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Quality Analysis of Hot Rolled Pickled and Oiled (HRPO) Products with Statistical Quality Control (SQC) And Failure Mode and Effect Analysis (FMEA) Methods (Case study: At PT Sun Rise Mill)

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Abstract

PT Sun Rise Mill is a company that is part of the SUNRISE GROUP domiciled in the Mojekerto area. PT Sun Rise Mill is a manufacturing company that has been established since 2018 which is engaged in the production of hot rolled pickle oil or HRPO rolled steel. PT Sun Rise Mill in every production there are still problems regarding defects that occur such as Under Pickle, Bad Trim, Protuding and Wavy Edge which affect the quality. The purpose of this study was to determine the presentation of the most dominant defects, the factors causing the defects, and the effects they caused, as well as to propose the appropriate improvements to improve the quality of hot rolled pickle oil rolled steel products. The methods used are Statistical Quality Control (SQC) and Failure Mode and Effect Analysis (FMEA). SQC tools are check sheets, stratification, histograms, paretto diagrams, scatter diagrams, control charts, and cause and effect diagrams. Meanwhile, FMEA is used as a proposal to improve the results of the cause-and-effect diagram. Based on the results of research on SQC, the most dominant defects were Under Pickle (50.86%), after that Bad Trim (22.63%), Wavy Edge (18.76%), and Wavy Edge (7.73%). Based on the results of analysis and calculations on FMEA, it is known that the problem causing disability with the highest RPN value of 294 is the human factor with the cause of the operator being less careful in the washing steps when mixing HCL is not appropriate. Recommendations for improvements that can be made are by conducting periodic monitoring when mixing HCL.

Keywords
product quality; statistical quality control; failure mode; effect analysis

I. Introduction

The development of the industry makes a company will monitor more in producing products to re-assure the performance and production, such as maintaining product quality. The quality of a product is important to meet product standards with maximum and minimum quality in its manufacture (time). Thus, it is also important to carry out repeated evaluations and improvements to the production process. According to Sofjan (2017), therefore, it is necessary to carry out quality control to ensure that the production process can be carried out in accordance with the provisions and if a deviation occurs, it can be immediately checked so that what is expected can be achieved.

The defect of a product is associated with quality characteristics that do not meet certain standards (Wiley, 2016) so quality control is necessary. Where is an important activity in management to improve or maintain the quality of a product and minimize the

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number of defective products. One of the methods for quality control is the statistical quality control (SQC) method by collecting and analyzing data in determining or monitoring the quality of production and applying probability theory when testing or examining samples in the quality control activities of a product. And to be able to identify potential failures that will arise, it is also necessary to use the failure mode and effect analysis (FMEA) method, so as to minimize the risk of disability.

PTSun Rise Mill is a company that is part of the SUNRISE GROUP domiciled in the Mojekerto area. PT Sun Rise Mill is a manufacturing company that has been established since 2018 which is engaged in the production of hot rolled steel pickle oil. These products are generally used as raw materials for other manufacturing industries, such as buildings, automotive components, household appliances, and many more. PT Sun Rise Mill in every production there are still problems regarding defects that occur such as Under Pickle (black color), Bad Trim (uneven cuts), Protuding (untidy rolls) and Wavy Edge (there are waves). The existence of several defects, the company continues to make improvements to the production process in order to reduce defects and increase company efficiency.

Based on the results of interviews that have been conducted, the existence of these defects can be influenced by raw materials, labor, machine facilities and others. Activities that can cause defects such as the quality of raw materials that do not meet standards, lack of operator accuracy when running machines, workers who accidentally make mistakes while working (initial setting errors and machine breakdowns often occur). The number of defects that are not controlled will create a large nominal loss and in the long run will affect consumer confidence.

Table 1. Data on Total Production and Number of Defects at PT SUN RISE MILL

Month	**Production Quantity**	**Number of Defects**			
		***There is a black color* (UnderPickle)**	***Uneven Cuts* (Bad Trim)**	***There are waves* (Wavy Edge)**	***Untidy Rolls* (Protuding)**
October	2140	50.96	23.56	17.31	8.17
November	2440	50	21.43	20.92	7.65
December	2520	52.2	20.88	19.78	7.14
Jan	3285	49.77	24.65	17.67	7.91
Feb	3520	49.16	22.69	19.75	8.4
March	2716	53.98	22.16	17.04	6.82

With the above problems, the researchers conducted a study to determine the most dominant presentation of defects, the main factors causing defects, and the effects they caused, as well as providing appropriate improvement suggestions to improve the quality of hot rolled pickle oil rolled steel products. This study uses the Statistical Quality Control (SQC) method to describe the causes of disability. And can provide suggestions for improvement with Failure Mode and Effect Analysis (FMEA) analysis as an analytical technique to identify potential failure points and their causes. Statistical Quality Control (SQC) and Failure Mode and Effect Analysis (FMEA) methods are considered suitable to be applied to PT Sun Rise Mill, which is one of the largest steel manufacturing companies in Indonesia.

II. Review of Literature

2.1 Definition of Quality

The definition of quality according to several experts expressed different opinions, namely:

1) According to W. Edwards Deming, in Hangsthi 2021 stated that quality is linear to market needs.
2) According to Suyadi Prawirosentono, in Hangsthi 2021 states that quality is a physical form, nature, and function of a product capable of satisfying the needs and desires of consumers and the value issued.
3) *American Society for Quality*quoted by Heizer and Render, in Vaundra 2021: "Quality is the totality of features and characteristic of a product or service that bears on its ability to satisfy stated or implied need".

It means:

Quality is the totality of features and characteristics of a product or service that depend on its ability to satisfy stated or implied needs

Quality is a condition for the condition of the product in the eyes of consumers, a good quality product is a product that can meet consumer expectations. By forming a quality product, the company can at least maintain existing consumers or even increase the number of consumers who consume a product. Quality does not have to be the absolute best but also needs to be generally the best within the limits of the circumstances desired by the user. (Siregar, 2019)

2.2 Definition of Quality Control

The definition of quality control according to several experts expressed different opinions, namely:

1) According to Vincent Gasperz, in Hangsthi 2021 "Control can mean an evaluation to indicate needed corrective responses, the act guiding, or the state of process in which the variability is attribute constant system of chance courses". represents the required correlative response, guiding action, or a process in which variability is a constant attribute of a particular system.
2) According to Ginting, in Hangsthi 2021 states that quality control is the result given after continuous inspection, expected corrective actions, accurate planning, use of equipment based on the results of the verification system and maintaining the quality level of a product.

In general, control is also defined as an activity carried out to monitor and ensure the actual performance carried out is in accordance with what was planned. Meanwhile, quality control is one of the techniques that needs to be carried out from start to finish (before the production process, during the production process to the end of the production process until it becomes a finished product). Quality control is carried out with the aim of improving the quality of a product (goods or service) that does not meet the standards so that it can produce products (goods or services) in accordance with the planned and established standards. In addition, as much as possible can maintain the appropriate quality.

So that it can be concluded that quality control is a quality control activity which is an effort to maintain the quality or quality of the goods created, so that they are in accordance with product specifications that have been planned and determined in accordance with company leadership policies. (Andri, 2018)

2.3 Quality Control Purpose

The main purpose of quality control is to get a guarantee that the quality of the product (goods or services) that is created is in accordance with the quality standards that have been planned and determined by incurring economic costs (as low as possible) in making an improvement. The other objectives of quality control are:

- So that the goods produced can meet the quality standards that have been set.
- In order for the costs incurred for inspection or other costs (design costs, production costs, etc.) to be lower (as small as possible).

2.4 Quality Control Factors

The factors that can affect the quality control carried out by the company are:

1. Process Capability
   It is the limit to be achieved that must be adjusted to the capabilities of the existing process. There is no point in controlling a process within limits that exceed the capabilities or capabilities of the existing process.
2. Applicable specifications
   Is a specification of the production results to be achieved must be applicable, when viewed in terms of process capability and the desires or needs of consumers to be achieved from these production results. In this case, it must be ascertained in advance whether the specifications can be applied from the two aspects mentioned above before the quality control in the process can be started.
3. Acceptable level of nonconformity
   It is related to the purpose of controlling a process is to reduce the product that is below the minimum standard as possible. The level of control applied depends on the number of products that are below acceptable standards.
4. Quality cost
   Is something that greatly affects the level of quality control in creating a product where the cost of quality has a positive relationship with the creation of a quality product. (Siregar, 2019)

2.5 Quality Improvement

Is an activity that uses certain factors to create goods that have better quality. (Soffian Assauri in Hangsthi, 2021). It can also be interpreted as an effort to improve quality better than before. According to some experts there are also differences of opinion in quality control measures, including:

1) Roger G. Schroeder in Hangsthi (2021)
   The steps in quality control according to Roger G. Schroeder are as follows:
   a) Definition of quality properties (attributes)
   b) Determining how to measure each characteristic
   c) Setting quality standards
   d) Determination of inspection program
   e) Substandard quality improvement
   f) Continuous improvement
2) MN Nasution in Hangsthi (2021)
   One of the quality control processes is PDCA. PDCA stands for Plan, Do, Check, and Action. This PDCA cycle is useful in implementing various changes in improving performance, processes, or a system in the future.

2.6 Statistical Quality Control

According to Agus Ahyari in Vaundra Cunning Hangsthi (2021) Quality Control has two principles, namely the use of diagrams and statistical principles. With supervision carried out by workers in the production process, then sample analysis is then used to represent the overall characteristics of the product.

The definition of statistical quality control is a statistical method or method with the aim of analyzing sample inspection data, then monitoring, and repairing (containing how to control and manage) so that it can find out the cause of the defect or damage. The solution is carried out using statistical quality control methods with the following objectives:

a. As supervision of a work implementation while the work is in progress
b. As a decision maker regarding to accept or reject the product produced
c. Provide quality audit reports to company leaders. Based on the three explanations above, the quality functions are
   - Quality control is used for prevention
   - *Statistical quality control*used for data collection and analysis
   - Quality assurance for audits and planning

In statistics, there are two kinds of normal quality variance, namely probabilistic and eratic. Where probabilistic is a variance that occurs by chance and cannot be avoided, while Eratic is a variation that occurs randomly due to unnatural causes. There is an initial step in quality monitoring with statistical methods, namely control charts and sampling inspections. (Hangsthi, 2021)

III. Research Method

The research location for the preparation of this final project was carried out at PT Sun Rise Mill. Company location is inJl. Bypass Mojokerto KM. 54, Jampirogo, Sooko, Padangan, Sumolawang, Kec. Puri, Mojokerto Regency, East Java 61361.This research was carried out in February 2022 until the data were met.

3.1 Identification and Definition of Operational Variables

In this research, it is necessary to identify the research variables. Referring to the title of the study, it can be identified the variables related to the following:

a. Dependent variable

The dependent variable is the variable that is influenced or that becomes the result because of the independent variable. In this study, the dependent variable is quality control with statistical quality control (SQC) and proposed improvements with Failure Mode and Effect Analysis (FMEA) on hot rolled pickle oil rolled steel products.

b. Independent Variable

The independent variable is the variable that causes changes in the dependent variable or as the main factor of the problem being studied. The independent variables in this study are as follows

1. Production Quantity
   Production data of pickle oil/HRPO hot rolled rolled steel used from October 2021 to March 2022.
2. Number of Product Defects
   Product defect data of pickle oil/HRPO hot rolled rolled steel used from October 2021 to March 2022.

3. Number of Types of Product Defect
   The number of types of product defects is data on the types of product defects including:
   a) There is a black color
      Definition: There is a blackish color on the surface of Pickle oil/HRPO hot rolled rolled steel
   b) Uneven Cuts
      Definition: There are uneven cut marks on the surface of Pickle oil/HRPO hot rolled rolled steel
   c) There are waves
      Definition: There is a wave on the surface of Pickle oil/HRPO hot rolled rolled steel
   d) Untidy Rolls
      Definition: Untidy roll-on product Hot rolled steel pickle oil/HRPO

IV. Result and Discussion

4.1 Statistical Quality Control (SQC)

In Statistical Quality Control there are several statistical quality control tools. In this study, several tools were used, including:

a. Check Sheet

Presentation of data in a communicative form by recording the results of data collection so that it becomes information is the use of check sheetsor check sheet. The following is Table 4.3 regarding the results of collecting disability data using a check sheet.

Table 2. Check Sheet On Hot Rolled Steel Pickle Oil

No	Month	Total Production	Total Production (Tons)				Total
			Under Pickle	***Bad Trim***	***Wavy Edge***	***Protuding***	
1	October 2021	2140	106	49	36	17	208
2	November 2021	2440	98	42	41	15	196
3	December 2021	2520	95	38	36	13	182
4	January 2022	3285	107	53	38	17	215
5	February 2022	3520	117	54	47	20	238
6	March 2022	2716	95	39	30	12	176
Total		**16621**	**618**	**275**	**228**	**94**	**1215**

(Source: PT. Sun Rise Steel, 2021-2022)

b. Histogram

The depiction of the amount of data grouped into intervals (class intervals) in the form of a bar chart graph is the use of a histogram. The following is Table 4.4 regarding the number of types of defects in hot rolled steel pickle oil for the period October 2021 to March 2022.

Table 3. Number of Defect Types in Oil Pickle Hot Rolled Roll Steel

Defect Type	Defect Type (Tons)	Defect Percentage (Tons)
There is a black color (UnderPickle)	618	50.86%

Cuts Uneven (Bad Trim)	275	22.63%
There are waves (Wavy Edge)	228	18.76%
Untidy Rolls (Protuding)	94	7.73%
Amount	**1215**	**100.00**

Based on Table 3, a bar graph or histogram can be made showing the interval of the number of defect products from each type of defect which can be seen in Figure 1.

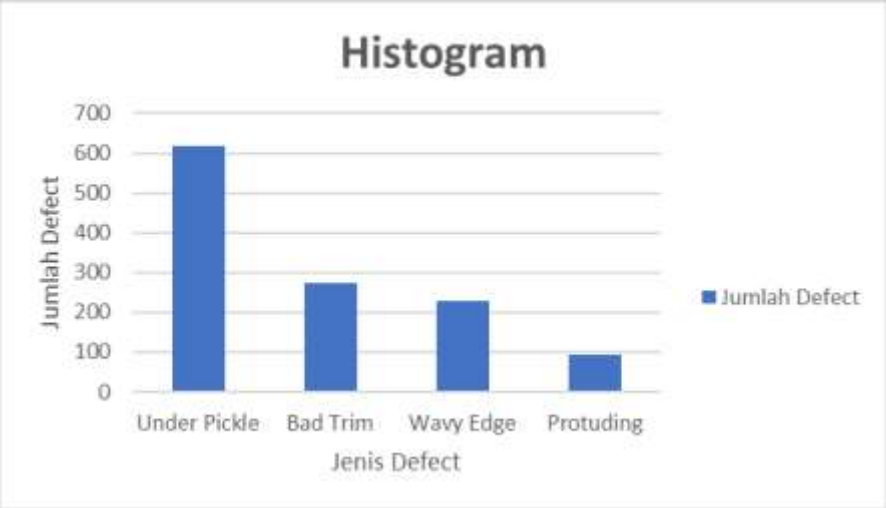

Figure 1.

Based on histogramonit can be concluded that the biggest defect occurred in the presence of a known blackish color of 618 tons, then the cut marks were uneven with the number of defects as much as 275 tons, then there were waves with the number of defects as much as 228 tons and untidy rolls with the number of defects as much as 94 tons.

c. Pareto chart

As an interpretation tool in determining the frequency of defects from the largest to the smallest by calculating the percentage of defects and the cumulative of each existing defect, in the form of a special bar graph is the use of a Pareto diagram.

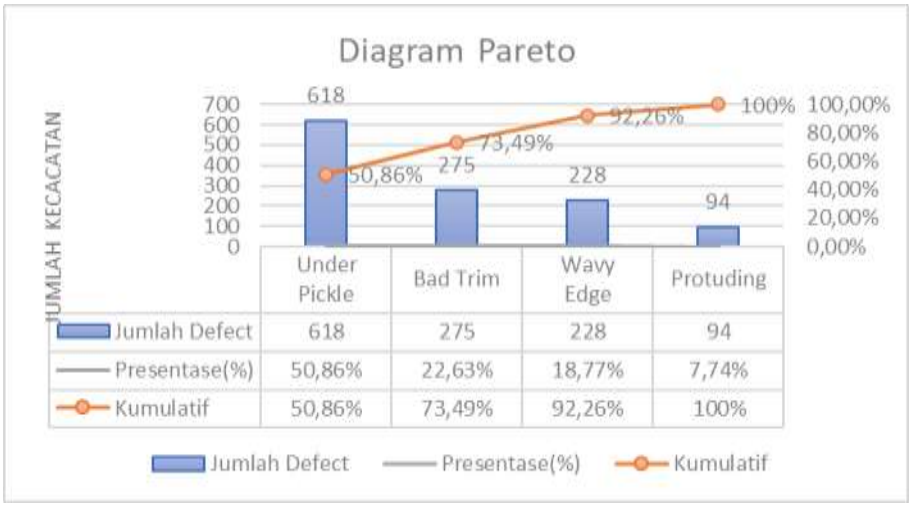

Figure 2. *Pareto Chart*

Based on Pareto chart aboveit can be concluded that the largest type of defect is a black color with a cumulative percentage of 50.86%. While the percentage of defects in the Pareto diagram above, it can be seen that the biggest cause of defects in hot rolled pickle oil rolled steel products is the defect with a blackish color with a total percentage of (50.86%) followed by defects from uneven cuts with a percentage of (22, 63%), then there was a wave defect with a percentage of (18.76%), then the defect of the roll was not neat with a percentage of (7.73%). With this Pareto diagram, it can be seen which defects should be prioritized first.

d. Process Diagram

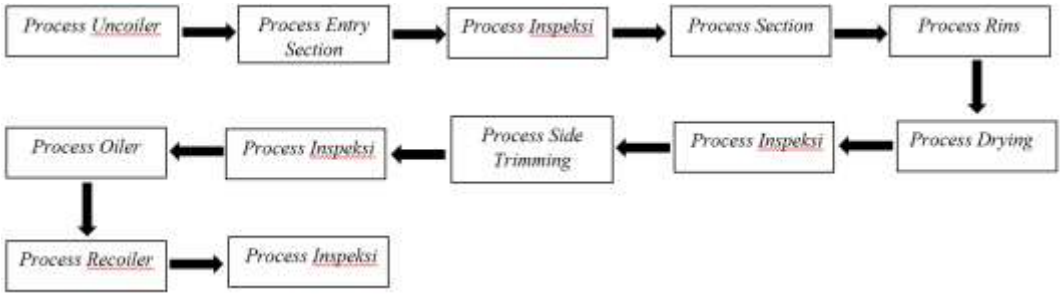

Figure 3. *Process Diagram*

Process diagram is a diagram that presents a graphical representation of a process or system and this tool is very good for understanding a process and explaining the steps of a process. As pictured is the flow of the production process that occurs in the production of pickle oil hot rolled steel, starting with the manufacture of the Uncoiler, Entry Section and Recoiler. For an explanation of each step of the pickle oil hot rolled steel production process, see section 2.6.

e. Scatter Diagrams

As a hint of correlation between two measurementsof the factors causing defects associated with a characteristic is the use of a scatter diagram. Based on the results of the Pareto diagram above, the dominant defects are Under Pickle (there is blackish color)

followed by Bad Trim (uneven cut marks), Wavy Edge (there are waves), and Protuding (untidy rolls). Then this scatter diagram will be used to identify the relationship (correlation) between the number of hot rolled pickle oil rolled steel produced and the number of defects from Under Pickle (blackish color), Bad Trim (uneven cut), Wavy Edge (waves), and Protuding (untidy rolls). The following Scater Diagram between Under Pickle (there is blackish color) and the amount of production can be seen in Figure 4.8.

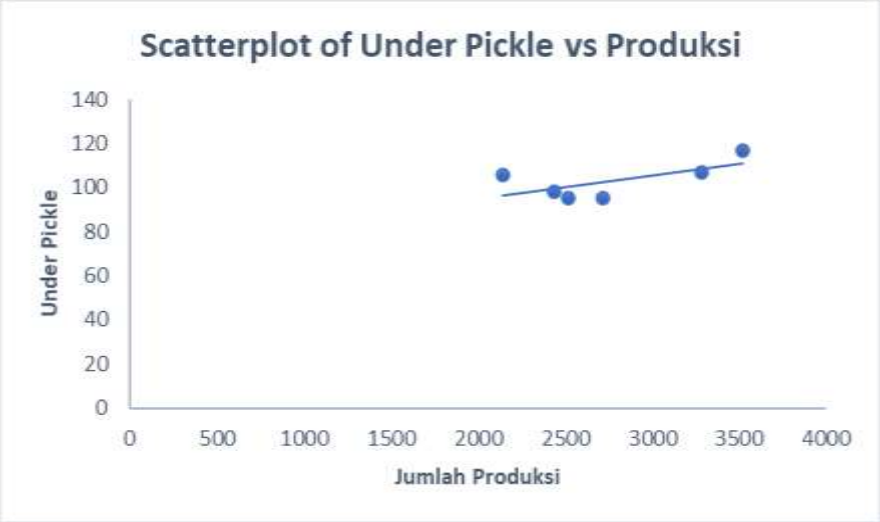

Figure 4. *Scatter DiagramsThere is a black color (Under Pickle)*

Based on the Scater Diagram which has a positive relationship (positive correlation) where an increase in the X variable is followed by an increase in the Y variable, the result is that the higher the amount of production will result in a higher blackish color (Under Pickle). So it can be concluded that the scatter diagram shows that there is a strong relationship between the presence of a blackish color (Under Pickle) and the amount of production.

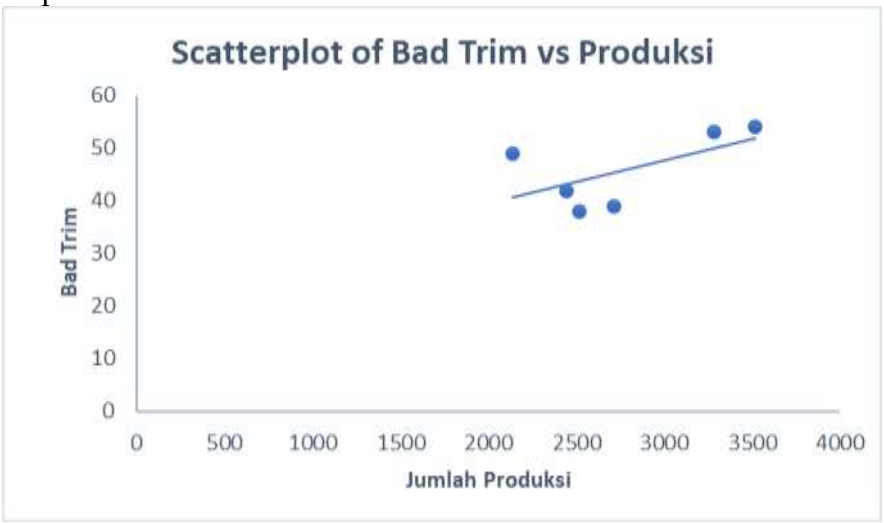

Figure 5. *Scatter DiagramsUneven cuts (Bad Trim)*

Based on the Scater Diagram which has a positive relationship (positive correlation) where an increase in the X variable is followed by an increase in the Y variable, the result is that the higher the amount of production, the higher the Bad Trim. So it can be

concluded that the scatter diagram shows that there is a strong relationship between Bad Trim and Total Production.

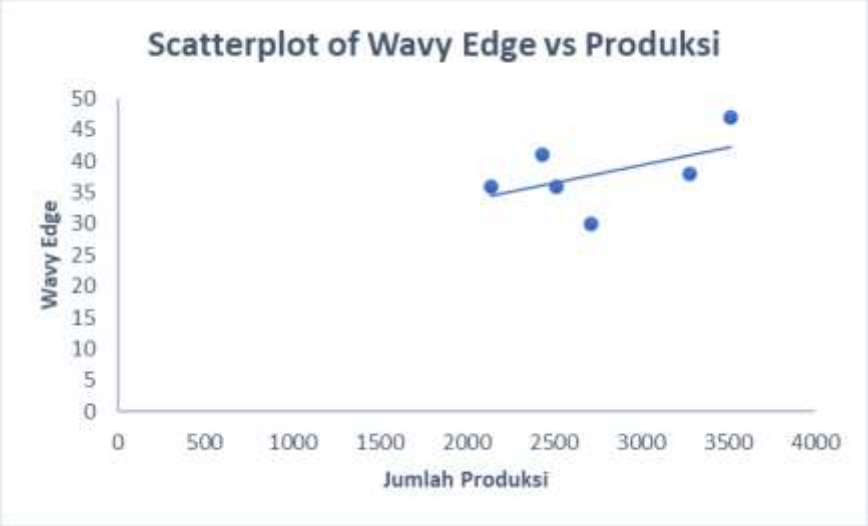

Figure 6. *Scatter DiagramsThere is a wave (Wavy Edge)*

Based on the Scater Diagram which has a positive relationship (positive correlation) where an increase in the X variable is followed by an increase in the Y variable, the result is that the higher the amount of production will result in a higher wave (Wavy Edge). So it can be concluded that the scatter diagram shows that there is a strong relationship between the presence of waves (Wavy Edge) and the amount of production.

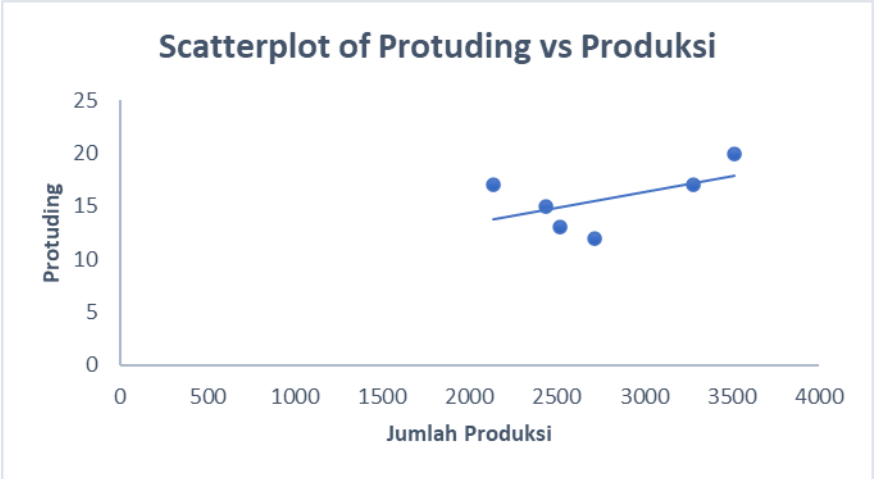

Figure 7*. Scater DiagramGulungan yang tidak rapih (Protuding)*

Based on the Scater Diagram which has a positive relationship (positive correlation) where an increase in the X variable is followed by an increase in the Y variable, the result is that the higher the amount of production, the higher the Protuding. So it can be concluded that the scatter diagram shows that there is a strong relationship between the untidy rolls (Protuding) and the amount of production.

f. Control Chart

As an indication of whether the number of defects that occur in the product is still within reasonable limits or not so that an analysis of product defects can be carried out, the use of control charts or control maps can be carried out. In this study, the attribute control chart is used, namely the p control chart. Where describes the part that was rejected because it does not comply with the desired specifications of the amount of production.

1. P-Chart on There is Blackish Color (Under Pickle)

The steps to create a p control chart are as follows:

a. Calculating the proportion of disability

An example of calculating the proportion of disability using the following formula:

$p1 = \frac{np1}{n1} = = 0.0495 \frac{106}{2140}$

$p2 = \frac{np2}{n2} = = 0.0401 \frac{98}{2440}$

Information :

npi = number of defects there is a black color

ni = number of pickle oil hot rolled roll steel production

b. Calculate the center line which is the average product defect ($\bar{p}$) or Center Line (CL)

$\bar{P} = \frac{\sum np}{\sum n} = = 0.0372 \frac{618}{16621}$

Information :

npi = number of defects with black color

ni = Number of hot rolled pickle oil rolled steel production

c. Calculating the Upper Control Limit (UCL)

$UCL1 = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0372 + 3\sqrt{\frac{0{,}0371(1-0{,}0371)}{2140}} = 0.0495$

$UCL2 = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0372 + 3\sqrt{\frac{0{,}0371(1-0{,}0371)}{2440}} = 0.0487$

d. Calculating the lower control limit (LCL)

$LCL1 = \bar{p} - 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0372 - 3\sqrt{\frac{0{,}0371(1-0{,}0371)}{2140}} = 0.0249$

$LCL2 = \bar{p} - 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0372 - 3\sqrt{\frac{0{,}0371(1-0{,}0371)}{2440}} = 0.0257$

If the disability proportion value of a subgroup is above the UCL or below the LCL, it will be counted as out of control data. The results of the calculation of the proportion of disability, CL or $\bar{p}$, LCL, and other UCL can be seen in table 4.5 below.

Table 4. Control Chart Calculation Results on Under Pickle

Month	Under Pickle	Total Production	P	$\bar{p}$	UCL	L
1	106	2140	0.0495	0.0375	0.0498	0.0252
2	98	2440	0.0402	0.0375	0.0490	0.0260
3	95	2520	0.0377	0.0375	0.0489	0.0261
4	107	3285	0.0326	0.0375	0.0474	0.0276
5	117	3520	0.0332	0.0375	0.0471	0.0279

6	95	2716	0.0350	0.0375	0.0484	0.0266
Total	618	16621				

Based on the calculation results in Table 4, the control chart p on the Under Pickle can be seen as shown in Figure 8

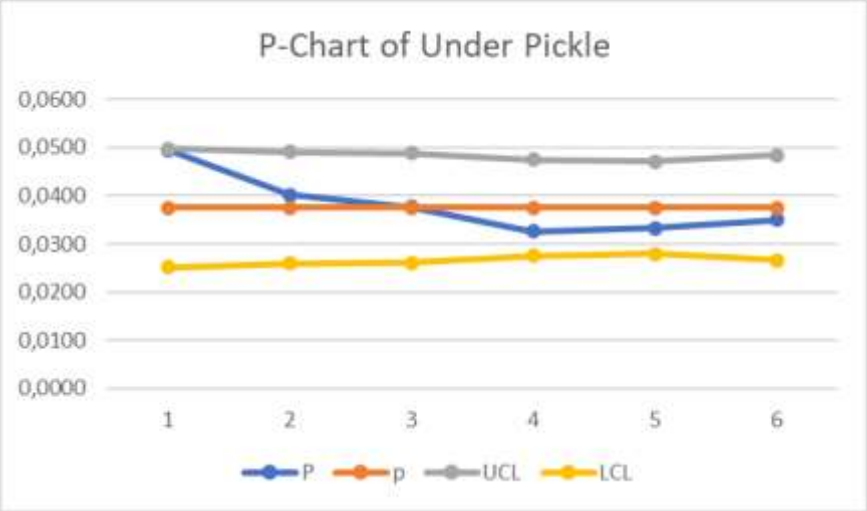

Figure 8. *P Control Map on Under Pickle*

Based on the visual image of the control map p for the Under Pickle defect above, it is found that all defects that occur are still within the control limits (nothing is out of control).

2. P-Chart on Uneven Cuts (Bad Trim)

The steps to create a p control chart are as follows:

a. Calculating the proportion of disability

An example of calculating the proportion of disability using the following formula:

$p1 = \frac{np1}{n1} = = 0.0228 \frac{49}{2140}$

$p2 = \frac{np2}{n2} = = 0.0172 \frac{42}{2440}$

Information :

npi = number of defects, uneven cuts

ni = number of pickle oil hot rolled roll steel production

b. Calculate the center line which is the average product defect ($\bar{p}$) or Center Line (CL)

$\bar{P} = \frac{\sum np}{\sum n} = = 0.0165 \frac{275}{16621}$

Information :

npi = Number of defects from uneven cuts

ni = Number of hot rolled pickle oil rolled steel production

c. Calculating the Upper Control Limit (UCL)

$UCL1 = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0165 + 3\sqrt{\frac{0{,}0165(1-\,0{,}0165)}{2140}} = 0.0248$

$UCL2 = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0165 + 3\sqrt{\frac{0{,}0165(1-\,0{,}0165)}{2440}} = 0.0242$

d. Calculating the lower control limit (LCL)

$$LCL1 = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.0165 - 3\sqrt{\frac{0{,}0165(1-0{,}0165)}{2140}} = 0.0082$$

$$LCL2 = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} = 0.0165 - 3\sqrt{\frac{0{,}0165(1-0{,}0165)}{2440}} = 0.0087$$

If the disability proportion value of a subgroup is above the UCL or below the LCL, it will be counted as out of control data. The results of the calculation of the proportion of disability, CL or $\bar{p}$, LCL, and other UCL can be seen in table 4 below.

Table 5.Control Chart Calculation Results on Bad Trim

Month	***Bad Trim***	**Total Production**	**P**	**$\bar{p}$**	**UCL**	**L**
1	49	2140	0.0229	0.0165	0.0248	0.0083
2	42	2440	0.0172	0.0165	0.0243	0.0088
3	38	2520	0.0151	0.0165	0.0242	0.0089
4	53	3285	0.0161	0.0165	0.0232	0.0099
5	54	3520	0.0153	0.0165	0.0230	0.0101
6	39	2716	0.0144	0.0165	0.0239	0.0092
Total	275	16621				

Based on the results of the calculations in Table 5, the control chart p on the Bad Trim uneven cuts can be seen as shown in Figure 9

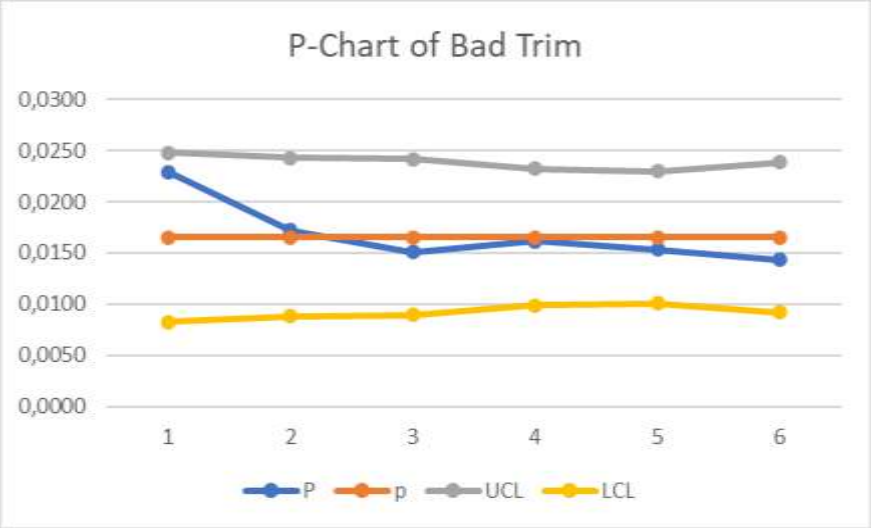

Figure 9. *P Control Map on Bad Trim*

Based on the visual image of the control map p for the Bad Trim defect above, it is found that all defects that occur are still within the control limits (nothing is out of control).

3. P-Chart on There is a Wave *Wavy Edge*

The steps to create a p control chart are as follows:

a. Calculating the proportion of disability

An example of calculating the proportion of disability using the following formula:

p1 = $\frac{np1}{n1}$ = = 0.0168$\frac{36}{2140}$

p2 = $\frac{np2}{n2}$ = = 0.0168$\frac{41}{2440}$

Information :

npi = number of defects there are waves

ni = number of pickle oil hot rolled roll steel production

b. Calculate the center line which is the average product defect ($\bar{p}$) or Center Line (CL)

$\bar{P} = \frac{\sum np}{\sum n}$ = = 0.0137$\frac{228}{16621}$

Information :

npi = Number of defects there are waves

ni = Number of hot rolled pickle oil rolled steel production

c. Calculating the Upper Control Limit (UCL)

$UCL1 = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0137 + 3\sqrt{\frac{0{,}0137(1-\,0{,}0137)}{2140}} = 0.0212$

$UCL2 = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0137 + 3\sqrt{\frac{0{,}0137(1-\,0{,}0137)}{2440}} = 0.0207$

d. Calculating the lower control limit (LCL)

$LCL1 = \bar{p} - 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0137 - 3\sqrt{\frac{0{,}0137(1-\,0{,}0137)}{2140}} = 0.0061$

$LCL2 = \bar{p} - 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0137 - 3\sqrt{\frac{0{,}0137(1-\,0{,}0137)}{2440}} = 0.0066$

If the disability proportion value of a subgroup is above the UCL or below the LCL, it will be counted as out of control data. The results of the calculation of the proportion of disability, CL or $\bar{p}$, LCL, and other UCL can be seen in table 5 below.

Table 6. Control Chart Calculation Results on Wavy Edge

Month	***Wavy Edge***	**Total Production**	**P**	**$\bar{p}$**	**UCL**	**L**
1	36	2140	0.01682	0.01372	0.02126	0.00617
2	41	2440	0.01680	0.01372	0.02078	0.00665
3	36	2520	0.01429	0.01372	0.02067	0.00677
4	38	3285	0.01157	0.01372	0.01981	0.00763
5	47	3520	0.01335	0.01372	0.01960	0.00784
6	30	2716	0.01105	0.01372	0.02041	0.00702
Total	228	16621				

Based on the calculation results in Table 5, the control chart p on Wavy Edge can be seen as shown in Figure 10

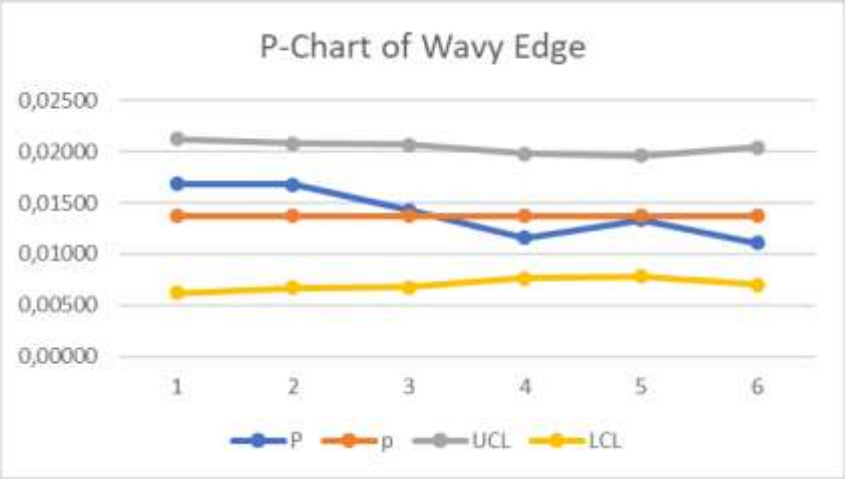

Figure 10. *P Control Map on Wavy Edge*

Based on the visual image of the control map p for the Wavy Edge defect above, it is found that all defects that occur are still within the control limits (nothing is out of control).

4. P-Chart on Untidy Scrolls (Ptotuding)

The steps to create a p control chart are as follows:

a. Calculating the proportion of disability

An example of calculating the proportion of disability using the following formula:

$p1 = \frac{np1}{n1} = = 0.0079 \frac{17}{2140}$

$p2 = \frac{np2}{n2} = = 0.0061 \frac{15}{2440}$

Information :

npi = number of roll defects not neat

ni = number of pickle oil hot rolled roll steel production

b. Calculate the center line which is the average product defect ($\bar{p}$) or Center Line (CL)

$\bar{P} = \frac{\sum np}{\sum n} = = 0.0056 \frac{94}{16621}$

Information :

npi = Number of roll defects not neat

ni = Number of hot rolled pickle oil rolled steel production

c. Calculating the Upper Control Limit (UCL)

$UCL1 = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0056 + 3\sqrt{\frac{0{,}0056(1-0{,}0056)}{2140}} = 0.0106$

$UCL2 = \bar{p} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0056 + 3\sqrt{\frac{0{,}0056(1-0{,}0056)}{2440}} = 0.0102$

d. Calculating the lower control limit (LCL)

$LCL1 = \bar{p} - 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0056 - 3\sqrt{\frac{0{,}0056(1-0{,}0056)}{2140}} = 0.0006$

$LCL2 = \bar{p} - 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}} = 0.0056 - 3\sqrt{\frac{0{,}0056(1-0{,}0056)}{2440}} = 0.0011$

If the disability proportion value of a subgroup is above the UCL or below the LCL, it will be counted as out of control data. The results of the calculation of the proportion of disability, CL or $\bar{p}$, LCL, and other UCL can be seen in table 6 below.

Table 7. Control Chart Calculation Results on Ptotuding

Month	***Protuding***	**Total Production**	**P**	**p̄**	**UCL**	**L**
1	17	2140	0.00794	0.00566	0.01064	0.00067
2	15	2440	0.00615	0.00566	0.01021	0.00110
3	13	2520	0.00516	0.00566	0.01014	0.00117
4	17	3285	0.00518	0.00566	0.01064	0.00067
5	20	3520	0.00568	0.00566	0.01021	0.00110
6	12	2716	0.00442	0.00566	0.01014	0.00117
Total	618	16621				

Based on the calculation results in Table 7, the control chart p on Protuding can be seen as shown in Figure 11

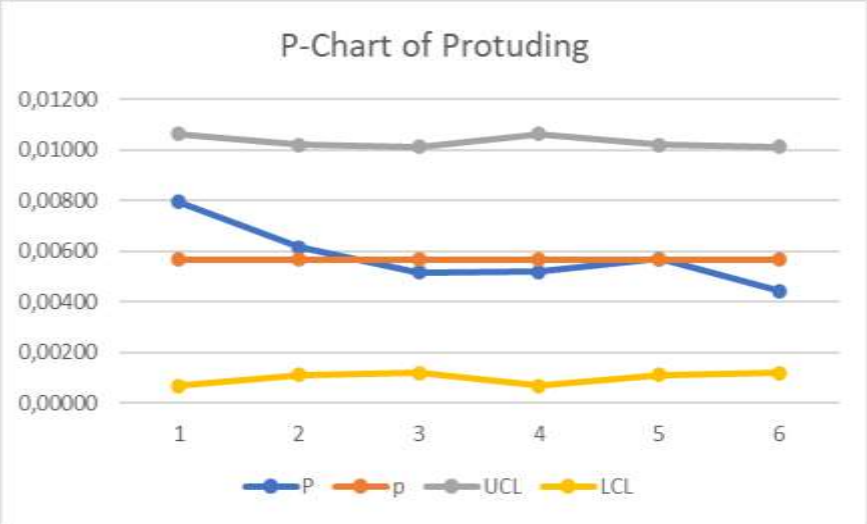

Figure 11. *P Control Map on Protuding*

Based on the visual image of the control chart p for the Protuding defect above, it is found that all defects that occur are still within the control limits (nothing is out of control).

g. Cause and Effect Diagram

Analyzing and knowing the most dominant factors occur is the use of cause and effect diagrams. In this stage, an analysis of the causes of Under Pickle, Bad Trim, Wavy Edge and Protuding defects is carried out using fishbone.

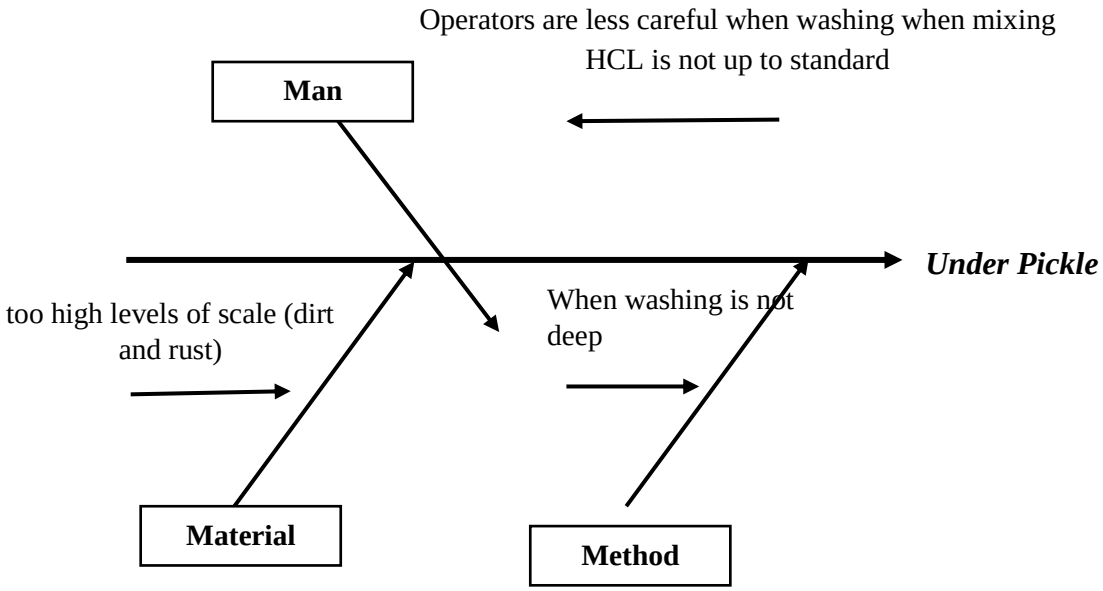

Figure 12. *Cause and Effect Diagram Defect Under Pickle*

Based on the results of the analysis of the cause and effect diagram for There is a Blackish Color / Under Pickle which causes the problem in terms of humans, materials, and methods. The following is a description of each cause of the problem:

1. Man
   In this case, what is meant by humans are workers, where workers are less careful at the washing stage. Workers mix HCL that is not in accordance with the standard so that there are still spots or blackish color on the steel coils.
2. Material
   In this case, what is meant by material is material with very high levels of scale (dirt and rust) so that it can affect the quality of production. Where levels of scale (dirt and rust) are very high, it is difficult to wash.
3. Method
   In this case, what is meant by the method is that at the washing stage using 4 tanks, it is not deep enough when the steel is immersed into the tank, causing the dyeing process to be less than perfect.

V. Conclusion

Based on research that has been done at PT. Sun Rise Mill, it can be concluded as follows:

1. Based on the results of data processing from October 2021 to March 2022, it was found that the most dominant defect in hot rolled pickle oil rolled steel products was Blackish/Under Pickle (50.86%), followed by Uneven Cuts/Bad Trim (22.63%), There were waves (18.76%)/Wavy Edge, and Untidy Rolls/Protuding (7.73%) of the total number of defects that occurred 1214 tons.
2. Based on the results of the analysis, there are several factors that can cause UnderPickle / There is a blackish color, including the operator being less careful at the washing stage when mixing HCL is not up to standard, the scale content (dirt and rust) is too high, and the washing is not deep enough. Furthermore, Bad Trim / Uneven cuts, for factors that can cause, among others, the operator is not careful when setting the blade distance, the operator does not monitor the sharpness of the blade during the side trimming process,

and the cutting machine often has errors. Furthermore, Wavy Edge / There is a wave, for the causative factors that can cause, among others, the operator is not careful when setting the Flatner machine, and the quality of the raw materials is not up to standard. Furthermore Protuding / Rolls are not neat,

3. Based on the results of the FMEA, the highest RPN value is 294, for the type of defect there is a black color with the cause of failure because the operator is not careful at the washing stage when mixing HCL is not up to standard. This value is a high failure and must be prioritized so that repairs can be made as soon as possible. Recommendations for improvement that can be done are by conducting periodic monitoring when mixing HCL.

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