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Quality Control of 3KG LPG Gas Cylinder Production with Six Sigma Approach at PT XYZ

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ABSTRACT

Quality control is essential to ensure that products meet predetermined specifications and align with company policies. Based on PT XYZ's production report from December 2023, the number of defective products requiring repairs was notably high, reaching 17.3% of the total 98,852 gas cylinders produced within 19 days. This study aims to evaluate the quality control performance and identify the factors influencing it. The Six Sigma DMAIC method was applied to assess performance. At the measurement stage, the Defects Per Million Opportunities (DPMO) was found to be 44,743, corresponding to a sigma value 3.203. The study identified four key factors contributing to production defects: machinery, materials, personnel, and methods. Although the company's quality control efficiency is deemed satisfactory, it has yet to prevent a significant sales decline of 20-40%. Therefore, implementing Six Sigma analysis is expected to uncover processes that can reduce manufacturing defects in 3 kg LPG cylinder production. By addressing these issues, the company can improve product quality, maintain customer satisfaction, and enhance competitiveness in the market.

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1. Introduction

Globalization is a process that involves the expansion, spread, and integration of various economic, social, and cultural aspects between countries. In the manufacturing industry, globalization significantly influences its development and impact. Its presence changes the production system, distribution, and consumption of goods and services. Competition in the industrial sector is getting tighter due to technological advances and the openness of information. Therefore, companies need advantages that add value to attract consumer interest (Maulana et al., 2023).

Product quality is an important aspect to ensure the sustainability of the company. In the business world, consumer demand for product quality is increasing, along with the increasing number of goods and services available. Low prices no longer determine competition and business continuity but the ability to add value to products through quality improvements (Lestari & Purwatmini, 2021).

The Six Sigma method is one of the tools commonly used in product quality control. This method has the concept of setting quality standards to reach 3.4 rejects per million possibilities. In the Six Sigma method, several stages are divided to improve product quality. The Six Sigma method can determine the causes and factors influencing rejects to reduce defective production. By knowing the

cause of the defect problem, improvements can be made to minimize the possibility of defects occurring (Kusumawati & Fitriyeni, 2017).

PT XYZ is a trusted manufacturing partner responsible for producing 3 kg LPG gas cylinders to meet the needs of various regions in Indonesia. Ensuring quality in the production process is a must, considering that the product will be used directly by the community. In the manufacture of 3kg LPG gas cylinders, there is a LeakTest process. LeakTest is a machine used to test for gas leaks by pressurizing the steel cylinder and then putting it in water; this process can determine the quality of the production results and whether or not it is suitable to continue to the following process.

In this process, it was found that the products produced were not suitable enough to continue to the following process. There were hundreds to thousands of gas cylinders that had to go through a rework process to be suitable for entering the following process, and this caused losses in terms of time and energy. Based on data obtained by researchers from the PT XYZ production report in December 2023, it was found that the number of products requiring repair was at a reasonably high level, with an average percentage of products undergoing repair reaching 17.3% of the total production of 98,852 gas cylinders in 19 days. On a particular day, the highest repair rate was recorded at 1,653 repairs out of 6,942 steel tubes produced in a day, with a percentage reaching 23.81%.

This high number of repairs needs to be minimized or eliminated because the more defective products or repairs made, the greater the losses incurred by the company in terms of costs and productivity. To overcome this, the company implemented control with the Six Sigma approach. This approach was chosen because it has been proven effective through various studies. For example, research (Lestari & Purwatmini, 2021) identified factors causing defects in table products, such as worker fatigue due to the heat of the room temperature reaching 32 degrees and standing too long, resulting in a lack of focus and training. In addition, recent research by (Carlawati & Setiawati, 2024)recommends steps such as recording product settings and room temperatures, increasing worker awareness of quality through meetings and direct reprimands, especially for machine operators, emphasizing the importance of accuracy in work, and conducting PPE checks before entering the production room.

Applying the Six Sigma method is expected to be an alternative to implementing quality control principles and an innovation in quality management. This method uses the DMAIC approach, which includes the stages of defining, measuring, analyzing, improving, and controlling, as a systematic and structured solution for companies in controlling the quality of 3KG LPG gas cylinder production (Lestari & Purwatmini, 2021).

This study aims to help companies evaluate the performance of quality control that has been carried out, identify various factors causing product defects, and provide recommendations for corrective steps that need to be taken. In addition, this study provides theoretical information that the Six Sigma method is one effective way to control quality. This study can also be a reference for the public to show that 3KG LPG gas cylinders are safe to use because the company has carried out quality control consistently to ensure reliable production results.

2. Literature Review

Quality Control

According to (Nasution, 2005) (Supriyadi, 2018), Click or tap here to enter text. five main experts provide views on quality control, although with different emphases, but have the same meaning. The following are the opinions of the five experts:

a. Juran (1998). Product quality is defined as the suitability of the product for use (fitness for use), which aims to meet customer needs and satisfaction.
b. Crosby (1979). Quality is conformity to requirements or standards (conformance to requirement). A product is considered quality if it meets the established quality standards.

c. Deming (1982). Quality is conformity to market needs. If Juran defines quality as fitness for use and Crosby as conformance to requirement, then Deming focuses quality on conformity to market or consumer needs and expectations.
d. Feigenbaum (1986). Quality is the ability of a product to provide full customer satisfaction, namely in accordance with consumer expectations and needs.
e. Garvin (1988). Quality is a dynamic condition involving products, people, labor, processes, tasks, and the environment, which must meet or exceed customer expectations. Because customer tastes or needs are always changing, product quality must also be continuously adjusted through improving workforce skills, changing production processes, and adapting to the environment.

Based on the views of the five experts, the researcher concluded that quality is an effort to design products or services to meet customer desires by ensuring their conformity to established standards.

Six Sigma

Etymologically, the term "six sigma" comes from two words, namely "six," which means six, and "sigma," which refers to the standard deviation symbol. This statistical measure indicates the capability of a process. Sigma values are often expressed in units of DPU (Defects Per Unit) or PPM (Parts Per Million). Epistemologically, Six Sigma is a structured methodology that aims to improve process quality by reducing variation (process variance) and reducing the number of products or services that do not meet specifications. This approach intensively uses statistical methods and various quality tools to achieve optimal results (Manggala, 2015).

3. Methodology

Field Study and Literature

This research was conducted in January 2024 in a production company using primary and secondary data. Primary data was collected through direct observation of the production process, including field conditions, employee situations, and the number of defective products produced. Meanwhile, secondary data was obtained from company files or documents containing production performance records over the past few months. The researcher also used data on defective products taken from company documents for 19 working days in December 2023. In addition, during the observation, the researcher referred to various previous literature as a source of supporting information related to the product quality issues discussed.

Data collection

The author collected data using the following methods:

a. Interviews with related parties, such as Production Managers, Maintenance Managers, Operators, and Supervisors at PT PQR. This method aims to obtain information about the production flow, problems that occur, and the causes and factors that influence product defects.
b. Observation, in the form of direct observation of the research object, to understand the overall production process and the implementation of quality control in the field.
c. Company documentation, which includes collecting data related to the amount of production, the number of defective products, and product demand based on company archives.
d. Based on the data obtained, the author analyzes the findings in the context of the Six Sigma method, especially at the Define stage.

Data processing

After collecting the data, the researcher processed the data using the Six Sigma approach consisting of five DMAIC steps, according to the guidelines (Pande & Holpp, 2021) in (Amri & Ardiansyah Ekoanindiyo, 2022) as follows:

a. Define

The Define stage aims to set quality improvement targets in Six Sigma. This step focuses on defining the action plans needed to improve each stage of the central business process. The responsibility for determining the primary business process lies with management. In this study, the researcher conducted the Define stage to identify problems that arise in the production process of 3 kg LPG gas cylinders.

b. Measure

The measure is a logical follow-up to the definition step and serves as a pathway to the next step. According to (Pande & Holpp, 2021) in (Sarbullah & Sutrisno, 2021), the assessment steps have two primary purposes. The first is to obtain data to validate and qualify the problem and opportunity; the second is to start a conversation with facts and figures showing the problem's root.

In a Six Sigma quality improvement program, the second step involves measurement. Three significant tasks to be completed at this stage are Identifying key quality characteristics (Critical to Quality), Developing a plan for collecting the necessary data, and Measuring baseline performance at the output level. The following are the calculations that will be used in this measure;

Calculating the Defect Proportion

$$P = \frac{Number\ of\ Defects}{Production\ Quantity} \quad \text{(1)}$$

Calculating Mean Value (Center Line/CL)

$$CL = P = \frac{\sum np}{\sum n} \quad \text{(2)}$$

Calculating Upper Control Limit (UCL) and Lower Control Limit (LCL)

$$UCL = \overline{P} + 3\sqrt{\frac{\overline{P}(1-\overline{P})}{n}} \quad \text{(3)}$$

$$LCL = \overline{P} - 3\sqrt{\frac{\overline{P}(1-\overline{P})}{n}} \quad \text{(4)}$$

In this performance baseline measurement, the DPMO and Sigma levels are sought from the calculation results. The DPMO value is converted using the Motorola Sigma table created by Vincent Gasperz.

c. Analysis

The analysis is the third step in a Six Sigma quality improvement program that involves several important activities, such as evaluating process stability and capability, setting performance targets for critical quality characteristics (CTQs), and identifying the sources and root causes of quality problems.

Researchers use Fishbone Diagrams to analyze problems and find the source of product defects. This diagram shows the causes, including materials, machines, labor, methods, and environment.

d. Improvement

At this stage, the action program to improve quality in Six Sigma begins to be implemented. The success of this program is seen from the increase in Sigma capabilities and the reduction in the percentage of quality failure costs (Cost of Poor Quality or COPQ) to total sales value. Each step implemented needs to be evaluated for effectiveness based on achieving targets in the Six Sigma quality improvement program.

The proposed actions proposed by the author to improve Six Sigma quality are carried out using the 5W+1H (What, Where, When, Who, Why, and How) approach in preparing improvement plans.

e. Control

This is the final step in a Six Sigma project to improve quality. The results of the improvements achieved are recorded and disseminated, best practices are standardized and shared, and procedures are compiled into documents that serve as standard guidelines for the work. Next, the process owner or manager is responsible for the work of the Six Sigma Team. The DMAIC (Define, Measure, Analyze, Improve, and Control) process can be applied to subsequent Six Sigma projects in other parts of the organization. With this approach, companies can improve integration, institutionalization, learning, and transfer of new knowledge throughout the organization.

4. Results and Discussion

Define

The initial stage of the Six Sigma approach begins with the identification process. At this stage, the SIPOC (Supplier-Input-Process-Output-Customer) diagram is used to map the process as a whole while identifying the Critical to Quality (CTQ) aspects of the inspection process that has been carried out.

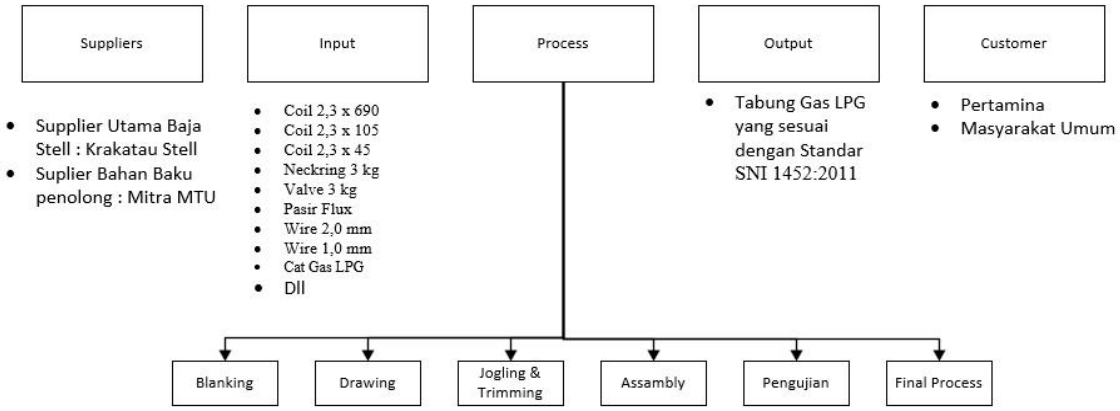

Figure 1. SIPOC Diagram

Based on the diagram, the author can understand the business flow of PT PQR in producing 3 kg LPG gas cylinders as follows.

a. Supplier

PT XYZ obtains its primary raw material in the form of steel from PT Krakatau Steel, while supporting raw materials are obtained through cooperation with partners who can meet production needs.

b. Input

The production process of 3 kg LPG gas cylinders uses standard materials, such as wire and coil, which are stored in the raw material warehouse.

c. Proces

In general, the main stages in production consist of six processes, namely blanking, drawing, jogling and trimming, assembly, leak test, and final process. The blanking process is carried out to form the iron plate into a circle. Furthermore, at the drawing stage, the circle plate is formed into a tube. The jogling and trimming stages are carried out by rolling at the joint between the bottom and top. After that, the assembly process is carried out to combine the two parts of the half tube using circum welding. The assembled tube is then tested for leaks using a leak test machine. The last process is the final process, namely giving color and identity to the tube before it is ready to be distributed.

d. Output

The resulting product is a 3 kg LPG gas cylinder that meets SNI 1452:2011 standards and is suitable for use.

e. Customer

PT PQR's primary customer is PT Pertamina Indonesia, which ensures that product standards and quality remain safe. After that, PT Pertamina fills LPG gas into cylinders and distributes it to the public as end users.

After understanding the production flow, the author grouped defective products in PT PQR's production process based on CTQ (Critical to Quality), which is presented in the following table.

Table 1 PT XYZ Production Data

Date	Production Quantity	Total Repair	% Repair	Repair Category							
				Bocor NR		Bocor HG		Bocor FR		Bocor Circum	
1	4308	434	10.1%	32	7.37%	22	5.07%	22	5.07%	358	82.49%
2	4520	643	14.2%	28	4.35%	28	4.35%	43	6.69%	544	84.60%
3	4512	913	20.2%	30	3.29%	28	3.07%	38	4.16%	817	89.49%
4	4854	677	13.9%	40	5.91%	19	2.81%	42	6.20%	576	85.08%
5	5224	719	13.8%	37	5.15%	22	3.06%	40	5.56%	620	86.23%
6	4524	752	16.6%	35	4.65%	26	3.46%	43	5.72%	648	86.17%
7	4264	686	16.1%	24	3.50%	20	2.92%	22	3.21%	620	90.38%
8	3494	556	15.9%	26	4.68%	13	2.34%	11	1.98%	506	91.01%
9	5370	818	15.2%	47	5.75%	32	3.91%	26	3.18%	713	87.16%
10	6736	1155	17.1%	100	8.66%	36	3.12%	59	5.11%	960	83.12%
11	4724	672	14.2%	21	3.13%	16	2.38%	35	5.21%	600	89.29%
12	5200	746	14.3%	102	13.67%	14	1.88%	10	1.34%	620	83.11%
13	4624	735	15.9%	59	8.03%	15	2.04%	10	1.36%	651	88.57%
14	3602	660	18.3%	32	4.85%	6	0.91%	15	2.27%	607	91.97%
15	4990	1194	23.9%	68	5.70%	12	1.01%	11	0.92%	1103	92.38%
16	6250	1486	23.8%	80	5.38%	14	0.94%	13	0.87%	1379	92.80%
17	6942	1653	23.8%	76	4.60%	18	1.09%	22	1.33%	1537	92.98%
18	7492	1557	20.8%	54	3.47%	14	0.90%	40	2.57%	1449	93.06%
19	7222	1436	19.9%	45	3.13%	22	1.53%	37	2.58%	1332	92.76%
Total	98852	17492		936		377		539		15640	
Rata-Rata		17.3%		5.4%		2.2%		3.1%		89.4%	

Based on Table 1, it can be concluded that there are constraints in product quality control, which causes many products to require repair. In testing using a leak test machine, four objects were identified as being in the critical to quality category. During 19 working days, total

production reached 100,307 3 kg LPG gas cylinders, with 17,492 products (17.3% of total production) requiring repair. This condition indicates weaknesses in the production process that must be addressed immediately because they can affect the efficiency of the company's time and operational costs. The following is a breakdown of defects that occurred during the production process.

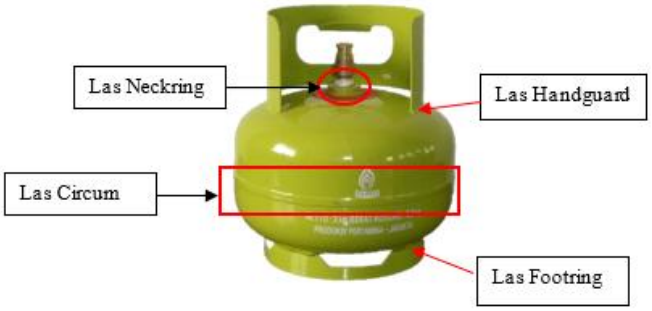

Figure 2. The production position is not good

Measure

a. Control Chart P

Calculating the Defect Proportion

$$P = \frac{Number\ of\ Defects}{Production\ Quantity}$$

$$P = \frac{434}{4308} = 0{,}10074$$

b. Calculating Mean Value (CL)

In data collection for 19 sample days, the total production (n) was 98,852 units, with a total of 17,492 defective or repaired products. Based on these data, the calculated Center Line value is:

$$CL = P = \frac{\sum np}{\sum n} = \frac{17492}{98852} = 0{,}17695$$

c. Calculating Upper Control Limit (UCL) and Lower Control Limit (LCL)

To calculate the UCL and LCL values on the P control chart on the first day, the following calculation results were obtained:

$$UCL = \overline{P} + 3\sqrt{\frac{\overline{P}(1-\overline{P})}{n}}$$

$$UCL = 0{,}17695 + 3\sqrt{\frac{0{,}17695(1-0{,}17695)}{4308}}$$

$$UCL = 0{,}19439$$

Lower Control Limit

$$LCL = \overline{P} - 3\sqrt{\frac{\overline{P}(1-\overline{P})}{n}}$$

$$LCL = 0{,}1769 - 3\sqrt{\frac{0{,}17695(1-0{,}17695)}{4308}}$$

$$LCL = 0{,}15950$$

The following is a measurement sheet that records sampling over 19 days. This data is used to determine the UCL (*Upper Control Limit*) and LCL (*Lower Control Limit*) values.

Table 2. Overall Data of P Control Chart

Hari ke-	N	Np	P	UCL	CL	LCL
1	4308	434	0.100743	0.19439	0.17695	0.15951
2	4520	643	0.142257	0.19398	0.17695	0.15992
3	4512	913	0.202349	0.19400	0.17695	0.15991
4	4854	677	0.139473	0.19338	0.17695	0.16052
5	5224	719	0.137634	0.19279	0.17695	0.16111
6	4524	752	0.166225	0.19397	0.17695	0.15993
7	4264	686	0.160882	0.19448	0.17695	0.15942
8	3494	556	0.15913	0.19632	0.17695	0.15758
9	5370	818	0.152328	0.19257	0.17695	0.16133
10	6736	1155	0.171467	0.19090	0.17695	0.16300
11	4724	672	0.142252	0.19361	0.17695	0.16029
12	5200	746	0.143462	0.19283	0.17695	0.16107
13	4624	735	0.158953	0.19379	0.17695	0.16011
14	3602	660	0.183232	0.19603	0.17695	0.15788
15	4990	1194	0.239279	0.19316	0.17695	0.16074
16	6250	1486	0.23776	0.19143	0.17695	0.16247
17	6942	1653	0.238116	0.19069	0.17695	0.16321
18	7492	1557	0.207822	0.19018	0.17695	0.16372
19	7222	1436	0.198837	0.19042	0.17695	0.16348
Jumlah	98852	17492				

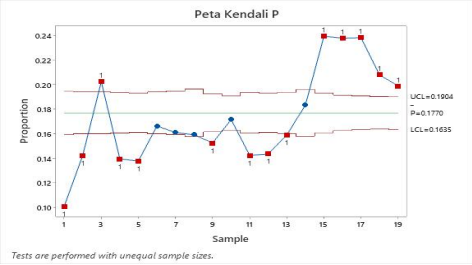

Figure 3. Control P Diagram

Based on Figure 3, it can be seen that there is data that is outside the established control limits. This shows that the quality control carried out by PT PQR is still not optimal. Therefore, the company needs to make improvements in product quality control in order to reduce the defect rate to 0%.

d. Six Sigma level measurement stage and Defect Per Million Opportunity (DPMO)

Table 3. Defect Per Million Opportunity (DPMO)

Period	Production Quantity	Total Repair	CTQ Cause Repair	Period DPMO	Sigma Process
1	4308	434	4	25185.7	3.457
2	4520	643	4	35564.2	3.305
3	4512	913	4	50587.3	3.139
4	4854	677	4	34868.1	3.314
5	5224	719	4	34408.5	3.320
6	4524	752	4	41556.1	3.233
7	4264	686	4	40220.5	3.248
8	3494	556	4	39782.5	3.253
9	5370	818	4	38081.9	3.273
10	6736	1155	4	42866.7	3.218
11	4724	672	4	35563.1	3.305
12	5200	746	4	35865.4	3.301
13	4624	735	4	39738.3	3.254
14	3602	660	4	45807.9	3.187
15	4990	1194	4	59819.6	3.056
16	6250	1486	4	59440.0	3.059
17	6942	1653	4	59529.0	3.059
18	7492	1557	4	51955.4	3.126
19	7222	1436	4	49709.2	3.148
Proses	**98852**	**17492**	**4**	**44237.9**	**3.203**

Based on Table 3, the DPMO value in December with a period of 19 days was recorded at 44,743.7. This shows that out of a million opportunities, there are 44,743.7 possibilities that the product does not meet the tolerance set by the company, so it is categorized as a defective product. The sigma value is at the level of 3.203, which indicates that the company's quality control is still relatively good compared to the average company in Indonesia. However, in terms of profit, the company can experience a potential loss of 20-40% of the total profit generated.

Analyze

a. Pareto Diagram

$$\%\ Demage = \frac{Number\ of\ Damage\ Types\ i}{Total\ Amount\ of\ Damage} X\ 100\%$$

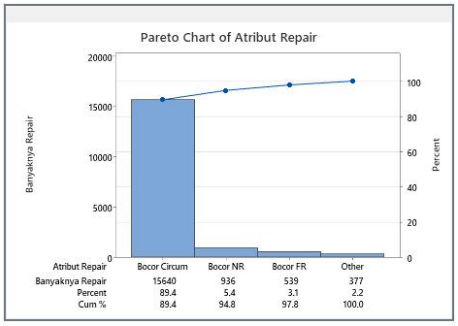

Figure 4. Pareto Diagram

The observation results showed that four types of defects were found in the production of 3 kg LPG steel cylinders during 19 working days. The percentage of damage was: leakage on the circum of 88.6%, leakage on the Neck Ring (NR) of 5.5%, leakage on the Foot Ring of 3.6%, and leakage on the Hand Guard of 2.2% of the total 17,492 damages. Therefore, the priority of repair should be focused on overcoming leakage defects on the circum, which reached 88.6%, so that the number of defective products can be minimized.

b. Cause and Effect Diagram

The next step is to identify the factors or root causes of the leakage in the circum. Based on data analysis, this defect is the most dominant, with a percentage of around 89.4% of the total 17,493 damages. For this reason, an analysis was carried out using a fishbone diagram to identify the factors that contributed to the occurrence of the defect. Furthermore, based on the factors that have been identified, a more in-depth analysis can be carried out to determine the corrective action to reduce the possibility of defects occurring.

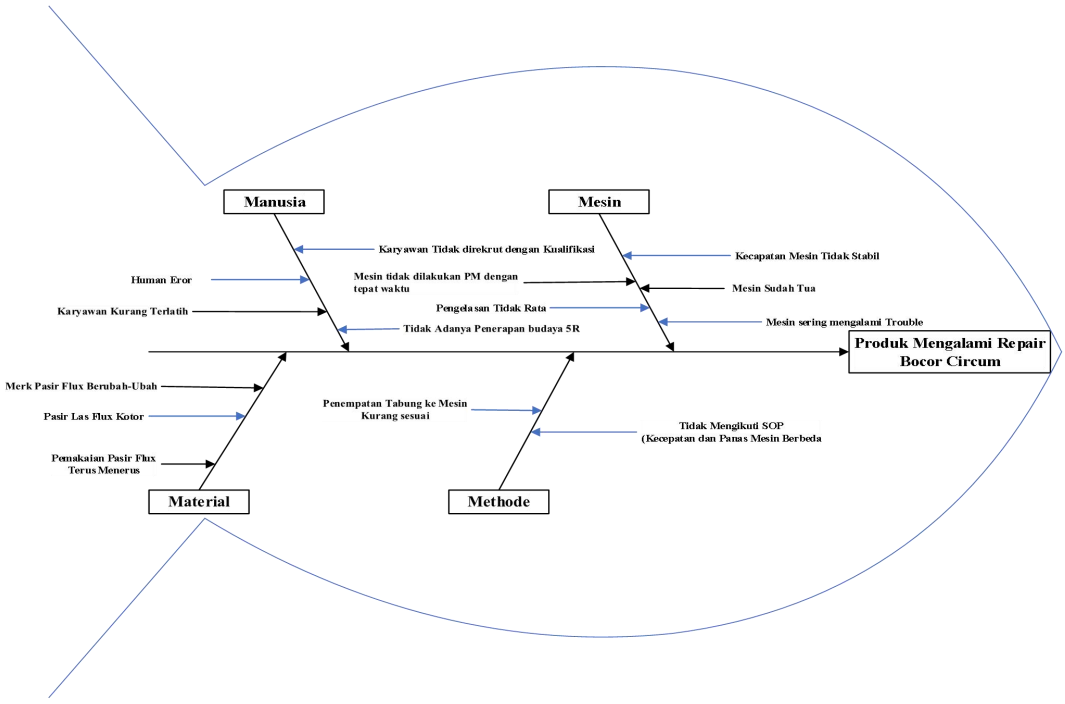

Figure 5. Cause and Effect Diagram

Improvement

After identifying the causes of defects in each type of product, this study proposes several corrective actions that can be implemented to overcome these failures. These steps are expected to reduce the possibility of defective products while increasing the sigma value. The following are proposed improvements that can be implemented.

Table 4. Recommendation Improvement

Factor	What	Who	When	Where	Why	How
Man	Employees are tired and lack focus and are under-trained.	Operator	Production Operating Hours (8x60 Minutes)	PT XYZ Producti on Plant	There is no production synchronization between work stations a and b. There is no special qualification when registering employees	Make production planning by considering employee workload. Conducting a job analysis that includes a job description and qualifications for the position being recruited. Create regular training schedules and employee performance evaluations for existing employees (Key Performance Indicators).
Machine	Engine performance is declining, and some engines are outdated, causing engine speed to be unstable.	Mainten ance Division	Production Operating Hours (8x60 Minutes)	Circum Machine	The limited number of available human resources causes a lack of discipline in machine maintenance. In addition, the production machines used are machines with a usage age of 10 years, which worsens the condition of the machine and increases the risk of damage and decreased performance.	To improve production performance, it is necessary to evaluate machine performance periodically. In addition, it is important to improve the quality maintenance system by checking the machine during setup and after use to ensure that the machine continues to function properly. In addition, analysis of the procurement of machine investment, especially machines for the circum process, also needs to be carried out to replace old machines and ensure smooth long-term production.
Method	Non-compliance with production SOPs.	Operator	Production Operating Hours (8x60 Minutes)	Circum Machine	Wire temperature and speed settings exceed standard limits.	Conduct routine evaluations related to operator knowledge and competency tests based on applicable SOPs.

Material	Use of dirty flux sand and inconsistency in the brand of flux sand used.	Purchasing Division	Production Operating Hours (8x60 Minutes)	Circum Machine	Continuous use of sand	To maintain quality consistency, standardization is needed to limit the use of flux sand. In addition, it is recommended that long-term cooperation be established with one to two trusted vendors in providing supporting raw materials to ensure that the quality of the material remains stable and does not change.

Control

The final stage in a Six Sigma project focuses on documenting and disseminating the results of the implementation of improvements that have been made. The main steps in this stage include:

a. Formation of the Change Team: This team is tasked with overseeing the transition process to improve production performance and ensure smooth implementation of improvements.
b. Monitoring and Documenting Machine Improvements: Regularly monitor machine improvements that have been implemented to maintain the sustainability of performance improvements.
c. Monitoring and Documenting Employee Compliance: Ensuring employees implement applicable standard operating procedures (SOPs) through structured supervision and recording.
d. Employee Performance Period Evaluation: Conduct regular evaluations of employee performance to identify achievements and opportunities for further improvement.

This approach aims to ensure the sustainability and effectiveness of the results of the implementation of the Six Sigma project.

5. Conclusion

In 19 days of data collection at PT XYZ, the DPMO value reached 44,237.9, with a sigma value of 3.203, indicating significant defects and potential losses of 20-40% of sales profits due to frequent repairs. Key causes include old machines, lack of maintenance, weak supervision, and unqualified employees lacking performance evaluations. Non-compliance with SOPs and material errors, such as flux sand misuse exacerbate defects. Improvements are needed in recruitment policies, regular performance evaluations, and machine maintenance to enhance production quality

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