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Maintenance system design on air jet loom (AJL) machine using Reliability Centered Maintenance (RCM) method

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Abstract. Air Jet Loom (AJL) is a critical machine in textile industries, used to convert thread into fabric. This research used a leading textile company in Yogyakarta as a case study. Preliminary observation in the case study showed that the AJL machine had a high downtime that affects the overall production process. This study aimed to identify critical components of AJL machine and designed maintenance system for AJL machine to reduce downtime. Reliability centered maintenance (RCM) method was used in designing maintenance system by focusing on improving machine reliability. The study began with the identification of critical components of AJL machine using a fishbone diagram and continued with pareto diagram. For each critical component, time between failure (TBF) data was collected. The collected TBF data was then used to calculate the level of reliability and maintenance schedule. The results found that there were six critical components of AJL machine, i.e., VPM, take up, insertion, kamran, oil circulation, and leno. The preventive maintenance scheduling interval for the six components was VPM 120 hours, belt take up 144 hours, insertion 72 hours, kamran 24 hours, oil circulation 144 hours and leno 96 hours. The proposed preventive maintenance schedule on the six critical components of AJL machine was able to reduce downtime by 30% and increase fabric production by 13%.

1. Introduction¹³

Machine is one of the important factors supporting the sustainability of the production process [1]. Machine may experience a decrease in performance or even failure, especially if it used continuously. The decrease in machine performance and failure will have an impact on the decrease of production process performance, both in terms of quality and quantity of production. There are two losses caused by machine failure, i.e., (1) a decrease in profits due to non-fulfilment of consumer orders; and (2) an increase in total production costs due to machine repairs [2]. Because of these losses, there are a need for machine maintenance, so the machine work optimally and the sustainability of the production process can be maintained.

Maintenance is defined as the activity of maintaining, repairing and improving machines and equipment in order to obtain the optimal conditions of the production process according to the desired planning [3]. Preventive maintenance, one of maintenance method, is a planning activity in preventing a damage or a failure in machinery and facilities. Preventive maintenance is designed to be able to maintain and improve the reliability of machines and facilities by replacing worn parts before the machine and facilities are completely failure [4]. Reliability centered maintenance (RCM) is the foundation of a machine maintenance, and techniques used to develop preventive maintenance scheduled [6]. RCM focuses on preventive maintenance against specific failure of production system [7].

Company X, one of the leading textile companies in Yogyakarta, was used as a case study. The production process of Company X is supported by machines and facilities that running continuously.

Continuous use of the machine will lead to decrease in performance or even a failure if it is not supported by an appropriate maintenance system. Company X has implemented preventive maintenance on the machine, which is applied through daily repairs in the form of checking and cleaning, weekly maintenance in the form of component lubrication, and monthly maintenance in the form of component replacement. Although preventive maintenance has been applied, the machine downtime was still very high. The downtime for six months of observation was 5,420 mins downtime on an air jet loom (AJL) machine, 2,880 mins downtime on a machine in preparation sections, and 2,334 mins downtime on a grey finishing machine. The high downtime is an indication of the lack of effective maintenance.

This study focuses on the weaving section of Company X, which is the critical section that influences the production sustainability of Company X. The research aims to design proper machine maintenance schedules using the RCM method. The RCM method is expected to help in designing proper maintenance schedule and providing effective maintenance task. Proper maintenance system will lead to reduced downtime and increased machine reliability. Through these two results, it is expected to increase the quantity and quality of fabric produced.

The remainder of this paper is organised as follows: in Section 2, a literature review of maintenance management, RCM, distribution of failure, and analysis of time between failure is presented; in Section 3, the research method used is explained; in Section 4, the data collection process is presented, and calculation results are discussed; finally, in Section 6, conclusions and suggestions for future research are given.

2. Literature review

2.1. Maintenance management

Maintenance is an activity in maintaining the capabilities of the facility as well as repairs or changes as planned so that the facility functions properly in a ready to use condition [8]. Management is a process of planning, organizing, and controlling the organization to achieve the desired goals [9]. Based on this description, it can be concluded that maintenance management is an activity of planning, organizing, and controlling of maintenance operations to maintain the ability of industrial facilities to continue to function properly in a ready to use condition [10].

2.2. Reliability centered maintenance (RCM)

Application of reliability can help in estimating components or machines to be able to work in a certain period. RCM is a process of what should be done to ensure that all assets can function properly during operation [11]. The RCM helps in developing maintenance system properly, obtaining information on what steps to take in the design of maintenance.

2.3. Distribution failure

Distribution used to analyse reliability is divided into 4 types of distributions: Weibull, Normal, Lognormal and Exponential. Weibull distribution is the most widely used for all failure characteristics of the product, especially for calculating component life. Weibull distribution can be used for either increasing or decreasing failure. There are two parameters used in Weibull distribution: θ which are called scale parameters and β which are called shape parameters. Reliability functions of Weibull distribution is as follow [5].

$$R(t) = e^{-\left(\frac{t}{\theta}\right)^\beta} \quad (1)$$

Where: $\theta > 0$, $\beta > 0$ and $t \geq 0$; β = shape parameter; θ = scale parameter; e = Euler number

2.4. Analysis of time between failure

To analyse trends in TBF data, it can be performed by two graphical tests. The first graphical test is conducted by plotting cumulative TBF data as X axis and cumulative frequency of failure (as Y axis). The second graphical test is conducted by plotting the previous TBF data ($i-1$ -th) (as the X axis)

and plotting the current TBF data or after i -th (as the Y axis). If the data shows a cluster of point, then the data is considered not to have a trend or if the data shows more than one cluster of points it is considered to have a trend [12].

3. Research method

The method of data collection consists of three methods: (1) direct observation; (2) interviewing head of maintenance and machine operators; and (3) literature studies. Data collection was carried out during six months of observation. The data collected comprises type of machine failure, failure frequency, failure interval, failure duration, repair duration, time between failure, and components downtime, as well as supporting data such as working hours (shift and unshift), amount of fabric production, length of fabric production, cost of production and selling price of fabric.

The failure data was then grouped by machine component and mapped into the pareto diagram. The mapping results showed the most dominant downtime of components, where these components will be analysed further. The time between failure (TBF) data of each component was then calculated. TBF data was then tested for trend plots to find out whether the data has a trend or not. Trend test was carried out with two graphical tests, trend plots and successive service life plots.

Through the trend test it will be known whether failure are increases, decreases or constants. If the TBF data does not have a trend, a goodness of fit test is conducted to determine the type of distribution. Furthermore, based on the type of distribution, a reliability value was calculated before and after maintenance of each component. Based on the calculation of reliability, the appropriate interval time for component maintenance as well as maintenance schedule will be obtained.

4. Result and discussion

4.1. Identification of critical components

Critical components are defined as components that have a significant impact on the production process. The results of the initial data collection showed that in the weaving process, the air jet loom (AJL) machine has the highest total downtime compared to other machines. The six months observation showed that the AJL machine experienced 5,420 minutes of downtime, while the machine in the preparation and finishing section respectively experienced 2,880 minutes and 2,334 minutes of downtime. The occurrence of downtime in AJL machine inhibits the whole production process, and it has an impact on the decrease of production quantity, delay in the production of products, poor product quality, and high production costs.

The root causes of the AJL downtime, showed from the fishbone diagram, were components failure, broken threads, power failure, dirty production environment, low operator capability, and low spare parts quality. The root causes were then mapped into pareto diagram. The mapping result showed that the main cause of AJL downtime was component failure, as shown in the Figure 1.

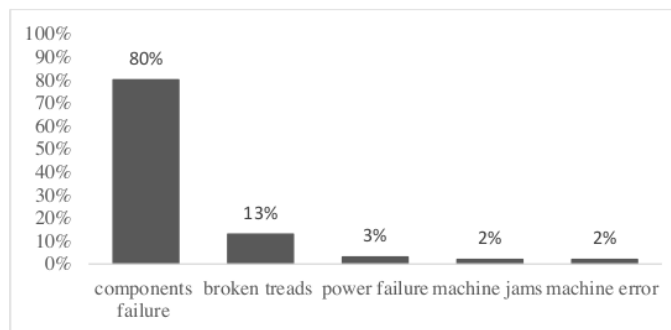


Figure 1. Root cause of AJL machine downtime.

Historical data on AJL component failure, showed that there were six components that were often damaged, namely:

1. VPM as a current divider on the warp thread.

2. Belt take up as a pulling and rolling of fabric.
3. Insertion as a weft insertion
4. Kamran as a mouth opening of warp.
5. Oil circulation as an oil diverter to all AJL components
6. Leno, as a component which functions to cut and tidy the edge of the fabric produced

4.2. Reliability analysis

The time between failure (TBF) data of the six components then performed the trend plot test and successive service life plot test. The trend plot test was performed by plotting the cumulative TBF (x axis) and the cumulative frequency of failure (y axis). Whereas the successive service life plot test was carried out by scatter plots the previous TBF data ($i-1$ th TBF) on x axis and the current TBF data (i or $i+1$ th TBF) on y axis. Figure 2 and Figure 3 show the results of the plot tests for VPM components. The figure indicates that the TBF data of VPM component has no trend. The plot test results of the others component, i.e., belt take up, insertion, Kamran, oil circulation and leno component also show that the TBF data have not trend.

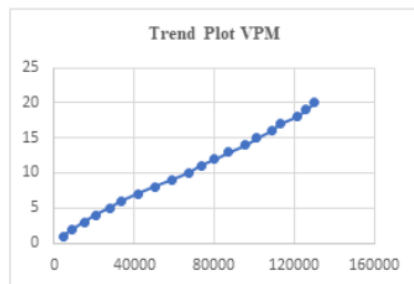


Figure 2. Trend plots of VPM component.

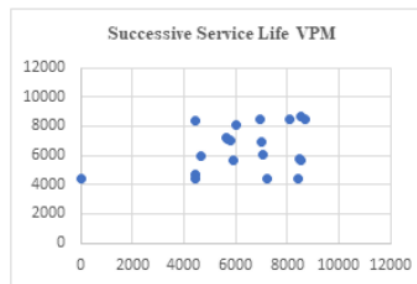


Figure 3. Successive service plots of VPM component.

The plot test results showed that the TBF data has no trend, so the goodness of fit test was performed. The test was carried out using Minitab 18 software. The test results showed that all components follow the Weibull distribution. The test results are shown in Table 1. Mean time to failure (MTTF) refers to the lifetime of a machine or a component. Whereas mean time to repair (MTTR) defines as the time required to repair a machine or a component. The VPM component has a MTTF value of 108,92 hours and MTTR value of 59,85. It means that the VPM component can operate normally until it fails for up to 108,92 hours, and it requires 59,856 minutes to repair the damage until the machine returns to normal.

Table 1. Results of reliability calculation.

Component	Dist.	Value	Scale parameter (h)	Shape parameter	MTTF (h)	MTTR (min)
VPM	Weibull	1.008	118.81	4.869	108.92	59.85
Belt take up	Weibull	1.175	102.11	2.039	90.47	32.85
Insertion	Weibull	0.993	53.112	1.599	47.62	41.39
Kamran	Weibull	5.035	33.65	1.825	29.91	48.15
Oli circulation	Weibull	1.137	97.55	1.954	86.50	24.76
Leno	Weibull	2.263	69.93	1.670	62.48	22.05

4.3. Discussion

The VPM component is simulated for repairs every 120 hours. The simulation results are shown in Figure 4, where $R(t)$ is the reliability of the current maintenance policy and $Rm(t)$ is the reliability of the proposed maintenance policy (repairs every 120 hours). The graph indicates a significant increase in the level of reliability of VPM machine. Preventive maintenance on VPM components at interval of 120 hours increases the machine lifetime by 21%. This number was obtained by conducting a series of maintenance activities on VPM component, such as checking, cleaning and replacing components. The activities were formulated according to the function of the VPM machine as a current divider in the AJL machine. Using the same method, a preventive maintenance schedule for the other five components, namely: belt take up scheduled every 144 hours, insertion scheduled every 72 hours, Kamran scheduled every 24 hours, oil circulation scheduled every 120 hours and leno scheduled every 96 hours.

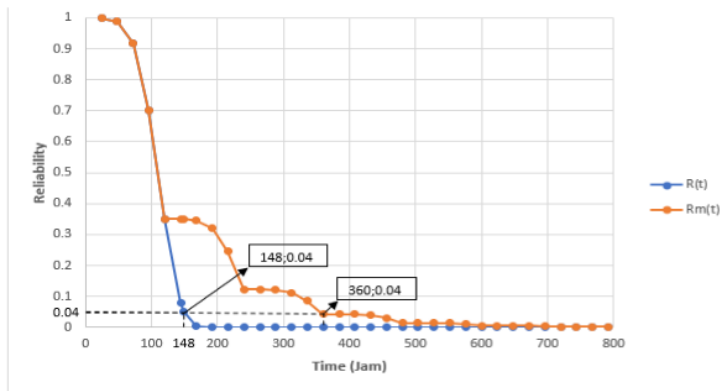


Figure 4. Reliability of VPM component.

A proposed maintenance policy is shown in Table 2. The VPM component has a MTTF value of 108,92 hours and a MTTR value of 59,8 minutes. The VPM component is proposed to be repaired every 120 minutes through component replacement. The maintenance tasks and maintenance interval for the other five components are shown in the following row.

Table 2. Summary of preventive maintenance policy for AJL machine.

No	Component	MTTF (hours)	MTTR (mins)	Maintenance tasks	Maintenance interval (hours)
1	VPM	108.92	59.8569	Component replacement	120
2	Belt take up	90.47	32.8567	Component replacement	144
3	Insertion	47.62	41.3919	Component replacement	72
4	Kamran	29.91	48.1544	Component replacement	24
5	Oli circulation	86.50	24.7695	Component replacement and repairment	120
6	Leno	62.48	22.0525	Component repairment	96

Proposed maintenance schedule then compared to the existing schedule. The calculations show that the proposed maintenance schedule lead to increase in the number of fabric production from 557,124.43 meters per month to 724,629 meters per month. Fabric production increased by 13%, equivalent to 167,505.26 meters of fabric per month.

5. Conclusion

Fishbone and pareto diagram showed the six critical components of the AJL engine, namely VPM components, take up belts, insertion, kamran, oil circulation and leno. The maintenance intervals for the six consecutive components are VPM scheduled every 120 hours, belt take up scheduled every 144 hours, insertion scheduled every 72 hours, Kamran scheduled every 24 hours, oil circulation scheduled every 120 hours and leno scheduled every 96 hours. While recommended maintenance activities include checking, cleaning, repairing, resetting and replacement. The proposed maintenance policy lead to increase the amount of fabric production by 13%, equivalent to 167,505.26 meters per month.

Research on maintenance, as conducted in this study, is very dependent on the completeness and accuracy of the data, so future research recommendations are how to design a system for recording machine failure and maintenance data, especially in small-medium companies.

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