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Product quality control analysis using the six sigma method

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ABSTRACT

Technological improvements and developments have significantly altered consumers' perceptions of product quality. The production of high-quality products is only possible through a robust manufacturing process. However, during the production process, various issues may arise, leading to the production of defective products. As a result, manufacturing companies like XYZ are now required to conduct product quality control to minimize the number of defects. The objective of this study is to control product quality by reducing defects at XYZ. To achieve this, we have employed the Six Sigma method, which involves several stages, such as define, measure, analyze, improve, and control. Our research indicates that product A is prone to defects, with density being the most common type. We have calculated the DPMO (defects per million opportunities) to be 2580.66, while the sigma value is 4.297. The process capacity that produces problems at XYZ is at an average level for US industry. Additionally, we have used the 5W + 1H approach to propose improvements during the Improve stage. However, our recommendation for enhancing the production process to reduce defects is still a work in progress and needs to be executed, assessed, and monitored to reach world-class industry standards.

1. Introduction

Nowadays, technological growth and development are influencing how customers perceive and choose quality products. In addition to competitive pricing, product quality is a critical factor when making a purchase decision. To meet industry standards, a manufacturing line must be supported by a robust production process. Achieving high efficiency in the production process is crucial for optimal performance and the production of high-quality products [1]. When customers have confidence in a product's excellence, they are more likely to be satisfied and use the product or service again in the future. This, in turn, enhances the company's reputation as satisfied customers share information about the product or service with others [2], [3], [4].

Quality is undoubtedly generated during the manufacturing process. A production process is considered good if it meets standard criteria. However, in reality, several challenges often arise during the production process, resulting in a product that is only partially successful and may have defects. This has happened at XYZ, a manufacturing company in Cilegon, and quality control is necessary to address production issues. Using the Six Sigma method is one way for a company to make repairs and quality improvements [1].

The Six Sigma method is a technique used to achieve an operational performance of 3.4 defects per million opportunities or activities. The uniqueness of Six Sigma lies in its emphasis on a thorough understanding of facts, data, and statistical analysis, along with careful business management, repair, and reinvestment. The utilization of Six Sigma can result in cost savings, productivity improvements, market share expansion, defect reduction, and the enhancement of manufacturing or service quality [5]. Six Sigma is a method that is now being implemented worldwide. The adoption of Six Sigma in the manufacturing industry is expected to reduce failures in achieving the necessary quality targets in construction projects [6].

Previous studies on production quality control also utilized the Six Sigma methodology. One such company is Citra Resins Industries, which produces resins. Resins are chemical polymers produced in a series of high-temperature and high-pressure reactors. One of the products manufactured by Citra Resins Industries is an amino resin that is in high demand but is often defective. Based on the data, the annual production was 931,375 kilograms, with 80,875 kilograms of defects, accounting for 8.54 percent, while the company expects

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a defect rate of only 1 percent. This results in significant losses for the business. Therefore, this study employed the Six Sigma quality control system to eliminate resin defects and improve the manufacturing process [7].

AAA has also previously conducted research using the six-sigma methodology. During the research period of November 2020 to April 2021, a significant number of defective items were discovered, with a percentage of 10.4% and a CTQ (Critical to Quality) value of 5%. Based on the Six Sigma calculations, the average DPMO (defect per million opportunities) value was 60,000 and the average Sigma value was 3.05, indicating that the manufacturing industry in Indonesia falls within the average category. To improve the efficiency of the purified gypsum production process, reducing process waste is an option. The organization must consider following Standard Operating Procedure (SOP) to achieve the desired level of quality, and regular employee training is also required to maintain the required skill level [8].

In addition to previous research conducted at ALX Logistics, the Lean Six Sigma methodology can also be utilized to enhance supply chain performance. This approach is used to identify the root causes of critical waste and improve processes with the goal of reducing waste. The research results reveal that the perfect order fulfillment indicator has a performance value of 84.60%, and the cost of goods sold is 70%. Proposed improvements include renewing the company's fleet management system, providing employee retraining, and strengthening motivation through reward and recognition programs [9].

The goals of this study are to determine which products are prone to defects, the types of defects detected in those products, the DPMO and sigma values, and the proposed improvements that must be implemented at XYZ to reduce deficiencies in the manufacturing process. As for the limitations in this study, it should be noted that this research was carried out until the improvement stage. The output of the research is a recommendation for enhancement since it has not yet progressed to the point of being implemented, evaluated, and controlled [10]. The implementation of Six Sigma is dependent on key factors such as the dedication and engagement of management, prioritizing customer satisfaction, and incorporating Six Sigma into overall business strategy [11].

2. Material and method

The method used in this study is the Six Sigma method. Six Sigma is an adaptable and measurable approach that aims to achieve, maintain, and maximize business success in an ever more competitive environment. It is a systematic and effective method for enhancing organizational performance by utilizing a range of statistical analysis techniques to improve quality [12]. There are 5 stages of the Six Sigma method for product quality control: Define, Measure, Analyze, Improve and Control.

The first step of Six Sigma methodology is to identify and define the problem. The Define stage is the starting point for Six Sigma quality improvement projects. The purpose of this stage is to define and explain the program or product that will undergo continuous improvement. The Define stage outlines the action plan to be implemented to address the identified problem or issue. It includes defining the problem, identifying customers and their requirements, establishing goals and objectives, and defining the scope of the project. By the end of the Define stage, a clear understanding of the problem and project scope is achieved, and a team is formed to work on the project [13].

Measure is an activity that involves measuring process performance and evaluating existing goals [14]. In this stage, a baseline performance measurement is performed on the process capability, which can be used to compare the performance of a process to its specified criteria [13].

Based on the data analysis performed, problems are recognized during the analysis stage. A Pareto chart is used to prioritize the necessary repairs. The fundamental cause of the problem is then identified and described in detail using a cause-and-effect diagram [15]. Improving is the stage of enhancing the method and removing the root cause of the defects. It includes recommendations for reducing defects at various levels. Control is a step used to evaluate the performance of the process and ensure that problems do not recur. The control chart is utilized to reduce variability, monitor performance, permit the repair process to prevent rejection, and identify outside trends and situations [15].

3. Results and discussions

This study's data collection contains all information related to the data processing. Table 1 contains the information collected at XYZ. Below are the results of DMAIC process in XYZ.

3.1. Define

The products to be evaluated for improving quality have been identified at this point. Based on the information gathered at XYZ and the interview with the Quality Control Coordinator at XYZ, the company's products still include defects, which causes concern for this research. Using the acquired data, the following Pareto chart indicates which products are most likely to have a defect.

According to the data collected, the defect rates for the different products at XYZ are as follows: Product A has a defects rate of 35.3%, product B has a defect rate of 12.7%, product C has a defect rate of 22.3%, product D has a defect rate of 8.4%, product E has a defect rate of 8.4%, and product F has a defect rate of 13.0%. Based on these figures, it is evident that Product A had the highest number of problems from January to December. Therefore, we focus the attention to reduce the defects in producing product A.

Table 1.
Number of defective products in January-December

Month	Product	Type of defect	Data outputs (%)	Defects (%)
January	Product A	High Density	99.23	0.77
February	Product B	High Gel	99.17	0.42
	Product B	Low Solid Content		0.42
March	Product C	Low Ph and Solid Content	97.81	0.55
	Product D	Low Solid Content		0.55
	Product E	High Gel		0.55
	Product A	High Density		0.55
		High Solid		0.33
April	Product A	High Density	99.01	0.33
		High Residual Monomer		0.33
November	Product C	High Particle Size	99.09	0.91
December	Product F	Abnormal Production Process	99.15	0.85
Total			593.46	6.54

Table 2.
Types and percentages of defect in product A

No	Type Defects	Jan	Mar	Apr	Total
1	Density	0.77	0.5475	0.33	1.65
2	Solid	0	0	0.33	0.33
3	Residual Monomer	0	0	0.33	0.33
	Total	0.77	0.55	0.99	2.31

Table 3.
Calculation of DPMO and sigma

No	Attribute	Value
1	Unit	298.050
2	Defect	2.31
3	CTQ	3
4	Defect Per Unit	0.00774199
5	Defect Per Opportunities	0.00258066
6	DPMO	2580.66
7	Sigma	4.297

3.2. Deviation measurement

The DPMO and sigma values for Product A were calculated based on the data collected during the DMAIC process. Table 2 presents the defect types for Product A that occurred in January, March, and April, showing that the value of defects varied based on the defect category. In April, solid defects contributed to 0.33% of the total defects, and the percentage of "residual monomer" defects in April was also 0.33%. The quantity of Product A's output, which was 99.23% in January, 99.81% in March, and 99.01% in April. Table 3 presents the calculation of DPMO and Sigma values, which showed that the DPMO value for Product A was 2580.66, and the sigma value was 4.297. This indicates that the process capability causing defects at XYZ is like that of the average US industry [16]. To achieve world-class quality, further improvement is needed by enhancing the production process to minimize defects.

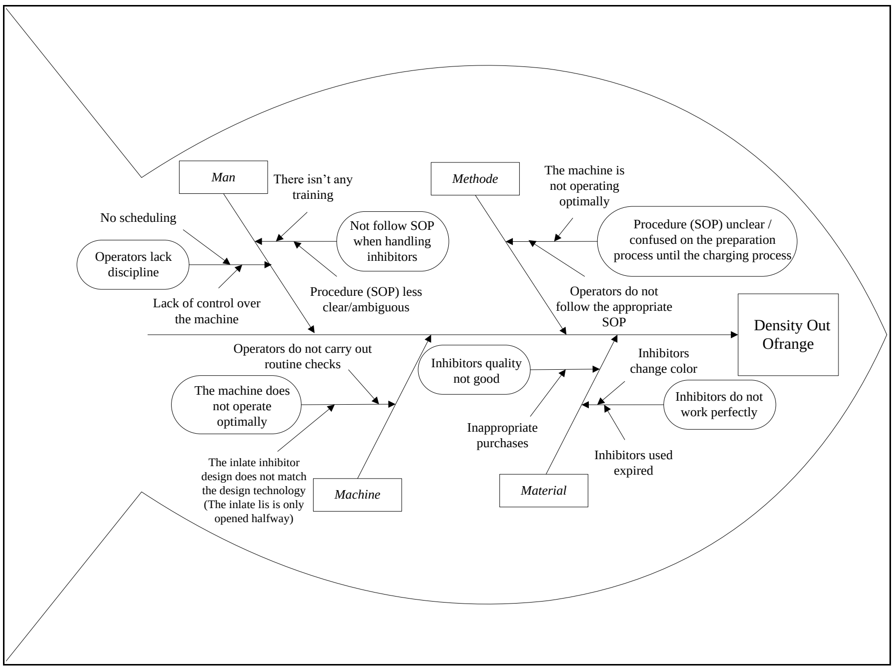

Figure 1. Fishbone diagram

Table 4.
Root cause analysis using 5W+1H

No.	5W + 1H	Description
1	Why	This defect occurs because the inhibitor does not work perfectly so that the reaction occurs prematurely.
2	What	This type of Density defect causes Density Out Of range or density out of range.
3	Where	This defect occurs in the production area.
4	When	This defect occurred in 2020.
5	Who	Defect occurs when the production process is carried out by operators.
6	How	As well as processes and operator training, it is necessary to define the solutions that may be used to eliminate defects for the most suitable way of step preparation of inhibitors for the charging process.

3.3. Analyze

Using Fishbone diagram in Fig. 1, the analysis phase is used to identify the root causes of quality problems. The most frequent type of defect is density, with a defect percentage of 71.4%. The defect percentage of solid is 14.3%, and the defect percentage of residual monomer is also 14.3%. This allows us to identify the most common type of defect. To be able to fix and minimize the frequent defects, we must understand the variables that cause them. A fishbone diagram can be used to identify the causes of the defect. Here's a factor in the defect type's fishbone diagram for density. According to the fishbone diagram in Fig. 1, the main contributor to the density defect is out-of-range density, or the product's out-of-range density, and the factors that cause it. The frequent causes of density defects include human, method, material, and machine variables.

3.4. Improve

To improve the quality of the product, we can use the 5W + 1H approach to identify the root causes of defects and propose solutions. Table 4 shows the solutions derived from the 5W + 1H approach, based on the type of defect. In addition to changes to processes and operator training, it is also important to define in detail the solutions that may be employed to eliminate defects. This research will help us to find the most suitable method of step preparation of inhibitors for the charging process.

4. Conclusions

The research found that product A was the most prone to defects between January and December 2020. The most common types of defects in product A were density, solid, and residual monomer. The DPMO value was 2580.66, and the sigma value was 4297, which is average for the US industry. Some proposed changes to reduce defects include finding the most appropriate approach from the inhibitor production stage to the charging process, outlining processes in detail, and conducting operator training.

Declaration statement

Asep Ridwan: **Conceptualization, Methodology, Supervision**, **Software, Writing - Original Draft**. Atia Sonda: **Conceptualization, Resources, Writing - Review & Editing, Data curation**. Amelia Amelia: **Resources, Validation**, **Writing - Review & Editing.**

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The authors report there are no competing interests to declare.

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article or its supplementary materials.

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