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Analysis of Curing Machine Maintenance Using Failure Mode and Effects Analysis (FMEA) and Reliability Centered Maintenance (RCM) Methods Case Study of PT. Krismasindo Printing

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A B S T R A C T

This study aims to identify critical components and determine a maintenance strategy for curing machines at PT. Krismasindo Printing using the Failure Mode and Effects Analysis (FMEA) and Reliability-Centered Maintenance (RCM) methods. The study was conducted through observation, interviews, and analysis of historical failure data for the period April–June 2026. FMEA was used to prioritize risks based on the Risk Priority Number (RPN), while RCM was used to establish a maintenance strategy. The analysis was supplemented by calculations of Mean Time Between Failure (MTBF), Mean Time to Repair (MTTR), determination of preventive maintenance intervals, and a Fishbone Diagram. The results indicate that bearings, gearboxes, and electric motors are priority components. The resulting maintenance recommendations are expected to improve curing machine reliability and reduce production downtime.

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INTRODUCTION

The development of the manufacturing industry, especially in the printing sector, pushes companies to boost productivity, product quality, and timeliness in meeting customer demands. One key factor in the success of the production process is the reliability of the machines used. Highly reliable machines can keep the production process running smoothly, while machine breakdowns can lead to downtime, reduced production capacity, and higher maintenance costs. That's why implementing an effective maintenance system is an important aspect to support smooth production and enhance a company's competitiveness (Wohon et al., 2023) .

PT. Krismasindo Printing is a company in the printing industry, with a curing machine being one of the main pieces of equipment in the production process. The curing machine works to dry and harden the ink on the printing media through heating, ensuring the print quality meets the set standards. From the observations, the curing machine still experiences repeated damage in several components, especially in the mechanical drive subsystem, the heating system, and the electrical system. This condition leads to increased downtime, disrupts the smooth running of production, and adds to maintenance costs. In addition, the maintenance system in place is still dominated by corrective maintenance, meaning repairs are only done after breakdowns occur and are not yet able to optimally prevent component failures (Samharil & Priyana, 2022).

One method that is widely used to analyze component failure risks is Failure Mode and Effects Analysis (FMEA). This method is used to identify failure modes, failure causes, failure effects, and to determine the risk priority level through the Risk Priority Number (RPN), which is obtained from the combination of Severity, Occurrence, and Detection values. However, FMEA can only determine the priority of failure risks and does not provide recommendations on the appropriate type of maintenance actions. Therefore, this study combines FMEA with the Reliability Centered Maintenance (RCM) method to determine the most suitable maintenance strategy based on the characteristics and consequences of each component failure (Moubray, 1997).

Some previous studies have shown that applying the FMEA and RCM methods can improve the effectiveness of maintenance systems in various types of production machines. Research by (Firmansyah & Rizqi, 2024) showed that the FMEA method is effective in identifying components with the highest failure risk through RPN values, while implementing RCM can create a more systematic and reliability-oriented maintenance strategy. However, the combined application of these two methods on curing machines in the printing industry is still relatively limited. In addition, previous studies generally focused only on identifying failure risks without including reliability analysis using Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), determining preventive maintenance intervals, and root cause analysis using the Fishbone Diagram. This situation forms a research gap that underlies the conduct of this study (Faizzah et al., 2025).

This research aims to identify critical components along with failure modes, causes of failure, and their impacts using the Failure Mode and Effects Analysis (FMEA) method, determine component priorities based on Risk Priority Number (RPN) values, and develop maintenance strategy recommendations using the Reliability Centered Maintenance (RCM) method. In addition, this study uses Mean Time Between Failure (MTBF) analysis, Mean Time To Repair (MTTR), determination of preventive maintenance intervals, and Fishbone Diagram to support the development of more comprehensive maintenance recommendations. The results of this research are expected to serve as a reference for PT. Krismasindo Printing in improving the reliability of curing machines, reducing downtime, and supporting smooth production processes (Qurnaini & Rauf, 2026).

LITERATURE REVIEW

The research analysis started by using the Failure Mode and Effects Analysis (FMEA) method to identify critical components, failure modes, failure causes, failure effects, and to determine the Risk Priority Number (RPN) based on Severity (S), Occurrence (O), and Detection (D) parameters. The assessment was carried out based on observations, historical failure data, and interviews with maintenance technicians. Components with the highest RPN were then analyzed using the Reliability Centered Maintenance (RCM) method through the steps of Logic Tree Analysis (LTA), RCM Decision Worksheet, and Task Selection to determine the appropriate maintenance strategy.

Next, we calculate the Mean Time Between Failure (MTBF) and Mean Time to Repair (MTTR) to evaluate the reliability and ease of maintenance for each component. MTBF is calculated based on the total operating time and the number of failures, while MTTR is calculated using the total downtime and the number of failures for each component. The MTBF analysis results are used as the basis for creating recommendations for preventive maintenance intervals that align with the maintenance strategy from the RCM method.

The final stage is done using a Fishbone Diagram to identify the root causes of failures in components with the highest RPN values. The causal factors are grouped into five categories: Man, Machine, Method, Material, and Environment. The results of this analysis are used as the basis for drafting maintenance action recommendations to improve the reliability of the curing machine and reduce downtime during the production process.

METHODOLOGY

This study is a quantitative descriptive research conducted at PT. Krismasindo Printing, Karanganyar Regency, focusing on curing machines. The data used consists of primary data obtained through field observations and interviews with maintenance technicians and machine operators, as well as secondary data in the form of historical records of machine breakdowns, downtime, and operating hours during the period of April–June 2026. The analysis objects include 12 components of the curing machines that experienced failures during the study period.

Data analysis was done using the Failure Mode and Effects Analysis (FMEA) method to identify failure modes and determine the Risk Priority Number (RPN) value, and then continued with the Reliability Centered Maintenance (RCM) method to determine maintenance strategies through Logic Tree Analysis (LTA), RCM Decision Worksheet, and Task Selection. Next, the Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), and recommended preventive maintenance intervals were calculated. Fishbone Diagram analysis was used to identify the root causes of damage in components with the highest RPN values so that appropriate maintenance recommendations could be obtained.

RESEARCH RESULT

Identification of Critical Components of Curing Machine

Based on the results of observations, interviews with maintenance technicians, and historical damage data during the period April–June 2026, 12 curing machine components were found to have failed, namely heaters, thermocontrols, relays, connectors, bearings, gearboxes, electric motors, roller conveyors, chain conveyors, sprockets, pulleys, and V-Belts. These components were then analyzed using the Failure Mode and Effects Analysis (FMEA) method to identify failure modes, causes of failure, impacts of failure, and determine risk priority levels.

Table 1. Frequency of Curing Machine Component Failure

No.	Component	Failure Frequency
1	Bearing	7
2	V-Belt	3
3	Relay	3
4	Roller Conveyor	3
5	Sprocket	3
6	Heater	2
7	Temperature Controller	2
8	Gearbox	3
9	Connector	3
10	Electric Motor	2
11	Chain Conveyor	2
12	Pulley	2

The identification results show that bearings are the components with the highest frequency of damage, making them the most dominant component causing curing machine downtime.

Failure Mode and Effects Analysis (FMEA)

FMEA analysis is performed by assessing the Severity (S), Occurrence (O), and Detection (D) parameters for each failure mode. The assessment results are used to calculate the Risk Priority Number (RPN) as the basis for determining maintenance priorities.

Tabel 2. Risk Priority Number (RPN) Calculation Results

No.	Component	RPN	Rank
1	Heater	192	9
2	Temperature Controller	224	4
3	Relay	210	5
4	Connector	100	12
5	Bearing	432	1
6	Gearbox	336	2
7	Electric Motor	252	3
8	Roller Conveyor	180	10
9	Chain Conveyor	210	5
10	Sprocket	210	5
11	Pulley	120	11
12	V-Belt	210	5

The analysis results show that bearings, gearboxes, and electric motors have the highest RPN values, so they are designated as priority components in the preparation of maintenance strategies.

Reliability Centered Maintenance (RCM) Analysis

Priority components were then analyzed using the Reliability Centered Maintenance (RCM) method through the Logic Tree Analysis (LTA), RCM Decision Worksheet, and Task Selection stages. The analysis resulted in three maintenance strategies: Condition Directed (CD), Time Directed (TD), and Condition Directed + Time Directed (CD + TD).

Table 3. Task Selection Results

No.	Maintenance Strategy	Number of Components
1	Condition Directed (CD)	4
2	Time Directed (TD)	5
3	Condition Directed + Time Directed (CD + TD)	3

MTBF and MTTR Analysis

Reliability analysis is carried out by calculating the Mean Time Between Failure (MTBF) and Mean Time to Repair (MTTR) to determine the level of reliability and the average repair time for each component.

Table 4. MTBF and MTTR Calculation Results

No.	Component	Failure Frequency	MTBF (Hours)	MTTR (Minutes)
1	Bearing	7	80.00	117.86
2	V-Belt	3	186.67	60.00
3	Relay	3	186.67	53.33
4	Roller Conveyor	3	186.67	90.00
5	Sprocket	3	186.67	90.00
6	Gearbox	3	186.67	150.00
7	Connector	3	186.67	43.33
8	Heater	2	280.00	120.00

9	Temperature Controller	2	280.00	90.00
10	Electric Motor	2	280.00	150.00
11	Chain Conveyor	2	280.00	95.00
12	Pulley	2	280.00	90.00

The calculations show that the bearings have the lowest MTBF of 80 hours, while the gearbox and electric motor have the highest MTTR of 150 minutes. This indicates that these three components are a priority for maintenance.

Preventive Maintenance Recommendations

Based on the results of the MTBF analysis and the maintenance strategy using the RCM method, recommendations for preventive maintenance intervals are prepared for each component of the curing machine.

Table 5. Recommended Preventive Maintenance Intervals

No.	Component	MTBF (Hours)	Maintenance Strategy
1	Bearing	80.00	CD + TD
2	V-Belt	186.67	TD
3	Relay	186.67	TD
4	Roller Conveyor	186.67	CD
5	Sprocket	186.67	TD
6	Gearbox	186.67	CD
7	Connector	186.67	TD
8	Heater	280.00	CD
9	Temperature Controller	280.00	CD + TD
10	Electric Motor	280.00	CD
11	Chain Conveyor	280.00	CD + TD
12	Pulley	280.00	TD

These recommendations are expected to reduce the frequency of damage and downtime so that the reliability of the curing machine can be increased.

DISCUSSION

The research results show that bearings, gearboxes, and electric motors are the components with the highest failure risk based on the Failure Mode and Effects Analysis (FMEA). This condition indicates that the mechanical drive subsystem is the part that has the most influence on increasing curing machine downtime, thus requiring priority in the implementation of maintenance activities. The implementation of Reliability Centered Maintenance (RCM) produces maintenance strategies in the form of Condition Directed (CD), Time Directed (TD), and Condition Directed + Time Directed (CD + TD) which are adjusted to the characteristics of each component. The results of reliability analysis through MTBF and MTTR show that components with a low level of reliability require shorter preventive maintenance intervals so that the potential for failure can be minimized before disrupting the production process. Fishbone Diagram analysis shows that component damage is influenced by Man, Machine, Method, Material, and Environment factors. Therefore, improving machine reliability is not only done through component replacement, but also through regular inspections, scheduled lubrication, monitoring machine conditions, and implementing preventive maintenance based on recommendations from FMEA and RCM analysis results.

CONCLUSION AND RECOMMENDATIONS

This study successfully identified 12 curing machine components that experienced failure during the period April–June 2026. The results of the Failure Mode and Effects Analysis (FMEA) analysis showed that bearings, gearboxes, and electric motors were the components with the highest failure risk levels, making them the main maintenance priorities. Through the Reliability Centered Maintenance (RCM) method, maintenance strategies were obtained in the form of Condition Directed (CD), Time Directed (TD), and Condition Directed + Time Directed (CD + TD). MTBF and MTTR analysis were used as the basis for preparing preventive maintenance intervals, while the Fishbone Diagram identified Man, Machine, Method, Material, and Environment factors as the main causes of damage. The implementation of maintenance recommendations is expected to reduce downtime and increase the reliability of curing machines at PT. Krismasindo Printing.

PT. Krismasindo Printing is recommended to implement a preventive maintenance program according to the strategy and intervals generated through the RCM method, prioritizing bearing components, gearboxes, and electric motors. Further research can develop the analysis using other reliability methods, such as Fault Tree Analysis (FTA) or maintenance cost analysis, so that the resulting maintenance recommendations are more comprehensive.

ADVANCED RESEARCH

This study has limitations because it uses historical data of curing machine failures during the period April–June 2026, so the results of the reliability analysis and preventive maintenance interval recommendations are still influenced by the relatively limited data coverage. In addition, the study only focuses on the application of the Failure Mode and Effects Analysis (FMEA) and Reliability Centered Maintenance (RCM) methods without considering the maintenance cost aspects or a more in-depth reliability analysis. Therefore, further research is recommended to use a longer observation period and combine the FMEA and RCM methods with other methods, such as Fault Tree Analysis (FTA), Reliability Block Diagram (RBD), or maintenance cost analysis, so that the resulting maintenance strategy recommendations are more comprehensive and optimal.

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