



Analysis of Yarn Materials Defects in the Warping Process using Fault Tree Analysis with Improvement Proposals 5W1H Based on the 5W1H Method

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Abstract

Quality control is a critical aspect of the textile industry, essential for maintaining product consistency. However, defects in yarn materials continue to persist, particularly during the warping process. This study investigates yarn defects at PT X using the Fault Tree Analysis (FTA) method, identifying 15 root causes and proposing corrective measures based on the 5W1H approach. The research specifically addresses defects in Tetoron Rayon (TR) yarn Ne 30, with a focus on Cross Defects, Defective Rolls, and Ngloklor Rolls. The FTA method offers a structured approach to failure analysis, while the 5W1H method is employed to derive strategic corrective actions. The findings demonstrate that the probability of defect occurrence varies between the Direct and Sectional Warping processes. Cross Defects occur with probabilities of 0.1333% and 0.126%, Defective Rolls with probabilities of 0.159% and 0.243%, and Ngloklor Rolls with probabilities of 1% and 0.171%, respectively. The analysis identifies 15 primary root causes contributing to these defects, which include machine-related failures, human error, and material inconsistencies. Based on these findings, the study recommends the implementation of preventive maintenance schedules, operator training programs, and a more rigorous adherence to standard operating procedures (SOPs). The proposed improvements are expected to optimize the warping process and enhance the overall quality of the product.

Introduction

Quality control of raw materials is a critical factor in ensuring product consistency and performance, particularly in the textile industry (Okoro, 2024; Begum et al., 2024; Chepkorir & Nderui, 2025). As stated by Assauri (2004) in Paquita and Laksono (2022), quality control refers to systematic efforts to maintain product quality in accordance with established company standards and procedures. Despite adherence to production protocols, defects may still occur, indicating the necessity for a more in-depth quality assurance mechanism. PT X, a textile manufacturing company specializing in used textile goods, utilizes Tetoron Rayon (TR) yarn Ne 30 comprising 65% polyester and 35% rayon as its primary raw material. This yarn is selected due to its moderate elasticity, smooth surface, and appropriate fineness, which support the production of dense and absorbent fabrics while minimizing breakage risks during processing (Hendra, 2022; Dejene et al., 2024; Othman et al., 2024). Nonetheless, defects continue to arise, particularly during the warping stage, even after undergoing quality inspections. Warping is conducted using both Direct Warping and Sectional Warping methods, wherein yarns are transferred from cones to warp beams in parallel alignment under

controlled tension and speed (Majumdar, 2017; Nawa, 2023; Eren et al., 2025). Friction between yarn and machine components during this stage contributes to physical degradation of the yarn, leading to defects such as Cross Defects, Defective Rolls, and Nglokor Rolls (loosened rolls). Company data indicate that the defect rate during Direct Warping reaches 4.09%, while Sectional Warping exhibits a higher defect rate of 6.09%, resulting in a cumulative defect rate of 10.18%. This figure exceeds the company's tolerance threshold of 6–8% and is thus classified as a major defect requiring corrective action. To address this issue, the Fault Tree Analysis (FTA) method is employed to identify and analyze the root causes of yarn defects. FTA is a top-down, deductive failure analysis technique that utilizes graphical fault tree models to represent the logical relationship between system failures and their causes (Imam et al., 2024; Dong et al., 2020). The analysis involves five main stages: problem identification and boundary setting, graphical modeling, determining minimal cut sets, qualitative analysis, and quantitative evaluation (Safira & Damayanti, 2022; Nurfatha & Herwanto, 2023; Lorenza & Rahman, 2023). In addition, a 5W1H approach is applied to formulate strategic improvement recommendations by answering key questions: What, Why, Where, When, Who, and How (Surya & Ririh, 2021; Ramadhani & Chairani, 2022). The integration of Fault Tree Analysis (FTA) and 5W1H is expected to facilitate effective identification of root causes, formulation of corrective actions, optimization of the warping process, and overall enhancement of product quality to meet industry standards.

Methods

Data analysis in this study employed the Fault Tree Analysis (FTA) method, a deductive, top-down approach widely utilized for identifying and analyzing the root causes of system failures (Jovanović et al., 2025; Abdulhamid et al., 2024). FTA systematically decomposes a primary failure event into its contributing sub-events, enabling the estimation of failure probabilities and assessment of systemic vulnerability (Du et al., 2021). It serves both proactive and reactive functions facilitating preventive maintenance strategies and supporting retrospective investigations into quality-related issues. The analytical process is typically visualized through a hierarchical logic diagram, mapping interdependencies between causal events and the top-level failure, thereby supporting structured reasoning and decision-making (Yazdi et al., 2023). In accordance with Sumasto et al. (2023), FTA is particularly effective in industrial settings for tracing defect origins and identifying latent factors that influence product nonconformities. The method supports the formulation of targeted corrective actions and continuous quality improvement by elucidating causal pathways that may not be readily observable through traditional inspection processes. Hence, its application in this study was deemed appropriate for diagnosing recurrent defects in PE plastic tarpaulin production, allowing for a structured evaluation of systemic weaknesses and quality risks (Vesely et al., 1981; Izzati & Donoriyanto, 2025; Gazeau et al., 2024).

The adoption of FTA in this research is further substantiated by a body of contemporary literature emphasizing its relevance in complex manufacturing environments (Afolabi et al., 2025; Rehman & Shakeel, 2025; Wiredu et al., 2024). Recent advancements have extended classical FTA through integration with probabilistic and fuzzy logic techniques to address uncertainties and continuous variable interactions often encountered in production systems (Akhtar & Kirmani, 2020; Wu et al., 2023; He et al., 2025; Izzati & Donoriyanto, 2025). For instance, Wu et al. (2023) applied a fuzzy FTA model to enhance diagnostic precision under uncertain operating conditions, while He et al. (2025) demonstrated the efficacy of coupling FTA with Bayesian Networks in predictive maintenance frameworks. Moreover, Izzati (2025) utilized the method specifically in the context of PE plastic tarpaulin manufacturing, successfully identifying dominant defect types and their root causes.

Despite its utility, FTA is not without methodological constraints. A notable limitation lies in its binary logic assumption wherein system elements are classified as either functioning or

failed thereby failing to account for gradual deterioration, stochastic fluctuations, or operator-dependent variations (Pan et al., 2022; Chen et al., 2024). Real-world production environments are often influenced by continuous variables such as humidity levels, mechanical wear, and human factors like fatigue, which are not adequately captured through Boolean fault trees. Nevertheless, in the context of this study, FTA remains a valuable exploratory framework for initial root cause identification, particularly in systems exhibiting repeatable failure patterns (Berri et al., 2024; Solouki et al., 2024; Jiang & Liu, 2025).

Results and Discussion

This research was conducted at PT X during February 2025, focusing on identifying and analyzing the causes of defects in TR 30 yarn raw materials during the warping process. Two primary analytical methods were employed: Fault Tree Analysis (FTA) and the 5W1H approach. The initial stage of the study involved identifying variables to determine contributing factors that lead to defects. The data used in this research consisted of both primary and secondary sources. Primary data were obtained through direct observation at the production site and interviews with relevant personnel, while secondary data included historical production records and defect data related to both Direct Warping and Sectional Warping. Data processing was conducted using the Fault Tree Analysis (FTA) method, a structured, top-down deductive approach effective for both proactive failure prevention and reactive root cause identification (Yazdi et al., 2023). The procedure involves: (1) identifying defect types in the warping process, (2) determining the Top Event as the most critical defect, (3) analyzing contributory causes, (4) identifying Basic Events as root causes, (5) constructing a fault tree diagram using logical gates (AND/OR) to illustrate causal relationships (Mahyar & Supryadi, 2020), (6) applying the Cut Set Method to identify minimal combinations of Basic Events leading to the Top Event, and (7) formulating corrective actions using the 5W1H framework (What, Why, Where, When, Who, and How).

In this study, the data utilized includes production volume data and the number of defects that occurred in the TR 30 yarn raw materials during the Direct Warping and Sectional Warping processes over a six-month period, as detailed in Table 1.1. Three types of defects were identified throughout these processes, namely Cross Defects, Defective Rolls, and Nglokor Rolls (loosened rolls).

Table 1. Total Production and Total Defects

Months	Total Production		Total Defects	
	<i>Direct Warping (Yard)</i>	<i>Sectional Warping (Yard)</i>	<i>Direct Warping (Yard)</i>	<i>Sectional Warping (Yard)</i>
July	14300	10213	1239,073	1073,69
August	11000	31005	709,259	725,311
September	38500	10210	896,18	1158,802
October	15400	5643	910,09	1150,841
November	31499	5576	567,89	819,69
December	24073	31201	1199,38	788,69
Total	134772	93848	5522	5717

Source: Company's Internal Data, 2024

Based on the data provided, a histogram diagram can be constructed for each process to determine the type of defects that occur most frequently. This method allows for the identification and visualization of trends in defect occurrences, enabling a better understanding of which process stages are most susceptible to errors or deficiencies. The analysis will highlight the most common defects and provide insight into areas requiring improvement, contributing to more effective quality control and process optimization.

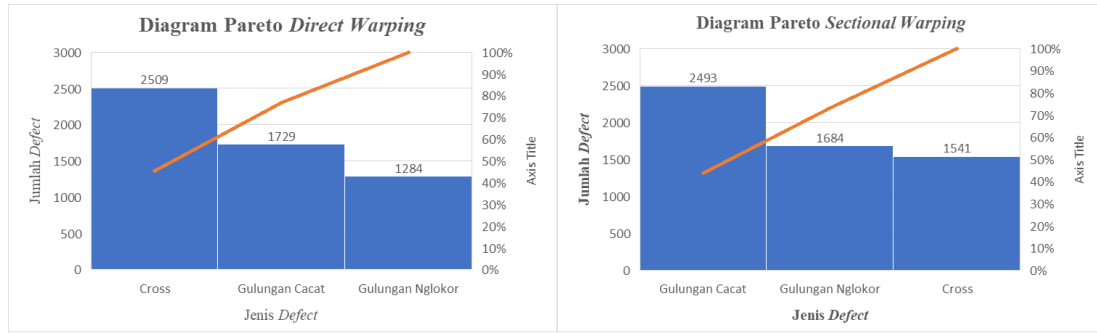


Figure 1. The Pareto of Defects in Direct Warming and Sectional Warming

Based on Figure 1, based on the Pareto diagram above, it can be concluded that the predominant defect in TR 30 yarn during the direct warming process is the Cross yarn break, which accounts for a total of 2,509 yards or 45.44% of all recorded defects. The corresponding Pareto diagram for the Direct Warming process indicates that Cross yarn break and Defective Rolls are the primary issues that require immediate corrective action, as they contribute to the majority of quality problems observed during the process. Furthermore, as shown in figure above, the dominant defect during the Sectional Warming process for TR 30 yarn is the Defective Roll, with a total of 2,493 yards or 43.60% of the total defects. According to the Pareto analysis for this stage, and following the Pareto principle (80/20 rule), it can be inferred that Defective Rolls and Nglokori Rolls are the most significant contributors to quality issues in Sectional Warming. Together, these two defect types account for approximately 71% of the total observed defects, indicating that the majority of production issues stem from these specific causes.

Fault Tree Analysis (FTA) in Direct Warming Process

Cross Defect

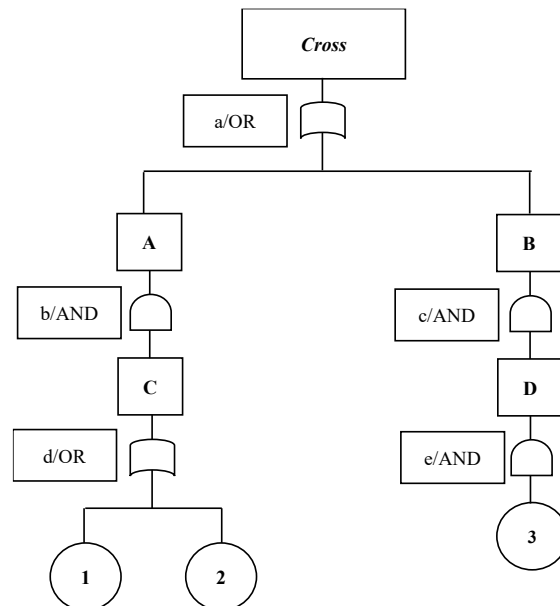


Figure 2. The Fault Tree Diagram of Cross Defect in Direct Warming Process

Description:

A : Machine

B : Man

- C : Machine Malfunction
- D : Human Error
- 1 : Malfunction of the Stop Motion mechanism
- 2 : Corrosion on the machine's Creel path
- 3 : Operator inattention during yarn setting on the creel path

The classification of defect causes in this study follows a coding system consisting of two primary categories: machine-related factors (A) and human-related factors (B). Machine-related issues are further detailed into malfunctions, such as the non-functioning of the stop motion mechanism (Code 1) and corrosion in the creel path of the machine (Code 2), both of which can disrupt the continuity and quality of yarn processing. On the other hand, human-related errors include operator inattentiveness during the yarn setting process on the creel path (Code 3), which may lead to improper tension or yarn breakage. These codes serve to identify and differentiate the root causes of defects. The next step involves conducting a defect evaluation using Cut Set Method, which will produce a Cut Set Matrix derived from corresponding fault diagram. This method allows for the systematic identification and analysis of all possible combinations of basic events that can lead to a system failure, thereby providing deeper insights into the root causes of defects.

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Figure 3. The Cut Set Matrix of Cross Defect in Direct Warping Process

Based on the results of the Cut Set analysis, it can be inferred that the occurrence of the Cross defect is attributed to three primary factors: the malfunction if the stop motion mechanism, corrosion in the creel path of the machine, and operator inattention during the yarn setting process. The Cross defect was found to be influenced by both machine-related and human-related factors. From the mechanical perspective, the occurrence of Cross defects is primarily due to malfunctioning equipment, specifically non-functional stop motion devices and rusted creel paths on the warping machine. On the human side, the defect arises due to operator error, particularly the lack of attention during the yarn setting process on the creel path. Probability calculations for the Cross defect indicate that the basic event of a non-functioning stop motion device yielded a probability value of 0.00013, equivalent to 0.33 yards of defective output. For the rusted creel path, the calculated probability was 0.00048, or 1.2 yards. Meanwhile, the basic event related to operator inattentiveness during yarn setting resulted in the highest probability, at 0.00072, or 1.81 yards. Thus, the total probability of the Cross defect before corrective evaluation was 0.00132, corresponding to 0.132% over a six-month period of direct warping operations.

Defective Rolls Defect

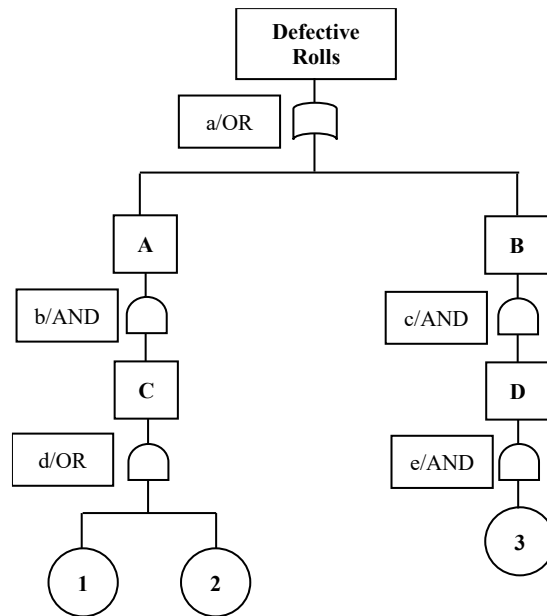


Figure 4. The Fault Tree Diagram of Defective Rolls Defect in Direct Warping Process

Description:

A : Method

B : Machine

C : Improper Splicing Method (not in accordance with SOP)

D : Loose Tension in Spinning and Winding Machines

1 : Yarn splice is too bulky

2 : Yarn entanglement of the beam

3 : Inadequate machine maintenance

The subsequent stage requires a defect evaluation utilizing the Cut Set Method, which will result in the generation of a Cut Set matrix based on the developed fault tree diagram.

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Figure 5. The Cut Set Matrix of Defective Rolls Defect in Direct Warping Process

The Cut Set analysis revealed that the root causes of Defective Rolls defect are contributed to oversized yarn splices, yarn entanglement on the beam, and insufficient machine maintenance. The Defective Roll defect in yarn raw material is influenced by two main factors: method and machine. Method-related causes include improper yarn splicing that does not follow the standard operating procedure (SOP), resulting in oversized joints and yarn entanglement on

the beam both of which lead to defective winding and subsequent yarn breakage. On the machine side, the defect is caused by loose tension in the spinning and winding machines due to insufficient maintenance, increasing the likelihood of winding failure.

The probability values for the basic events oversized splicing and yarn entanglement are each 0.0005 (0.86 yards), while poor machine maintenance contributes a probability of 0.00059 (1.02 yards). The total probability of the Defective Roll defect prior to evaluation was 0.00158 (0.158%), and after evaluation, it was slightly higher at 0.00159 (0.159%). These results indicate no significant change, but both methods produced outcomes within optimal performance limits.

Nglokor Rolls Defect

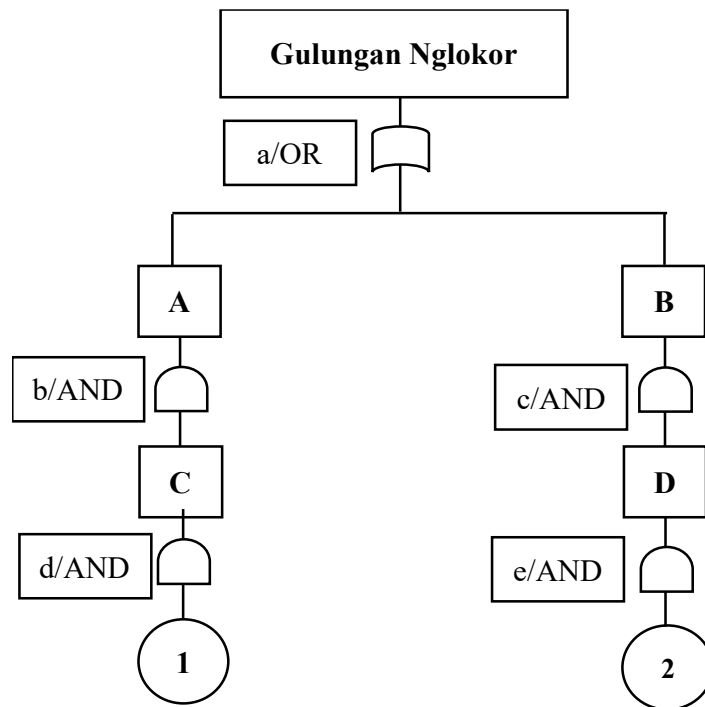


Figure 6. The Fault Tree Diagram of Nglokor Rolls Defect in Direct Warping Process

Description:

- A : Material
- B : Machine
- C : Yarn sticking together
- D : Dirty combs in the spindle
- 1 : Yarn condition is damp
- 2 : Excessive fly waste on the machine

The next step involves conducting a defect evaluation using the Cut Set Method, which will generate a Cut Set matrix derived from the constructed fault tree diagram.

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Figure 7. The Cut Set Matrix of Nglokora Rolls Defect in Direct Warping Process

The Cut Set analysis in Figure 7 indicates that the root cause of the Nglokora Rolls is influenced by two main factors: a material-related factor, specifically the damp condition of the yarn, and a machine-related factors, namely the accumulation of excessive fly waste on the machine. The defect is primarily caused by two major factors: material quality and machine condition. On the material side, the defect arises from sticky yarns due to high moisture content, which causes the yarns to adhere to one another and form tangled rolls during the warping process. From the machine perspective, the issue is linked to dirty reed combs caused by excessive fly waste accumulation, which disrupts the smooth operation of the warping machine.

The probability associated with the basic event of moist yarn condition is 0.00056 (0.72 yards), while the basic event of excessive fly waste yields a probability of 0.00045 (0.58 yards). Thus, the total probability for the Gulungan Nglokora defect, both before and after evaluation, remains constant at 0.001 (1%) over a six-month period of direct warping operations. These results indicate that no significant change occurred, and both methods produced consistently optimal outcomes.

Fault Tree Analysis (FTA) in Sectional Warping Process

Cross Defect

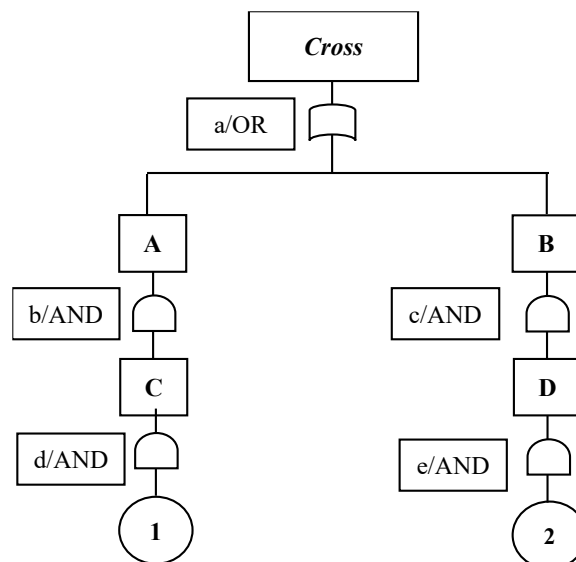


Figure 8. The Fault Tree Diagram of Cross Defect in Sectional Warping Process

Description:

A : Machine

B : Man

C : Declining machine reliability

D : Human Error

1 : Worn expansion comb on the spindle

2 : Operator inattention during yarn setting in the creel path

The subsequent stage requires a defect evaluation utilizing the Cut Set Method, which will result in the generation of a Cut Set matrix based on the developed fault tree diagram.

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Figure 9. The Cut Set Matrix of Cross Defect in Sectional Warping Process

Based in the Cut Set analysis, it can be concluded that there are two main factors contributing to the Cross defect in the Sectional Warping process: machine-related and human-related factors. On the human side, the defect occurs due to operator inattentiveness during yarn setting on the creel path. On the mechanical side, it is caused by the deterioration of machine components, specifically the worn expansion reed, which reduces machine accuracy. These factors collectively increase yarn misalignment, ultimately resulting in the Cross defect.

Probability analysis indicates that the basic event Operator Error during Yarn Setting contributes a probability of 0.00085 (1.31 yards), while Worn Expansion Reed contributes 0.00041 (0.63 yards). The total pre-evaluation probability for this defect was 0.00125 (0.125%), and post-evaluation it slightly increased to 0.00126 (0.126%) over a six-month period of Sectional Warping. These results show no significant change, and both conditions were found to produce optimal outcomes within acceptable quality limits.

Defective Rolls Defect

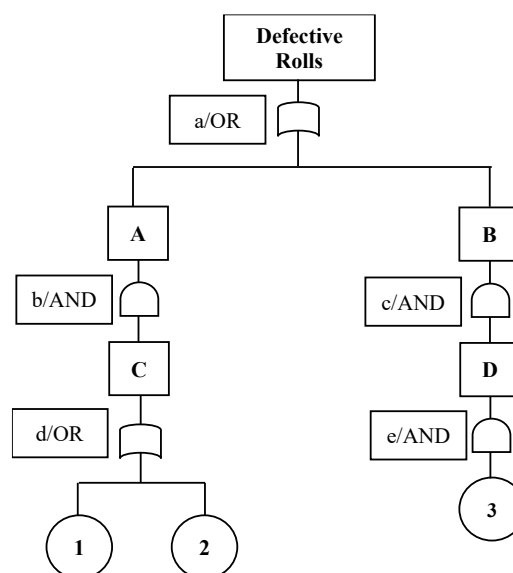


Figure 10. The Fault Tree Diagram of Defective Rolls Defect in Sectional Warping Process

Description:

A : Man

B : Machine

C : Human Error

D : Loose tension on the temporary winding cylinder

1 : Operator did not pay attention to the winding direction

2 : Operator incorrectly set the machine speed

3 : Inadequate machine maintenance

The following stage entails performing a defect evaluation through the application of the Cut Set Method, which will produce a Cut Set matrix based on the constructed fault tree diagram.

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Figure 11. The Cut Set Matrix of Defective Rolls Defect in Sectional Warping Process

Based on figure above, the root causes of the Defective Rolls defect are identified as originating from two primary sources: human-related and machine-related. The human-related are attributed to operator negligence, specifically the failure to monitor the winding direction and incorrect configuration of machine speed on the Sectional Warping equipment. These operational mistakes are classified as human errors that directly contribute to the occurrence of the defect. Meanwhile, the machine-related cause is linked to insufficient tension on the temporary winding cylinder, which stems from inadequate machine maintenance.

The calculated probability for the defect, based on the basic event Operator failing to monitor roll direction, was 0.00075 (1.87 yards). The basic event Incorrect machine speed setting by the operator contributed a probability of 0.00078 (1.94 yards), while Poor machine maintenance resulted in a probability of 0.0009 (2.24 yards). The total probability before evaluation was 0.00242 (0.242%), and after evaluation, it slightly increased to 0.00243 (0.243%) over a six-month Sectional Warping period.

These results indicate that there was no significant difference between pre- and post-evaluation outcomes. Nevertheless, both methods demonstrated optimal performance within acceptable quality thresholds.

Nglokor Rolls Defect

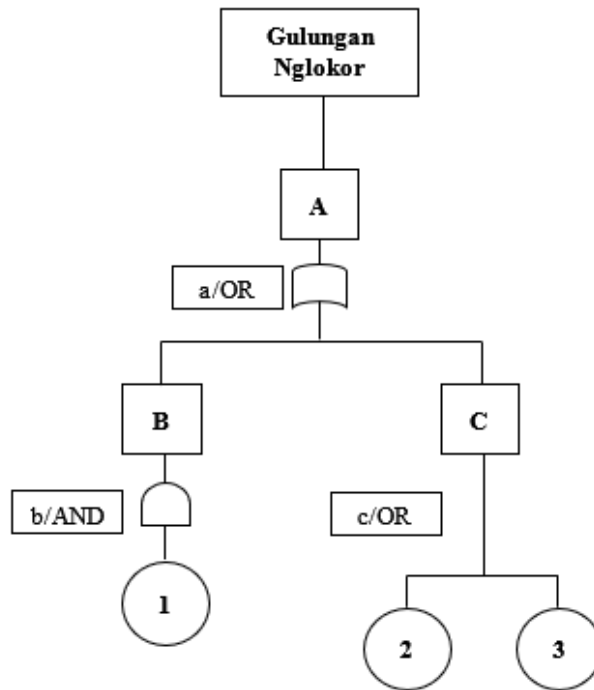


Figure 12. The Fault Tree Diagram of Nglokor Rolls Defect in Sectional Warping Process

Description:

- A : Machine
- B : Dirty expanding reed machine
- C : Corroded lease rods
- 1 : Yarn entangled with fly waste forming clumps
- 2 : Frayed yarn condition
- 3 : Excessive temperature fluctuations

The subsequent phase involves assessing the identified defect using the Cut Set method, which will yield a Cut Set matrix based on the established fault tree diagram.

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Figure 13. The Cut Set Matrix of Nglokor Rolls Defect in Sectional Warping Process

The Cut Set matrix presented above indicates that there are three causes contributing to occurrence of the Nglokor Rolls defect in TR 30 yarn material. Both causes originate from the same resources: machine-related factors. This includes a dirty expandible reed, where yarn becomes entangled with fly waste forming clumps, and rusted lease rods, where extreme temperature conditions induce condensation and corrosion. The presence of rust leads to yarn surface damage, causing the fibers to fray upon contact and contributing to the occurrence of the defect.

Probability analysis showed that the basic event yarn entangled with fly waste contributed 0.00084 (1.41 yards), while the basic event frayed yarn due to rusted machine parts had a probability of 0.00088 (1.48 yards). The total probability before evaluation was 0.00171 (0.171%), and after evaluation, it slightly increased to 0.00172 (0.172%) over a six-month Sectional Warping period. These results indicate no significant change, while both scenarios demonstrated optimal outcomes under current production conditions.

The Proposed Improvement Recommendation

To address the recurring defects identified in the warping process, several improvement actions are proposed using the 5W1H approach. What needs to be improved is the quality control of yarn winding, particularly in reducing defects such as Cross, Defective Rolls, and Nglokor Rolls. Why these improvements are necessary is due to the high defect rates that impact production efficiency, material waste, and product consistency. Where the improvements should be implemented is at critical points in the Direct and Sectional Warping processes, especially at the creel area, winding section, and machine maintenance zones. When the improvements should be carried out is continuously throughout the production period, with initial actions prioritized following the completion of this study. Who is responsible includes both operators and the maintenance team, supported by production supervisors and quality control personnel. How the improvements will be implemented involves corrective actions such as enhanced operator training, revision of standard operating procedures (SOP), regular machine cleaning and maintenance schedules, and improved monitoring systems.

Table 2. Improvement Recommendations for The Warping Process

THE IMPROVEMENT RECOMMENDATIONS FOR THE DIRECT WARPING PROCESS							
DEFECT TYPES	ROOT CAUSES	WHAT The Primary Goal of the Improvement	WHERE Location of The Planned Improvement	WHEN Scheduled Time for Improvement	WHY Justification for The Improvement	WHO Responsible Party for the Improvement	HOW Method of Improvement
Cross	Malfunction of the Stop Motion mechanism	To restore the functionality of the Stop Motion system	On the tension equipment	During the idle Stop Motion machine times and through daily checks	To detect yarn breakage during winding and ensure yarn tension remains intact on the machine	Maintenance Specialist	Replacement of the Stop Motion unit if needed; routine inspections to prevent equipment failure
	Corrosion on the machine's Creel Path	To repair the body part of the Creel Path to prevent corrosion	On the body part of the Creel Path	During inspection or preventive maintenance	To reduce yarn breakage and Cross-type defects caused by corroded Creel Paths	Maintenance Specialist	Clean the creel path using rust remover and re-coat with anti-rust layers; replace parts with

							stainless steel if worn
	Operator inattention during yarn on the Creel path	To improve operator performance	On the creel oath	During morning briefing sessions as operator reminders	To prevent yarn misalignment that can lead to Cross defects during the warping process	Shift Supervisor & Staff	Conduct periodic operator training and increase SOP inspection frequency
Detective Rolls	Yarn splice is too bulky	To improve the yarn splicing method	At the location of yarn breakage	During yarn break conditions	To ensure operators follow SOP to minimize splicing-related defect	Operator dan Staff	Provide regular training for proper yarn splicing according to SOP
	Yarn entanglement of the beam	To enhance the yarn joining method	On the beam of the winding section	When defect occurs causing yarn breakage	To prevent yarn misplacement that results in entanglement and defects	Operator and Staff	Ensure correct yarn path and machine speed are set based on yarn type; recheck yarn alignment post-process
	Inadequate machine maintenance	To improve machine performance	On the spinning and winding machines	During inspection or preventive maintenance	To maintain machine stability and reduce the risk of Nglokor Rolls defects	Maintenance Specialist	Perform regular machine inspections and weekly routine maintenance
Nglokor Rolls	Yarn condition is dump	To prevent yarn sticking and Nglokor defects	On the yarn material	When yarn appears sticky or moist	To ensure yarn remains in proper condition prior to warping	Operator and Staff	Check yarn condition before the warping process
	Excessive fly waste on the machine	To optimize machine functionality	On the expansion comb equipment	During preventive maintenance inspection	To ensure optimal comb performance and prevent defect generation	Maintenance Specialist	Clean and maintain the equipment regularly
THE IMPROVEMENT RECOMMENDATIONS FOR THE SECTIONAL WARPING PROCESS							
DEFECT TYPES	ROOT CAUSES	WHAT	WHERE	WHEN	WHY	WHO	HOW
		The Primary Goal of the Improvement	Location of The Planned Improvement	Scheduled Time for Improvement	Justification for The Improvement	Responsible Party for the Improvement	Method of Improvement
Cross	Worn expansion comb on the spindle	To improve machine performance	On the expansion comb of the spindle	During inspection or preventive maintenance	To restore the reliability of machine functionality and reduce the occurrence of defects	Maintenance Specialist	Replace worn components, perform weekly inspections to assess machine condition,

							and conduct routine cleaning and maintenance
	Operator inattention during yarn setting in the Creel path	To improve operator performance	On the Creel path	During morning briefing as operator reminder	To prevent yarn misalignment on the path, thereby avoiding defects during the process	Shift Supervisor & Staff	Conduct regular operator training to reinforce SOP compliance and enhance inspection frequency by supervisors
Detective Rolls	Operator didn't pay attention on the winding direction	To improve operator performance	On the winding path	During the warping process	To prevent operator error in winding direction, thus minimizing defect occurrence	Operator and Staff	Conduct regular training to emphasize SOP clarity and raise awareness about work focus
	Operator incorrectly set the machine speed	To improve operator performance	On the warping machine	During the warping process	To avoid operator oversight when setting machine speed	Operator and Staff	Conduct recurring operator training to clarify SOP and emphasize focus and awareness during operations
	Inadequate machine maintenance	To improve machine performance	On the temporary winding cylinder machine	During inspection or preventive maintenance	To ensure the winding cylinder operates under ideal tension conditions	Maintenance Specialist	Perform routine machine inspections and establish a weekly maintenance schedule
Nglokor Rolls	Yarn entangled with fly waste forming clumps	To optimize machine functionality	On the Expandle Reed machine	During inspection or preventive maintenance	To restore optimal machine performance and prevent yarn entanglement caused by accumulated contaminants	Maintenance Specialist	Perform regular cleaning and machine maintenance
	Frayed yarn condition	To optimize machine functionality	On the Lease Rods machine	During inspection or preventive maintenance	To restore machine performance degraded by corroded components, preventing excessive friction that causes yarn fraying	Maintenance Specialist	Conduct routine cleaning using rust remover across the component surface. Apply anti-rust coatings and conduct regular

							inspections to anticipate potential part damage
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Conclusion

There are three types of defects that occur in TR 30 yarn raw material during both the Direct Warping and Sectional Warping processes. In the Direct Warping process, the probability of occurrence for the Cross defect is 0.1333%, the Defective Rolls defect is 0.159%, and the Nglokor Rolls defect is 1%. Meanwhile, in the Sectional Warping process, the probability of occurrence for the Cross defect is 0.126%, the Defective Roll defect reaches 0.243%, and the Nglokor Roll defect is 0.171%. To reduce the occurrence of these defects in TR 30 yarn raw material at PT X, it is recommended to implement a regular preventive maintenance schedule. This measure aims to maintain machine reliability and prevent disruptions or breakdowns during the warping process. In addition, operator training programs should be conducted, and stricter supervision must be enforced to ensure that operators adhere to the established standard operating procedures (SOP).

The primary objective of this investigation is to systematically delineate the causal structure underlying product defects in the yarn production process. In this regard, FTA is employed as a first-line analytical tool, capable of isolating high-risk failure pathways and prioritizing areas for intervention. The findings are interpreted with methodological caution, and it is acknowledged that complementary techniques such as Statistical Process Control (SPC), Failure Mode and Effects Analysis (FMEA), or fuzzy inference systems may be employed in future studies to address limitations related to data uncertainty and continuous input parameters. Nonetheless, the application of FTA in this study provides a rigorous foundation for defect analysis and offers practical insights to guide systemic quality improvements in the production workflow.

Suggestion

I would like to express my deepest gratitude to Allah SWT for the strength, patience, and guidance granted throughout the completion of this thesis. I am also sincerely thankful to my supervisor, Rochmoeljati, for their invaluable guidance and support. My heartfelt appreciation extends to my parents for their unwavering support, insightful feedback, and encouragement, which have played a crucial role in shaping the direction and quality of this research. I also want to thank the lecturers and all my friends in the Industrial Engineering Department at Universitas Pembangunan Nasional “Veteran” Jawa Timur for their knowledge, motivation, and dedication throughout the course of my studies.

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