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Quality Improvement Using The DMAIC Method In The Light Brick Industry

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Abstract

Background: The growing industrialised world will lead to more rivalry. Companies who are able to compete are able to maintain the quality of their products to ensure client happiness. Consequently, quality control is required.

Methods: This study focuses on decreasing red brick product faults at PT. Surya Rezeki Timber Utama using the Six Sigma-DMAIC method (Define, Measure, Analyze, Improve, and Control).

Result: The result shows a 6.59% decrease in defects/rejects from 28.71% defects/rejects produced by AAC (Autoclaved Aerated Concrete), accompanied by a decrease in the DPMO value from 13,660.26 PPM to 2,912.66 PPM and an increase the sigma value of 3.7069 to 4.2575.

Conclusion: The effects of the examine segment the use of a fishbone diagram decide the reasons of the defect/ break, such as: personnel do now no longer understand fine standards, product inspection isn't always implemented, people do now no longer understand paintings procedures, device overall performance is unpredictable, people are careless, the range of milling is unknown, and brick

Keywords: Six Sigma, DMAIC, Quality Improvement, PVC Compound

1. Introduction

In today's world global competition, we must always be ready where companies compete to maximize profits and stay afloat in a competitive environment. The company always strives to outperform its competitors in the industry. In today's competitive environment, customer happiness is an important aspect in determining a company's competitiveness. Quality control will help the business in lowering costs and increasing sales, which in turn will increase profits. Continuous quality control is essential to succeed in the industry (Kholil & Prasetyo, 2017).The suitability of using a product to meet customer demand is defined as quality (Rimantho & Mariani, 2017). Quality is described as complete satisfaction of the customer's request without any defects. A quality product is a product that performs as expected by buyers (Judi et al., 2011). As a result, quality control is a process that ensures product results meet consumer expectations. The advantage of product quality control is that it will developing the products excellencewhich produced and evaluate and develop the causes of defects in a product, which can then be used to repair and minimize faulty products (Wisnubroto & Rukmana, 2015). The basic goals of controlling in quality system to reduce the number from defective goods, improve product quality, and keep defective products from the hands of consumers (Prihastono & Amirudin, 2017). Lower product prices are the result of quality control, which aims minimizing the amount of rejected items. Thus, the company's performance increases and can compete with other companies (Salomon et al., 2013).

PT. Surya Rezeki Timber Utama company is a that produces building raw materials and red brick products. The longer the need for higher quality and more competitive bricks, the more important it is to the long term viability of PT. The proceedingcreation in Surya Rezeki Timber

Utama. The production process of PT. Surya Rezeki Timber Utama often faces obstacles because of his age which results in many defective items. Problems broken/broken, charred, chipped are common things for red brick products. The six sigma approach is a quality assurance strategy minimizing the amount of rejection in a product so that improvement efforts can be made (Harahap et al., 2018). Quality control using a six sigma-DMAIC approach is needed as a result of this problem to minimize the quantity of wrong items while increasing the quality of the resulting product(Girmanová et al., 2017).

A number of studies have shown that Six Sigma can minimize the number of faulty items. According to research from (Ray et al., 2011), (Fransiscus et al., 2014), (Wardhana et al., 2015), and (Karenza et al., 2016),(Hernadewita et al., 2019),(Elfanda, 2021), (Ishak et al., 2020) six sigma can develop the product standard, resulting in decrease in the number of damaged goods. PT. Surya Rezeki Timber Utama, the six sigma-DMAIC approach projected in developing the standard from red brick products. By identifying procedures that do not provide value, PT. Surya Rezeki Timber Utama `can reduce process variation, lower costs by reducing the number of defective items.

2. Methodology

2.1. DMAIC framework

The type and design of research is needed to clearly identify the studies layout which includestatistics collection and the statistics analysis, so that it is easier to understand(Bosnjak et al., 2021). This study uses Mixed Methods Research method from a combination of Quantitative Research and Qualitative Research, so that the research is objective and scientific with data in the form of product values. Research design is a strategy as a guide in the research process to achieve stated goals (Alshaali & AlYammahi, 2022). This study uses an exploratory descriptive design to provide a description, explanation, and validation of the phenomena studied regarding the AAC HB-075 sized lightweight brick reject product. Descriptive research can describe facts related to the population systematically and accurately, then it can be used for analytical research. (Nursalam, 2003). In this research, the framework of DMAIC describe in Figure 1 below.

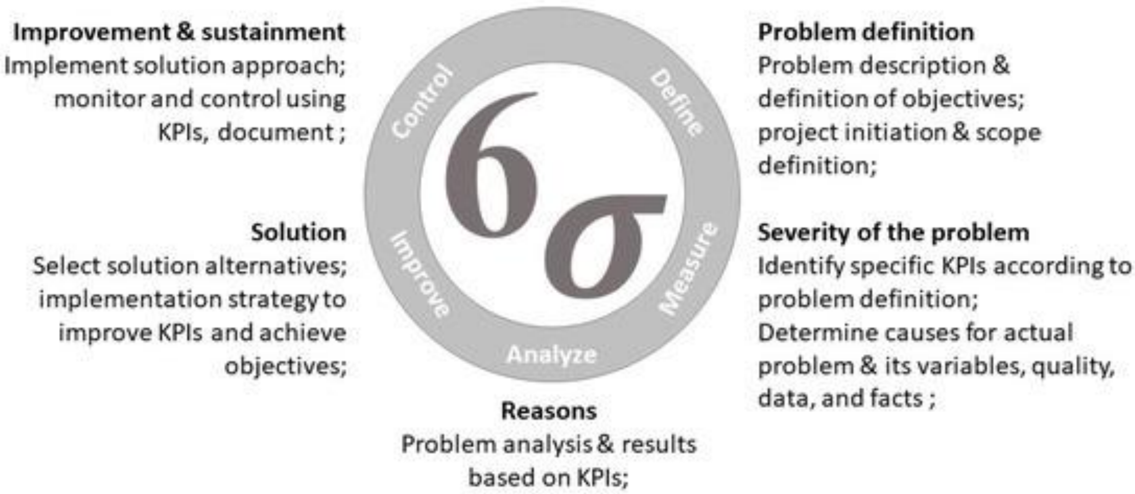

Figure 1. DMAIC Framework (Rodriguez et al., 2022)

2.1.1 Define

This stage is the beginning stage carried out in implementation of the sixsigmamethod. In define stage, product identification is carried out which will be a priority for problem solving(Vendrame Takao et al., 2017). Several stages are carried out in define stage, namely the selection of products that are a priority for handling problems and making a chart of the operation process.

2.1.2 Measure

Measure is the second stage to calculate DPMO values and Sigma levels, create a Control Map P, and calculate Process Capabilityand Process Capability Index(Damsiar et al., 2018).We can see the calculation formula in the Measuring Stage below.

$$\mathbf{p} = \frac{x}{n} \quad (1)$$

$$\mathbf{p} = \frac{\text{Total Produk Cacat}}{\text{Total Produk}} \quad (2)$$

$$CL = \bar{p} \quad (3)$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} \quad (4)$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} \quad (5)$$

$$\bar{c} = \frac{\sum c}{k} \quad (6)$$

$$UCL = \bar{c} + 3\sqrt{\bar{c}} \quad (7)$$

$$LCL = \bar{c} - 3\sqrt{\bar{c}} \quad (8)$$

$$DPU = \frac{D}{U} \quad (9)$$

$$DPO = \frac{D}{UxOP} = \frac{D}{TOP} \quad (10)$$

2.1.3 Analyze

Analyze comes up as the third stage for analyze data using Ishikawa Diagram and Pareto Diagram accompanied by Benchmarking. Fishbone diagrams are useful for looking for all possible causes of problems from the dominant defect, in terms of people, machines, methods, materials, and the environment(Kurnia et al., 2022). Pareto diagrams are useful for identifying various types of defects that occur, determining priority defects that contribute predominantly to the lack of overall product quality, and determining critical areas for improvement(Wulandari et al., 2022).

2.1.4 Improve

Improve is the fourth stage to improve production performance in industry and improve the quality of products produced using Failure Mode and Effect Analysis (FMEA) and Brainstroming.

2.1.5 Control

Control is the last stage to managing application of improvement efforts as a performance standard for the production process in producing quality products through the Creation of Control Charts After Improvement and Evaluation of DPMO and Six Sigma Values After Improvement.

2.2. Data Collection

This study uses Mixed Methods Research method from a combination of Quantitative Research and Qualitative Research, so that the research is objective and scientific with data in the form of product values(Kinnebrew et al., 2021). The mainstatisticshad been received overobservation, discussion, and questioner. Those main data on this observe had been received via way of means of observation and discussion, which had been executed in the course of ordinary running hours from eight am to five pm, to take a look at the manufacturing system and the gathering of statistics should offer records associated with the form of disorder, the range of product rejects, and the reasons of the disorder product, in addition to evaluation of the delight and traits preferred via way of means of clients of the product. The secondary data was takenof monthly reports from the Production and Quality Control division collected, including the quantity and type of reject products, as well as the causes of reject products and how to overcome them.

3. Result and Discussion

For this section, a synchronous development evaluation is executed using the technique used, particularly DMAIC. The result of thisstudies is likewise mentioned on the quit to discover the contribution of this studies to the homogeneous industry.

3.1. Analysis DMAIC

3.1.1 Define

At define stage, product identification is carried out that will be a priority for handling problems. Some of the stages carried out at define stage are product selection that is a priority for handling problems and making a map of the operation process. Based on the calculations and observations that have been made previously, the type and number of defects that occurred during the observations in January - February 2022as below:

Table 1. Types and Number of Defects for the Period January - February 2022

Type of Disability	Amount
Low Compressive Strength	268
Broken Surface	194
Torn Down	163
Total	**625**

The number of defects seen from the data above is different for each type of disability. Based on these data, it is necessary to analyze the most dominant disability among three existing defects. Theevaluation made use of a diagram Pareto along with the 80/20 basis, wherein 20% of the varieties of failureswhichpresent are prompted with the aid of using 80% of the primary varieties of defects. The following is a Pareto diagram of the three types of disability based on their respective amounts:

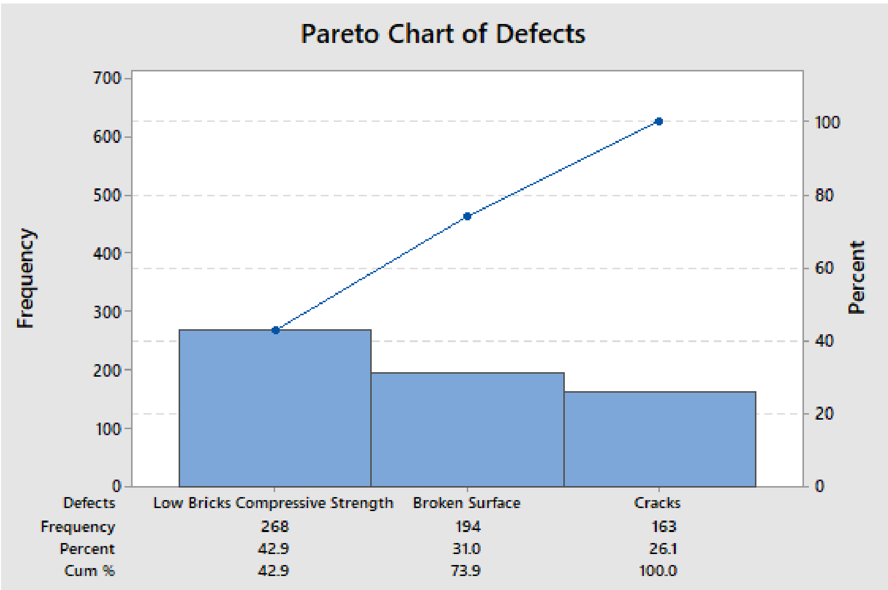

Figure 1. Pareto Diagram of DefectsHB-075 sized

In the picture above, low compressive strength defects is 42.9%, fracture is 73.9%, and chunks is 26.1%. Thus, the dominant defects in HB-75 sized lightweight brick product with the 80/20 principle are low compressive strength and surface fracture. The total percentage in these dominant defects is 73.9%.

3.1.2 CTQ Identification

CTQ is a characteristic of defects that have the potential to cause products not to meet customer demands. The afterwards are some of the characteristics of defects in the HB-075 sized product:

- Low Brick Compressive Strength

  This type of defect occurs because it does not pass the strength test due to the low brick compressive strength, which is below 23.9 kN.

- Broken Brick Surface

This type of defect can be seen visually by the presence of a brick part that is split into two or more parts.

- Torn Down

This type of defect can also be seen visually by finding one or more parts of the brick surface that are detached from the main part.

3.1.3 Measure

The measure stage is the measurement stage of the company's performance before repairs are made. The performance measurement is based on the collection of observational data which consists of collecting data on product quality.

Measurement inthe quality of the product is achieved of numerous proceed. The first process is to determine the characteristics of defects that can affect customer satisfaction with the product and potentially cause the product to be unfit to be marketed. The next process is to make a control chart to find out whether the procedure is within the control boundaries. The procedure is within the control boundaries, followed by the calculation of DPMO which is then imported to level of sigma to decide the company's level of sigma.

3.1.4 P Control Chart

The P control chart made based on the number of defective HB-075 sized bricks. Observations were made 24 times. Observations were made per day with the number of samples used as many as 99 pcs for every day in one shift to produce, starting from January 2022 - February 2022. To monitor the ongoing process, whether the proceedingin the limit of controlstatistical or not, a P control chart determined the defects number in observation sample unit. The software used in making this p chart is Minitab 2017 software. The following figure is a plot of the p chart for defective product units.

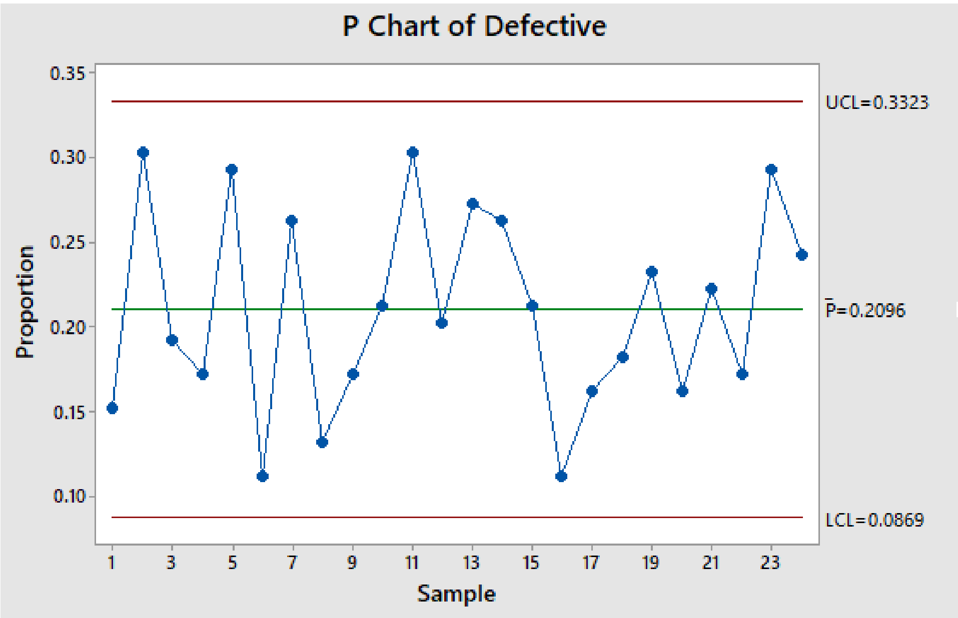

Figure 1. P Chart of Defect Product

According to the control chart P in Figure, all data fall inside the control limit, which is within Upper Control Limit (UCL) and the Lower Control Limit (LCL). The data suggest the proceed is operating normally. Consequently, there is no need to update the data. The calculation below use the P control chart:

$$CL = \bar{p} = \frac{\sum p_i}{k} = \frac{5.03}{24} = 0.2096$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.2096 + 3\sqrt{\frac{0.2096(1-0.2096)}{99}} = 0.3323$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.2096 - 3\sqrt{\frac{0.2096(1-0.2096)}{99}} = 0.0869$$

The product quality was decided from the defects amounts which included in product. To describe the size of the number of defects in the HB-075 sized product, a control chart C was used with the calculated sample size being the same for each observation. The sample used in this study was 99 pcs for every one shift to produce every day. Observations were made from January to February 2022.

3.1.5 C Chart

Thebricks check with compressive strength is finished through counting on a compression checking out machine to measure the bricks strength. The light-weight brick product to be examined for compressive strength is positioned beneath the compression checking machine through positioning the devicewithinside the center of the brick. The compression testing machine can only function for 1 pcs of bricks in the process. The compressive strength test of bricks was carried out in the laboratory.

To monitor the ongoing process, whether the proceed inbetweenthe limits of statistical control or not, C chart is program to decide the failure amount in the observation sample unit. The software used in making this c chart is Minitab 2017. The picture below is a c chart plot for defective product units.

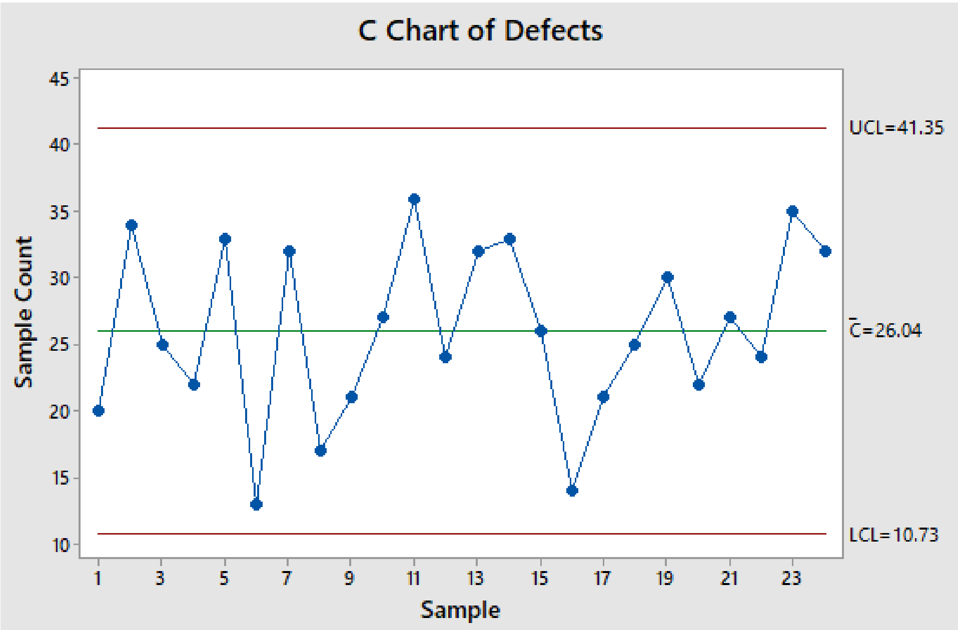

Figure 3. C Chart of Defective

Based on the graph of c chart in the picture above, All data are in control (inside the control limit) since they fall between the UCL and LCL. These statistics suggest the process is operating normally. Consequently, there is no requirement to alter the data. The following is the calculation for the control chart c:

$$CL = \bar{c} = \frac{\sum C_i}{k} = \frac{625}{24} = 26.04$$

$$UCL = \bar{c} + 3\sqrt{\bar{c}} = 41.35$$

$$LCL = \bar{c} - 3\sqrt{\bar{c}} = 10.73$$

3.1.6 DPMO

The steps in the DPMO calculation are as follows:

- Unit (U)
- Oppurtunities(O)
- Defect (D)
- Defect per Unit (DPU)

$$DPU = \frac{D}{U} = \frac{625}{2376} = 0.26$$

- Total Oppurtunities(TOP)

$$TOP = U \text{ x } OP = 2376 \text{ x } 3 = 7128$$

- Defect per Oppurtunities(DPO)

$$DPO = \frac{D}{TOP} = \frac{625}{7128} = 0.087$$

- Defect per Million Oppurtunities (DPMO)

DPMO = DPO x 1.000.000
= 0.087 x 1.000.000
= 87000

From the DPMO above, the probability of

defects in HB-075 sized lightweight brick product is 87000 defects per one million opportunities. From that, it stills very distantof the 6 sigma target, that is 3.4 defects per one million chances.

3.1.7 Sigma Level

Calculation of the sigma level can be done by converting the results of the DPMO calculation into a 6 sigma level. The conversion of DPMO to sigma level is as follows:

= NORMSINV ((1.000.000 – DPMO)/1.000.000) + 1.5

= NORMSINV ((1.000.000 – 87000)/1.000.000) + 1.5

= 2.85 sigma

From the calculation of the sigma level, the company's sigma level is 2.85 sigma. Thus, the company's level of sigma has not reached target of 6 sigma. Therefore, further analysis and improvement is needed in order to increase the company's sigma level.

3.2. Cause-and-Effect Diagram

Cause-effect diagram is diagram which is used to show the circumstancescouldeffect the failure of quality of a product. Influencing factors include methods, raw materials, machines, environment, and humans obtained from the results of brainstorming with the company and direct observations on the production floor. The cause-and-effect diagram is based on the types of defects found in the HB-075 sized lightweight brick product.

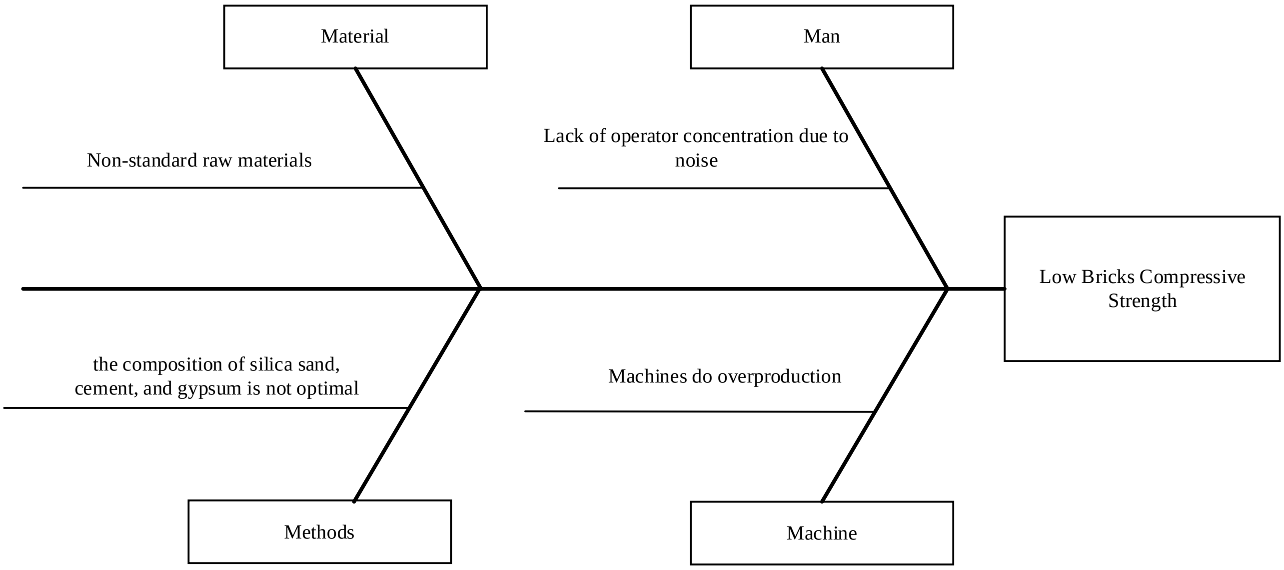

Figure 4. Fishbone Diagram of Low Brick Compressive Strength

Based onthe Low Brick Compressive Strength of Fishbone Diagram above, we representsuch as:

- Man as the operator, losing concentration due to the noise of production causing the negative effects in the process of pouring raw material as the ingredients that resulting low bricks compressive.
- Material, the non-standard raw material ingredients have an impact to the product which has low compressive cause of emptiness in the product itself.
- Machine, overproductive machines causing few faults that producing the low compressive of bricks.
- Method, the compositions of silica sand, cement and gypsum isnot that optimal, thus strength compressive of the bricks is low.

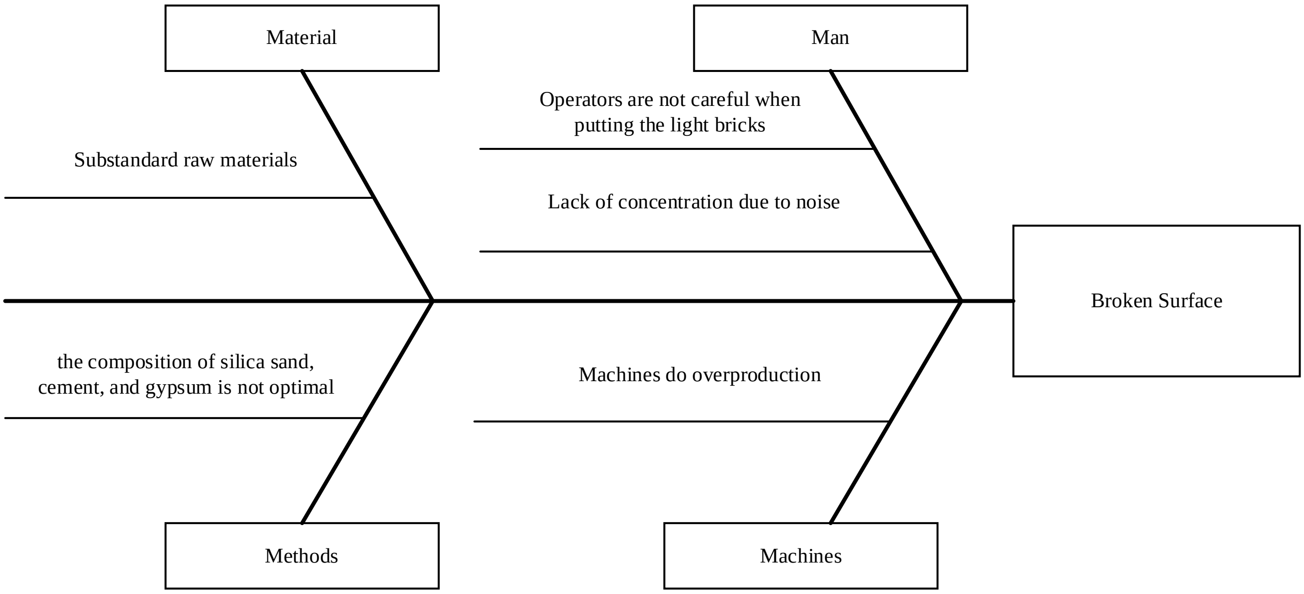

Figure 5. Fishbone Diagram of Broken Surface

Based onthe Broken Surface of Fishbone Diagram above, we represent such as:

- Man as the operator, losing concentration due to the noise of production and their carefulness when attempting the light bricks causing broken surface bricks.
- Material, substandard raw material compositions have an impact for the outcome of product which broken surface of the bricks.
- Machine, the overproductive machines may cause some error that producing the broken surface of the bricks.
- Method, the compositions of silica sand, cement and gypsum is not that optimal, thus the bricks surface is easily broken.

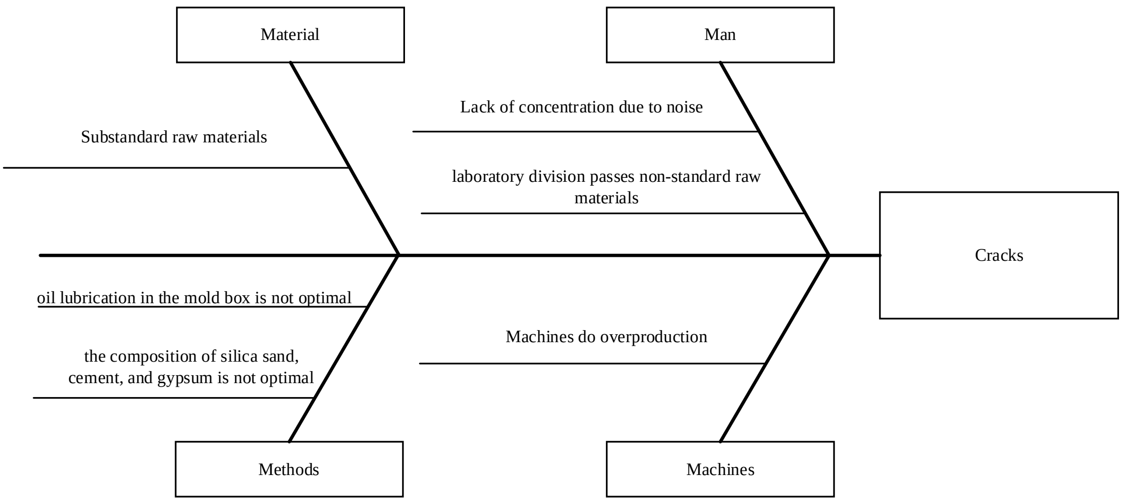

Figure 6. Fishbone Diagram of Cracks

Based onthe Cracks of Fishbone Diagram above, we represent such as:

- Man as the operator, losing concentration due to the noise of production and the lab divisions giving them the non-standard materials causing some cracks of the bricks that they produce.
- Material, substandard raw material compositions have an impact for the outcome of product which some cracks of the bricks.
- Machine, the overproductive machines may cause some errors that resulting the brick

cracks more often.

- Method, the compositions of silica sand, cement and gypsum is not that optimal, thus the bricks arecracking easily.

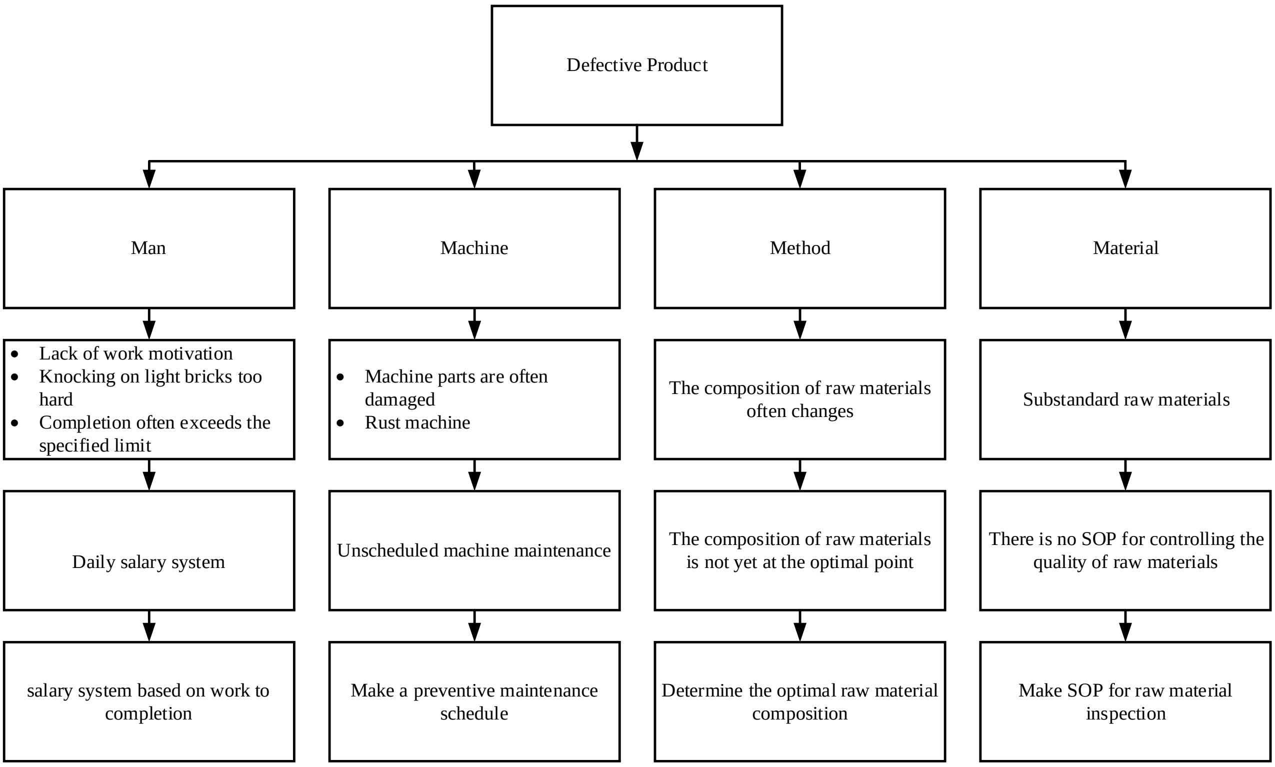

Figure 7. Root Cause Failure Analysis

Based on the chart above, then we made the details analysis of root cause failure with 4 main factors in the light brick industry, such as:

- Man or the operators, could lack of work motivation, knocking brick hard and completion over the limit cause of their salary system based on daily payment, and to fix that the company should have made regulations which can give them salary based on work completion.
- Machine, some parts often already damaging & rusting that needs preventive maintenance to check the machines.
- Method, the company should determine the material composition to the optimal point which the composition shouldn't change so that the exact method continuously applied.
- Material, the material itself didn't have the standard, then the company should've made SOP for the material production to check the raw material.

3.3. Failure Mode and Effect Analysis (FMEA)

The FMEA table formed after making cause-and-effect diagram. The goals in making the table to analyze causes failure in proceeding of the production that cause defects. The FMEA table consists of several standard including severity, circumstance, and detectability. Filling in the FMEA table is based on observations and direct interviews with the company. The following table FMEA on the production process of lightweight brick HB-075 sized in the table below.

Table 2. Failure Mode and Effect Analysis (FMEA)

No	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	DET	RPN	Action Recommended
1	Lack work motivation	Operators frequentlyfinish work the past in particular time limit	7	Daily system salary	4	3	84	Payroll system is done in bulk
2	Most of engine parts worn out	The machine has problemsoperating frequently	6	Maintenance unscheduled	3	4	72	Made schedule for preventive maintenance
3	Still searching the best composition	The change of raw materials elementsfrequently	3	The raw materials elements not optimal yet	8	5	120	Decide the maximumstructurefor raw materials
4	Pass the non-criteria roughelements	Specifications of the raw materials	5	No SOP to inspectthe raw material	4	5	100	Create SOP to analyze raw material

3.4 Improve

In this section, the proposals improvement providedfrom the components inflicting the defectwhich have been recognized on the last stage. The priority of improvements made is based on the highest RPN value obtained.

3.4.1 Taguchi Analysis

Table 3. Matrix Orthogonal Array L_4 (2^3)

Run	Factor		
	Silica Sand (kg)	Cement (kg)	Gypsum (kg)
1	1700	250	160
2	1700	350	200
3	1900	250	200
4	1900	350	160

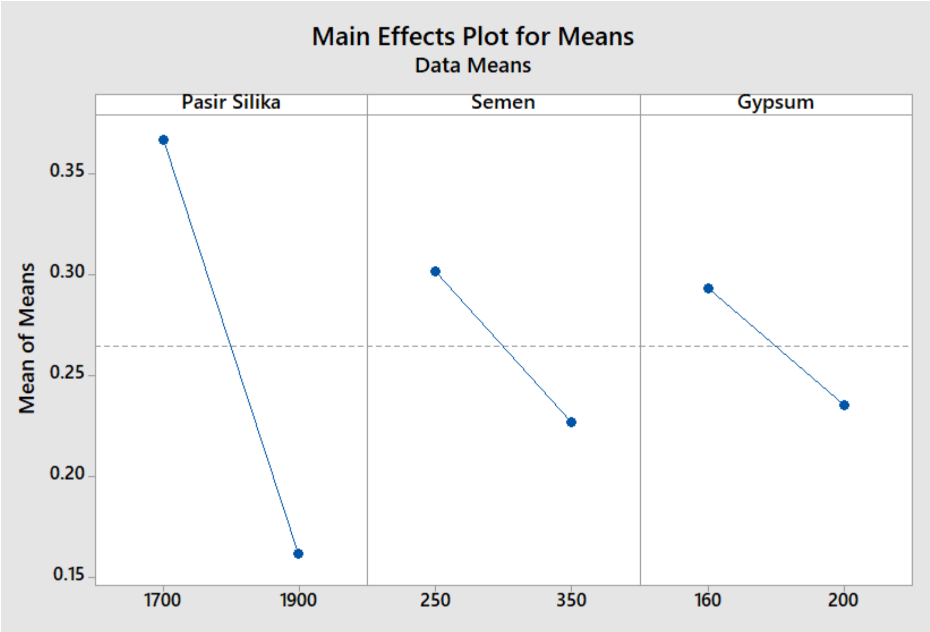

Figure 9. Main Effects Plot For Means

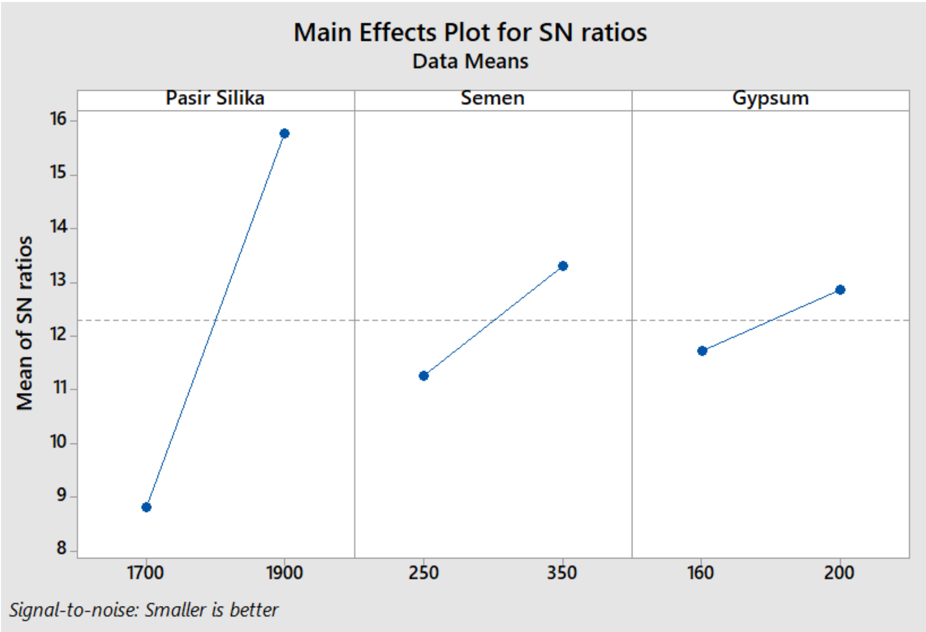

Figure 10. Main Effects Plot For SN ratio

Taguchi Analysis: Y1, Y2, Y3 versus Pasir Silika, Semen, Gypsum

Response Table for Signal to Noise Ratios
Smaller is better

Level	Pasir Silika	Semen	Gypsum
1	8.806	11.033	11.714
2	15.541	13.314	12.633
Delta	6.734	2.282	0.918
Rank	1	2	3

Response Table for Means

Level	Pasir Silika	Semen	Gypsum
1	0.3667	0.3067	0.2933
2	0.1667	0.2267	0.2400
Delta	0.2000	0.0800	0.0533
Rank	1	2	3

Figure 11. Taguchi Analysis

In thisanalysis, the writer needs to decrease the standard deviation and optimalize the ratio of S/N and the Means.

- Silika Sand (Delta 6.734, Rank = 1) has the biggest effect on the S/N ratio, andCement (Delta 2.282, Rank = 2), after that Gypsum (Delta 0.918, Rank = 3).
- Silika Sand (Delta 0.2000, Rank = 1) has the biggest effect on the Means, andCement (Delta 0.0800, Rank = 2), after that Gypsum (Delta 0.0533, Rank = 3).

Factor Information

Factor	Type	Levels	Values
Pasir Silika	Fixed	2	1700, 1900
Semen	Fixed	2	250, 350
Gypsum	Fixed	2	160, 200

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Pasir Silika	1	0.120000	0.120000	76.60	0.000
Semen	1	0.019200	0.019200	12.26	0.008
Gypsum	1	0.008533	0.008533	5.45	0.048
Error	8	0.012533	0.001567		
Total	11	0.160267			

Figure 2. Analysis of ANOVA

Fromthe analysis of ANOVA, 3 factors was determined which are Silika Sand, Cement and Gypsum. The total level of every factors used was levels of 2.

3.4.2 Changing the Payroll System

The form of implementation of this human error is to provide work motivation. In the packing department, the work method used is still the manual method and employee salaries are calculated on a daily basis.Seeing the many opportunities for defective products in the department, the form of implementation of the improvements that have been carried out is to change the employee payroll system, namely from daily to wholesale. The salary given is with the following provisions:

a. 1 (one) pallet of hebbel products with KW1 specifications produced, priced at Rp. 20,000 / pallet.
b. 1 (one) pallet of hebbel products with KW 2 specifications produced, priced at Rp. 17,000 / pallet.
c. 1 (one) pallet of hebbel products with KW 3 specifications produced, priced at Rp. 10,000 / pallet.

With this kind of provision, the operator will be more careful in tapping the product, because defective products are priced much lower than the price of non-defective products. This means that the greater the number of defective products that are packed, the lower the salary received by the operator, and vice versa.Check and laboratory sampling is only carried out once at the time of determining the selection of permanent suppliers. Such a process causes the chances of acceptance of raw materials that do not have higher standard specifications. If raw materials that do not meet standard specifications increase, then product defects will increase.With problems like this, the quality of raw materials must be controlled, to control the quality of raw materials that have an impact on product quality, it is recommended to improve the process. The standard criteria for testing the feasibility of aluminum are as follows:

- Color: Silver – Gray

Table 4. Implementation of Aluminum Sampling

- Development Time: 40 – 50 Minutes
- High Rise: ± 66

If one of the criteria cannot be met with the above standard criteria, then the raw material is rejected, and vice versa.

Here are the standard criteria that must be met:

a. Gypsum :
   - Color: Clear Yellow – Gray
   - Density : 1.2 – 1.3 Kg/L
   - Moisture Content: ≤ 20%
   - Residue: ≤ 10%

b. Lime :
   - Density: ≤ 1.2 Kg/L
   - Stone Diameter: ≤ 15 cm
   - 5th Minute Temperature : 60 °C
   - Maximum Temperature: 70 °C
   - CaO Chemical Content: ≤ 80%

c. Mould Oil :
   - Color: Yellow – Brown
   - Stickiness: Not Sticky

d. Sand :
   - Density: 1.5 – 1.7 Kg/L
   - Sludge Content: ≤ 18%
   - Moisture Content: ≤ 8%
   - Clay: ≤ 4 %

e. Cement:
   - Density : ≤ 1.3 Kg/L
   - SM residue 200/0.075 mm : < 5 %

	PT. HI BRICK Jl. Tipar Cakung No.59, RT.9/RW.8, Cakung Bar., Kec. Cakung, Kota Jakarta Timur							
Number : 001/RM/TQA/BTM/2022 Name : ALUMUNIUM PASTA Code : -				Specification Number : 005/RMS/BTM/2021 Total Sample : 2,5 KG				
No.	Date	Analysis Specification			Reject	Accept	Operator
		Color	Time (Minutes)	Height Ascension			
1	05/01/2022	SILVER	40	65		√	ASEP ABDULAH
2	05/01/2022	GRAY	39	58	√		ANDRI GINANJAR
3	09/01/2022	SILVER	38	60	√		ASEP ABDULAH
4	09/01/2022	SILVER	46	66		√	ASEP ABDULAH
5	30/01/2022	GRAY	41	59	√		ANDRI GINANJAR
6	30/01/2022	SILVER	47	66		√	ASEP ABDULAH

3.5 Control

3.5.1 P Map

The chart of P control was based from the amount of defective products of HB-075-sized lightweight brick. Observations were made 24 times. Observations were made per day with the number of samples used as many as 99 pcs for one shift to carry out each production, starting from January 2022 - February 2022.

Table 5. P Map Calculation After Implementation

No of Sub group	Date	Total of Production (pcs)	Total of Sample (pcs)	Total of Defect (pcs)	Defect Proportion
1	21/04/2022	7892	99	6	0.06
2	22/04/2022	7892	99	11	0.11
3	23/04/2022	7892	99	9	0.09
4	25/04/2022	7892	99	7	0.07
5	26/04/2022	7892	99	12	0.12
Total		39460	495	45	0.45

To monitor the ongoing process, whether the proceeding within the limits of statistical control or not, a PMap is used to decide the amount of defects in observation sample unit—the software used in making the PMap is Minitab 2017. The picture below is thePMap for defective product units.

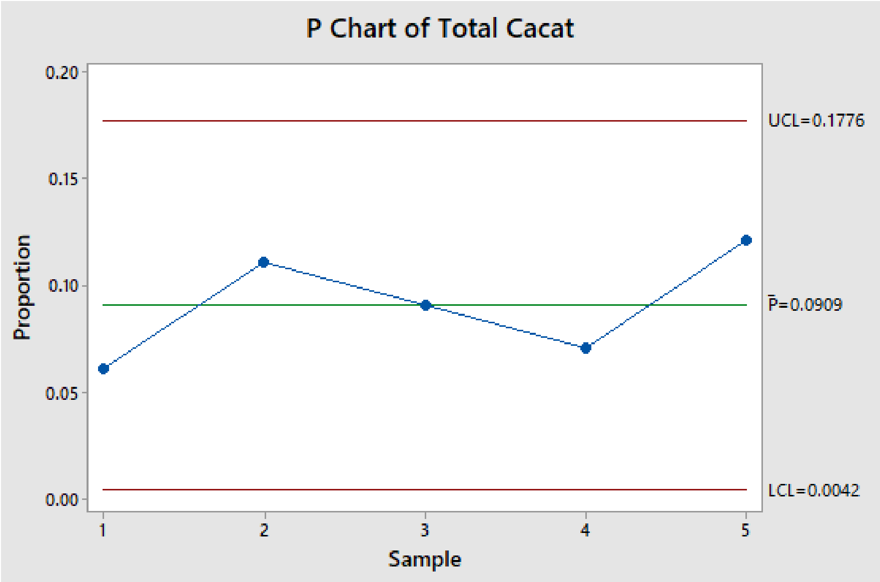

Figure 3. Map of P Control After Implementation

From the P Map graph in the image above, the data are including the limitcontrol, which is among the UCL and the LCL. The results indicating the proceedgoing stably. Thus, no revision for the data. The following is the calculation using the P control chart:

$$CL = \bar{p} = \frac{\sum p_i}{k} = \frac{0.45}{5} = 0.09$$

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.09 + 3\sqrt{\frac{0.09(1-0.09)}{99}} = 0.177$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.395 - 3\sqrt{\frac{0.395(1-0.395)}{50}} = 0.004$$

3.5.2 C Map

The product quality is also determined by the defects product amount. To describe the size of defects amount in HB-075-sized product, a control chart C was used, with the calculated sample size being the same for each observation. The sample used in this study was 50 pcs for every shift to produce daily. Observations were made from November – December 2019. Data on the number of disabilities in below.

Table 6. Observation Data on Mild Brick Defects HB-075 Size

No of Sub group	Date	Total of Production (pcs)	Total of Sample (pcs)	Total of Defect (xi)	Type of Defect		
					Low Bricks Compressive Strength	Broken Surface	Crack
1	21/11/2019	7892	99	16	6	6	4
2	22/11/2019	7892	99	12	4	2	6
3	23/11/2019	7892	99	14	2	8	4
4	25/11/2019	7892	99	18	6	6	6
5	26/11/2019	7892	99	26	10	12	4
Total		39460	495	86	28	34	24

The following is the observational data for each subgroup's sub-standard compressive strength test against HB-075-sized lightweight bricks.Chart C control was used to decide the number defects in observation sample unit to monitor the ongoing proceed and if the proceed is within statistical control limits or not. The software used in making the control chart is the Minitab 2017 software. The picture below is a C control chart for the non-conformance of defective product units.

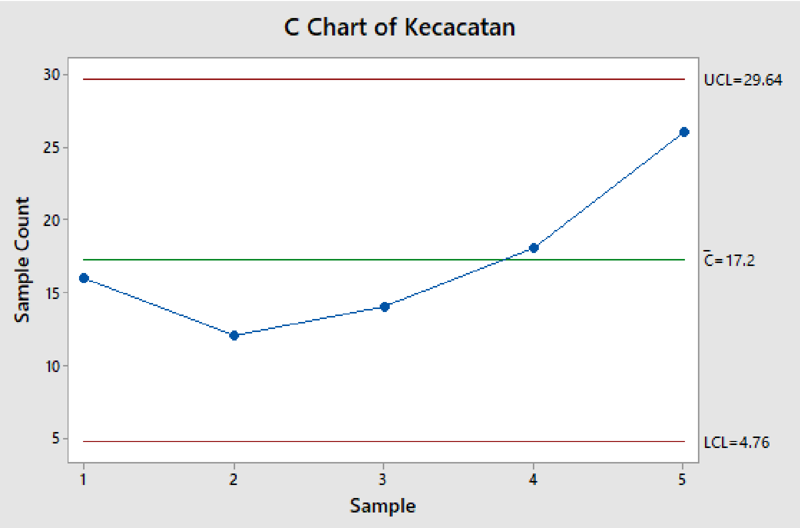

Figure 4. C Control Map After Implementation

From the chart C control, the data are inside the limit control due tothe data among the UCL and LCL. These results indicate that the process runs stably. Thus, no need revisionfor the data. The following is a calculation using the C control chart:

$$CL = \bar{c} = \frac{\sum C_i}{k} = \frac{86}{5} = 17.2$$

$$UCL = \bar{c} + 3\sqrt{\bar{c}} = 29.64$$

$$LCL = \bar{c} - 3\sqrt{\bar{c}} = 4.76$$

The control section used to manage the improvements made and tests of validation. In this section of Implementation by monitoring the results of whole production and noticing the proceedto make Standard Operation Procedures (SOP). Following the repairimplementation, re-measurements are conducted to decide the impact after repair. Measurements are conductedfrom accummulating the value of DPO, DPMO and levels of sigma after repair. The following calculation results can be seen below.

Measurement of DPMO Value After Repair:

- Defect per Unit (DPU)

$$DPU = \frac{D}{U}$$

$$= \frac{86}{495} = 0.173$$

- Total Oppurtunities(TOP)

TOP = U x OP

= 495 x 3

= 1485

- Defect per Oppurtunities(DPO)

$$DPO = \frac{D}{TOP}$$

$$= \frac{86}{1485}$$

= 0.057

- Defect per Million Oppurtunities (DPMO)

DPMO = DPO x 1.000.000

= 0.057 x 1.000.000

= 57.000

Measurement of Sigma Value After Repair:

DPMO = NORMSINV ((1.000.000 – DPMO)/1.000.000) + 1.5

= NORMSINV ((1.000.000 – 57000)/1.000.000) + 1.5

= 3.08 sigma

4. Discussion

4.1 Key Findings

The purpose of this study was to identify defective products to determine the main factors causing defects in HR-plate steel products and to make improvements to the production process to reduce or minimize these defective products. Improvements made using the Six Sigma method approach by carrying out the D-M-A-I-C stages. The main findings in this study are the results of data processing and analysis based on the stages of D-M-A-I-C as follows.

In Define stage, the Process Operation Chart formed and Critical to Quality determination is made. The Operation Process Chart describes the process steps to be passed with a description of the quantity of material in it. The process that goes through starts from the grinding of raw materials, printing of raw materials, cutting, until the maturation of the bricks that have been formed. Characteristics of defects formed are divided into three types, namely low brick compressive strength, broken brick surface, and chipped.

In the Measure stage, via way of means of measuring the troubles which have been diagnosed via way of means of reading manufacturing manipulate the use of P-chart and C-chart manipulate diagrams with the Minitab17 application, it's far located that the gathered records is properly controlled. The sigma value before implementation is 2.85. These results indicate that the sigma value still has to be improved by reducing existing product defects.

In the stageofAnalyze. An analysis of the factors that cause disability through fishbone diagrams and priority problem improvement through FMEA is carried out. The factors that cause disability are reviewed based on the causes of man, material, machine, method, and environment. The biggest potential causes are that the dose of sand, cement, and gypsum is not optimal with an RPN value of 120. Furthermore, the operator is not careful when laying bricks with an RPN value of 100, the quality of non-standard raw materials with an RPN value of 100, and the scales of raw materials have problems with an RPN value of 100. RPN 84.

Stage of Improve, providing improvement proposals based on the factors causing the defect that known in the previous stage. Improvements were made using the Taguchi method for subtituting the structure of raw materials, payroll system, and making SOPs for checking raw materials. Switching the structure of raw materials with several experimental designs using the Taguchi method resulted in the smallest number of defects from one of the design compositions of raw materials, namely 1900 kg of silica sand, 350 kg of cement, and 200 kg of gypsum. This can be used as an improvement in reducing product defects. Changing the payroll system is one of the methods used to provide more motivation in reducing human error.

The phase control is conducted by assessingrestorativeperformances to decreasethe defectsproduct. At this stage, P chart and C chart are used as well as the calculation of sigma value after repair. P chart and c chart data are already within the control limits so that they are categorized as good and there is an increase in sigma to 3.08 so that corrective actions are declared effective to be implemented.

4.2 The Results Obtained Are

This study applies the control in quality method with method for the Six Sigma, as for relationship with previous research. As a comparison material, several international research references were obtained that carried out research with the Six Sigma approach and obtained different results so that this became a measure of the results of research conducted. Research (S.P et al., 2017) with the method of Six Sigma in application to reduce rejects in oil pump at castings and to increase productivity. Favorably reduced hollow rejects in casting parts from 28.3% to 7.1%. thus increase the productivity. So that productivity has been accumulated to meet customer needs. This study provides the six sigma application method to recognizeissues during the molding proceed and figure outissues by deciding the optimum operating boundaries to reduce inclusion failures in oil pump. Research (Kumar et al., 2018) with the method of Six Sigma in application to reduce automotive component coupling rejects in the automotive industry resulted in a reduction in coupling rejects from 15 from 220 to 2 from 220 in one filter, increasing the Sigma level from 2.99 to 3, 86, with optimal results. In this era, Six

Sigma has been considered like strong business tactic that uses a well-structured continuity improvement methodology to reduce rejects in manufacturing processes with the application of effective statistical tools and techniques. Research (Barot et al., 2020) with the method of Six Sigma in application to decrease product failures in the metal proceed molding. The level of Sigma developed to 3.0 of 2.6, whichsupports to decrease the fee of production, offers quality that consistently, decreasingthe rates of reject, henceassingthe revenue. A systematic approach to quality control can lower the rate of rejected items. Using lean principles, the proposed study identifies a considerable rise in work area and sigma levels. According to the results of the analysis, the sand drop defect fell from 15.9 percent to 6.4%. The author's research, applying the method of Six Sigma to reduce defective products in lightweight brick HB-075, the DPMO results were obtained from 87000 ppm to 57000 ppm and the level of Sigma enhanced from 2.85 to 3.08 Sigma.

The impact of findings in this research to decreasing product failures that occur in production of lightweight bricks. By applying the DMAIC method, namely identifying the problem, then looking for the factors causing the problem and making improvements to the factors causing the problem, it is proven to be able to decrease the failures level in lightweight brick products studied. To keep the product quality obtained so that it does not return to its original worse condition before corrective steps are taken, it is necessary to properly monitor and control the schedule of engine repairs, schedule checks and control of machine components and facilities as well as implement work procedures properly. The strategy that needs to be carried out so the proceeding of production can performeffortlessly is the accuracy and experience in the operator of conducting inspections, checking and controlling is needed and also requires intensive supervision of the operator's performance and it is also hoped that the relevant management will provide training to operators on standard work procedures (SOPs).

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