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Engine Assembly & Testing Process Quality Improvement Using DMAIC Approach (Six-Sigma) - Case Study

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***Abstract*—the Six Sigma's problem solving methodology DMAIC has been one of several techniques used to improve quality. This paper demonstrates the empirical application of Six Sigma and DMAIC to reduce product defects within an Engine manufacturing organization. The paper follows the DMAIC methodology to investigate defects, root causes and provide a solution to reduce/eliminate these defects.**

In the present work, DMAIC (Define, Measure, Analyze, Improve and Control) has been used to reduce the number of an engine rejection. In define phase, problem was defined by selecting the core issues concerned. In the measure phase, data was collected to determine the current performance & also MSA study has been carried out i.e. R & R study. During Analyzing phase, Pareto chart was used for selecting top five engine defects & root causes of engine rejection were identified. In the improvement phase solutions were arrived at 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 17162 PPM to 714 PPM. Cost of poor quality (COPQ) has been significantly reduced from 45 % per annum (18% to 10% of sale).

***Index Terms*—Six-Sigma, DMAIC, Engine Assembly & Testing, Process Quality, COPQ.**

I. INTRODUCTION

Six-Sigma is a business improvement approach that seeks to find and eliminate causes of mistakes or defects in business processes by focusing on process outputs that are of critical importance to customers. The philosophy of Six Sigma recognizes that there is a direct correlation between the number of product defects, wasted operating costs, and the level of customer satisfaction.

Six-Sigma is a business strategy that enables organizations to increase their profits by optimizing their operations, improving quality and eliminating defects. Six-Sigma theme pivots on drastic reduction of variability in the processes. The companies that adopt Six Sigma approach will have to reduce the process variation to such a level that the number of defective parts per a million of produced parts would be less than 3.4. Embarking on a Six Sigma program means delivering top-quality products and service while virtually eliminating all internal deficiencies.The DMAIC is both a philosophy and a methodology that improves quality by analyzing data to find root cause of quality problems and to implement controls.

DMAIC is a methodology (Shown in figure- 1) to

1. Identify improvement opportunities.
2. Define and solve problems
3. Establish measures to sustain the improvement.

The DMAIC technique is an overall strategy to accelerate improvements in its processes, products and services. This approach is a project driven management approach to improve the Organization products, services and processes by continually reducing defects in the Organization.

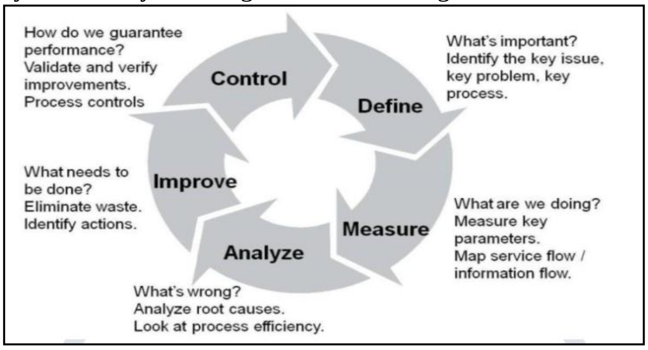

Figure 1. DMAIC Approach of Six-Sigma

II. LITERATURE REVIEW ON DMAIC APPROACH (SIX-SIGMA)- INDUSTRY CASE STUDY

Neha Gupta and Dr. P.K.Bharti [1] presented a quality improvement study applied at a yarn manufacturing company based on six sigma methodologies. More specifically, the DMAIC (Define, Measure, Analyze, Improve, and Control) project management-methodology & various tools are utilized to streamline processes & enhance productivity. Defects rate of textile product in the yarn manufacturing process is so important in industry point of view.

Lona, Reyes and Meier [2] implemented the Six Sigma's problem solving methodology DMAIC has been one of several techniques used to improve quality. Particular, the design of experiments (DOE) and two-way analysis of variance (ANOVA) techniques were combined to statistically determine the correlation of the oven's temperature and conveyor's speed with defects as well as to define their optimum values needed to reduce/eliminate the defects. As a result, a reduction of about 50% in the "leaking" gloves defect was achieved, which helped the organization studied to reduce its defects per million opportunities (DPM) from 195,095 to 83,750 and thus improve its Sigma level from 2.4 to 2.9.

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S. Suresh, A. L. Moe and A. B. Abu [3] presented Six Sigma is one of the best emerging approaches for quality assurance and management in automobile parts manufacturing. In this research, Quality Management tools such as COPQ analysis, Data Analysis, Pareto charts, Cause and Effect diagrams, Process Capability Study, Failure Mode Effects Analysis (FMEA), Design of Experiments (DOE), Visual and Control Charts etc. are used in defining the problems in order to find the root causes for the problem and carrying out experiments in order to suggest improvements, through which the company could bring in Quality and Stability in their process. Using the six sigma method, the rejection percentage is reduced by 13.2% from the existing 38.1% of rejection.

Dr. Rajendra Takale and Swapnil Dere [4] presented DMAIC deals with strategies of continuous improvement & defect reduction to achieve a quality standard of not more than 3.4 defects per million (DPM).Manufacturing of five different types of fuses namely HN-000, HN-0, HN-1, HN-2, and HN-3. Company had found that rejection of fuses of all types was more than 7 %. Implementation of Six Sigma methodologies at one of the suppliers of company to improve the process of manufacturing HN Fuse link. the additional benefits achieved by post implementation of Six sigma methodology like minimizing lead time, defects, rejections to name a few. Overall improvement in quality and raised the sigma level from 4.34 to 4.56.

Siddhant Aphale, Kiran Kakade [5] studied reduction in Rework of an Engine Step Bore Depth Variation using DMAIC and Six Sigma approach. As the quantum of rework was too high and machine could not be stopped for complete experimentation the FTA analysis was selected and it proved to be efficient. After successful implementation it was observed that the engine bore rework was reduced from 18 % per month to 2.2 % per month.

E. V. Gijo, Johny Scaria and Jiju Antony [6] presented application of Six Sigma methodology to Reduce Defects of a Grinding Process. The DMAIC (Define–Measure–Analyze–Improve–Control) approach has been followed here to solve the underlying problem of reducing process variation and improving the process yield. The application of the Six Sigma methodology resulted in reduction of defects in the fine grinding process from 16.6 to 1.19%.

Dr. R.L. Shrivastava, Khwaja Izhar Ahmad and Tushar N. Desai [7] studied engine Assembly Process Quality Improvement using Six Sigma. Manufacturing performances tend to produce defects due to various reasons which can be improved by identifying and eliminating them using six-sigma. The study reports process quality improvement through reduction in defects, from 7243 PPM to 687 PPM. Cost of poor quality (COPQ) has been significantly reduced from $ 30, 000to $ 9, 000 per annum, a reduction of 333%.

S.M.Balaji Paramesh [8] has implemented six sigma methodologies at cable harness manufacturing industry. The cable harness manufacturing industry has been growing in a fast pace during the recent years in India. Cable harnesses are used to link together all the electrical components scattered throughout any electrical equipment. It includes collection of defects data, analysis of the defects data using FMEA methodology, determining the causes and taking corrective actions to eliminate the defects. Process flow chart and manufacturing lead time are determined and lean tools such as one-piece flow and job instruction are implemented. There were total 29 problems found out of cable harness rejection using FMEA and again their RPN values are improve.

M Naga Phani Sastry, M. Devaki Devi and E. Siva Reddy [9] implemented Six- sigma methodology on process improvement and variation reduction with the application of DMAIC. It shows the application of Six Sigma in Amara Raja Batteries manufacturing to reduce the production defects like paste rejection. It is a practical work done at Amara Raja Batteries, Tirupati where initially the percentage of paste rejection was nearly 3.09%, which drastically 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.

Virender verma, Amit Sharma, Deepak juneja [10] studied Utilization of six sigma (DMAIC) approach for Reducing Casting Defects. DMAIC approach is a business strategy used to improve business profitability and efficiency of all operation to meet customer needs and expectations. The emphasis was laid down towards reduction in the defect (Blow holes, Misrun, Slag inclusion, Rough surface) occurred in the sand castings by controlling the parameters with DMAIC technique. The results achieved shows that the rejection due to sand casting defects has been reduced from 6.98% to 3.10 % which saved the cost of Rs.2.35 lac appx.

III. PROBLEM STATEMENT

In all processes the smallest variation in quality of raw material, production conditions, operator behavior and other factors can result in a cumulative variation (defects) in the quality of the finished product. DMAIC approach aims to eliminate these variations and to establish practices resulting in a consistently high quality product. Present study was done at Greaves cotton, Aurangabad on application of DMAIC methodology. High rejection rate of automobile engine after testing was found due to engine quality defects.

The thesis describes different problems in quality perspective in assembly & testing process and identifies the reason for these problems are carelessness of employees during manufacturing, tool & Equipment adequacy & also an engine parts quality. Training of employees and preventive action against any failures in the department is necessary for any organization. DMAIC tool is used to identify, measure, analysis the problems, in assembly, testing department where the chances of defects of engine is more.

IV. OBJECTIVE OF STUDY

The present work deals with elimination of engine defects in an assembly & testing department. DMAIC approach is justified when root cause of defect is not traceable. In the present work, an attempt has made to reduce engine defects in an assembly and testing process with the application DMAIC approach.

The objectives for DMAIC approach implementation at Greaves cotton, Aurangabad are as follows:--

1. To identify the root factors causing engine defects.

2. To improve the quality by reducing the engine defects.
3. To reduce PPM level of the process. (Sigma level).
4. To achieve Cost saving by reducing rejections i.e. reduce rework of engine. (COPQ)

V. METHODOLOGY

DMAIC is a closed-loop process that eliminates unproductive steps, often focuses on new measurements, and applied technology for continuous improvement. Implementation of DMAIC Methodology took place in five phases as outlined earlier and established at Motorola. Problem identification and definition takes place in define phase. After identifying main processes, their performance is calculated in measure phase with the help of data collection. Root causes of the problem are found out in analysis phase. Solutions to solve problem and implementing them are in improve phase. Improvement is maintained in control phase.

ROADMAP TO DMAIC APPROACH (SIX-SIGMA)

1. DEFINE- Set project goals and objectives
2. MEASURE - Measure the defects where they occur.
3. ANALYZE - Evaluate data/information for trends, pattern and root causes,
4. IMPROVE - Develop, implement and evaluate solution targeted at identified root causes
5. CONTROL - Make sure that almost the problems have cleared, and method is improving.

1. DEFINE PHASE:

These phases determine the objective and scope of the study & also identify the project opportunity and to verify or validate that it represents legitimate breakthrough potential. Information about the present processes is collected, determination of customers and deliverables to customers are also determined.

The rejection of the engine was a serious concern as evidenced by the customer complaints and an urgent need was felt to fix this problem. Time frame for the team was three months for accomplishing the set objectives.

A. Opportunity Statement

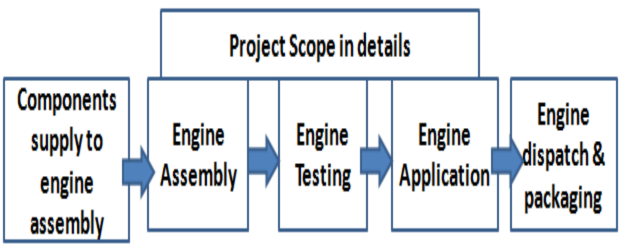
During Engine dispatch at Engine testing process Quality Defects were reported. Total PPM For Engine Quality was 16217 PPM.

B. Goal Statement

Problems after engine testing process due to Engine Quality issue to be reduced from 17162 PPM to 714 PPM.

C. Project Scope

A brief idea about the project scope is shown below. The outline was drawn to understand the boundaries of the project.



D. Project Plan

Project plan, as under, was established after taking into consideration various constraints.

Milestones	Planned start date	Planned end date	Actual start date	Actual end date
Define	1.12.15	17.12.14	1.12.15	17.12.14
Measure	18.12.14	10.01.15	18.12.14	10.01.15
analysis	11.01.15	30.1.15	11.01.15	30.1.15
improve	31.1.15	14.02.15	31.1.15	14.02.15
control	15.02.15	28.02.215	15.02.15	28.02.215

The SIPOC diagram is a high-level map of a process. SIPOC diagrams give a simple overview of a process and are useful for understanding and visualizing basic process elements.

The various INPUT required for the engine manufacturing process and the SUPPLIERS for the same are as per Table-1

The Customer (CUSTOMER) was engine PDI and Dispatch process their Requirement (OUT PUT) was defect free engine assembly & testing process, which can be achieved only after they get a defect free engine. They were expecting a stable Process (PROCESS) for the same.

Table-1 SIPOC Diagram

SUPPLIER	INPUT	PROCESS	OUTPUT	CUSTOMER
STORES	CHILD PARTS	ENGINE ASSEMBLY / TESTING	DEFECT FREE ENGINE ASSEMBLY & TESTING	PDI & DISPATCH
GID	PRODUCT INSPECTION			
MACHINE SHOP	FINISH PARTS			
HR	MANPOWER			
ME DEPT.	PROCESS TOOL			
MAINTAINCE	UTILITY			
PPC	PRODUCTION PLAN			
MATERIALS	BOP			
EXTERNAL SUPPLIER	EXT. PARTS			

Process maps provide a detailed picture of the process or system of interest. Process mapping is the preferred technique in a DMAIC methodology because it can be used to draw a process at various levels of details.

Engines are assembled using manually with conveyor. There are four types of engines assembling i.e. automotive, marine, base engine & pump sets. Automotive engine are diesel or petrol engine having more demand in market compare with another three types of engine. Mixed– model line is producing more than one model. They are made simultaneously on the same line. Every station is equipped to perform various tasks needed to produce any model that moves through it. There are 35 stages for engine assembly in that 21 assembly stages run on conveyor i.e. online engine assembly & 14 stages are manually operated i.e. engine go to next stage using operator's hands. There are nearly 260 engine are assembled in general shift if one operate is given to one assembly stage.

Testing is quality control activity. Purpose of testing is generally concerned with the functional specification of final product rather than with the individual part go into the product.

Parameters checking during Engine testing are

1. Smoke checking
2. Pressure test
3. Lub oil pump
4. Power setting
5. Specific fuel consumption
6. Fuel setting

The Define Phase can be summed up as follows:-

1. Finalized Project Team charter
2. Completed Process mapping
3. SIPOC Diagram

2. MEASURE PHASE:

The "measure" phase of the DMAIC problem solving methodology consists of establishing reliable metrics to help monitoring progress towards the goals, which in this project consisted of reducing the number of quality defects in the engine assembly/testing process.

Process indicator means that product is check for quality i.e. in term of defects or rejections. For this project output indicator is in term of PPM (part per million). This phase started with identification of indicators as given in Table-2

Table-2 List of Indicators

INPUT INDICATOR	PROCESS INDICATOR	OUTPUT INDICATOR
SOP adequacy	Buy of check at assembly	
Skill level of assembler	Buy of check at testing	Total engine defects are in term of PPM
Issues related to consumables		
Tools ,gage and equipment adequacy		
Schedule change		
Cleaning of components		

A very effective method of capturing the Voice of the Customer and relating it to process input variables is the cause-and-effect matrix. This type of matrix helps you filter out less important steps and inputs so you can focus on the parts of your process containing the relatively few critical input variables that truly have an effect on your key process output variable. Table-3 cause & effect matrix

Table-3 Cause & effect matrix for indicators

	10	Output importance
	PPM for engine manufacturing process	
Process input	Correlation of I/P to O/P	TOTAL
SOP adequacy	1	10
Skill level of assembler	3	30
Issues related to consumables	1	10
Tools ,gage and equipment adequacy	9	90
Schedule change	3	30
Cleaning of components	1	10

Rejection Data Was Collected On Sample Basis. Total sample was checked daily approximately 290. Table also gives detail about type of quality defects occur in diesel engine which affect on loss of production at engine testing. Defect rate are out of control basis on rejection of engine due to this customers are not satisfied. Table-4 Engine quality defect with defective quantity show total no of defective engine was rejected due to these top five defect having more contribution for reduce quality of assembly/ testing process.

Table-4 Engine quality defect with defective quantity

Sr.No.	Engine Quality defects	Total defective quantity
1	Oil Leak From Rocker Shaft	40
2	Starting Trouble	38
3	Flywheel Bolt Loose	20
4	High Smoke	19
5	Fuel Filter & Pipe Position Wrong	10
	Total engine quality defect quantity	127
	Total production	7400

The manufacturing environment, by its very nature, relies on two types of measurements to verify quality and to quantify performance: (1) measurement of its products, and (2) measurement of its processes.

Generally in the Gauge R&R studies, repeatability and reproducibility observations illustrate how much of the production process variations belong to the measurement system dispersion. Various methods could calculate an instrument's R&R index and persisting some of them are evaluated. Table-5 shows that R & R method is used for measurement system analysis. In this project, average & range method is use for measurement system analysis.

MSA study has been carried out initially by selecting 3 appraisers to measure 10 different engines 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 height (shim selection) of 10 different engines, one engine repeating at 3 times, thus we came up with 90 measured readings. This data is been processed in PRO-MSA Software and GR&R Study has been carried out. Following are the outcomes of the study and GRR values.

Table 5 Detail about MSA on gauge

SR.NO.	METHODS	INSTRUMENT
1	R & R study	Shim selection gauge
2	R & R study	Bumping clearance gauge

Engine Quality Defect in terms of leakage, aesthetics, missing operation …etc was measured to work out PPM as under-

1) PPM & Sigma level calculation:

PPM for Engine Quality Defect

= (Defect X 10, 00,000)/ (Production)

= (127 X 1000000)/ (7400)

= 17162-------------------- (DUPM)

Corresponding Sigma level = 3.7

2) Cost of Poor Quality (COPQ):

A simple definition of the cost of poor quality (COPQ) is all the costs that would disappear if your manufacturing process was perfect. This includes all appraisal, prevention, and failure costs. Anyone running a company knows these costs exist, but what they may not realize is how much of their expenses are tied directly to COPQ. In this engine manufacturing, sigma level value is 3.7. Cost of poor quality is approximately 18%.

Measure Phase can be Summed up as follows:-

Input, Process & Output Indicators
Cause & Effect Matrix for Indicators Prioritization
Data collection plan
MSA (R & R Study)
Current base line performance.

3. ANAYSIS PHASE:

The purpose of the analyze phase is to allow the project team to target improvement opportunities by taking a closer look at the data to determine the root causes of the process problems and inefficiencies.

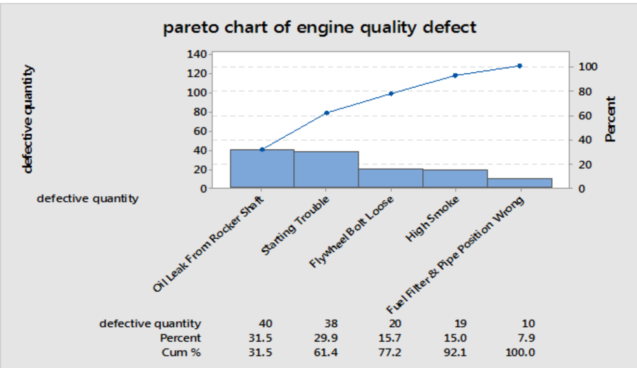


Figure-2 Pareto chart of Engine Quality Defects

The Pareto chart was prepared to prioritize defects and to find out probable causes. Specific data collected was analyzed to prioritize root causes. And the same was validated by using statistical techniques. After analyzing the data it was found out that 80% of the defects were due to four / five reasons (Refer Figure-2) such as oil leak from rocker shaft, starting trouble and flywheel bolt loose/bolt missing, high smoke etc. all this defect are analysis using why-why analysis, fishbone diagram & test of hypothesis.

Why-Why analysis was carried out to found out the problem of oil leak from rocker shaft.

PROBLEM	WHY	WHY
Oil leak from rocker shaft	While pressing rocker fulcrum by brass hammer & small crack generated on head due to hammering	Burr is getting generated & got trap between washer & banjo sealing face

Root Cause Identified:

Brass hammer used for pressing of rocker shaft in hole of cylinder head. Purpose of rocker shaft is use for to support rocker arms (inlet & exhaust). Due to this hammering, crack & burr is generated on cylinder head. Burr is got between washer & banjo sealing face that why oil leak problem is occur. Improper pressing method is main cause of this problem & other two causes are entry chamfer not proper on cylinder barrel & problem is not detected in testing method. (Figure-3)

Similarly why-why analysis was carried out for Starting trouble, Flywheel bolt loose, high smoke, fuel filter & pipe position wrong. After the analysis root causes were found out and the solutions were implemented. Analysis was carried out on starting trouble & its causes were found that FIP rack not located in FDC lever rack.

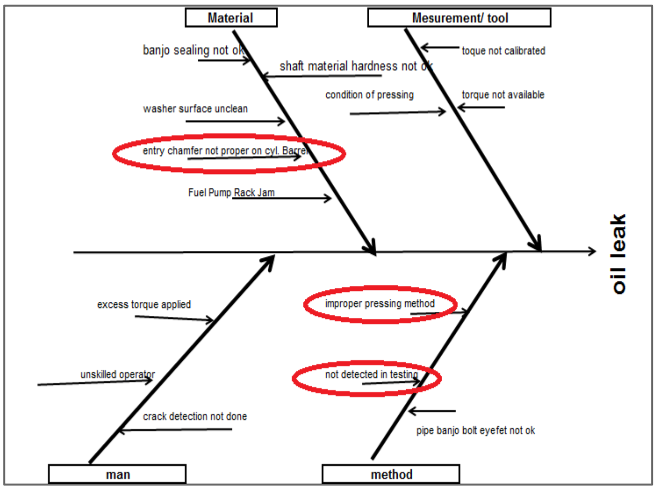


Figure-3 Cause & effect diagram for oil leak from rocker fulcrum

Second cause is FIP fitment on line after timing adjustment is difficult due to PTO cover fitted on engine. Operator can't see FIP rack engagement in FDC lever.

Analysis was carried out on flywheel bolt loose. Torque gun problem & Mix-up of bolts in Engine assembly for fitment of adapter plate on flywheel was found out to be the cause and it was taking place due to the reason that there was no identification mark on bolts. Since two types of bolts were used in Engine Assembly. (Full threaded & half threaded) they were not segregated in different bins hence the problem. By carrying out cause and effect analysis various reasons for the problem were found out such as bolt not engaged properly, bolt thread under size, improper tightening of the bolts, operator fail to tight, gun torque not taken and wrong bolts on the line.

Analysis was carried out on High Smoke. RC lever crack in Engine assembly for fitment of RC lever was found out to be the cause and it was taking place due to the reason that there was more torque given to fitment of RC lever. By carrying out cause and effect analysis various reasons for the problem were found out such as bumping more, NTP less, testing setting not ok, and injector hole block etc.

Analysis was carried out on fuel filter & pipe position wrong. Fuel filter inlet & out pipe are fitted with wrong position is problem in engine assembly. It was taking place due to reasons that 1) mistake of skill of operator 2) mix up of model of engine assembly.

4. IMPROVEMENT PHASE:

Improvement in term of quality which consist of two approaches i.e. inspection side & cause side. Inspection side means improvement was done in term of inspection & solve problem that place by using inspection through skill of operator. Inspection side is one recent solution to stop problem. To add inspection stage in engine Assembly & testing for detect problem.

After that if problem has occur more time then permanent type solution is installed for solving problem. Cause side method means solution in term of pokayoke or kaizen.

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.

A) Oil Leak from Rocker Shaft

Inspection side: To use developer spray to detect the oil wetness on shaft & cylinder head (Barrel) after to pressing shaft using brass hammer. (Figure-4)

Cause side: Hydraulic press install for fitment of rocker shaft into cylinder barrel. Cylinder head OD 15 mm chamfer added for easy entry of shaft into hole of cylinder Barrel.

Figure-4 Developer spay use for detect oil wetness

B) Staring Trouble

Inspection side:

1) Skill matrix to be displayed at SIT stage.

2) Procedure of pump fitment after shim adjustment to be displayed at SIT stage.

3) Stage Owner Identified For Sit Adjustment.

Cause side:

1) PTO fitment stage to be shifted after SIT stage.

2) Fixtures for dummy PTO covers to be installed on the conveyor.

After Cause side – FIP fitment online after timing adjustment will be easy because of operator can see FIP Rack engagement FDC Lever.

Work to be done for cause side improvement:

1) DC Nut Runner to be shifted.

2) PTO covers loctite dispensing machine to be shifted.

3) Conveyor Layout to be changed

C) Flywheel Bolt Loose

Inspection side: The Reconfirmation of Flywheel bolt torque & digital manual torque wrench stared in inspection stage of Engine Assembly/ testing process & paint marking on flywheel.

Cause side:

1) DCNR Integration with Assembly Conveyor.

2) DCNR data collection & review to detect bolt loose/ at engine assembly.

D) High Smoke

Inspection side:

1) 100% smoke check at various levels of the testing.

2) 100% RC lever checking is in place.

Cause side: RC lever material change is in process (ADC 12 to ADC6) will be implementing.

Table 6 Specification of RC lever material

Grade	Si	Cu	Mg	Zn	Fe	Mn	Ni	Sn
A514 / ADC 6	1.0	0.4	2.5-4.0	0.1	0.5	0.4	0.4	0.1
A383 / ADC 12	9.6-12.0	1.5-3.5	0.3	1.0	0.9	0.5	0.5	0.1

E) Fuel Filter Pipe Position Wrong

Inspection side:

1) Skill matrix to be displayed at fuel filter fitment stage.

2) Separate bin provide for inlet & outlet pipe of fuel filter because of different models are assembled in engine Assembly.

3) Fuel Filter & Pipe Matrix to be Display according to Size & Shape.

Cause side:

1) Fuel filter fixtures are modified shown in (figure-5)

2) Standardization of inlet & outlet pipe for all models of engine.

Figure-5 Modified fuel filters of various model

Table 7 Results after implementation of solutions

SR.NO.	Quality Defect	Defective quantity before solution	Defective quantity After solution
1	Oil Leak From Rocker Shaft	40	0
2	Starting Trouble	38	0
3	Flywheel Bolt Loose	20	2
4	High Smoke	19	3
5	Fuel Filter & Pipe Position Wrong	10	0
	Total engine quality defect Quantity	127	5
	Total Production	7400	7000
	PPM	**17162**	**714**

Table-3.13 Show Defective quantity after implementation of solution & PPM level for that improvement. Within the target dates, the implemented solutions provided the desired results, which are tabulated below.

Statistical evaluation of implemented solution was carried out.

Ho-Defectives proportion before solution implementation = Defectives proportion after solution implementation

Ha-Defectives proportion before solution implementation > Defectives proportion after solution implementation

SAMPLE	X	N	SAMPLE P
1	127	7400	0.017162
2	5	7000	0.000714

Difference = p (1) - p (2)
Estimate for difference: c
95% lower bound for difference: (0.0134233, 0.0194724)
Test for difference = 0 (vs. > 0): Z = 10.66
P-Value = 0.000
Result: **P value is <0.05, OR Z at 0=10.66 > Z at 0.05=1.645**
So, **Ho is rejected.**

It shows that after implementation of solutions at various stages of Engine manufacturing there is significant improvement at engine Assembly/testing process.

5. CONTROL PHASE:

During control phase, the implemented solutions were monitored with the help of various charts such as OPL Display chart, 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. Standard operation procedure (SOP) were monitored & updated according to improvement. Control chart is used to monitoring rejection of engine quality defect quantity.

VI RESULTS

SIGMA IMPACT

This criterion describes the main goal of this project that was to reduce the problems (defects) in engine Assembly/ testing process due to Engine Quality Issue and to improve the sigma level. After calculation Sigma level was found out to be improved considerable.

PPM for Engine Quality Defect
= **(**Defect X 10, 00,000)**/** (Production)
= (5X 1000000)**/** **(**7000)
= 714-------------- (DUPM)
Corresponding Sigma level = 4.7

COST / BENEFIT IMPACT

Cost of poor quality (COPQ) has been significantly reduced By 45 % per annum (18% to 10% of sale).

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.

VII CONCLUSION

The Six Sigma method is a project-driven management approach based on the theories and procedures to reduce the defects for a specified process. This paper presents the step-by-step application of the Six Sigma methodology for increase sigma level of the assembly/testing process. Several statistical tools and techniques were effectively utilized to make inferences during the project.

- It has been found that organization achieved breakthrough in reducing engine defects due to Six Sigma DMAIC Methodology.
- 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.
- Six-sigma implementation on engine assembly/testing process resulting into huge savings and other associated benefits leading to improved and robust process.
- DMAIC Methodology was found to be the greatest motivator behind moving everyone in the organization. It has been used to improve quality of diesel engine mostly.

It may hence, be concluded that DMAIC (Six Sigma) methodology has potential to address many Quality and productivity Improvement problems of modern times.

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