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Implementation of Statistical Process Control and Failure Mode and Effect Analysis for Quality Control of Steel Plate Products

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Abstract. *The rapid growth of the manufacturing industry has heightened the demand for high-quality products, particularly steel plates, which are extensively utilized across various construction and engineering sectors. To ensure consistent product quality, a systematic quality control approach is essential. This study was conducted at PT XYZ with the objective of implementing Statistical Process Control (SPC) and Failure Mode and Effect Analysis (FMEA) to monitor and analyze potential failures throughout the production process. The research focused on evaluating production data and the number of defective products over a one-year period. SPC was employed to assess the stability of the production process, while FMEA was utilized to identify the most critical failure modes based on their Risk Priority Number (RPN). The analysis revealed that the total percentage of defective products reached 9.1%, significantly exceeding the company's tolerance threshold. Among the identified defect types, Under Length and Wavy Edge were the most dominant, each contributing 4.5% to the total defects. These findings highlight the urgent need for corrective actions to reduce the defect rate and improve overall product quality.*

Keywords: *Statistical Process Control; Failure Mode and Effect Analysis; Risk Priority Number; Steel Plate; Quality Control.*

I. INTRODUCTION

Quality is a fundamental aspect in the industrial and business sectors, referring to the extent to which a product or service meets or exceeds customer expectations and requirements. It encompasses various elements such as dimensional accuracy, durability, strength, and aesthetic appearance (Waluyo et al., 2020). Quality is not limited to compliance with technical specifications, but also includes the product's or service's ability to satisfy customers and meet expected standards. High-quality products enhance customer satisfaction, trust, and loyalty, while also strengthening a company's reputation and competitiveness in the market (Setiawan & Safitri, 2019). The primary objective of quality control is to minimize variability in production and ensure that each product meets the desired criteria (Lestari & Purwatmini, 2021). The steel manufacturing industry faces significant challenges in quality control due to the complexity of its production processes, which involve multiple stages that must be carefully monitored (Saputra, 2022).

PT XYZ is a manufacturing company based in Indonesia that focuses on steel production (Andre & Sudaryanto, 2022). The steel products produced by PT XYZ are widely utilized in various industrial applications, including shipbuilding, bridge construction, stadium development, and offshore oil refinery projects. Product quality control is closely linked to the production process, which involves a sequence of stages to transform raw materials into finished goods ready for delivery to customers (Djunaidi et al., 2024). At PT XYZ, the steel production process follows a make-to-order (MTO) concept, where products are manufactured specifically based on customer requirements (Heitasari et al., 2019). The following is the production workflow implemented at PT XYZ.

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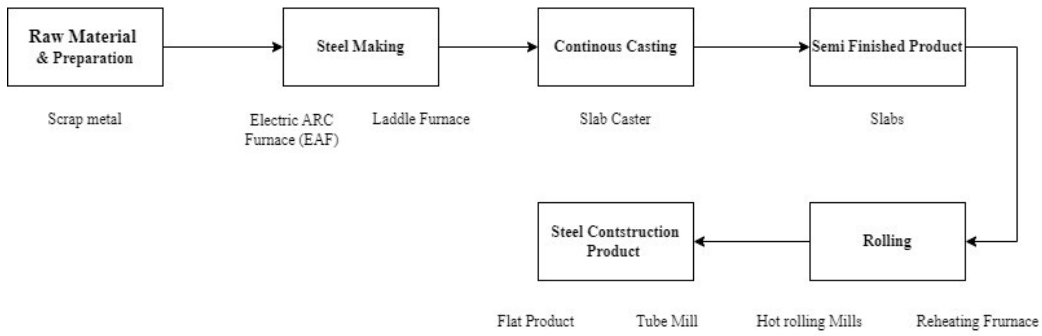

Figure 1. Production Workflow

The steel manufacturing process begins with the raw material and preparation stage, where the primary input—scrap metal—is collected and recycled into new steel. In the steel making stage, the scrap is melted using an electric arc furnace (EAF), which generates heat through electric current. The resulting molten steel is then refined in a ladle furnace to adjust its chemical composition in accordance with required standards (Irwanto, 2020). The process continues to the continuous casting phase, where the molten steel is continuously solidified into semi-finished slabs through a slab caster machine. These slabs are subsequently processed in the rolling stage. Prior to rolling, the slabs are reheated in a reheating furnace to soften the material, allowing it to be formed more easily. They are then passed through hot rolling mills to obtain the desired dimensions and thickness. The resulting products include steel construction components such as flat products (e.g., steel plates) and tube mills (e.g., steel pipes) (Putri et al., 2023).

The long and complex nature of the production process makes it susceptible to various errors, such as improper melting temperature, casting inaccuracies, or disturbances during rolling operations (Setiawati et al., 2024). These issues may result in product defects, including inconsistent thickness, rough surfaces, or small surface cracks. In an effort to maintain product quality, the company has implemented an offline statistical process control (SPC) system as part of its quality control strategy. Offline SPC involves manual measurements of steel plate attributes such as thickness, dimensions, and surface defects, using tools like rulers, threads, gauges, and visual inspection by operators. However, the main limitation of offline SPC lies in its delay in defect detection, as quality control is typically carried out only after the entire production process is completed.

In 2024, the percentage of defective products exhibited notable inconsistency, as illustrated in Figure 2.

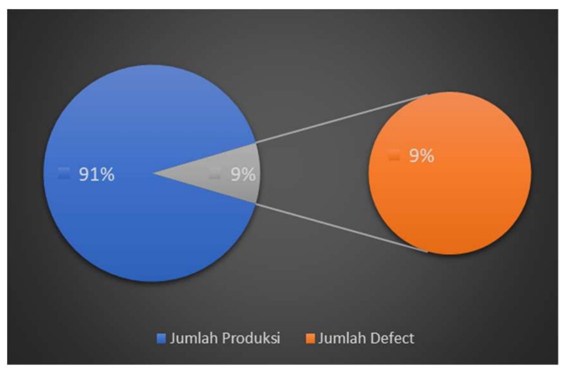

Figure 2. Percentage of Defective Products

PT XYZ is currently facing a significant increase in product complaints, reaching 9% of total production, which is far above the company's target of below 1%. This condition indicates the presence of underlying issues in the production process or quality control system that require immediate attention. If this trend is not addressed promptly, the company risks experiencing a decline in customer trust, reduced order volumes, and financial losses due to increased costs of product rework or replacement (Rofieq & Septiari, 2021).

The majority of PT XYZ's customers are golden customers, who place orders based on international quality standards such as JIS and ASTM. The company's primary product is the steel plate, which is considered a golden product due to its high production volume and strategic importance in meeting market demand. To achieve an optimal production process with minimal defect rates, it is essential for the company to strengthen its existing quality control system (Rofieq & Septiari, 2021). This is particularly important given the high market demand for consistent product quality, especially for flagship products like steel plates.

II. RESEARCH METHOD

This study necessitates the collection of various data to support analysis and derive conclusions. Two types of data were utilized: primary and secondary. Primary data were obtained through interviews with staff from the Quality Control division within the QHSE department. Secondary data comprised production records of steel plates from January to December 2024. Statistical tests and data visualizations were employed to effectively represent the processed results.

The methodologies applied in this research include Statistical Process Control (SPC) and Failure Mode and Effects Analysis (FMEA). The data processing stages are as follows:

A. Statistical Process Control (SPC) Stages

1. Creating a check sheet organized in a tabular format that includes information on production quantities and the number of defects occurring. This data serves as the basis for analyzing quality issues.
2. Constructing a histogram using defect data from production results. The purpose of this histogram is to depict the distribution of defect counts in steel plate production.
3. Calculating control charts to determine whether the obtained data are within control limits. If data points are detected outside the control limits, the next step is to analyze the causes of these deviations. The formulas used in the control chart are:

Upper Control Limit (UCL) = $\bar{P} + 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}}$ .... (1)

Center Line (CL) = $\bar{P} = \frac{\text{Total defective products}}{\text{Total inspected products}}$ .... (2)

Lower Control Limit (UCL) = $\bar{P} - 3\sqrt{\frac{\bar{p}\,(1-\bar{p})}{n}}$ .... (3)

4. Creating a Pareto diagram to identify the most frequently occurring types of failures and determine the most significant primary failures, focusing on improvement efforts to eliminate defects and enhance operations.
5. Developing a scatter diagram to ascertain the correlation between production quantities and the number of existing defects.
6. Defining the actual problem using a fishbone diagram.

B. Failure Mode and Effect Analysis Stages

1. Identifying the types of failures occurring in

Table 1. Rating in *Severity*

Rating	Criteria
1	No impact on the product.
2	The product can still be processed despite minor effects.
3	There is an impact on the product, but no repair is required.
4	There is a moderate impact, and the product requires repair.
5	Decreased product criteria, but it is still processable.
6	The product cannot be processed for its intended use but can still be utilized for other purposes.
7	The product requires repair before it can be processed.
8	The product cannot be processed for its intended use but may still be used for alternative purposes.
9	The product requires repair in order to proceed to the next process.
10	The product cannot be processed any further.

Source: (Kristanto, Rumita and Sriyanto, 2020)

Table 2. Rating in *Ocurrance*

Degree	Based on the Frequency of Occurrence/Month	Rating
Remote	0 - 50	1
Low	51 - 100	2
Low	101 - 150	3
Moderate	151 - 200	4
Moderate	201 - 250	5
Moderate	251 - 300	6
High	301 - 350	7
High	351 - 400	8
Very High	401 - 450	9
Very High	451 - 500	10

Source : (Syarifudin, and Wati, 2023)

Tabel 3. Rating in *Detection*

Detection	Description	Rating
Almost Certain	Control tools are almost certain to detect the form and cause of failure.	1
Very High	Control tools have a very high ability to detect the form and cause of failure.	2
High	Control tools have a high ability to detect the form and cause of failure.	3
Moderately High	Control tools have a moderate to high ability to detect the form and cause of failure.	4
Moderate	Control tools have a moderate ability to detect the form and cause of failure.	5
Low	Control tools have a low ability to detect the form and cause of failure.	6
Very Low	Control tools have a very low ability to detect the form and cause of failure.	7
Rare	Current control tools are rarely able to detect the form or cause of failure.	8
Very Rare	Current control tools are very rarely able to detect the form or cause of failure.	9
Almost Impossible	There are no control tools capable of detecting the failure.	10

Source : (Alifka & Apriliani, 2024)

the production process.

2. Determining the potential impacts of failures in production.
3. Identifying the factors causing failures in the production process.
4. Identifying detection systems for each type of failure in the production process.
5. Assigning ratings to the criteria of severity, occurrence, and detection according to the criteria in the Table 2.

Severity assessment in Failure Mode and Effects Analysis (FMEA) refers to the degree of impact a failure has on the product, rated on a scale from 1 to 10. A score of 1–3 indicates very low impact, requiring no corrective action. Scores of 4–5 suggest the need for improvement before proceeding, even though the product remains usable. Scores of 6–8 imply that the product cannot function as intended but may still be repurposed. Scores of 7 and 9 highlight the necessity for rework to make the product processable again. The highest score, 10, denotes total product failure, rendering it unprocessable. This assessment serves as a basis for prioritizing failure handling in the production process.

The occurrence rating in Failure Mode and Effects Analysis (FMEA) measures the frequency of failure on a scale from 1 to 10. A low frequency (0–150 occurrences per month) is assigned a rating of 1–3, moderate frequency (151–300) a rating of 4–6, high frequency (301–400) a rating of 7–8, and very high frequency (401–500) a rating of 9–10. This assessment aids in determining the priority of addressing failures based on their occurrence rate.The detection assessment in Failure Mode and Effects Analysis (FMEA) evaluates the system's ability to identify failures before they affect the product, using a scale ranging from 1 to 10. A low score (1–3) indicates that the detection system is highly effective in identifying failures. A moderate score (4–5) suggests that the detection capability is reasonably effective, while a high score (6–9)

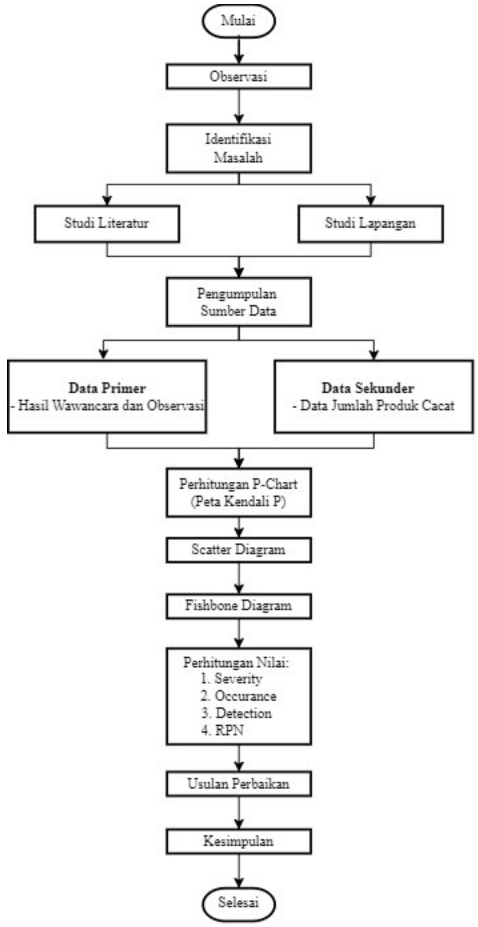

Figure 3. Research Framework

reflects a low level of detection, meaning failures are less likely to be identified before impacting the product. If no control system is in place to detect the failure, a maximum rating of 10 is assigned. This assessment is crucial for prioritizing corrective actions for failures that are difficult to detect.

6. Providing Improvement Recommendations Based on RPN Values

Based on the obtained Risk Priority Number (RPN) values, the next step is to provide improvement recommendations for the production process. Processes with the highest RPN values indicate the most significant risks and require greater attention.

The research frameworkis illustrated in Figure 3.

III. RESULT AND DISCUSSION

The steel plate production data were obtained from the total monthly production data from January to December 2024. In this study, two types of defects were identified as having relatively high percentages, namely under length (UNL) and wavy edge (WVE) defects, which can be seen in the Figur 4 and Figure 5.

The following is a recap of the production volume and defect quantities of steel plate products at PT. XYZ from January to December 2024. Based on the production and defect data of steel plate products at PT. XYZ from January to December 2024, monthly production volumes fluctuated throughout the year. The total annual production reached 39,689 units, with 1,281 units categorized as under length (UNL) defects, 496 units as wavy edge (WVE) defects, and a total of 1,777 defective units, accounting for 4.5% of total production. The highest defect percentage occurred in May, with 270 defective units (8.0% of monthly production), indicating potential production issues such as machine malfunction, poor raw material quality, or human error. In contrast, March recorded the lowest number of WVE defects—only 1 unit (0.03% of total production)—suggesting better quality control during that period. However, UNL defects remained high in the same month, reaching 92 units (3.1% of total production), implying the need for further improvement in specific areas. The annual trend shows fluctuations in the number of defective products, with notable increases in November and December at 5.6% and 6.9%, respectively. These increases may be attributed to worker fatigue or reduced machine maintenance effectiveness toward the end of the year. October recorded the highest production volume at 4,151 units, while April had the lowest at 2,188 units. However, the defect rate in April remained relatively high (3.9%), indicating that production volume alone is not the sole factor influencing defect levels—quality control and operational efficiency also play critical roles.

The scatterplot above illustrates the relationship between production volume and the number of defects over a one-year period. Each point on the graph represents monthly data. A positive trend is observed—higher production volumes tend to correlate with an increased

Figure 4. Under Length Defect

Figure 5. Wavy Edge Defect

Table 4. Production and Defect Data from January to December 2024

Month	Total Production	Defect Type				Number of Defective Products	Defect Percentage
		UNL	% defect	WVE	% defect		
January	3337	70	2.1%	43	1.3%	113	3.4%
February	2735	85	3.1%	31	1.1%	116	4.2%
March	2992	92	3.1%	1	0.03%	93	3.1%
April	2188	77	3.5%	8	0.4%	85	3.9%
May	3392	211	6.2%	59	1.7%	270	8.0%
June	3062	73	2.4%	28	0.9%	101	3.3%
July	3256	100	3.1%	16	0.5%	116	3.6%
August	4060	105	2.6%	45	1.1%	150	3.7%
September	4044	120	3.0%	70	1.7%	190	4.7%
October	4151	98	2.4%	50	1.2%	148	3.6%
November	4023	140	3.5%	85	2.1%	225	5.6%
December	2449	110	4.5%	60	2.4%	170	6.9%
TOTAL	**39689**	**1281**	**3.3%**	**496**	**1.2%**	**1777**	**4.5%**

number of defects. This tendency is reinforced by the upward-sloping trend line. However, the relationship is not particularly strong, as indicated by the wide dispersion of data points from the trend line, reflecting high variability. Several points appear as significant outliers, suggesting that certain months experienced unusually high defect levels compared to the general pattern.

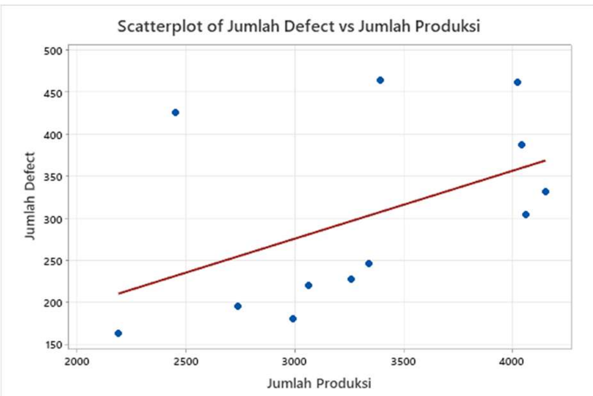

Figure 6. Scatterplot of Defect Quantity vs. Production Volume

This condition implies that, in addition to production volume, other process-related factors also contribute to the occurrence of defects. The scatterplot is not intended for statistical process control but serves as an initial visual indicator of the upward trend in defects. Based on these findings, further analysis is conducted using a more appropriate method for process control—namely, the application of a control chart.

To monitor process stability and control production quality, a type of attribute control chart, specifically the P-chart, is constructed. This chart is used to illustrate the proportion of defective products relative to total monthly production. Through the P-chart, it can be determined whether the variation in defects remains within statistical control limits or indicates significant deviations.

It is important to emphasize that within the context of this research, the control chart serves as a visualization tool for defect trends, rather than as definitive evidence that the process is under control. This is because the monthly defect percentages exceed the company's tolerance threshold of 1%. Therefore, although the data points may fall within statistical control limits, the production process cannot be considered statistically or qualitatively controlled.

The P-Chart for the analysis of under length defects is presented in Figure 7. In the analysis of the UNL defect proportion using the P-control chart, fluctuations in the defect proportion are observed throughout the period. The proportion of defects ranges from 2.10% to 6.22%, with a significant spike in May reaching 6.22%, which

Table 5. P-Chart Calculation Results

No	UNL	Proportion of UNL Defects	CL	UCL	LCL
1	70	0.0210	0.0323	0.0429	0.0216
2	85	0.0311	0.0323	0.0429	0.0216
3	92	0.0307	0.0323	0.0429	0.0216
4	77	0.0352	0.0323	0.0429	0.0216
5	211	0.0622	0.0323	0.0429	0.0216
6	73	0.0238	0.0323	0.0429	0.0216
7	100	0.0307	0.0323	0.0429	0.0216
8	105	0.0259	0.0323	0.0429	0.0216
9	120	0.0297	0.0323	0.0429	0.0216
10	98	0.0236	0.0323	0.0429	0.0216
11	140	0.0348	0.0323	0.0429	0.0216
12	110	0.0449	0.0323	0.0429	0.0216

exceeds the upper control limit (UCL = 4.29%). This indicates an anomaly in the production process that requires further investigation, such as possible machine malfunctions, operator errors, or declining raw material quality. Conversely, some months such as June (2.38%), October (2.36%), and August (2.59%) show lower and more stable defect levels, indicating more effective quality control during those periods. However, in December, the defect proportion rises to 4.49%, again exceeding the control limit and suggesting irregularities in the production process.

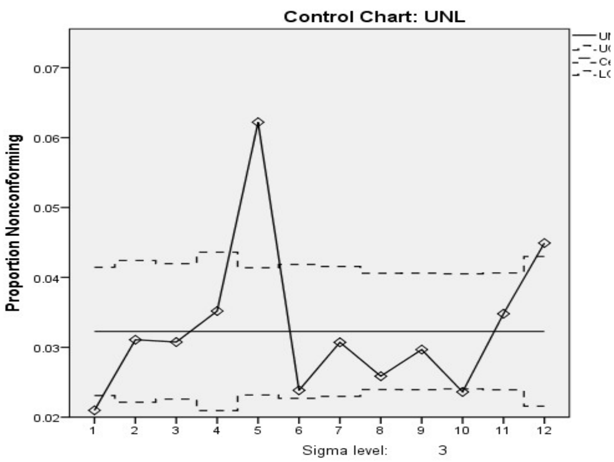

Figure 7. P-Control Chart for UNL Defect Analysis

Overall, although most of the data points fall within the control limits, the presence of months with defect spikes warrants special attention. This inconsistency indicates the need for periodic evaluations, especially during months with high defect proportions. Recommended actions include enhancing machine maintenance and closely monitoring production process parameters to prevent defect proportions from exceeding control limits.

The P-Chart for the analysis of wavy edge defects is presented in Figure 4.4 below.

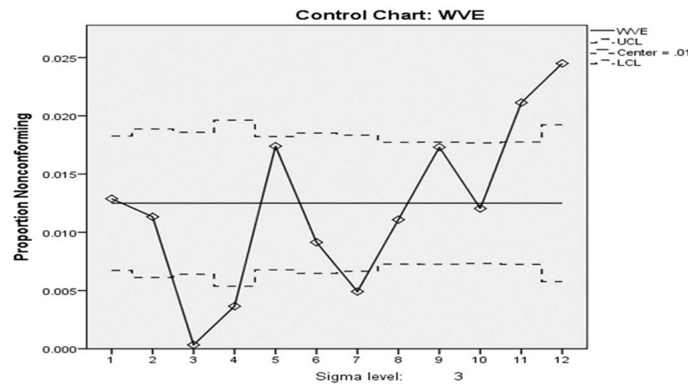

Figure 8. P-Control Chart for Wavy Edge (WVE) Defect Analysis

Based on Figure 8, it can be observed that several data points lie outside the upper and lower control limits (UCL and LCL), specifically in the months of March, November, and December. The defect proportion ranges from 0.03% to 2.45%, with significant anomalies in November (2.11%) and December (2.45%), both exceeding

Table 6. Calculation of P-Control Chart for WVE Defect

No	WVE	Proportion of WVE Defects	CL	UCL	LCL
1	43	0.0129	0.0125	0.0192	0.0058
2	31	0.0113	0.0125	0.0192	0.0058
3	1	0.0003	0.0125	0.0192	0.0058
4	8	0.0037	0.0125	0.0192	0.0058
5	59	0.0174	0.0125	0.0192	0.0058
6	28	0.0091	0.0125	0.0192	0.0058
7	16	0.0049	0.0125	0.0192	0.0058
8	45	0.0111	0.0125	0.0192	0.0058
9	70	0.0173	0.0125	0.0192	0.0058
10	50	0.0120	0.0125	0.0192	0.0058
11	85	0.0211	0.0125	0.0192	0.0058
12	60	0.0245	0.0125	0.0192	0.0058

the upper control limit (UCL = 1.92%). This indicates disturbances in the production process that require further investigation, such as potential operator errors, suboptimal machine conditions, or inconsistencies in raw materials.

Conversely, certain months such as March (0.03%), April (0.37%), and July (0.49%) show very low defect levels, indicating more effective quality control during these periods. However, the spikes observed in other months, particularly in May (1.74%) and September (1.73%), suggest an upward trend that warrants further attention. Therefore, the P-control chart for WVE defects indicates an out-of-control condition, and corrective recommendations are necessary.

Based on the analysis results of the P-control charts, it is evident that defects in steel plate products of types UNL and WVE exhibit data points that fall outside both the upper and lower control limits (UCL and LCL). This condition indicates that the production process still contains variations that are statistically out of control. As a result, follow-up actions are required to identify the root causes of this instability. To address this, a fishbone diagram analysis is conducted to identify and categorize the potential factors that may affect product quality and lead to defects.

The fishbone diagram, or cause-and-effect diagram, is a schematic that lists the causes and sub-causes associated with the problem at hand. Once the dominant issue contributing to product defects has been identified using a histogram, the root cause analysis is carried out using the fishbone diagram. Furthermore, the fishbone diagram is used to illustrate the systematic relationship between an effect or symptom and its possible causes (Milah, 2022). This diagram is developed based on interviews with quality control staff working in the field. Figure 7 presents the fishbone diagram for UNL steel plate defects, while Figure 9 shows the fishbone diagram for WVE steel plate defects.

Based on the fishbone diagram shown in Figure 9, it can be identified that there are four (4) categories that can be analyzed as causes of UNL defects. These categories include factors related to human, machine, method, and material.

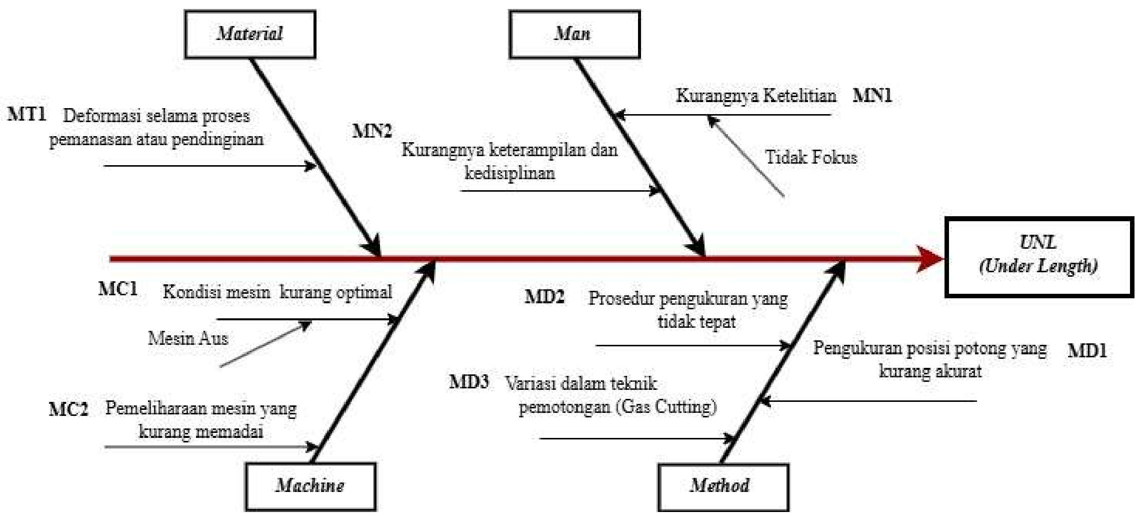

Figure 9. Fishbone Diagram of UNL Steel Plate Defects

Based on the fishbone diagram in Figure 10, it can be observed that there are five (5) categories that can be analyzed as causes of WVE defects. These categories include factors related to human, machine, method, and material. Below is the cause-and-effect table for UNL and WVE steel plate defects, which can be seen in Table 7. Cause-and-Effect Factors.

After identifying the causes of defects using the fishbone diagram, the next step is to conduct a risk analysis using the Failure Mode and Effects Analysis (FMEA) method. This step is crucial given that the previous Statistical Process Control (SPC) analysis indicated that the production process

Table 7. Cause-and-Effect Factors

No	Factor	Cause	Effect
1	Man	1. Lack of precision and loss of focus during cutting 2. Insufficient skills in using the tools and lack of worker discipline 3. Inadequate supervision during the cutting process	1. Causes measurement errors due to lack of focus. 2. Some operators lack the necessary qualifications to operate or supervise the machines optimally, resulting in improper settings and thickness deviations that do not meet specifications. 3. Imprecise cutting, producing dimensions that do not conform to standards.
2	Material	1. Deformation during the cooling process. 2. The slab has initial dimensions that are not in accordance with specifications.	1. Inconsistent room temperature differences cause variations in the cooling process, resulting in deformation beyond the specified limits. 2. The rolling process becomes inconsistent, affecting the surface quality or internal structure of the plate.
3	Machine	1. Machine condition is less than optimal or worn out 2. Inadequate machine maintenance 3. Uneven pressure on the rolling machine	1. Worn or damaged crosscut machine blades can cause inconsistent cutting results. 2. Lack of routine maintenance can lead to decreased machine performance, such as uneven rollers and dull blades. 3. Plate thickness becomes uneven (wavy).
4	Method	1. Inaccurate measurement procedures 2. Variations in cutting techniques (gas cutting) 3. Inaccurate measurement of cutting position 4. Rolling technique not according to standards 5. Inspection without using accurate measuring tools (caliper)	1. Errors in measurement procedures or unreliable instruments can cause inaccurate measurement results. 2. Differences in operator skills cause variations in cutting techniques (gas cutting), resulting in products not meeting specifications. 3. Differences in cutting position references for each product can cause inaccurate cuts. 4. Results in plate surfaces that are not flat. 5. Product results are not precise (under gauge).

was out of control. Ideally, SPC is performed using sampled data from each production batch to observe process tendencies against standard specifications. However, in this study, the available data consists of the total number of defects per month without detailed quantitative measurements of defect dimensions or characteristics. Therefore, the use of SPC in this research is indicative, serving as an initial tool to identify that the process exhibits statistically unstable tendencies. The SPC results suggest that potential failures in the production process may persist and even worsen if corrective actions are not promptly implemented.

Based on these conditions, the FMEA method is employed as a more in-depth subsequent analysis to identify the root causes of failure, assess the risk levels, and develop appropriate corrective action recommendations. The FMEA procedure begins with determining the Severity rating, which reflects the seriousness of the effect caused by the failure mode on the overall system. The second step involves assigning the Occurrence rating, representing the probability or likelihood of the failure occurring. The third step is to determine the Detection rating, which evaluates the likelihood that the current controls will detect the potential cause of the failure mode. Subsequently, the Risk Priority Number (RPN) is calculated by multiplying the Severity, Occurrence, and Detection ratings. The final step is to prioritize the failure modes based on the calculated RPN values. The results of the FMEA calculations are presented in Table 8.

Table 8. Results of the FMEA Calculation

Defect Type	Effect of Defect	S	Cause of Defect	O	Detection Mode	D	RPN
Under Length	The length of the steel plate is inconsistent, making the product unusable for the current order but can be stored for future orders.	9	Lack of precision during manual measurement	6	Re-inspection of results visually	7	378
			Inappropriate measurement procedure	6	SOP Review	7	378
			Inaccurate or misaligned cutting position setting	6	Visual inspection of cutting position	6	324
			Variation in cutting techniques (gas cutting)	5	Implementing rules to apply one or two cutting techniques	7	315
			Deformation during heating and cooling processes	4	Dimensional testing after cooling	5	180
			Dull or worn crosscut machine blade	5	Cutting performance test	6	270
			Inadequate machine maintenance	5	Maintenance history review	5	225
Wavy Edge	Uneven or wavy surface at the edge of the product, which cannot be repaired (re-melted).	10	Incorrect rolling machine settings	6	Inspection of machine parameters (pressure, temperature, speed)	6	360
			Inconsistent quality control	6	Analysis of inspection data over time	6	360
			Improper milling procedures	5	Review of milling SOP	6	300
			Material contamination during rolling process	4	Visual inspection	7	280
			Uneven material thickness	5	Thickness measurement with accurate instruments	6	300
			Improper roll adjustment	6	Regular inspection of roll position	6	360
			Worn or uneven roll condition (machine maintenance)	7	Visual inspection and surface flatness testing of rolls	7	490

Based on the Failure Mode and Effect Analysis (FMEA) conducted on two types of product defects, namely under length and wavy edge, it was identified that several dominant causes possess high Risk Priority Number (RPN) values and require special attention in quality control. For the under-length defect, the highest RPN value of 378 was attributed to insufficient accuracy during manual measurement and improper measurement procedures. This indicates that measurement activities play a crucial role in ensuring the product length conforms to specifications. Errors at this stage have a high severity level (Severity = 9) and a relatively frequent occurrence (Occurrence = 6), with a moderate detection capability (Detection = 7). Additionally, other significant contributing factors include errors in cutting position settings (RPN = 324), variations in cutting techniques (RPN = 315), and dull machine blades (RPN = 270). These factors highlight the importance of consistency in the cutting process as well as the necessity for regular equipment maintenance.

Meanwhile, for the wavy edge defect, the most critical cause was identified as worn or uneven rolls, with the highest RPN value of 490. Although the severity level is not as high as that of the under-length defect, the combination of frequent occurrence and low detection ability results in a very high-risk value. Furthermore, improper roll adjustment, incorrect rolling machine settings, and inconsistent quality control also have high RPN values (each at 360), indicating the need for special attention to rolling process control. Other factors, such as inadequate milling procedures, uneven material thickness, and material contamination, also contribute to the wavy edge defect, albeit with relatively lower RPN values.

IV. PROPOSED IMPROVEMENTS

Based on the production analysis of steel plates at PT XYZ in 2024, it was found that the defects UNL (Under Length) and WVE (Wavy Edge) contributed significantly, accounting for 4.5% of the total defects of 9%, which requires immediate corrective actions. Through the application of control charts, fishbone diagrams, and FMEA, several root causes of the Under Length and Wavy Edge defects have been identified. The following presents the recommended improvement proposals aimed at minimizing the defect rate and enhancing overall production quality.

As a follow-up, improvement proposals have been formulated with the aim of minimizing defect rates and enhancing overall production quality. If these improvement measures are implemented—such as optimizing the pressure settings during the rolling process—the severity rating, which was previously at 9, can be reduced to 8 or even lower. This reduction will directly impact the Risk Priority Number (RPN), potentially decreasing it significantly from 490 to 336 or below. It is expected that with a lower severity rating, as well as reductions in occurrence or detection ratings, the risk of defects can be effectively mitigated, resulting in a more stable and controlled production process.

V. CONCLUSION

Based on the results of the research and

Table 9. Proposed Improvements

Factor	Issue	Proposed Improvement
Man	1. Lack of accuracy and focus during cutting 2. Insufficient skills in operating equipment and lack of worker discipline 3. Inadequate supervision during cutting	1. Conduct stretching exercises before each cutting session to help workers relax and regain focus 2. Provide regular training to operators to improve their machine operation skills and understanding of order specifications 3. Organize periodic training sessions to enhance operators' supervision skills
Material	1. Deformation during the cooling process 2. Material contamination during milling and rolling 3. Uneven material thickness	1. Ensure stable ambient temperature conditions to prevent extreme deformation 2. Perform thorough material inspections before further processing 3. Implement thickness inspections during the production process, not only at the end, to quickly detect and correct defects
Machine	1. Suboptimal or worn-out machine condition 2. Inadequate machine maintenance 3. Uneven pressure on rolling machines	1. Conduct regular machine inspections and promptly replace damaged or worn parts to maintain optimal machine condition 2. Perform routine maintenance and record every repair to ensure machine readiness 3. Check roll equipment before production begins
Method	1. Improper measurement procedures 2. Variation in cutting techniques (gas cutting) 3. Inappropriate cooling method settings	1. Review and revise Standard Operating Procedures (SOP) 2. Standardize cutting techniques to ensure consistency 3. Supervise cooling methods to ensure compliance with SOP

quality control analysis of steel plate production at PT XYZ during the period from January to December 2024, the following conclusions can be drawn:

1. The Statistical Process Control (SPC) method has proven effective in monitoring product quality; however, process instability is still evident due to the occurrence of UNL and WVE defects exceeding control limits. This indicates that offline quality control alone is insufficient. Therefore, an online quality control system is necessary to provide real-time monitoring and prompt response to deviations during the production process, enabling a more stable process and more consistent product outcomes.
2. Failure Mode and Effect Analysis (FMEA) successfully identified potential failure modes, with primary causes arising from human factors, machinery, methods, and materials, particularly concerning UNL and WVE defects. This identification is supported by the fishbone diagram analysis, which demonstrates that these factors significantly contribute to the occurrence of defects.
3. The application of SPC and FMEA methods offers a comprehensive approach that supports early detection and root cause analysis, facilitating precise and continuous quality improvement.

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