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Defect Analysis of Ceramic Products with Statistical Quality Control (SQC) and Failure Mode Effect Analysis (FMEA) Methods at PT. XYZ

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A B S T R A C T

Ceramic product company is one of the companies engaged in the ceramic industry. Ceramic product company produces various types of floor tiles with various sizes including sizes 40x40 cm, 50x50 cm, and 60x60 cm. Problems that arise at ceramic product company is that there are still defects in the 50x50 cm ceramic production line which is quite high, this certainly cannot be separated from the company's losses. Therefore, to reduce the level of defects in products, it needs to be supported by maintenance management and employee expertise. The purpose of this study is to determine product defects and propose improvements to reduce product defects. This research uses the Statistical Quality Control (SQC) method to control quality from the initial process to the finished product and Failure Mode Effect Analysis (FMEA) is used to identify and prevent problems that occur in products and processes. Based on the results of the analysis from October 2022 to March 2023, with a total production of 327,600 products, there are 56,543 defective products. Based on the results of the Pareto diagram for chipping before firing with a percentage of (34.3%), crack defects of (25.6%), chipping before vela of (21.2%), and ink drop defects of (18.9%). The calculation of RPN for ceramic production measuring 50x50 cm obtained several risks with the highest priority level, obtained the highest RPN of 288 from the type of crack defect with a proposed improvement, which emphasizes the operator to always pay attention to the running machine settings.

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1. INTRODUCTION

The increasingly advanced industrial world makes industrial competition tighter both in the field of services and manufacturing. One of the keys to the company's success is the quality of the products produced. Products that can compete are products that have high quality and can meet consumer needs. In addition, products with high quality are also judged by the lack of defects produced. Therefore, to maximize quality, the company must be able to utilize resources to achieve certain goals. Quality is a hot topic in the business and academic worlds. However, the term requires a careful response and needs careful interpretation (Ishak et al., 2020). The main factor that determines the performance of an enterprise is the quality of the goods and services produced. Quality products and services are products and services that follow what consumers want (Ariani D. W, 2020). If the quality of the goods is very high, the goods will be easy to find and the price will be affordable, so that consumers are interested (Fachrurrozi Adi et al., 2022).

In producing quality products, several factors tneeds to be prioritized, namely the production process (Erwindasari et al., 2019). It is possible for a company to produce a defective product, it may be possible fixe or update, but will increase costs for companies and customer complaints due to slower delivery times. Therefore, the company strives to implement quality control on the products it produces (Syahrullah et al., 2021). Product quality is the entire combination of product characteristics obtained from marketing, engineering, production, and maintenance that make the product usable to meet consumer expectations (Nuruddin & Andesta, 2022). Quality control is a very useful tool in making products according to specifications from the beginning of the process to the end of the process. Every production process will always have disturbances that can arise unexpectedly (Kamal & Sugiyono, 2019).

This study aims to determine the defects of ceramic products measuring 50x50 cm and provide improvement proposals based on the causes of defects. In the 50x50 cm ceramic production line there are still problems, namely the high level of product defects. When producing 50x50 cm floor tiles, there are still several defects, namely Ink Drop Defects, CBF Defects (Chipping Before Firing), CBV Defects (Chipping Before Vela), and Crack Defects. From all parts of the production process, it is known that the overall average percentage of defects is 18.3% of the specified standard limit of 5%. This certainly cannot be separated from the problem of loss, to eliminate these defects the company spends more time and money to be able to reduce it. The method used in this study is the Statistical Quality Control (SQC) method, where this method is used to control defects from the initial process to the final process in the company (Saepul Milah, 2022) and Failure Mode Effect Analysis (FMEA) where the advantage of the FMEA method is that it can provide priority actions seen from the effects of failures on each production process to make it easier to control and minimize the level of defects (Adawiyah & Donoriyanto, 2022). This method is used so that companies can focus more on the causes that produce the most defective products, to reduce risk and can be used sustainably to improve the quality of the results of the production process (Syahrullah et al., 2021).

2. LITERATURE REVIEW

Statistical Quality Control (SQC) is a system that eliminates causes or deviation factors in quality control to meet production standards applied by the company (Zilfianah et al., 2022). There are several tools used in SQC including: (a) Histogram. The histogram is the most commonly used chart in any quality tool. A histogram is a graphical representation of numeric data used to indicate how often different values appear in a data set. The histogram is used to determine the shape of the dataset. Histograms work best when there is little data, but when there is a lot of data, researchers choose Pareto charts because Pareto charts also sort data in descending order (Andespa, 2020). (b) The Pareto Diagram. The Pareto diagram shows the frequency distribution of attribute data by category. Pareto diagram is in the form of a bar chart that shows the frequency of occurrence of a problem from the most to the least (Rucitra & Amelia, 2021). (c) Scatter Diagram. Scatter diagrams show the relationship between two measurements. Scatter diagrams have several kinds of patterns, the first is a positive correlation pattern if the increase in the value of variable X is followed by the addition of the value of variable Y (Pranata Primisa Purba et al., 2022). (d) Process Diagram. A process diagram is a diagram that represents a process or system using interconnected boxes and lines. This diagram is very useful for understanding the process or explaining the steps in the process (Alkharami et al., 2022). (e) Control Chart. The control chart used in this study is a p-chart due to defects that occur in the form of attribute data, the amount of production data is not fixed and the product that has the defect can only be divided into defective data and not defective or good and bad (Dharmayanti et al., 2018). (f) Fishbone Diagram. Using the fishbone diagram, the factors causing the failure are analyzed and the reason solution is also provided. The author exposes the failure problem through data analysis and interviews with relevant departments (Mislan & Purba, 2020).

Failure Mode Effect Analysis (FMEA), The stage in making an FMEA table for the production of ceramics measuring 50x50 cm is that researchers make a list of potential failures (failure mode) for each defect. then determine the rank on the value of Severity (S), Occurrence (O), and Detection (D), then calculate RPN by multiplying severity, occurrence, and detection, then the highest RPN that gets the highest priority scale for improvement (Pratama & Rochmoeljati, 2022).

3. RESEARCH METHOD

This research was conducted at PT. XYZ is located in Mojokerto City, East Java. This study began in October 2022 until March 2023. The data used in this study was collacted interviews with the company. The secondary data used in this study is a defective 50x50 cm ceramic product data document that the author obtained from PT. XYZ. The data analysis technique used is with statistical quality control tools, namely Statistical Quality Control (SQC) and proposed improvements using the Failure Mode Effect Analysis (FMEA) method.

Based on Fig. 1, are the steps of problem-solving, the first stage begins with the introduction of the research location, then there is a field survey and literature study, followed by the formulation of existing problems in the ceramic factory, followed by research objectives, the next step is to identify variables, then there is data collection including total production data, production defect data, and defect type data. The next stage is data processing using statistical quality control methods where the author uses 6 tools, namely histograms, and Pareto diagrams calculate the percentage of each defect with the formula:

$$\% \ of \ Crack = \frac{total \ crack \ defect}{total \ defect} \times 100\% \qquad (1)$$

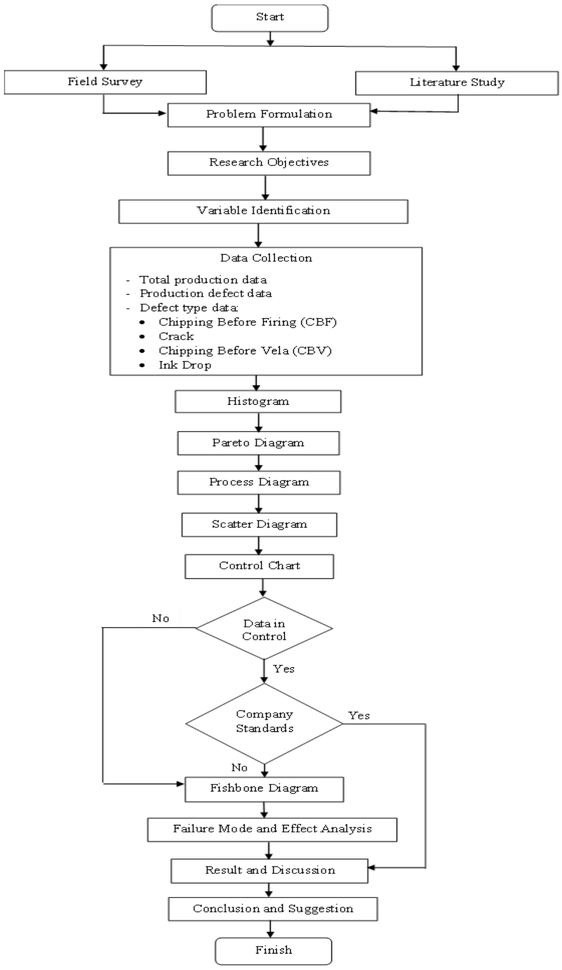

Fig. 1. Research stage

The next step is process diagrams, scatter diagrams, and control charts used for presenting data over time with upper and lower limits to describe the stability of a process, for formulas than CL, UCL, and LCL are as follows:

$$\bar{P} = \frac{\sum np}{\sum n} \qquad (2)$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \qquad (3)$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \qquad (4)$$

Description:
npi = defect
ni = production per item
UCL = Upper Control Limit
LCL = Lower Control Limit

The next step is cause-effect diagrams or fishbone diagrams. After knowing the cause of each defect, the next step is the recommendation stage using failure mode effect analysis where at this stage determine the severity, occurrence, and detection which will later look for the RPN value with the formula

$$RPN = Severity \times Occurance \times Detection \quad (5)$$

The last step is to calculate the RPN results as defects that are corrected or eliminated.

4. RESULT AND DISCUSSION

The data collected are total production data and production defect data from October 2022 to March 2023. In the 50x50 cm ceramic production line there are still problems, namely the high level of product defects. The total data on the production of ceramics measuring 50x50 cm are as follows

Table 1. Data on total ceramic production size 50x50 cm

No	Month	Production Quantity (unit)
1	October 2022	55.800
2	November 2022	54.000
3	December 2022	55.800
4	January 2023	55.800
5	February 2023	50.400
6	March 2023	55.800
	Total	**327.600**

Table 2. Defect data ceramic production size 50x50 cm

No	Month	Type of Defect				Total
		Crack	Chipping Before Vela (CBV)	Chipping Before Firing (CBF)	Ink Drop	
1	October 2022	2.312	1.961	3.374	1.699	9.346
2	,Nopember 2022	2.361	2.034	3.007	1.927	9.329
3	December 2022	2.372	2.047	3.402	1.749	9.570
4	January 2023	2.607	2.218	3.800	1.845	10.470
5	February 2023	2.145	1.800	2.600	1.587	8.132
6	March 2023	2.652	1.930	3.222	1.892	9.696
	Total	**14.449**	**11.990**	**19.405**	**10.699**	**56.543**

Statistical Quality Control (SQC)

1) Histogram

A histogram is a bar chart that illustrates a several data groups into classes with certain intervals. The following histogram is made based on product defects from October 2022 to March 2023.

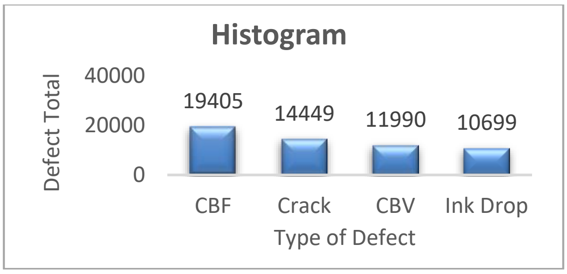

Fig. 2. Histogram of total defect products

Based on Fig 2, this is histogram data processing, it shows that the interval order of each type of defect that occurs the most is Chipping Before Firing (CBF) of 19,405 units, then Crack defect of 14,449 units, then Chipping Before Vela (CBV) defect of 11,990 units, and Ink Drop defect of 10,699 units.

2) Pareto Diagram

A Pareto diagram is a bar graph that is often used as an interpretation tool to rank each type of defect from largest to smallest. The data processed to determine the percentage of defective product types is as follows

Table 3. Percentage of ceramic production defects size 50x50 cm

No	Type of Defect	Total Defect	Percen tage	Cumulative Percentage
1	Crack	14.449	25,55%	25,55%
2	Chipping Before Vela (CBV)	11.990	21,21%	46,76%
3	Chipping Before Firing (CBF)	19.405	34,32%	81.08%
4	Ink Drop	10.699	18,92%	100%
	Total	**56.543**		

Based on Table 3, it can be seen that the most dominant type of defect is the Gupil defect before burning by looking at the cumulative value. In accordance with the image on the Pareto diagram above, it can be seen that the biggest cause of defects in ceramic products size 50x50 cm is Chipping Before Firing with a percentage of (34.32%), then followed by Cracking defects with a percentage of (25.55%), then Chipping Before Vela with a percentage of (21.21%), then Ink Drop defects with a percentage of (18.92%). With this Pareto diagram, it can be seen which defects should be prioritized first.

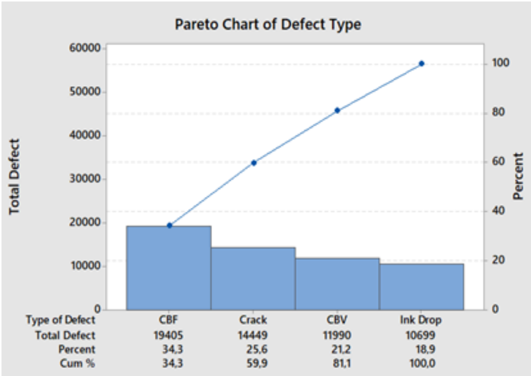

Fig. 3. Pareto diagram

3) Process Diagram

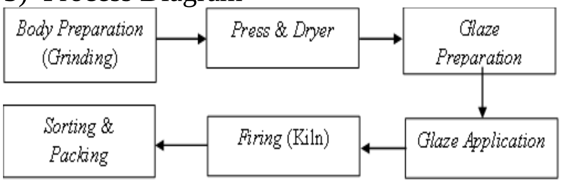

Fig. 4. Process diagram

Based on Fig. 4 shows the flow of production processes that occur in the production of ceramics starting with body preparation (grinding) is the earliest process in the production of ceramics, which aims to change the initial raw material into powder form. Next is the press & dryer is basically, the purpose of this process is to make biscuit tiles from powder that has been produced at the beginning, after that the glaze preparation and application process is the process of preparing the tools needed to create motifs or decoration of the front surface of the tile. After that firing using a kiln machine is the process of burning ceramics, which have been applied with glaze or glaze in the roller. The last process is sorting & packing is the last product inspection process before the product is sent to consumers and markets.

4) Scatter Diagram

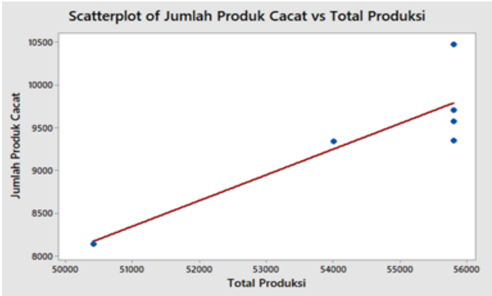

Fig. 5. Scatter diagram

Based on Fig. 5, shows that there is a positive relationship (positive correlation), meaning that the higher the production, the higher the product defects will be. So it can be seen that the four scatter diagrams above show that there is a strong relationship between product defects and production.

5) Control Chart

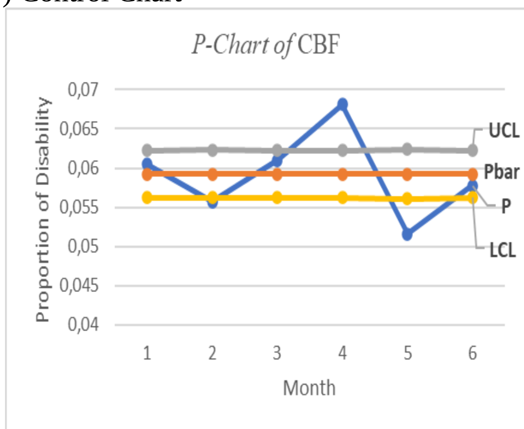

Fig. 6. Control chart chipping before firing (CBF) defect

Based on Fig. 6, it can be seen that the data from October 2022 to March 2023 has 2 points outside the control limits, namely in January 2023 and February 2023, which means that the process is not running well and improvements must be made.

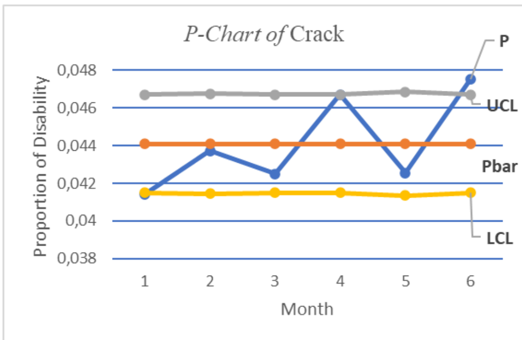

Fig. 7. Control chart crack defect

Based on Fig. 7, it can be seen that the data from October 2022 to March 2023 has 1 point outside the control limits, namely in March 2023, which means that the process is not running well and improvements must be made

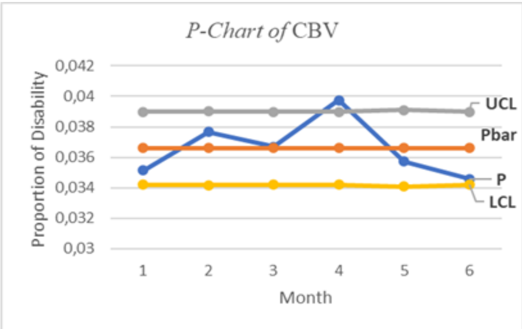

Fig. 8. Control chart chipping before vela (CBV) defect

Based on Fig. 8, it can be seen that the data from October 2022 to March 2023 has 1 point outside the control limits, namely in January 2023, which means that the process is not running well and improvements must be made.

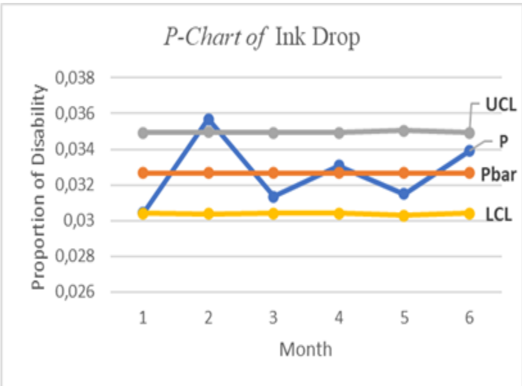

Fig. 9. Control chart ink drop defect

Based on Fig. 9, it can be seen that the data from October 2022 to March 2023 has 1 point outside the control limits, namely in November, which means that the process is not running well and improvements must be made.

6) Fishbone Diagram

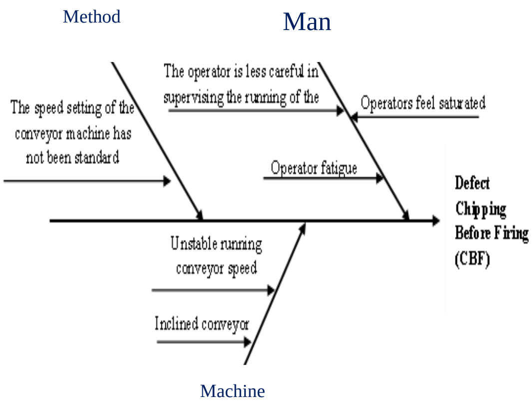

Fig. 10. Fishbone chipping before firing (CBF)

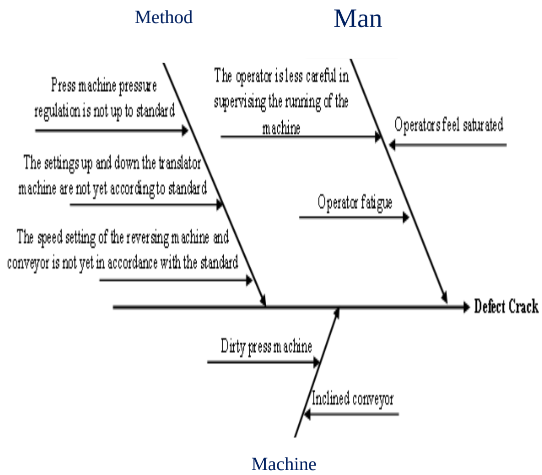

Fig. 11. Fishbone crack

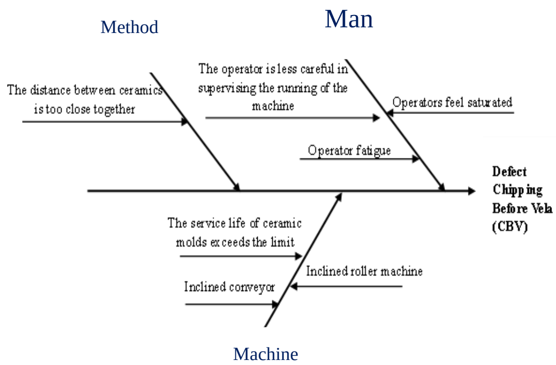

Fig. 12. Fishbone chipping before vela (CBV)

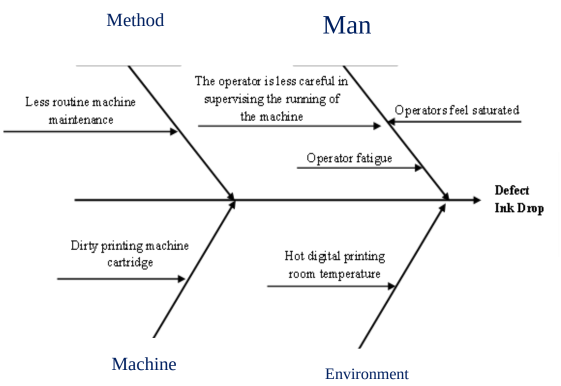

Fig. 13. Fishbone ink drop

Based on Fig. 10-13, it is known that the cause and effect diagram of each defect is known, where there are several factors, namely humans, environment, machines, and methods. where each cause is obtained from interviews and observations in the field during the research. For the first defect, namely chipping before the Type of Failure Analysis of the cause of failure of one type of failure is carried out using a fishbone diagram which can be seen in the previous figure. (2) Determination of Failure Effect Value (Severity, S) Based on the results of interviews with the company, the failure effect value of one type of failure can be determined. (3) Identification of Potential Causes of Failure Based on the fishbone diagram in the previous section, the main cause firing (CBF) defects, there are 3 causes, namely from conveyor settings, tired operators, and machines experiencing discrepancies. crack defects have 3 causes, namely from inappropriate machine settings, tired operators, and dirty machines due to lack of maintenance. There are 3 chipping before vela (CBV) defects, namely inappropriate machine settings, human fatigue in supervising the running of the machine, and tilted conveyors. The last defect, namely ink drops, has 4 defects caused by non-routine machine maintenance, operator fatigue, dirty machines, and hot ambient temperatures.

Failure Mode Effect Analysis (FMEA)

Making Failure Mode and Effect Analysis (FMEA) aims to identify and assess the risks associated with potential failures. The stages of making Failure Mode and Effect Analysis (FMEA) are as follows: (1) Determination of of failure is obtained. (4) Determination of the Failure Probability Value (Occurance, O) Guided by FMEA, the failure probability value can be given. (5) Identification of Failure Control Methods Taking into account the causes of failure contained in the fishbone diagram which can be seen in the previous section, control or control of the causes of failure can be carried out.

Table 8. FMEA ceramic product size 50x50 cm

Potential Failure Mode	Potential Effect of Failure	S	Potential Cause	O	Current Control	D	RPN
Chipping Before Firing (CBF)	Will cause a ceramic surface called chipping during the pre-firing process, so that the ceramic surface is sharp	7	Inclined conveyor	6	Adjusting conveyor settings	6	252
			Conveyor speed is not suitable.	6	Adjust speed according to procedure	5	210
			Less thorough during the kiln input process before firing due to fatigue and burnout	4	Reminded kiln operators to check conveyor settings and roll work	7	196
Crack	Will cause wrinkles on the surface of the ceramic called Cracks and make the ceramic surface uneven	8	Dirty press machine	4	Cleaning the press machine periodically	6	192
			Pressure setting of the press machine is not up to standard	4	Adjust the pressure of the press machine according to the procedure	5	160
			Conveyor speed setting is not up to standard	6	Adjust conveyor speed according to standard	6	288
			The up and down setting of the translator machine is not up to standard	5	Adjust the translator engine settings	6	240

			The reversing machine speed setting is not up to standard	5	Adjust the speed of the turning machine according to the procedure	6	240
			Not careful enough in setting up the press, translator, and turning machine due to fatigue and burnout.	4	Reminded operators in the machine section to check the machine settings and rotate jobs	7	224
Chipping Before Vela (CBV)	There will be chipping or gouging defects on the side of the ceramic during the process before glazing, so that the surface of the ceramic becomes uneven and the gouges are covered by the glaze.	7	Inclined roller		Adjust roller settings		
			Inclined conveyor	6	Adjusting conveyor settings according to standards	6	252
			Ceramic punch wear time exceeds limit	5	Replacing the punch according to the specified time.	5	175
			Less thorough in supervising the ceramics due to fatigue and burnout	4	Reminded the operator in charge of the glaze coating machine to check the conveyor settings and job rolling.	7	196
Ink Drop	It will reduce the aesthetic value because the visual appearance is not good and make the ceramic surface uneven due to ink drops.	5	The distance between tiles is too close	4	Adjusting the distance between tiles so that they are not too close together	5	140
			Less routine engine maintenance	6	Schedule periodic machine maintenance	6	180
			Room temperature is hot	4	Check the air conditioner temperature is at least 18°C	5	100
			Dirty printing machine cartridges	6	Cleaning the cartridge every 30 minutes	5	150
			Production capacity too high.	6	Adjust production capacity with machine capacity	6	180

5. CONCLUSION

Based on the results of the research that has been done, as well as the descriptions that have been presented, it can be concluded that the defect level of ceramic products measuring 50x50 cm, namely chipping before firing with a percentage of (34.3%), crack defects of (25.6%), chipping before vela of (21.2%), ink drop defects of (18.9%). Recommendations for proposed improvements to reduce the defective rate of ceramic products measuring 50x50 cm based on the largest RPN value include affirming to the operator to always pay attention to the running machine settings, especially on the conveyor settings, adjusting the conveyor settings so that they are not tilted, adjusting the reversing speed according to the procedure, ensuring the settings up and down the translator machine are not up to standard, supervising the operator more strictly when setting the press machine so that There are no errors that result in defects and rolling work, insisting to the operator to always pay attention to the setting of the machine that is running, especially in the conveyor settings. For future researchers, product quality control can be carried out with other control tools.

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