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(Research Article)

Application of Modern Quality Tools in Reducing Rejections: A Case in Machining Section of a Foundry

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Abstract

The global market is becoming more and more quality conscious. To compete in such an environment, companies need to adopt efficient techniques that can assess and take a diagnostic approach to meet customer needs and expectations. Using different quality tools, it is possible to resolve quality related issues and achieve near to zero defect rates. Pareto analysis and Root cause analysis are quality tools that provide certainly a viable solution to quality problems and can help a company to achieve expected goal through proper implementation. The aim of this study is to minimize the defects that will reduce rework and rejection rate of a component in a foundry unit. Defect data has been collected for a period of six months and Pareto analysis is performed on them. Cause and effect diagram is employed for analyzing the major defects. Feasible solutions are provided to the problems and also implemented. The significance of the result obtained is also indicated.

Keywords: Engine cylinder liner, Pareto analysis, Root cause

1. Introduction

In an Internal combustion engine, a cylinder liner forms the internal cylindrical space of the engine cylinder in which the piston reciprocates. It is responsible for ensuring the extremely hot exhaust gases not to damage the internal components of the engine. Present study is focused on reducing the rejection rate of such engine cylinder liners, in the machining section of a foundry unit. Selection of the product is done by collecting the data of monthly production and rejection report of the company. Process flow chart is studied to understand the production process. Pareto analysis is carried out to prioritize the various defects in the product. Root cause analysis is done by using Cause and Effect diagram. Improvement actions are suggested and implemented to resolve the root causes identified. The implementation of improvement actions resulted in significant reduction in the rejection of the considered product.

2. Literature Review

Earlier empirical studies suggested that the successful implementation of quality tools will result in improved quality, reduced defect rates, increased productivity, enhanced organization’s profit and customer’s satisfaction. Researchers implemented the quality tools in variety of cases to improve the existing process. D.R. Jana, et.al. Implemented Pareto Analysis and Cause and Effect analysis to identify and prioritize the problems associated with the performance of milling and boring operations on ‘Gear Housing’ in CNC milling machine. An improvement has been achieved in the process by the application of the corrective measures and total elimination of errors has been obtained [1]. F. Talib, et.al. used Pareto analysis to sort and arrange the critical success factors according to the order of criticality, which contribute to the success of TQM efforts [3]. T. Mahboob, et.al. represented a detail investigation on quality improvement of a garment factory by applying Pareto analysis and Cause-Effect Diagram, that resulted in minimization of defects that reduced rework and rejection rate [5]. T. Ahmed, et.al. presented a general classification of quality management tools applied in different industry branches. From among these tools the authors have chosen a pareto chart to present a detailed analysis of mining machines participating in the mining process [7]. X. He and M. Khouja implemented pareto analysis to supply chain contracts under satisfying objectives. They analyzed the Pareto improvements offered by modified buy-back, revenue sharing, and profit guarantee contracts [8]. Z.O. Kadiri, et.al. examined the major causes of accidents using Cause-Effect Diagram and ensured safety working environment by suggesting the ways of mitigating these accidents on construction sites [9].

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From the detailed literature review it can be observed that pareto analysis and cause and effect diagram are the effective quality tools to determine the problem and vital causes for the defined problem. The process/product quality can be improved by implementing the corrective actions against the respective causes. This case study establishes a significant result in terms of defect reduction, improved quality, reduced scrap, rework and operator fatigue and increased profit.

3. Brief profile of the company

M/s. Shree Lakshmi foundry is an ISO certified company, situated in Harihar, Karnataka state, India, and was established in the year 1975. The company produces Centrifugal Castings for Cylinder liners, Shell moulded air cooled Cylinders, Castings for CNC machines, Railway spares, and so on. The annual capacity of the company is about 3000 tons of castings. This foundry is a vendor for original equipment manufacturers (OEMs) like Eicher Tractor Ltd. Alwar, Ace Designers Ltd. Bangalore, Ace Manufacturing Systems Ltd. Bangalore, etc. The products of the company are also exported to Germany, South Africa, Turkey, Spain, Egypt, Argentina, Malaysia, Brazil, England and Italy.

4. Methodology

The main objective of this study is to reduce defects and improve quality and reliability of the product by using modern quality tools. This facilitates satisfying customer demand and improving the profit of the company by achieving fewer defects during critical stages of production processes and also saving production time by eliminating rework/reprocessing.

4.1 Data Collection: The production and rejection data of foundry and machine shop sections in the foundry unit is collected for a period of six months. It is revealed from the data analysis that the rejection percentage is high at the machine shop section than that at the foundry section. Foundry section defects are relatively less and even account for lower level of loss comparing to defects occurring in machine shop section. This prompted the study to be focused on the machine shop section for significant outcome.

The average percentage of rejection of Eicher 115-honed engine cylinder liner is found to be at about 3%. The cylinder liner considered for the current study is shown in figure1 and figure 2.

Figure 1. Pictorial View of an engine cylinder liner

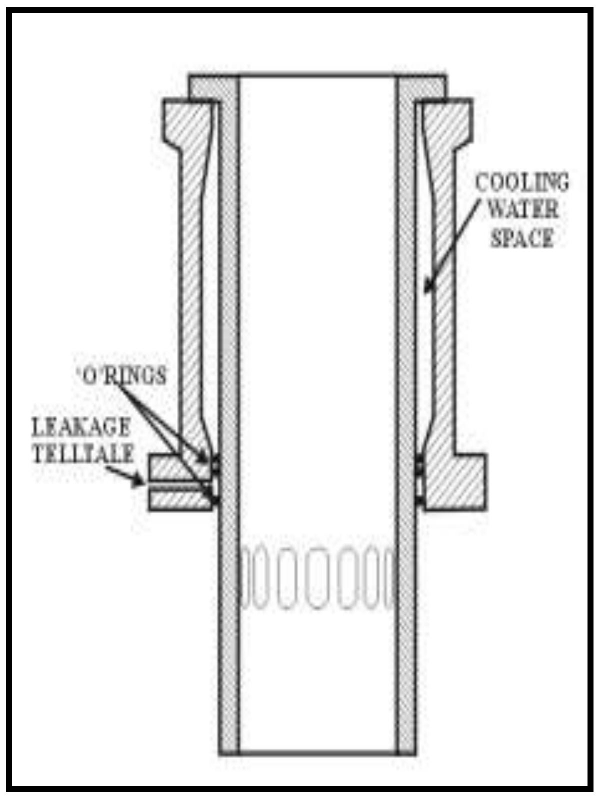

Figure 2. Sectional orthographic view of engine cylinder liner

Process flow chart for the considered product is prepared as shown in figure 3, and analyzed to understand the prevailing production process at the machine shop section in detail.

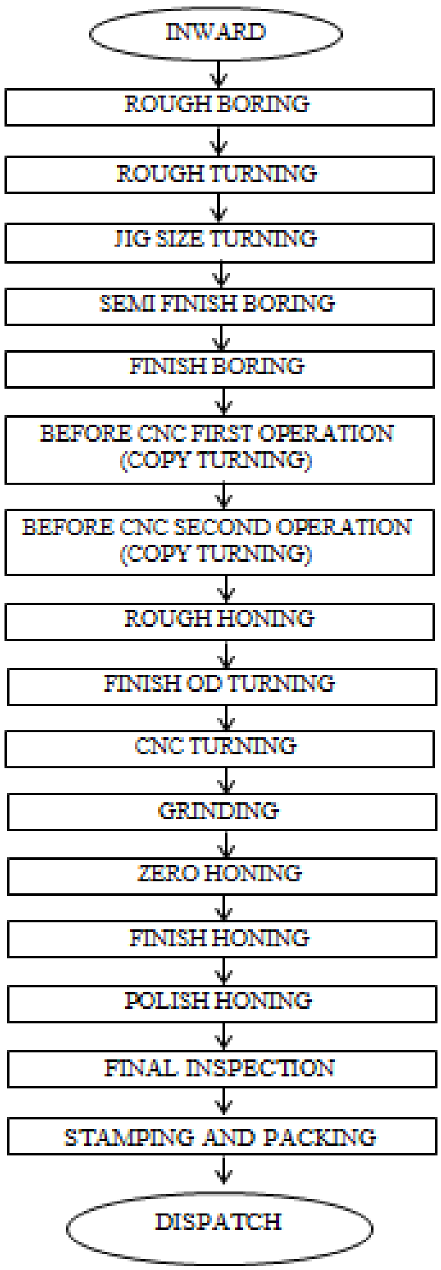

Figure 3. Production process at the machine shop

The rejection data of the product occurring at each of the production stage in the machine shop during the past one year is collected and studied. The percentage rejection in major stages of production process in the machine shop is obtained from the collected data and is indicated in Table.1.

Table 1. Annual Rejection rate at various stages of production in the machine shop

Sr. No.	Operation Description	Number of Rejection	Rejection Percentage
01	Rough Section	61	5.95%
02	Finish Bore	327	31.90%
03	Copy Turning	24	2.34%
04	Rough And Zero Honing	114	11.12%
05	Finish Honing	70	6.82%
06	OD Turning	97	9.46%
07	CNC Finish Turning	236	23.02%
08	Grinding	96	9.36%

From the table it may be observed that the highest rejection zone is CNC finish turning stage, which accounts for rejection of 31.90%. Since CNC turning is a finishing operation occurring almost towards the end of the value chain in this foundry unit, very low percentage of non-confirming products are attributable to foundry defects at this stage. Thus, the major rejections are due to machining errors or variation in machining process. Further, CNC machine, its maintenance and labour costs are relatively high and cost per unit produced at this stage is also large compared to all other stages of production. The rejection of the component at this stage leads to an approximate loss of about Rs.355 per component. This clearly established the need to focus on and reduce the rejection rate of the product at the CNC finishing stage.

4.2 Pareto Analysis: The previous section explained defect occurrence in each machining stage and also identified the critical stage contributing to most rejections (CNC finishing stage).

From the observation and data collected pertaining to CNC finishing stage, it is found that there are different types of defects occurring in the production line. These defects cause rework and rejection leading to waste of time and decrease in productivity. By concentrating on the few repetitive defects and reducing/eliminating them loss of time and waste can be minimized [1]. In this backdrop, those particular defects are identified using Pareto Analysis.

To find out the type of defects occurring in CNC finish turning, data corresponding to 50 rejected components have been collected and analyzed. The type of defects found leading to rejection and their percentage occurrence are listed in Table 2.

Table 2. Defects and their relative share

Type of Defect	Occurrence	Occurrence %	Cumulative %
Deviation in step length	16	32%	32%
Deviation in collar OD	16	32%	64%
Deviation in location OD	15	30%	94%
Ovality	01	02%	96%
Damage due to mishandling	01	02%	98%
Foundry defect	01	02%	100%

The major types of defects are identified through Pareto Chart as shown in figure 4.

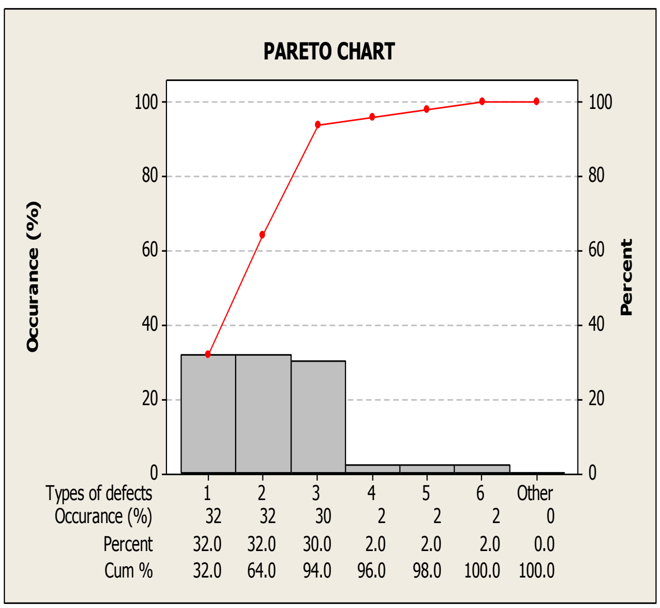

Figure 4. Pareto chart for defects

Pareto analysis served the purpose of separating the "vital few from trivial many". The identified vital few areas where maximum defects occur in CNC finish turning are further probed. This investigation found that rejections are mainly due to the deviation in the critical dimensions, viz.,

1) Step length
2) Location outer diameter
3) Collar outer diameter

*4.3 Cause and Effect Diagram:*To identify the potential root causes which have the maximum impact on the critical problem, cause and effect diagram (fish bone/ishikawa diagram) is constructed. The possible causes for the rejection of CNC turned components are found through brain storming session and discussion with the experts. The diagram is constructed to identify and organize the possible causes for a particular single effect. [6] The causes for the problem identified under each category are as shown in the figure 5.

Figure 5. Cause and effect diagram for rejection of product in CNC turning

4.4 Preventive measures and corrective actions: Several root causes for the problem of component rejection at CNC finish turning under various categories of causes have been found using fishbone diagram. Proper actions are derived to resolve those root causes in this phase. The categories of causes which are needed to be improved are Machine, Man, Method, and Measurement. The actions for each identified root cause of each category are discussed below:

4.4.1.Machine:

- Cause: Shim breakage
- Root cause: Accumulation of foreign particles
- Action: Use of compressed air blower

Shim is a metallic pad resting between tool holder and cutting tool (insert) and acts as a supporting structure for insert. Breakage of shim is observed eventually in the machine-tool and that was causing misalignment of insert there by affecting the dimensional accuracy of the product [5]. When the situation was carefully observed, it is understood that the breakage of shims is mainly due to the development of high thrust force. The major cause for the development of high thrust force is observed as misalignment of shim and/or insert, which is due to the accumulation of chips and other foreign particles in recesses of shim, insert and tool holder. Compressed air blower is utilized to remove off chips and other foreign particles in tool holder assembly and that avoids the shim from misalignment in turn reduces the thrust force.

4.4.2.Man:

- Cause: Negligence
- Root cause: Work load
- Action: Increased number of Breaks

Men/personnel are a prime factor that decides the quality of any product. It is always necessary to establish what system, policy or process allowed the human error to occur. It is observed that negligence of the operators due to over work load resulted in defective products. Thus, in order to reduce fatigue of operators, number of breaks is to be increased from one break to three and some refreshments are to be provided.

4.4.3.Measurement:

- Cause: Wrong inspection
- Root cause: Poor Knowledge of Statistical Process Control (SPC)
- Action: Dial indicator with digital display

Piece-to-piece inspection to check the dimensional accuracy of finished components is primarily done by the operators. Sample inspection is carried out in the interval of two hours by the shift supervisors. Inspection of each turned component using conventional micrometer is observed to be impractical and also time consuming. Dial indicators with digital display helps to measure the dimensions accurately with less time consumption.

4.4.4.Method:

- Cause: Improper maintenance of run chart
- Root cause: Poor Knowledge of SPC
- Action: Strict adherence to maintaining run chart

It is seen that the operators were not maintaining the run chart, as there is not enough instruction provided to them since the inspection department is not aware of statistical process control techniques. Run chart, being a graphical tool helps to identify the patterns of deviation in the process and the points of extreme variation. The operators are strictly instructed to maintain run charts for all the critical dimensions to avoid rejection rate by taking corrective actions whenever the points are out of control limits on such charts.

5. Results and discussions

The solutions for each cause of variation are implemented and post-implementation study is carried out by considering the monthly production and rejection report of the product from the month of implementation.

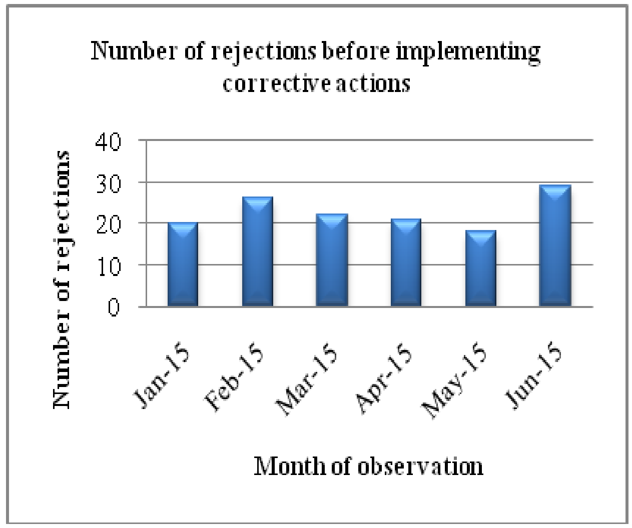

Figure 6. Trend of number of rejections of component in CNC finish turning before implementing corrective actions

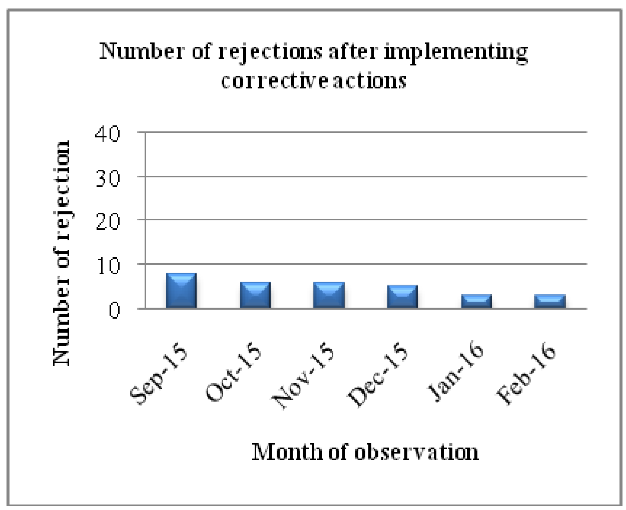

Figure 7. Trend of number of rejections of component in CNC finish turning after implementing corrective actions

From the figure 6, it can be observed that prior to implementation of the study recommendations; the number of rejections of the component has increased consistently from January 2015 to June 2015. However, figure 7 depicts clearly that after implementation of improvement actions the number of rejections has reduced drastically from September 2015 to February 2016.

6. Conclusion

The implementation of quality tools in the production process of Eicher 115-honed engine cylinder liner at the machine shop of a foundry unit revealed that Pareto analysis is an effective way to diagnose where the significant problems lie and Cause and Effect diagram is an equally effective tool to fix the problem.

Systematic application of these tools in the production of Eicher 115-honed engine cylinder liner resulted in following significant benefits:

- Reduced rejection rate from 23.02% to 8.05%
- Reduced costs of poor quality (COPQ) from Rs. 6982 to Rs.1686
- Reduced scrap and rework from 4.5% to 2.15%
- Reduced operator fatigue significantly.

It is believed that the outcome of this study has helped in enhancing the profitability and quality of the Eicher 115-honed engine cylinder liner production in the selected foundry unit.

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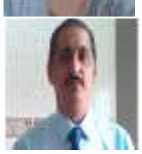

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