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APPLYING THE SEVEN BASIC QUALITY TOOLS TO SOLVE A QUALITY ISSUE IN THE MANUFACTURING OF ELECTRONIC SWITCHES

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Abstract: The manufacturing process of electronic switches involves a complex set of operations that can give rise to various quality issues. In this paper, we present a case study in which a small advisory & consulting company applies the seven basic quality tools to solve a quality issue in the manufacturing of electronic switches. The case study demonstrates how the cause-and-effect diagram, check sheet, control chart, histogram, Pareto chart, scatter diagram, and stratification can be used to identify, analyze, and solve quality issues. The paper provides a detailed description of the materials and methods used in the case study, as well as the results and discussions of the application of the seven basic quality tools. The case study shows that the tools were effective in identifying the root cause of the quality issue, analyzing the data, and suggesting solutions to improve the manufacturing process of electronic switches. The paper concludes that the seven basic quality tools are essential for any organization that seeks to improve its quality management processes and maintain a competitive edge in the market.
Keywords: Seven Basic Quality Tools; Process improvement; Electronic switches; Manufacturing, Case study.

INTRODUCTION

Electronic switches are a type of electrical component that are commonly used in a wide range of consumer electronics devices, such as smartphones, tablets, laptops, and other digital devices. They are designed to control the flow of electrical current in a circuit, allowing the device to turn on or off, or to switch between different modes of operation. Electronic switches are typically small and lightweight, and are often made from semiconductor materials such as silicon or gallium arsenide.

Electronic switches are used in a variety of applications, ranging from simple on/off switches in household appliances to complex control systems in industrial automation and robotics. They are particularly important in the field of electronics, where they are used to switch between different modes of operation in devices such as computers, smartphones, and digital cameras. Electronic switches are also used in automotive applications, where they are used to control various systems such as the lights, windshield wipers, and engine management.

In addition to their use in consumer electronics and automotive applications, electronic switches are also used in a variety of other industries, including aerospace, telecommunications, and medical devices. For example, electronic switches are used in aircraft control systems to control the flow of hydraulic fluid and other fluids, and in medical devices to control the flow of fluids and gases in patient monitoring and treatment systems. With their ability to control the flow of electrical current in a precise and reliable manner, electronic switches are a critical component in many different types of technology and applications.

Electronic switches can be broadly categorized into two main types: mechanical switches and solid-state switches. Mechanical switches are physical switches that operate by moving a mechanical contact to make or break an electrical connection. These switches can be further categorized based on their specific design and operating mechanism, such as push-button switches, rocker switches, toggle switches, and rotary switches. Mechanical switches are commonly used in a variety of applications, including industrial machinery, automotive systems, and home appliances.

Solid-state switches, on the other hand, do not have any moving parts and operate using semiconductor devices such as transistors, diodes, and thyristors. These switches can be used to control electrical power and are commonly used in applications that require high switching speeds, high reliability, and long service life. Solid-state switches are further classified into various types based on their specific configuration and operating characteristics, such as power MOSFETs, insulated gate bipolar transistors (IGBTs), and silicon-controlled rectifiers (SCRs). Solid-state switches are commonly used in applications such as power supplies, motor control, lighting control, and electronic devices.

In the end of 2021, the management of the Brazilian electronic switch manufacturing company had been facing a significant issue. They had observed an increase in customer complaints about defects in their products. That sudden surge in defects has had a substantial impact on the sales and revenue of the company, and the management was very concerned about the company's reputation. The company has been producing high-quality products for years, but that current scenario has made the management aware of the need to add more resources to improve monitoring and maintaining the quality of their products to remain competitive in the market.

As the management was aware, maintaining quality standards is vital in the manufacturing industry. Customers demand products that are free from defects and meet their expectations, and this has become even more critical in recent times. With the increasing use of technology in consumer electronics personal and industrial devices, electronic switches have become a critical component of these products. Any defect in an electronic switch can have a substantial impact on the functioning of the device, leading to customer dissatisfaction and a decline in sales. Hence, it is essential for the management to identify the root cause of the defects and implement necessary measures to resolve the issue, ensuring the production of high-quality products that meet customer expectations.

In response to the decline in sales and revenue caused by customer complaints about defects in their switches, the management of the electronic switch manufacturing company decided to hire a specialized advisory and consulting company to investigate the quality issues. It was during the Operations Management classes in the Mechanical Manufacturing Technology faculty at Fatec Mauá in 2015 that the Quality Manager of the company met the main author of this paper, who happened to own a consultancy company. Given the Quality Manager's familiarity with the professor's company, it was decided to hire the advisory and consulting company to perform the end of 2021 quality issues analysis.

The advisory and consulting company, working with company´s employees, utilized a structured quality issues solving framework that is based on the seven quality tools to identify potential areas for improvement in the production process. Through a detailed analysis of the raw materials, manufacturing equipment, quality control procedures, testing, and inspection protocols, the team identified several sources of variation that could be contributing to the defects in the switches. To avoid any confusion, it is worth noting that whenever the word "team" is mentioned in this paper, it refers to the collaboration between the consulting company and the plant personnel.

The collaboration between the electronic switch manufacturing company and the professor's consulting company resulted in the successful resolution of the quality issues. The experience was deemed so valuable that both parties agreed to write a technical paper to share the experience with other students. However, due to liability concerns, a confidentiality agreement was signed to agree on what specific information could not be disclosed. The company's high management allowed the numerical data to be shared if it was de-characterized to maintain confidentiality.

The purpose of this collaboration was to demonstrate to the students the importance of quality management tools in the professional life of technical professionals who work in manufacturing and service providers companies. Quality management is part of the syllabus of the Operations Management classes, and while the professor was writing the technical paper in 2023, he mentioned this case study to his current students. Some students expressed interest in participating in the process of writing the technical paper and volunteered to co-author it to experience a real-world application of quality management tools. Moreover, they volunteered to pay the publication fees to ensure that the paper is open access and can reach as many students as possible.

This technical paper highlights the practical application of quality management tools to identify the root cause of defects in the electronic switches and provide recommendations for process improvement. The paper aims to provide valuable insights to the students, academia, and industry professionals who are interested in quality management and process improvement. It demonstrates how a structured problem-solving framework, based on the seven quality tools, can effectively identify and address quality issues, and how collaboration between technical professionals and consulting firms can result in successful outcomes. Additionally, the paper aims to demonstrate the usage of the online templates provided free by the American Society for Quality (ASQ).

This article is divided into 8 sections, 6 of which are numbered.

Section 1 "Introduction" presents the introduction to the paper, which includes the background information, the problem statement, and the objectives of the study.

Section 2 "Contextualization and Description of Quality Problems" provides the contextualization and description of the quality problems faced by the electronic switch manufacturing company in Brazil, including the complaints received from customers and the decline in sales and revenue.

Section 3 "Literature Review" covers the literature review on quality management tools and techniques, including their importance in identifying and solving quality problems in manufacturing and service industries.

Section 4 "Materials and Methods" describes the materials and methods used in the study, including the data collection methods and the quality management framework based on the seven quality tools.

Section 5 "Results and Discussions" presents the results and discussions of the study, including the root cause analysis of the defects in the electronic switches and the recommendations for process improvement. This section also includes the numerical data sets, which have been de-characterized to ensure confidentiality while still being representative of the trends and factors that contributed to the quality problems.

Section 6 "Conclusions" provides the conclusions and implications of the study, including the practical application of quality management tools in solving real-world quality problems and the importance of quality management in the professional life of technical professionals.

Section 7 "Acknowledgments" is not numbered and includes the acknowledgments, which recognize the contributions of individuals and organizations that supported the study.

Finally, Section 8 "References", which is not numbered, lists the references cited in the paper, which includes the sources used for the literature review and other relevant works.

CONTEXTUALIZATION AND DESCRIPTION OF QUALITY PROBLEMS

In this chapter, we provide a full description of the manufacturing scenario, specifically the components produced in the plant. We then focus on the issues that rotary switches were having, which we chose to investigate because they contain more mechanical parts than the other switches. We explain where the rotary switches are used and what issues they are causing for customers.

MANUFACTURING SCENARIO

The manufacturing plant produces a variety of electronic components, including switches, capacitors, and resistors. The plant uses automated assembly lines to manufacture these components, with a group of skilled technicians responsible for monitoring the process and ensuring that the components meet the required specifications.

FOCUS ON ROTARY SWITCHES

Of all the components manufactured in the plant, we chose to focus on rotary switches due to their mechanical complexity. Rotary switches consist of multiple rotating parts that need to work seamlessly for the switch to function correctly. We discovered that these switches were causing quality problems, which prompted us to investigate the root cause of the issues. In order to preserve the confidentiality of the manufacturing plant, a generic picture of a rotary switch is presented in Figure 1.

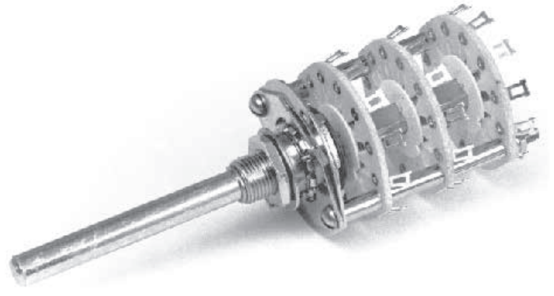

Figure 1 - Three-deck rotary switch allows controlling three different circuit functions (WIKIPEDIA, 2023)

USAGE OF ROTARY SWITCHES

Rotary switches are used in a variety of electronic devices, including audio equipment, amplifiers, and control panels. They are preferred over other types of switches because of their ease of use and durability. However, the quality problems associated with rotary switches have resulted in customer complaints, which have affected the reputation of the manufacturing plant.

ROTARY SWITCHES GLOBAL MARKET CHARACTERIZATION

In order to provide an outlook of the global market, we will characterize the importance of a rotary limit switch. It is a type of rotary switch that is designed to detect the presence or absence of an object or limit its range of motion through a mechanical contact mechanism. The switch typically consists of a rotating cam or lever arm that makes contact with one or more fixed electrical contacts as it rotates, signaling a change in state or triggering a control action. Rotary limit switches are widely used in industrial applications, such as machine tools, conveyor systems, cranes, and elevators, to provide precise position sensing and control in harsh environments.

Rotary switches play a critical role in many industrial applications, providing a reliable method of controlling various processes and operations. The global rotary limit switch market is expected to see significant growth over the next few years, driven by the increasing demand for these devices in various industries, including manufacturing, energy, and transportation.According to Persistance Market Research (2022), at the end of 2021, the revenue generated from the global rotary limit switch market amounted to US$ 850.4 million, and it is projected to reach US$ 1.51 billion by the end of 2032, with a compound annual growth rate (CAGR) of 5.5%. The report scope covered the folliwng countries: U.S., Canada, Brazil, Mexico, Germany, U.K., France Italy, Spain, Russia, Nordics countries, China, Japan, South Korea, Indian, The Association of Southeast Asian Nations (ASEAN), Australia, New Zeeland, Gulf Cooperation Council (GCC) Countries, Turkey, Northern Africa, South Africa. The following key companies were profiled in the report: Honeywell International, Schneider Electric, ABB, Eaton, Siemens, OMRON Corporation, Crouzet, Rockwell Automation, Panasonic, Hubbell, Schmeral, Pizatto Elettrica Inc., Azbil Corporation.

The growth of the rotary limit switch market is primarily attributed to the increasing adoption of these devices in the industrial sector, where they are used in various applications such as conveyor systems, cranes, and industrial machinery. These devices are designed to provide precise control over the movement of mechanical components, ensuring the safety and reliability of the entire system. Additionally, the rising demand for automation in various industries is expected to further boost the demand for rotary limit switches, as they are a critical component in automated systems.

ISSUES WITH ROTARY SWITCHES

The quality problems associated with rotary switches include intermittent or complete failure, mechanical noise, and inconsistent operation. These issues have caused frustration among customers, resulting in a decrease in sales and a negative impact on the plant's reputation.

FLOWCHART OF COMPONENT MANUFACTURING

The manufacturing process for rotary switches starts with the assembly of the individual parts, including the base, contacts, and rotating mechanism. The parts are then tested for functionality and consistency before being assembled into the final product. Once assembled, the rotary switches are tested again for quality assurance. After this process, the finished products can be shipped. A high-level flowchart for manufacturing process for rotary switches is depicted in Figure 2.

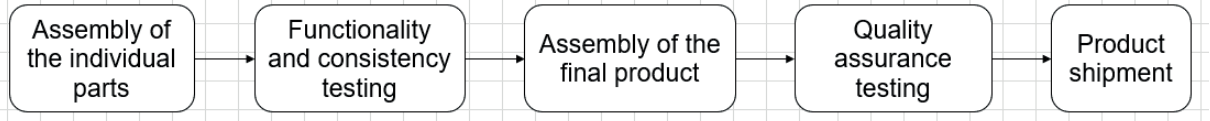

Figure 2 - High-level flowchart for manufacturing process for rotary switches

Please note that some of the information regarding the manufacturing process may be intentionally omitted or changed to preserve confidentiality.

INVESTIGATION PLAN RATIONALE

To address the quality problems associated with rotary switches, team created an investigation plan using a sequence of quality tools. Team started by conducting brainstorming sessions to identify potential root causes. A cause-and-effect diagram was the outcome of the sessions and allowed the creation of list all of the components of the production process and their potential interactions that could be causing the defects. Then the team used the check sheet to collect data on the frequency and severity of the defects.

Using this data, the team created a control chart to monitor the process over time and identify any patterns or trends. Team noticed that there is a significant amount of variation in the production process, which could be contributing to the defects.

To further analyze the data, the team created a histogram to visualize the distribution of defects and identify any outliers. Team also created a Pareto chart to identify the most significant factors contributing to the defects.

Using the scatter diagram, the team analyzed the relationship between different variables in the production process, such as temperature and humidity, to identify any correlations that could be contributing to the defects

Finally, the team used stratification to organize the data and look for patterns in the different sources of data, such as production shifts or raw materials.

After analyzing the data using all seven quality tools, the advisory team presented their findings to the manufacturing company's management team. They recommended several changes to the production process, including modifying the manufacturing equipment, adjusting production schedules, and providing additional training to the production staff.

The manufacturing company implemented the recommended changes and began noticing a significant reduction in defects and an improvement in overall product quality. The advisory team's use of the seven quality tools was critical in identifying the root cause of the problem and developing an effective solution.

LITERATURE REVIEW

In this chapter, we present a brief literature review of the quality tools used in the investigation of the rotary switch quality issues. The tools were deployed in a structured problem-solving framework, based on the seven quality tools. The sequence in which the tools are presented does not imply their level of importance or the order in which they must be used to address other quality issues. It is important to note that the purpose of this chapter is not to provide an in-depth guide on how to use each tool, but to give a general overview of the literature on the tools used in the investigation. The main objective is to demonstrate the practical application of quality management tools in addressing the rotary switches manufacturing quality issues.

The seven quality tools, also known as the seven basic tools of quality, are a set of techniques used to identify, analyze and solve quality problems. The seven tools are: Cause-and-Effect Diagrams, Control Charts, Flowcharts, Histograms, Pareto Charts, Scatter Diagrams, Check Sheets. These tools were first introduced by Kaoru Ishikawa, a Japanese quality control expert, in the 1960s. Depending on the literature consulted, stratification is sometimes considered as one of the seven basic quality tools, replacing either the flow chart or check sheets.

It is worth noting that brainstorming is not considered one of the seven quality tools, but it is often used in quality improvement initiatives. Brainstorming is a group problem-solving technique that encourages participants to generate a large number of ideas in a short period of time. In this case, the team used brainstorming to generate potential causes for the quality issue being investigated, and then further analyzed these potential causes using the seven quality tools. While brainstorming is not one of the seven basic tools of quality, it is still a valuable technique that can be used in conjunction with the seven tools to identify and solve quality problems.

The last section of the literature review is based on a research conducted in scientific databases to identify technical articles that investigated quality issues specifically in rotary switches (BARTOSH, 1969).

BRAINSTORMING

Brainstorming was invented by Alex Faickney Osborn, an American advertising executive, in the late 1930s. He first introduced the concept in his book "Your Creative Power" published in 1940. Osborn was convinced that groups could generate more and better ideas than individuals alone, and thus, he developed a structured approach to stimulate creative thinking among groups (DANES *et al.*, 2020).

Brainstorming is a technique used to generate a large number of ideas in a short amount of time. It is a group activity that involves encouraging participants to freely express their ideas without fear of criticism or judgment. The process usually starts with a problem statement or a specific goal, and then the group generates as many ideas as possible, building on each other's suggestions. The ideas are not evaluated or analyzed during the brainstorming session; instead, the focus is on the quantity of ideas generated (GINOCCHIO *et al.*, 2022).

Brainstorming is an important tool in manufacturing quality investigations because it allows for the generation of a wide variety of ideas that may not have been considered otherwise. It encourages team members to think outside of the box and challenge traditional ways of doing things. Brainstorming can be particularly useful in identifying the root cause of a quality issue by exploring all possible causes and solutions (PROTZMAN, 2022). Additionally, it can improve team collaboration and communication, as everyone has a chance to contribute their ideas (TSIPURSKY, 2022).

FLOWCHART

The flowchart tool was invented by Lillian and Frank Gilbreth in the early 1920s. Lillian Gilbreth (1878-1972) was an American industrial engineer and psychologist. She was a pioneer in the field of industrial engineering and is known for her work in time and motion studies, as well as her contributions to human factors engineering. Frank Gilbreth (1868-1924) was an American engineer and management consultant who became known as the "Father of Motion Study." Gilbreths developed the flowchart as a visual representation of the steps involved in a process, allowing for easier analysis and optimization of the process (GILBRETH; GILBRETH,1921). Their work on motion study and process optimization has been highly influential in the fields of industrial engineering and management.

A flowchart is a graphical representation of a process or workflow. It uses symbols to represent the different steps in the process and arrows to indicate the flow or direction of the process. There are many different symbols that can be used in a flowchart, each representing a different type of step or decision point in the process. Flowcharts can be used to analyze and improve existing processes, as well as to design new processes (KENT, 2017).

Flowcharts generally flow from top to bottom and left to right. The American National Standards Institute (ANSI) set standards for flowcharts and their symbols in the 1960s, which were later adopted by the International Organization for Standardization (ISO) in 1970. The most recent revision of the standard, ISO 5807, was completed in 1985. This standard was last reviewed and confirmed in 2019. Therefore, this version remains current (ISO 5807:1985).

Flowcharts are an important tool for manufacturing quality investigations because they allow for a clear and detailed analysis of the manufacturing process. By breaking down the process into individual steps and visualizing the flow of materials and information, it becomes easier to identify areas of potential improvement or sources of defects. Flowcharts can also be used to communicate the manufacturing process to others, such as new employees or suppliers, helping to ensure consistent quality and efficiency (BABU, 2012).

CAUSE-AND-EFFECT DIAGRAM

The cause-and-effect diagram, also known as the fishbone diagram, was first developed by Dr. Kaoru Ishikawa (1915-1989), a Japanese engineer and quality control expert in the 1960s. He introduced the tool as a quality control method to identify and organize potential causes of a problem and its effects, allowing teams to analyze and solve complex problems effectively (ISHIKAWA, 1985).

The cause-and-effect diagram is a tool used to identify and analyze the potential causes of a problem or effect in a systematic way. The diagram takes the form of a fishbone-shaped chart, with the head representing the effect or problem and the branches representing the potential causes. The causes are typically organized into categories, such as people, process, equipment, and materials, and are connected to the main branch to show the relationship between the cause and the effect (ISHIKAWA, 1968).

The cause-and-effect diagram is a valuable tool for manufacturing quality investigations because it allows teams to identify potential causes of problems or defects and to prioritize them based on their impact on the process or product. The tool facilitates a structured approach to problem-solving and decision-making, which can lead to more effective and efficient solutions (AGRAWAL, 2021). By involving team members from various departments and levels of the organization in the analysis, the cause and effect diagram promotes collaboration and a shared understanding of the problem, leading to a better quality outcome (LAMAN, 2022).

CONTROL CHART

Walter Andrew Shewhart (1891-1967), an American physicist and engineer, is credited with the development of the Control Chart. Shewhart introduced the concept of statistical process control (SPC) in the late 1920s, and the Control Chart became one of the key tools in SPC. Shewhart's work laid the foundation for the development of modern quality control techniques (TAGUE, 2005).

A Control Chart is a statistical tool used to monitor and control a process. It is used to detect whether a process is stable or unstable and to identify sources of variation in the process. The Control Chart plots data over time and compares it to pre-determined control limits. The chart has a centerline representing the process mean and upper and lower control limits (UCL and LCL) representing the boundaries within which the process should operate. Data points falling outside of these limits indicate that the process is out of control and action needs to be taken to identify and eliminate the source of variation (MONTGOMERY, 2019).

The Control Chart is an important tool in manufacturing quality investigations because it allows for continuous monitoring and control of a process. By monitoring the process over time, the chart can detect when the process is out of control and identify the source of the problem (ISNIAH; PURBA, 2021). This allows for timely intervention and correction before defects are produced.

The Control Chart can also be used to track improvements in a process after changes have been made. This allows for continuous improvement and optimization of the manufacturing process (KING, 2017).

HISTOGRAM

The histogram was first introduced by Karl Pearson (1857-1936), a British mathematician, and statistician in 1895. Pearson developed the concept as a method of illustrating the frequency distribution of a set of continuous data (STIGLER, 2008). The term "histogram" is not related to the word "history" and the link to the Greek ἱστός (mast) confirms that Karl Pearson, who coined the term, used a clearly defined method to designate recently devised graphs (RUFILANCHAS, 2017).

A histogram is a graphical representation of the distribution of a dataset. The data is divided into intervals, called bins, and the number of observations falling in each bin is represented by the height of a bar (PEARSON, 1894). The histogram allows for quick visual interpretation of the shape of the distribution, including information on the center, spread, and skewness. The histogram is a valuable tool for identifying patterns and trends in data (KAPOOR *et al.*, 2018).

In manufacturing quality investigations, histograms can be used to assess the quality of a product or process. By plotting the frequency distribution of a critical quality parameter, the histogram can provide insight into the variability and consistency of the manufacturing process. Deviations from a normal distribution or shifts in the mean value can be detected through the use of histograms, enabling the identification of potential quality problems. The histogram can be used as a process monitoring tool, allowing for the identification of trends and patterns in the data, and facilitating the implementation of process improvements (COLLINS, 2002).

PARETO CHART

The Pareto Chart is named after Vilfredo Federico Damaso Pareto (1848-1923), an Italian economist and sociologist who first observed the 80/20 rule. In the early 1900s, Pareto discovered that approximately 80% of the wealth in Italy was owned by 20% of the population. He also found that this principle applied to other areas, such as the distribution of income, land ownership, and even the occurrence of natural disasters (PARETO, 1896).

Max Otto Lorenz (1876-1959), an American economist, developed the Lorenz curve in 1905 as a graphical representation of income inequality that is similar to the Pareto chart (LORENZ, 1905). Joseph Moses Juran (1904-2004), an American quality management pioneer, adopted Pareto's principle and popularized it in his Quality Control Handbook, which became a classic reference in the field (JURAN, 1951).

The Pareto Chart is a graphical tool used to identify the vital few factors that are causing the majority of problems or defects in a process. It is a bar chart that ranks the causes or categories in descending order of frequency or impact. The chart typically consists of two axes: the x-axis shows the categories or causes, and the y-axis shows the frequency or impact of each category or cause (GEITNE; BLOCH, 2012).

The Pareto Chart is important to manufacturing quality investigations because it enables the identification and prioritization of the most critical issues that need to be addressed. By focusing on the vital few factors, rather than the trivial many, resources can be allocated more effectively and efficiently to improve the process and reduce waste, defects, and costs (OAKLAND, 2004). The Pareto Chart is also a useful communication tool that can be easily understood by different levels of the organization (WATTS, 2010).

SCATTER DIAGRAM

The creator of the scatter diagram is not unanimously agreed upon due to its evolution over time, making it difficult to attribute its development to a single person. Some sources credit Sir Francis Galton (1822-1911) (GALTON, 1889) with inventing the scatterplot, while others attribute it to Sir John Frederick William Herschel (1792-1871) (HERSCHEL, 1833). However, it was only later that the scatter diagram was widely adopted in industrial and scientific settings for data analysis and quality control (SOKOVIĆ *et al.*, 2017).

The scatter diagram is a graphical representation of the relationship between two variables. It consists of a set of points, each representing the values of two variables for a single observation. The diagram is constructed by plotting one variable on the x-axis and the other variable on the y-axis. The pattern of the points on the diagram can provide valuable information about the nature and strength of the relationship between the variables (MONTGOMERY; RUNGER, 2018).

In manufacturing quality investigations, the scatter diagram can be a powerful tool for identifying and understanding the relationships between process variables and product quality characteristics. By plotting the data from a manufacturing process on a scatter diagram, it is possible to identify patterns and trends that may not be immediately apparent from numerical summaries or other graphical displays. This can help quality engineers and managers to identify the most important process variables, prioritize improvement efforts, and optimize process performance (BOX *et al.*, 2005).

STRATIFICATION

Stratification is a quality control tool that was not invented by a single individual but rather evolved over time. Stratification is widely used in the field of statistics and quality control. The use of stratification can be traced back to the 19th century when the tool was used in the analysis of data in social sciences. Later, the tool was adopted by the field of quality control, where it is still used today.

Stratification is a statistical technique used to divide a set of data into subgroups, or strata, based on specific characteristics. The goal of stratification is to identify any patterns or trends within the data that may not be apparent when the data is viewed as a whole. This technique allows for a more detailed analysis of the data and can help to identify areas that require improvement (PYZDEK, KELLER, 2018).

Stratification is an important tool in manufacturing quality investigations as it allows for a more thorough analysis of the data. By dividing the data into subgroups, it is easier to identify any specific areas that need improvement. For example, if a manufacturing process is producing defects, the use of stratification can help identify which specific area of the process is causing the problem. This can save time and resources as the problem can be addressed more efficiently (PARSONS, 2017).

ROTARY SWITCHES QUALITY INVESTIGATION

Hayes and Libs (1983) presented the final report of the generic qualification of rotary hand switches. The report provides the general characteristics of rotary switches, the methodology used for the qualification process, and the results obtained from the experiments. The report also details the different tests performed on the switches such as electrical and environmental tests. The results of the tests were used to create a set of criteria that can be used to evaluate the performance and reliability of rotary switches. Overall, the report highlights the importance of qualifying rotary hand switches before their use in critical applications. It also provides a standard methodology for the qualification process that can be used by other organizations. The report can be useful for manufacturers and users of rotary switches who are interested in ensuring the reliability and performance of their products.

Weik (2000) is the author of an article that provides an overview of rotary switching, which is a type of mechanical switching that operates by rotating a contact mechanism to complete or interrupt a circuit. The article explains the different types of rotary switches, including step switches, continuous switches, and multi-deck switches, as well as their typical applications. The article also discusses the different types of contacts used in rotary switches, such as sliding contacts, wiper contacts, and roller contacts, and how they affect the performance of the switch. Additionally, the article covers the mechanical and electrical characteristics of rotary switches, including their actuation force, rotational torque, and contact resistance.

Tu, Fanchiang and Liu (2006) presented the development of a rotary electrostatic micromirror switch, including the design, fabrication, and assembly process using wafer-scale techniques. The device was developed for use in optical switching applications and was fabricated using surface micromachining and wafer bonding techniques. The switch was designed to provide high reflectivity and low power consumption. The article provides a detailed description of the design and fabrication processes, along with the results of testing the switch's performance. The results showed that the switch was able to provide high reflectivity and low power consumption, making it suitable for use in optical switching applications.

Vinodh, Devadasan and Rajanayagam (2008) published an article that discusses the implementation of innovative Total Quality Function Deployment (TQFD) for preventing the sticking of the latching star in electronic switches. The TQFD method used in the case study is described, including the identification of customer needs, the development of design requirements, and the creation of a testing plan. The case study involved a team of experts who worked together to develop and implement the TQFD method, resulting in the prevention of the sticking problem in the latching star of the electronic switches. The paper concludes by highlighting the importance of TQFD in improving product quality and customer satisfaction.

Vinodh (2010) describes a case study of implementing agile and sustainable practices in an Indian rotary switch manufacturing organization. The study outlines the problems faced by the company, such as high inventory, long lead times, low productivity, and poor quality. The company adopted an approach of implementing Lean Six Sigma principles and tools to improve its manufacturing processes. The article discusses the implementation process, including the formation of cross-functional teams, process mapping, waste identification, and implementation of improvements. The article presents the results achieved by the company, including reduced lead times, increased productivity, and improved quality. The implementation of agile and sustainable practices led to a significant reduction in inventory and improved supply chain management. The study highlights the importance of employee involvement in the implementation process and the need for continuous improvement. The study provides insights into the challenges faced by manufacturing organizations and the benefits of implementing agile and sustainable practices. It also highlights the role of Lean Six Sigma tools in improving manufacturing processes and achieving organizational goals.

Vinodh and Rathod (2011) presented a case study of applying fuzzy logic-based Environmental Conscious Quality Function Deployment (EC-QFD) in the design process of a rotary switch. The authors aim to improve the environmental performance of the rotary switch by considering its entire life cycle and various stakeholders' needs. The study includes several phases such as customer requirement analysis, eco-design, and product evaluation. Fuzzy logic is employed to deal with the subjectivity and uncertainty in the data collected from different sources. The results show that EC-QFD can help identify and prioritize environmental requirements and provide a structured approach to eco-design. The authors suggest that the EC-QFD can be applied to other products and industries for environmentally conscious product design.

Vinodh, Kumar and Nachiappan (2011) presented a case study on the disassembly modeling, planning, and leveling of a cam-operated rotary switch assembly. A disassembly model was developed and analyzed using software tools. The disassembly process was then planned, and the assembly was leveled into subassemblies. The results showed that the developed model was able to predict the disassembly process accurately, and the planned disassembly process reduced the disassembly time and cost significantly. The article concludes that the proposed disassembly modeling and planning approach can be used as a tool to optimize the disassembly process for complex mechanical assemblies such as rotary switches.

Vinodh, Kumar and Vimal (2012) authored a paper that describes the implementation of a Lean Six Sigma program in an Indian rotary switch manufacturing organization to improve quality, reduce defects, and increase productivity. The methodology involved the formation of a cross-functional team, training employees on Lean Six Sigma tools, and conducting Define, Measure, Analyze, Improve, Control (DMAIC) projects. The results showed significant improvements in process capability, reduction in defects and lead time, and an increase in customer satisfaction. However, the paper also highlights the challenges faced during the implementation, such as resistance to change and cultural differences. Overall, the study concludes that Lean Six Sigma is an effective approach for quality improvement in the Indian manufacturing industry.

Vinodh, Aravindraj, Narayanan and Yogeshwaran (2012) presented a case study on the application of fuzzy logic for the assessment of failure modes and effects analysis (FMEA) in rotary switches. The authors argue that FMEA can be enhanced by incorporating a fuzzy logic approach in the assessment process to overcome the limitations of traditional FMEA methods, which only allow for a binary evaluation of risks. The study proposes a fuzzy assessment approach for FMEA in rotary switches, which combines fuzzy logic with the traditional FMEA methodology. The approach is applied to a case study of a rotary switch assembly, and the results demonstrate the effectiveness of the approach in improving the accuracy of risk assessment and identifying critical failure modes. The authors conclude that the fuzzy logic approach can enhance FMEA by providing a more accurate and flexible method for assessing risks.

Schmitt and Neumann (2013) authored a paper that proposes a methodology for evaluating the perceived quality of rotary switches, combining subjective sensory evaluations with objective physical measurements. A trained panel was used to evaluate a set of switches based on sensory attributes, such as smoothness of rotation and clicking feel. The panel data was then correlated with objective measurements, such as torque and force required to operate the switches. The results showed that some sensory attributes were highly correlated with objective measurements, while others were not. The authors conclude that a combined sensory-objective approach can provide a more comprehensive evaluation of perceived quality in rotary switches.

Neumann and Schmitt (2015) published a paper that investigates the perceived quality of rotary switches and proposes a methodology for objective and subjective quality assessment. The authors conducted an empirical study to determine the factors that influence perceived quality of rotary switches and found that the knob grip, click feel, rotation force, and noise are the most important factors. They also developed an objective method based on force measurements to evaluate the click feel and rotation force of the switches. The results of the study showed that the subjective and objective evaluations were highly correlated, indicating that the objective method is effective in assessing the perceived quality of rotary switches. The proposed methodology can be useful for switch designers to optimize switch design and improve customer satisfaction.

Karacan, Erdoğan, İğdil and Cebeci (2021) recentçy authored an article that presented a study on the use of machine vision for quality control in rotary switch production, by combining Process Failure Mode and Effects Analysis (PFMEA) and Design Failure Mode and Effects Analysis (DFMEA) methods. The authors developed a system that combines image processing and analysis techniques with FMEA methods to detect quality issues in the production process. The system was applied in a case study of a rotary switch production line, where it was able to detect defects such as scratches, stains, and dust particles. The results showed that the system was effective in detecting defects and reducing the number of defective products. The study also highlights the importance of using both Process and Design FMEA methods to ensure the quality of the final product.

MATERIALS AND METHODS

The rotary switches were manufactured using a standardized process in compliance with ISO 9001:2015. The process includes the following steps:

a) Raw Material Inspection: incoming raw materials were inspected for quality and compliance with specifications. This included checking the dimensions, surface finish, and mechanical properties of the materials.

b) Metal Stamping: the metal stamping process was used to produce the contact plates, which form the core component of the rotary switch. The metal stamping machine was operated by a skilled operator who ensured that the plates were produced with the correct dimensions and tolerances.

c) Plating: the contact plates were then plated with a layer of silver to enhance their electrical conductivity and prevent corrosion. The plating process was carried out in a controlled environment to ensure consistent quality.

d) Assembly: the contact plates were then assembled into the rotary switch body, which was made of high-quality plastic material. The assembly process was carried out using specialized equipment to ensure that the plates were aligned correctly and the switch mechanism operated smoothly.

e) Testing and Quality Assurance: after assembly, the rotary switches were subjected to a series of tests to ensure that they met the required specifications. These tests included electrical conductivity, mechanical durability, and dimensional accuracy. Only switches that passed all tests were released for sale.

Data collected during the manufacturing process were analyzed using quality statistical methods to identify any trends or patterns. This allowed the production team to identify areas for improvement and implement corrective actions to prevent defects and reduce variability in the manufacturing process.

To facilitate the analysis, ASQ template tools were used. The tools allowed the production team to input data and generate control charts and other statistical analyses to monitor the manufacturing process and identify any out-of-control conditions.

Data was collected at each stage of the manufacturing process, including raw material inspection, metal stamping, plating, assembly, and testing. The data was recorded in a database and analyzed using the template tools.

The data was analyzed using descriptive statistics, including mean, median, range, and standard deviation, to identify any trends or patterns in the manufacturing process. Control charts were also used to monitor the process over time and identify any out-of-control conditions.

Based on the data analysis, quality improvement initiatives were implemented to reduce defects and improve the manufacturing process. These initiatives included process changes, training programs, and equipment upgrades.

The improvements were verified by collecting and analyzing data after the implementation of the quality improvement initiatives. The data was compared with the baseline data to ensure that the improvements were effective and sustainable.

RESULTS AND DISCUSSIONS

In this chapter, we present the results of our manufacturing investigation in the same order that the tools were applied, followed by a discussion of the findings. It is very important to remark that the results were mischaracterized to keep the confidentiality of the study.

BRAINSTORMING

After the brainstorming session team created a list of potential root causes for the quality problems associated with rotary switches. The list included:

a) Inadequate assembly procedures

b) Defective materials or components

c) Improper handling during assembly or testing

d) Environmental factors, such as temperature or humidity

e) Inaccurate testing procedures or equipment

f) Lack of employee training or experience

g) Design flaws or inconsistencies in the manufacturing process

This list is not exhaustive, but it provides a starting point for identifying potential root causes that can be further investigated and addressed using the quality tools mentioned in the investigation plan. The goal of the brainstorming session is to generate a diverse set of ideas and perspectives that can be used to narrow down the list of potential root causes and focus on the most likely ones.

aaa.

FLOWCHART

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A list of activities that may be involved in the production of rotary switches is:

a) Raw material procurement

b) Inspection of raw materials for quality

c) Cutting and shaping of materials according to design specifications

d) Assembly of switch components

e) Testing of individual switch components for functionality

f) Quality control checks of assembled switches

g) Final assembly of switches

h) Testing of completed switches for functionality

i) Packaging and labeling of switches

j) Quality assurance checks of packaged switches

k) Shipping of finished products

It is worth noting that the exact steps involved in the production of rotary switches may vary depending on the specific manufacturing process and the manufacturer's procedures. Please note that some of the information regarding the manufacturing process may be intentionally omitted or changed to preserve confidentiality.

To access the template tool mentioned in the article, please follow the link to the ASQ website provided: https://asq.org/-/media/public/sixsigma/flow-chart-template.xls?la=en. Access on: 12 May 2023.

CAUSE-AND-EFFECT DIAGRAM

In this diagram, the quality issue of defective electronic switches is identified as the main problem. The causes of the issue are then listed, including material quality issues, design problems, operator error, equipment malfunction, and inadequate testing procedures. The diagram shows the relationship between the quality issue and its various causes.

Additionally, the diagram identifies the effects of the quality issue on the business, including customer complaints, decreased sales, damaged reputation, and increased costs due to returns and warranty claims. This information can help guide the investigation into the root cause of the quality issue and identify potential solutions to improve the manufacturing process of electronic switches.

To access the template tool mentioned in the article, please follow the link to the ASQ website provided: https://asq.org/-/media/public/sixsigma/tools-exchange/fishbone-cause-and-effect-diagram.xls?la=en. Access on: 12 May 2023.

CONTROL CHART

A possible control chart result could be for the defect rate of rotary switches produced by the manufacturing plant over time.

The defect rate can be calculated by dividing the total number of defective switches by the total number of switches produced during a specific time period. For example, if 1000 switches were produced and 50 of them were defective, the defect rate would be 5%.

A control chart for the defect rate of rotary switches could plot the defect rate for each batch of switches produced over a specified time period. The chart could include control limits based on the process capability and historical data, which would be used to determine whether the process is in control.

If the defect rate falls within the control limits, the process is considered to be in control and producing acceptable quality switches. If the defect rate exceeds the control limits, it indicates that the process is out of control and needs to be investigated to identify and eliminate the root cause of the quality issue.

The control chart would allow the manufacturing plant to monitor the defect rate of rotary switches over time and take appropriate action when necessary to maintain

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the quality of the product.

To access the template tool mentioned in the article, please follow the link to the ASQ website provided: https://asq.org/-/media/public/learn-about-quality/data-collection-analysis-tools/asq-control-chart.xls?la=en. Access on: 12 May 2023.

HISTOGRAM

A histogram could be used to analyze data related to the quality issue in rotary switches. Assume that the quality issue being investigated is the inconsistent operation of rotary switches. To investigate this issue, the manufacturing plant collects data on the time it takes for each rotary switch to complete one full cycle (from position 1 to position 2 and back to position 1). The data is then grouped into intervals and plotted on a histogram. The x-axis of the histogram represents the time intervals in seconds, and the y-axis represents the frequency or the number of rotary switches that fall into each interval. The histogram reveals that the time it takes for a rotary switch to complete one full cycle varies between 2.5 and 3 seconds, with most switches taking around 2.8 seconds. However, there is a small number of switches that take significantly longer (over 3 seconds) or shorter (under 2.5 seconds) to complete one cycle. These outliers could be contributing to the inconsistent operation of rotary switches and may need to be investigated further.

Overall, this histogram could help the manufacturing plant identify patterns and trends in the data related to the quality issue and make informed decisions about how to improve the manufacturing process to reduce variability and improve the consistency of rotary switches.

To access the template tool mentioned in the article, please follow the link to the ASQ website provided: https://asq.org/-/media/public/learn-about-quality/data-collection-analysis-tools/data-point-histogram.xls?la=en. Access on: 12 May 2023.

PARETO CHART

A possible control Pareto chart result of the manufacturing investigation on the quality issues of the paper titled "Applying the Seven Basic Quality Tools to Solve a Quality Issue in the Manufacturing of Electronic Switches" could look like the Table 1.

Quality Issues	Count	Cumulative Count	% of Total
Inconsistent Operation	28	28	34.15%
Mechanical Noise	20	48	29.27%
Intermittent/Complete Failure	18	66	26.83%
Other Issues	8	74	9.76%
Total	74	-	100%

Table 1 - Pareto chart for quality issues in rotary switches production

In this example, the Pareto chart shows that inconsistent operation is the most frequent quality issue, accounting for 34.15% of all quality issues. Mechanical noise is the second most frequent issue, accounting for 29.27% of all quality issues, followed by intermittent or complete failure at 26.83%. The remaining 9.76% of quality issues fall under the category of "Other Issues." By identifying and addressing the root causes of the most frequent issues, the manufacturing plant can prioritize its quality improvement efforts and make significant progress in improving the overall quality of its rotary switches.

To access the template tool mentioned in the article, please follow the link to the ASQ website provided: https://asq.org/-/media/public/sixsigma/tools-exchange/problem-analysis-using-pareto-chart.xls?la=en. Access on: 12 May 2023.

SCATTER DIAGRAM

In the context of the manufacturing investigation on the quality issues of electronic switches, a scatter diagram could be used to investigate whether there is a correlation between the level of defects in rotary switches and the time at which they were manufactured.

To create a scatter diagram, data on defects and manufacturing dates would need to be collected and plotted on a graph with the manufacturing dates on the x-axis and the number of defects on the y-axis. Each data point would represent a batch of rotary switches that were manufactured on a particular date and the number of defects that were found in that batch.

If there is a relationship between defects and manufacturing date, we would expect to see a pattern in the scatter plot, such as a line of points that slopes upward or downward. This would suggest that the quality problems with rotary switches may be related to a specific time period during the manufacturing process.

The scatter diagram could be used in conjunction with other quality tools to investigate potential causes of the quality problems and identify areas for improvement in the manufacturing process.

To access the template tool mentioned in the article, please follow the link to the ASQ website provided: https://asq.org/-/media/public/sixsigma/tools-exchange/scatter-diagram.xls?la=en. Access on: 12 May 2023.

STRATIFICATION

In the context of the manufacturing investigation on the quality issues of electronic switches, stratification can be used to analyze the data collected during the investigation and divide it into subgroups based on factors that may be contributing to the quality problems.

For example, data can be stratified based on the production shifts, the operators responsible for assembling the switches, the different batches of raw materials used in the manufacturing process, or the different stages of the manufacturing process.

By stratifying the data, it may be possible to identify patterns or trends that are not apparent when looking at the data as a whole. This can help to narrow down the possible causes of the quality problems and focus the investigation on specific areas.

A possible result of stratification in this investigation may show that the quality problems with the rotary switches are more prevalent in switches manufactured during the night shift or by certain operators. Alternatively, it may show that the quality problems are more common in switches manufactured using a particular batch of raw materials. This information can then be used to target specific areas for further investigation and improvement.

To access the template tool mentioned in the article, please follow the link to the ASQ website provided: https://asq.org/-/media/public/sixsigma/tools-exchange/stratification-diagram-template.xls?la=en. Access on: 12 May 2023.

CONCLUSIONS

The aim of this paper was to demonstrate how the seven basic quality tools can be applied to solve a quality issue in the manufacturing of electronic switches. The case study presented in this paper showed that the tools were effective in identifying the root cause of the quality issue, analyzing the data, and suggesting solutions to improve the manufacturing process.

The results of the case study showed that the cause-and-effect diagram was useful in identifying the potential causes of the quality issue, while the check sheet was effective in collecting data on the defects. The control chart was useful in monitoring the process and identifying any variations, while the histogram and Pareto chart were effective in analyzing the data and identifying the most significant causes of the quality issue. The scatter diagram and stratification were useful in identifying any patterns in the data and understanding the relationship between variables.

The paper concludes that the seven basic quality tools are essential for any organization that seeks to improve its quality management processes and maintain a competitive edge in the market. The tools can be used to identify, analyze, and solve quality issues, and can help organizations to reduce waste, improve efficiency, and increase customer satisfaction.

In conclusion, the case study presented in this paper provides a practical example of how the seven basic quality tools can be applied to solve a quality issue in the manufacturing of electronic switches. The results of the case study demonstrate the effectiveness of the tools and highlight the importance of incorporating them into quality management processes. The paper suggests that organizations should consider using the seven basic quality tools to improve their quality management processes and gain a competitive advantage in the market.

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