Continuous Improvement of Automobile Engine Assembly Line: A Review and Case Study

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Abstract – Currently manufacturing industries are facing a greater competition in the market. Due to this competition industries are trying to improve and increase both quality and productivity continuously. Continuous improvement is well known method for improving an organisation step by step. Many automobile organizations have realized the need to improve the quality of products & services to be a competitive opponent. To remain competitive in changing environment, these organizations have to develop new methodologies and remain flexible at the same time so that they can respond to the new demands. Organisations over the years have done continuous improvement as a necessity for staying competitive. Continuous improvement helps to streamline workflow. The main objective of this study is to find out the major breakdowns causing production losses to the company and to suggest counter measures by which these problems can be reduced. For this root cause analysis is conducted to find the root cause of breakdowns and some parallel improvement opportunities also identified for implementation so as to reduce the downtime. In this paper focus is given on review of recent research related to continuous improvement of automobile engine assembly line and a case study of automotive industry is considered for the study.

Keywords: Continuous Improvement, Quality, Breakdown, Root Cause Analysis.

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INTRODUCTION

A continuous improvement process, also called as a continual improvement process is never ending efforts to improve products, services, or processes. These efforts can find or discover “incremental" improvement over time or remove barriers for improvement all at once. Continuous improvement is never-ending change which is focused on increasing the effectiveness and efficiency of an organisation to fulfil its planned actions and objectives. It is not limited to quality initiatives, improvement in business strategy, customer, employee and supplier relationships can be subjected to continual improvement that means getting better all the time. Continuous improvement is a method for identifying opportunities for streamlining work and reducing waste. Practicing continuous improvement begins with identifying a current process of working, procedure, and workflow etc. Continuous improvement helps company to decrease production lead time and increase product throughput the key performance indicators with less expenditures. For continuous improvement, we can use various tools and methods like Six Sigma, Failure Mode Effect Analysis, Theory of Constraints, Failure Classifier, Swim-line diagram. [1].

The manufacturing industries have gone through significant changes in the last decade. New industries in markets have increased competition fiercely. Frequently most of them focus on product quality, production time and cost of product. Due to this, a company should introduce a system which improves and increases both quality and productivity continuously. Root Cause Analysis (RCA) is a method of problem solving that identifies the root causes of problems. RCA tries to solve problems by identifying the root causes of events, opposite to simply addressing their symptoms. By focusing correction on root causes, problem recurrence can be prevented. Continuous improvement is never ending process and there is always scope for improvement so everyone must strive for it. Continuous improvement is not such that we have to invest more. Whatever we have, use it for process, product quality improvement. In this paper focus is given on breakdown analysis of machine and quality improvement of product for continuous improvement of engine assembly line.

PROBLEM DEFINITION

Even after following standardized tasks by operators and also scheduled maintenance activity in a manufacturing industry there is still breakdown, and losses in quality, production, etc. So manufacturing firm has to reduce these unwanted stoppages of production so as to maintain steady production levels and meet the customer demands. It is necessary to reduce the breakdown (down time) of machines or equipment in the company for the efficient and effective production to meet the demands. Breakdowns are the most common reasons of efficiency loss in manufacturing industries. Elimination of downtime or breakdown of machines, which occurs unexpectedly, is very important for improving overall equipment efficiency. It is not only important to know how much time is lost due to process but also we must know lost time to the specific source or reason for the loss. Case study is conducted on the breakdowns of machines or equipment of the manufacturing industry, to find out the root causes of these breakdowns. So as to eliminate them and to decrease the downtime caused due to these breakdown.

LITERATURE REVIEW

Literature Review for Process Improvement

Gejdosa [1] this article deals with the application of selected tools of statistical process control, through which continuous quality improvement can be achieved. The advantage of these tools is that we can identify the effects of the processes that cause unnatural variability in processes that result of errors and poor quality. Tools like capability index, histogram, model DMAIC, control chart, etc. can reliably determine the variability in the process and contribute to quality improvement. Use of DMAIC model as well as other statistical quality tools is a way to achieve continuous quality improvement.

Azizi [2] discussed about how manufacturing firms are focusing on improving the productivity output in order to survive in the competitive market. High productivity performance has a direct relationship with the equipment efficiency and process control. He proposed the integration between the statistical process control (SPC), overall equipment efficiency (OEE), and autonomous maintenance (AM) to achieve continuous improvement in the production capability. This integration can enhance the productivity performance of manufacturing firms. He used seven quality tools to reduce manufacturing process variations.

Sahno et al. [3] showed a new framework and applied six sigma DMAIC (Define-Measure-Analyze-Improve-Control) methodology with the help of new framework, company can decrease production lead time and subsequently increase production throughput that improve product on time delivery to a customer. This framework integrates various tools and methods that help engineer to find out problematic operation in the process and eliminate root causes of problem quickly and with less expenditure. He provided the background of basic concept and definition like KPI (Key Performance Indicators), production route (PR), failure classifier (FC), failure mode effect analysis (FMEA), six sigma, lead time in manufacturing, theory of constraints (TOC).

Muralidharan [4] shows that most of the quality philosophies work in isolation and do not promote technicalities in the organizational activities. The only six sigma philosophy advocates extensive use of statistical methods. By using statistical process control (SPC) and control charts constitutes the ideal way of monitoring current process performance, predicting future performance and suggesting the need for corrective action. It integrates all the quality philosophies (Deming, Crosby, Juran, Feigenbaum, Ishikawa and Taguchi Quality Philosophy) and promotes a structured problem-solving approach to reduce variation in a process, in the process of improving quality across organizations.

Filho and Uzsoy [5] discussed about how continuous improvement on the shop floor is a major component of many popular management movements, such as lean manufacturing and six sigma, etc. There are few quantitative studies of the cumulative effects of such improvement programs over time. In this paper, they use a system dynamics model based on the factory physics relationships proposed by Hopp and Spearman to examine the effect of different continuous improvement programs on the relationship between lot sizes and cycle times. They compare two different types of improvement programs large improvements in a single parameter, such as might be obtained by a focused project, or small improvements in many parameters simultaneously.

Malik et al. [6] shows that businesses are depending on continuous improvement (CI) and total quality management (TQM). Spanish and Pakistani industries both have been engaged in continuous improvement practices with different implementation strategies and outcomes. This paper analyses the outcomes and comparisons of continuous improvement practices carried out in Spanish and Pakistani manufacturing firms. Finally they conclude that Spanish industry is comparatively more experienced and advanced than Pakistani industry, their collectivistic culture is also playing a major role in successful implementation of TQM practices.

Kumbhar et al. [7] discussed about how automobile manufacturing organizations are currently encountering a necessity to respond to rapidly changing customer needs, desires and fluctuating market demand. Many automobile organizations have realized the need to improve the quality of products and services to compete successfully. To compete in dynamic environment, these organizations must have to develop new methodologies allowing them to remain competitive and flexible simultaneously.

Literature Review for Breakdown Analysis of Machines

Kumar and Rudramurthy [8] discussed in this paper about how to increase the availability a machine and reduce the down time of a machine, to maximize production capacity and to improve new preventive maintenance schedule. They did study on hydraulic press, studied all repeated breakdowns and analysed along with the critical parts, which were under breakdown condition are also identified and analyzed. Also the reason for the breakdown has been analyzed by the method of fish bone diagram and why-why analysis. By this analysis and methods the root causes of the breakdowns were identified. This in turn helped to develop and improve a new preventive maintenance checklist for the machine. The aim of their study is to increase availability and MTBF (Mean Time between Failures) of critical manufacturing equipment.

Kiran et al. [9] discussed the ways to increase the productivity to increase the availability of existing machines; total productive maintenance helps to increase the availability of existing equipment so no further capital investment is needed. Also, they discussed about how the availability of machines can be increased by reducing the downtime or breakdowns of the machines. The main objective of their study was to find out the major breakdowns causing production losses to the company and to suggest counter measures by which these problems can be reduced. In the study a root cause analysis was conducted to find the root cause of breakdowns and some parallel improvement opportunities were also identified for implementation so as to reduce the downtime.

Eti et al. [10] presented a methodology for the development of PM using the modern approaches of FMEA, root-cause analysis, and fault-tree analysis. Applying PM leads to a cost reduction in maintenance and less overall energy expenditure. Implementation of PM is preferable to the present reactive maintenance procedures. They discussed about Nigerian industries, how maintenance is not given a high priority there and due to that how plants are often underutilized and run at high costs.

Uche and Ogbonnaya [11] identified the root causes of machine and equipment breakdowns in a production line. The evil effects of machine shutdown on manufacturing targets in volume and deadlines are comprehensively highlighted. They found that the major maintenance challenges in a typical production line are poor spare parts inventory management, lack of technical competence of production and maintenance operatives, ageing machines and equipment, inadequate maintenance budget, and poor leadership of the firm's management team. They suggested robust technical solutions as remedies which include adequate consideration of maintenance during the project initiation phase, strategic inventory control, adoption of computerized maintenance management system (CMMS), adherence to condition based maintenance or predictive maintenance, aggressive pursuit of total productive maintenance (TPM), and staff competence development and motivation.

Marqueza and Guptaab [12] presented a holistic framework for managing the maintenance function heretofore inundated by myriad tools, trappings, practices, and prescriptions. It begins by reviewing the concepts, state-of-art processes and standards available to help maintain today's complex systems. It then proposes a framework in which to couch the various maintenance functions in an organization. They closely analyse the strategic, tactical and operational aspects of maintenance and sets up a structure to help complete the tasks at each of these levels.

Rakesh et al. [13] discussed the use of failure mode and effects analysis (FMEA) for improving the reliability of sub systems in order to ensure the productivity which in turn improves the bottom line of a manufacturing industry. Thus the various possible causes of failure and their effects along with the prevention are discussed in this work. Severity values, occurrence number, detection and risk priority number (RPN) are some parameters, which need to be determined. The preventions suggested in this paper can considerably decrease the loss of production hours in the industry due to the breakdown of machines.

Mahto and Kumar [14] discussed about root cause identification of quality and productivity related problems for manufacturing processes. It has been a very challenging engineering problem, particularly in a multistage manufacturing where maximum number of processes and activities are performed. However, it may also be implemented with ease in each and every individual set up and activities in any manufacturing process. In their work root-cause identification methodology has been adopted to eliminate the dimensional defects in cutting operation of CNC oxy flame cutting machine and a rejection has been reduced from 11.87% to 1.92% on an average

Sokovic et al. [15] presented a review of possibilities of the systematic use of seven basic quality tools (7QC tools). It is shown that 7QC tools can be used in all process phases, from the beginning of a product development up to management of a production process and delivery. It is further shown how to involve 7QC tools in some phases of continuous improvement process (PDCA-cycle), Six Sigma

(DMAIC) and design for six sigma (DMADV) methodologies, and lean six sigma. In the next section case study is discussed in details.

CASE STUDY

This case study is focused on reducing breakdown at assembly line in multinational company situated in Pune. The objective of this case study is to improve processing time at engine assembly line by reducing breakdowns or eliminating non value added activities using value stream mapping methodology.

Methodology

In methodology first step includes data collection of breakdowns and time associated with breakdowns. After data collection identification of critical breakdown causing more downtime is the next step followed. Root cause analysis of breakdown is done using seven quality tools. Implementation of countermeasures based on root cause of breakdown is the methodology followed for the research work.

Data Collection and Analysis

Breakdown data is collected for 4 month from the log book of the company and is shown in table 1. The breakdowns and frequency of occurrence are given. Breakdown data collected consist of maximum breakdowns that occur at engine assembly line. But our area of interest is the breakdown causing production stoppages also problems which are having high frequency and more downtime at engine assembly line. The breakdowns causing stoppages of production process and more downtime at engine assembly are identified from the data

Table 1 Breakdown data and its frequency

Sr. No.	Loss Description	Frequency
1	LBLT retest	300
2	Engine N/A from tappet	290
3	Punching Nok	250
4	Vision system shows Nok	190
5	Reintroduce late	50
6	Oil pan bolt torque Nok	42
7	TTT Retry	34
8	EUN Print Not Come	33
9	Debolt Machine Down	30
10	Yoke Pin Problem	30
11	Bed Plate Bolt Torque Nok	27
12	Empty Pedestal	27
13	TTT Overcycle	20
14	Block Host Query Nok	20
15	MB Cap Loosening Torque Nok	19
16	Engine Reject	17
17	Front Cover Bolt Torque Nok	17
18	Tool Hang	17
19	Balancer Gear Bolt Torque Not Ok	16
20	Dowel Insertion Hard	16
21	RTV Profile Nok	15
22	Rear Seal Bolt Torque NOk	15
23	Crank Jam	15

Fig 1 shows Pareto analysis for top breakdowns causing production losses and breakdown at assembly line. From the Pareto chart it is clear that LBLT retest, engine not arrived from tappet and engine unique number punching, are the three problems which are causing near about 70% of downtime at engine assembly line. Fig. 2 gives the percentages of time spend for different breakdown. By considering time lost due to breakdowns and frequency of problem three problems considered for improvement. LBLT retest, Engine not arrived from tappet, Engine unique number punching not ok. By using seven quality control tools analysis of problems is done and according to that countermeasures are suggested. From seven quality control tool fishbone diagram, Pareto chart is used for study and to find root cause of problem why why analysis is used.

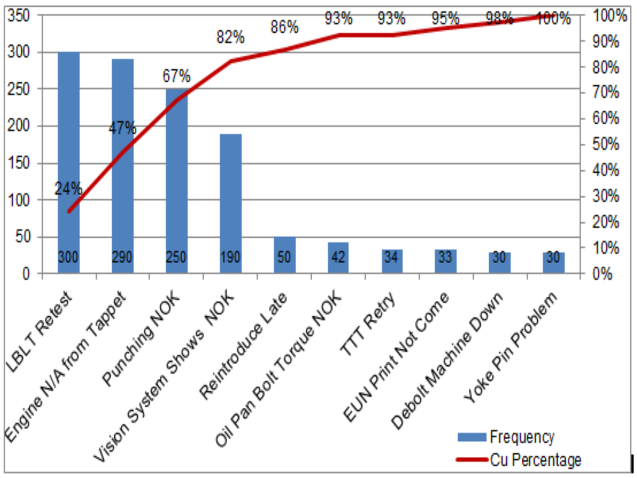

Fig.1 Pareto analysis for top breakdowns

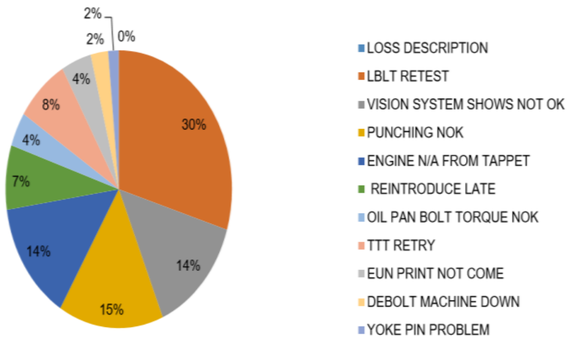

Fig. 2 Time spent to rectify breakdowns

Considering the frequency of occurrence and the time wasted due to breakdown maintenances, it is identified that LBLT retest causes production loss in the company. So root cause analysis is conducted for identification of root cause of the problem.

Cause Charting and Root Cause Identification

Cause-and-effect diagrams or Ishikawa diagrams (Fish bone diagram) is one of the seven basic tools of quality, which is used to identify potential factors causing an overall effect.

A. Root cause identification for LBLT retest

Long Block Leak Test Machine (LBLT) is used to check leakage of engine. In this water gallery and oil gallery of engine is checked for leakage. Air is allowed to pass through both the galleries i.e., oil and water if volume of air is in the specified range then engine is leak proof. If volume of air is not within range engine has leak and it is retested to identify through which part leakage occurs. The range of volume of air for petrol engine for water gallery 0 to 40 SCC/M (standard cubic centimeters per minute) and for oil gallery 0 to 60SCC/M. Similarly for diesel engine for water gallery 0 to 40 SCC/M and for oil gallery 0 to 100 SCC/M. To find out most probable causes, cause and effect diagram is drawn. Figure 3 shows the fish bone diagram for LBLT retest with probable causes. From the fishbone diagram 3 most probable causes are found the probable causes are related with material or parts attached to engine. It is clear that LBLT retest is majorly due to leakage through engine parts. Other causes are also present related to man, machine and method but it does not affect much or its occurrence chance is less.

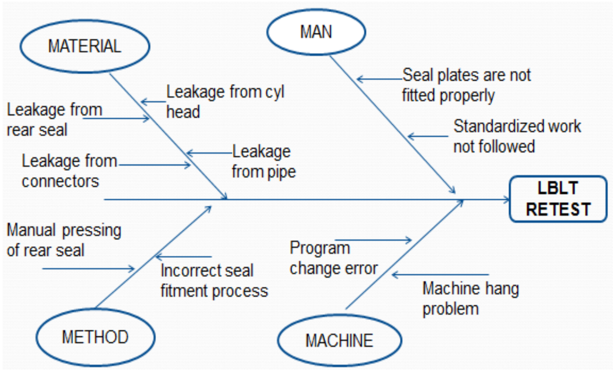

Fig. 3 Fish bone diagram for LBLT retest

Again Pareto chart is constructed as per the frequency of leakage through various engine parts. Fig. 4 shows Pareto chart for leakages through engine, from chart it is clear that leakages through rear seal, leakages through cylinder head and weared seal are the major causes of LBLT retest. Hence detailed analysis of these three problems is done in the current study. To find the root cause of this problem why why analysis is done

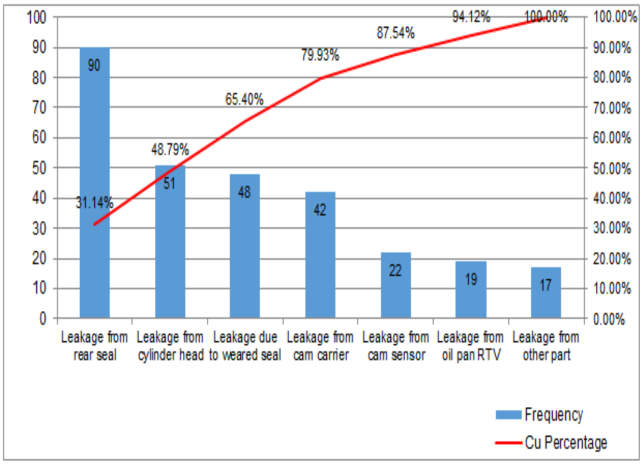

Fig. 4 Pareto chart for leakages through engine

B. Why why analysis for LBLT retest

Why why analysis is a method to determine the cause effect relationship in a problem. Using the why-why analysis, it is a simple way to try solving given problem without detailed investigation. It is one of the simplest investigation tools easily applied without statistical analysis. (See table 2)

Table 2 Why why analysis for leakage through rear seal

Why?	LBLT Retest
Why?	Leakage From rear seal

Why?	Seal is not pressed properly	
Why?	Air gap present or seal folded while assembly	Seal pressing machine stroke not uniform
Why?	Seal is not getting provision to rotate after installation	Pneumatic seal pressing machine used

From analysis, root causes are found for the leakage though rear seal and LBLT retest. Based on root cause corrective action is taken for minimizing the problem. Fig 5 shows location of rear seal and leakage through it.

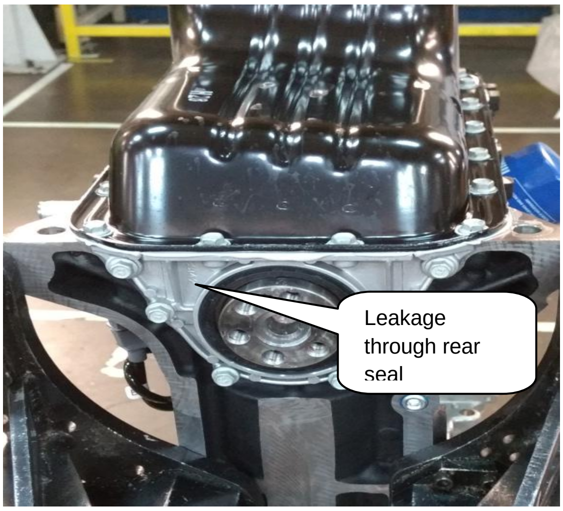

Fig. 5 Leakages from rear seal

- ***Corrective action taken***

For first cause, i.e., seal is not getting provision to rotate after installation. Previously after assembly of rear seal on crankshaft there is no scope of crankshaft rotation between LBLT station and seal assembly station. So action taken is shifting of assembly station of rear seal in such a way that after installation of rear seal on crankshaft. The crankshaft is rotated and as crank is rotated it will ensure proper resting of rear oil seal on crank surface which is helpful to eliminate air gap and press seal properly if folded. This will help to avoid seal leakage issue at LBLT and further. For this rear seal assembly station is shifted before TTT station where crankshaft is rotated to check the torque required to turn the engine.

For second cause, i.e., seal is not fitted properly in housing because pneumatic seal pressing machine used to press seal in housing. The action taken is replacing of current pneumatic machine by hydro pneumatic machine whose stroke is uniform so seal will be pressed in a housing uniformly. Also with hydro pneumatic machine tolerance limit within which rubber seal must be pressed in a housing is reduced from 0.50mm to 0.25mm. Also supporting arrangement for supporting seal from bottom side is provided in this hydro pneumatic machine which is not with pneumatic machine.

C. *Why why analysis for leakage through cylinder head*

Leakage through cylinder head is the second highest frequency problem due to which LBLT retest problem occurs. So similarly for this problem root cause is found using 5 why analysis as listed in table 3.

Table 3 Why why analysis for leakage through cylinder head

Why?	LBLT retest
Why?	Leakage from cylinder head
Why?	Scratches and burrs present at head
Why?	While installing head on cylinder block operator moves head
Why?	No guide tool to assemble head on block

- ***Corrective actions taken***

Based on root because it is found that while doing cylinder head assembly on cylinder block there is no guide tool used. Cylinder head loading on engine was done using tackle and bolts as guide tool. Sometimes team member is following non standardized work and loading head without using bolts. Due to that cylinder head damage takes places which are responsible for leakage. In new process guide tool is used by operator for loading head on block due to which chances of damage to cylinder head are eliminated. Ultimately chance of LBLT retest is reduced. Fig. 6 (a) and (b) shows assembly of head on block with guide tool and guide tool used for assembly

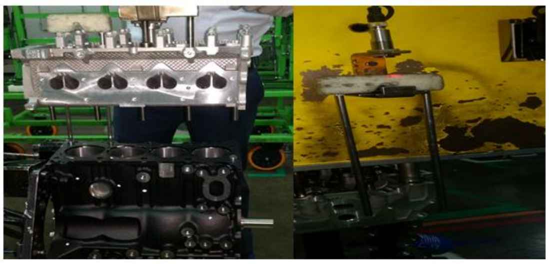

Fig.6 (a) Assembly of head on block with guide tool

(b) Guide tool

D. Parallel Improvement Done

a. *LBLT rear seal rework process improved*

- ***Old process of rework***

In LBLT when leakage is found through rear seal it need to be changed. The following procedure was used to change rear seal before improvement. In this process first they open oil pan. In second step whole rear seal housing is removed. After this old rubber seal housing is removed and new housing installed with new oil pan. Then engine with new rear seal is tested and reintroduced on line. For this whole process time required was minimum 30 minute as engine is repaired offline. In this rework process oil pan was getting damaged as it is hit by hammer while removing and new oil pan is assembled. So total rejection cost per engine was Rs 560/- per engine.

- ***New process implemented***

In new process there is no need to remove oil pan. Here only rubber seal is removed without removing housing using screw driver and new seal is pressed with the help of pressing tool. In this process there is no need to remove engine from assembly line the whole rework is carried out while line is running. Rework time is also reduced to 2 minute also rejection cost decreased to Rs 88/- per engine.

Fig. 7 Rework process for rear seal

Fig 7 shows rework process for rear seal with pressing tool and rubber seal.

RESULTS

a) Fig 8 shows comparison of leakages through engine parts before and after improvement for two months. It is clear from chart that frequency of problem is decreased after taking corrective action. The effect of decrease of leakages through engine parts means ultimately breakdown due to LBLT retest is reduced. Due to reduction in LBLT retest the uptime of line approximately increased from 87% to 90%.

b) Benefits of change of rework process for rear seal at LBLT. In old process time required per engine was minimum 30 minutes with new process it is reduced to 2 minutes as engine rework is done on online. Total time saving is 28 minutes per engine. Before, the rejection cost per engine was RS 560 and with new process it is reduced to RS 88 per engine. Total cost saving RS 472 per engine.

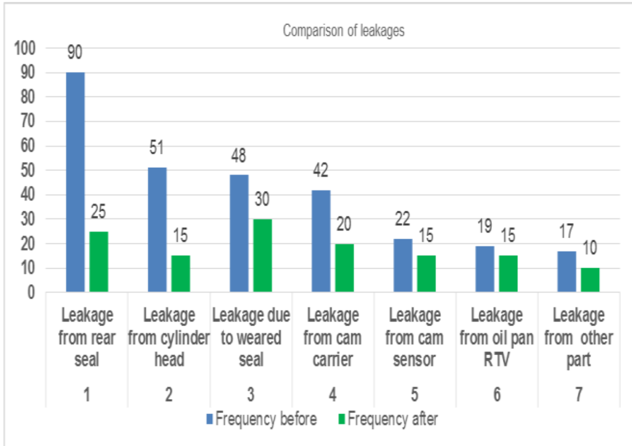

Fig. 8 Comparison of leakages through engine parts before and after improvement

CONCLUSIONS

The present work gives an overview of previously done research work and for new research; it gives a direction for continuous improvement of automobile engine assembly line. Also with the help of case study it is explained how to reduce major breakdown causing production loss at engine assembly line. This paper contains analysis of only one problem as study is going on and results given are based on current status of the study only. Complete results will be ready at the end of the study. Root cause analysis is conducted for the major breakdowns causing production loss to the company. Root causes of breakdowns are identified with the help of cause and effect diagram, 5 why analysis, etc.

Reduction in leakages through rear seal, cylinder head and other parts of engine decreases the LBLT retest problem. Decrease in LBLT increases the uptime of line. Similarly Kaizens suggested like rear seal rework process change also decreases the downtime of line and cost saving too. From the improvement made the uptime of assembly line increased by 3%, i.e., from 87% to 90%.

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