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Implementing Quality Control to Improve Quality in The Metal Fabrication Industry

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Abstract

This study aims to improve the quality of Company A, a South African metal fabrication company, using quality control tools. These tools are crucial for continual improvement worldwide in various industries. The seven quality tools include Check Sheet, Histogram, Pareto Chart, Fishbone Diagram, Control Chart, Flowchart, and Scatter Diagram. Only two Quality Control tools were used in this research: Fishbone and Pareto diagrams. Various steps were taken to define problems, measure their impacts, identify root causes, and propose recommendations to ensure the production of non-defective items. This study shows how the tools of quality can be useful and effective in identifying and removing defects from the manufacturing process. Two machines were selected to identify the causes of non-conform products. The Ishikawa diagram identified various causes of the problem, but the Pareto diagrams revealed that the dominant causes include low properties of metal, scratches and dents, overproduction, metal misplaced, shortage from the press, and twists. This study also used a quantitative methodology where questionnaires were collected. 27 employees participated in the study, and the results revealed that most employees need training. The company must clearly define its quality policy, as many employees are unaware of it. This study adds value to the metal fabrication industry by identifying processes to improve quality and raise awareness about meeting quality standards.

Keywords
Quality improvement, Quality Control, Quality control tools, Metal industry

1. Introduction
Quality has been a significant concern in the field of business management since the 1970s when the rapid and consistent increase of competition in the market has constrained companies to search for new ideas and strategies to improve their processes to remain competitive within the market continuously (Wibowo and Adisty, 2017). Maintaining quality is crucial for achieving strategic competitiveness, employee empowerment, employee involvement, customer repetition, diminishing rework, continuous improvement, increasing productivity, enhanced budget performance, and comparatively more desirable schedule performance (Sadikoglu and Olcay, 2014). Different organizations seek to provide quality products or services to consumers through quality management disciplines. One of these disciplines is Quality Control (QC).

In the Industrial Revolution era and the proliferation of mass production, it became crucial to establish a standardized approach to ensure consistent quality control of products. By establishing clear guidelines and procedures,

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manufacturers could mitigate defects and dissatisfactory products, thus avoiding potential loss of revenue and customer trust (ASQ 2024). Quality was initially meant to meet engineering requirements for final products. It later became a discipline for controlling process variation to produce better-quality products (ASQ 2024).

Metal fabrication is defined as producing metal structures through cutting, bending, and assembly processes (Kalpakjian and Schmid, 2014; Bathrinath et al. 2019). The metal fabrication sector of South Africa is the most advanced and diverse metal fabrication sector in Africa (investSA 2020). Over the past two decades, the metal fabrication industry has become more competitive because of changes in customer expectations and advancements in manufacturing technology. These advancements include the incorporation of laser and abrasive water jet technology, as well as improvements in robotic technology (Bathrinath et al., 2019). Consequently, Metal fabrication companies must adapt to maintain competitiveness.

1.1. Problem statement

Manufacturing operations are now expected to deliver more personalized, high-quality products while meeting high production volume demands in less time, lowering production costs, and improving sustainable manufacturing processes (Anholon and Sano 2015). Increasing or even sustaining the competitiveness of companies and the quality of their products is critical (Anholon et al., 2018). The lack of quality implementations in the manufacturing industry, such as metal fabrication, has a significant impact. The problem with producing goods that are not of good quality is that there will be no sales, and no sales means no profit, and if there is no profit, then there will be no jobs. Therefore, it is important for managers to incorporate quality controls and processes in their strategies. This will allow them to identify gaps in their current processes, if any, on whether they need to up-skill or increase resources to ensure that they produce quality goods.

Employees from Company A, A metal fabrication company in South Africa, do not seem to understand the importance of integrating quality into their duties. Due to the lack of quality and continuous improvement implementation on the shop floor, there is a high rate of non-conformity produced by the operators, which affects the quality, productivity, and cost of the company. Figure 1 depicts an example of non-conform products. Two machines, Machine A and Machine B, have been selected to study and identify the causes of poor-quality products. Quality is an important feature of every organization as it determines the degree of excellence of the product as per the customer specification. Product quality is considered a global issue in today's markets. An organization that can supply conforming products will have a competitive edge in the market and meet the customer satisfaction principles (Chilanga, 2010).

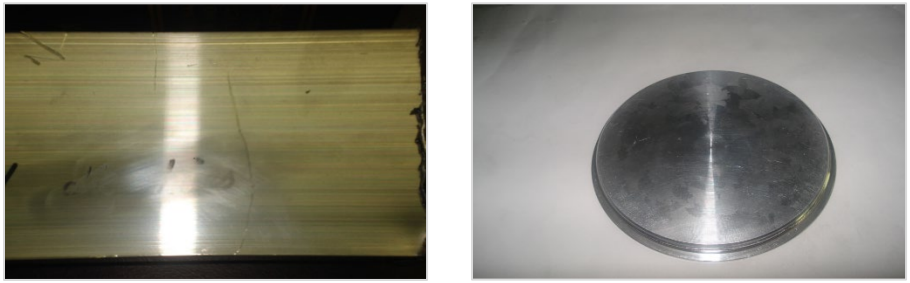

Figure 1. Poor surface appearance on a metal component

1.2. Aim and objectives of the study

This study aims to use Quality Control tools in Company A, a metal fabrication company, to prevent and manage any non-conformity, scrapping of products, and cost related to fabricated products.

The research objectives (RO) of this study are defined as follows:

(RO1) To Identify the importance and benefits of Quality Control.
(RO2) To implement Quality Control tools in Company A to improve quality.
(RO3) To identify the challenges Company A faces.

1.3. Research questions

The research questions (RQ) of this study are defined as follows:
What are the benefits of Quality Control?

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(RQ1) What are the importance and benefits of implementing Quality Control tools?
(RQ2) What Quality Control tools can be used in Company A?
(RO3) What are the challenges faced by Company A?

1.4. Scope of the study
This research study focuses on the importance of implementing quality controls to ensure the manufacturing of quality goods. The investigation will focus on the degree of quality implementation in the metal fabrication industry. In addition, it will determine any possible root causes of poor quality and analyze the impact of the lack of implementing quality controls.

1.5. Limitations of the study
This research only focuses on the metal fabrication industry to produce an informative study that can add value as this area lacks study. Despite the limitations, the findings of this study can be used as a source that will contribute to the understanding of best quality practices to adopt when implementing quality control and processes in the metal fabrication industry.

Different quality control tools are applied to improve product quality according to expectations. In this study, two quality control tools, the Ishikawa and Pareto Diagram, will be examined. Companies experience decreased profitability, productivity, and production quality due to excessive defects during production (Demirkaya, 2022).

1.6. Importance of study
This study is important because it brings value to the metal fabrication industry by identifying processes that will improve quality and create awareness among employees and companies about quality and the importance of meeting quality standards. This research study will improve current knowledge and help future researchers improve on current findings.

1.7. Background of the study
The Quality of the material in the metal fabrication industry is critical. This becomes a priority if the metal is used in automotive, construction, and appliances. The characteristics of the metal, such as shape, surface appearance, and mechanical properties, must be specified and standardized to produce as per the required specifications. Metal that does not meet any of the specifications and does not conform to the requirement of the customer on the concession must be scrapped. As per 'seven wastes', scrap should be reduced or eliminated from the process to avoid the cost of non-quality (Lawler, 1992; Domingo, 2015; Silva et al., 2020; Widodo et al., 2021; Byrne et al., 2021; Singh et al., 2020).

2. Literature Review
According to the American Society for Quality (ASQ, 2024) and Mitra (2016), Quality control (QC) is part of quality management that ensures the fulfillment of quality requirements. The American Society for Quality alternatively defines Quality Control as "the operational techniques and activities used to fulfill requirements for quality (ASQ, 2024). QC, which plays an important role in maintaining quality and updating it according to expectations, may generally be defined as a system that maintains a desired level of quality through feedback on product/service characteristics from a specified standard (Mitra 2016). According to Demirkaya (2022). Quality Control (QC) is an active process that detects defects in a product claimed to be ready for delivery, so it can be said that QC is the key to maintaining quality.

Maintaining and improving quality according to expectations requires a robust quality control mechanism. Different quality control equipment can be used to intervene in processes as needed. Keeping the quality control mechanism up-to-date and continuous ensures that the quality of the processes meets the ever-changing expectations of the customers (Demirkaya 2022). Customer satisfaction is key to the success of a new product. High-value products meet customer needs by performing well throughout their lifecycle. This requires consistent production processes and high-quality, reliable, and safe product design (Mrugalska and Tytyk 2015).

2.1. Quality Control process
The Quality Control process involves a few fundamental steps. Firstly, the production process that needs to be monitored is chosen, and then the quality standards that the product should meet are established. The production output

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is evaluated, and the intended and final product quality standards are compared. If there is any difference between the two, research and development studies are conducted, and the product is sent back into production until it meets the targeted quality standard (Demirkaya 2022).

2.2. Quality Control tools

There are several methods and tools available to perform statistical quality control. Still, one of the most popular uses seven tools, also known as the 'magnificent seven tools'. Paliska et al. (2007) say that quality tools can be applied at every production stage, from manufacturing to product sales.

There are Seven quality control tools that are very effective in solving quality problems at the Quality Control stage. These include stratification (Flowchart), Histogram, Check Sheet, Cause and Effect Diagram (Fishbone or Ishikawa Diagram), Pareto Chart, Scatter Diagram, and Shewhart Chart (Abdel-Hamid and Abdelhaleem 2019; Demirkaya, 2022; George et al. 2018; McDermott et al. 2023; Suryoputro et al. 2017; Mesele et al. 2021; Gupta et al. 2021):

- ***Stratification:*** Also known as Flowchart, is one effective method for defining a process. Flow Chart is a simple drawing of a process from start to finish.
- ***Histogram:*** Histograms are bar charts that display the distribution pattern of observations grouped in class intervals and arranged by magnitude. They are useful in studying distribution patterns and drawing conclusions about the process based on the observed pattern.
- ***Check sheet:*** Check sheets are tools for collecting data systematically. Examples include maintenance check sheets, attendance records, production logbooks, etc.
- ***Fishbone Diagram:*** The Cause-and-Effect Diagram, or the Ishikawa Diagram, is a structured tool to display the relationship between a result and its possible causes. Dr. Kouro Ishikawa invented this tool to generate ideas about the causes of problems.
- ***Pareto Diagram****:* The Pareto Diagram is a tool that arranges items based on their level of impact, allowing for the identification of main contributors. It is used for quality improvement, prioritizing projects, identifying recurring problems, and other similar purposes. The tool is based on the Pareto principle, also known as the 80/20 rule, which suggests that 20% of items account for 80% of the total value. Dr. Juran suggested separating the "vital few" problems from the "useful many."
- ***Scatter Diagram:*** To study the relationship between two variables, one can use a Scatter Diagram. This involves plotting a series of points on a graph, with one variable on the X-axis and the other on the Y-axis. Examining how the points are scattered in the quadrant allows one to gain insight into the relationship between the two variables.
- ***Shewhart Chart or Control chart:*** A control chart is a graphical tool used in quality control to determine the upper and lower control limits of process performance. Its main objective is to identify any uniformities that can be avoided. It is a quick way to determine whether the quality of goods being processed is under or out of control. There are five types of control charts: X – Chart, P - Chart, Pn - Chart, and C – Chart.

2.3. Benefits of Quality Control

The benefits of Quality Control include the following (Neyestani, 2017; Besterfield, 2006; Bruce, 2015; Gupta et al., 2021):

- ***Customer satisfaction:*** Customers benefit the most from improved product quality, receiving the best from their preferred company.
- ***Cost reduction:*** Inspection of production and operations reduces costs significantly by controlling wastage and preventing low-quality products.
- ***Resource utilization:*** Quality control ensures efficient use of resources, reducing inefficiencies and waste.
- ***Inspection cost reduction:*** By having control over quality, the inspection cost can be greatly reduced.
- ***Increased goodwill:*** If quality products are produced, customers will be satisfied and the company's reputation will improve, making it easier to secure financing.
- ***Price fixation:*** Quality control measures ensure consistent product quality, helping companies avoid price fixation. It brings benefits like better customer satisfaction, lower costs, and an improved reputation. Quality is crucial for long-term success.

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2.4. Training

Knowledge generation has been recognised as critical in process improvement initiatives. Process management is central to improvement because process management develops 'structured goals' that lead to visible improvement. Process management changes the routines in the process to achieve process improvement. Process improvement leads to increased customer satisfaction (Linderman et al. 2010)

Providing skills that assist the workforce in understanding links in process steps is critical if quality improvement is to be attained. Developing workforce skills and training can lead to better performance for the organisation and give the organisation a competitive edge. Creating an environment of learning and providing employees with the opportunity to attain important skills related to their jobs results in increased quality of work and increased speed at which tasks are completed. Maintenance of a competitive edge and improved workforce output can be attained by relevant training with the line of work the employee(s) performs. On-the-job training is also important in equipping the workforce with the required skills to perform their daily duties. Employee training should not be limited to basic skills related to their jobs but should extend to technical training to assist employees in understanding business performance and improving employee participation (Mendes 2012). Pycraft et al. (1997) noted that training provides a base from which employees gain skills to eliminate errors in performing their duties. Training enables employees the ability to comprehend the technical side of process improvement and acts as the foundation to ease communication around process improvement. Employee training improves the rate at which decisions are implemented; therefore, process improvement takes place much quicker (Elnaga and Imran 2013).

2.5. Quality policy and Organisation culture

Organisational culture needs to change and become conducive to thriving process improvement initiatives. Culture must be such that process problems are solved through a fact-based approach and root cause analysis and not intuition and emotions. The organisational culture must see process improvement to achieve higher customer satisfaction (Linderman et al. 2010). Organisations should encourage a culture that continually views quality as a main goal.

A Quality Policy is a brief statement that aligns with an organization's mission and strategic direction. It sets the framework for quality objectives and includes a commitment to meet all applicable requirements while continually improving. It can also drive cultural change by incorporating it into routine meetings and employee objectives (Huckabone 2020).

3. Methodology

This study used a quantitative research approach, which focuses on quantifying and measuring variables and involves using and analyzing numerical data (Apuke, 2017). The main advantage of collecting quantitative data is that it allows for generalization to the population (Dowd, 2018). The quantitative approach is a quick method that employs statistical tools such as SPSS. However, it has limitations - it fails to uncover the deeper underlying meanings and explanations. Moreover, positivism cannot fully explain how social reality takes shape and is maintained or how people perceive their actions and those of others (Rahman 2016).

3.1. Population and Sampling

The population of this study includes shop floor employees and managers in Company A. 30 employees participated in the study. Research trustworthiness, also known as the rigor of a study, ensures data quality, interpretation, and methodology (Connell 2016). Every employee had an equal chance of receiving and answering a questionnaire. The sample was mainly comprised of shop floor employees and members of middle management.

This study's trustworthiness was assessed through reliability and validity tests. Validity refers to the extent to which a measuring tool fulfills its intended purpose and produces accurate results. The validity test includes various types, such as content, face, criterion-related, concurrent, predictive, convergent, and discriminant validity. Reliability is a measurement that delivers dependable, equal values results that measure the study's dependability, correctness, repeatability, and trustworthiness (Mohajan 2017).

3.3. Data collection

Data developed during the cause of the project, such as the Pareto chart and Ishikawa diagram, were used to show the status and how the project was tracked and controlled throughout. A questionnaire was distributed to all employees.

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The questionnaire was completed by 27 employees. The questionnaire comprised 6 sections covering various aspects of quality.

4. Results and Discussion

This section discusses the interpretation of data collected through questionnaires given to employees at Company A using descriptive analysis.

5.1. Descriptive analysis of the respondents

The organization's demographic reveals that most employees are male, as depicted in Figure 2. 77.78% of the respondents are male, and 22.22% are females. The high ratio of males to females is because the company used to be a male-only workplace before 2004.

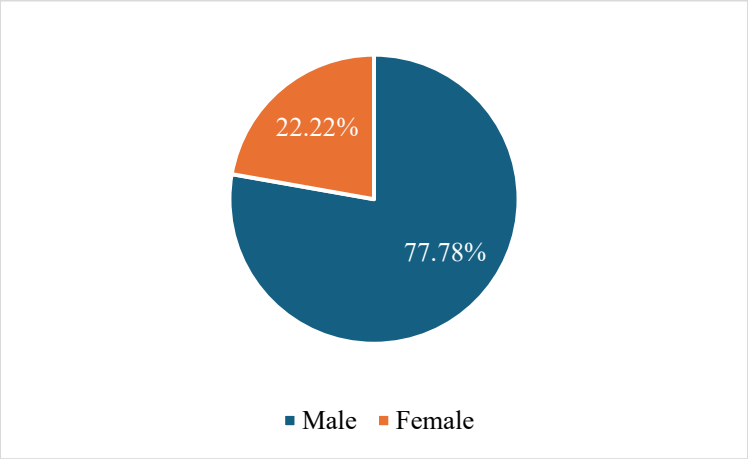

Figure 2. Gender distribution of Respondents

Table 1 shows the occupation and gender of the respondents who participated in the study. Most respondents were shop-floor employees with different types of occupations. Three managers who work on the shop floor participated in the study.

Table 1. Descriptives of the respondents

Respondent	***Gender***	***Occupation***	***Respondent***	***Gender***	***Occupation***
A	Male	Foreman	N	Male	Progressor
B	Female	Saw operator	O	Female	Key operator
C	Male	Planner	P	Male	CTL operator
D	Male	Safety officer	Q	Male	Packing Manager
E	Female	Process technician	R	Male	Furnace loader
F	Male	Machine Operator	S	Male	Key operator
G	Male	Pres operator	T	Male	Production Manager
H	Female	Internal sales	U	Male	Packing foreman
I	Male	Electrician	V	Male	Straightening operator
J	Female	Packer	W	Male	Rear end operator
K	Male	Quality Inspector	X	Male	CTL operator
L	Male	Operator	Y	Male	Machine Operator
M	Female	Straightening operator	Z	Male	Toolmaker
N	Male	Progressor	AA	Male	QA Manager

5.2. Fishbone diagram and Pareto chart

The Pareto analysis and fishbone diagram would help the company explore the root cause of the problem identified. The Fishbone diagram was used to collect the causes of the problem in Machines A and B. These machines are

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producing non-conforming products, and the causes of the problem are manpower, material, and machines. Figure 3 reveals a Pareto analysis of machine A. Causes such as low properties of metal, scratches and dents, overproduction, metal misplaced, shortage from the press, twists, and other causes should be investigated to decrease non-conformity as they impact the cost of production and quality of the products.

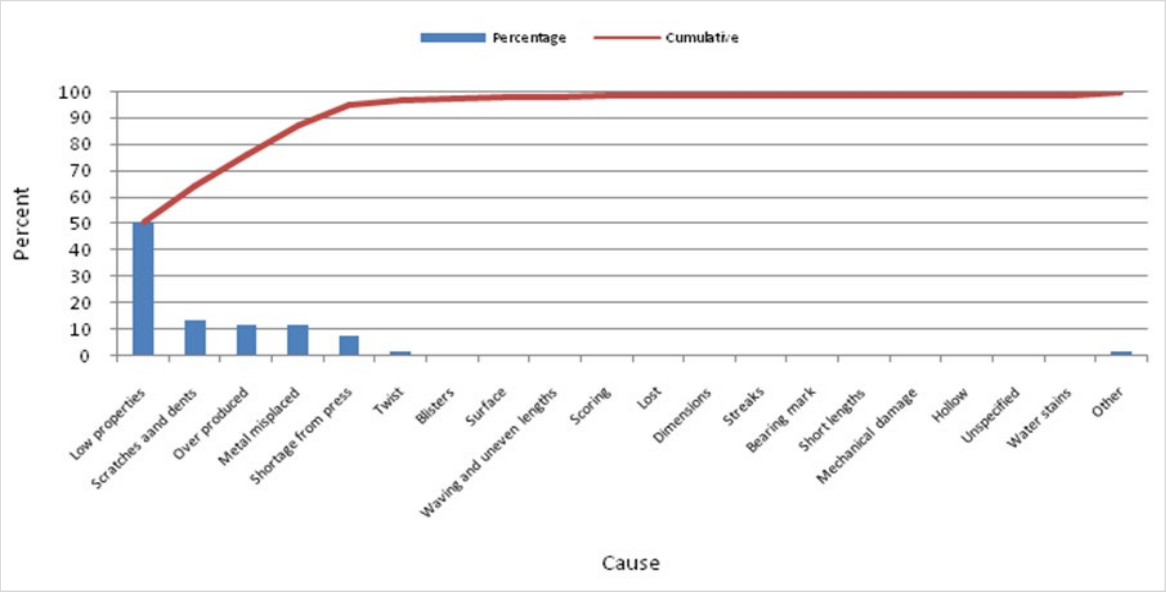

Figure 3. Machine A

Figure 4 depicts the Pareto analysis of machine B. This machine presents similar causes to Machine A. Causes identified in Machine B, such as scratches and dents, twists, overproduction, shortage from the press, blisters, bearing marks, and other causes, should be investigated too.

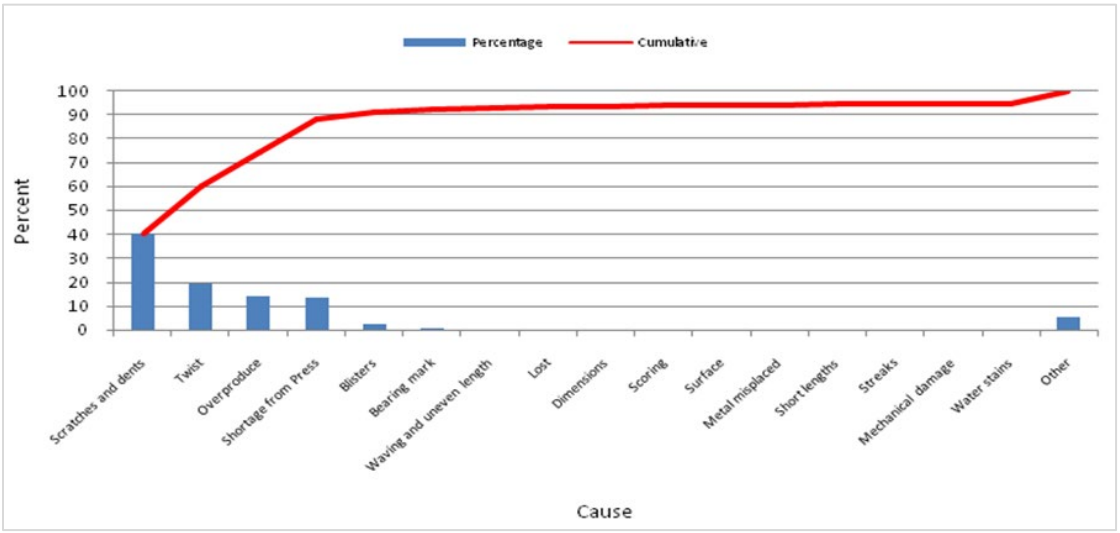

Figure 4. Machine B

5.2. Training

Most shop floor employees have at least grade 12 education in math and science. Employees undergo safety, health, and environmental induction when employed by the company. Employees also undergo process training, which includes work instructions, customer requirements, and ISO 9001 requirements. Selected foreman and management employees are qualified ISO 9001 auditors. The training is based on needs analysis to ensure that the training exercise improves employees' competence. However, 67.41% agree that the company sends employees on courses to acquire

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skills related to their jobs. Furthermore, 62.96% agree that employees are offered resources to further their education. These results reveal the need to train all the employees to improve quality processes and products.

5.3. Knowledge of quality

93.33% of the respondents understand the meaning and importance of quality, which is a good and important sign for the company. 87.41% know how their work affects conformity to product requirements. 62.22% are aware of the company's quality policy, which raises concern because all the employees must be familiar with the company's quality policy to produce good quality products that satisfy the customers' needs. 84.44% agree that communication of all non-conforming products and causes of nonconformities reach them, and 93.33% agree that the company communicates the importance of meeting customer requirements. The results revealed that employees know quality. However, the company should clearly define the quality policy for all employees, from top management to shop-floor employees.

6. Conclusion and recommendations

This study shows that using quality control tools can be effective for companies in identifying and preventing non-conforming products and improving quality. Seven Quality Control tools exist, but this study used only the Ishikawa Diagram and Pareto analysis to identify the causes of poor-quality products. The most common defects that occur in machines A and B come from the machines. Few causes come from manpower and material.

- The company should try to reduce defects in terms of the material. The quality of their raw material should be inspected before production.
- In terms of manpower, the company should give their employees, particularly shop-floor employees, clear directions or training to prevent defects. Strict supervision and inspection from managers should be reinforced before, during, and after production.
- In terms of the machines, actions should be taken to improve the maintenance of machines. Routine engine maintenance and the cleanliness of the engine should be implemented to prevent the engine from being damaged and prevent defects such as scratches and dents.
- The shop-floor employees should follow quality and standard operating procedures that have been defined.

The result of this study shows that the Quality Control tools could be effectively used in this company or any other company. Therefore, this company can use other tools, such as Statistical Process Control (SPC), which are not used in this study. Future studies can use the seven QC tools in other metal fabrication companies for comparison.

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