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Development Of A Fuzzy Reliability Centered Maintenance (Fuzzy-Rcm) Based Maintenance Strategy For Production Machines At Pt Kimia Farma Tbk, Banjaran Plant

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RCM Method, Fuzzy-RCM, Machine Maintenance Strategy.

ABSTRACT
This research was conducted at PT Kimia Farma Plant Banjaran, a pharmaceutical manufacturer producing various types of medicines. The relatively high frequency of machine failures has become a serious issue that disrupts the production process and reduces productivity. Currently, the company employs a System Corrective and Planned Maintenance method carried out once a month depending on the type of machine. However, this approach is less effective, as it still results in high downtime, unexpected maintenance costs, and potential secondary damage. This study discusses the maintenance strategy for the Blistering Machine using the Fuzzy Reliability Centered Maintenance approach. The maintenance strategy is determined based on the risk level of each machine component. Components with Very Low Risk are maintained using the Run to Failure or simple routine monitoring strategy. Low Risk components are handled through periodic Preventive Maintenance. Medium Risk components are managed using Predictive Maintenance through actual condition monitoring. Components of High Risk are managed through Condition-Based Maintenance supported by real-time data without interrupting operations. Meanwhile, components with Very High Risk require Immediate Action supported by a Failure Mode and Effect Analysis. This approach enables a more effective and efficient maintenance system that minimizes the potential for machine failures.

INTRODUCTION

Operations management is an organizational function related to the planning, organizing, controlling, and improvement of processes that transform inputs into outputs in the form of goods and services (Heizer & Render, 2015). These activities involve the management of resources such as labor, raw materials, machinery, and production facilities. Heizer and Render (2015) state that maintenance comprises all activities aimed at keeping equipment functioning optimally. PT Kimia Farma, Tbk is one of the largest and oldest pharmaceutical companies in Indonesia, playing a crucial role in the provision of medicines and healthcare products. In its operations, the continuity of the production process heavily depends on the performance of reliable and efficient production machines. Any disruption or machine failure can directly affect product quality, smooth distribution, and compliance with quality standards such as Good Manufacturing Practice (GMP). The relatively high frequency of machine breakdowns has become a serious issue that can disrupt the production process and reduce productivity.

Table 1. Machine Downtime in 2023

No	Machine Name	Downtime/hours	Total Breakdown
1	Blistering Marchesini	182	80
2	IGL	176	74
3	Siebler	166	66
4	Filling Capsule MG2	96	28
5	Fette P	53	25
6	Coating	12	23
7	KTP 720	34	14
8	Roller Compactor	24	12
9	Sacheting	33	11

Source: Company data

Based on the data above, PT Kimia Farma Plant Banjaran is still experiencing breakdowns on several machines, with the highest machine downtime recorded on the Blistering Marchesini Machine, occurring 80 times with a total downtime of 182 hours. Sudden machine failures (breakdowns) can lead to significant downtime, delays in product delivery, excessive repair costs, and potential risks to occupational safety and product quality. Therefore, an appropriate maintenance strategy is essential to anticipate potential failures and reduce the risk of operational losses.

Reliability Centered Maintenance (RCM) is a systematic approach used to design maintenance strategies based on the reliability and operational functions of equipment. The Fuzzy-RCM approach was developed by integrating fuzzy logic theory into RCM analysis. Fuzzy logic allows uncertain, vague, or linguistic data (such as “high,” “medium,” or “low”) to be transformed into more objective quantitative values. In this way, failure risks can be assessed more realistically based on a range of possibilities. The application of Fuzzy-RCM to blistering machines in the pharmaceutical industry is particularly relevant because these systems consist of many critical components with high levels of complexity and varying failure modes. By implementing Fuzzy-RCM, PT Kimia Farma is expected to improve production system reliability, reduce downtime, and optimize maintenance resources. This study aims to develop a production machine maintenance strategy at PT Kimia Farma based on systematic and data-driven Fuzzy-RCM principles.

Currently, the company applies to the System Corrective Maintenance method, which involves repairing machines after a breakdown occurs, along with Planned Maintenance performed once a month depending on the type of machine. However, these methods are less effective because high downtime still occurs (resulting in prolonged production stoppages), unexpected maintenance costs, and potential secondary damages. Since pharmaceutical companies must maintain high reliability and regulatory compliance, the development of the Fuzzy-RCM method provides an advantage in managing system complexity more effectively. It enables the determination of maintenance programs that focus on critical components, thereby reducing maintenance costs.

LITERATURE REVIEW

Maintenance ensures the reliability, availability, efficiency, and proper production capability of a production system according to operational needs (Pintelon and Muchiri, 2009: 615). Reliability Centered Maintenance (RCM) is an analytical technique used to identify actions required to ensure that a system continues to perform its intended functions effectively (Rahardito, 2016). By applying the RCM method, information regarding the steps needed to ensure optimal machine or equipment operation can be obtained. Fuzzy Reliability Centered Maintenance (Fuzzy-RCM) is an enhancement of the traditional RCM method, combined with a fuzzy logic approach to address the limitations of subjective failure parameter assessment. The fuzzy approach transforms qualitative assessments into linguistic membership functions such as low, medium, and high, which are then processed through a fuzzy inference system to generate a more representative risk priority value, known as the Fuzzy Risk Priority Number (FRPN). This approach has been proven to improve the accuracy of risk prioritization and reduce subjective bias compared to conventional RCM (Sharma & Kumar, 2008; Wang et al., 2010).

METHODS

This study employs the Fuzzy Reliability Centered Maintenance (Fuzzy-RCM) approach. In analyzing the optimal maintenance strategy for the blistering machine, this method was chosen because it can effectively handle uncertainty and subjectivity in the decision-making process, particularly in assessing risk levels and equipment reliability, which are often difficult to measure precisely.

In this research, the stages are carried out based on the risk-based RCM concept, with the following steps:

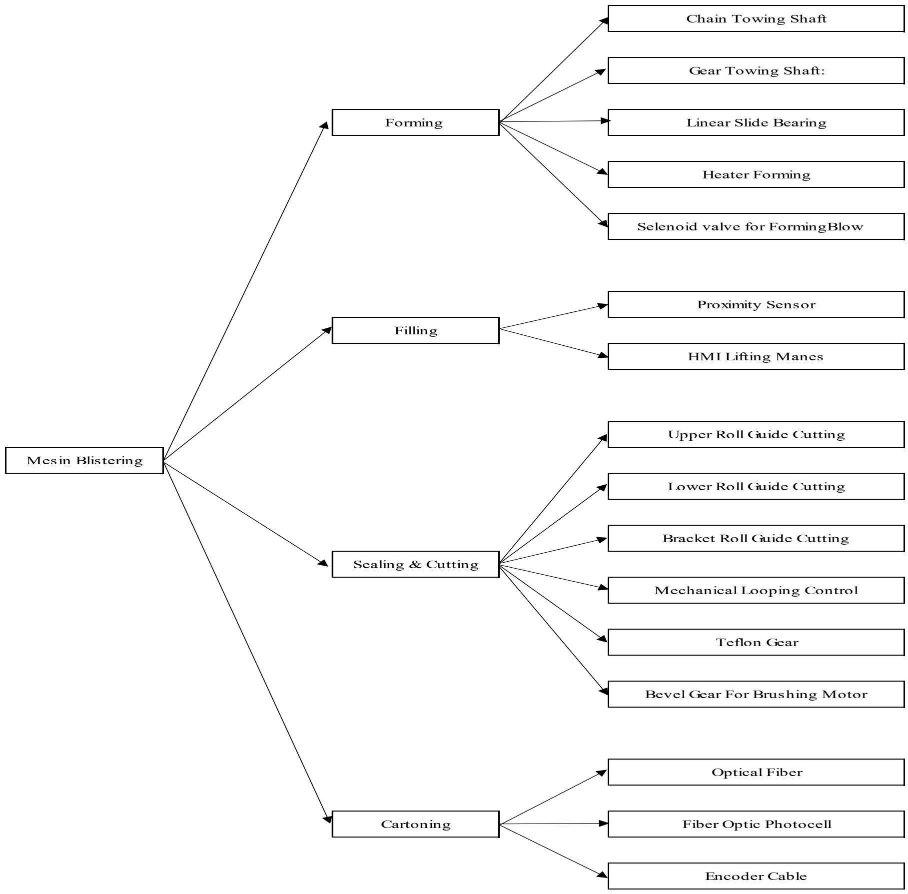
- Identifying machine functions and failure modes
- Describing the machine's working system using a Functional Block Diagram (FBD)
- Developing a System Function and Functional Failure analysis
- Preparing a risk assessment in the form of Failure Mode and Effect Analysis (FMEA)
- Integrating the Fuzzy Logic method
- Determining the appropriate maintenance strategy based on the prioritized failure modes.

RESULTS

A critical machine is one with the highest frequency of failures and downtime. Based on Table 1, it is known that the Blistering Marchesini Machine has the highest failure frequency, with 80 occurrences, contributing to the highest total downtime of 182 hours throughout 2023.

The System Breakdown Structure (SBS) serves as a tool to document, analyze, and facilitate the identification process of machine components at the system, subsystem, and component levels in a structured and detailed manner. The following is the System Breakdown Structure (SBS) for the Blistering Marchesini Machine:

Figure 1. System Breakdown Structure (SBS) Blistering Machine



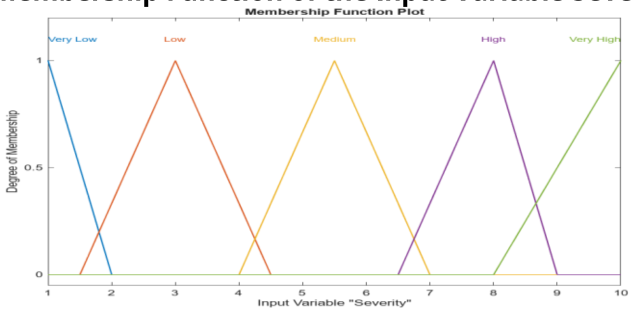
Source: Processed Data 2025

The FMEA (Failure Mode and Effect Analysis) is used to determine the types of failures, their causes, and the resulting effects on the Blistering Marchesini Machine. FMEA also illustrates the frequency of failure occurrence, severity, and detection level, which are represented by the RPN (Risk Priority Number) value. In developing the FMEA table, discussions were held with the Production Machine (MP) department and the Production Equipment and Laboratory (APL) department of PT Kimia Farma Plant Banjaran to determine the Severity, Occurrence, and Detection values. The RPN value serves as a key factor for prioritizing the handling of issues listed in the FMEA table. From the FMEA analysis, the highest RPN values were identified as follows in the Forming section is Heater Forming with an RPN of 432, in the Filling section is HMI Lifting Manes with an RPN of 315, in the Sealing and Cutting section Mechanical Looping Control and Bevel Gear for Brushing Motor with an RPN of 400 and in the Cartoning section is Encoder Cable with an RPN of 360.

The Task Selection process in RCM is carried out using a series of logical decision questions. These questions help determine the most appropriate type of maintenance action based on the characteristics of each failure mode. The result of the Task Selection stage is an initial recommendation of the most suitable maintenance tasks, such as On-Condition Task, Restoration Task, Discard Task, Failure-Finding Task, Redesign Task, and Run-to-Failure Task.

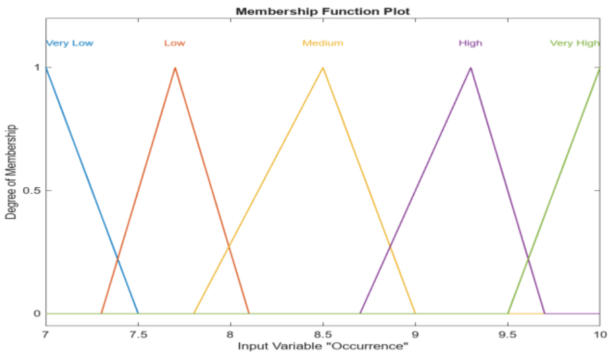
To obtain more objective and measurable results, the analysis was continued using the Fuzzy Reliability Centered Maintenance (Fuzzy-RCM) approach. The Fuzzy-RCM approach is used to quantify the results of the RCM analysis by utilizing a fuzzy logic inference system. In this study, the fuzzy system employs three input variables Severity, Occurrence, and Detection and two output variables, namely Risk Level and Maintenance Recommendation. The membership functions of the input and output variables are defined using triangular fuzzy numbers, with parameters based on the table above, as illustrated in Figures 2 to 6.

Figures 2. Membership Function of the Input Variable Severity



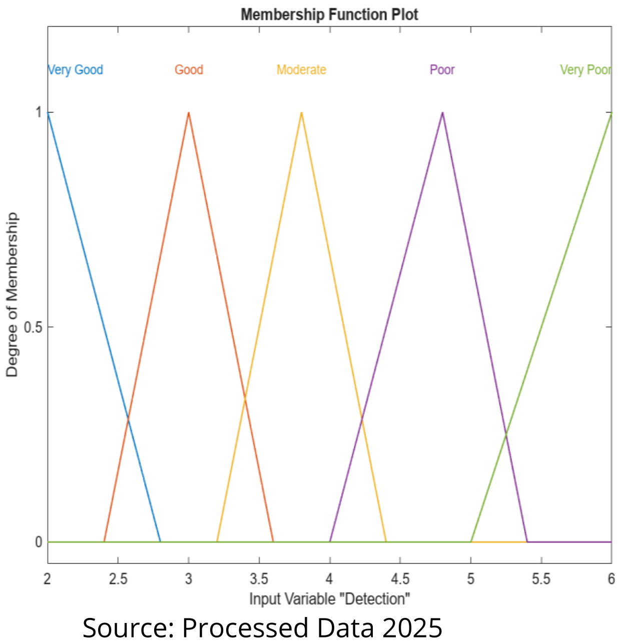
Source: Processed Data 2025

Figures 3. Membership Function of the Input Variable Occurance



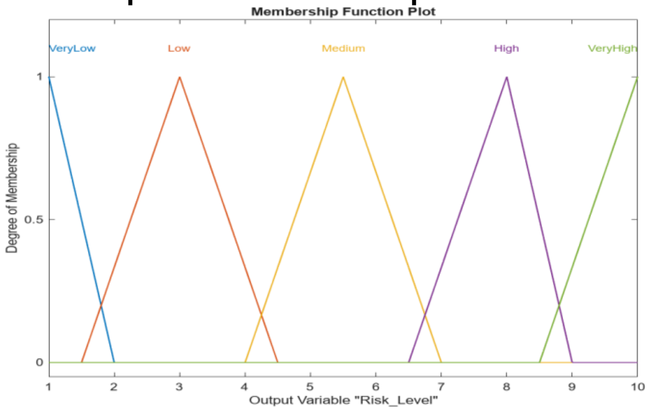
Source: Processed Data 2025

Figures 4. Membership Function of the Input Variable Detection



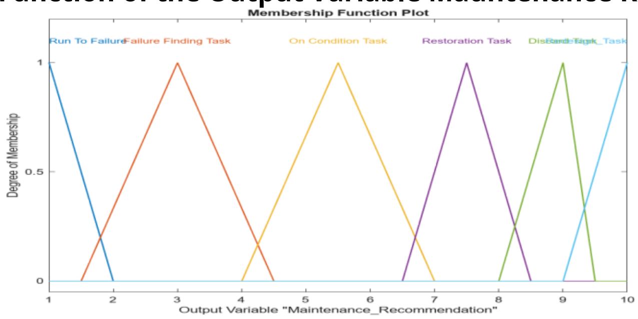
Source: Processed Data 2025

Figures 5. Membership Function of the Output Variable Risk Level



Source: Processed Data 2025

Figures 6. Membership Function of the Output Variable Mauntenance Recommendation



Source: Processed Data 2025

In this study, the Mamdani method was used for fuzzy inference, and the centroid (center of area) defuzzification method was applied to achieve better continuity and clarity. The following are the results of the Fuzzy-RPN values:

Table 2. Fuzzy-RPN Value

Machine Parts	Componens	Input				Output	
		S	O	D	FRPN	Risk Level	Maintenance Recommendation
Forming	Chain Towing Shaft	5	8	2	3,00	Low	Failure Finding Task
	Gear Towing Shaft:	8	8	5	8,42	High	Restoration Task
	Linear Slide Bearing	1	7	2	1,30	Very Low	Run to Failure
	Heater Forming	9	8	6	9,37	Very High	Redesign Task
	Selenoid valve for Forming Blow	5	9	5	9,44	Very High	Discard Task
Filling	Proximity Sensor	6	9	3	5,50	Medium	On-Condition Task
	HMI Lifting Manes	7	9	5	9,39	Very High	Discard Task
Sealing and cutting	Upper Roll Guide Cutting	5	8	6	7,78	High	Restoration Task
	Lower Roll Guide Cutting	5	7	5	3,00	Low	Failure Finding Task
	Bracket Roll Guide Cutting	6	9	5	9,44	Very High	Discard Task
	Mechanical Looping Control	8	10	5	9,48	Very High	Redesign Task

Machine Parts	Componens	Input				Output	
		S	O	D	FRPN	Risk Level	Maintenance Recommendation
	Teflon Gear	9	7	5	7,81	High	Restoration Task
	Bevel Gear For Brushing Motor	8	9	5	9,44	Very High	Discard Task
Cartoning	Optical Fiber	5	8	5	6,60	Medium	On-Condition Task
	Fiber Optic Photocell	1	8	5	4,32	Low	Failure Finding Task
	Encoder Cable	9	8	5	9,37	Very High	Discard Task

Source: Processed Data 2025

The component with the highest FRPN value is Mechanical Looping Control in the Sealing and Cutting unit, with a score of 9.48, classified as Very High Risk. This component is recommended for a Discard Task, which involves total replacement to prevent potential significant failures. Additionally, the Bracket Roll Guide Cutting and Bevel Gear for Brushing Motor components also show high FRPN values of 9.44 each, categorized as Very High Risk and similarly recommended for Discard Tasks. Conversely, components with Very Low Risk, such as the Linear Slide Bearing in the Forming unit, have an FRPN value of only 1.3. This component is recommended for a Run-to-Failure strategy, as its failure impact is minimal and tolerable. Most components categorized as Medium and High Risk are directed toward On-Condition Tasks or Restoration Tasks, depending on their early failure detection capability and ease of functional recovery. By considering Severity, Occurrence, and Detection values simultaneously in a defuzzified fuzzy format, the risk prioritization mapping becomes more adaptive and accurate. This enhances maintenance efficiency by shifting the approach from time-based to risk-based, using FRPN outputs from the Fuzzy-RCM system. The following presents the proposed maintenance schedule adjustments based on the Fuzzy Risk Priority Number (FRPN) analysis results, replacing the conventional fixed time-based maintenance approach.

Table 3. Proposed Maintenance Schedule Adjustment for the Blistering Machine

No	Componens	FRPN	Risk Level	Old Schedule (Time Based)	New Schedule (Fuzzy-RCM Based)	Task Type
1	Chain Towing Shaft	3,00	Low	900 h	630 h	Failure Finding Task
2	Gear Towing Shaft	8,42	High	900 h	150 h	Restoration Task
3	Linear Slide Bearing	1,30	Very Low	300 h	265 h	Run-to-Failure
4	Heater Forming	9,37	Very High	300 h	20 h	Redesign Task
5	Solenoid Valve for Forming Blow	9,44	Very High	300 h	20 h	Discard Task
6	Proximity Sensor	5,50	Medium	300 h	135 h	On-Condition Task
7	HMI Lifting Manes	9,39	Very High	300 h	20 h	Discard Task
8	Upper Roll Guide Cutting	7,78	High	900 h	200 h	Restoration Task

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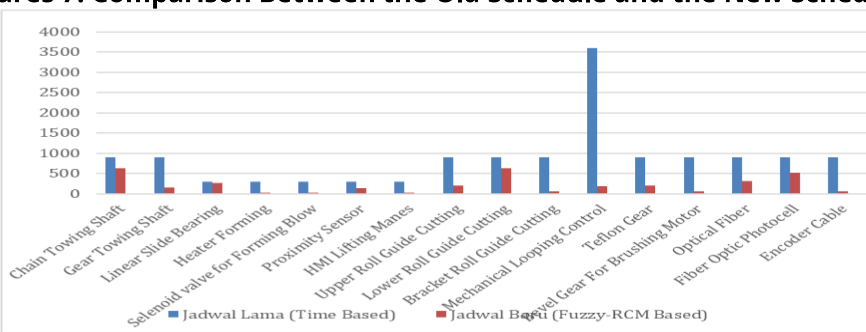
No	Componens	FRPN	Risk Level	Old Schedule (Time Based)	New Schedule (Fuzzy-RCM Based)	Task Type
9	Lower Roll Guide Cutting	3,00	Low	900 h	630 h	Failure Finding Task
10	Bracket Roll Guide Cutting	9,44	Very High	900 h	50 h	Discard Task
11	Mechanical Looping Control	9,48	Very High	3600 h	190 h	Redesign Task
12	Teflon Gear	7,81	High	900 h	200 h	Redesign Task
13	Bevel Gear for Brushing Motor	9,44	Very High	900 h	50 h	Discard Task
14	Optical Fiber	6,60	Medium	900 h	310 h	On-Condition Task
15	Fiber Optic Photocell	4,32	Low	900 h	515 h	Failure Finding Task
16	Encoder Cable	9,37	Very High	900 h	60 h	Discard Task

Source: Processed Data 2025

The results of the Fuzzy-RCM analysis presented in Table 3 above provide a comparison between the old schedule (time-based) and the new schedule (component risk/FRPN-based), along with the corresponding maintenance strategy. The following is a chart comparing the old schedule with the new schedule based on the Fuzzy-RCM approach:

Figures 7. Comparison Between the Old Schedule and the New Schedule



Source: Processed Data 2025

DISCUSSION

Components categorized as Very Low Risk, such as the Linear Slide Bearing, are recommended to follow a Run-to-Failure strategy with a new maintenance interval of 265 hours.Components with Low Risk, such as the Chain Towing Shaft, Lower Roll Guide Cutting, and Fiber Optic Photocell, are recommended to apply the Failure Finding Task strategy with new intervals of approximately 515–630 hours. Medium Risk components, including the Proximity Sensor and Optical Fiber, are recommended for On-Condition Maintenance Tasks, with new intervals ranging from 135 to 310 hours. High Risk components, such as the Gear Towing Shaft, Upper Roll Guide Cutting, and Teflon Gear, are recommended to undergo Preventive Maintenance with Restoration or Replacement actions. Meanwhile, components classified as

Very High Risk including Heater Forming, Solenoid Valve for Forming Blow, HMI Lifting Manes, Bracket Roll Guide Cutting, Mechanical Looping Control, Bevel Gear for Brushing Motor, and Encoder Cableare assigned very short maintenance intervals (20–190 hours) compared to the previous schedule (300–3600 hours), with a recommendation for Preventive (Restoration/Replacement) maintenance actions.

CONCLUSION

The maintenance system currently implemented at PT Kimia Farma Plant Banjaran is Preventive Maintenance based on Periodic Maintenance, where maintenance activities are carried out at specific time intervals. For the Blistering machine, the periodic maintenance intervals are set at 300 hours, 900 hours, 1200 hours, 1800 hours, and 3600 hours.

To identify critical components and potential failure modes, this study first developed a System Breakdown Structure (SBS) to facilitate critical analysis and failure identification, followed by the use of the Failure Mode and Effect Analysis (FMEA) method to calculate the Risk Priority Number (RPN). Subsequently, the Fuzzy RCM method was applied to determine the risk level of each component.

The optimal maintenance strategy for the Blistering machine at PT Kimia Farma Plant Banjaran is based on the Fuzzy Reliability Centered Maintenance (Fuzzy-RCM) approach. Maintenance strategies differ for each component and are determined according to their risk levels. Components with Very Low risk, such as the Linear Slide Bearing, follow a Run-to-Failure strategy because the impact of their failure is minor and it is more efficient to operate them until failure before replacement. Low-risk components, such as the Chain Towing Shaft, Lower Roll Guide Cutting, and Fiber Optic Photocell, implement a Failure-Finding Task strategy, i.e., periodic functional inspections to ensure reliable performance without routine replacement. Medium-risk components, such as the Proximity Sensor and Optical Fiber, are recommended to undergo On-Condition Tasks through condition monitoring (vibration, temperature, or visual inspection) to detect early signs of failure. High-risk components, such as the Gear Towing Shaft, Upper Roll Guide Cutting, and Teflon Gear, require Preventive Maintenance (Restoration/Replacement) with shorter intervals to prevent actual failures. Finally, Very High-risk components—such as Heater Forming, Solenoid Valve for Forming Blow, HMI Lifting Manes, Bracket Roll Guide Cutting, Mechanical Looping Control, Bevel Gear for Brushing Motor, and Encoder Cable—need Preventive Maintenance (Restoration/Replacement) at very high frequency, along with design evaluation to reduce the likelihood of recurring failures.

LIMITATION

At the time this study was conducted, part of the operational data and historical machine failure data was still stored in manual records that were not systematically documented. This condition caused the available information to be incomplete, less consistent, and to require additional verification processes to ensure accuracy. These limitations may have affected the accuracy of the analysis, particularly in the stages of identifying failure patterns and determining risk parameters for each machine component.

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