Determining Preventive Maintenance Schedule on Press Machine Components using Age Replacement Methods

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Abstract. To minimize severe damage and reduce maintenance costs, it is essential to monitor and control the performance decline of machines periodically. Implementing regular preventive maintenance on the machines used in production activities is a key approach to achieve this goal. By performing scheduled maintenance on a regular basis, the strength of the machines can be maintained, ensuring their stability, and facilitating smooth production processes. Notably, the press machine serves as the primary printing equipment for the company's product manufacturing. Any breakdown in this machine can significantly disrupt production and lead to losses for the company. Frequent production interruptions due to sudden inspections and repairs are among the challenges faced by the company. To address this issue, it is recommended for the company to establish a specific preventive maintenance schedule for the press machine to ensure its stability. The Age Replacement method can be employed in creating this preventive maintenance schedule, as it determines the optimal replacement interval based on the component's age. By utilizing the Age Replacement method, the company can generate the most effective proposed scheduling required for maintaining the press machine in optimal condition.

1 Introduction

Purchasing industrial machinery is one of the major investments that a company must consider carefully. When a company decides to buy a new machine, there are several factors to consider, including the risks associated with the maintenance of the machine. Maintenance is one of the major activities that account for up to 40% of total costs [1]. System maintenance is a series of actions taken to keep the system functioning properly or restore the system to its original condition [2]. Small and medium scale industries sometimes ignore it because they feel the costs incurred are quite large. They choose to add these costs to operational costs, so that the machines they have will only be repaired if there is damage.

The high rate of operating failures causes the company to be unable to operate efficiently, resulting in decreased productivity [3]. When a company fails to perform proper

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maintenance on its production machines, the risk of unexpected machine breakdowns becomes higher. The losses that can arise due to damaged machines without adequate maintenance are significant. Moreover, the repair costs required to address such breakdowns can be substantial, including the cost of replacing parts or even replacing the entire machine. What's more, unexpected machine breakdowns can cause delays in meeting production targets, disrupt supply chains, and even damage a company's reputation in the eyes of customers. Therefore, neglecting machine maintenance can have a serious negative impact on a company's sustainability and profitability.

Indonesia, the second largest rubber producer in the world after Thailand [4], has a few thriving rubber industries. One of the prominent rubber industry centres is in Bandung, West Java. The city has become an important base for various rubber companies engaged in the production of various types of rubber products, such as tires, automotive equipment, industrial components, and others. Within the rubber industry, presses play a major role. Presses are used to shape, mold, and compress rubber materials in various shapes and sizes. The strong presence of the rubber industry in Bandung reflects Indonesia's important role in the global rubber market, as well as its significant contribution to the country's economy.

Rubber companies in Bandung are mostly small and medium scale, so they are included in companies that do not think too much about machine maintenance. Based on the data obtained, the machine that often experiences damage is the press machine. To solve the problem of machine failure, the Age Replacement method can be used. This method can increase the effectiveness of machine maintenance, thereby reducing downtime and increasing company productivity. This method can also provide an accurate maintenance time interval schedule for the machine. The Age Replacement method is a component replacement model that is based on the service life of the component. The goal is to avoid replacing components that are still new and to adjust the component replacement schedule according to the condition of the components [5].

2 Methodology

The sequence of research in general is carried out in several stages, namely, collecting machining data, damage interval data, calculating TTF and TTR, determining critical components, determining index of fit and goodness of fit, determining damage distribution tests, calculating MTTF, and determining maintenance time intervals.

Data collection in this study uses historical data on machine damage for the last 2 years. The data used includes data on damaged components, time intervals between damage, downtime, repair time, component prices, costs incurred by the Company when damage occurs.

The data processing stages in Age Replacement are as follows:

1. Determination of critical components determined based on the amount of damage to each component that most often occurs using Pareto diagrams.
2. Calculation of damage and repair time intervals, after obtaining the required data, calculating, and analysing data on the time interval for damage and repair of components, by calculating Time to Failure (TTF) and Time to Repair (TTR) critical components on the press machine.
3. Identification of damage distribution, to determine the most suitable distribution model for time between damage (TTF) and time to damage (TTR) data, the Index of Fit calculation is carried out. This calculation is done using four distribution models, namely the Weibull distribution, exponential distribution, normal distribution, and lognormal distribution. The largest r value of the four models will be selected as the most suitable distribution model.

4. Goodness of Fit test, this test is carried out to determine whether the data obtained is suitable or close to the distribution of the largest r value. If the calculation results state that the data does not fit the selected distribution, then retesting is carried out using the second largest r value and so on until compliance with a particular distribution is obtained. The data used are the TTF and TTR values of the press machine.
5. MTTF calculation, at this stage the parameter calculation is carried out in accordance with the selected distribution. Parameter calculations for each distribution are different from one another. The calculated parameters will be used to calculate the MTTF (Mean Time to Failure) value.
6. Calculation of component replacement costs due to repair (Cp) and component replacement costs due to damage (Cf), for component replacement costs due to maintenance (Cp) includes labor costs (operators), maintenance or mechanical labor costs, and component prices. Meanwhile, the cost of replacing components due to damage (Cf) includes operator costs, mechanic costs, lost production costs, and component prices where all of these costs are losses caused by component damage.
7. Determination of component repair and prevention replacement intervals, carried out after calculating MTTF, then further making maintenance scheduling using the Age Replacement method, where this method aims to minimize the downtime that occurs.

3 Result and Discussion

3.1 Critical Component Determination

The results of the calculation of the determination of critical components using a pareto diagram. Critical components are determined based on the frequency of component damage as shown in Table 1.

Table 1. Component Breakdown Frequency

Component	Frequency	Percentege	Cum Percentage
Seal Hydraulic	5	25%	25%
Seal Ball Valve	4	20%	45%
Hydraulic Hose	4	20%	65%
Relief Valve	4	20%	85%
Hydraulic Lever	1	5%	90%
Asbestos Plates	1	5%	95%
Pressure Gauge	1	5%	100%
Total	20		

Based on Table 1, a parametric diagram can be made, as shown in Figure 1.

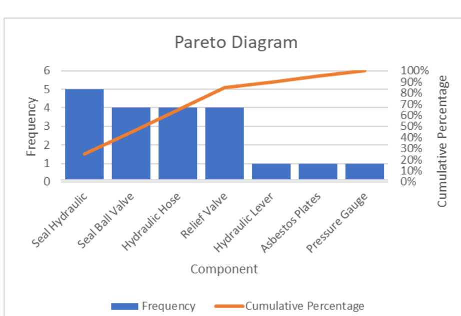

Fig. 1. Pareto Diagram of Critical Component Selection

The selected critical components are Hydraullic Seal, Ball Valve Seal, Hydraulic Hose and Relieve Valve.

3.2 Time Interval between Breakdown and Repair

Calculation of damage intervals consists of calculating Time to Failure (TTF) and Time to Repair (TTR) on critical components for the time interval between damage (TTF) can be seen in Table 2, while for the time interval between repairs (TTR) can be seen in Table 3.

Table 2. Time to Failure

Number	Date of Failure	TTF (days)	Date of Failure	TTF (days)
Seal Hydraulic			Seal Ball Valve	
1	20/03/2021		06/04/2021	
2	17/07/2021	119	05/10/2021	182
3	18/02/2022	216	04/02/2022	122
4	20/05/2022	91	13/09/2022	221
5	24/10/2022	157		
Hydraulic Hose			Relief Valve	
1	18/01/2021		17/05/2021	
2	27/07/2021	190	27/10/2021	163
3	10/03/2022	226	14/02/2022	110
4	18/08/2022	161	19/10/2022	247

Table 3. Time to Repair

Number	Date of Failure	TTR (days)	Date of Failure	TTR (days)
Seal Hydraulic			Seal Ball Valve	
1	20/03/2021	0,292	06/04/2021	1,104
2	17/07/2021	0,292	05/10/2021	1,104
3	18/02/2022	0,292	04/02/2022	1,104
4	20/05/2022	0,292	13/09/2022	1,104
5	24/10/2022	0,292		
Hydraulic Hose			Relief Valve	
1	18/01/2021	0,396	17/05/2021	0,354
2	27/07/2021	0,396	27/10/2021	0,354
3	10/03/2022	0,396	14/02/2022	0,354
4	18/08/2022	0,396	19/10/2022	0,354

3.3 Index of Fit

The index of fit (r) value of the critical component is used to determine the damage distribution pattern. The largest r value indicates the most suitable damage distribution pattern [6]. The r value of critical components is calculated using time between failures (TTF) data with four distribution models, namely Weibull, exponential, normal, and lognormal distributions. The results of calculating the index of fit with TTF data can be seen in Table 4.

Table 4. Index of Fit TTF

Component	Distribution	Index of Fit	Selected Distribution
Seal Hydraulic	Weibull	0,039	Weibull
	Exponential	-0,015	
	Lognormal	0,029	
	Normal	0,013	
Seal Ball Valve	Weibull	0,241	Exponential
	Exponential	0,549	
	Lognormal	0,320	
	Normal	0,391	
Hydraulic Hose	Weibull	-0,414	Weibull
	Exponential	-0,598	
	Lognormal	-0,488	
	Normal	-0,445	
Relief Valve	Weibull	0,441	Exponential
	Exponential	0,740	
	Lognormal	0,514	
	Normal	0,608	

3.4 Goodness of Fit

The distribution suitability test (Goodness of Fit) is carried out based on the selected distribution from the calculation of the Index of Fit [6]. The results of the distribution fit test (Goodness of Fit) of the TTF data of the critical components of the press machine can be seen in Table 5.

Table 5. Goodness of Fit TTF

Component	Selected Distribution	Distribution fit test	Criteria Value	Calculation Result	GoF Result
Seal Hydraulic	Weibull	Mann's Test	6,388	-2,538	Accepted H_0
Seal Ball Valve	Exponential	Barlett's Test	0,216 - 9,35	6,790	Accepted H_0
Hydraulic Hose	Weibull	Mann's Test	19,247	-5,938	Accepted H_0
Relief Valve	Exponential	Barlett's Test	0,216 - 9,35	6,896	Accepted H_0

Based on Table 5, the goodness of fit for TTF data for all critical components is the same as the index of fit results.

3.5 Distribution Parameter

The damage distribution parameters are calculated based on the selected distribution pattern, while the calculation of the selected distribution parameters aims to find out the component damage rate and support for the calculation of the distribution function [7]. This parameter calculation is based on the distribution used. Distribution parameters are determined based on the results of the distribution fit test (Goodness of Fit). The results of determining the distribution parameters of the TTF data for critical components of the press machine can be seen in Table 6.

Table 6. Distribution Parameter of TTF

Component	Distribution	Parameter
Seal Hydraulic	Weibull	θ = 139,390
		β = 69,266
Seal Ball Valve	Exponential	λ = 0,0076
Hydraulic Hose	Weibull	θ = 184,246
		β = -13,741
Relief Valve	Exponential	λ = 0,0077

3.6 Mean Time to Failure dan Mean Time to Repair

Calculation of Mean Time to Failure (MTTF) on critical components is carried out based on the distribution selected from the goodness of fit results and distribution parameters on each individual component [8]. The results of the MTTF and MTTR calculations for critical components can be seen in Table 7.

Table 7. MTTF for Critical Component

Component	MTTF (days)	MTTR (days)
Seal Hydraulic	138	0,292
Seal Ball Valve	193	1,104
Hydraulic Hose	131	0,396
Relief Valve	130	0,354

Preventive replacement time (Tp) is the time starting from the initial replacement of critical components without damage until the tool can be used again, while for damage replacement time (Tf) is the time starting from the initial damage until the tool can function again. The calculation of Tp and Tf is the time data that will be used to calculate the cost of replacing repairs (Cp) and the cost of replacing damage (Cf), as well as calculating the preventive replacement interval and the cost of preventive replacement maintenance with the Age Replacement method [9]. Table 8 is the result of the calculation of Tp and Tf of the critical components of the press machine.

Table 8. Tp and Tf for Critical Component

Component	**Tp (hours)**	**Tf (hours)**
Seal Hydraulic	3	7
Seal Ball Valve	2,5	26,5
Hydraulic Hose	4,5	9,5
Relief Valve	3,5	8,5

3.7 Cost of Preventive and Cost of Failure

The calculation of Cost of Preventive (Cp) and Cost of Failure (Cf) is related to the repair costs and damage costs incurred by the company [9]. Table 9 is the result of the calculation of Cp and Cf on the critical components of the press machine.

Table 9. Cp and Cf for Critical Component

Component	Cp	Cf
Seal Hydraulic	Rp 501.095,05	Rp 578.849,84
Seal Ball Valve	Rp 262.579,21	Rp 680.967,67
Hydraulic Hose	Rp 382.642,58	Rp 477.429,05
Relief Valve	Rp 859.610,89	Rp 954.397,37

3.8 Component Replacement Time Interval

The Age Replacement method used aims to minimize the downtime that occurs. The preventive replacement interval is determined by performing trial and error calculations, until the minimum maintenance cost is obtained [9]. Table 10 is the result of the calculation of the critical component preventive replacement interval.

Table 10. Component Replacement Time Interval Calculation

Component	Prevention Time Interval (days)	C(tp)
Seal Hydraulic	130	Rp.2.605,99
Seal Ball Valve	155	Rp.1.959,89.
Hydraulic Hose	120	Rp.1,602,76
Relief Valve	120	Rp.4.090,64.

In this study, calculations were made if all components were replaced at the same time, seeing that the component replacement schedule was not so far away. If one maintenance is carried out to replace the four critical components, it will reduce other related costs. A comparison of the total cost of preventive maintenance if the components are combined and the components are not combined can be seen in Table 11.

Table 11. Maintenance Cost Comparison

	Total Cost Maintenance	Saving
Before Merged	Rp 3.773.402,98	45%
After Merged	Rp 2.057.783,18	

4 Conclusion

The results of the calculation of preventive replacement time intervals for certain critical components are as follows: hydraulic seal components 130 days, ball valve seal components 155 days, hydraulic Hose components 120 days, and Relief Valve 120 days. As for even more savings, because the component replacement time is not far apart, it is done simultaneously to make it more efficient. The comparison of maintenance costs if done separately is higher than the maintenance costs if combined, which can save 45%.

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