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QUALITY CONTROL USING THE SIX SIGMA METHOD TO MINIMIZE DAMAGE TO TYPE 2268.2 JARS AT PT X

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ABSTRACT

PT X is a plastic jar manufacturing company that produces 14,000 jars per day using 12 machines. A recurring problem is the high number of defective products, which makes lid-to-body assembly difficult. This study aimed to identify the causes of defects and recommend quality improvements using the Six Sigma method. The results showed that the most frequent defects were falling breakage (1,004 cases) and ejection defects (712 cases). Statistical control values (CL, UCL, and LCL) were still within control limits, while the cause-and-effect analysis indicated that human factors were the main source of defects. The key improvement priorities are strengthening SOP implementation and providing better training on injection machine operation. Although the sigma level of 4.1 indicates fairly good performance, quality improvement remains necessary to enhance productivity.

Keywords: *Quality Qontrol; Six Sigma; DMAIC; Defective Products; Jar Products*

I. INTRODUCTION

In today's global era, competition in the business world is intensifying and evolving, resulting in significant changes in people's perspectives on purchasing products (Caesaron, 2015). Customer satisfaction is one of the most important factors in attracting consumer purchasing power towards a product (Yulistria, 2023). Quality plays an important role for consumers in making decisions about purchasing an item (Amir, 2018). Companies that pay attention to quality and quality aspects can minimize the risk of damage (defects) to their products (Apriliana, 2023). So in this case, the company can reduce production waste costs and make the selling price of the product competitive (Nisa, 2023). The high productivity of a company is not a benchmark in business competition, but rather the product quality factor has a major influence on the selling value of goods (Tristianto, 2022).

Quality control has important value for companies in order to minimize losses arising from production deviations in terms of both quality and quantity (Faritsy, 2022). Control and supervision are a series of operational activities to ensure that there are no deviations in the production process. To minimize product defects, companies must conduct regular inspections on raw materials, semi-finished products, and finished goods. These inspections aim to produce the best possible product and enable companies to identify the underlying factors and causes (Tristianto, 2022). Six Sigma is a method that discusses quality management and quality, used to minimize defects in products (Kurniawan, 2024). There are 5 stages of steps called DMAIC (Define, Measure, Analyze, Improve, Control), (Waruwu, 2022). The Six Sigma method was developed by Motorola Corporation with the aim of reducing defects and improving overall quality (Zulfikar, 2021).

PT X is a manufacturing industry company engaged in the manufacture of plastic jars by implementing a make-to-stock system for both finished goods and work-in-process products in its production. Products produced by company X include jar bodies and lids of types 2268.2, 555.2, 255.5.2, 505.14 and so on. The raw material used in making jar products comes from GPPS (general-purpose polystyrene) plastic pellets. In each production process, this company is capable of producing 14,000 jar products per day, supported by 12 available machines. The problem often experienced by PT X is that many product qualities do not meet specifications (standards), making the assembly process between the lid and the jar body difficult. If this continues for a long time, it will result in cost losses, double handling, and a lack of consumer trust. This research aims to determine the causes of defective products and provide quality improvement suggestions using the Six Sigma method. The product being researched is the jar body type 2268.2 because it had the highest number of defects in January 2025 like Figure 1 bellow.

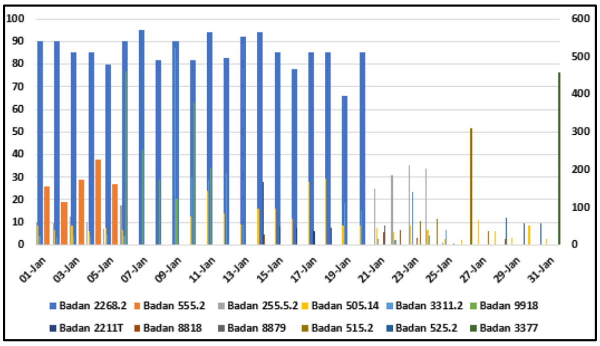

Figure 1. Product Defects in Jar Bodies for January 2025

II. METHOD

A. Qualitiy Control

Quality control is a crucial activity for companies to support and maintain their products for customers (Wardah, 2022). The purpose of quality control is to ensure that the goods produced meet standards and minimize costs resulting from material handling (Wardah, 2022). In other words, quality control is a stipulation established by company management to maintain product and service specification policies (Sulaeman, 2014).

B. Six Sigma

Six Sigma is a method tool used in quality improvement considering five stages (Define, Measure, Analyze, Improve, Control) (Suhartini, 2020). Six Sigma has proven very effective in efforts to improve product quality by reducing the occurrence of defects to 3.4 times per million possibilities (Nursasongko, 2022).

1) Define

Define is the initial stage of identifying the problem or defect criteria and the objectives of the research, in this case involving the identification of needs, desires, and expectations of consumers or often known as CTQ (Critical to Quality) (Cahyo, 2024).

2) Measurement
Measurement is the second stage used for data collection. Measurement has a very important role in the process of understanding the level of data variation (Cahyo, 2024).

a) Calculate the proportion of defects P-value

$$P = \frac{Number\ of\ Defect}{Number\ of\ Production}$$

b) Calculate the mean value of CL (Center Line)

$$CL = P = \frac{\Sigma np}{\Sigma n}$$

c) Calculate the upper value of UCL (Upper Control Limit)

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

d) Calculate the lower value of LCL (Lower Control Limit)

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

e) Calculate DPU value (Defect Per Unit)

$$DPU = \frac{Number\ of\ Defect}{Number\ of\ Production}$$

f) Calculate DPO value (Defect Per Opportuinity)

$$DPO = \frac{DPU}{DPU\ /\ CTQ}$$

g) Calculate DPMO value (Defect Per Million Opportunity)

$$DPMO = \frac{Number\ of\ Defect}{(Number\ of\ Production \times CTQ)} \times 1.000.000$$

h) Calculate Sigma Level value
Sigma = Norm.S.Inv((1.000.000-5.267) / 1.000.000)) + 1,5

3) Analysis
Analysis is the third stage used to identify and find the root cause of the problem. Analysis has an important role in identifying factors that cause a decline in product quality and quality, (Cahyo, 2024).

4) Improvement
Improvement is the fourth stage used in the improvement process to reduce the level of defects. Improvements are carried out to identify risks and prevent defects from occurring in the product (Cahyo, 2024).

5) Control
Control is the final stage aimed at maintaining and monitoring product quality, and has an important role to play in assisting long-term activities.

III. RESULTS AND DISCUSSION

This research was conducted at PT X using the Six Sigma DMAIC method. The following data shows the production results and defective products of type 2268.2 jar bodies in January 2025. The production results and the number of defects observed during the study period are presented in Table 1.

Table 1. Production Results and Defects

Date Month and Year 2025	Production Target Jar Type 2268.2 Body	Production Results Jar Type 2268.2 Body	Types of Product Defects		Total Broken	Persentase
			Broken Eject	Broken Fall		
1 Jan	8.229	8.544	50	40	90	1,05%
2 Jan	8.229	8.565	55	35	90	1,05%
3 Jan	8.229	7.965	45	40	85	1,07%
4 Jan	8.229	8.605	85	0	85	0,99%
5 Jan	8.229	8.543	30	50	80	0,94%

6 Jan	8.229	8.545	67	23	90	1,05%
7 Jan	8.229	8.630	70	25	95	1,10%
8 Jan	8.229	8.602	53	29	82	0,95%
9 Jan	8.229	8.585	30	60	90	1,05%
10 Jan	8.229	8.566	33	49	82	0,96%
11 Jan	8.229	8.557	24	70	94	1,10%
12 Jan	8.229	8.543	56	27	83	0,97%
13 Jan	8.229	8.552	30	62	92	1,08%
14 Jan	8.229	8.542	37	57	94	1,10%
15 Jan	8.229	8.570	40	45	85	0,99%
16 Jan	8.229	8.574	78	0	78	0,91%
17 Jan	8.229	8.580	50	35	85	0,99%
18 Jan	8.229	8.555	85	0	85	0,99%
19 Jan	8.229	7.314	46	20	66	0,90%
21 Jan	8.229	8.542	40	45	85	1,00%
22 Jan		0	0	0	0	0
23 Jan		0	0	0	0	0
24 Jan		0	0	0	0	0
25 Jan		0	0	0	0	0
26 Jan		0	0	0	0	0
27 Jan		0	0	0	0	0
28 Jan	Machine Stops	0	0	0	0	0
29 Jan		0	0	0	0	0
30 Jan		0	0	0	0	0
31 Jan		0	0	0	0	0
Total	164.580	169.479	1.004	712	1.716	1,0%
Average	8.229	8.474	50	36	86	4,29

Based on the table above, it can be seen that the total production of type 2268.2 jar body products is 164,580 pieces with 2 product defect criteria (fall breakage and eject breakage). The production target calculation has been set by the company with the following calculation:

A. Production Target

Production Target = 60 (1 minute) × 60 (1 hour) = 3,600 × 8 Working Hours = 28,800 Hours

= 28,800 / 10.5 (seconds) cycle time = 2,743 Pcs

= 2,743 Pcs × 3 Shifts = 8.229 Pcs

1) Define

In the definition stage, the company must be able to identify the problems that cause product defects. From the results of research conducted by researchers, there are two types of defects: falling breakage and eject breakage at PT X. Critical to quality (CTQ) is an important role in the company to minimize product defects in the type 2268.2 jar body and the sound required by consumers.

2) Measurement

In the measurement stage, researchers collect data obtained from the problem identification (defined). A checksheet is used to facilitate problem analysis and generate defect proportion values, the median CL, UCL, and LCL. Table 2 shows the results of the measurements conducted on the observed process.:

a) Calculation of the proportion of defective products on 1 January 2025, obtained as follows:

$$\text{P 1 January 2025} = \frac{90}{8.544} = 0{,}011$$

b) Calculation of the center line (CL) value

$$\text{CL} = \text{P} = \frac{1.716}{169.479} = 0{,}010$$

c) Calculation of the upper control limit (UCL) value

$$\text{UCL} = 0{,}010 + 3\,\frac{\sqrt{0{,}010\,(1-0{,}010)}}{169.479} = 0{,}011$$

d) Calculation of the lower control limit (LCL) value

$$\text{LCL} = 0{,}010 - 3\,\frac{\sqrt{0{,}010\,(1-0{,}010)}}{169.479} = 0{,}009$$

Table 2. Measurement

Date Month and Year 2025	Production Result	Number of Defects	Product Defect Proportion	UCL	CL	LCL
1 Jan	8.544	90	0,011	0,011	0,010	0,009
2 Jan	8.565	90	0,011	0,011	0,010	0,009
3 Jan	7.965	85	0,011	0,011	0,010	0,009
4 Jan	8.605	85	0,010	0,011	0,010	0,009
5 Jan	8.543	80	0,009	0,011	0,010	0,009
6 Jan	8.545	90	0,011	0,011	0,010	0,009
7 Jan	8.630	95	0,011	0,011	0,010	0,009
8 Jan	8.602	82	0,010	0,011	0,010	0,009
9 Jan	8.585	90	0,010	0,011	0,010	0,009
10 Jan	8.566	82	0,010	0,011	0,010	0,009
11 Jan	8.557	94	0,011	0,011	0,010	0,009
12 Jan	8.543	83	0,010	0,011	0,010	0,009
13 Jan	8.552	92	0,011	0,011	0,010	0,009
14 Jan	8.542	94	0,011	0,011	0,010	0,009
15 Jan	8.570	85	0,010	0,011	0,010	0,009
16 Jan	8.574	78	0,009	0,011	0,010	0,009
17 Jan	8.580	85	0,010	0,011	0,010	0,009
18 Jan	8.555	85	0,010	0,011	0,010	0,009
19 Jan	7.314	66	0,009	0,011	0,010	0,009
20 Jan	8.542	85	0,010	0,011	0,010	0,009
21 Jan		0	0	0	0	0
22 Jan		0	0	0	0	0
23 Jan		0	0	0	0	0
24 Jan		0	0	0	0	0
25 Jan		0		0	0	0
26 Jan	Machine Stops	0	0	0	0	0
27 Jan		0	0	0	0	0
28 Jan		0	0	0	0	0
29 Jan		0	0	0	0	0
30 Jan		0	0	0	0	0
31 Jan		0	0	0	0	

Total	169.479	1.716	0,202	0,220	0,202	0,180
Average	8.474	86	0,010	0,011	0,010	0,009

Based on the calculation results at the measurement stage, no values exceeded the total defective product limit. It can be concluded that the company's production processes are still in a stable (good) condition. However, quality control and continuous improvement must be implemented to minimize defective products and increase the company's productivity. The measurement setup used in this study is depicted in Figure 2.

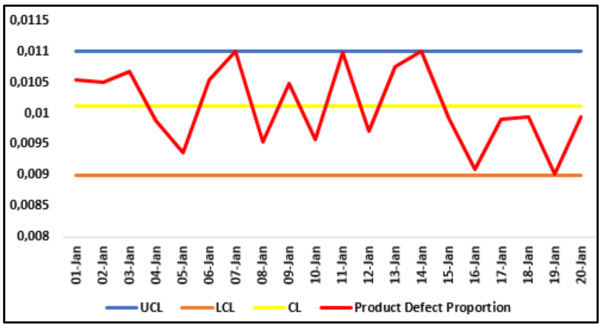

Figure 2. Measurement

B. Six Sigma and DPMO Values

The next step is to calculate the Six Sigma and Defects Per Million Opportunity (DPMO) values. The sigma values calculated for each observation period are presented in Table 3.

1) Calculate the Defect Per Unit (DPU) value

$$\text{DPU} = \frac{90}{8.544} = 0{,}011$$

2) Calculating Defect Per Opportunity (DPO)

$$\text{DPO} = \frac{0{,}011}{0{,}011\ /\ 2} = 0{,}0053$$

3) Calculating Defects Per Million Opportunities (DPMO)

$$\text{DPMO} = \frac{90}{(\ 8.544 \times 2)} \times 1.000.000 = 5.267$$

4) Calculating Sigma Values Using Microsoft Excel Formulas and Matching Them to Table Conversions

Sigma = Norm.S.Inv((1.000.000-5.267) / 1.000.000)) + 1,5

Table 3. Sigma Values

Date Month and Year 2025	Production Result	Number of Defects	DPU	DPO	DPMO	Sigma Value
1 Jan	8.544	90	0,011	0,0053	5.267	4,1
2 Jan	8.565	90	0,011	0,0053	5.254	4,1
3 Jan	7.965	85	0,011	0,0053	5.336	4,1
4 Jan	8.605	85	0,010	0,0049	4.939	4,1
5 Jan	8.543	80	0,009	0,0047	4.682	4,1
6 Jan	8.545	90	0,011	0,0053	5.266	4,1
7 Jan	8.630	95	0,011	0,0055	5.504	4,0
8 Jan	8.602	82	0,010	0,0048	4.766	4,1
9 Jan	8.585	90	0,010	0,0052	5.242	4,1
10 Jan	8.566	82	0,010	0,0048	4.786	4,1
11 Jan	8.557	94	0,011	0,0055	5.493	4,0
12 Jan	8.543	83	0,010	0,0049	4.858	4,1
13 Jan	8.552	92	0,011	0,0054	5.379	4,1
14 Jan	8.542	94	0,011	0,0055	5.502	4,0
15 Jan	8.570	85	0,010	0,0050	4.959	4,1
16 Jan	8.574	78	0,009	0,0045	4.549	4,1
17 Jan	8.580	85	0,010	0,0050	4.953	4,1
18 Jan	8.555	85	0,010	0,0050	4.968	4,1
19 Jan	7.314	66	0,009	0,0045	4.512	4,1
20 Jan	8.542	85	0,010	0,0050	4.975	4,1
21 Jan	Machine	0	0	0	0	0
22 Jan	Stops	0	0	0	0	0

23Jan		0	0	0	0	0
24 Jan		0	0	0	0	0
25 Jan		0	0	0	0	0
26 Jan		0	0	0	0	0
27 Jan		0	0	0	0	0
28 Jan		0	0	0	0	0
29 Jan		0	0	0	0	0
30 Jan		0	0	0	0	0
31 Jan		0	0	0	0	0
Total	169.479	1.716	0,202	0,101	101.190	81,446
Average	8.474	86	0,010	0,005	5059,515	4,1

C. Analyze

In the analyze stage, the primary causes of product defects in this study can be identified and depicted in the form of Pareto diagrams at Figure 3.

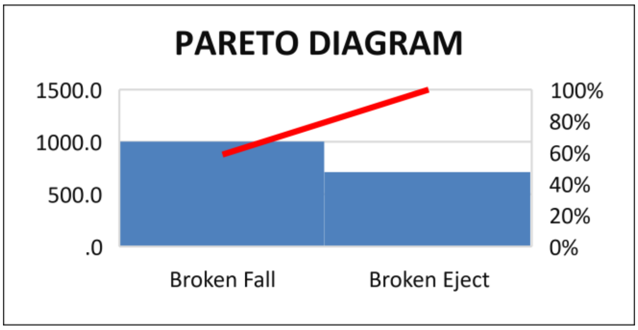

Figure 3. Pareto of Defective Products

Based on the results of the image above, there are 2 types of product defects, namely falling breakage and ejection breakage. The highest value for falling breakage is 59% and ejection breakage is 41%.

The main priority in quality improvement is the value with the highest percentage. The following is a Table 4 explaining the percentage of the number and type of the 2 defect criteria:

Table 4. Percentage of Number and Type of Drop Breakage Defects

Date Month and Year 2025	Production Result	Number of Defects	Broken Fall	Persentase
1 Jan	8.544	1.004	50	5,0%
2 Jan	8.565	1.004	55	5,5%
3 Jan	7.965	1.004	45	4,5%
4 Jan	8.605	1.004	85	8,5%
5 Jan	8.543	1.004	30	3,0%
6 Jan	8.545	1.004	67	6,7%
7 Jan	8.630	1.004	70	7,0%
8 Jan	8.602	1.004	53	5,3%
9 Jan	8.585	1.004	30	3,0%
10 Jan	8.566	1.004	33	3,3%
11 Jan	8.557	1.004	24	2,4%
12 Jan	8.543	1.004	56	5,6%
13 Jan	8.552	1.004	30	3,0%
14 Jan	8.542	1.004	37	3,7%
15 Jan	8.570	1.004	40	4,0%
16 Jan	8.574	1.004	78	7,8%
17 Jan	8.580	1.004	50	5,0%
18 Jan	8.555	1.004	85	8,5%

19 Jan	7.314	1.004	46	4,6%
20 Jan	8.542	1.004	40	4,0%

The table above is the result of an explanation of the percentage value of the number of types of defects. The explanation of the types of eject defects will be explained as follows.

Table 5. Percentage of Number and Type of Ejection Breakage Defects

Date Month and Year 2025	Production Result	Number of Defects	Broken Eject	Persentase
1 Jan	8.544	712	40	5,6%
2 Jan	8.565	712	35	4,9%
3 Jan	7.965	712	40	5,6%
4 Jan	8.605	712	0	0,0%
5 Jan	8.543	712	50	7,0%
6 Jan	8.545	712	23	3,2%
7 Jan	8.630	712	25	3,5%
8 Jan	8.602	712	29	4,1%
9 Jan	8.585	712	60	8,4%
10 Jan	8.566	712	49	6,9%
11 Jan	8.557	712	70	9,8%
12 Jan	8.543	712	27	3,8%
13 Jan	8.552	712	62	8,7%
14 Jan	8.542	712	57	8,0%
15 Jan	8.570	712	45	6,3%
16 Jan	8.574	712	0	0,0%
17 Jan	8.580	712	35	4,9%
18 Jan	8.555	712	0	0,0%
19 Jan	7.314	712	20	2,8%
20 Jan	8.542	712	45	6,3%

Based on the explanations in the two tables above, it can be concluded that the highest value of defects due to expenditure was 9.8% and the highest value of defects due to falls was 8.5%. The following graph at Figure 4 explains the percentage results for these two types of defects.

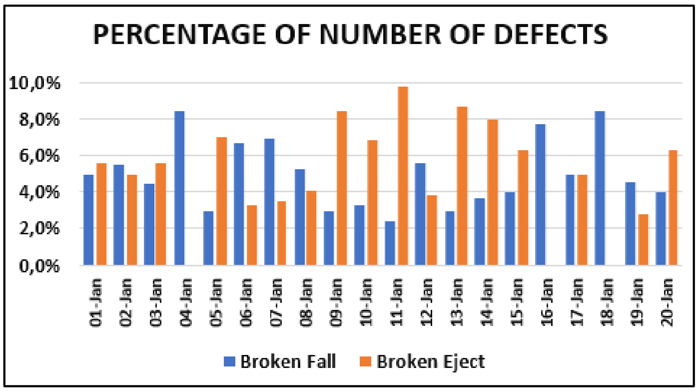

Figure 4. Percentage of total number of defects

D. Cause and Effect Diagram

1) Types of Ejection Rupture Defects

Identify problems at Company X using a cause and effect diagram to determine the possibility of product defects caused by human, machine, method, or material factors. The following Figure 5 is a specific explanation of the fishbone diagram:

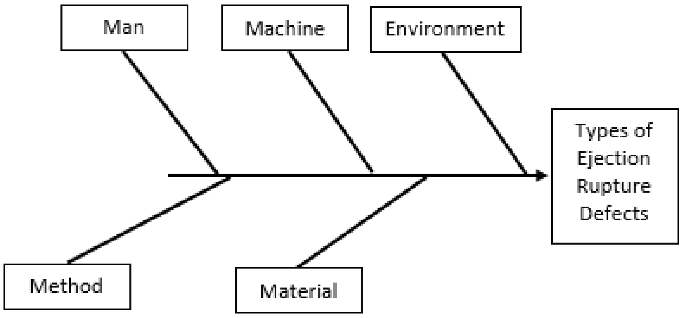

Figure 5. Cause and Effect Diagram

a) Man
The operator was not well-trained in setting up the injection machine and was too rough when removing the jars from the machine.

b) Machine
The injection machine setting at hot/cold temperature is not perfect, so the jar is easily brittle, and it is not fully cooked when it comes out of the mold.

c) Environment
Lack of cleanliness in the work area has an impact on the quality of topless products.

d) Method
Lack of supervision and SOP during trials before being used in mass production requires periodic checks on the machine cycle time.

e) Material
The quality of the material (poor) and the wetness are not completely dry, so the jar results are not optimal.

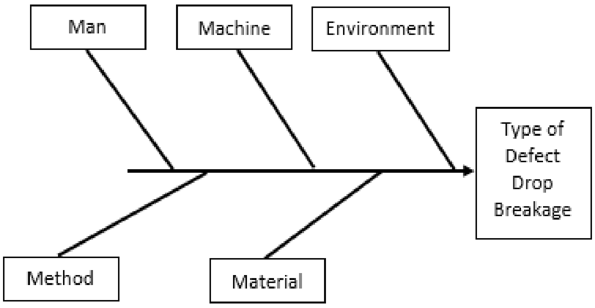

Figure 6. Cause and Effect Diagram

2) Type of Defect Drop Breakage

The following Figure 6 is a specific explanation of the fishbone diagram above.

a) Man
Carelessness and lack of caution when removing jars from the machine, as well as operators rushing to retrieve products.

b) Machine
The lack of protective guards around the machine, along with machine vibrations, can cause jars to be easily dropped.

c) Method
Stacking jars too high can lead to falls and breakage, and manual handling is still used.

d) Material

Wet material quality can lead to inaccurate product thickness (thinness) and brittleness.

e) Environment
Heavy activity around the production area can make it difficult for operators to handle the product (prone to falls).

E. Improvement

The next stage is the improvement used to improve the quality of the Type 2268.2 Body jar product by using the proposed improvements explained in the table below:

1) Man
   a) Improved working hours, providing a 15-minute break every 2 hours of work and a 1-hour rest period to reduce fatigue caused by hot areas in production.
   b) Training was provided on how to use the injection machine.
2) Machine
   a) The need for regular machine maintenance checks and care.
   b) The availability of tools and support on the machine to prevent excessive vibration.
3) Method
   a) Improve the layout design for safe material handling.
   b) The need for training and SOPs for injection machine use.
4) Material
   Conducting material inspection test to ensure products meet company standart
5) Environment
   Requiring all workers to maintain orderly cleanliness and neat product layout in both production and warehouses.

F. Control

This stage involves monitoring and controlling the entire series of activities after the improvement stage is completed. Improvement plans and quality control proposals are developed to address defects in products caused by machinery, humans, materials, methods, and the work environment. This control stage is crucial for minimizing defects in Type 2268.2 jar bodies, ensuring the company's quality, effectiveness, and efficiency.

IV. CONCLUSION

Based on the results of data analysis and discussion above, it can be concluded that there are 2 criteria for falling and ejecting defects of the jar body product type 2268.2. The measurement stage shows that the CL value is still on the threshold, while the average sigma value is 4.1 in the fairly good category. Analyze using a Pareto diagram, the highest value is caused by falling breakage defects, which are explained in the cause and effect diagram, and proposed improvements.

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