Effect of Spare-Part Replacement and Machine Modification on Yarn Breakage Reduction in Type L Twist For One (TFO) Machine

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Abstrak

Background : High yarn breakage during the twisting process in Twist For One (TFO) machines significantly reduces production efficiency and increases the proportion of Grade B yarn. Although machine maintenance is routinely performed, limited studies have experimentally evaluated the effectiveness of specific spare-part replacement and machine modification in minimizing yarn breakage and improving yarn quality

Purpose : This study aims to identify the dominant causes of yarn breakage and evaluate the effectiveness of bearing bolster replacement and pipe tensor modification in reducing yarn breakage and improving yarn quality on the Murata 310 Type L CPU TFO machine.

Methodology : An experimental approach employing a **One Group Pretest–Posttest** design was used by comparing machine performance before and after corrective actions. Data were collected through direct observation, interviews, documentation, and spare-part inspections. A Fishbone (Ishikawa) analysis was conducted to identify the root causes of yarn breakage, followed by the implementation of bearing bolster replacement and pipe tensor modification on **17 Murata 310 Type L CPU TFO machines**.

Findings : The Fishbone analysis identified the machine factor as the primary cause of yarn breakage, particularly worn bearing bolsters, improper rotary disk clearance, and an unsuitable pipe tensor configuration that caused unstable yarn ballooning. After implementing the proposed improvements, the percentage of Grade B yarn decreased from **14.7%** to **8.9%**, representing a **5.8% reduction**, while the proportion of Grade A yarn increased accordingly. These results demonstrate that bearing bolster replacement and pipe tensor modification effectively improve yarn winding stability, reduce yarn breakage, and enhance overall product quality.

Implications : The proposed maintenance strategy provides a practical approach for improving production efficiency and yarn quality in textile manufacturing. Future studies should evaluate the long-term effectiveness of condition-based preventive maintenance, investigate its economic impact, and validate the proposed modifications across different TFO machine models and operating conditions.

Originality : This study contributes by experimentally validating the combined effect of **bearing bolster replacement** and **pipe tensor modification** on the performance of the **Murata 310 Type L CPU TFO** machine. Unlike previous studies that primarily focused on identifying the causes of yarn breakage, this research demonstrates a practical maintenance intervention capable of significantly reducing yarn breakage and improving yarn quality in an industrial production environment.

Keywords: Fishbone analysis; Preventive maintenance; Textile manufacturing; Twist For One (TFO); Yarn breakage; Yarn quality.

INTRODUCTION

The rapid development of the manufacturing industry has intensified competition, compelling companies to enhance both productivity and product quality to remain competitive. Modern industrial competition is no longer determined solely by the ability to produce goods in large quantities but also by the capability to consistently deliver products that meet stringent quality standards. Consequently, manufacturers are required to optimize their production processes to achieve high productivity, superior product quality, and minimal defect rates. Maintaining consistent product quality is therefore a critical indicator of operational excellence, customer satisfaction, and sustainable competitive advantage.

The textile industry is one of the manufacturing sectors that heavily depends on the stability and reliability of its production processes. One of the most critical stages in textile manufacturing is the **pre-weaving** process, particularly the **twisting** operation, in which two or more yarns are combined by applying a specific number of twists to improve their tensile strength, elasticity, and appearance according to product specifications. The quality of the twisting process directly influences the quality of the woven fabric produced in subsequent manufacturing stages.

The twisting process is commonly performed using a **Twist For One (TFO)** machine. During operation, the yarn passes through several key machine components, including the **tensor, spindle, rotary disk,** and **snail wire**, before being rewound into twisted yarn. The condition of these components significantly affects yarn tension and balloon formation throughout the twisting process. Excessive wear or damage to machine spare parts increases yarn friction, leading to frequent yarn breakage. Conversely, insufficient balloon formation results in unstable yarn tension, which negatively affects the quality of the twisted yarn.

According to Noerati (2013), increasing the twist level generally improves yarn elongation before breakage. However, the benefits of higher twist cannot be fully realized when the twisting process is performed using poorly maintained machinery. Inadequate machine conditions increase the frequency of yarn breakage, resulting in lower machine efficiency, longer production downtime, and reduced product quality.

Machine maintenance plays a fundamental role in preserving equipment performance and production stability. Maintenance comprises a series of activities aimed at maintaining or restoring equipment to its intended operating condition (Hauzan & Ida, 2025). Effective maintenance minimizes component deterioration, supports continuous production, and ensures consistent product quality (Felecia & Limantoro, 2013). In TFO machines, maintenance effectiveness depends not only on preventive maintenance schedules but also on the service condition and lifespan of critical spare parts. Worn components can increase friction, reduce spindle rotational stability, alter yarn tension, and ultimately lead to higher yarn breakage rates.

According to the operational standard of **PT X**, the acceptable yarn breakage rate for TFO machines is **no more than 3%**, equivalent to approximately **8 broken spindles** out of **256–310 operating spindles** per machine. However, production records collected over the previous four months indicate that the yarn breakage rate consistently exceeded the company's quality standard, as illustrated in **Figure 1**. This persistent deviation suggests that the existing production process has not yet achieved optimal performance and that several operational factors continue to contribute to the high frequency of yarn breakage.

Although previous studies have highlighted the influence of machine condition on yarn quality, most have focused on general maintenance practices without experimentally validating the effectiveness of specific corrective actions on TFO machine performance. In particular, limited attention has been given to evaluating the combined effect of **bearing bolster replacement** and **pipe tensor modification** in reducing yarn breakage under actual industrial operating conditions. Therefore, this

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study aims to identify the dominant causes of yarn breakage using **Fishbone analysis** and experimentally evaluate the effectiveness of targeted spare-part replacement and machine modification in improving yarn quality and production performance on the **Murata 310 Type L CPU TFO** machine.

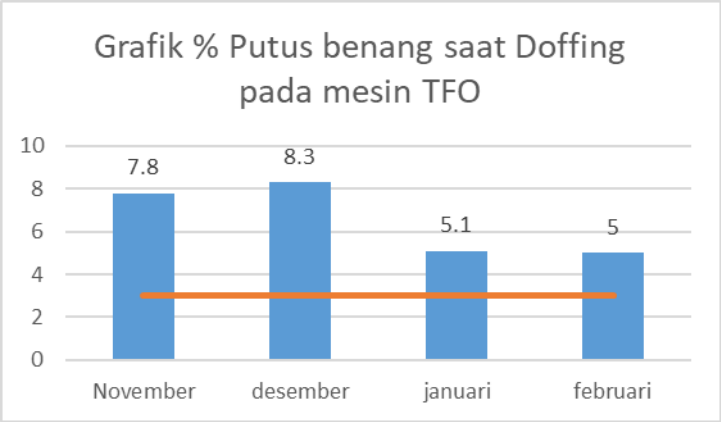


Figure 1. Graph Number of yarn break when doffing in machine TFO

Excessive yarn breakage not only reduces machine efficiency but also results in inconsistencies in the final yarn package weight. Yarn cones with weights below the production specification (*underweight*) cannot proceed directly to subsequent manufacturing stages and therefore require additional reworking, including yarn unwinding and rewinding, to achieve the required weight. When such corrective actions are unsuccessful, the affected yarn is classified as *afval* (production waste), leading to increased material loss, higher production costs, and reduced overall manufacturing efficiency.

Given these challenges, a systematic investigation is required to identify the critical spare parts that contribute to excessive yarn breakage in TFO machines. Identifying the dominant failure components will enable the company to establish more effective maintenance priorities, optimize spare-part replacement strategies, and implement targeted machine modifications. Such improvements are expected to reduce yarn breakage, enhance machine efficiency, maintain consistent yarn quality, and minimize production losses associated with underweight products and manufacturing waste. Ultimately, this study seeks to provide an evidence-based maintenance strategy that improves both operational performance and product quality in industrial TFO operations.

METHODOLOGY

This study employed a **quantitative experimental research** approach to evaluate the effect of machine spare-part condition and modification on yarn breakage during the twisting process using a **Twist For One (TFO)** machine. An experimental design was adopted because specific corrective interventions, including spare-part replacement and modification, were intentionally implemented to examine their impact on machine performance. The effectiveness of these interventions was assessed by comparing the yarn breakage rate before and after treatment under actual production conditions. The independent variables were selected based on the dominant causes of yarn breakage identified during the preliminary investigation, namely **worn and damaged bearing bolsters on the spindle, improper rotary disk clearance, and pipe tensor configuration**. The dependent variable was the yarn breakage rate observed during the twisting process.

Data were collected using three complementary techniques. First, **direct observation** was conducted to monitor the operating conditions of the TFO machines, evaluate the condition of critical spare parts, and record the frequency of yarn breakage during production. Second, **semi-structured**

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interviews were carried out with production supervisors, maintenance technicians, and machine operators to obtain practical insights into the operational factors contributing to yarn breakage. Third, **documentation** was used to collect historical production records, yarn breakage data, maintenance reports, and spare-part inspection records to support the experimental analysis and validate the research findings.

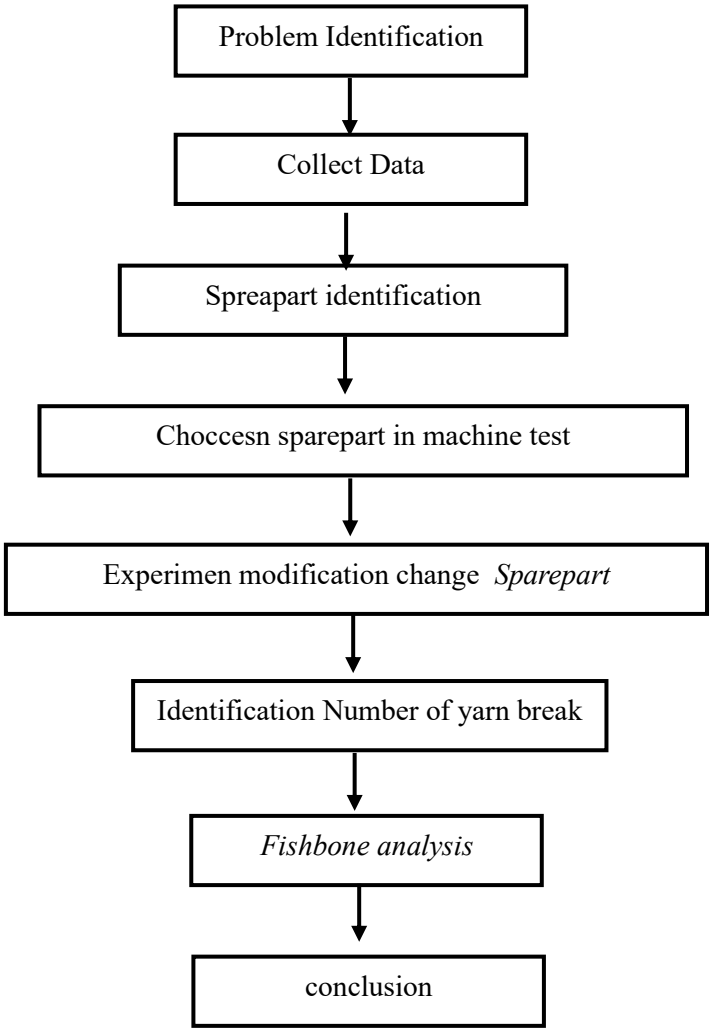


Figure 2 Design Research

To identify the root causes of yarn breakage, direct observations were conducted on the **Murata 310 Twist For One (TFO)** machine under actual production conditions. The observations focused on the operational performance of the machine, the condition of critical spare parts, and the occurrence of yarn breakage throughout the twisting process.

Observation Preparation

The raw material used in this study was **Polyester ITY 50/48 yarn**, which was selected based on its regular use in the production process. Prior to the experimental trials, the yarn was characterized by measuring its **tensile strength** and **elongation** to ensure that the material met the required production specifications and to minimize variations in yarn properties that could influence the experimental results. The mechanical properties of the yarn used in this study are presented in the following table.

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Table 1. Result testing of *strength* and *elongation* materials ity 50-48 before in TM

PRODUCT SPECIFICATIONS **BENANG ITY 50-48 LOT HF-1070550488 SEBELUM DI *TWIST* METER**		
ITEM	UNIT	HASIL
Denier	Gr/9000 m	49.5
Strength	Gr/Denier	2,100
Elongation	%	46.10
BWS	%	49.5
OPU	%	0.92
Interlace	Dot/m	28

Table 2. Result testing strengt and elongation raw materials ity 50-48 after in TM

PRODUCT SPECIFICATIONS **BENANG ITY 50-48 LOT HF-1070550488 SETELAH DI TM 2500**		
ITEM	UNIT	HASIL
Denier	Gr/9000 m	57.8
Strength	Gr/Denier	2,453
Elongation	%	55.08
BWS	%	1.78
OPU	%	1.98
Interlace	Dot/m	-

The specifications of the **Murata 310 Twist For One (TFO)** machine used in this study are presented below:

- **Machine Brand:** Murata 310
- **Country of Origin:** Japan
- **Machine Type:** CPU/L
- **Year of Manufacture:** 1997
- **Balloon Guide Scale:** 5
- **Steel Ball Weight:** 7.9 g × 2
- **Twist per Meter (TPM):** 2,500
- **Spindle Speed:** 12,000 rpm

Before the experimental investigation, the TFO machine underwent a comprehensive inspection conducted by the maintenance department to ensure that its operating condition was accurately documented. The inspection focused on evaluating the condition of critical machine components, including the bearing bolster, rotary disk, spindle assembly, and pipe tensor, to identify wear, damage,

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or mechanical abnormalities that could influence yarn breakage during the twisting process. The inspection results served as the baseline for determining the required spare-part replacement and machine modifications implemented in this study.

Table 3. Result checking part in machine TFO

VALIDASI MESIN TFO NO : 161
Jenis benang ITY 50-48

ITEM CHECK	Jumlah	Keterangan	
		Service	Ganti
Blade Spindle	256	256	0
Bearing Spindle	512	0	512
Bearing bolster	256	240	16
Bottom Step	256	256	0
Bearing Cradle	512	0	512
Spindle Set + Pirn	0	0	0
Driven Belt	2	2	0
Bearing Un Roll	12	0	12
Bearing Up Roll	8	0	8
Bolster	0	0	0
Roll Guide	512	512	0
Feedrool Assy	256	256	0
Coupling Drum	32	32	0
Coupling Feedroll	32	32	0
Spacer	768	752	16
Skala Drum	256	256	0
Tension Pully	36	36	0
Pully RPM	2	2	0
Drop Wire	256	247	9
Casing Feedroll	256	256	0

Inspection of Yarn Breakage

A comprehensive patrol inspection was conducted on **59 Twist For One (TFO) machines** to identify the factors contributing to yarn breakage during the twisting process. The inspection was carried out by the maintenance and production teams through direct observation of machine operating conditions and the condition of critical spare parts. Each occurrence of yarn breakage was examined to determine its primary cause, and the identified factors were subsequently classified and quantified.

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The inspection results indicate that yarn breakage was associated with several machine-related and operational factors, each contributing at different frequencies. The distribution of these factors provides an overview of the dominant causes of yarn breakage and serves as the basis for selecting the components requiring corrective action through spare-part replacement and machine modification. The detailed distribution of the identified causes is presented in **Figure 3**.

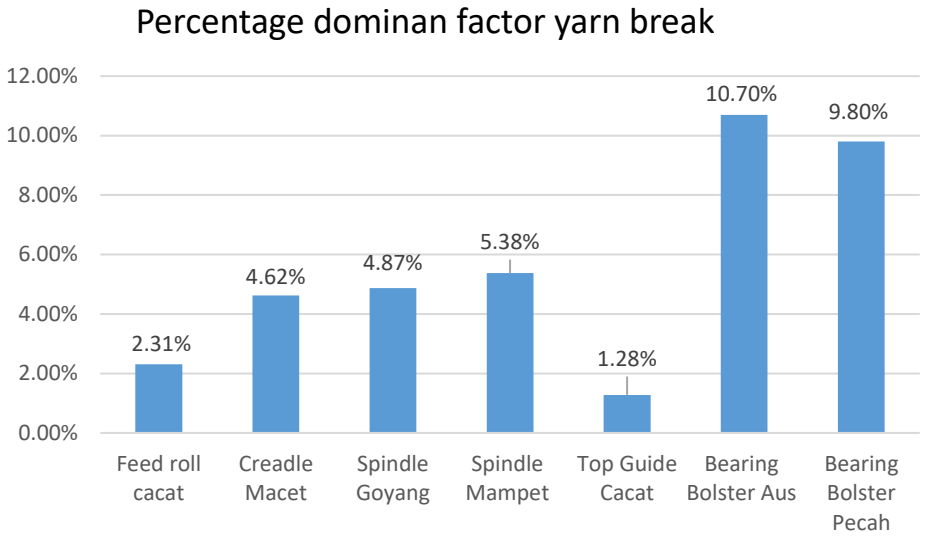


Figure 3. Factor dominan cause break

Among the TFO machines operating with **Polyester ITY 50/48 yarn**, three machine configurations were identified in the production line:

1. **Type A Gear**
2. **Type A CPU**
3. **Type L CPU**

Although all three machine types are used to process the same yarn specification, differences in their mechanical configurations and component designs may influence machine performance and the frequency of yarn breakage. In this study, the experimental investigation focused on the **Murata 310 Type L CPU** machine because preliminary production and maintenance records indicated that this machine exhibited the highest incidence of yarn breakage and therefore represented the most appropriate case for evaluating the effectiveness of spare-part replacement and machine modification.

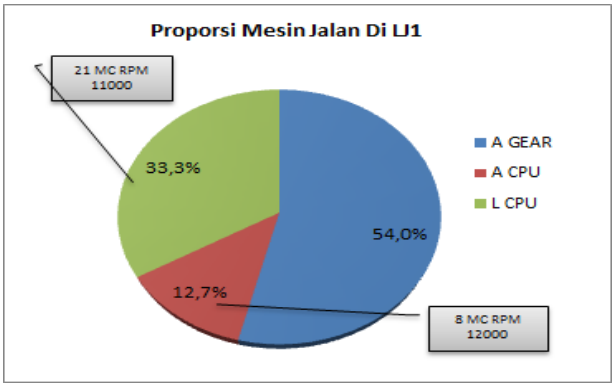


Figure 4. Proposion machine per type MC

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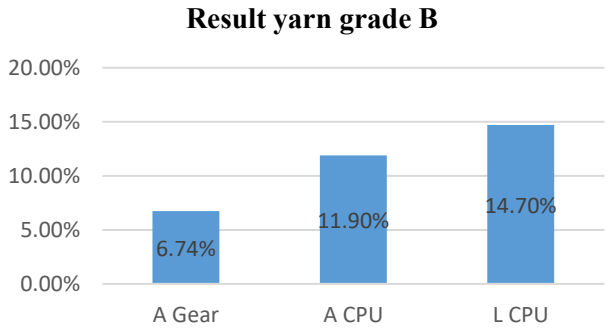


Figure 5. Percentage yarn grade B in each type machine

As shown in **Figure 5**, **Type L CPU** machines accounted for **33.0%** of the TFO machines in operation but produced the highest proportion of **Grade B yarn (14.70%)**. In contrast, **Type A Gear** machines represented **54.0%** of the installed machines while producing only **6.74% Grade B yarn**. Despite their lower proportion in the production line, the **Type L CPU** machines contributed disproportionately to the generation of Grade B products, indicating inferior production performance compared with the other machine types.

The high percentage of Grade B yarn is closely associated with the increased frequency of yarn breakage occurring during the twisting process. Frequent yarn breakage disrupts yarn winding stability, resulting in underweight yarn packages and reduced product quality. Consequently, corrective measures are required to minimize yarn breakage and improve the production of **Grade A yarn**. Based on the preliminary inspection results presented in **Figure 3**, the dominant causes of yarn breakage were identified as **worn bearing bolsters** and **damaged (broken) bearing bolsters**. These findings indicate that the condition of the bearing bolster is a critical factor affecting yarn breakage and justify its selection as the primary target for spare-part replacement and machine modification in this study.

RESULT AND DISCUSSION

The high frequency of yarn breakage in TFO machines directly contributes to a decline in yarn quality, resulting in a higher proportion of Grade B products. Among the various factors affecting yarn breakage, the condition of machine spare parts plays a critical role in maintaining stable yarn tension and smooth yarn movement throughout the twisting process. As spare parts deteriorate through prolonged operation, their ability to maintain proper machine performance decreases, thereby increasing the likelihood of yarn breakage.

Machine modification refers to the process of improving the function, configuration, or design of an existing component to achieve better operational performance and reliability. In the context of this study, component modification was implemented to improve yarn guiding performance and reduce the mechanical conditions that contribute to yarn breakage.

Based on the preliminary inspection results presented in Figure 6, the dominant causes of yarn breakage were identified as worn bearing bolsters and damaged (broken) bearing bolsters. A subsequent inspection conducted by the maintenance department confirmed that many of the bearing bolsters installed on the TFO machines had experienced significant wear and physical damage due to prolonged service. These findings indicate that bearing bolster deterioration is a major contributor to yarn breakage and support its selection as the primary component for replacement and performance improvement in this study.

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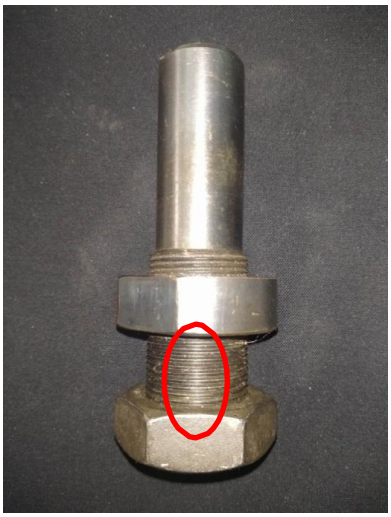


Figure 6. (a) *Bearing bolster Spindle Condition*



Figure 6. (b) *Bearing bolster Spindle*



Figure 6. (c) Centering *ballooning* normal

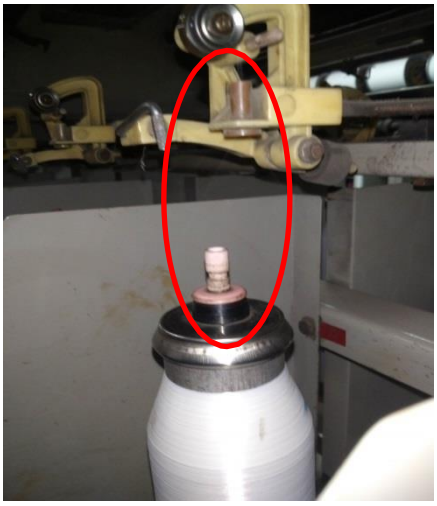
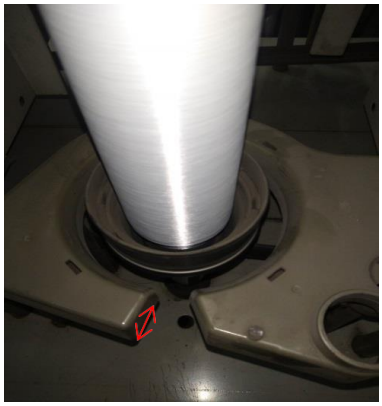
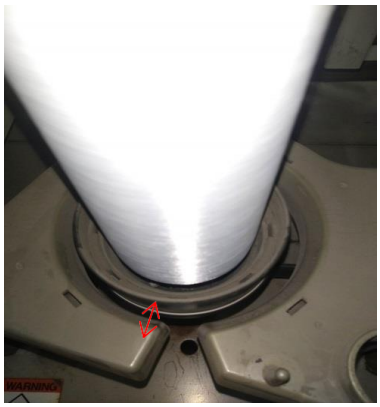


Figure 6. (d) Centering *ballooning* is not normal

As illustrated in Figures 6(a) and 6(b), wear of the spindle bearing bolster significantly affects the yarn winding process. Under normal operating conditions, the balloon is properly centered, allowing





the yarn to be wound smoothly around the spindle with stable yarn tension. However, the inspection revealed that worn bearing bolsters caused misalignment between the balloon guide and the assembly body, resulting in an off-center balloon formation. This misalignment was further aggravated by improper rotary disk clearance, leading to unstable yarn ballooning and increased friction during the

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winding process. Consequently, the yarn movement became irregular, substantially increasing the frequency of yarn breakage.

Because the deterioration of the bearing bolster involves permanent mechanical wear, the damaged component cannot be restored through modification or repair. Therefore, replacing the worn bearing bolster with a new component is the most appropriate corrective action to restore spindle alignment and improve yarn winding stability.

In addition to bearing wear, the bearing bolster pipe type was also found to influence machine performance. The TFO machines evaluated in this study were equipped with the Type L bearing bolster, whose configuration was identified as one of the factors affecting yarn balloon stability. Accordingly, the subsequent stage of this research investigated both bearing bolster replacement and Type L pipe tensor modification as complementary interventions to reduce yarn breakage and improve yarn quality.



Figure 7 (a) standart *pipe tensor* in machine TFO Type L



Figure 7 (b) Pirn if opened condition

As shown in **Figure 7**, a clearance exists between the **pipe tensor** and the **spindle**, allowing the yarn to form an internal balloon during the twisting process. This internal ballooning causes unstable yarn tension and increases friction as the yarn passes through the spindle assembly, thereby increasing the likelihood of yarn breakage.

To address this issue, the **Type L pipe tensor** was modified to eliminate the excessive clearance by extending its contact position so that it directly reaches the spindle. This modification minimizes the formation of internal ballooning, stabilizes yarn tension throughout the winding process, and improves the smoothness of yarn movement around the spindle. As a result, the frequency of yarn breakage is expected to decrease while the consistency of yarn winding and overall product quality are improved.
The schematic illustration of the proposed **Type L pipe tensor modification** is presented in the following figure.

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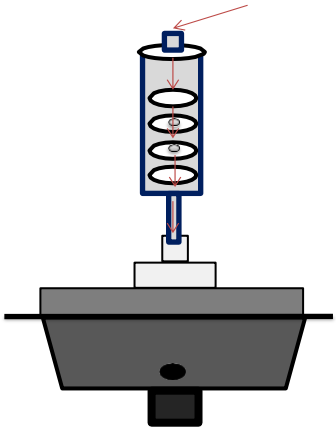




Figure 8.(a) Ilustration Modification pipe tensor after modification **Figure 8. (b)** *Pipe tensor* after modify



Figure 8. (c) Chapter in *pirn* after modify

Following the implementation of the **pipe tensor modification** on **17 Murata 310 Type L CPU TFO machines**, the yarn breakage rate was evaluated to determine the effectiveness of the proposed improvement. The post-modification results indicate a significant reduction in yarn breakage compared with the condition prior to modification, demonstrating that the modified pipe tensor successfully improved yarn guidance and stabilized the ballooning process during twisting.

The comparison between the **pre-modification** and **post-modification** conditions shows a clear improvement in machine performance, reflected by the lower frequency of yarn breakage and the corresponding increase in the proportion of **Grade A** yarn. These findings confirm that the combined implementation of **bearing bolster replacement** and **pipe tensor modification** effectively enhances yarn winding stability and contributes to improved production quality. The comparison of yarn breakage rates before and after the modification is presented in the following figure.

Table 4 Evaluation Grade TFO HZ ITY 50-48 TM 2500 SZ TFO TYPE CPU L

NO	NO MC	Before Modify					After Modify				
		SPINDLE CHECK	GRADE A		GRADE B		SPINDLE CHECK	GRADE A		GRADE B	
			JML CY	%	JML CY	%		JML CY	%	JUMLAH CYL	%

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			L			L			L			
1	MC TFO 135	256	220	85,9%	36	14,1%	768	686	89,3%	82	10,7%
2	MC TFO 153	512	424	82,8%	90	17,6%	768	679	88,4%	89	11,6%
3	MC TFO 156	768	624	81,3%	134	17,4%	1024	913	89,2%	111	10,8%
4	MC TFO 157	1024	878	85,7%	144	14,1%	512	455	88,9%	57	11,1%
5	MC TFO 161	768	610	79,4%	158	20,6%	512	466	91,0%	46	9,0%
6	MC TFO 126	512	450	87,9%	62	12,1%	768	724	94,3%	44	5,7%
7	MC TFO 160	256	222	86,7%	34	13,3%	512	486	94,9%	26	5,1%
8	MC TFO 134	256	222	86,7%	34	13,3%	512	453	88,5%	59	11,5%
9	MC TFO 128	256	204	79,7%	52	20,3%	256	226	88,3%	30	11,7%
10	MC TFO 159	256	223	87,1%	33	12,9%	256	226	88,3%	30	11,7%
11	MC TFO 136	256	230	89,8%	26	10,2%	256	234	91,4%	22	8,6%
12	MC TFO 171	256	226	88,3%	30	11,7%	256	256	100,0%	0	0,0%
13	MC TFO 154	256	226	88,3%	30	11,7%	512	464	90,6%	48	9,4%
14	MC TFO 133	256	226	88,3%	30	11,7%	512	456	89,1%	56	10,9%
15	MC TFO 127	256	234	91,4%	22	8,6%	512	463	90,4%	49	9,6%
16	MC TFO 155	256	229	89,5%	27	10,5%	256	230	89,8%	26	10,2%
17	MC TFO 163	256	220	85,9%	36	14,1%	256	223	87,1%	33	12,9%
	TOTAL	6656	5668	85,2%	978	14,7%	8448	7187	85,1%	749	8,9%
						Varians					*-5,8%*

Based on the evaluation of **Grade B yarn** produced by the modified **Type L TFO machines**, a substantial improvement in product quality was observed after the implementation of the proposed corrective actions. The percentage of **Grade B yarn** decreased from **14.7%** before the intervention to **8.9%** after the replacement of the bearing bolster and the modification of the pipe tensor, representing an overall reduction of **5.8 percentage points**.

This improvement demonstrates that the implemented maintenance strategy effectively reduced yarn breakage and enhanced yarn winding stability during the twisting process. Consequently, the proportion of **Grade A yarn** increased, indicating improved production performance and product quality. The comparison of the **Grade B yarn percentage** before and after the implementation of the proposed modifications is presented in **Figure 15**.

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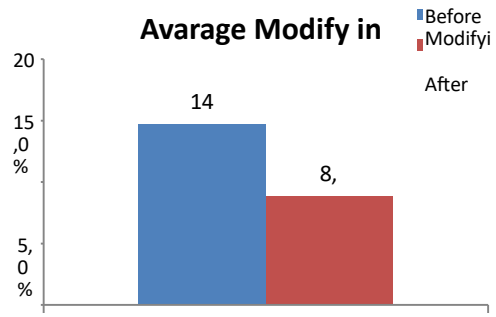


Figure 9. Graph grade B before modify and after modify

Following the implementation of the **pipe tensor modification** on **17 Murata 310 Type L CPU TFO machines** processing **Polyester ITY 50/48 yarn** at **2,500 TPM**, the production evaluation demonstrated a **5.8% reduction in the proportion of Grade B yarn**. This result indicates that the proposed modification effectively improved yarn winding stability by reducing internal ballooning and minimizing yarn breakage during the twisting process. The improvement confirms that the modification contributes positively to both machine performance and final product quality.

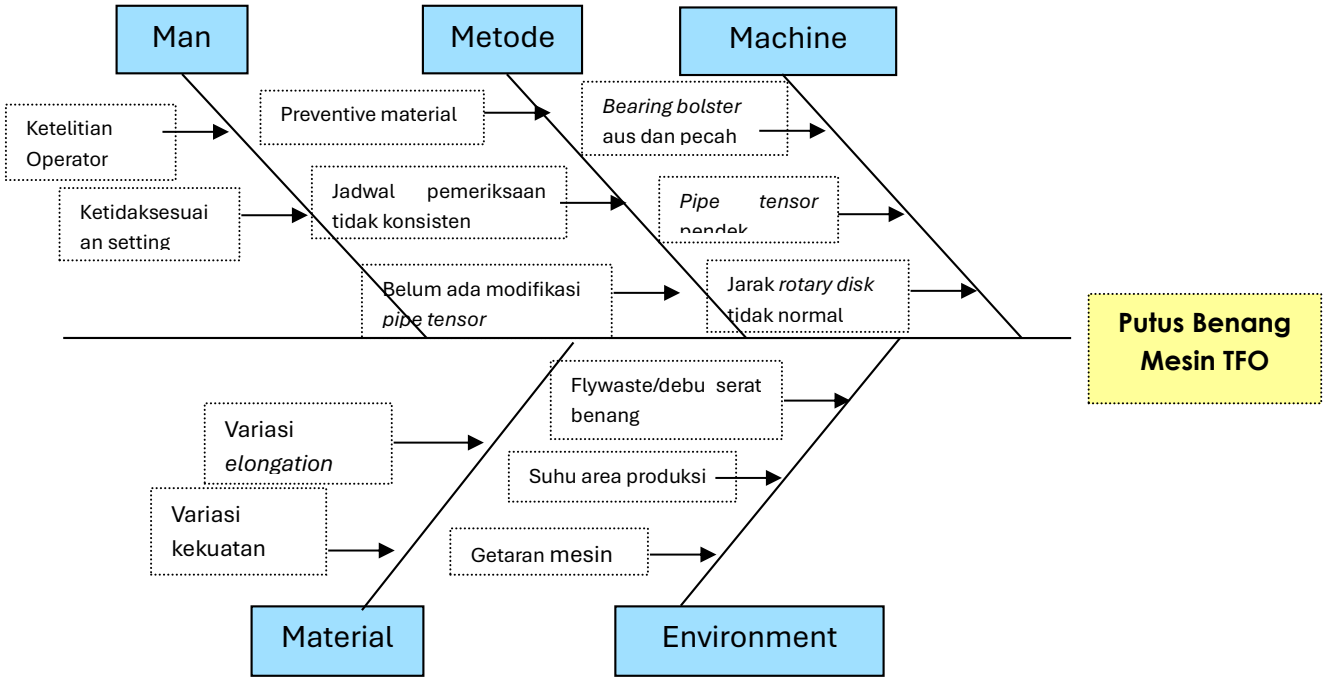


Figure 10. Result identification fishbone diagram

The **Fishbone (Ishikawa) analysis** revealed that the high frequency of yarn breakage was influenced by five major factors: **Machine, Method, Material, Man,** and **Environment**. Among these categories, the **Machine** factor was identified as the dominant contributor. This finding was supported by patrol inspections and machine validation, which revealed **worn and damaged bearing bolsters, excessive rotary disk clearance, and an inadequately short pipe tensor**. These mechanical deficiencies disrupted normal yarn balloon formation, increased yarn tension during the winding process, and consequently led to a higher frequency of yarn breakage.

The **Method** factor was associated with the absence of an optimized preventive maintenance program and the lack of a standardized pipe tensor modification procedure. The **Material** factor was

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related to variations in yarn properties, particularly tensile strength and elongation, which may influence yarn behavior during twisting. The **Man** factor reflected the operator's ability to perform accurate machine inspections, machine settings, and routine maintenance activities. Meanwhile, the **Environment** factor included production-floor conditions such as the accumulation of **fly waste** and machine vibration, both of which could adversely affect machine stability and yarn processing.

Based on these findings, this study focused on the **Machine** factor because it represented the most significant source of yarn breakage. Specifically, the replacement of worn **bearing bolsters** and the modification of the **pipe tensor** were selected as the primary corrective actions. The implementation of these interventions successfully reduced the proportion of **Grade B yarn** from **14.7%** to **8.9%**, demonstrating that targeted improvements to critical machine components can substantially enhance yarn winding stability, reduce yarn breakage, and improve overall production quality.

CONCLUSION

This study demonstrated that the Machine factor is the primary cause of excessive yarn breakage in the Murata 310 Type L CPU Twist For One (TFO) machine. Fishbone (Ishikawa) analysis identified worn and damaged bearing bolsters, improper rotary disk clearance, and the Type L pipe tensor configuration as the dominant factors contributing to unstable yarn ballooning, increased yarn tension, and frequent yarn breakage during the twisting process. To address these issues, bearing bolster replacement and pipe tensor modification were implemented as corrective maintenance actions.

The experimental results confirmed that replacing worn bearing bolsters improved spindle rotational stability, while the modified pipe tensor reduced internal balloon formation and stabilized yarn movement during winding. The combined implementation of these interventions on 17 TFO machines significantly enhanced production performance, reducing the proportion of Grade B yarn from 14.7% to 8.9%, equivalent to a 5.8 percentage-point reduction, while increasing the proportion of Grade A yarn. These findings demonstrate that targeted spare-part replacement and machine modification are effective strategies for reducing yarn breakage and improving product quality.

Based on these findings, it is recommended that textile manufacturers implement condition-based preventive maintenance for bearing bolster components, conduct periodic inspections of rotary disk clearance, and standardize the pipe tensor modification for Type L TFO machines. Future research should evaluate the long-term effectiveness and economic benefits of these maintenance strategies and investigate their applicability to other TFO machine models and yarn specifications to further enhance production reliability and quality.

AUTHORS CONTRIBUTION

Filly Pravitasari conceived the study, designed the research methodology, conducted the experiments, analyzed the data, and prepared the original manuscript draft. Feny Nurherawati contributed to the research methodology, validated the experimental results, supervised the research process, and critically reviewed and revised the manuscript. Lupi Sugianto participated in data collection, experimental implementation, validation of the findings, and resource management. Luciana supervised the overall research, contributed to the conceptual development of the study, reviewed and edited the manuscript, and approved the final version for publication. All authors have read and approved the final manuscript and agree to be accountable for the integrity and accuracy of the work.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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