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ROOT CAUSE ANALYSIS OF DEFECTS IN AUTOMOBILE FUEL PUMPS: A CASE STUDY

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ABSTRACT

Quality can be directly measured from the degree to which customer requirements are satisfied. Some problems were reported by the customers of the automobile company under study in the fuel pumps; which is used in an automobile to transfer the fuel from fuel tank to fuel injection system after filtration.This paper presents the implementation of Quality Control tools– Check Sheet, Fishbone Diagram(or Ishikawa Diagram), ParetoChartand 5-Why analysis tools for identification and elimination of the root cause/s responsible for malfunctioning of the fuel pump in customers' cars. From the Check sheet and Pareto analysis, two major defects were identified which accounted for more than 80% of the problems being reported. The root causes of these two defects affecting the product quality of the company were then further analyzed using the 5-Why analysis.

Keywords: Quality Control Tools, Ishikawa Diagram, Pareto Chart, 5-Why Analysis

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1. INTRODUCTION

Kaoru Ishikawa, the former professor at University of Tokyo, after being inspired by Quality Guru W. Edwards Deming's lectures, formalized the seven basic Quality Control tools in order to democratize the quality. These tools are Check Sheet, Control Chart, Histogram, Pareto Chart, Ishikawa Diagram, Flow Chart and Scatter Diagram. These techniques are useful in understanding the approaches for identification of deviations from standards and improvement of production processes. These tools act as key indicators of quality and help to identify and hence troubleshoot the problems,ultimately leading to improvement in quality. To enhance the quality, productivity and business, continuous quality and process improvements are required in the organization. Together, all these tools provide excellent techniques of process analysis and tracking that make quality improvements easier to implement, track and review.

The seven basic Quality Control tools are briefly described as follows:

1.1 Ishikawa Diagram

Ishikawa diagram, also known as Fishbone diagram or Cause-Effect relationshipestablishes a diagnostic relationship between potential causes of a problem leading to a particular effect.

1.2 Check Sheet

Check sheet is used for gathering and organizing the data by categorizing the various defects. This is basically employed to collect the raw data which can be further analyzed; using a Pareto chart.

1.3 Pareto Chart

This tool is used for establishing a set of priorities to be dealt with first. It is based on Pareto's 80-20 principle which says that "Almost 80% of the problems can be attributed to only 20% of the causes".It helps to analyze the problem by prioritizing the reasons leading to most of the defects.

1.4 Histogram

To illustrate the frequency and the extent in the context of the two variables, Histogram is used which represents the distribution by mean.

1.5 Scatter Diagram

The Scatter diagram in a Cartesian plane illustrates the correlation between the two variables. From this, further investigation such as a trend analysis can be performed on the values.

1.6 Flow Chart

This chart is implemented to analyze the sequence of events from start to finish with each step of the process being clearly indicated. It is used to understand a complex process and find relationships between the events.

1.7 Control Chart

Control chart is used to track and monitor the performance of a process. Samples are occasionally received, inspected or measured, and thus the results are plotted on the chart. The chart shows how the variation in a specific indicator changes over time.

Besides the above mentioned tools, 5 Why Analysis is also a model to analyze and solve any problem where the root cause is unknown. It was a model first implemented in Toyota Production System by Sakichi Toyoda. This analysis is used to uncover usually a simple or moderately difficult problem by asking "why" in a repetitive manner. For wider ranging method the Ishikawa Diagram is used for the identification of root problem.

2. LITERATURE REVIEW

Goh (2000) outlined the functions of statistical tools and examined the steps in which they are adopted by non-statisticians in industry. A "seven S" approach is explained, highlighting a strategy for the effective deployment of statistical quality engineering. In a manufactured product attainment of superior quality and reliability depends upon the existence of a framework integrating an organization's capabilities in management, technology and information utilization.

Evans and Peters (2005) applied Pareto analysis to test the breadth of appeal of the 2005 Emerald Management 'Xtra' collection of over 100 business and management journals using aggregated usage data gathered from the Emerald web site. The analysis was made on the basis of articles downloaded by all Emerald customers from COUNTER Journal Report 1 Release 1 compliant usage data.

Prajapati and Mahapatra (2007)discussed a very simple and effective design of joint X-bar and R chart to monitor the process mean and standard deviation. The concept of the process chart is based upon the sum of chi-square (χ^2) to compute and compare Average Run Length values (ARLs).They compared the performance of the proposed chart with VSS, VSI and VSSI joint scheme proposed by Costa (1999).

Mazur et al. (2008) evaluated Toyota Production System (TPS) analysis procedure to tackle a medication delivery problem by making use of QC tools like Flow diagram and PDCA Cycle. "5 Whys" tool was utilized as one of the A3 tools for determining the root causes of the problem. The particular advantage of using this tool is that it is iterative since not all problems have a unique root cause. Multiple root causes can be identified by asking different sequences of questions. The 5 Whys analysis can be primarily performed through a Fishbone diagram or a Tabular format. Other A3 tools used to conduct the study included Map-to-Improve (M2I) to complete the process improvement.

Talibet al. (2010) performed Pareto analysis of total quality management factors; critical to success of Service industries. To accomplish this objective, they identified some key factors that contribute to the success of TQM efforts.

Goicoechea and Fenollera (2012) investigated automotive industry so as to establish a significant relationship between the quality tools and various stages of PRP– Product Realization Process. This was aimed at providing support to the organizations when it is required to select some effective quality control tools in accordance with the quality strategy adopted by them. The paper examined and classified various quality tools like Deming (or PDCA) Cycle; Q7; M7 and Planning, Control and Improvement Techniques. They conducted surveys in industries producing entirely different products in order to be consistent with the fact that product type does not affect the type of quality tool chosen. They structured a proper and valuable relationship which shows the type of quality tools to be used at different stages of product development. For example, FMEA to be used to inspect quality in design; Poka-yokes to inspect quality in initial samples; Q7 and 8D Tool to check quality in series; etc. Further, developing a global standard for quality tools to be used at each PRP stage would help industries to identify the quality they are able to establish in their operations.

Aichouni (2012) used basic quality tools to study the manufacturing process of Ready Mix Concrete (RMC) of a construction company. The Histogram tool brought to highlight the variations in the concrete compressive strengths being delivered which were found to exceed the process targets, thus, indicating towards over-designed mixtures. This variability in concrete was further analyzed with the help of a Cause-Effect diagram from which the reasons leading to concrete variability were identified. Apart from this, he employed Control charts to figure out that production processes were out of statistical control and hence narrowed down an assignable cause influencing the production process and quality of concrete. From this case, he concluded that the seven QC tools demonstrate a great capacity to improve processes in manufacturing industries on account of their ability to provide diagnostic information and their effectiveness in defects and errors prevention.

Magar and Shinde (2014) reviewed the seven Quality Control tools to give a systematic approach for the implementation of each tool to analyze and ultimately improve the quality levels in manufacturing processes. They established an easy to implement and step-by-step procedure for collection and analysis of data related to quality issues, identification of their causes and measurement of results using 7 QC tools– Pareto Chart, Ishikawa diagram, Histogram, Check sheets, Scatter diagram, Control charts and Flow charts. Besides, they also suggested steps for a Plan-Do-Check-Act (PDCA) Cycle for effective implementation of QC tools. With the help of a statistical quality control in place, the problem solving skills of the management can be improved.

Vante and Naik (2015) applied the Pareto Analysis, Ishikawa Diagram and Why-Why analysis to solve the problem of variations in dimensions in 3 cylindermetric block castings. It was identified that variation in dimension of casting wall thickness was the major defect that lead to the rejection of casting block.The analysis of root cause in detail resulted into the permanent action to be implemented for the problem. The successful implementation of the permanent action reduced the rejection rate of casting thus improving the quality of the product.

Sharma et al. (2016) furnishes a good example of putting into practice these 7 QC tools by attempting to reduce defects in aluminum alloy wheel casting. The study used a diagnostic approach to reach the root cause of major defects in aluminum casting in a systematic manner. Initially, Pareto’s 80-20 rule was followed to identify the major casting defects– shrinkage, porosity, cracks and inclusion– leading to as much as 86% of rejections of alloy wheels. Control chart between molten metal temperature and specific gravity gave way to reduce porosity defect. Also, by using Histogram, shrinkage defect was observed to be more for hub than for rim and spokes. Check sheets enabled them to collect data regarding the number of rejections. On the whole, the study well illustrates the use of 7 QC tools.

Perera and Navaratne (2016) assessed the raw material waste generation of powder filling and packing process through Pareto analysis and Fishbone diagram. After identifying that overfilling alone contributed to 91% of waste generation, it became the centre of study and further Fishbone diagram was constructed to find the root cause of this high bulk powder waste. Other key root causes identified during Cause-Effect analysis included high number of dry/wet cleaning and lack of focus among operators. This was followed by a Why-Why Analysis of key root causes to test their underlying reasons and this helped to develop a Corrective and Preventive Action (CAPA) Plan to mitigate the major causes of waste generation.

3. ABOUT THE INDUSTRY

The automobile industry under consideration is one of the biggest automobile industries in the world. The particular plant in which study was conducted is situated in western part ofthe India. It manufactures automobiles in the category of passenger vehicles. The fuel pump used in the passenger vehicle of the company is an out-sourced part; manufactured by a different supplier. The dealers of the company’s cars used to replace the defected fuel pump in customers’ cars with the new one. The defected fuel pumps were then received back at the plant for analysis purpose.

4. FUEL PUMP ASSEMBLY

A pumping unit, DC motor (usually permanent magnet) and an end support for electrical and hydraulic pipe connections form the major components of an electric fuel pump generally employed in an automobile. A pump housing, folded at the edge, holds the entire fuel pump assembly.

The fuel pump intakes fuel from the fuel tank. The fuel pressure is increased to specified value by compression (by gerotor) or transfer of momentum (by turbine) which is controlled by a pressure regulator. Then, the fuel pump transfers the fuel at a higher pressure to the engine fuel injectors through supply lines. A pressure regulator sets the fuel pressure. It consists of an air chamber, a diaphragm with relief valve assembly and a regulator spring. As the fuel injector spray tip is exposed to regular changes in the pressure of air inside intake port, the regulator varies fuel pressure and hence, maintains a constant pressure drop across the fuel injector.Relief valve prevents the rise of excessive pressure in case the fuel lines are blocked. Besides, a check valve is incorporated to isolate the system when the pump is turned off.
The delivery mechanism of a fuel pump in an automobile is shown in Fig. 1.

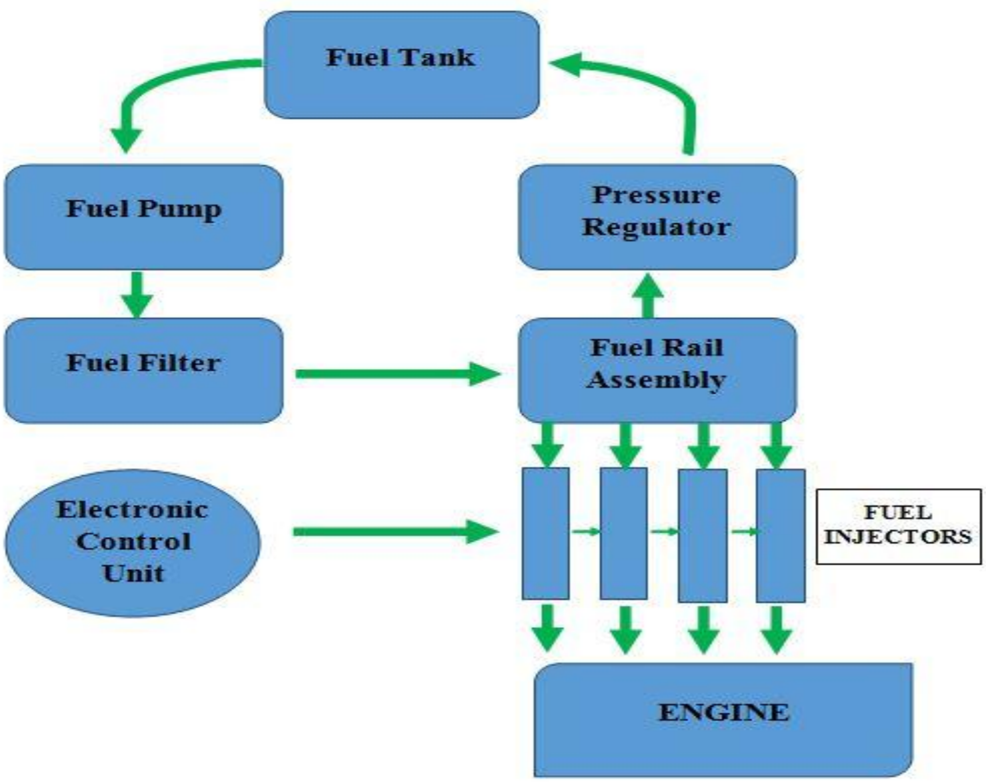

Fig. 1: Fuel pump delivery system

5. ANALYSIS

In this research, the root cause analysis of the problems in the fuel pump has been conducted. The quality issuesare identified after the voice of customers is noted, which is nothing but a feedback of the problem from the customers. Fuel pump is an automobile component that pumps the liquid fuel to fuel injection system of the engine from the fuel tank. It pushes or pumps fuel from the gas tank to the fuel injector or carburetor. It creates the adequate amount of pressure to ensure that the required amount of fuel shall be supplied to the engine, regardless of external conditions.The 47 numbers of fuel pumps were received back from the dealers in February 2016; which were still in warranty period. The data regarding the quality issues were then gathered through Voice of customers. An analysis of those 47 fuel pumps was performed in the plant; using various quality control tools, including Cause-Effect diagram, Checksheet, Pareto analysis and 5-Why analysis, and presented in the following section:

5.1 Fish-Bone Diagram/Ishikawa Diagram

A fish bone diagram is presented in order to find the causes of the effect. In this study, various men, materials, methods, equipments, environment causes have beenanalyzed against the effect of defective fuel pumps and the resulting Ishikawa diagram is shown inFig. 2.

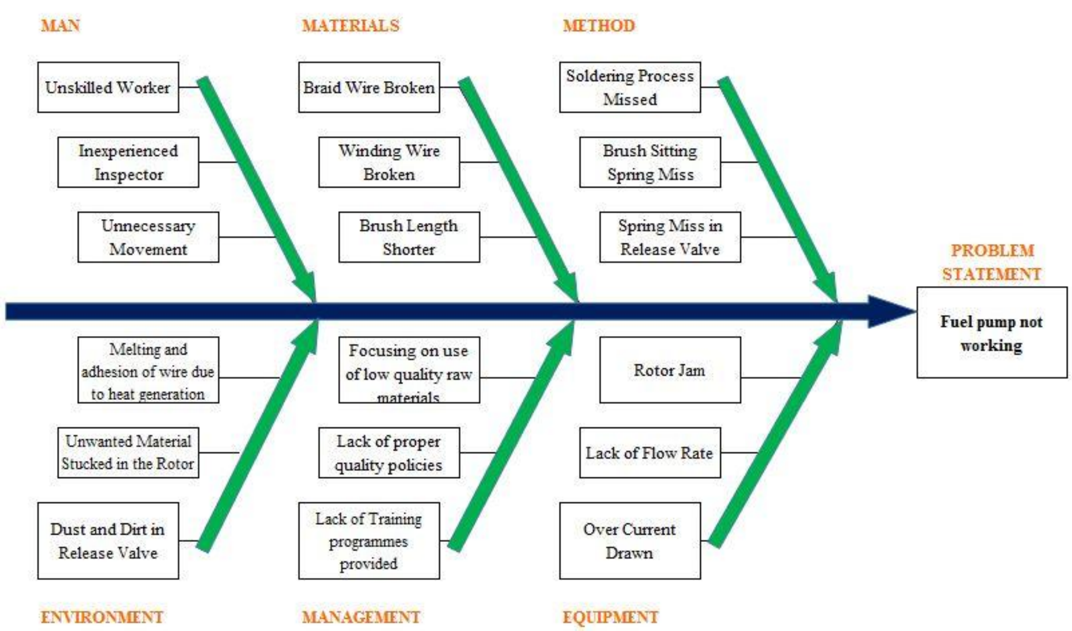

Fig 2: Fishbone diagram for defective fuel pumps

5.2 Check Sheet

The number of occurrence of each effectin the fuel pumps i.e. the frequency of defects is gathered and organized using the Check sheet; shown in Table 1.

Table 1: Check Sheet of the defects

Defects	No. of Defects	Frequency of Defects
Positive brush length shorter than specifications	~~||||||||||||||||~~ |	21
Negative brush length is shorter than specifications	~~||||||||||||~~ ||	17
Winding wire broken	||||	4
Over current in vehicle system	||	2
Winding wire short circuit	|	1
Soldering process missed	|	1
Dust on release valve	|	1
Total		47

5.3 Pareto Chart

The data obtained from the Check sheet was further employed for the construction of Pareto Chart. Pareto analysis helped to identify and prioritize two major defects–Positive Brush length- shorter than specification and Negative Brush length- shorter than specification, contribute about 81% of the defective fuel pumps.

The Pareto analysis of various defects is represented in Table 2 and Fig. 3.

Table 2: Percentage of the defects

Defects	Frequency of Defects	Cumulative Frequency	Percentage
Positive brush length shorter than specifications	21	21	44.68 %
Negative brush length is shorter than specifications	17	38	80.85 %
Winding Wire Broken	4	42	89.36 %
Over Current in Vehicle System	2	44	93.62 %

Winding Wire Short Circuit	1	45	95.74 %
Soldering Process Missed	1	46	97.87 %
Dust on Release Valve	1	47	100.00 %

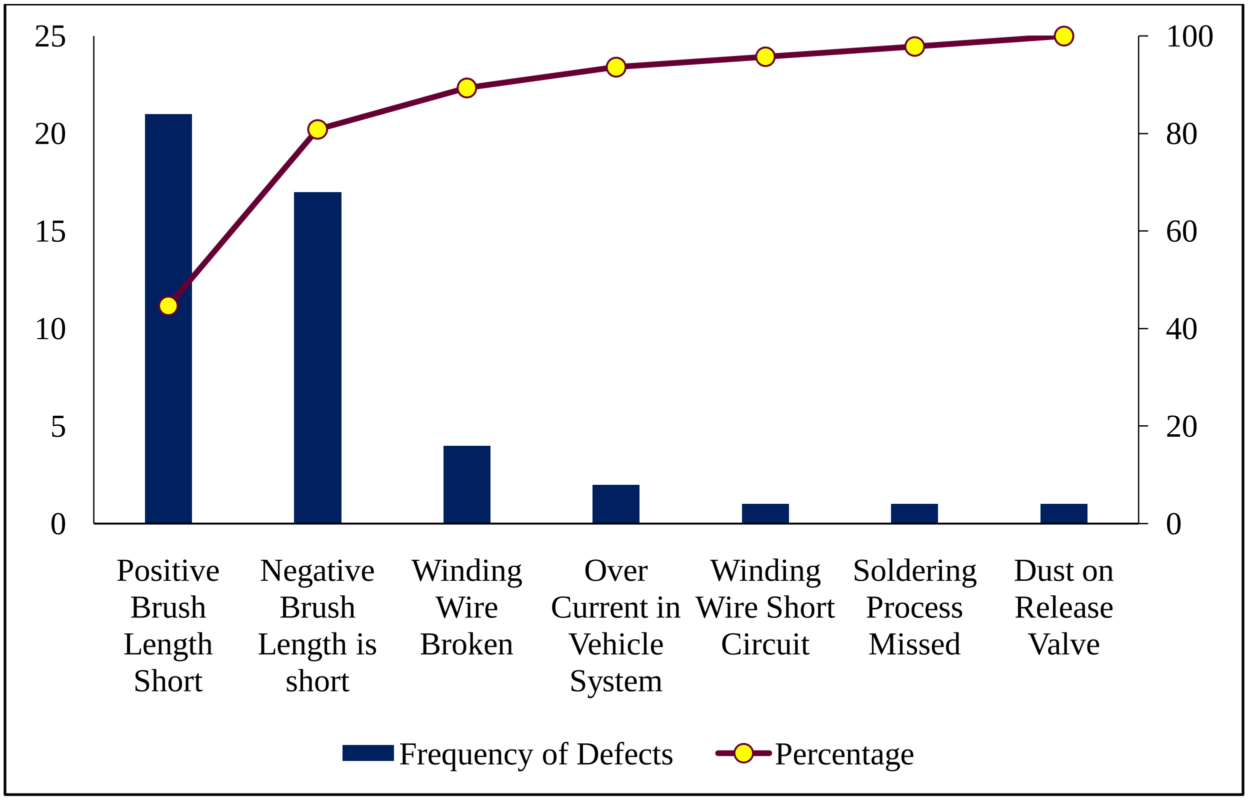

Fig 3: Pareto Diagram for defects analysis

5.4 Why-WhyAnalysis

The Why-Why analysis wasalso done in order to identify the root cause of the two major defects which was identified using Pareto chart. These "whys" were posed to concerned people in management and workers to obtain precise reasons behind the defects.Table 3 shows the 5 Why's for Positive Brush length and Table 4 shows the 5 Why's for negative Brush length.

5.4.1 Root Cause 1: Positive Brush Length

Table 3: Root Cause Analysis of Positive Brush Length Shorter than Specifications

Why 1	Fuel Pump isn't working

Why 2	Positive brush length is shorter than specification
Why 3	Wear out of positive brush is caused with use of product
Why 4	Arcing on positive side leading to wear
Why 5	Low resistance of brush leading to high arcing
Root Cause	Low resistance of brush leading to high arcing

5.4.2 Root Cause 2

Table 4: Root Cause analysis of Negative Brush length-shorter than specifications

Why 1	Negative brush length is shorter than specifications
Why 2	Brush wear out with use of product
Why 3	High current flow through the brushes
Why 4	Short circuit (Hypothesis): “Coil to armature” or “Coil to Coil”
Why 5	Insulation of wire is insufficient
Root Cause	Insulation of wire is insufficient

6. RESULTS AND DISCUSSION

It was observed from the Fishbone diagram and Check sheet that brush length is shorter than the specified, winding wire broken, over current drawn, winding wire short circuit, soldering process missed and dust in the release valve are the main causes for the defective Fuel pumps.

Further, a Pareto analysis of these causes identified from Cause-Effect relationship, the two major defects– ‘Positive brush length’ and ‘negative brush length’ contributed to more than 80% of the total returned and defected fuel pumps.

As a next step, the root causes of these two major defects were determined through implementation of the 5 Why’s tool. Low resistance of brush leading to high arcing was identified as the root cause of positive brush length being shorter than specified length and insufficient insulation of wire was identified as the root cause of negative brush length being shorter than specified length.

The concerned authorities have been conveyed these suggestions to eliminate the root causes of the defects resulting in operational-level malfunctioning in most of the automobile fuel pumps. The implementation of a preventive action shall definitely lead to reduce the defects in fuel pumps which shall improve the product quality.

7. CONCLUSION

All manufacturing firms aim for the continuous improvement of the products in order to provide complete customer satisfaction which depends on an un-interrupted part functioning. Seven Quality Control tools and 5-Why Analysis are important instruments in order to analyze defects in quality of products of the organizations at customer operation levels. By implementing these tools, manufacturing as well as service organizations can clearly identify the ground reasons affecting their quality levels and can take necessary steps to reduce the short-comings and enhance their product or service quality.

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