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Analysis of Ceramic Quality Control in PT. XYZ Using Six Sigma and FMEA Methods

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***Abstract*: Quality control is an integrated activity in the company to maintain and maintain the quality of products produced in order to run well and according to established standards. Quality control needs to be carried out at PT. XYZ, a manufacturing company that produces ceramics. The problem that occurs is the number of defective products found in the finishing process. Data collection is done by interview, field observation and documentation. The data used in this study is the amount of production from May to October. This study aims to find the DPMO value and how the most appropriate improvement efforts, with the six-sigma method through the DMAIC approach. Analysis to find the most dominant cause of defects is done with the fishbone diagram method, which is one of the methods/tools in improving quality. This diagram is also often called a cause-and-effect diagram. Based on the fishbone, the RPN value is calculated to determine the most dominant cause and the most appropriate improvement proposal.**

***Keywords*: quality, defect, six sigma, fishbone.**

1. Introduction

Quality is a level of excellence or standard that describes the degree to which a product, service, or process meets or exceeds consumer expectations and needs. It includes a wide range of attributes such as reliability, durability, efficiency, aesthetics, and adherence to specifications. Quality includes not only physical or technical aspects, but also aspects such as customer service, corporate responsibility, and environmental impact. A product or service is considered to have good quality if it can provide consistent and satisfactory benefits, in accordance with agreed and established standards, and meet consumer expectations and needs.

This research was conducted at PT XYZ, a manufacturing company that produces ceramics. Problems that exist in the production process include the number of product *defects* in the *finishing* process, such as *broken, crack, decoration defect, holes, peeled, planarity, dirty,* and *uneven edge*. Based on these problems, this study aims to determine the causes of *defects* or product defects using the Six Sigma method with the DMAIC *(Define, Measure, Analysis, Improve, and Control)* approach and analyze the factors causing failure using FMEA *(Failure Mode and Effect Analysis)* and *fishbone* diagrams. With this method, it is expected to minimize defective products and improve the quality of operations on the production line.

2. Research Methodology

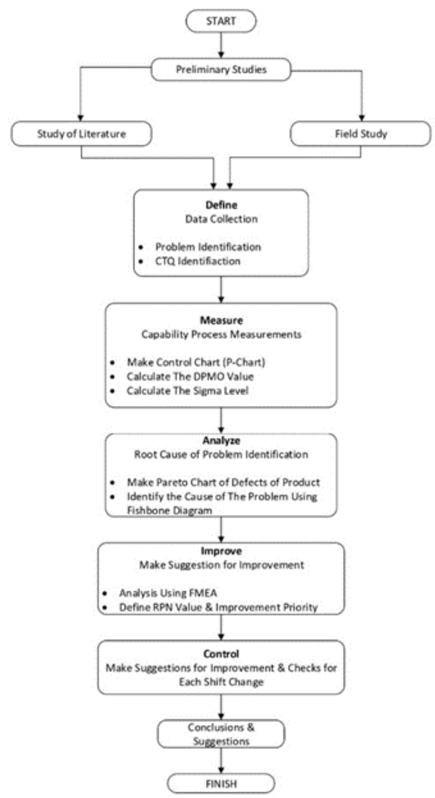

Fig. 1. Flowchart

This research was conducted at PT XYZ, which is one of the companies engaged in the modern ceramic industry in Indonesia that produces ceramic glassware. This research takes production data for 6 months. The research method in preparing the report uses quantitative data, namely production data. Quantitative itself means a set of information that is measured, calculated and compared on a numerical scale. Data collection is done by interview, field observation and documentation. Interviews were conducted to find out whether there were process difficulties experienced by employees. Observations were made to find out the work process from the initial stage of production to *finishing*. Documentation is done to get real data in writing. This problem-solving stage uses the DMAIC stage to identify problems to improvise improvements to the ceramic

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production line.

In quality improvement efforts using the Six Sigma method, there are five stages/phases that need to be taken, known as DMAIC:

1. *Define* is the stage to define the problem. At this stage, *stakeholder's requirements* specifications are formulated which are CTQ (*Critical to Quality)* and the objectives of the research project. The main result of this step is a well-defined problem statement or project.
2. *Measure* is a step that involves collecting data to measure the current performance of the process. The data collected will help in assessing the extent to which the process conforms to the desired standards. This measurement often involves the use of statistical tools to identify trends and variability in the process. The techniques used are the measurement of DPMO values and sigma values.
    a. *Defect per Million Opportunity* (DPMO)
    It is a measure that converts the number of product *defects* produced from the entire production quantity into the number of product *defects* produced per one million opportunities.

$$DPU = \frac{Total\ Defect}{Total\ Unit\ Produksi}$$

$$DPMO = DPU \times 1.000.000$$

    b. *Sigma Level*
    To determine the sigma level, a tool is used in the form of a DPMO-Sigma conversion table, as shown below:

Sigma Level Conversion Table

Yield	DPMO	Sigma	Yield	DPMO	Sigma	Yield	DPMO	Sigma
6.6%	**934,000**	**0**	**69.2%**	**308,000**	**2**	**99.4%**	**6,210**	**4**
8.0%	920,000	0.1	72.6%	274,000	2.1	99.5%	4,660	4.1
10.0%	900,000	0.2	75.8%	242,000	2.2	99.7%	3,460	4.2
12.0%	880,000	0.3	78.8%	212,000	2.3	99.75%	2,550	4.3
14.0%	860,000	0.4	81.6%	184,000	2.4	99.81%	1,860	4.4
16.0%	840,000	0.5	84.2%	158,000	2.5	99.87%	1,350	4.5
19.0%	810,000	0.6	86.5%	135,000	2.6	99.90%	960	4.6
22.0%	780,000	0.7	88.5%	115,000	2.7	99.93%	680	4.7
25.0%	750,000	0.8	90.3%	96,800	2.8	99.95%	480	4.8
28.0%	720,000	0.9	91.9%	80,800	2.9	99.97%	330	4.9
31.0%	**690,000**	**1**	**93.3%**	**66,800**	**3**	**99.977%**	**230**	**5**
35.0%	650,000	1.1	94.5%	54,800	3.1	99.985%	150	5.1
39.0%	610,000	1.2	95.5%	44,600	3.2	99.990%	100	5.2
43.0%	570,000	1.3	96.4%	35,900	3.3	99.993%	70	5.3
46.0%	540,000	1.4	97.1%	28,700	3.4	99.996%	40	5.4
50.0%	500,000	1.5	97.7%	22,700	3.5	99.997%	30	5.5
54.0%	460,000	1.6	98.2%	17,800	3.6	99.9980%	20	5.6
58.0%	420,000	1.7	98.6%	13,900	3.7	99.9990%	10	5.7
61.8%	382,000	1.8	98.9%	10,700	3.8	99.9992%	8	5.8
65.6%	344,000	1.9	99.2%	8,190	3.9	99.9995%	5	5.9
						99.99966%	**3.4**	**6**

Fig. 2. Sigma level conversion table

3. *Analyze* to identify the cause of the problem or the cause of variation in the process. Six Sigma teams use a variety of statistical analysis tools and techniques to find the root cause of the problem. The goal is to gain a deep understanding of the process and identify key factors that affect its performance. The analysis stage in this research is carried out on the 4M + 1E factors (*man, material, machine, method,* and *environment*) using the *fishbone diagram tool*. The results obtained from analyzing the root cause of the problem are then compiled into a Pareto chart to see the dominant cause of product *defects*.
4. Improve is a further stage after analyzing all problems and potential root causes obtained from the analyze stage. At this stage, failure analysis is carried out using the FMEA (Failure Mode and Effect Analyze) method to find, identify, and eliminate potential failures and known problems in the system. From the analysis carried out, an improvement proposal will be produced which is given to the company management.
5. *Control*, at this stage conclusions are given on the research conducted. In this study, it did not reach the implementation of improvements but only to the point of proposing improvements to the analysis that had been carried out.

3. Results and Discussion

The table 1 is the production data for 6 months in 2023.

A. Define

The first step in the DMAIC approach is *define,* which is to identify critical problems that exist in the production line. Based on the production data above, there are several types of defects that arise in the ceramic production process, including application defects, broken, cracks, decoration defects, holes, peeled, planarity, dirty uneven edges. From the production process carried out for 6 months, it was found that there were 4 types of defects that had the highest value, namely *Peeled, Application, Broken,* and *Holes defects*

B. Measure

The measure stage is the second stage in improving the quality of a product using the six sigma method. This stage has the aim of measuring the main problem. This stage is carried out to find the *defect per million opportunity* (DPMO) value which aims to determine the number of def*ects* in one million opportunities.

Table 1
Types of product defect

No.	Month	Defect Type								Total Production (n)	Total Defects (np)
		Application	Broken	Crack	Decoration	Holes	Peeled	Planarity	Uneven Edge		
1	May	5500	7208	102	1499	7509	10023	1476	2402	325441	35719
2	June	7333	9451	135	1651	1875	11388	4234	443	261447	36510
3	July	7483	3333	154	1243	4401	9685	5444	2366	185641	34109
4	August	6211	4803	87	1350	6424	7215	1370	2296	193249	29756
5	September	8116	6995	209	1350	1749	9029	2794	2072	243147	32314
6	October	6894	6590	193	1127	4314	7891	5289	2298	197232	34596
Total		**41537**	**38380**	**880**	**8220**	**26272**	**55231**	**20607**	**11877**	**1406157**	**203004**
Average		**6922.83**	**6396.67**	**146.67**	**1370**	**4378.67**	**9205.167**	**3434.5**	**1979.5**	**234359.5**	**33834**

Table 2
DPMO data

No.	Month	Total Production (n)	Total Defects (np)	DPU	DPMO
1	May	325441	35719	0.11	109755.7
2	June	261447	36510	0.14	139645.9
3	July	185641	34109	0.18	183736.4
4	August	193249	29756	0.15	153977.5
5	September	243147	32314	0.13	132899
6	October	197232	34596	0.18	175407.6

Table 3
Defect proportion table

Total Production (n)	Total Defects (np)	UCL	CL	LCL	Defect Proportion
325441	35719	0.146	0.144	0.143	0.11
261447	36510	0.146	0.144	0.142	0.14
185641	34109	0.147	0.144	0.142	0.18
193249	29756	0.147	0.144	0.142	0.15
243147	32314	0.147	0.144	0.142	0.13
197232	34596	0.147	0.144	0.142	0.18

Table 4
DPMO value

Month	Total Production (n)	Total Defects (np)	DPU	DPMO
May	325441	35719	0.11	109755.7
June	261447	36510	0.14	139645.9
July	185641	34109	0.18	183736.4
August	193249	29756	0.15	153977.5
September	243147	32314	0.13	132899.0
October	197232	34596	0.18	175407.6
Average	234359.5	33834	0.15	149237.0

1) P Chart

A *P-chart* is a type of control chart used in industry or business to monitor the proportion of nonconformities in a sample, where the proportion of nonconformities is defined as the ratio of units that have the following nonconformities compared to the number of samples. Here is a P diagram according to the sigma calculation.

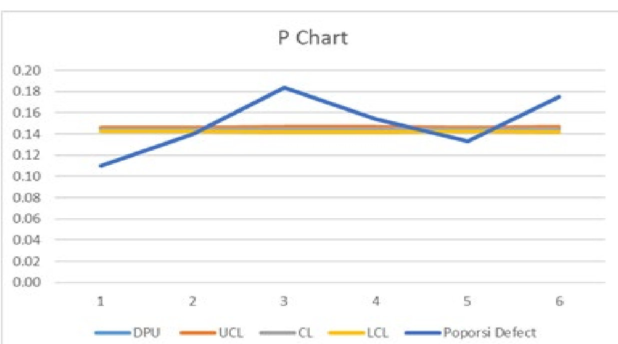

Fig. 3. P-Chart

2) DPMO value

DPMO (Defect Per Million Opportunity) is a measure of failure in six sigma that shows the damage of a product in one million items produced. The table 4 shows the DPMO value obtained:

3) Sigma Level

To obtain the sigma level, a linear interpolation method is used based on the sigma level conversion table as shown in Figure 1.

Example: sigma level in May

$$\frac{DPMO_a - DPMO_x}{DPMO_x - DPMO_b} = \frac{Level_a - Level_x}{Level_x - Level_b}$$

$$\frac{115.000 - 109.755{,}7}{109.755{,}7 - 96.800} = \frac{2{,}7 - x}{x - 2{,}8}$$

$$\frac{5.244{,}3}{12.955{,}7} = \frac{2{,}7 - x}{x - 2{,}8}$$

$$x = 2{,}728$$

Table 5
Sigma level

Month	DPU	DPMO	Sigma Level
May	0.11	109755.7	2.73
June	0.14	139645.9	2.58
July	0.18	183736.4	2.40
August	0.15	153977.5	2.52
September	0.13	132899.0	2.61
October	0.18	175407.6	2.43
Average	0.15	149237.0	2.54

C. Analyze

The analyze stage aims to find the cause of the problem and analyze the problem. At this stage, the data that has been collected is evaluated in depth to identify the root cause of the problem. Analysis is done to understand the factors that contribute to existing problems.

1) Pareto Diagram

To find out the most dominant type of defect, the percentage of defects is calculated using a Pareto diagram. The data taken is according to the production data. The following is a pareto diagram of product defects:

Table 6
Pareto diagram's data

Defect	Peeled	Application	Broken	Holes	Planarity	Uneven Edge	Decoration	Crack
Total	55231	41537	38380	26272	20607	11877	8220	880
Cumulative	55231	96768	135148	161420	182027	193904	202124	203004
Percentage	27.21%	20.46%	18.91%	12.94%	10.15%	5.85%	4.05%	0.43%
Cumulative Percentage	27.21%	47.67%	66.57%	79.52%	89.67%	95.52%	99.57%	100.00%

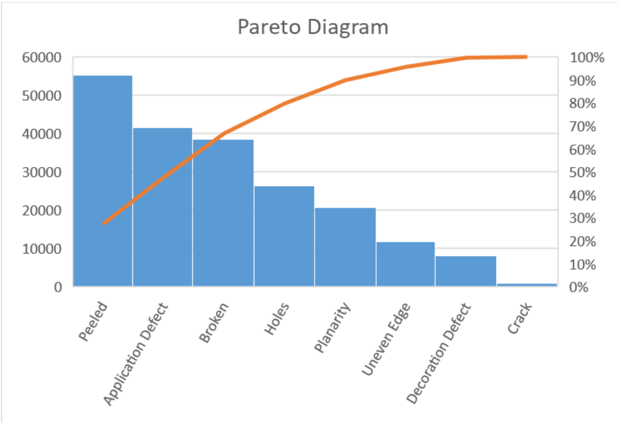

Fig. 4. Pareto diagram of product defect types

Based on the diagram above, the most dominant defects are Peeled defect, Application defect, Broken defect, and Holes defect.

2) Fishbone Diagram

Based on the pareto diagram above, an analysis is carried out to find the cause of the defect using a cause and effect diagram (*fishbone diagram*). The fishbone of each defect is as follows:

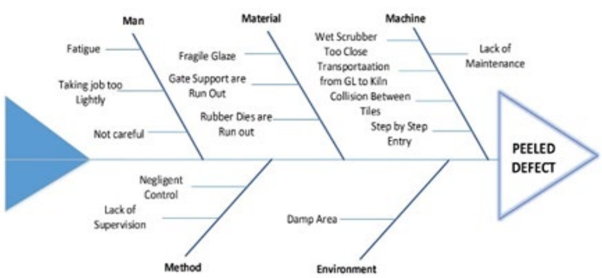

Fig. 5. Fishbone diagram of peeled defect

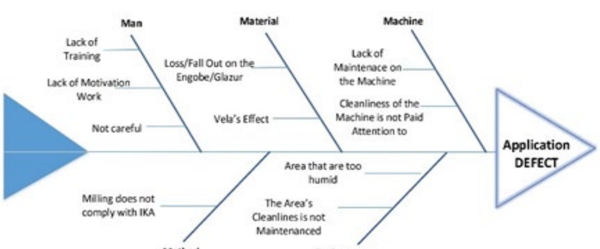

Fig. 6. Fishbone diagram of application defect

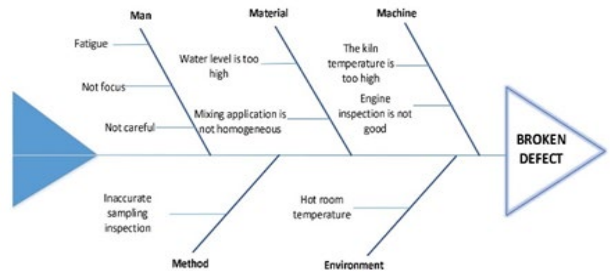

Fig. 7. Fishbone diagram of broken defect

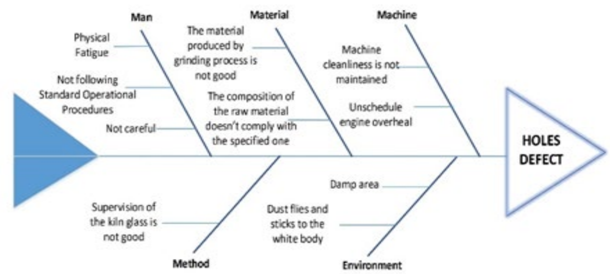

Fig. 8. Fishbone diagram of holes defect

3) Risk Priority Number (FMEA Analysis)

Risk Priority Number is a quantitative measure used in Failure Modes and Effects Analysis (FMEA) to prioritize and assess the relative risk of potential failure modes. The RPN calculation aims to find the value of severity *rating, occourance rating* and *detection* value. *The* RPN value is obtained by multiplying the *severity, accuracy* and *detection* scale values to determine the *risk priority number* on the *defect*. It's can be seen in the table:

Based on the *Risk Priority Number* (RPN) table, it can be seen that the most important potential failure occurs in the lack of maintenance on the machine with a value of 40 in the table 7.

The proposed improvements are expected to be applied or considered for the company, including scheduling checks on the glazing line and machine maintenance.

D. *Improve*

This improve stage has several suggestions for improvement and control obtained from calculations at the analyze stage. Some suggestions for improvement and control are focused on the most dominant causal factors in the ceramic wall production process.

Table 7
RPN value

No.	Potential Failure	Severity	Occurrence	Detection	RPN
1	Wet scrubber is too tight	4	4	1	16
2	Transportation from glazing line to in kiln	2	3	2	12
3	Row pormer (collision between tiles)	4	3	2	24
4	Step by step entry tile is too close	2	2	1	4
5	Lack of maintenance on the machine	5	4	2	40

Table 8
Proposed corrective action

Elements	Causal Factors	Proposed Corrective Action
Machine	Wet Scrubber Too Fast	1. Checking the Engine Speed Setting 2. Machine Check and Line Speed to Be More Stable
	Row Pormer (Collision Between Tiles) Transportation from Glazing Line to In Kiln	1. Each Tile Squad Must Be Paused to Avoid Collisions 2. Gate Support Teplon must be stretched according to the size of the tile. 3. Checking and Controlling the Gate Support Teplon
	Step By Step Entry	Spacing Between Tiles
	Lack of Maintenance on the Machine	Inspection and maintenance of machines in the glazing line, input and output areas of kilns and sorting machines.

Table 9

No.	Advice	Description
1	Set the speed of the machine, check and control the process.	Unstable speed will affect the results of the ceramics, the machine speed is too high will cause the ceramics to become gompel, peeling on the ceramics.
2	Make a report on every inspection and maintenance on the machine	With the report form control, it has a history of the development of machine conditions so that when a problem occurs on the machine, you already know the first step to do.
3	Checking the machine settings per shift	Checking the engine settings functions so that the engine does not experience changes to the initial engine settings that have been previously set.
4	Replace the wet scrubber if it is no longer good.	Checking the wet scrubber and replacing if the wet scrubber is worn.
5	Replace the gate support teplon that is no longer good	Checking and replacing the gate support teplon that is no longer good

E. Control

The Control stage is the last stage of the six sigma method which is carried out to evaluate the results of the six sigma method.

This control stage emphasizes the dissemination of the actions that have been carried out as shown in table 9.

4. Conclusion

Based on data analysis and discussion, it can be concluded that:

1. Based on production data at PT XYZ, it is obtained that the average production amount is 234,359.5 ceramic units with an average number of defective products that occur during production of 33,384 ceramic pcs with a possible defect of 149,237 defects in one million production (DPMO).
2. Based on the pareto diagram, there are 4 most dominant types of defects, namely peeled with a percentage of 27.21%, application defects with a percentage of 20.46%, broken with a percentage of 18.91%, and holes with a percentage of 12.94%. Therefore, the company must be stricter in quality management, especially in the selection of materials and work processes carried out, in order to reduce product defects that occur.
3. Based on the fishbone diagram, the RPN value is calculated to determine the most dominant cause of product defects. In the RPN calculation, the most dominant cause is the lack of maintenance on the machine.
4. Proposed improvements to reduce product defects that occur include always checking the machine before production and carrying out regular maintenance.

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