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Quality Control Analysis to Reduce the Number of Defects in DTY Yarn Products Using the Six Sigma (DMAIC) Method at PT. XYZ

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Abstract. This study aims to identify the dominant types of defects, analyze the root causes of product defects, and propose quality improvement recommendations to reduce the defect rate of DTY products. The research employed the Six Sigma method using the Define, Measure, Analyze, Improve, and Control (DMAIC) approach integrated with Failure Mode and Effect Analysis (FMEA). In the Define phase, the production process was identified through a SIPOC diagram and the determination of Critical to Quality (CTQ) characteristics. The Measure phase included the calculation of defect proportions, control charts, Defects per Million Opportunities (DPMO), sigma level, and process capability. The Analyze phase utilized Pareto diagrams, Fishbone diagrams, and FMEA to identify the root causes of defects and determine improvement priorities based on the Risk Priority Number (RPN). The Improve phase generated improvement recommendations using the 5W+1H approach, while the Control phase provided recommendations to sustain the implemented improvements. The results showed that during the January–December 2025 period, total production reached 3,793,630 kg, with 116,148 kg of defective products, resulting in a defect rate of 3.06%, which exceeded the company's maximum tolerance limit of 1%. Pareto analysis identified four dominant defect types: Dyeing Reject (31.73%), Damaged (23.76%), DP Handling (23.25%), and Cutting (20.39%). The FMEA results indicated that the highest-priority risks were Dyeing Reject caused by misthreading and Cutting caused by material property problems, both with an RPN value of 300. The proposed improvements focus on enhancing operator competence through training, ensuring consistent implementation of Standard Operating Procedures (SOPs), performing preventive machine maintenance, strengthening raw material quality control, improving workplace cleanliness, and enhancing production process supervision. The implementation of these recommendations is expected to reduce product defects, improve process capability, and support the achievement of product quality standards established by the company.

Keywords: *Six Sigma, DMAIC, Failure Mode and Effect Analysis (FMEA), Drawn Textured Yarn (DTY), Quality Control.*

A. INTRODUCTION

The textile industry is a manufacturing sector that plays a vital role in supporting Indonesia's economic growth. Increasingly fierce competition demands that textile companies produce high-quality products at efficient production costs while meeting customer needs (Sopheat, 2026). Product quality is a key factor in determining a company's competitiveness, as it directly impacts customer satisfaction, productivity, and business sustainability (Aziz, 2023a; Dharma et al., 2025; Kenny & Nugroho, 2026a). Therefore, companies need to implement an effective quality control system to minimize the occurrence of defective products during the production process (Aghsanu Fahri et al., 2025)

PT. XYZ is a company engaged in the production of Drawn Textured Yarn (DTY). In its production process, the company still faces the problem of high product defect rates, which leads to an increase in the number of rejects and reworked products (Setiawan & Pramudito, 2026; Vista Sukma Sonata et al., 2025; Wulandari et al., 2022). This situation not only increases production costs but also reduces process efficiency and potentially hinders the achievement of production targets. Based on production data for the January–December 2025 period, production reached 3,793,630 bobbins, with a total of 116,148 bobbins, or 3.06%, of defective products. This percentage still exceeds the company's maximum tolerance limit of 1%. Therefore, corrective measures are needed to reduce the product defect rate (Dewi et al., 2024; Fitria et al., 2023; Harianto et al., 2025)

Initial identification results indicate that there are four main types of defects that contribute the most to the total product defects: Dyeing Rejects, Damage, DP Handling, and Cutting. These four types of defects are Critical to Quality (CTQ) because they have a high frequency of occurrence and affect the quality of the final product. Therefore, a method is needed that can identify the main causes of defects and determine improvement priorities so that quality improvement efforts can be carried out effectively (Aktar Demirtas et al., 2023; Purbohastuti, 2021; Saragih & Fauziah, 2024)

One method widely used in quality control is Six Sigma, using the Define, Measure, Analyze, Improve, and Control (DMAIC) approach. This method aims to reduce process variation and reduce the number of defects through systematic steps, from problem identification to controlling the resulting improvements (Imam & Lestari, 2026; Kenny & Nugroho, 2026b; Montgomery & Wiley, n.d.). In the analysis phase, this research was combined with the Failure Mode and Effect Analysis (FMEA) method (Nugraha & Mulyani Sari, 2024)) to identify potential causes of failure and determine improvement priorities based on the Risk Priority Number (RPN) value. The combination of these two methods is expected to produce more targeted improvement recommendations that align with the company's production process conditions (Aziz, 2023b; Regan Fadhillah et al., 2026; Silaningsih et al., 2026; Suhardi & Kuraesin, 2021)

Based on these problems, this study aims to identify the dominant types of defects in the DTY yarn production process, analyze the factors causing defects using the Six Sigma method with the DMAIC and FMEA approaches, and compile recommendations for improvements that can be implemented by companies to reduce the level of product defects and improve the quality of the production process.

B. METHOD

This research uses a quantitative approach with the Six Sigma method, using the Define, Measure, Analyze, Improve, and Control (DMAIC) stages combined with Failure Mode and Effect Analysis (FMEA). The research was conducted at PT. XYZ, a company engaged in the production of Drawn Textured Yarn (DTY). The data used were secondary data, consisting of production data and product defect data for the period January–December 2025, as well as primary data obtained through direct observation and interviews with production and Quality Control personnel.

The Define stage was conducted to identify quality issues in the production process by compiling a flow process chart, creating a Supplier-Input-Process-Output-Customer (SIPOC) diagram, determining Critical to Quality (CTQ) based on the dominant defect type, identifying key issues, and identifying customer requirements for product quality(Sukrisna et al., 2026)

The Measure stage aims to measure the performance of the production process by calculating the proportion of defects, preparing a control chart (P-Chart), calculating Defects per Million Opportunities (DPMO), determining the sigma level, and analyzing process capabilities using the Cp and Cpk indices (Sukrisna et al., 2026)

The Analyze stage is carried out to identify the main causes of product defects. The analysis begins with the preparation of a Pareto Diagram to determine the most dominant types of defects(Gumilang Heliadi & Saefudin, n.d.; Ivan Arfelli & Alvina Prima Hapsari, 2025) Next, the root causes of defects are analyzed using a Fishbone Diagram based on human, machine, material, and method factors. The identified causes are then evaluated using Failure Mode and Effect Analysis (FMEA) through Severity (S), Occurrence (O), and Detection (D) assessments to obtain a Risk Priority Number (RPN) as the basis for determining repair priorities (Mohammad Faisal Nurfaizi & Widya Setiafindari, 2024)

The Improve stage is carried out by compiling improvement recommendations based on the results of the FMEA analysis using the 5W+1H approach (What, Why, Where, When, Who, and How). Improvement proposals are focused on the causes with the highest RPN values so that the actions taken are more effective in reducing the level of product defects(Maulana Isya Nursa et al., n.d.)

The Control phase involves providing control recommendations so that proposed improvements can be implemented sustainably. Control is achieved through regular defect level monitoring, consistent implementation of Standard Operating Procedures (SOPs), preventive maintenance on production machines, and periodic evaluation of quality indicators such as DPMO, sigma levels, and process capabilities to ensure quality improvements can be maintained (Al-Bar & Tjahyono, 2026; Fitria et al., 2023; Kusuma et al., 2024). Systematically, the research stages used can be described in Figure 1.

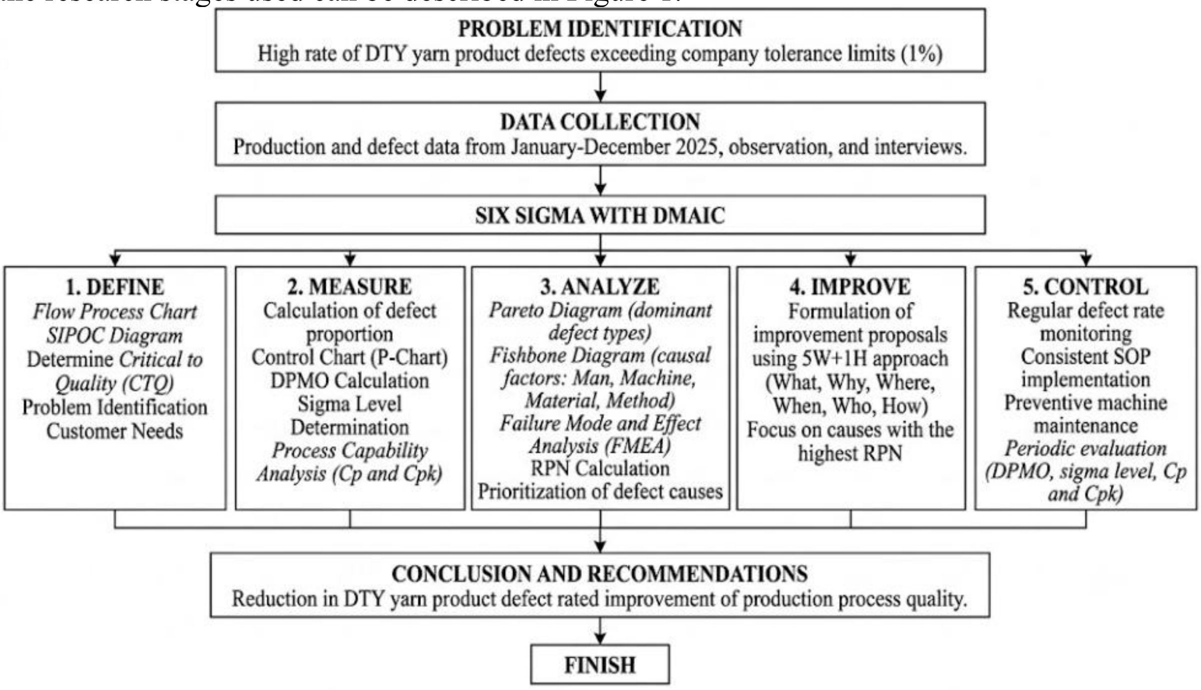

Figure 1. Research Flowchart

Based on Figure 1, the research phase begins with identifying problems that occur in the Drawn Textured Yarn (DTY) production process, followed by a literature review, collection of production data and product defect data, and data processing using the Six Sigma method through the DMAIC (Define, Measure, Analyze, Improve, and Control) stages. In the Analyze phase, root causes are identified using the Pareto Diagram, Fishbone Diagram, and Failure Mode and Effect Analysis (FMEA). Furthermore, improvement recommendations are formulated using the 5W+1H approach, and concluded with conclusions and suggestions.

C. RESULT AND DISCUSSION

1. Define Stage

The Define stage is carried out to identify quality issues in the Drawn Textured Yarn (DTY) production process at PT. XYZ. Identification begins with the preparation of a Flow Process Chart to describe the overall production flow, then continued with the preparation of a SIPOC (Supplier, Input, Process, Output, Customer) diagram to determine the relationship between suppliers, raw materials, processes, products, and customers (Ivan Arfelli & Alvina Prima Hapsari, 2025). Based on the identification results, four types of Critical to Quality

(CTQ) were obtained which were the focus of the research, namely: These four types of defects were chosen because they had the highest frequency of occurrence and made the largest contribution to the total product defects.

Table 1. Production Amount in 2025

Month	Total Production Quantity	Total Defective Quantity	Defect Proportion
January	291,600	9,557	3%
February	319,176	8,307	3%
March	291,600	9,321	3%
April	319,176	9,544	3%
May	291,600	6,053	2%
June	319,176	12,754	4%
July	291,600	17,562	6%
August	319,176	7,763	2%
September	369,875	11,377	3%
October	369,875	10,939	3%
November	291,600	5,738	2%
December	319,176	7,233	2%
Total	**3,793,630**	**116,148**	-

Source: PT XYZ Production 2025

a. Process Mapping and Process Definition

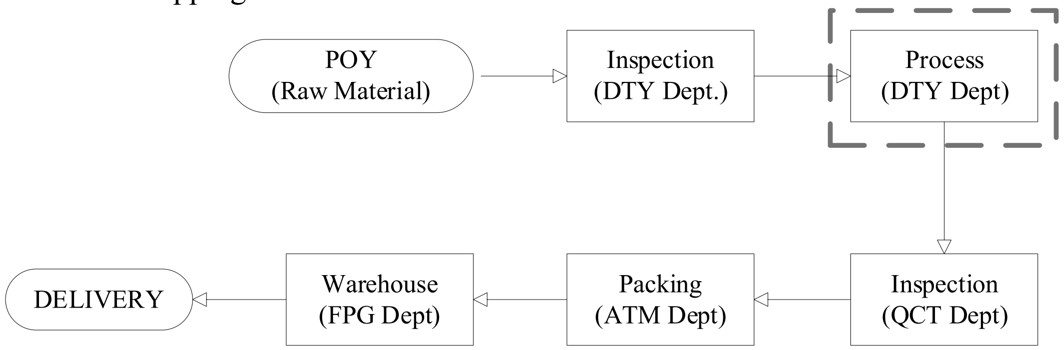

Figure 2. Production Flow Chart

Source: Research Results

Of the entire Drawn Textured Yarn (DTY) production process at PT. XYZ, this research focuses on the DTY Department because it is the core process of yarn formation and the source of various types of defects that affect product quality. Based on company data, four main types of defects are still found, namely Dyeing Reject, Damage, DP Handling, which causes an increase in the number of rejects and reworked products. This condition has an impact on decreasing the efficiency of the production process and has the potential to hinder the achievement of the company's production targets.

b. Diagram Sipoc

To define an action plan in six sigma, it is necessary to understand the SIPOC (Supplier-Input-Process-Output-Customer) process model. In process improvement management, the SIPOC diagram is one of the most useful and frequently used techniques to display the workflow at a glance. Starting from where the material is ordered and what type it is, continuing to what materials are used for the Drawn Textured Yarn production process, what processes the material goes through, then what output is to be achieved to meet customer needs, and the final stage, namely where the Drawn Textured Yarn product is distributed. The SIPOC diagram of the Drawn Textured Yarn production process at PT. XYZ can be seen in Figure 3 as follows.

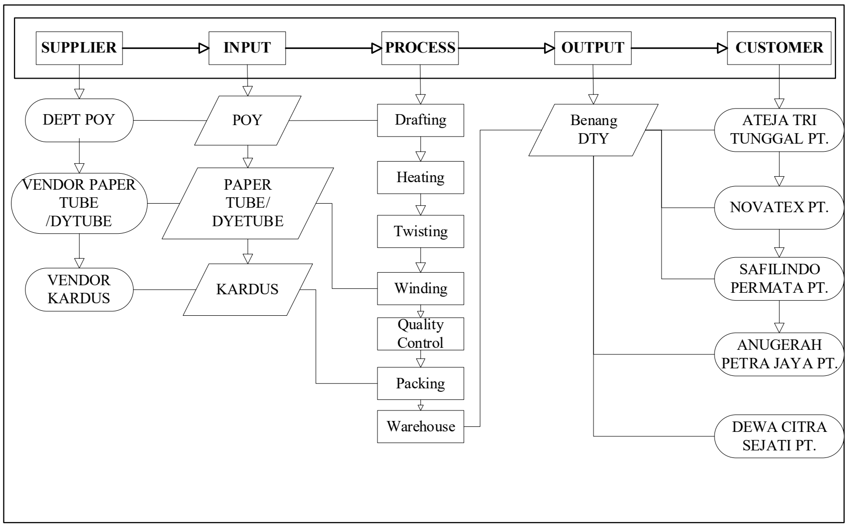

Figure 3. Sipoc Diagram

Source: Research Results

c. Determine Critical to Quality

Critical to Quality (CTQ) is a quality characteristic that is the main focus in quality control because it directly influences product quality. CTQ determination is carried out based on historical defect data and the results of observations of the Drawn Textured Yarn (DTY) production process. Based on the identification results, four main types of CTQ were obtained: Dyeing Reject, Damage, DP Handling, and Cutting, which have the highest frequency of occurrence and are the focus of analysis and proposed improvements in this study.

Table 2. Critical to Quality (CTQ) DTY Products

No.	Critical to Quality (CTQ)	Description
1	Dyeing Reject	Products exhibiting nonconforming color or dyeing quality, resulting in visible shade variation in the Draw Textured Yarn (DTY).
2	Physical Damage	Physical damage to DTY caused by dropping or impact during the packing process, resulting from machine malfunction or operator error.
3	DP Handling	DTY contaminated with dirt or foreign materials during the doffing process from the machine to the trolley due to improper handling.
4	Cutting	Automatic yarn breakage occurring during the winding process when the yarn tension exceeds the established tolerance limit.

Source: Research Results

2. Measure Stage

a. Creating a control chart (p-chart)

The comparison between the defect proportion and the control limits shows that several months had defect proportions outside the control limits, particularly June and July, which were above the UCL. This situation indicates process variation that requires further analysis to determine the cause of the increase in defects. Hopefully, the defect proportion can be controlled and the production process will become more stable.

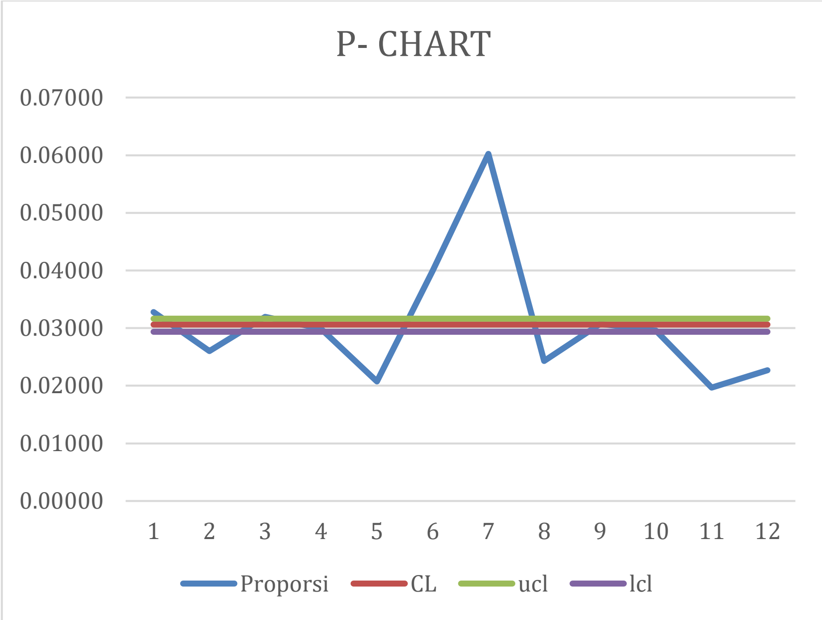

Figure 4. P-Chart Diagram

Source: Research Results

b. DPMO Measurement and Sigma Level

Table 3. DPMO Calculation and Sigma Level

No.	Month	Year	Total Production	Total Defects	CTQ	DPO	DPMO	Sigma Level
1	January	2025	291,600	9,557	4	0.3291	329,131.7974	1.9
2	February	2025	319,176	8,307	4	0.2861	286,083.2731	2.1
3	March	2025	291,600	9,321	4	0.3210	321,004.2360	2.0
4	April	2025	319,176	9,544	4	0.3287	328,684.0927	1.9
5	May	2025	291,600	6,053	4	0.2085	208,458.1741	2.3
6	June	2025	319,176	12,754	4	0.4392	439,232.7031	1.7
7	July	2025	291,600	17,562	4	0.6048	604,814.5470	1.2
8	August	2025	319,176	7,763	4	0.2673	267,348.5553	2.1
9	September	2025	369,875	11,377	4	0.3918	391,810.4487	1.8
10	October	2025	369,875	10,939	4	0.3767	376,726.2458	1.8
11	November	2025	291,600	5,738	4	0.1976	197,609.9459	2.4
12	December	**2025***	319,176	7,233	4	0.2491	249,095.9810	2.2

Source: Research Results

Based on the measurement results, the DPMO value and sigma level are used to evaluate the stability and capability of the production process. These results also serve as the basis for determining improvement priorities at production stages with the highest defect rates. Therefore, measuring DPMO and sigma levels can help companies improve product quality, reduce waste, and increase production process efficiency on a sustainable basis.

c. Process Capability Calculation(Cp,Cpk)

Cpk = min [Cpu,Cpl]

$$\text{Cpu} = \frac{USL - X}{3\sigma} = \frac{7{,}553 - 2{,}420}{3\ x\ 2039.167} = 0.84$$

$$\text{Cpl} = \frac{X - LSL}{3\sigma} = \frac{2{,}420 - 41}{3\ x\ 2039{,}167} = 0.39$$

Cpk = min [0.84 ; 0.39] = 0.39

Based on the process capability calculation, the CPU value was 0.84 and the CPL value was 0.39, resulting in a Cpk value of 0.39. This value indicates that the production process is not yet capable of meeting the specified specification limits because the Cpk value is still below 1.00.

d. Creating a Pareto Diagram

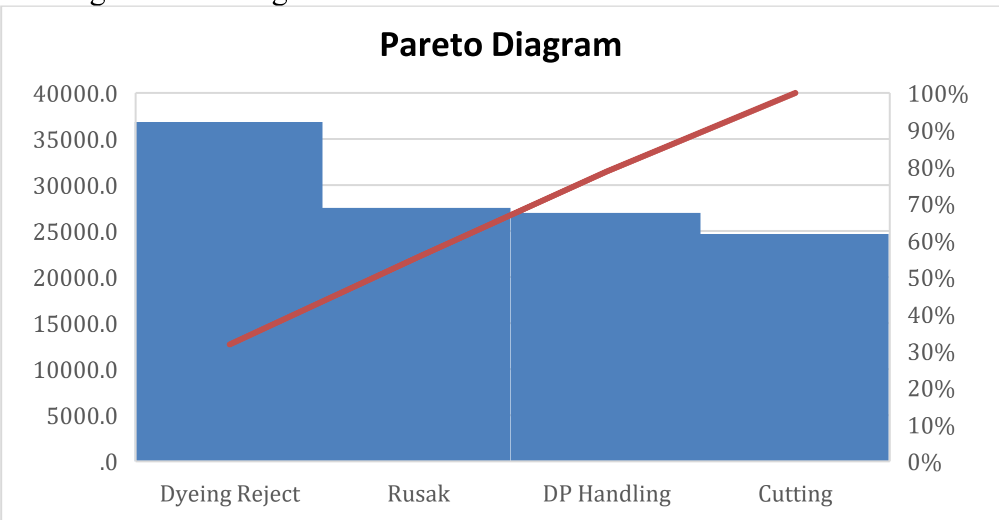

Figure 5. Pareto Diagram
Source: Research Results

Based on Figure 5, there were four main types of defects during the period January–December 2025, namely Dyeing Reject, Damage, DP Handling, and Cutting. Dyeing Reject had the highest frequency of 36,858 bobbins (31.73%), followed by Damage at 27,599 bobbins (23.76%), DP Handling at 27,009 bobbins (23.25%), and Cutting at 24,682 bobbins (21.25%). Cumulatively, the first three types of defects contributed 78.75% of the total defects, making them the top priority for analysis using Fishbone Diagram and FMEA to identify root causes and determine improvement priorities.

3. Analysis Stage

A high percentage of defects indicates unstable process variations and weak quality control at certain production stages. The following is a cause-and-effect diagram for Deying, Rusak, DP Handling, Cutting

a. Fisbhone

1). Dyeing

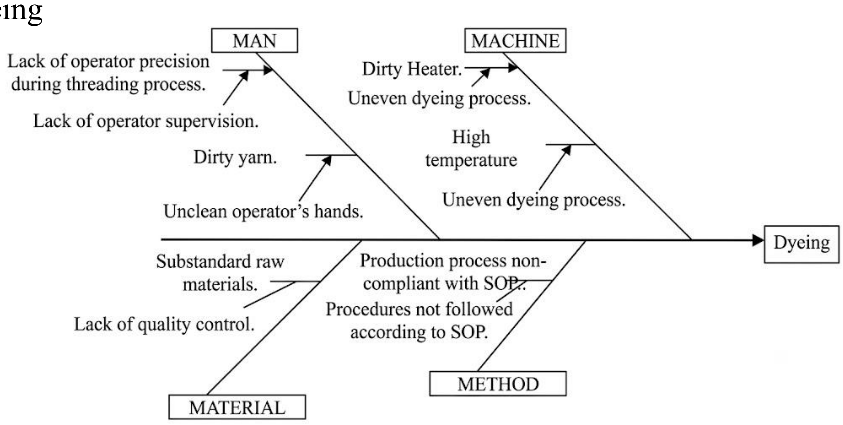

Figure 6. Fishbone Diagram of Causes of Dyeing Reject Defects
Source: Research Results

2). Defective

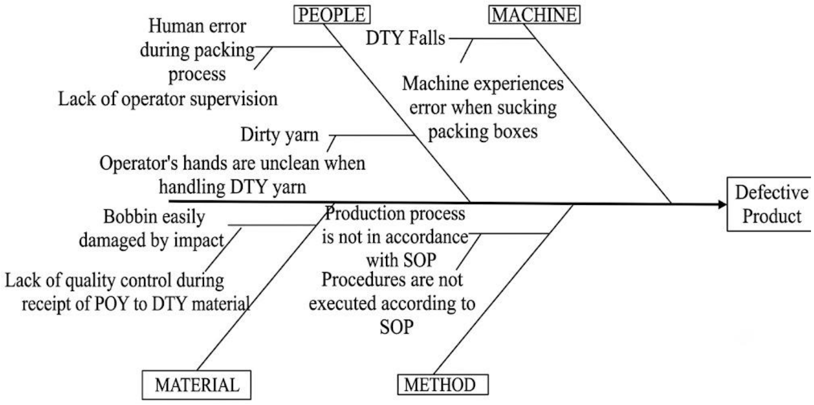

Figure 7. Fishbone Diagram of Causes of Defective
Source: Research Results

3). DP Handling

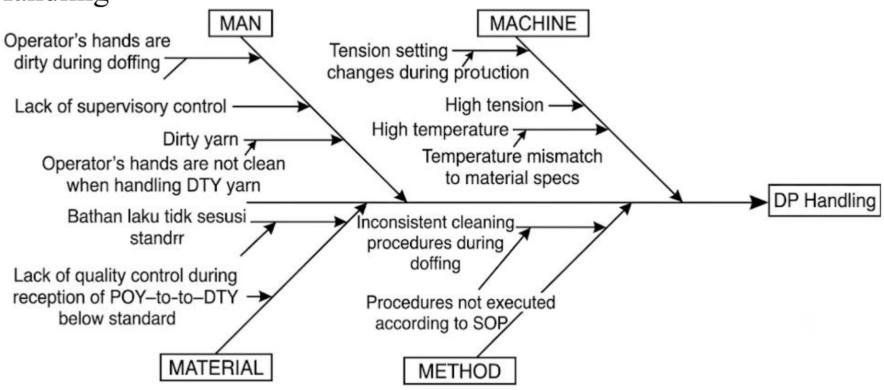

Figure 8. Fishbone Diagram of Causes of DP Handling
Source: Research Results

4). Cutting

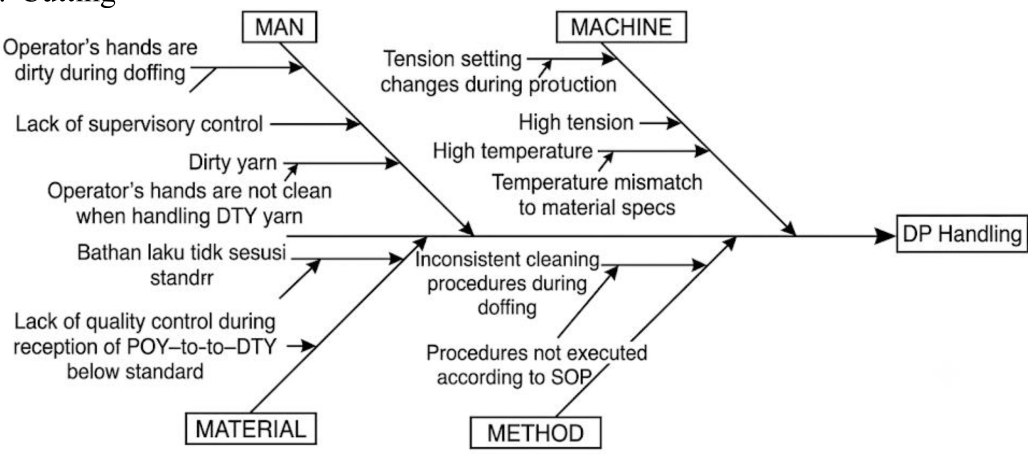

Figure 9. Fishbone Diagram of Causes of Cutting
Source: Research Results

b. FMEA Analysis

Table 4. Critical to Quality (CTQ) DTY Products

Failure Mode	Effect of Failure	Cause of Failure	Current Control	S	O	D	RPN
Dyeing Reject	The product does not meet the required quality standards, requiring rework or rejection.	Misthreading during the DTY production process.	Visual inspection by operators and process output inspection by the Quality Control team.	5	6	10	300
Physical Damage	The product suffers physical damage and fails to meet quality standards.	Human error during handling and process deviations related to machine operation.	Product inspection by operators and continuous monitoring during the handling process.	3	3	10	90
DP Handling	The product becomes contaminated and fails to meet quality standards.	Dirty machine conditions and operators performing the doffing process with unclean hands.	Machine cleanliness inspection and operator work instructions prior to the doffing process.	10	2	2	40
Cutting	Yarn breakage causes the product to fail to meet quality specifications.	Issues related to the material properties of the raw material.	Raw material quality inspection before production and continuous monitoring of machine parameters.	5	6	10	300

Table 4 shows the results of the Failure Mode and Effect Analysis (FMEA) analysis obtained two causes of failure with the highest Risk Priority Number (RPN) values, namely Dyeing Reject caused by misthreading during the production process and Cutting caused by problems with material characteristics (material properties), each of which has an RPN value of 300. Furthermore, the Damaged defect has an RPN value of 90, while DP Handling has an RPN value of 40. Therefore, the proposed improvements at the Improve stage are prioritized on the cause of failure with the highest RPN value, then followed by causes with lower RPN values as part of efforts to continuously improve quality.

4. Improvement Stage

Based on the results of the Fishbone Diagram and FMEA analysis, improvement proposals were developed using the 5W+1H method. This method is used to explain the necessary actions, the rationale, the person responsible, the implementation time, the location of the implementation, and the implementation method.

Improvements for Dyeing Rejects focused on improving operator understanding of thread installation techniques according to SOPs and checking machine parameters before production. For Damaged defects, improvements were implemented through product handling training and standardized transfer procedures to reduce damage due to human error. Meanwhile, for DP Handling, improvements focused on improving machine and work area cleanliness and the disciplined use of PPE to prevent contamination. For Cutting defects, improvements were implemented through raw material inspections and regular machine preventive maintenance to prevent thread breakage.

5. **Control Stage**

In this study, the Control phase was carried out by emphasizing monitoring the factors causing DTY yarn defects that had been previously identified, namely human, machine, method, material, and environmental factors. Control was carried out so that any corrective actions were not only temporary, but became part of the permanent work procedures in the production department of PT XYZ.

a. Control of Human Factors (Man)

Human-related factors should be controlled by ensuring that all operators understand and comply with the established Standard Operating Procedures (SOPs). The company should conduct periodic evaluations of operator discipline, comprehension of work instructions, and adherence to production procedures. In addition, routine pre-shift briefings should be maintained to reinforce awareness of potential defects and the preventive measures required to avoid them.

b. Control of Machine Factors (Machine)

Machine-related factors should be controlled through the implementation of a regular preventive maintenance program. Machine conditions should be inspected before and after operation, with all findings documented in maintenance records to facilitate the early identification of potential failures. Whenever irregular machine conditions are detected, maintenance technicians should perform corrective actions before the equipment is returned to production.

c. Control of Method Factors (Method)

Method-related factors require consistent implementation of the revised Standard Operating Procedures (SOPs). Any modifications to production methods should be communicated to all operators before implementation. Furthermore, work instructions should be written in a clear and standardized manner to minimize variations in work practices among operators. Continuous supervision by production supervisors is also necessary to ensure compliance with standardized operating procedures.

d. Control of Material Factors (Material)

Material control should begin with the inspection of raw materials before they enter the production process. Materials that do not meet the required specifications should be segregated to prevent their use in manufacturing. In addition, appropriate storage conditions should be maintained to preserve material quality and prevent deterioration resulting from improper storage practices.

e. Control of Environmental Factors (Environment)

The production environment should be maintained in a clean and organized condition, as workplace cleanliness directly contributes to product quality. The company should also ensure that temperature, humidity, and lighting within the production area remain within acceptable operating ranges. Where necessary, the production layout should be optimized to eliminate process flow interruptions that may negatively affect production efficiency.

f. Monitoring Improvement Outcomes

To verify the effectiveness of the implemented improvements, the company should continuously monitor defect rates. Monitoring may be conducted using quality control sheets or daily and monthly defect reports. The collected data should then be compared with baseline performance before improvement implementation to evaluate whether a significant reduction in product defects has been achieved.

g. Standardization of Improvements

To sustain improvement outcomes, effective corrective actions should be incorporated into the company's standard operating procedures. Standardization may include updating SOPs, providing refresher training for operators, and assigning clear monitoring responsibilities to the production and quality control departments. Through systematic standardization, the production process becomes more consistent, enabling the long-term reduction of product defects and supporting continuous quality improvement.

6. Quality Improvement Recommendations

Based on the findings of the analysis, several recommendations are proposed to improve the quality of the program and address the challenges identified during implementation. These recommendations are intended to strengthen operational effectiveness, enhance stakeholder participation, and support the sustainability of program outcomes. The proposed quality improvement strategies are presented in Table 5.

Table 5. Quality Improvement Recommendations

No.	Dominant Defect	Root Cause	Recommended Improvement	Improvement Objective
1	Dyeing Reject	Inconsistent dyeing process, unstable machine settings, and non-uniform raw materials.	Standardize dyeing process parameters, inspect machine conditions before production, and ensure that raw materials comply with the required specifications.	To reduce nonconforming dyeing results and improve color consistency.
2	Physical Damage	Improper product handling and noncompliance with material transfer procedures.	Provide product handling training, clarify standard operating procedures (SOPs) for material transfer, and strengthen operator supervision.	To prevent physical damage to products during the production process.
3	DP Handling	Errors during product handling and transfer between production stages.	Develop clear handling work instructions, improve product transfer workflows, and conduct regular operator briefings.	To reduce defects caused by improper product handling.
4	Cutting	Inaccurate cutting equipment, improper machine settings, and worn cutting blades.	Perform periodic inspection and calibration of cutting equipment and replace worn cutting blades.	To ensure cutting results meet product specifications and reduce cutting-related defects.

Based on the results of the Pareto chart analysis, the dominant defect types identified in the DTY yarn products at PT XYZ were Dyeing Reject, Physical Damage, DP Handling, and Cutting. Since each defect is associated with different root causes, specific improvement recommendations are required to ensure that corrective actions are both effective and appropriately targeted.

Dyeing Reject was identified as one of the highest-priority defects because it directly affects color conformity and the final product quality. To address this issue, the company should ensure that the dyeing process operates under stable process parameters, that raw materials conform to the required specifications, and that production equipment is thoroughly inspected and verified to be in proper working condition before the dyeing process begins.

The Physical Damage and DP Handling defects are primarily influenced by human factors and work methods. Accordingly, the company should improve standard operating procedures (SOPs) related to product handling, provide comprehensive operator training, and strengthen supervision throughout the product transfer process between production stages. These measures are expected to minimize physical damage resulting from improper handling and operator errors.

For the Cutting defect, improvement efforts should focus on enhancing equipment accuracy and maintaining stable machine settings. Regular inspection of cutting equipment, timely replacement of worn components, and periodic calibration are recommended to ensure cutting precision and reduce defects caused by products failing to meet the required specifications. These corrective actions are expected to improve process capability and contribute to continuous quality improvement in the DTY yarn production process.

D. CONCLUSION

This study shows that the Drawn Textured Yarn (DTY) production process at PT. XYZ still faces quality issues, with a defect rate of 3.06% during the January–December 2025 period. Based on the Pareto Diagram analysis, the most dominant type of defect is Dyeing Reject, contributing 31.73%, followed by Damage (23.76%), DP Handling (23.25%), and Cutting (20.39%). The Fishbone Diagram analysis indicates that the causes of defects are related to human, machine, material, and method factors. Furthermore, the FMEA analysis indicates that Dyeing Reject due to misthreading and cutting due to material characteristic issues are the highest priority risks, each with an RPN of 300.

The application of the Six Sigma method with the DMAIC approach, supported by the Pareto Diagram, Fishbone Diagram, FMEA, and 5W+1H analysis, resulted in more targeted improvement proposals based on the root causes of defects. These recommendations include improving operator competence and discipline through training, consistent implementation and monitoring of SOPs, preventive maintenance on machines, improved raw material quality control, and regular process monitoring. With the continued implementation of these recommendations, it is hoped that product defect rates can be reduced, process stability can be increased, and the quality and capability of the DTY yarn production process can be consistently maintained.

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