are major contributor for poor process capability.

I. Improvement Phase:

The target process was achieved by designing creative solutions to prevent the occurrence of the problems. Some of the implemented solutions for causes are as follows.

\[
\text{PPM for engine quality defect} = \frac{(8) \times 10^{0,00,000}}{2697} = 2966 \text{ PPM}
\]

1) Improvement in MSA
   a) Replaced the Worn Out Dial Mounting Plate:
      Replace worn out dial indicator mounting plate with new one. Dial indicator mounting plate flatness parameter updated in drawing and in calibration plan. Design modification in dial indicator mounting plate.

2) Time Impact:
   Time impact is also important to this project, the benefits obtained are intangible. Considerable time was saved by not producing the defective engines and rework of the same.

J. Control Phase:

During control phase the implemented solutions were monitored with the help of various charts such as Eye charts, daily, weekly and monthly reports, Daily production report, and process and product audit on sample basis. The improvements should be adhered to by providing training to the staff, implementing various incentives schemes and adhering to the modified systems. The Improve and control phase has to be carried out after implementing the solution to the problem. SPC tools are to be applied for the process control study.

V. Conclusion

The study reported six sigma implementation on engine assembly line resulting into huge savings and other associated benefits leading to improved and robust process. Such improvements are possible with many processes in various application areas in both manufacturing and service
sectors. The structured DMAIC process leads to all round improvement in a systematic manner and the evolution of many statistical soft ware’s has made the analysis and application of various tools look simple and easy.

The issue of dimensional variation is addressed by increasing the process capability of engine block and improvement in MSA. With this the higher level of productivity can be achieved and customer rejection level of 20.7% can be reduced to a significant level and cost of operation in turn increasing customer satisfaction.

REFERENCE