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Proposed Quality Control Using the Six Sigma (DMAIC) Method to Reduce Defects in Partially Oriented Yarn Products at PT XYZ

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Abstract. The high defect rate of Partially Oriented Yarn (POY) demands systematic Quality Control to maintain the competitiveness of the textile industry. This study aims to propose Quality Improvements to reduce the number of defective products using the Six Sigma Method. The research was conducted at a textile manufacturing company using production data from January-August 2025. The Measured variables include Denier, DTI, Elong, and Uster defects. The process was evaluated through the Define, Measure, Analyze, Improve, Control (DMAIC) phases. The root cause analysis was supported by the P-Chart, DPMO calculation, Pareto Diagram, Fishbone, and Failure Mode and Effect Analysis (FMEA). Initial Measurements showed the process capability was at 3.16 Sigma with a DPMO of 48,851. DTI (61.76%) and Denier (22.29%) defects were identified as the most dominant. The main failures were caused by Machine instability, lack of maintenance, and operator fatigue. The proposed Improvements using the 5W+1H principle projected a 78% reduction in the Risk Priority Number (RPN). The post-Improvement estimation results showed an increase in process capability to 3.80 Sigma and a DPMO reduction to 10,747. The application of Six Sigma (DMAIC) effectively identifies root causes and formulates strategic Improvements capable of significantly reducing defects and increasing process capability.

Keywords: *Quality Control, Six Sigma, DMAIC, Product Defect, FMEA.*

A. INTRODUCTION

Product quality is one of the most critical factors determining a company's competitiveness in the manufacturing industry, including the textile sector. In textile manufacturing, yarn serves as a fundamental component that significantly influences the quality of final products such as fabrics and garments. Defects in yarn can substantially reduce product quality, leading to decreased market value, increased customer complaints, and higher production costs resulting from rework and product rejection. Therefore, stringent quality control during the yarn production process is essential to ensure product consistency and minimize operational losses.

PT XYZ is a company operating in the textile and petrochemical industry that produces various types of polyester yarn, including Partially Oriented Yarn (POY). Based on historical production data from January to August 2025, the company experienced a high rate of product defects. Out of a total production volume of 1,659,690 units, 324,310 units were found to be defective, resulting in a defect ratio of 19.54%. The defects were classified into four main categories: draw tension instability (DTI), yarn thickness deviation (Denier), unevenness (Uster), and elongation defects (Elong). This high defect rate indicates inefficiencies within the production system that require systematic evaluation and corrective action.

To address this complex problem, the Six Sigma method with the Define, Measure, Analyze, Improve, and Control (DMAIC) approach provides an appropriate solution. Six Sigma is a data-driven quality management methodology designed to reduce process variation and minimize defects to near-zero levels (3.4 defects per million opportunities). Through the DMAIC phases, companies can systematically identify root causes, measure current process capability, and formulate sustainable improvement strategies. The implementation of this method focuses not only on final product inspection but also on improving core production processes to prevent recurring defects. The effectiveness of Six Sigma in the textile industry has been demonstrated in previous studies. Rastiawan, Susandi & Perwiranegara (2021) applied Six Sigma to the twisting process and successfully reduced Defects Per Million Opportunities (DPMO) while significantly improving the Sigma level. Furthermore, Diva Altezza and Susanty (2022) implemented the DMAIC methodology for grey fabric quality control and increased process capability to 3.60 Sigma. Other studies conducted by Badillo Ruiz et al. (2026) and Ahmed et al. (2022) also confirmed that integrating DMAIC with tools such as Failure Mode and Effects Analysis (FMEA) is highly effective in reducing quality failure costs and continuously minimizing production defects.

Although Six Sigma has been widely applied in the textile industry, most previous studies have focused on quality control of final products such as garments, finished fabrics, or macro-level visual defects. The novelty of this study lies in its focus on an intermediate technical product, namely Partially Oriented Yarn (POY). POY possesses considerably more complex technical and engineering characteristics, where defects such as DTI and Denier are not merely visual imperfections but are influenced by micro-mechanical and chemical variables, including polymer viscosity, spinneret conditions, and fluctuations in drawing process parameters.

Based on the foregoing background, this study aims to measure the quality level, identify the factors causing defects, and propose quality improvement strategies for POY production at PT XYZ using the Six Sigma (DMAIC) method. The primary contribution of this research is the development of a comprehensive problem-solving framework through the integration of FMEA and the 5W+1H approach to formulate preventive and corrective actions. The proposed solutions are expected to reduce the defect ratio, improve the Sigma level of the production process, and optimize overall operational efficiency.

B. METHOD

This study employed a descriptive quantitative research design focusing on the quality control of Partially Oriented Yarn (POY) products. Primary data were collected through direct observation on the production floor and interviews with operators and Quality Control staff at PT XYZ. Secondary data consisted of historical production and product defect records from January to August 2025. The measured variables included production volume, the number of defective products, and four critical defect categories: Denier, DTI, Elong, and Uster.

The primary analytical approach employed was Six Sigma using the Define, Measure, Analyze, Improve, and Control (DMAIC) framework. In the Define phase, Critical to Quality (CTQ) characteristics were identified and the production process was mapped using a SIPOC diagram. According to Gaspersz (as cited in FINSA AULIA, 2022), SIPOC is a process-mapping tool used to understand the relationships among process elements comprehensively.

In the Measure phase, process performance was evaluated using a P Control Chart (P-Chart). According to NABILLA DEVI SHAKILA (2018), control charts are statistical quality control tools used to identify processes operating under uncontrolled conditions. Process performance was also measured by calculating Defects Per Million Opportunities (DPMO). The resulting DPMO values were subsequently converted into Sigma Levels based on the Sigma conversion table proposed by Gaspersz (Zulkhulaifah & Apriliani, 2024).

The Analyze phase aimed to identify the root causes of product defects. Defect data were prioritized using a Pareto Diagram, which, according to ROY JOHANNES SIHALOHO (2019), is used to identify the problems with the greatest impact. Root cause analysis was then conducted using a Fishbone Diagram, originally introduced by Prof. Kaoru Ishikawa in 1943. Furthermore, Failure Mode and Effects Analysis (FMEA) was applied to evaluate potential failure modes. Risk assessment in the FMEA was determined by calculating the Risk Priority Number (RPN), which integrates the severity of failure effects (Severity), the probability of occurrence (Occurrence), and the ability to detect failures (Detection).

In the Improve phase, corrective action proposals were systematically formulated using the 5W+1H framework. Finally, in the Control phase, continuous monitoring was conducted to ensure that the implemented improvements could be sustained, in accordance with the objective of quality control to ensure that operational processes continue to perform as planned.

C. METHOD

The primary materials used in the production process of Partially Oriented Yarn (POY) at PT XYZ consisted of Polyester Chips (Textile Grade, PT XYZ), PTA (Pure Terephthalic Acid, Industrial Grade), MEG (Monoethylene Glycol, Industrial Grade, 99%), and Spin Finish Oil (Lubricant Grade). The main equipment employed in the research and production process included an Extruder (Barmag), a Spinning Pack/Spinneret (Barmag), a Quenching Air System or Air Handling Unit (Barmag), a Winder/Take-Up Machine (Barmag), and an Uster Tester (Uster Technologies) for yarn physical property testing.

The research methodology employed the Six Sigma approach using the DMAIC (Define, Measure, Analyze, Improve, and Control) framework to address the high rate of defective products. In the Define phase, the production problems were identified and the Critical to Quality (CTQ) characteristics were determined, including Denier, DTI, Elong, and Uster defects. The Measure phase involved collecting production data from January to August 2025 and evaluating process stability using a P Control Chart (P-Chart), Defects Per Million Opportunities (DPMO) calculations, and Sigma Level conversion.

The Analyze phase focused on identifying the root causes of defects using a Pareto Diagram to determine priority defects, followed by a Fishbone Diagram to classify the causes according to the 4M factors (Man, Machine, Method, and Material). The risk level associated with each root cause was assessed using Failure Mode and Effects Analysis (FMEA) to obtain the Risk Priority Number (RPN). In the Improve phase, corrective actions were systematically proposed using the 5W+1H framework to reduce the RPN values. Finally, the Control phase concluded with the standardization of operating procedures and a projected improvement in process Sigma capability following the implementation of the proposed corrective actions.

D. RESULT AND DISCUSSION

1. Define Phase

The Define phase involves identifying the problem, determining customer requirements, defining the process area to be improved, and establishing objectives such as reducing defect rates or production costs and setting the target timeframe for improvement. In this phase, the production process is mapped using a SIPOC diagram, followed by the identification of Critical to Quality (CTQ) characteristics related to customer needs and expectations, as described by Alya Nur Khofifah (2024).

The Define phase is the initial stage of the Six Sigma methodology, aimed at clearly identifying and defining the quality problem. In this study, the primary focus was on yarn products that did not meet the quality standards established by the company. Furthermore, Critical to Quality (CTQ) characteristics were identified to obtain information on the total production output and the number of defective products. These data were subsequently used to calculate the percentage of rejected products, thereby quantifying the magnitude of the quality problem occurring in the production process.

Table 1. Defective Product Data for 2025

No	Month	Production Volume	Defect Type				Total Defects	Defect Ratio
			DENIER	DTI	ELONG	USTER		
1	January	211730	8.907	25.678	2.135	3.578	40298	19.03%
2	February	191240	9.986	24.859	1.966	3.600	40411	21.13%
3	March	211730	9.238	27.903	2.117	4.775	44033	20.80%
4	April	204900	8.890	24.769	1.598	3.200	38457	18.77%
5	May	211730	7.686	25.893	1.879	5.800	41258	19.49%
6	June	204900	8.723	24.876	1.769	4.300	39668	19.36%
7	July	211730	8.986	23.389	1.327	5.300	39002	18.42%
8	August	211730	9.862	22.935	1.986	6.400	41183	19.45%
	Total	**1659690**	**72278**	**200302**	**14777**	**36953**	**324310**	**19.54%**

Source: PT. XYZ

Based on the data presented in Table 1, the total yarn production during the January–August period reached 1,659,690 cones, with a total of 324,310 defective cones. This indicates an overall defect rate of 19.54%, which is considered relatively high. Therefore, the company needs to implement more intensive quality control measures to reduce the number of defects generated during the production process.

The identified defect types consisted of Denier, DTI, Elong, and Uster defects. Among these, DTI was the most dominant defect type, accounting for 200,302 cones, followed by Denier with 72,278 cones, Uster with 36,953 cones, and Elong with 14,777 cones. These defect categories are classified as potential Critical to Quality (CTQ) characteristics, representing the key factors that significantly influence overall product quality.

a. Critical to Quality (CTQ)

Table 1. Critical to Quality (CTQ)

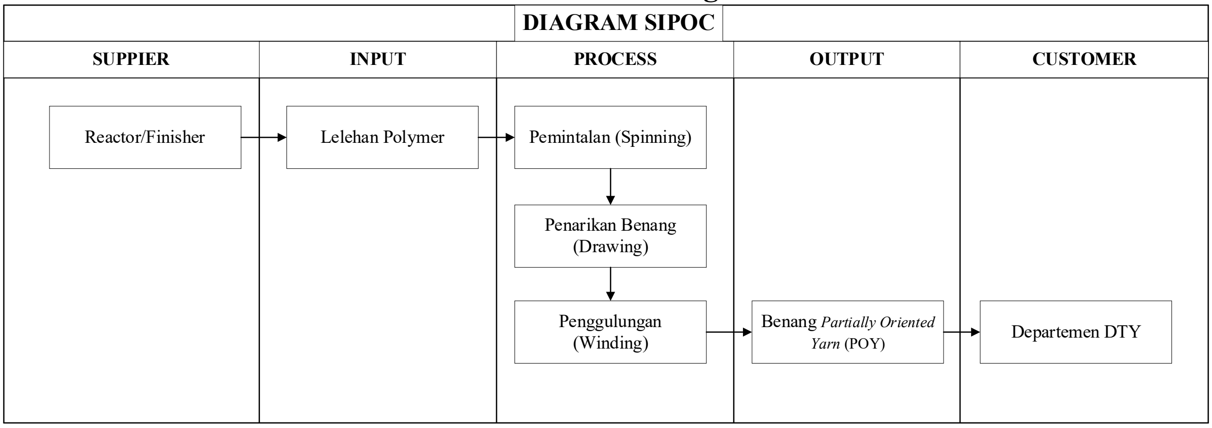
No	Critical to Quality (CTQ)	Information
1	DENIER	Yarn Thickness Deviation
2	DTI	Draw Tension Instability
3	ELONG	Elongation Level
4	USTER	Yarn Unevenness

Sourcer: PT. XYZ

Denier represents the thickness of the yarn, where defects occur when the yarn diameter deviates from the specified standard due to instability in the spinning process. DTI (Draw Tension Irregularity) refers to fluctuations in yarn draw tension during production, which are generally caused by wear and deterioration of machine components. Elong (Elongation) relates to the yarn's elasticity or its ability to stretch before breaking and is influenced by production temperature and the quality of raw materials. Finally, Uster is an indicator of yarn evenness, where defects arise from variations in yarn thickness caused by inconsistencies in machine performance or material quality.

b. Sipoc Diagram

Table 2. SIPOC Diagram



Source: PT. XYZ

The figure above presents a SIPOC diagram, which is used to illustrate the relationship between the production process and its inputs and outputs.

2. Measure Phase

According to Muhammad Nova Rizky (2024), the Measure phase is intended to evaluate the current performance of the production process. This phase begins with an analysis of the measurement system to ensure data accuracy and serves as a bridge between the Define phase and the subsequent stages of the DMAIC methodology.

a. P-Chart

A P-Chart is an attribute control chart used to monitor the proportion of defective products in a production process with variable sample sizes. This method is most appropriate when the sample size is greater than 30 (n > 30) and the number of sample groups ranges from 20 to 25 sets (Dani Pambudi, 2019).

Table 4. P-Chart Calculation Results

No	Month	Production Volume	Defect Type				Total Defect	Defect Proportion (p)	CL	UCL	LCL
			DENIER	DTI	ELONG	USTER					
1	January	211730	8.907	25.678	2.135	3.578	40.298	0,190	0,195	0,1980	0,1928
2	February	191240	9.986	24.859	1.966	3.600	40.411	0,211	0,195	0,1981	0,1927
3	March	211730	9.238	27.903	2.117	4.775	44.033	0,208	0,195	0,1980	0,1928
4	April	204900	8.890	24.769	1.598	3.200	38.457	0,188	0,195	0,1980	0,1928
5	May	211730	7.686	25.893	1.879	5.800	41.258	0,195	0,195	0,1980	0,1928
6	June	204900	8.723	24.876	1.769	4.300	39.668	0,194	0,195	0,1980	0,1928
7	July	211730	8.986	23.389	1.327	5.300	39.002	0,184	0,195	0,1980	0,1928
8	August	211730	9.862	22.935	1.986	6.400	41.183	0,195	0,195	0,1980	0,1928
Total		**1659690**	**72278**	**200302**	**14777**	**36953**	**324.310**				

a. Calculating the Defect Proportion

$$\tilde{p} = \frac{np}{n} \qquad (1)$$

$$\tilde{p} = \frac{40298}{211730} = 0{,}190$$

Where:

np = Total Defect

n = Total Production

b. Center Line (CL)

$$CL = \tilde{p} = \frac{\sum np}{\sum n} \qquad (2)$$

$$CL = \tilde{p} = \frac{324.310}{1.659.690} = 0{,}195$$

Where: CL = P Center Line
Σnp Total Number of Defective Products
Σn = Total Production Volume

c. Calculating the Upper Control Line (UCL)

$$\mathrm{UCL} = \tilde{\mathrm{p}} + 3\sqrt{\frac{\tilde{\mathrm{p}}(1-\tilde{\mathrm{p}})}{\mathrm{n}}} \quad (3)$$

$$\mathrm{UCL} = 0{,}195 + 3\sqrt{\frac{0{,}195(1-0{,}195)}{1.659.690}} = 0{,}1980$$

Where:
$\bar{p}$ = Center Line / Average Defect Rate
n = Total Production

d. Calculating the Lower Control line (LCL)

$$\mathrm{LCL} = \mathrm{p} - 3\sqrt{\frac{\tilde{\mathrm{p}}(1-\tilde{\mathrm{p}})}{\mathrm{n}}} \quad (4)$$

$$\mathrm{LCL} = 0{,}195 - 3\sqrt{\frac{0{,}195(1-0{,}195)}{1.659.690}} = 0{,}1928$$

Where:
$\bar{p}$ = Center Line / Average Defect Rate
n = Total Production

The calculation results of the Upper Control Limit (UCL) and Lower Control Limit (LCL) are then used as the basis for constructing the P-Chart. The visualization of the control chart is presented in the following figure to illustrate the quality control conditions during the observation period.

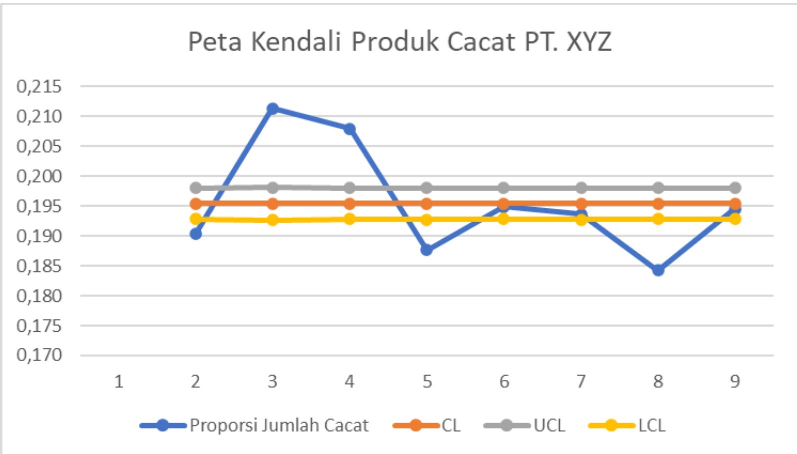


Figure 1. P-Chart Control Graph

P-Chart analysis indicates that the production process is not yet statistically controlled, as evidenced by the presence of data points exceeding the upper control limit during the February–March period and falling below the lower control limit during the January, April, and July periods. These variations indicate the presence of special causes that require further investigation to improve the stability and consistency of production quality.

b. Calculating DPMO and Sigma Level

In this study, the sigma level was calculated using Microsoft Excel. The use of this application aims to simplify the data analysis process and obtain accurate calculation results. The formulas used are as follows:

1). Calculating Defect Per Million Opportunities (DPMO)

$$DPMO = \frac{Number\ of\ Defective\ Products}{Total\ Production\ X\ Number\ of\ Defect\ Types}\ X\ 1.000.000\ (5)$$

$$DPMO = \frac{324.310}{1.659.690\ X\ 4}\ X\ 1.000.000 = 48.85$$

2). Calculating Sigma Level

$$Sigma\ Level = NORMSINV\ \frac{1.000.000 - DPMO}{1.000.000} + 1{,}5(6)$$

$$Sigma\ Level = NORMSINV\ \frac{1.000.000 - 48.851}{1.000.000} + 1{,}5 = 3{,}16$$

Table 5. DPMO and Sigma Level Calculation Results

Month	Production Volume	Total Defects	CTQ	DPMO	Sigma Level
1	211730	40298	4	47582	3,17
2	191240	40411	4	52828	3,12
3	211730	44033	4	51992	3,13
4	204900	38457	4	46922	3,18
5	211730	41258	4	48715	3,16
6	204900	39668	4	48399	3,16
7	211730	39002	4	46052	3,18
8	211730	41183	4	48627	3,16
Total	**1659690**	**324310**	**4**	**48851**	**3,16**

Based on the calculations presented in the table above, the Defects Per Million Opportunities (DPMO) values during the January–August period ranged from 46,052 to 52,828. After conversion using the sigma level conversion table, the monthly sigma values were found to range from 3.12 to 3.18 sigma. The highest sigma level was recorded in April and July at 3.18 sigma, while the lowest sigma level occurred in February at 3.12 sigma. Overall, the average process capability of the production process during the January–August period was approximately 3.16 sigma.

3. Analyze Phase

The Analyze phase is the third stage of the Six Sigma methodology and is used to identify the root causes of product defects. In this phase, a Pareto chart is employed to determine the types of defects that occur most frequently, while a Fishbone (Ishikawa) diagram is used to identify the factors contributing to defects in the production process. Subsequently, the Failure Mode and Effects Analysis (FMEA) method is applied to evaluate and prioritize the root causes of these factors based on their level of risk. Through FMEA, each potential failure mode is assessed in terms of Severity, Occurrence, and Detection to calculate the Risk Priority Number (RPN), which serves as the primary basis for determining the most urgent corrective actions.

a. Pareto Chart

Table 6. Frequency of Defects

No	Defect Type	Total Defects	Percentage	Cumulative Percentage
1	DTI	200302	61,76%	61,76%
2	Denier	72278	22,29%	84,05%
3	Uster	36953	11,39%	95,44%

4	Elong	14777	4,56%	100,00%
Total		**324310**		

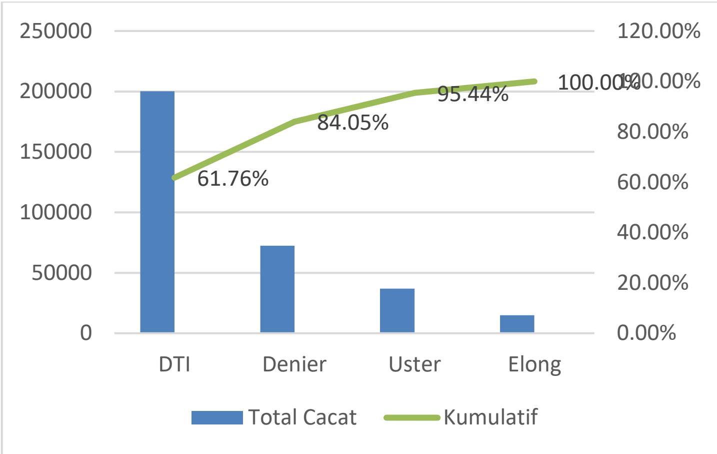


Figure 2. Pareto Chart

Based on Table 6, the total number of defects recorded was 324,310 units, consisting of DTI, Denier, Uster, and Elong defects. DTI was the most dominant defect type, accounting for 200,302 units (61.76%), followed by Denier with 72,278 units (22.29%), Uster with 36,953 units (11.39%), and Elong with 14,777 units (4.56%). According to the Pareto principle (80/20), the majority of quality problems are typically caused by a small number of critical factors. As shown in the table, DTI and Denier defects together contributed a cumulative 84.05% of the total defects. Therefore, these two defect types were identified as the highest priority for quality improvement efforts because they contributed the largest proportion of the overall defects.

b. Fishbone Diagram

Based on the Pareto chart analysis using the 80/20 principle, DTI defects (61.76%) and Denier defects (22.29%) were identified as the primary contributors (the vital few), with a cumulative contribution of 84.05% of the total 324,310 defects. Therefore, the subsequent Fishbone Diagram analysis focuses specifically on identifying the root causes of these two dominant defect types.

1). Fishbone Diagram of DTI Product Defects

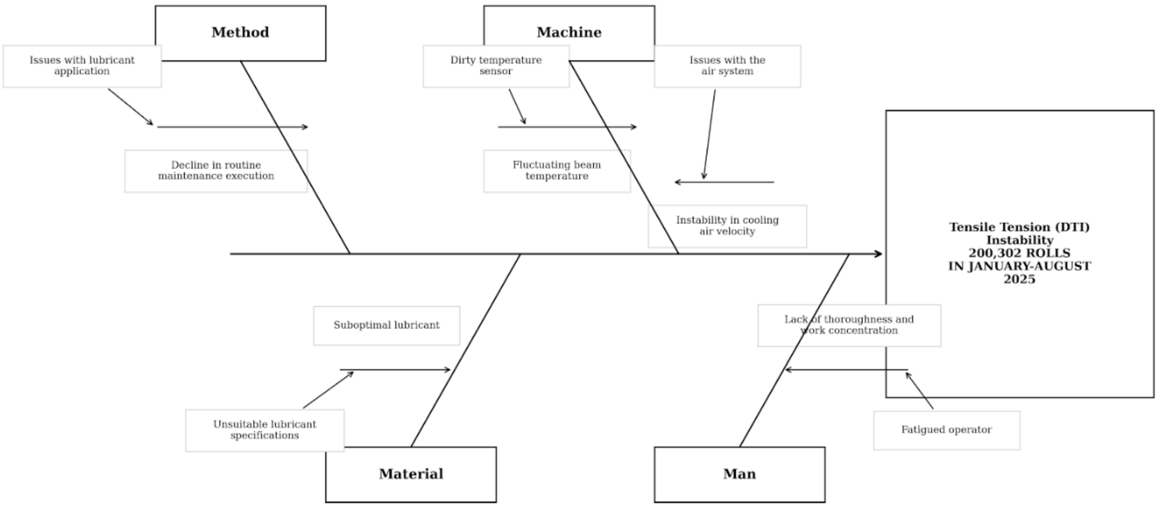


Figure 3. Fishbone Diagram for DTI Defects

The Fishbone analysis identified four main factors contributing to DTI defects in the production process. The human factor was associated with operator fatigue, which reduced

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the level of accuracy and concentration in monitoring process parameters. The machine factor was caused by temperature fluctuations resulting from contaminated sensors and unstable cooling airflow within the air system. The method factor was related to declining adherence to routine maintenance procedures, particularly those concerning lubricant application. Finally, the material factor was attributed to the use of lubricants that did not meet the operational specifications of the machine, thereby reducing component performance.

2). Fishbone Diagram for Denier Defects

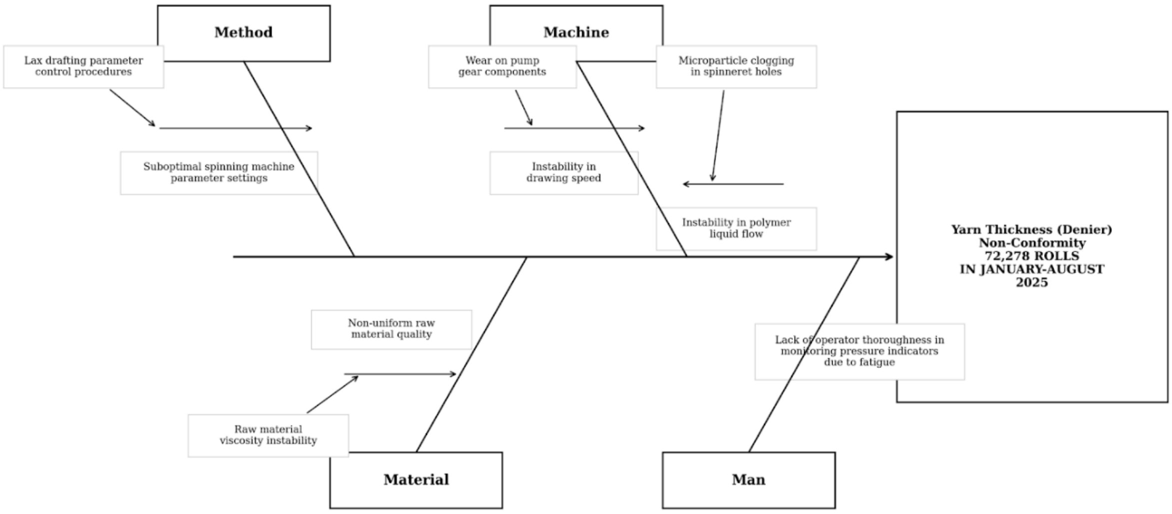

Figure 4. Fishbone Diagram for Denier Defects

The Fishbone analysis identified four main factors contributing to Denier defects. The human factor was associated with operator fatigue, which reduced the accuracy of monitoring machine pressure parameters during the production process. The machine factor included spinneret clogging caused by micro-particles and wear of the gear pump, both of which resulted in unstable polymer flow. The method factor was attributed to suboptimal drafting parameter settings due to inadequate control and calibration procedures. Finally, the material factor was caused by inconsistencies in polymer viscosity between production batches, which directly affected yarn thickness uniformity.

c. Failure Mode and Effect Analysis (FMEA)

Based on the root causes identified through the Fishbone diagrams presented in the previous subsection, the next analytical step was to evaluate the risk level associated with each contributing factor using the Failure Mode and Effects Analysis (FMEA) method. The application of FMEA in this study aimed to systematically quantify and classify potential failures in the production process. Each failure mode was assessed using three main parameters: Severity, Occurrence, and Detection. The multiplication of these three parameters produces the Risk Priority Number (RPN), which serves as an objective basis for determining the priority of corrective actions. The results of the data analysis using the FMEA matrix are presented below:

1). RPN Before Improvement

Table 7. RPN Calculation Before Improvement

Failure Mode	Potential Failure Mode	Sev	Occ	Det	RPN
Method	Declining implementation of routine maintenance	8	6	6	288
Machine	Instability in the take-up speed	8	6	6	288
Machine	Fluctuating beam temperature	8	5	6	240
Method	Suboptimal spinning machine parameter settings	7	6	5	210
Machine	Instability in cooling air speed	7	6	5	210
Man	Lack of operator accuracy in monitoring pressure	7	5	5	175

	indicators due to fatigue				
Machine	Instability in polymer liquid flow	7	5	5	175
Material	Inconsistent raw material quality	6	5	5	150
Man	Lack of accuracy and work concentration	6	6	4	144
Material	Insufficient lubrication performance	6	4	4	96
Total RPN					**1976**

RPN Formula $= S \ x \ O \ x \ D$

RPN $= 8 \ x \ 8 \ x \ 6 = 288$

Based on the attached FMEA analysis table, the total Risk Priority Number (RPN) of the ten potential failure modes evaluated reached 1,976. This value was obtained by multiplying the level of impact severity (Severity or Sev), the frequency of occurrence of the problem (Occurrence or Occ), and the difficulty of detecting the problem (Detection or Det).

There are two potential failure modes with the most critical risk, each having the highest RPN value of 288. The first problem originates from the Method factor, namely the declining implementation of routine maintenance, while the second problem originates from the Machine factor, namely instability in the take-up speed. Both issues are considered highly urgent because they have a very severe impact on production, occur very frequently, and are very difficult for operators to detect at an early stage. The third highest risk is also dominated by the Machine factor, namely fluctuating beam temperature, with an RPN value of 240, which has the same level of severity but a slightly lower occurrence frequency than the two previous problems. At the medium-priority level, there are two problems, each with an RPN value of 210, namely suboptimal spinning machine parameter settings under the Method factor and instability in cooling air speed under the Machine factor. Furthermore, the Man factor contributes to operational risk through the lack of operator accuracy in monitoring pressure indicators due to fatigue, resulting in an RPN value of 175. This RPN value of 175 is also shared by the problem of instability in polymer liquid flow under the Machine factor, where both have moderate levels of severity, occurrence, and detection difficulty.

On the other hand, there are three potential failure modes that rank as the lowest risks in this production line evaluation. Inconsistent raw material quality contributes an RPN value of 150, followed by the lack of operator accuracy and work concentration with an RPN value of 144. The failure mode with the lowest risk level in the entire table is insufficient lubrication performance under the Material factor, which records an RPN value of only 96. This is because lubrication-related problems are considered relatively rare in the field and their symptoms can be detected very easily before causing more severe damage

2). RPN After Improvement

Table 8. RPN Calculation After Improvement

Failure Mode	Potential Failure Mode	Sev	Occ	Det	RPN
Material	Inconsistent raw material quality	6	3	3	54
Method	Declining implementation of routine maintenance	8	2	3	48
Machine	Fluctuating beam temperature	8	2	3	48
Machine	Instability in the take-up speed	8	2	3	48
Man	Lack of operator accuracy in monitoring pressure indicators due to fatigue	7	2	3	42
Method	Suboptimal spinning machine parameter settings	7	2	3	42
Machine	Instability in cooling air speed	7	2	3	42
Machine	Instability in polymer liquid flow	7	2	3	42
Man	Lack of accuracy and work concentration	6	3	2	36
Material	Insufficient lubrication performance	6	2	2	24
Total RPN					**426**

RPN Formula = $S \; x \; O \; x \; D$
RPN = $6 \; x \; 3 \; x \; 3 = 54$

Based on the FMEA (Failure Mode and Effects Analysis) table after improvement that you attached, the operational condition shows a controlled level of risk with a total Risk Priority Number (RPN) of 426. In this final evaluation, the highest-priority failure mode has shifted to the Material factor, namely inconsistent raw material quality, which records an RPN value of 54. This position occurs not because its impact is extremely severe (the severity level is only 6), but because its occurrence frequency and detection difficulty remain at a score of 3, making it the highest accumulated risk among the remaining factors on the production floor.

The next highest risk consists of three critical failure modes, each of which has been reduced to an RPN value of 48. These include the declining implementation of routine maintenance under the Method factor, as well as fluctuating beam temperature and instability in the take-up speed under the Machine factor. A notable aspect of these three failure modes is that, although they still have a very high severity score of 8, the corrective actions have proven highly effective in reducing their occurrence frequency to a rare level (score of 2) while also improving their detectability (score of 3).

Furthermore, within the medium-risk category, there are four failure modes with identical RPN values of 42. These include the lack of operator accuracy in monitoring pressure indicators due to fatigue, suboptimal spinning machine parameter settings, instability in cooling air speed, and instability in polymer liquid flow. These four failure modes exhibit a similar risk profile after improvement, with a severity score of 7, while their probability of occurrence has been successfully reduced to 2 and their detection score remains stable at 3.

Finally, two failure modes represent the lowest risk levels in the spinning machine operation. The lack of accuracy and work concentration under the Man factor records an RPN value of 36, with a detection score of 2, indicating that the problem can be identified and corrected very easily in practice. Meanwhile, the least critical failure mode is insufficient lubrication performance under the Material factor, with an RPN value of 24. Overall, the table confirms that the implemented corrective and preventive actions have successfully reduced the probability of occurrence and improved the detectability of failure modes consistently across the entire production line.

a). Comparison of RPN Before and After Improvement

Table 9. Comparison of RPN Before and After Improvement

No	Failure Mode	Cause of Failure (Potential Cause of Failure)	RPN Before Improvement	Recommended Action	RPN After Improvement	RPN Reduction
1	Declining implementation of routine maintenance	The preventive maintenance schedule is not consistently followed due to time constraints, labor limitations, or production target priorities.	288	Establish a stricter preventive maintenance schedule and monitor it through a reminder system, while allocating dedicated maintenance time outside production hours.	48	240

2	Instability in the take-up speed	The drive motor or take-up speed control system is experiencing malfunctions.	288	Perform periodic calibration of the motor and speed control system, and replace worn components according to the preventive maintenance schedule.	48	240
3	Fluctuating beam temperature	The beam heating/temperature control system is not functioning optimally or is insufficiently calibrated.	240	Conduct scheduled inspection and maintenance of the machine heating system, and install a temperature limit alarm so that fluctuations can be detected earlier.	48	192
4	Suboptimal spinning machine parameter settings	Machine parameters (temperature, pressure, and speed) are set based on estimation or operator experience rather than optimized standard settings.	210	Develop and implement standard operating procedures (SOPs) for machine parameter settings based on testing and optimization data, and verify the settings before production begins.	42	168
5	Instability in cooling air speed	The blower/cooling system experiences technical problems or is insufficiently calibrated.	210	Perform routine calibration and inspection of the blower system, and install an air-speed sensor to monitor stability in real time.	42	168
6	Lack of operator accuracy in monitoring pressure indicators due to fatigue	Operators experience fatigue due to long working hours or extended shifts, resulting in reduced alertness and concentration.	175	Implement a more balanced shift rotation schedule and regular rest periods, and install an automatic alarm on the pressure indicator so that deviations can still be detected even when operator focus decreases.	42	133

7	Instability in polymer liquid flow	The polymer extrusion pump pressure is inconsistent, or clogging occurs in the nozzle/filter.	175	Perform periodic cleaning and replacement of the filter/nozzle, and routinely monitor pump pressure to maintain stable polymer flow.	42	133
8	Inconsistent raw material quality	Raw materials are sourced from different batches or suppliers with inconsistent specifications.	150	Implement strict inspection and quality testing of raw materials before use, and establish raw material specification standards that suppliers must meet.	54	96
9	Lack of accuracy and work concentration	Work concentration decreases due to a high workload, insufficient rest periods, and a lack of refresher training.	144	Conduct periodic refresher training and implement a work checklist to ensure that every inspection step is carried out consistently.	36	108
10	Insufficient lubrication performance	The type or quantity of lubricant used does not meet the machine's technical specifications.	96	Establish a lubricant replacement schedule according to the machine manufacturer's recommendations and ensure that the lubricant specifications comply with the required standards.	24	72
Total RPN			**1976**		**426**	**1550**
Average Effectiveness			**78%**			

Based on the results of the improvement evaluation using the FMEA method, the corrective actions implemented on the production floor have proven to be highly effective. This is demonstrated by the significant reduction in the total Risk Priority Number (RPN) from 1,976 to 426. The reduction of 1,550 points indicates that the average improvement effectiveness reached 78%.

Operational risk was successfully reduced, particularly in the Machine and Method factors. Corrective actions such as implementing a disciplined preventive maintenance schedule, conducting routine calibration, developing standardized operating procedures (SOPs), and installing automatic sensors effectively reduced the frequency of machine failures and improved the operators' ability to detect potential problems at an early stage.

With the internal issues related to machines and work methods brought under control, the current risk priority has shifted toward the external factor of inconsistent raw material quality from suppliers. Overall, the implemented improvements have successfully created a production system that is significantly more stable, safer, and better controlled, allowing the company to focus future efforts on strengthening incoming raw material inspection standards.

4. Improve Phase

In the Improve phase, the analysis was conducted to formulate solutions to the identified problems in order to reduce the product defect rate. Through the use of a Fishbone Diagram, various factors contributing to defects in Partially Oriented Yarn (POY) products were successfully identified. Subsequently, improvement recommendations for DTI and Elong defects were developed by applying the 5W+1H framework. This approach was used to design problem-solving strategies within the company. All proposed corrective actions were based on the root causes that had previously been identified through the Fishbone Diagram.

Table 10. Table of 5W + 1H Improvement Recommendations

No	Factor	Cause	What	Why	Where	When	Who	How
1	Man	Lack of operator accuracy in monitoring pressure indicators due to fatigue	Operators fail to recognize process pressure deviations because they do not carefully monitor the pressure indicators on the machine control panel.	Operators experience fatigue due to long working hours or extended shifts, resulting in reduced alertness and concentration.	Spinning machine control panel and pressure indicator area.	Occurs during high-risk periods, especially near the end of a shift or during the night shift.	Spinning machine operators assigned to the respective shift.	Implement a more balanced shift rotation schedule and regular rest periods, and install an automatic alarm on the pressure indicator so that deviations can still be detected even when operator focus decreases.
		Lack of accuracy and work concentration	Process errors occur because operators are not sufficientl y focused while performin g production monitorin g tasks.	Work concentration decreases due to a high workload, insufficient rest periods, and a lack of refresher training.	Throughout the production line requiring manual operator supervision.	During production hours, particularly after break periods and before shift changes.	Production operators.	Conduct periodic refresher training and implement a work checklist to ensure that every inspection step is carried out consistently.
2	Material	Inconsistent raw material quality	Variations in final product quality due to non-homogene ous raw materials between batches.	Raw materials are sourced from different batches or suppliers with inconsistent specifications.	Raw material receiving and storage areas before the production process.	Occurs during changes in raw material batches or suppliers.	Quality Control personnel responsible for raw material inspection.	Implement strict inspection and quality testing of raw materials before use, and establish raw material specification standards that

								must be met by suppliers.
		Insufficient lubrication performance	Increased wear and friction of machine componen ts due to improper lubrication .	The type or quantity of lubricant used does not comply with the machine's technical specifications.	Machine components requiring lubrication, such as bearings and moving parts.	During machine operation, especially when lubricant replacement is not performed on time.	Maintenance team responsible for machine lubrication.	Develop a lubricant replacement schedule according to the machine manufacturer's recommendatio ns and ensure that the lubricant specifications comply with the required standards.
3	Machine	Instability in cooling air speed	The spinning cooling process is inconsiste nt due to fluctuating cooling air speed.	The blower/cooling system experiences technical problems or is insufficiently calibrated.	Cooling system unit (cooling chamber/blo wer) of the spinning machine.	During the fiber cooling process.	Machine technicians responsible for the cooling system.	Perform routine calibration and inspection of the blower system, and install an air-speed sensor to monitor stability in real time.
		Fluctuating beam temperature	Inconsiste nt fiber quality due to temperatur e fluctuation s in the machine beam.	The beam heating/temper ature control system does not function optimally or is insufficiently calibrated.	Beam section of the spinning machine.	During the production process, especially when the machine workload is high.	Technicians responsible for the machine heating system.	Conduct scheduled inspection and maintenance of the machine heating system, and install a temperature limit alarm to detect fluctuations at an early stage.
		Instability in the take-up speed	Non-uniform fiber thickness and strength due to unstable drawing speed.	The drive motor or take-up speed control system experiences malfunctions.	Drawing/tak e-up unit of the spinning machine.	During the fiber drawing process.	Machine technicians responsible for the drawing/win ding system.	Perform periodic calibration of the motor and speed control system, and replace worn components according to the preventive maintenance schedule.
		Instability in polymer liquid flow	Non-uniform fiber diameter and quality due to unstable polymer liquid flow.	The polymer extrusion pump pressure is inconsistent, or clogging occurs in the nozzle/filter.	Polymer extrusion/pu mp unit of the spinning machine.	During the polymer extrusion process.	Technicians responsible for the polymer extrusion system.	Perform periodic cleaning and replacement of filters/nozzles, and routinely monitor pump pressure to maintain stable polymer flow.

5. Control Phase

The Control phase is an important stage in the Six Sigma methodology that aims to maintain and ensure the sustainability of quality improvements achieved during the Improve phase. In this phase, the main focus is directed toward standardizing new processes, documenting best practices, and implementing continuous monitoring mechanisms to prevent the recurrence of defect root causes in the future. Therefore, this phase serves as the foundation for establishing a production system that is stable, consistent, and oriented toward continuous improvement.

a. Process Standardization

All improvement recommendations formulated through the 5W+1H approach must be permanently integrated into the company's work system. This step includes updating procedures, conducting training, and documenting changes to ensure that every process operates according to the established quality standards. All results of quality improvements and process modifications must be officially documented and communicated to all relevant departments. The improved work procedures are then used as the company's standard operating guidelines to maintain consistency in implementation on the production floor.

b. Continuous Quality Monitoring Mechanism

To ensure that the process remains in a controlled condition with a sigma capability above 3.4, the company needs to strengthen its quality monitoring and evaluation system continuously. The steps implemented include:

1). The P-Control Chart (P-Chart) is used to monitor the defect proportion. This chart functions as an early warning system, where every data point exceeding the control limits will be immediately followed up with direct corrective actions.

2). The Production Department needs to improve raw material control to ensure that all materials used meet quality standards and do not contribute to defect occurrence.

3). The success of the Control phase highly depends on the competence and awareness of all personnel involved in the production process. Therefore, continuous training programs are an essential component that cannot be overlooked in this phase. The training programs that need to be implemented include training on the latest SOPs and updated work instructions, training on the importance of cleanliness and proper yarn handling, and training on raw material inspection procedures.

c. Communication and Development

The success of the Control phase cannot be separated from effective communication and strong cooperation among the departments involved. Best practices that have been proven effective in reducing defect rates need to be standardized as official company procedures and thoroughly communicated to all sections directly involved in the production process. In this context, close coordination between the Production Department, Machine Technicians, and Human Resources Department is highly required. The synergy among these three parties will ensure that every planned improvement action can be implemented optimally, both in terms of effectiveness and efficiency.

With the implementation of all established control mechanisms, the company will become increasingly capable of minimizing the possibility of recurring defect root causes in the production process. Through structured monitoring and the implementation of standardized operational discipline, PT XYZ is expected to achieve statistically stable process conditions, continuously reduce defect rates, and move toward the zero-defect target as a concrete manifestation of the company's commitment to consistently and comprehensively implementing the Six Sigma approach.

6. Comparison of DPMO Before and After Improvement

Table 11. DPMO Calculation After Improvement

Month	Production Quantity	Defect Reduction Based on RPN Effectiveness	Total Defects	CTQ	DPMO	Sigma Level
January	211730	34253	6045	4	7137	3,95
February	191240	31521	8890	4	11622	3,77
March	211730	34346	9687	4	11438	3,78
April	204900	29996	8461	4	10323	3,81
May	211730	32181	9077	4	10717	3,80
June	204900	30941	8727	4	10648	3,80
July	211730	30422	8580	4	10131	3,82
August	211730	32123	9060	4	10698	3,80
Total	**1659690**		**68527**	**4**	**10322**	**3,81**

a. Calculating RPN Effectiveness Value

$$RPN\ Effectiveness = \frac{Total\ RPN\ Before\ Improvement\ -\ Total\ RPN\ After\ Improvement}{Total\ RPN\ Before\ Improvement}$$

$$\frac{1976\ x\ 426}{1976}\ x\ 100\% = 78\%$$

b. Reducing Production Defects through Effectiveness Values

= Total Defects Before Improvement − RPN Effectiveness Value of Total Defects Before Improvement

c. Calculating Defect Per Million Opportunities (DPMO)

$$DPMO = \frac{6584}{1659690\ X\ 4}\ X\ 1.000.000 = 15867$$

d. Calculating Sigma Level

$$Sigma\ Level = NORMSINV\frac{1.000.000 - 15867}{1.000.000} + 1{,}5 = 3{,}65$$

Table 12. Comparison of DPMO Before and After Improvement

Month	Production Quantity	Total Defects	CTQ	DPMO	Sigma Level
Total	1.659.690	324.310	4	48.850	3,16
Total	**1.659.690**	**71.348**	**4**	**10.747**	**3,80**

Based on the projected process capability table after improvement, it can be observed that the estimated quality improvement (expected condition) of production was calculated using the success percentage of the proposed Failure Mode and Effects Analysis (FMEA) improvements. The effectiveness value of 78% previously obtained from the percentage reduction in the total Risk Priority Number (RPN) was directly applied as the basic assumption for calculating the estimated reduction in the number of defective products based on the company's historical data. In other words, the proposed improvements are assumed to be capable of eliminating 78% of the total defects occurring during the production process.

The impact of this improvement effectiveness provides a significant result on the company's quality performance. In total, from a production volume of 1,659,690 units, the number of defective products, which previously reached 324,310 units, is projected to be drastically reduced to only 71,348 units. This substantial reduction in defective products automatically improves the overall Six Sigma performance metrics of the company.

This improvement is demonstrated by the Defects Per Million Opportunities (DPMO) value, which decreases from 48,850.99 to only 10,747. As the most crucial final result, the estimated process capability of the company shows a significant improvement, where the

Sigma level increases from 3.16 to 3.80. This improvement in performance metrics confirms that the implementation of the proposed operational improvements is theoretically highly effective in minimizing waste and enhancing quality reliability on the production floor.

E. CONCLUSION

The POY yarn production process during the January–August 2025 period generated a total of 29,926 defective rolls from a total production volume of 1,659,690 rolls. The process capability measurement results showed a Defects Per Million Opportunities (DPMO) value of [insert DPMO value] with a sigma level of [insert sigma level]. These results indicate that the production process still requires continuous improvement efforts to achieve the zero-defect target.

The Pareto Diagram analysis identified that the dominant defects in POY products were DTI (Deep Texture Irregularity) defects with 17,046 occurrences (56.96%) and Elong (Elongation) defects with 6,154 occurrences (20.56%). These two defect types contributed 77.52% of the total defects, making them the main priorities for improvement planning.

The root cause analysis using the Fishbone Diagram identified that DTI and Elong defects were caused by four main factors (4M), namely Man, Machine, Method, and Material. The Man factor was related to the lack of operator accuracy and concentration due to fatigue, as well as communication errors during parameter adjustments at shift changes. The Machine factor was associated with fluctuations in beam temperature, unstable machine drawing processes, and worn machine components. The Method factor was related to non-standardized calibration procedures and inadequate preventive maintenance implementation. Meanwhile, the Material factor was caused by fluctuating raw material quality due to mixed material lots and non-optimal technical lubricant specifications.

Improvement recommendations developed through the 5W+1H approach in the Improve phase resulted in several proposed actions, including the implementation of visual Standard Operating Procedures (SOPs)/One Point Lessons (OPL), standardization of calibration checklists, strengthening of the Total Productive Maintenance (TPM) system, improvement of raw material inspection, scheduled maintenance of machine components, and implementation of work rotation systems and written handover procedures between shifts to minimize human errors.

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REFERENCES

Ahmed, T., Toki, G. F. I., Mia, R., Li, J., Islam, S. R., & Rishad, M. M. A. (2022). Implementation of the six-sigma methodology for reducing fabric defects on the knitting production floor: a sustainable approach for knitting industry. *Text Leather Rev*, *5*(1), 223-239. https://doi.org/10.31881/TLR

Altezza, A. D., & Susanty, A. (2023). Analisis Pengendalian Kualitas Kain Grey Dengan Metode Six Sigma (Studi Kasus: PT. Iskandar Indah Printing Textile Surakarta). *Industrial Engineering Online Journal*, *12*(3).

Aulia, F. (2022). *Perbaikan Kualitas Produk Periuk dengan Menggunakan Metode Six Sigma pada CV. Bintang Terang Deli Serdang* (Doctoral dissertation, Universitas Medan Area).

Khofifah, A. N. (2024). Analisis pengendalian kualitas menggunakan metode Six Sigma dan TRIZ guna mengurangi produk defect (Studi kasus pada CV. Karya Wahana Sentosa). *Skripsi, Universitas Islam Indonesia*.

NovaRizky, M. (2024). Analisis Pengendalian Kualitas Produk menggunakan Pendekatan Dmaic Six Sigma (Studi Kasus: Umkm Elkanz Coffee Roastery). *Universitas Islam Indonesia*.

Pambudi, D. (2019). *Peta Kendali Atribut dan Variabel*. Retrieved from: https://www.scribd.com/document/429211949/Peta-Kendali

Rastiawan, H., Susandi, D., & Perwiranegara, A. A. (2021, August). ANALISIS Kualitas Produk Pada Proses Twisting Dengan Metode Six Sigma Di Pt. Xyz. In *SEMINAR TEKNOLOGI MAJALENGKA (STIMA)* (Vol. 5, pp. 323-329).

Ruiz, A. B., Cruz, E. U. M., Olvera, K. P. M., Zúñiga, E. M. E., & Uribe, R. C. (2025). Quality Improvement in Interlining Manufacturing Through the Six Sigma DMAIC Methodology: A Case Study. *ARANDU UTIC*, *12*(4), 3317-3333. https://doi.org/10.69639/arandu.v12i4.1881

Shakila, N. D. (2018). *Penerapan Metode Six Sigma Dalam Upaya Pengurangan Defect Karung Plastik DI PT. Yanaprima Hastapersada TBK* (Doctoral dissertation, Universitas Brawijaya).

Sihaloho, R. J. (2019). *Pengendalian Kualitas Botol 1L dengan Metode Six SIgma di PT. Pacific Medan Industri* (Doctoral dissertation, Universitas Medan Area).

Zulkhulaifah, J. A., & Apriliani, F. (2024). Penerapan *Six Sigma* dan Metode *Define*, *Measure*, *Analyze*, *Improve*, *Control* (DMAIC) untuk Analisis Green Tyre Shortage di PT Merpati Putih. *Factory Jurnal Industri, Manajemen dan Rekayasa Sistem Industri*, *2*(3), 119–133. https://doi.org/10.56211/factory.v2i3.495