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Mechanical Sub-System Machine Maintenance Analysis Using Reliability Centered Maintenance Method at PT XYZ

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Abstract

The automotive manufacturing industry requires high operational reliability to prevent defects caused by machine failures. This research was conducted at PT XYZ, focusing on the mechanical subsystem of Line SA. The problem identified was the high frequency of machine breakdowns, specifically in the Compacting process on the PMM-60-N2 machine. This study applies the Reliability Centered Maintenance (RCM) method, utilizing Fault Tree Analysis (FTA) to find root causes and Failure Mode and Effect Analysis (FMEA) for risk assessment. The FTA results showed that the root cause of frequent breakdowns (conveyor jams and die eject failures) is the accumulation of residual powder material. FMEA calculations indicated that the Die Eject component has the highest Risk Priority Number (RPN) of 160. Based on the Logic Tree Analysis (LTA), the recommended maintenance strategy is a Scheduled On-Condition Task, emphasizing thorough cleaning and visual inspections. Implementing this strategy is expected to minimize unexpected downtime and improve overall production efficiency.

Keywords : compacting, FMEA, maintenance, RCM, RPN

INTRODUCTION

The automotive manufacturing industry is characterized by stringent product quality standards and high operational complexity. A primary challenge within this sector is the elevated rate of product defects originating from production process failures caused by unreliable machinery or equipment (Wibowo *et al*, 2021). At PT XYZ, machines are required to operate continuously on a massive scale, making equipment reliability crucial for sustaining operational continuity. The degradation of machine performance significantly amplifies the potential for defects, which subsequently leads to an escalation in production costs, a decline in overall efficiency, and compromised customer satisfaction. Consequently, this environment necessitates a maintenance system that is not only highly responsive but also capable of comprehensively anticipating potential equipment failures.

The implementation of the Reliability Centered Maintenance (RCM) approach emerges as a highly strategic solution, as it fundamentally focuses on optimizing the reliability and specific functions of the equipment. RCM integrates various maintenance paradigms, such as condition-based maintenance, preventive maintenance, and run-to-failure strategies, grounded in rigorous risk assessments. The ultimate objective is to systematically minimize financial and operational losses associated with machine downtime and defective products through a data-driven framework. Therefore, this study aims to apply RCM principles to analyze and formulate a comprehensive maintenance strategy for production machinery, specifically targeting the mechanical sub-system of Line SA, thereby mitigating the machine failure rate.

LITERATURE REVIEW

Significant contributions from previous research on Reliability Centered Maintenance (RCM) are summarized in the table below.

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Tabel 1. Literature Review

Authors	Key Findings & Recommendations
Wibowo e*t al*. (2021)	Applied RCM and FMEA on a lathe machine. Identified the bearing, stator, and rotor as the most critical components. Proposed a combination of Condition Directed (CD), Failure Finding (FF), and Time Directed (TD) tasks to improve overall machine reliability.
Sulistiawan *et al.* (2023)	Utilized RCM to transition a plastic manufacturing plant from corrective to preventive maintenance. Identified the screw and hydraulic valve as high-risk components. The proposed maintenance strategy significantly mitigated long-term financial losses by 47.73%.

METHODS

This research commenced with a literature review to gather relevant references concerning the maintenance procedures for the mechanical sub-system of the PMM-60-N2 machine on Line SA at PT XYZ. The subsequent phase involved direct field observations of the machine's operations, coupled with in-depth interviews with the maintenance technicians. This methodological approach was undertaken to acquire comprehensive primary data regarding the failure history and the actual maintenance strategies implemented at the facility. The methodology of this research is systematically carried out through the following stages:

1. System Selection
   The system selection phase is determined by identifying the system with the highest failure frequency. Subsequently, within that selected system, the specific machine exhibiting the highest breakdown rate is designated as the primary object for further analysis
2. The Seven Core RCM Questions
   The seven core RCM questions systematically evaluate equipment reliability by defining asset functions, identifying failure modes and their consequences, and ultimately guiding the selection of optimal proactive maintenance tasks or default actions
3. Fault Tree Analysis
   Fault Tree Analysis (FTA) is a top-down, deductive analytical technique that commences with a postulated system failure (top event) and systematically traces it downward to identify the fundamental underlying causes.
4. System Failure Analysis
   System Failure Analysis is a comprehensive evaluation stage aimed at identifying and documenting the breakdown mechanisms, the defective components, and the operational impacts of a functional failure
5. Failure Mode and Effects Analysis
   FMEA is a proactive and systematic analytical technique utilized to evaluate and prioritize component failure risks. This prioritization is based on the calculation of the Risk Priority Number (RPN), which is derived from the multiplication of Severity, Occurrence, and Detection values. In this study, the formulation procedure and the assessment guidelines for the FMEA parameters, comprising Severity, Occurrence, and Detection, are based on the framework outlined by wibowo *et al.* (2021)
6. Maintenance Task Selection
   Guided by the component criticality levels established through the FMEA, the Task Selection phase translates these risk priorities into applicable maintenance work instructions. This approach ensures that maintenance resources are allocated efficiently to prevent the occurrence of downtime on the PMM-60-N2 machine

RESULTS AND DISCUSSION

Frequency of Mechanical Subsystem Failures across Production Processes within the SA Line at PT XYZ

Tabel 2. Failure Frequency on Line SA

Process	Freq.
Compacting	42
Paletizing	2
Lane Device	1
Weight Checker	0
Baritori	0
Sintering	4
Sizing	18
Banishing	0
Machining	0
Lathing	11

Process	Freq.
Drilling	6
Auto Drilling	5
Washing	1
Steam	0
Shot Blast	1
Part Feeder	0

Based on operational data, the Compacting process is identified as the most critical area, with a dominant total of 42 damage incidents. Within this process line, the PMM-60-N2 machine was found to be the most vulnerable asset, experiencing 8 functional failures during the observation period

Tabel 3. Failure Frequency in the Compacting Process

Machine Unit	Freq.
PMM-20-N1	3
PMM-40-N1	3
PMM-40-N2	0
PMM-40-N3	1
PMM-40-N4	3
PMM-40-N5	6
PMM-60-N1	2
PMM-60-N2	8
PFS-40-N1	4
PFS-40-N2	6
PYS-20-N1	6
SA-80-N4	0

Overall, twelve different machine types were analyzed, showing varied operational frequencies. The PMM-60-N2 unit exhibited the highest frequency of incidents, signifying the most recurrent breakdown rate among the evaluated assets

Tabel 4. Seven Core RCM Questions

No.	RCM Questions	Responses
1	What are the functions and associated performance standards of the asset in its present operating context?	To perform the compacting of mixed powder materials under high pressure to form an initial mold with the desired geometry.
2	In what ways does it fail to fulfill its functions?	Production Failure: The machine is unable to execute the compacting process.
		Material Handling Failure: The conveyor system jams, resulting in the cessation of material flow.
		Product Ejection Failure: The die eject mechanism malfunctions, preventing the product from being extracted from the die.
3	What causes each functional failure?	Conveyor System: Torn belt, jammed roller, defective bearing (NG), worn roller, entangled belt.
		Eject Mechanism: The presence of debris or material fragments within the mold

No.	RCM Questions	Responses
		cavity (causing the die eject to cease rotation).
4	What happens when each failure occurs?	The conveyor is incapable of transporting materials (at C2, C3, or C4).
		The product cannot be ejected from the die (at the Die Eject mechanism).
		The machine may experience an emergency stop or jamming.
5	In what way does each failure matter?	Operational Consequences: Complete production downtime occurs during the compacting process, halting the entire manufacturing workflow.
		Economic Consequences: Incurrence of spare part replacement costs (Belt, Roller, Bearing), repair labor costs, and financial losses due to diminished production volume.
6	What can be done to predict or prevent each failure?	1.Condition-based maintenance.
		2.Scheduled maintenance.
7	What should be done if a suitable proactive task cannot be found?	Run-to-Failure (RTF): Exclusively applied to components where the failure impact is minimal and repairs can be executed swiftly and effortlessly.

Functional analysis within the RCM framework utilizes questions 1 through 5 to identify asset performance expectations, failure modes (such as conveyor jams or die eject malfunctions), and their respective root causes and consequences regarding operational, economic, and safety aspects. Conversely, questions 6 and 7 serve as strategic outputs to establish proactive maintenance tasks aimed at preventing failure modes, such as belt tears or bearing degradation. In instances where preventive measures are not technically or economically feasible, default actions, including component redesign or a run-to-failure strategy, are implemented to ensure the overall stability of the production system

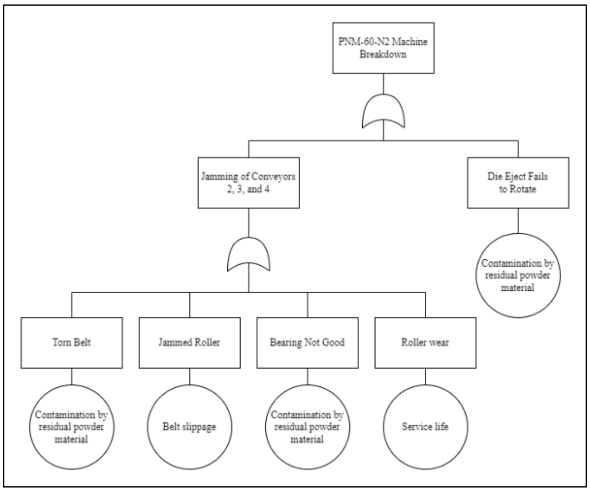

Figure 1. Fault Tree Analysis

The mapping of root causes through Fault Tree Analysis (FTA) confirms that routine exposure to residual powder material contamination acts as the fundamental factor (root cause), triggering a cascading failure that affects bearings, belts, and mold components

Tabel 5. Machine Failure Data

Date	Failure Mode	Breakdown Time	Percentage (%)	Repair Time
11/05/2024	Conveyor 4 Jamming	2.82	14.23	1.41
29/06/2024	Conveyor 4 Jamming	6.35	32.04	3.35
15/08/2024	Die Ejector Failure to Rotate	2	10.09	1
03/09/2024	Conveyor 3 Jamming	1.08	5.45	1
20/09/2024	Conveyor 4 Jamming	1.5	7.57	1.5
21/09/2024	Conveyor 2 Jamming	2.24	11.3	1.33
03/10/2024	Conveyor 4 Jamming	2.17	10.95	1.08
07/01/2025	Conveyor 4 Jamming	1.66	8.38	1.25

Based on the data presented in Table 5, the failure analysis for the PMM-60-N2 compacting machine components is delineated below, classifying the results according to the affected components, types of failure, failure impacts, and the underlying causes of the incidents

Tabel 6. Failure Cause and Effect Analysis

No	Component	Function	Failure Mode	Failure Effect	Failure Cause
1	Conveyor 2	Transports the compacted product to Conveyor 3	A. Jamming	The conveyor is unable to transport materials	1. Torn belt
2	Conveyor 3	Transports the compacted product to Conveyor 4	A. Jamming	The conveyor is unable to transport materials	1. Jammed roller and torn belt
3	Conveyor 4	Transports the compacted product to Conveyor 5	A. Jamming	The conveyor is unable to transport materials	1. Torn belt, jammed roller, and defective bearing
					2. Torn belt
					3. Worn roller
					4. Entangled belt
4	Die Eject	Ejects the finished product or residual material from the mold cavity after the forming process	A. Failure to Rotate	The product cannot be ejected from the die	1. Presence of debris or material fragments

The production system at PT XYZ encounters significant constraints within the material handling line due to mechanical failures of Conveyors 2, 3, and 4, as well as the Die Eject components. All three conveyors experienced jamming induced by a combination of belt tearing, roller seizure or wear, and bearing contamination; notably, the failures in Conveyor 4 were the most complex, encompassing all aforementioned factors. Concurrently, the Die Eject component failed to rotate due to the accumulation of debris or material fragments that obstructed its mechanical movement. This obstruction prevented product ejection from the mold, subsequently resulting in a complete standstill of the production flow

Tabel 7. FMEA Calculation

No	Component	Failure Mode	Failure Cause	Severity	Occurent	Detection	RPN
1	Conveyor 2	A	1	6	5	4	120
2	Conveyor 3	A	1	6	5	4	120
3	Conveyor 4	A	1	6	5	4	120
			2	6	5	4	120
			3	5	5	4	100
			4	6	6	4	144
4	Die Eject	A	1	8	5	4	160

Based on the Failure Mode and Effects Analysis (FMEA) calculations, mitigation priorities are mapped across several key components. The Counter Die Eject component presents the most critical risk level, with a Risk Priority Number (RPN) of 160 attributed to the accumulation of debris or material fragments, contributing 18.10% to the total risk profile. This is followed by Conveyor 4, where jammed belts resulted in an RPN of 144 (a 16.29% risk contribution). Meanwhile, other failure modes, such as belt tearing and bearing degradation, exhibit an average RPN of 120, each contributing approximately 13.57% to the overall risk. Although the Pareto principle suggests prioritizing a few vital causes, the RPN values in this study are relatively evenly distributed and do not exhibit a significant gap. Consequently, all identified causes are subjected to further analysis to ensure that improvement efforts are comprehensive and address all potential failure points

Tabel 8. Logic Tree Analysis

Component	Failure Mode	Failure Cause	Consequences				HI / S1 / O1 / N1	H2 / S2 / O2 / N2	H3 / S3 / O3 / N3	H4	H5	S4
			H	S	E	O						
1	A	1	Y	N	N	Y	Y					
2	A	1	Y	N	N	Y	Y					
3	A	1	Y	N	N	Y	Y					
		2	Y	N	N	Y	Y					
		3	N				Y					
		4	Y	N	N	Y	Y					
4	A	1	N				Y					

The Task Selection table within the Reliability Centered Maintenance (RCM) methodology serves to map component failure modes into appropriate maintenance actions based on consequence categories: Hidden (H), Safety (S), Environment (E), and Operational (O). Analysis of Components 1 through 4 reveals a significant dominance of operational (O) consequences, indicating that failures in these units directly impact production downtime and output degradation. Although most failure modes do not exert a direct impact on environmental (E) or safety (S) aspects, positive indications in the Hidden/Hazardous (H) column for certain failure modes in Components 1, 2, and 3 necessitate more rigorous preventive inspection procedures. These are essential to mitigate latent risks that could potentially jeopardize overall system stability

Tabel 9. Task Selection

Component	Failure Mode	Failure Cause	Proposed Maintenance Task
1	A	1	Scheduled on-condition task: Conduct scheduled visual inspections of the belt for cracks and tears, and remove abrasion-causing dust.
2	A	1	Scheduled on-condition task: Perform scheduled visual and auditory inspections of the rollers (detecting abnormal noises or jamming) and the belt (identifying tears). Routinely clear dust from the roller-belt area.
3	A	1	Scheduled on-condition task: Execute scheduled visual inspections of the belt, rollers, and bearings. Perform comprehensive dust removal. Monitor bearing temperature and vibration.
		2	Scheduled on-condition task: Conduct scheduled visual inspections of the belt for cracks and tears, and remove abrasion-causing dust.
		3	Scheduled on-condition task: Perform scheduled visual inspections and wear measurements of the rollers. Clean dust from the rollers. Monitor connection/coupling vibrations.
		4	Scheduled on-condition task: Conduct scheduled visual inspections of the belt track (checking for foreign objects and dust accumulation) alongside scheduled cleaning. Monitor belt tension.
4	A	1	Scheduled on-condition task: Execute scheduled visual inspections of the components and perform comprehensive cleaning to remove dirt and dust. Conduct functional testing.

The evaluation of failure consequences during the Logic Tree Analysis (LTA) phase confirms that all identified failure modes directly result in Operational Consequences (O), leading to production flow interruptions. Consequently, the Task Selection matrix recommends 'Scheduled On-Condition Tasks' as the primary strategy. The operational focus centers on visual inspections and the detection of abnormal temperature and vibration; most critically, it mandates detailed and routine cleaning of residual powder contamination within the Conveyor and Die Eject areas to eliminate the root causes of abrasion and mechanical seizure

CONCLUSION

The compacting process of the PMM-60-N2 machine constitutes the most critical asset, dominating the frequency of operational failures caused by conveyor jamming and Die Eject malfunctions. Contamination from residual powder material has been identified as the fundamental root cause of these breakdowns. The risk prioritization derived from the FME) indicates that the Die Eject component possesses the highest level of risk, with a RPN of 160. As a corrective measure, the recommended maintenance strategy is the implementation of *Scheduled On-Condition Tasks*, with a primary focus on periodic thorough cleaning and visual inspections of component integrity. It is highly recommended that the management establish specific Standard Operating Procedures (SOPs) for residual powder extraction. Furthermore, facility modifications should be considered, such as the permanent installation of a vacuum system within the Die Eject mechanism area, to facilitate the instantaneous removal of material residue. Finally, the progressive development and application of RCM mapping across other critical machinery lines is strongly advocated

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