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Research Article

Six Sigma Methodologies for Increasing the First Pass Rate of Engines in Manufacturing

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I N F O

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A B S T R A C T

The purpose of this paper is to show the use of the Six Sigma methodology in improving the first pass rate of an ALH4CT engines during manufacturing. The paper follows case study, design and manufacturing approach. The case study was performed in a leading automotive based company in India. The application of the Six Sigma methodology resulted in a reduction of tolerance-related problems and improved the first pass yield from 95 to over 99 percent. A number of tools and techniques in the Six Sigma tool box have been utilized for data analysis and drawing valid and sound conclusions. Using Pareto analysis, the primary causes for each of the defects were analyzed. As per the analysis, it is absorbed that the loss of power due to wrong flywheel marking was the major cause for engine rejection. The fixture of the rotary table has been modified by placing a sleeve in the dwell pin locator. This sleeve used to reduce the play between the flywheel and the table. This in turn would correct the flywheel marking, thereby increasing the pass of percentage. The results of the case study have provided greater stimulus within the production facilities for wider application of the methodology as a powerful problem solving methodology.

Keywords: Six Sigma, Business Process Improvement, Automotive Industry, Change Management, Data Analytics

Introduction

Increased competition in international level is one of the most important achievements of economic globalization. The speed and quality to achieve superior performance in a competitive world, is depending on selecting proper methods and the use of organization ability and their key competencies. Automotive industry is one of the most active industries involved in the quality improvement, lower production cost and continuous improvement activities.[1] Establishment of quality management systems, which have been evolved day by day with direct impact on management of organizations, the qualitative objective clarification, considering the process management, use of improvement cycles have changed organization situation. The improved quality of processes and products is one of the most important modern business strategies. Development and implementation of an effective quality strategy is an important factor in the long-term success of organization.[2] In this regard, the Six Sigma methodology is a project-oriented approach to reduce the process variation and defect and in other words, increasing the process capability.[3] The Six Sigma was developed for the first time in Motorola Inc. in 1986. The Six Sigma is a powerful method in order to improve the quality and reduce the defect rate. Over the years, the Six Sigma is greatly developed in both manufacturing organizations and service organizations. The Six Sigma is one of the best techniques to improve business processes. The Six Sigma is a teamwork-based project and will solve the main problems of customers and processes.

The Six Sigma can help the engineers in dealing with multitasking issues with uncertain solutions. In many cases, the root causes are unclear and should be identified systematically using Define-Measure-Analyze-Improve-Control (DMAIC) methodology. Researchers have not treated Six Sigma in much detail in automotive industry. Moreover, previous studies of Six Sigma have not dealt with gridding process. Besides, most studies in the field of Six Sigma have only focused on DMAIC but this study used change management approach in improvement implementation. There is a hope that this article encourages the car manufacturer's managers and car industry suppliers in using Six Sigma to solve the difficult problems, especially when the root of the problem is not clear. This article used Six Sigma instead of Kaizen or quality circles, in order to solve the problem of the increased processing defects, because Six Sigma integrated a series of techniques and tools regularly. This article presents the application of DMAIC methodology in an automotive supplier based in Iran to reduce the defects in shaft manufacturing process. This article explored the engine manufacturing process parameters are the key factors affecting the run out significantly. Run out is critical to customer feature. Then, the optimum process parameters determined by means of the DOE method and the control chart adopted to monitor the effect of process improvement. The specific objective of this study was to improve first-pass yield significantly in gridding processes. The rest of the article is organized as follows. The second section presents related words. The third section provides information about the and the nature of the problem. The next section provides the use of modified DMAIC methodology and expression of techniques used in problem-solving process. The final section provides discussion, the results and main lessons learned during project implementation.

Background

Six Sigma has several dimensions such as philosophy, which resulted in low defects in operation, statistical measurement, which helps the accuracy of product, service and process measurement, measurement tool, which establishes the measurement system and finally a business strategy because high-quality reduce the business costs. Using effective techniques proposed in the Six Sigma methodology causes identification of the strength and weak points of the processes and paves the way to improve the production and service processes. Supporting techniques, which also named as Six Sigma tools such as cause and effect analysis have appropriate performance in dealing with issues and problems and help the identification of the problems and provide certain image from the performance to the authorities for further investigation. Much of the current literature on Six Sigma pays particular attention to industrial processes.[4] Applied Six-Sigma methodology to the flywheel casting process found that the efficiency and performance level of the sand-casting process can be improved by adopting the Six-Sigma approach.[5] Designed and successfully implemented Lean Six Sigma methodology to facilitate defect reduction in an automotive component manufacturing organization. There has been 50% reduction in DPU.[6] Indicated that the implementation of Six Sigma will pave the way for achieving the Six Sigma level quality in the companies with little revenue. During the conduct of the research reported in this paper, the case of rejecting the furnace nozzles due to the deviation in the diameter of the furnace nozzle hole was considered as the main problem. In order to overcome this problem, Six Sigma phases were applied. Moreover,[7] applied DMAIC methodology to the riveting process. Process capability was substantially improved on short and long term, Cpk increased from 0.96 to 1.72, Sigma Level short-term increased from 2.9 to 5.2, Sigma Level long-term increased from 1.4 to 3.7, DPMO. In another major study,[8] integrated Six Sigma practices into traditional quality management theory by investigating its relation to traditional QM practices as well as its direct effect on organizational performance. So far, very little attention has been paid to the role of six sigma in automotive industry[10-15] Explained a detailed application of Six Sigma methodology for reducing the shell scrap of foam production and lamination process. As a result of the approach, the process capabilities and the sigma levels increased and shell scrap percentage decreased. The average decrease is around 3.5% which is greater than the project target of 2%. Additionally, the financial benefit of this project is approximately $45,000 per year.[10] Illustrated the power of the Six Sigma methodology in improving the first pass yield of a high-precision engine manufacturing Process. Moreover,[10] presented the successful implementation of Six Sigma methodology in an automotive part manufacturing.[10] Implemented Six Sigma approach and resulted in reduction of process capability-related problems and improved the first pass yield from 94.86 % to 99.48 %. Although there are reluctant managers to implement the Six Sigma process, but[16] showed that the efforts put for implementing Six Sigma in the form of DMAIC process resulted in financial gain and improved customer satisfaction. Furthermore, Quality requirements for, in particular, ground components are increasing all the time; whilst the integrity of the engine manufacturing process also remains an important criterion.[17] Overall, these studies highlight the need for addressing Six Sigma in automotive industry and pay particular attention to engine manufacturing.

Problem Definition

The case study was done in Engine Assembly shop of the located in Chennai. The area of the study chosen as in Engine

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tests Rejection because it is one of the most important bottle necks in the process of engine manufacturing. Out of the various types of engines being manufactured in the company, ALH4CT engines has been selected because of its market status and varied applications in both automobile and industrial sectors. The present status of the pass off percentage (engine being passed after testing in its first attempt) in ALH4CT cylinder engines is around 95%, the technical solutions which we have arrived at will tend to increase the first pass off percentage by at least 2 or 3 percentage. This would mean a drastic reduction in the manufacturing cost of ALH4CT engines. The various problems identified during examination of engine manufacturing process that lead to engine rejection are loss of power, no oil supply to rocker; water and oil mix up, heavy breathing etc. Among the various problems identified in the engine rejection report, the main problem identified loss of power. This leads to time loss, gradually resulting in non-achievement of target. The techniques used to analyze the problems are pareto analysis and cause and effect diagrams.

Six Sigma Methodology

Define

In numerable causes of small and large engine magnitude occur in any industry. Each problem has its uniqueness. Problem identification and selection is a very important step. In engine manufacturing, the bottleneck was the test bed rejections. Thus we aimed at rectifying this bottleneck in engine test bed rejection i.e. to increase the first pass off percentage of ALH4CT engines. Before plunging into the solution a lot of pre work has to be done, like firstly engine manufacturing was thoroughly studied, this included. Study on engine parts, assembly, testing, engine dressing. All pre work was done so that we had a clear knowledge on engine manufacturing and also to find the key areas which caused major defects in engine test bed. The causes for engine rejection were obtained from various departments in Company. These data was being maintained as daily and weekly reports. These data was collected and consolidated as monthly reports. After collecting the data for engine rejection, different causes were grouped under 13 major causes. To find the severity of each cause, the frequency of these occurrences of each cause was collected for a time span of 6 months. Various quality tools were used to analyses the collected data. Pie charts were drawn to find the critical reason in each and every major defect. Pareto graph was used to find the critical major causes which on solving will have a drastic effect in increasing the first pass off percentage. Thus by using all these quality charts, the critical causes and reasons to work upon were found. The causes were zeroed in such a way that the solution found could be implemented i.e. the implementation is within the scope of Company. After finalizing the critical causes and reasons, work was carried to solve those problems. A lot of interaction was done with the workers and engineers to zero onto the solution for these causes. The solution was given by us during our project tenure will be implemented by the quality department on a test run basis and implementation of the solutions permanently will be based on the results of the trails runs in the test bed.

Measure

During engine testing, there are various causes due to which an engine gets rejected. Amongst these causes, there can be noticed a clear trend of certain causes occurring frequently. These causes have been segregated and termed as the major causes for engine rejection. The causes have listed in decreasing trend quality. This trend of defects was noticed during our period of study of rejection analysis i.e. 6 months. The relative importance of each cause for engine rejection is specified using pareto graph. The bar diagram in the chart depict the numerical value of the defects occurred during the period of analysis and the line represents the percentage of each defect in a cumulative way. It has been noticed that every defect has sub-causes which are notified in a form of table after each cause. The relative occurrence of the sub-causes for defect is represented by using pie charts. Trend graphs were drawn to depict the occurrences of defect in the individual months during the period of analysis. The measurement system variation was estimated about 20%. The measurement system can be acceptable when the Gauge R&R is lower than 30%.[18] The engines are rejected during testing on the basis of symptom, an observable phenomenon arising from and acing a defect. Usually a defect will have multiple symptoms. Based on this symptom the rejected engines re investigated for finding the exact defects and corresponding primary causes. These defects and primary causes are recorded for each rejected engine on day to day basis. These data were used for our project of increasing the first pass rate of engine by six sigma.

Analysis

To address process incapability, cause and effect analysis of the new process was performed. The analysis target is to determine the root cause of the defects or main sources of variation and develop the initial solutions. The brainstorming session in connection with the causes and effects of the problem was held. The cause and effect analysis output is shown in Figure 2. The cause and effect diagram was used to find the root causes. The important point in cause and effect analysis is that the causes listed in the diagram should be validated. For validation, the data related to the causes must be collected. Based on the data related to a cause, consultant and team can discuss. Finally, all the causes were examined and listed.

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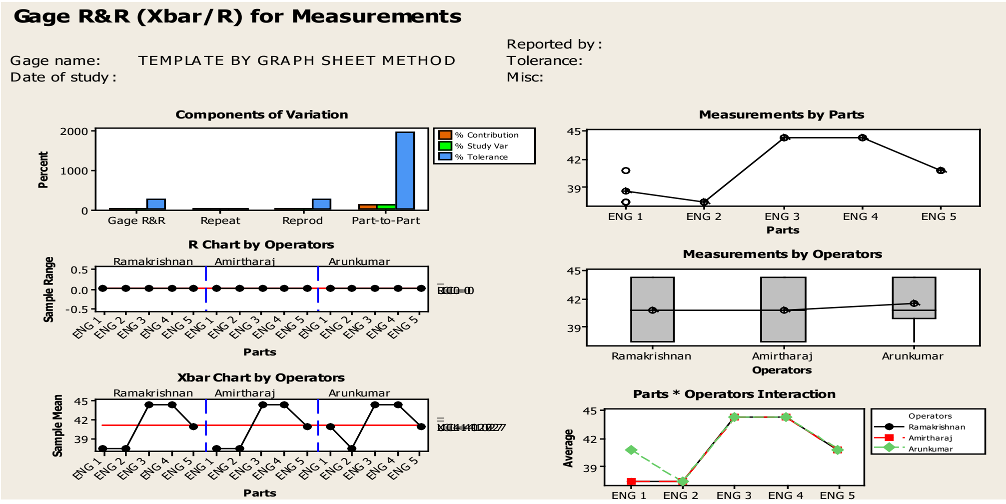

Figure 1.Gage R&R Report

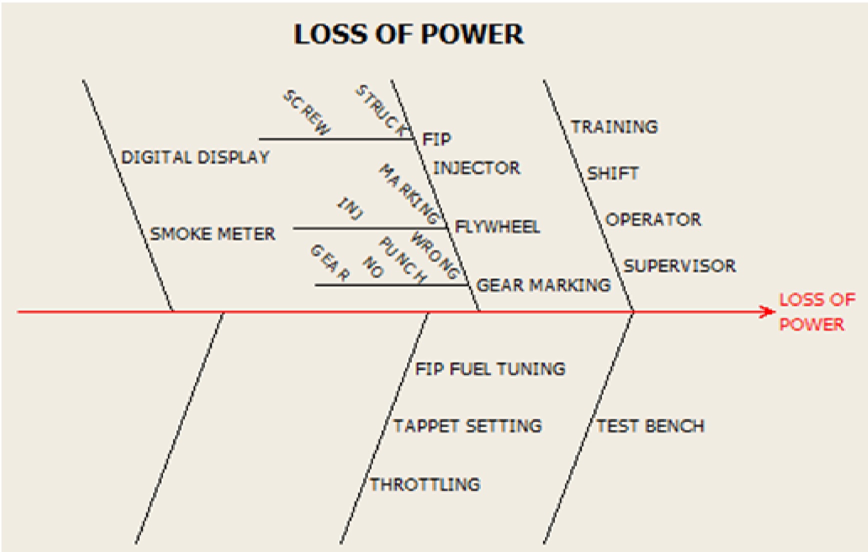

Figure 2.Cause and Effect Diagram For Loss of Power

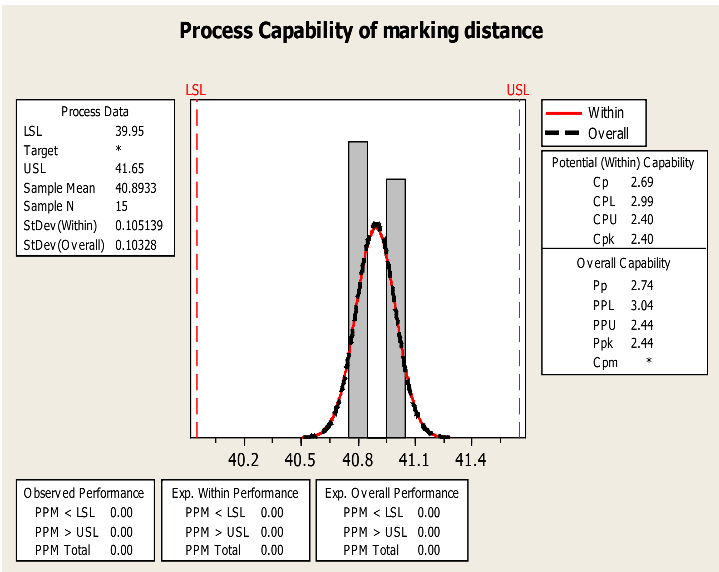

Figure 3.Process Capability

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Table 1.Testing of Rejection

Defects	Aug 2017	Sep 2017	Oct 2017	Nov 2017	Dec 2017	Jan 2018	Total
Injector failure	1	7	14	5	6	4	36
FIP delivery failure	2	6	8	3	6	4	29
Wrong timing	8	2	9	1	4	3	27
Flywheel marking wrong	10	6	15	2	9	8	50

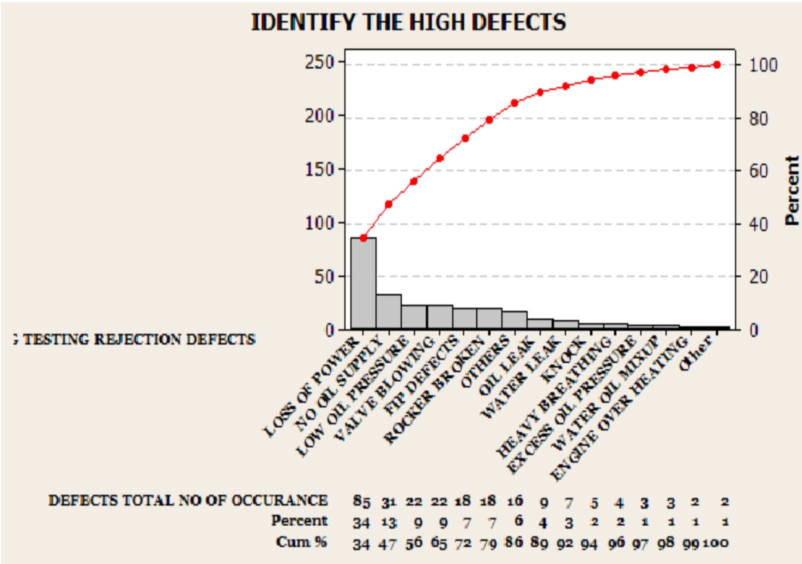

Figure 4.Defects Identification

As per the pareto analysis and from the six months data, we found that that the engines are mainly rejected due to loss of Power.

Manage Change and Improve

In the case of this project, solutions were generated through a brain storming session.[19] For optimization of the machinery parameters specified in the previous phase, it was determined to emphasize on the most important root cause based on Pareto analysis, therefore, the agreement was obtained on optimization of flywheel. Additionally, it was decided to design experiments. Thus, ANOVA was used to evaluate main cause effects. Solution testing was performed correctly. After experiments, fly wheel fixture modification was considered as a main solution. The wrong flywheel marking is due the play arising between the rotary table and the fixture in it. Since there is no clamping device for holding the flywheel, the play is more between the surfaces. Since only a single Dwell pin is used to locate the flywheel hole from centre, the making is being varied. So we decided to introduce a sleeve which can withstand high ware rate. As per the analysis, we found that the loss of power due to wrong flywheel marking was the major cause for engine rejection. In order to increase the first pass off percentage, we decided to change the fixture of the rotary table by placing a sleeve in the dwell pin locator so that this would reduce the play between the flywheel and the table. This in turn would correct the flywheel marking, thereby increasing the pass of percentage.

Table 2.Testing of Rejection

Defects	April	May	June	July	Sum of defects
Loss of power	0	0	1	0	1
Excess smoke	3	2	1	0	6
Fip defects	0	4	0	0	4
Low oil pressure	2	0	4	0	6
Valve blowing	2	0	0	0	2
Rocker assy broken	2	1	1	0	4
Water leak	0	0	0	1	1
Oil leak	2	0	0	9	11
No oil supply to rocker assy	5	2	0	0	7
Heavy breathing	0	1	1	1	3
Abnormal noise	1	2	2	3	8
Others	0	1	6	1	8

Control

The objective of this phase is to keep and maintain the

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improvements resulted in the previous phase. Due to different inter-organizational reasons such as job rotation, the maintenance of the improvements is too difficult. One of the useful tools in this regard, is the use of Standard of Operation (SoP). Furthermore, the process changes should be documented in form of the procedures in the quality management system. This greatly helps the standardization of the improvements in a Six Sigma project. In addition, CTQ was added to the process audit checklist and validated by internal auditors in a few audit sessions. Additionally, if there were any changes reported in the process, the corrective measures will be performed. Control chart was another powerful and useful tool to ensure the improvements sustainability during the time. Figure 4. The mean and range control chart used to monitor the process along with control plan in order to deal with specific causes. The instructions are also considered for those involved in the new improved process using new methods to increase their skill. Control charts and metrics established correctly. Figure 5.

of high wear withstanding capacity, so it won't wear out Soon. Because of the implementation of the project the target per each shift was achieved.

Conclusion

Six Sigma is one of the most important strategies to decrease defect and improve the process capability. This case study was implemented to improve the engine manufacturing process output from 95 to 99%. A multidisciplinary team was formed to examine the process defects and Six Sigma methodology was performed by the corresponding team. After implementation of this project, the defect costs were decreased sharply. In table 2, a defect of after Six Sigma implementation is shown. This case study opened the management eye on the efficiency of Six Sigma. Although, high-level technical capabilities are required to achieve the benefits of Six Sigma, but correct adjustment of objectives, correct selection of team members and correct atmosphere for project implementation are important factors in the project success. In fact, both technical and managerial aspects are effective in the project success.

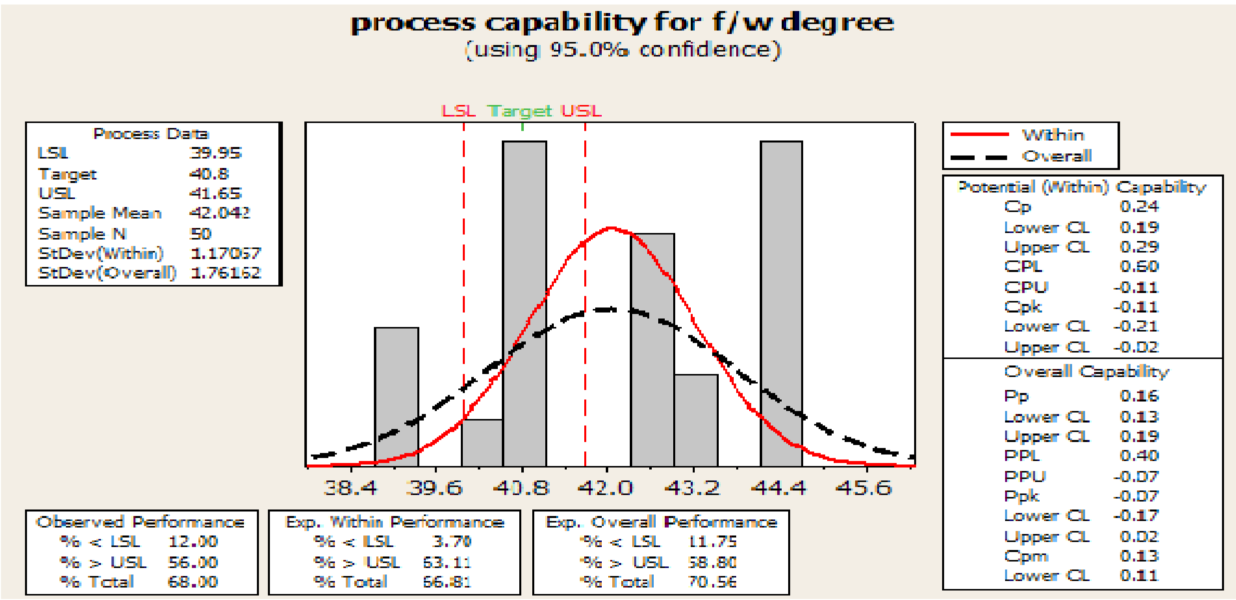

Figure 5.Process capabilities (f/w degree)

Result and Dissussion

This paper presented a successful case study of defects reduction in an engine manufacturing process by applying Six Sigma methodology. Therefore, the paper can be used as a reference for industrial managers to guide specific process improvement projects, in their organizations, similar to the one presented in this paper. By considering this, a reduction in the amount of defects was obtained by determining the optimum technology. With the introduction of sleeve, we were able to bring down the engine rejection rate. The introduction of sleeve not only brought down the engine rejection rate due to Loss of Power mainly because of Wrong Flywheel Marking but also will tend to increase the First Pass Off Percentage by 1.5-2%. The sleeve is designed

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