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Research Article

Number of Failures during the Piston Ring Manufacturing Process

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ABSTRACT

A perfect circle company (Anand group) is a significant supplier of piston rings to both Indian and international original equipment manufacturers and replacement markets. Factors including production flaws, competitive consumer demand and customer demanded price reductions have pushed the company to change its business strategy to provide high-quality goods at lower costs and shorter lead times. Through quality control techniques, the primary objective is to reduce the defect rate for a piston ring throughout all production processes while enhancing productivity. Recently, investigations into the production process and equipment usage were conducted using QC tools. Based on the collected data, monitoring and data collection calculations were made and analysis was done to determine the key elements contributing to a productivity reduction. An in-depth analysis resulted in a fishbone diagram identifying the many elements impacting the key quality characteristic for another operation. A study on the production process has been published to examine the ongoing manufacturing losses at every stage. Perfect circles India limited (Anand group) has performed comprehensive work in Nashik, Maharashtra, India.

Keywords: Piston rings; Quality control tool; Fishbone diagram; Perfect circles India limited

INTRODUCTION

An IC engine's piston is attached to an open-ended piston ring that slides into a groove on the piston's outer diameter. When it comes to automobile pistons, there are often three rings. The lowest ring controls lubricating oil flow, while the first two are compression rings for compressing seals (oil control ring). The massive number of recent articles about the manufacturing issues with the contacts caused by the piston rings demonstrates how much attention they have gotten over the years. This case study aims to investigate the problem of piston ring manufacturing quality. This piston ring image is taken from perfect circles India limited (Anand group) in Nashik, Maharashtra, India (Figure 1) [1].

Figure 1: Piston rings.

MATERIALS AND METHODS

The largest maker of piston rings, plates and piston ring casting in India is perfect circles India limited. A perfect circle, which was founded in 1976 and has since gained recognition in the Indian automotive sector, is a significant supplier of piston rings to both Indian and international original equipment manufacturers and replacement markets. The business has a technical license with Mahale, engine components, USA, a

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global leader in the automotive sector. The firm makes production plates, a specific part for fuel pumps and transmissions and piston rings, a vital automotive component sold under the global label by perfect circle. The production facilities in Nasik, Maharashtra, are casting, plating and machining plants for piston rings [1]. India's perfect Circle (Anand group) has received certification from bureau veritas quality International, UK, for TS 16949, ISO 14001 and OHSAS 18001 standards.

There are many procedures used to manufacture grey forged iron piston rings. Other ring makers cut the individual ring from pots or cuffs, whereas grey iron piston rings are produced as a single, noncircular ring [1].

Steel piston rings are constructed from a profiled wire initially wound into a circular shape before the gap is cut away. The required type is produced using a heat treatment procedure in which the rings are positioned on an arbour to impart the desired radial pressure distribution [1].

Gases from the combustion chamber were intended to leak into the crankcase through the piston/wall clearance; hence, piston rings were created to contain these gases. A single-piece copper ring with a nominal diameter 10% bigger than the cylinder bore's diameter was used by Rams bottom to build a steam engine. When the ring was put into a piston groove, its inherent elasticity drove it up against the cylinder bore. Miller changed the design such that the inner rim of the ring could be affected by the steam pressure, increasing the sealing force [2]. Piston rings in engines are crucial because they protect the combustion chamber and reduce gas leaks into the crankcase. This not only assists in optimizing the heat transmission from the pistons to the cylinder wall but also helps maintain the necessary oil level, resulting in proper oil consumption and emission controls. Achieving BS-VI emission regulations becomes critically dependent on the radial thickness of such rings. The radial thickness of the rings under control in this inquiry must be kept within the predetermined range of 2.9 ± 0.15 0.1. A narrow tolerance value must be used for the rings to perform as intended throughout production. Their study into the waviness and straightness of piston rings yielded comprehensive data on the influence of manufacturing flaws [3]. Six sigma, cost of poor quality, FMEA, DOE and other strategies have been used to reduce piston ring rejection rates [4]. The requirements for the piston ring as a dynamic seal for linear motion that functions under brutal temperatures and chemical conditions are detailed in piston ring tribology, which is discussed [5]. Several piston rings are utilised depending on the application, including chrome plated, plasma coated and scraper rings.

Several wear resistant Mo composite coatings for piston ring applications have been presented [6]. Heat and melted materials are sprayed onto a surface to create a coating using a thermal spraying technique like plasma spraying. Plasma spraying protects surfaces from wear, corrosion and erosion. Metals, alloys, ceramics, composites and other materials cover the surface. When plasma is sprayed, gas is heated to extremely high temperatures and injected through a nozzle equipped gun as a plasma jet. After being injected into the plasma jet, the mentioned coating material melts and attaches itself to the surface it has coated [7]. While thermal spraying uses a high spraying rate and deposition, plasma spraying is frequently used to enhance the surface of piston rings. A significant level of wear resistance is shown in the molybdenum coatings created by atmospheric plasma spraying [8]. According to friction measurements, Hydrodynamic Lubrication (HL) predominated most of the engine cycle. In 1936, they initially argued for hydrodynamic lubrication between a piston ring and a cylinder liner [9]. Introduce the theory of hydrodynamic lubrication and piston ring analysis [10]. Based on the assumption of a symmetric parabolic curve, the ring's oil coating thickness and friction force were calculated [11]. With a ring profile with a flat centre and two circular arcs at the endpoints, the proposed application of force on the piston ring in the radial direction is thought to be made up of the pressure at the ring's inner side and the elastic pressure of the piston ring.

RESULTS

Quality control is defined as an effective method for integrating the normal development, quality maintenance and quality improvement activities of the various groups in an organization to modify production and repair at the top economic level, allowing maximum client satisfaction. Perfect circle India limited in Nasik is the company finishing the dissertation. The casting facility, the piston ring machining plant and the plate machining plant for perfect circle India are all located in Nasik, which is in the Indian state of Maharashtra. The company manufactures high-quality piston rings for a variety of markets. The corporation concentrates on quality improvement since severe errors and their causes have become unpredictable in recent years. In the dissertation report, the cause and effect diagram is recommended and realistically used.

Modern manufacturing ideas focus on the requirements for a manufacturing organization to manufacture goods successfully and efficiently and are more proactive in design. Modern manufacturing is challenging and it tests a company's ability to provide in the shortest timeframe at the lowest cost without compromising the product's superiority. Organizations must use resources to the best possible capacity and minimise non-value-added operations to operate effectively. The critical aspects, such as setup time, tool life, machine breakdown time, etc., must be managed by an organization to improve production capacity while reducing waste. The essential elements impacting productivity may be chosen using quality control technologies. A thorough investigation was required to improve the overall productivity of the various piston ring production processes.

The detailed work was completed at perfect circles India limited in Nasik, Maharashtra. Through quality control techniques, the primary objective is to reduce the defect rate for a piston ring throughout all production processes while enhancing productivity. Quantitative tools and Total Quality Management (TQM) allow improved decision making, problem solving, product quality and productivity.

Detailed analysis and proposal

Factors including production flaws, competitive consumer demand and customer demanded price reductions have pushed the company to change its business strategy to provide high quality goods at lower costs and shorter lead times. Recently, investigations into the production process and equipment usage were conducted using QC tools. Based on the collected data, monitoring and data collection calculations were made and analysis was done to determine the key elements contributing to a productivity reduction.

The methodology adopted to meet the objective:

- Studies on the production process will be published to examine the on-going manufacturing losses at every stage.
- It is critical to examine all flaws and occurrences during the procedure thoroughly.
- Changes to improve productivity should be recommended to management, along with a cost-benefit analysis.

DISCUSSION

Cause and effect diagram

A fishbone diagram is an analytical tool that looks at effects and the reasons that produce or contribute to those effects in an organized way. A cause and effect diagram identifies and arranges the known or potential cause of quality or lack thereof. There are a variety of views on what causes a problem when using a team approach to issue resolution. The cause and effect diagram may be used to record these many suggestions and encourage the team to explore potential fundamental causes. This diagram is one technique that someone just getting started with process improvement can easily use. The link between variables is depicted in the cause and effect diagram. This figure is influential in group settings and when minimal quantitative data is available for analysis. The usage of cause and effect diagrams in research, production, marketing, office management and other areas is almost limitless. The involvement and input of everyone participating in the brainstorming are some of its key advantages. To address the fundamental reasons and enhance the process, solutions are created. Cost, practicality, resistance to change, effects, training and other factors will be considered while evaluating alternative solutions. Testing and implementation come next after the team has approved the solutions (Figure 2).

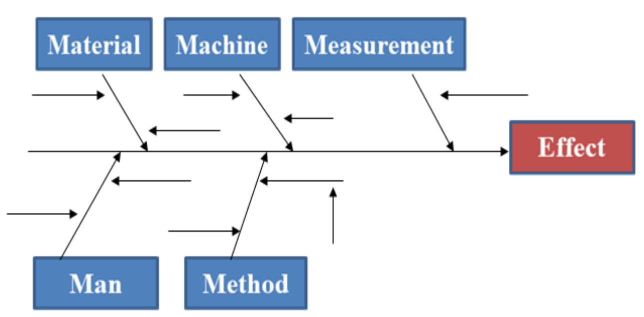

Figure 2: Fishbone diagram.

The fishbone diagram was used for examining real-life situations to enhance the quality of a product or service, make more effective use of resources, keep costs down, reduce factors that lead to nonconforming services and products, complaints from customers and standardization of the proposed and current operations.

Analyze the cause and effect diagram (fishbone diagram)

A cause and effect chart can minimize the possible reasons and help identify which one to focus on first. Look at the "balance" of these diagrams, ensuring that many subcategories have comparable detail.

Flow process chart for the plain ring: We attempted to analyze the proportion of plain ring rejection in percentage form in various manufacturing processes. The flow process diagram revealed that the CBT process had the most incredible plain rejection rate (about 38%), followed by the grinding process (around 22%) and while the missing ring rejection rate (approximately 2%) and laser marking rejection rate (around 3%) had the lowest rates. Procedures cause nearly 60% of all plain ring rejections in manufacturing operations (Figure 3).

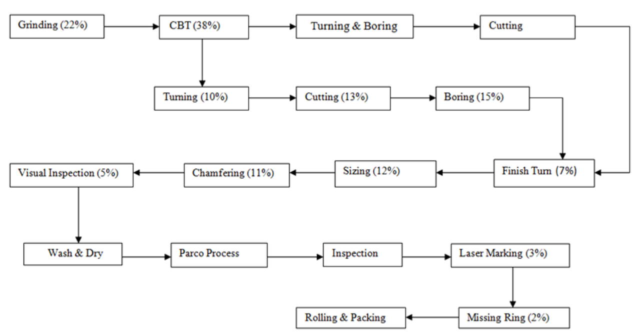

Figure 3: Flow process chart for the plain ring.

Acceptance NOS plan rings: The goal has always been to produce as many high-quality automobile manufacturing parts as possible. Due to the rising demand for certain manufacturing parts, this manufacturer is typically under much pressure. The industry always sets a monthly deadline for component delivery to relieve this burden. Nevertheless, despite our best efforts, we regularly fall short of the monthly output targets we set for ourselves. The graph will help us comprehend our target of monthly producing 8.5 lakh plain piston rings (Figure 4).

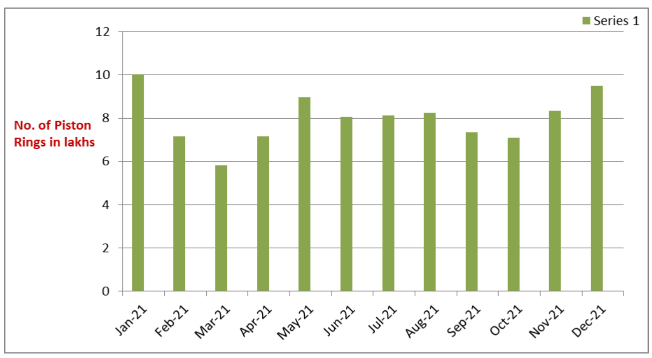

Figure 4: Acceptance NOS plain rings 2021.

We have made an effort to comprehend the deficiency using Table 1. Usually, the term "deficiency" refers to the difference between the expected and actual outcomes. The firm must manufacture at least 8.50 lakh simple piston rings monthly to reach a monthly target. The firm produced approximately 10.4 lakh plain piston rings in January, which is about 1.5 lacks higher than the benchmark. Still, the deficiency rate became negative in the three months that followed and only three times in a year have we been able to produce more plain piston rings than the set target.

Table 1: Deficiency between the set target and the achieved target.

Serial no.	Year	Acceptance in lacks	Deficiency
1	Jan-21	10.04	1.54
2	Feb-21	7.16	-1.34
3	Mar-21	5.81	-2.69
4	Apr-21	7.15	-1.35
5	May-21	8.97	0.47
6	Jun-21	8.07	-0.43
7	Jul-21	8.11	-0.39
8	Aug-21	8.25	-0.25
9	Sep-21	7.35	-1.15
10	Oct-21	7.09	-1.41
11	Nov-21	8.35	-0.15
12	Dec-21	9.48	0.98

Input-output rejections in plain rings: Even though every manufacturing company aims to manufacture perfect, high-quality products, we rarely achieve this while manufacturing parts. As a result, every industry aims to produce as few rejects as possible. According to this, perfect circle company maintains a minimum rejection target below 7% each month, although it has been shown that we see more rejections than 7% every month.

Since the rejection of plain piston rings has exceeded a monthly target, Table 2 illustrates the percentage of rejections achieved during manufacturing each month and the month of January had the highest rejection rate of 8.75% and the highest deficiency rate of 1.75%, while June had the lowest rejection rate of 7.16% and the lowest deficiency rate of 0.16% (Figure 5).

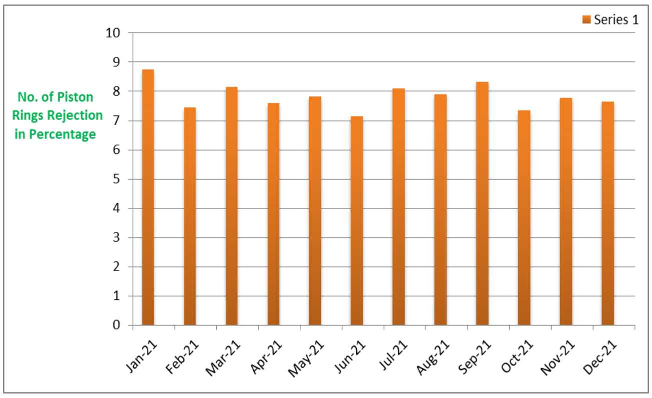

Figure 5: Each month, rejection of plan rings in percentage.

Table 2: A table is shown between the set target of rejection and rejection during the process.

Serial no.	Year	Percentage of rejection	Deficiency
1	Jan-21	8.75	1.75
2	Feb-21	7.45	0.45
3	Mar-21	8.15	1.15

4	Apr-21	7.61	0.61
5	May-21	7.83	0.83
6	Jun-21	7.16	0.16
7	Jul-21	8.1	1.1
8	Aug-21	7.9	0.9
9	Sep-21	8.32	1.32
10	Oct-21	7.35	0.35
11	Nov-21	7.78	0.78
12	Dec-21	7.64	0.64

Total number of rejected rings during manufacturing

We have combined all the data to determine how many rejections there were for the plain piston ring each month.

Table 3 shows how many plain piston rings were manufactured in a month and what proportion was rejected. The highest numbers of piston rings were produced in January, along with the highest rejection rate. However, the lowest piston rings were created in March, although the rejection rate was significantly higher than in the other months except for January and September. The most significant rejection of piston rings was 87850 in January, the lowest rejection was 47351 in March and the average number of rejected plain piston rings in one year was 62667 (Figure 6).

Table 3: Total number of rejected rings during manufacturing.

Serial no.	Year	Acceptance in lacks	% Rejection	Total no. of rejected rings
1	Jan-21	10.04	8.75	87850
2	Feb-21	7.16	7.45	53342
3	Mar-21	5.81	8.15	47351
4	Apr-21	7.15	7.61	54411
5	May-21	8.97	7.83	70235
6	Jun-21	8.07	7.16	57297
7	Jul-21	8.11	8.1	65691
8	Aug-21	8.25	7.9	65175
9	Sep-21	7.35	8.32	61152
10	Oct-21	7.09	7.35	52111
11	Nov-21	8.35	7.78	64963
12	Dec-21	9.48	7.64	72427
Total no. of Average rejected rings			62667	

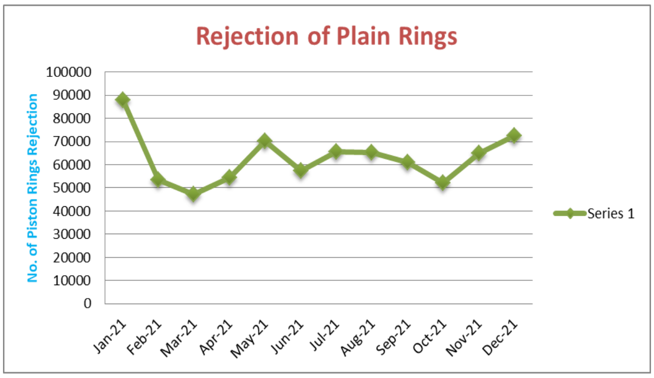

Figure 6: Rejection of plain rings in each month.

Various manufacturing processes in piston rings (plain rings)

Each corporation must go through several steps in producing a product, some of which go to the starting stage and others to the final stage. Every procedure has a percentage of parts that are rejected. The several processes in piston rings are described below and a flow chart for the plain ring is shown in Figure 6.

Table 4 shows the percentage of piston ring estimations in various manufacturing procedures. The most considerable rejection rate was 38% in CTB manufacture (cutting, turning, boring), with 23814 plain piston rings discarded, followed by a 22% rejection rate and 13787 plain piston rings rejected in the grinding process. The lowest 2% and 1253 plain piston rings were removed in the missing ring (Figure 7).

Table 4: Percentage loss in various manufacturing processes in plain rings.

Serial no.	Process	Loss in percentage (Approx)	No. of piston rings rejected
1	Grinding	0.22	13787
2	CTB		
	Turning	0.1	6267
	Cutting	0.13	8147
	Boring	0.15	9400
3	Finish turn	0.07	4387
4	Sizing	0.12	7520
5	Chamfering	0.11	6893
6	Visual inspection	0.05	3133
7	Missing ring	0.02	1253
8	Laser marking	0.03	1880

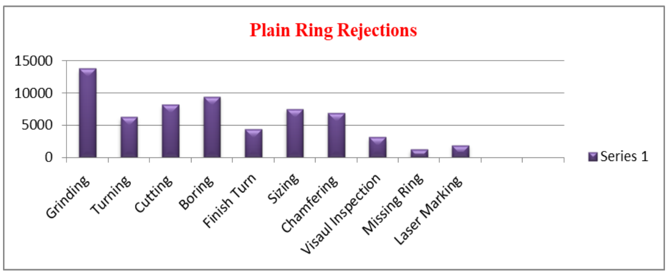

Figure 7: Plain ring rejections according to the various manufacturing process.

The concept of the fundamental fishbone diagram is expanded upon and improved by the cause mapping methodology. The research aims to find the best options to enhance the output and quality of the piston rings. Using the fishbone diagram, Perfect circle India limited aims to increase productivity and quality by around 10% overall.

CONCLUSION

Methods using cause-and-effect diagrams are crucial to determining product or service quality as well as how to monitor and improve it. Experimental design is required to achieve the best configuration for control variables in manufacturing. Fishbone diagrams are helpful tools used with engineering, management and other disciplines to achieve quality, which must be developed into products and services to gain a competitive advantage and increase profitability.

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