Reducing Internal Customer Complaints [ICC] Due to Camshaft Binding in H-Engine Assembly using Lean Six Sigma Approach

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Abstract— currently all the manufacturing industries are facing major challenges in continuous improvement in productivity and quality of the product. In this highly competitive environment customer satisfaction plays a vital role. Reducing internal customer complaints is one of the critical tasks at engine assembly. This requires the use of continuous improvement methodologies, such as lean six sigma which enable companies to improve customer satisfaction and meet their expectation. This paper is a six sigma project, undertaken within the company for reducing the internal customer complaints of camshaft binding problem, which deals with identification and reducing the internal customer complaints of camshaft binding in engine assembly line. The data collection of 11 months has shown that 26% of ICC (internal customer complaints) is due to camshaft binding. The applied six sigma approach includes works through several phases: define measure, analyze, improve, and control (DMAIC). The problem was defined by selecting the core issues concerned. The possibility of application of several six sigma tools such as Pareto diagrams, project charter, sipoc, critical to quality (CTQ), in define phase. In measurement phase data related to engine block – camshaft binding was collected following the validation of measurement system by MSA study and process capability is determined. During analysis phase root cause of engine losses were identified. In improvement phase the damage of camshaft due to metal contact during handling and storage were solved. And finally in control phase various tools were implemented for tracking the process and putting it under control. The study reports quality improvement through reduction in defects, from 11374 PPM to 4450 PPM.

Key words: Six Sigma, DMAIC, Camshaft, Engine Assembly, ICC, Engine Losses

I. INTRODUCTION

Six Sigma is new, emerging, approach to quality assurance and quality management with emphasis on continuous quality improvements. The main goal of this approach is reaching level of quality. Six Sigma is an organised and systematic methodology used to improve processes or products' performance with impact on customers, and is based on scientific and statistical methods. The selected company for the project is a multinational from the automotive sector that uses six sigma projects to improve quality. This project is a Six Sigma project, since the internal customer complaints of camshaft binding problem is repetitive. This type of projects uses formal mechanisms to assess and control project execution.

Six Sigma is a breakthrough strategy employed to eliminate defects in a process. 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 situation. The benefits of the Six Sigma approach are diverse including Reduction in quality losses, Improvement in Productivity, and Increase in internal Customer satisfaction. Six Sigma offers a wealth of tangible benefits when skilfully applied.
Camshaft binding problem is occurring between camshaft and engine block. the objective was to significantly reduce these defects. The study hence was taken as a six sigma improvement project.

II. LITERATURE REVIEW

Six Sigma in order to improve the quality of their process and products for embellishing competitive advantage methodology is executed on one of product assembly for trimming down defects level which are critical to customers and its implementation has had a significant financial hit on the bottom-line of the enterprise. Dr. Rajeshkumar U. Sambhe [1]. Defects due to various reasons which can be improved by identifying and eliminating them are using six sigma. In the present work, DMAIC (Define, Measure, Analyze, Improve and Control) has been used to reduce the number of vehicle engine rejection. The study reports process quality improvement through reduction in defects, from 7243 ppm to 687 ppm. Sigma-Dr. R.L. Shrivastava, Khwaja Izhar Ahmad and Tushar N. Desai [2].

III. PROBLEM STATEMENT

In the camshaft fitment stage of H-engine assembly, Cam shaft binding problem takes place between camshaft and engine block which leads to quality loss. This creates 26% of quality defects in engine assembly (figure 1). Total PPM for engine quality was 11374 with reference to the data of loss analysis from Apr 14 to Feb 2015.

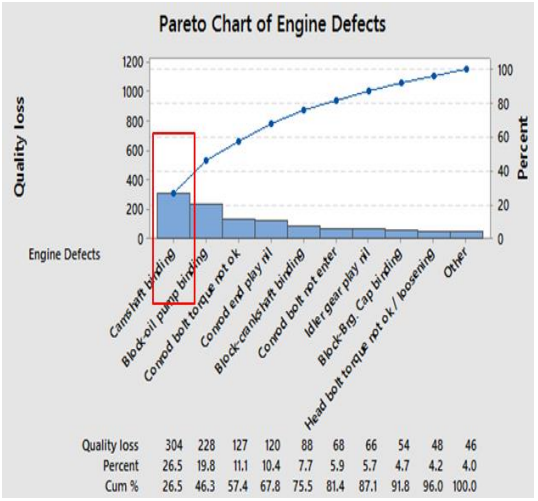

Fig. 1: Pareto Chart

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IV. DMAIC-PROCESS

A typical Six Sigma project for quality improvement follows a structured methodology for the resolution of problems. The DMAIC methodology consists of, succinctly, in defining (D) and measure (M) the problem, analyse (A) data to discover the root causes, improve (I) the process to remove the root causes and control (C) or monitor the process to prevent the reappearance of defects.

In each phase a set of quality tools and techniques are used with the purpose of making the whole process objective and measurable, allowing analysing the current system performance, to propose and implement improvements and to keep the system under control.

A. Define:

Outline for define phase:-

- Project charter (Table 1)
- SIPOC (Figure 2)

Due to frequent complaints from internal customer define phase articulated problem description, objectives and metrics as well as solutions. The main goal was to identify and decrease camshaft binding problem. There were several major causes for camshaft binding in engine assembly to many metal contact storage and in process.

The main objectives of undertaken projects were to identify areas in the process where the problem is coming out. In the 2nd stage of H-engine assembly line the camshaft fitment takes place.

Project charter				
Organization	Ashok Leyland Limited, Unit-1, Hosur			
Project Title	Reduction of Engine Loss due to Cam Shaft Binding in H-Series Engine Assembly.			
Problem Statement		**Business Case**		
Cam shaft Binding in H-Series Engine between Cam shaft and Engine Block which affects the Engine Life.		To minimize operational defect and Improve in engine deliverables		
Goal Statement		**Scope**		
Metric :	**PPM**	Engine Assembly area, Machining area and Store (Handling)		
From :	11374			
Target :	4450			
Support Required	**1.** H-series Engine Camshaft M/C Shop **2.** Quality **3.** Engine Assembly Line			
Team Members		**Project timeline**		
Sponsor	Mr. K.N Mahesh,	**Key Milestone**	**Start**	**End**
BB	Mr. Praveen,	**Define**	Feb 12	Feb 23
GB	Mr.Govindhan	**Measure**	Feb 24	March 14
Project leaders	Mr. Niranjana. B	**Analysis**	March 14	March 18
Project Start Date	09-02-2015	**Improvement**	March 18	April 22
Project End Date	09-05-2015	**Control**	April 23	May 02

Table 1: Project Charter

1) SIPOC:

Sipoc is focus on capturing the set of inputs and outputs along with the needs of customer.

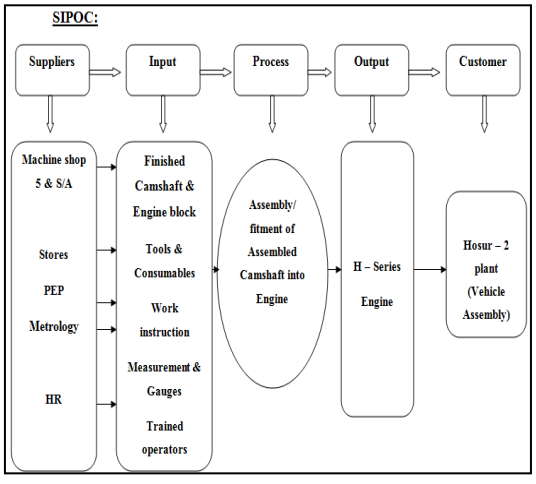

Fig. 2: SIPOC

2) CTQ 'Y' (Critical To Quality):

Here the parameter 'Y' which is critical to quality is camshaft binding and its increased PPM level.

B. Measurement:

Measurement phase outline

- Engine quality defects in metrics
- Measurement system analysis (MSA study) (Figure 3)(Table 2)
- Process capability

The engine defect data was collected. Measurement system analysis was also carried out which was found satisfactory. The current process results into engine defects at 11374

$$PPM = \frac{(Defect) * 10,00,000}{(Production)}$$

$$PPM = \frac{292 * 10,00,000}{25674} = 11374$$

1) MSA – Study:

In this project system under MSA study is 'snap dial Gauge' which is used to measure and inspect various dimensional parameters of journal diameters...

MSA study has been carried out initially by selecting 3 appraisers to measure 10 different journals repeatedly for 3 times to check with the Reproducibility and Repeatability of the machine,. i.e., Gauge - R&RStudy.

Appraisers are asked to cam journals diameters of 10 different cam shafts, one camshaft 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.

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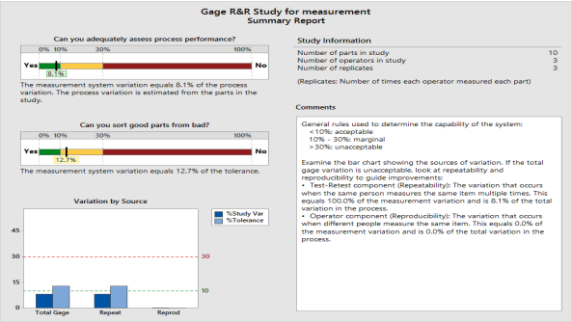

Fig. 3: GRR Value

	Journals	<10% acceptable (10%-30%) marginal	Cam bore	<10% acceptable (10%-30%) marginal
MSA	J 1	GRR=8.1%	Dia 1	GRR=10.2%
	J 2	GRR=7.4%	Dia 2 & 4	GRR=10.5%
	J 3	GRR=8.6%	Dia 3	GRR=9.2%
	J 4	GRR=8.8%		

Table 2: GRR Value

2) Process Capability:

Process capability study has been carried out for machine operation that is cam journals grinding operations and cam bore machining. The process is found statistical control. Process is stable.

Process capability study cam journals dia-
Gauge – snap dial gauge
Sample size – 30
Sampling method – Random sampling
Using software Minitab 17
Minitab file extract –

All the cam journals and cam bore machining process are validated. (Figure 4, 5, Table 3)

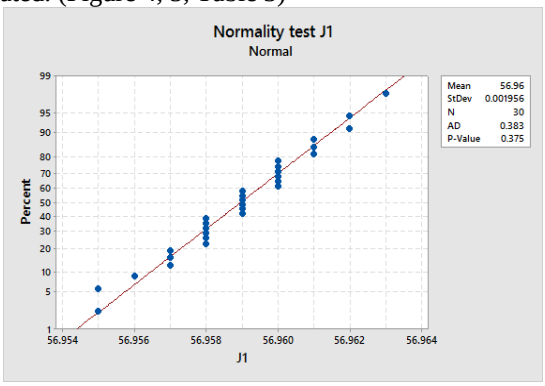

Fig. 4: Probability Plot

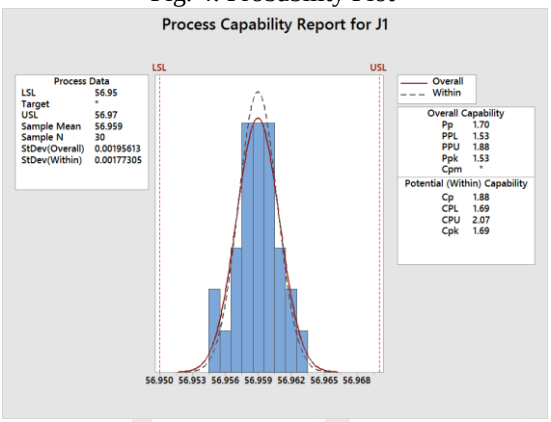

Fig. 5: Process Capability

Journals	J1	Normality test (p>0.05)	0.375	Follows normal distribution
		Cpk (min 1.33)	1.69	Capable
	J2	Normality test (p>0.05)	0.254	Follows normal distribution
		Cpk (min 1.33)	1.88	Capable
	J3	Normality test (p>0.05)	0.221	Follows normal distribution
		Cpk (min 1.33)	1.80	Capable
	J4	Normality test (p>0.05)	0.371	Follows normal distribution
		Cpk (min 1.33)	1.86	Capable
Cam bore	Dia 1	Normality test (p>0.05)	0.351	Follows normal distribution
		Cpk (min 1.33)	1.32	Capable
	Dia 2	Normality test (p>0.05)	0.274	Follows normal distribution
		Cpk (min 1.33)	1.90	Capable
	Dia 3	Normality test (p>0.05)	0.334	Follows normal distribution
		Cpk (min 1.33)	1.78	Capable
	Dia 4	Normality test (p>0.05)	0.523	Follows normal distribution
		Cpk (min 1.33)	1.47	Capable

Table 3: Normality and Cpk

C. Analysis:

The Pareto chart prioritizes defects and finds out probable cause. Specific data collected was analyzed to prioritize root cause.

Hypothesis test for comparing cam journal grinding operation between 2 machines in m/c shop

The measurement of 10 cam shaft journals diameter is taken from machine 1 and machine 2 and 2-sample t-test is carried out in Minitab 17 and files are extracted below (Figure 6)

Gauge used – snap dial gauge
Sample – random sampling
Sample size – 10

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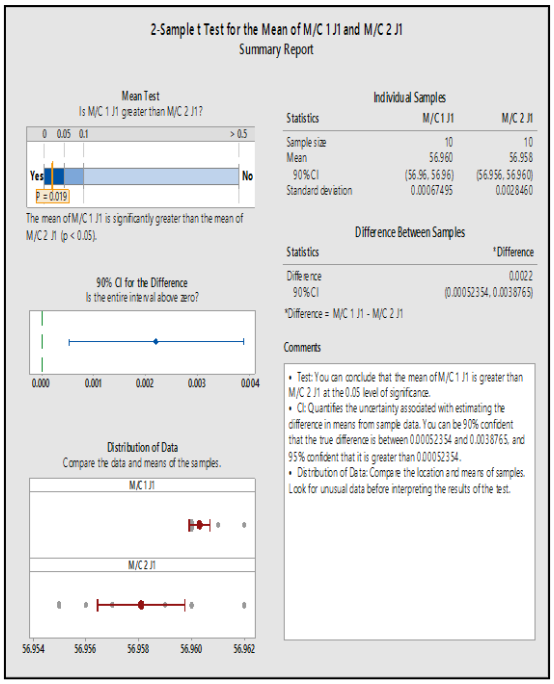

Fig. 6: Two Sample T Test

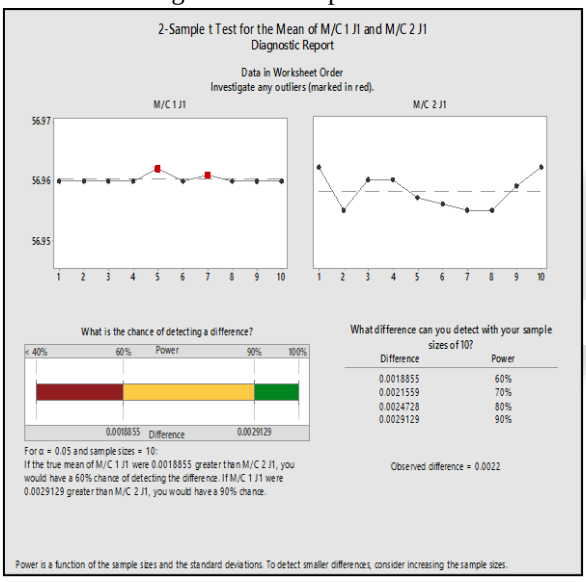

Fig. 7: Two Sample T Test

Machines	Journals mean	P – values (p < 0.05)
M/c 1& M/c 2	M/c 1 J1 mean > M/c 2 J1	P=0.019
	M/c 1 J2 mean > M/c 2 J2	P=0.026
	M/c 1 J3 mean > M/c 2 J3	P=0.034
	M/c 1 J4 mean > M/c 2 J4	P=0.040
So Machine 1 is more efficient than Machine 2 hence machine 1 can be used more for the grinding operations		

Table 4: Hypothesis Test

1) Root Cause Identified:

After analysing all the stages of camshaft and engine block right from the supply to engine assembly it is found that the root cause is from the operator and damage to the camshaft because of metal to metal contact during handling and storage.

Analysis is summed up by using C & E diagram (Figure 8) that man power causes and material causes is responsible for cam shaft binding

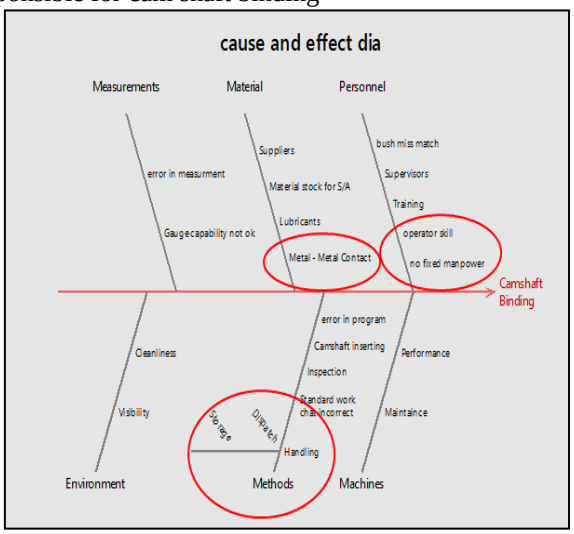

Fig. 8: Cause and Effect Diagram

D. Improvement:

The target process was achieved by designing new solutions to prevent the problem that is occurring. Some of the improvements were taken to avoid cam shaft binding problem.

No Damages in Cam journals at assembly stage – To avoid camshaft binding

1) Handling of Finish camshaft with modifying transfer hook in machine shop. (Picture: 1)

1) Sample hooks will be made on trial basis.
2) Based on trials further 100% modification will be carried out

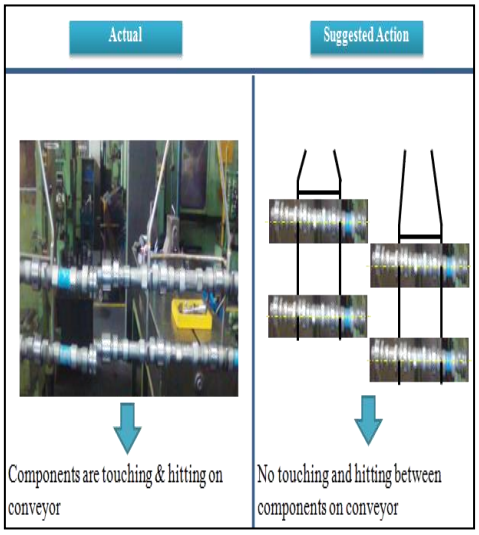

Fig. 9

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2) Handling Of Finished Camshaft With Modified Trays To Washing. (Picture 2):

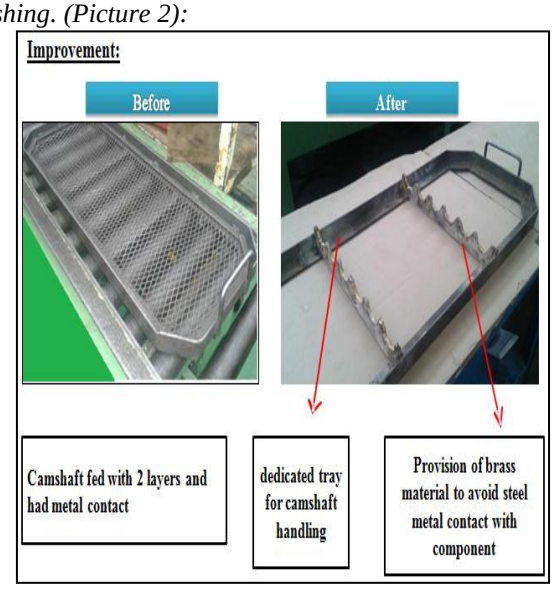

Fig. 10

3) Handling Of Finished Camshaft In Modified Storing Racks (Picture 3):

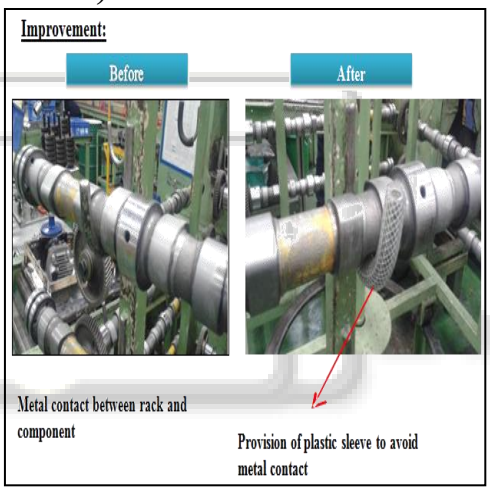

Fig. 11

4) By Improving Insertion Method Of Camshaft In Assembly, By Tilting The Crank Case By 45° (Picture 4)

1) Concept will be studied and further action will be decided

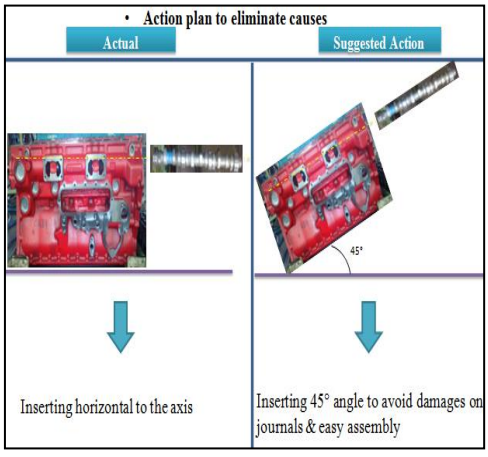

Fig. 12

5) Suggestions for the improvement related to man power (Table 5):

Identified weak factors and suggested improve methods

Seria lNo.	Weak Factors	Improvement Method
1.	No Fixed men	Fixed men system
2.	No regular employer – employee meeting not conducted	Regular meeting will convey the company objective clearly
3.	Employee skills at assembly	Regular training can be given
4.	set of instruction for fitment of camshaft are not displayed	Display the set of instruction during fitment of camshaft

Table 5

After implementation the camshaft binding problem in Mar data is collected to calculate the present PPM (Table 6)

PPM = (Defect) * 10, 00,000
(Production)

PPM = (12) * 10, 00,000 = 4450
25674

Description	2014-15 (Apr-Feb)	Mar	Apr	May	June
Total Quality passed	25674	2697			
Total camshaft binding	292	12			
In PPM	11374	4450			

Table 6

E. Control:

During control phase the implemented solutions were monitored with the help of various charts such as Visual 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.

V. CONCLUSION

The study reports six sigma implementation on engine assembly line resulting into quality losses reduced and other associated benefits leading to improved process. Such improvements are possible with many processes in various application areas in manufacturing sectors. The material causes such as metal to metal contact is solved. Hence quality of engine assembly line is improved. The structured DMAIC process leads to all round improvement in a systematic manner and the evolution of many statistical

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software's has made the analysis and application of various tools look simple and easy. It may hence, be concluded that Six Sigma methodology has potential to address many Quality and productivity Improvement problems.

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