Design of preventive maintenance system at PT. Y with reliability engineering approach

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Abstract. Maintenance has a very decisive role in the production activities of a company that concerns the smoothness and congestion of production, delays, and the volume of production and production efficiency. The use of semi-automatic machines at PT. Y influences engine reliability. The reliability of the engine depends on the period of use, the older the machine's age, its function also decreases. The problem formulated in this study is the preparation of maintenance schedules with due regard to the reliability of critical components on the sterilizer machine. The development of the program is based on the reliability engineering approach, which covers the distribution test of engine damage time interval data, calculation of the mean time between failure (MTBF) of the engine, and the reliability of the engine (reliability) when it is repaired. Secondary data obtained from preventive maintenance at PT. Y.

1. Introduction

Maintenance is a series of various actions to take care of an item in or repair to an acceptable condition. Support has a very decisive role in the production activities of a company that concerns the smoothness and congestion of production, delays, and the volume of production and production efficiency. Thus, maintenance has the same function as significant as other functions in the company. Using probabilistic expressions, system reliability is the ability to perform the wanted function, such as the system failure probability after a specified time, expected failure period, and the number of expected failures [1,2].

The purpose of maintenance is to extend the use of assets (every part of a workplace, building and its contents), guarantee availability of equipment for industrial activities, guarantee operational preparation of all equipment needed under emergency circumstances and ensure workers’ safety. Meanwhile, preventive maintenance is supposed to prevent equipment or machine breakdown during operating time. The acceptable criteria of support are availability, which assessed the effectiveness of maintenance. The formula of availability is the ratio of mean working time to mean total time, for example, mean operating time plus mean repair time. Five elements to formulate maintenance strategies are breakdown maintenance, backup equipment, regularly scheduled preventive maintenance, inspection, and equipment upgrades [3,4,5].

Preventive maintenance is all actions taken in a planned, periodic, and specific schedule to maintain a device in the specified operational conditions, through a process of inspection and reconditioning [6].

Reliability is the probability that a component or system can fulfill the function specified within a specific time under stable operating conditions. The security of the machine depends on the period of
use; the machine is used continuously; the reliability will continue to decline. This reliability has the main indicator of the security of a system that is the probability function. Probability Density Function (f(t)) is a function that describes the shape of a failure distribution. Reliability function (R(t)) is a probability function of a machine or component not to be damaged in a specific time (t). Hazard Rate Function (α(t)) is a function that shows the number of failures per unit time (t). Each probability function can calculate the reliability of a machine or component from several perspectives. The damage characteristics of each piece of equipment are generally not the same, mainly if operated under different environmental conditions. Equipment that has the features and is operated in the same conditions may also provide a value of time interval between various damages [7].

Distribution of damage is information about the useful life of a population of equipment. Distribution of damage to equipment has different forms. Commonly used are Exponential, Weibull, Normal, and Lognormal distributions, where the damage distribution can meet various damage phases. If the sample size is small, the distribution parameter estimation is done using the least-squares method (Least - Squares Curve Fitting). The exponential distribution is usually used if the rate of damage does not change and is constant with time. The normal distribution is generally suitable for the phenomenon of wear out region. Weibull distribution can be used on models that experience an increase or decrease in damage rates. While the Lognormal Distribution has similarities with the Weibull Distribution, so if in a case, it has a Weibull Distribution, then the case is also suitable to use the Lognormal Distribution [8].

Previous research by Maukarshows shows that implementation of the proposed maintenance schedule has increased 45% of machine reliability and decreased maintenance cost by 48% [9]. Research related to the Reliability Engineering method was conducted by Sembiring on a crumb rubber company. It can be concluded that maintenance efficiency also improved with the application of preventive maintenance for several critical machines [10]. Another research done by Sembiring shows the result of Reliability Centered Spares can be used to obtain essential components needed and maintenance during a year [11].

2. Research methods
PT. Y is a palm oil processing factory with a capacity of 60 tons/hour. The final product produced is CPO (Crude Palm Oil) and PK (Palm Kernel). The factory uses semi-automatic machines and equipment to carry out production activities.

PT. Y has CPO product quality standards, consisting of free fatty acids (3.5%), moisture (0.15%), and impurity (0.02%). Problem identification will be carried out on free fatty acids because it plays the most crucial role in controlling the quality of palm oil. The problems to be discussed are from machine factors, namely downtime and breakdown at the sterilizer station. Sterilizer station aims to boil fresh fruit bunches until soft. Also, boiling can deactivate the lipase enzyme that triggers the increase in free fatty acid levels in FFB, so the role of the sterilizer station is crucial in maintaining the quality of raw materials. If fresh fruit bunches are not immediately boiled, free fatty acid levels continue to increase and cause a decrease in the quality of the final product.

Maintenance system at PT. Y is preventive maintenance, which is maintaining the condition of the machine regularly to anticipate engine damage. Implementation of preventive maintenance at the plant is still general, such as RPM, grounding, vibration, and plate thickness, which does not cover all engine components. The replacement and maintenance of each engine component are based on visual observations such as wear and rust, as well as engine life (hours meters). Essential alternative like this is not entirely accurate. There are many other factors that trigger damage to the machine prematurely, such as human error, material resistance, overload, and other factors that are not identified. This can trigger engine downtime and breakdown during the production process and harm the company so that further efforts are needed to maximize the preventive maintenance system.

The problem-solving idea that can be given in the preparation of a maintenance schedule by taking into account the reliability of critical components on the sterilizer machine. The development of the
program is based on the test distribution of the engine damage time interval data, calculation of the mean time between failure (MTBF) of the engine, and the reliability of the machine (security) when it is repaired.

Secondary data obtained from preventive maintenance at PT. Y. Data assumption on the frequency of engine damage in the sterilizer station can be seen in Table 1.

**Table 1. Data on Frequency of Machine Damage at Sterilizer Station**

| No | Machine Name | Frequency of Machine Damage per Month | Total | Percentage |
|----|--------------|--------------------------------------|-------|------------|
| 1  | Sterilizer 1 | Aug 3 Sept 2 Oct 6 Nov 3 Dec 3 Jan 1   | 22    | 20%        |
| 2  | Sterilizer 2 | May 1 Feb 1 Mar 1 Apr 1 Mei 1 Jun 1    | 16    | 15%        |
| 3  | Sterilizer 3 | Jan 2 Feb 2 Mar 3 Apr 5 Mei 1 Jun 2    | 18    | 17%        |
| 4  | Sterilizer 4 | Feb 2 Mar 1 Apr 2 Mei 3 Jun 1          | 14    | 13%        |
| 5  | Sterilizer 5 | May 1 Jun 1 Jul 2                     | 12    | 11%        |
| 6  | SFB Scrapper no. 1 line 1 (SFB Hopper–Tipper–Thresher) | 1 3 2 1 1 1 | 8 | 7% |
| 7  | SFB Scrapper no. 2 lines 1 (SFB Hopper) | 2 1 1 1 1 1 1 | 7 | 6% |
| 8  | SFB Scrapper no. 3 line 1 (SFB Hopper–Tipper–Thresher) | 1 1 1 1 | 3 | 3% |
| 9  | Horizontal Scraper to Sterilizer 1 | 1 1 1 1 | 4 | 4% |
| 10 | Horizontal Scraper to Sterilizer 2 | 1 1 1 | 3 | 3% |
| 11 | Sterilizer Condensate Pit | 1 | 1 | 1% |
| 12 | Sterilizer Air Compressor | 1 | 1 | 1% |

Total 109 100%

3. Result and analysis

Based on data on the frequency of engine damage in the last one year period, an analysis is done with a Pareto diagram to get critical machines, shown in Fig.1.

![Pareto Engine Damage Diagram at the Sterilizer Station](image)

**Figure 1. Pareto Engine Damage Diagram at the Sterilizer Station**

The result of the pareto diagram of engine damage with the principle of 80%-20% shows that there are five sterilizer machines that often suffer loss up to a cumulative percentage of 80%. Data on the frequency of critical engine component damage can be seen in Table 2.
| No | Components Name                  | Sterilizer 1 | Sterilizer 2 | Sterilizer 3 | Sterilizer 4 | Sterilizer 5 | Total |
|----|----------------------------------|--------------|--------------|--------------|--------------|--------------|-------|
| 1  | Liner Telescopic                 | 2            | 1            | 3            |              |              |       |
| 2  | Hydraulic Chute                  |              |              |              |              |              |       |
| 3  | Steam Umbrella Pipe              | 1            | 1            |              |              |              |       |
| 4  | Condensate Pipe                  |              |              |              |              |              |       |
| 5  | Panel Cable                      |              |              |              |              |              |       |
| 6  | Liner                            |              | 1            |              | 1            |              |       |
| 7  | Steam Pipe                       |              | 1            |              | 1            |              |       |
| 8  | Strainer Pipe                    |              |              |              |              |              |       |
| 9  | Chute                            |              |              |              |              |              |       |
| 10 | Chute Telescopic Plate           |              |              | 1            | 1            | 9            |       |
| 11 | Actuator Valve Inlet             |              |              |              |              |              |       |
| 12 | Bottom Liner                     | 4            | 5            | 5            | 1            | 1            | 16    |
| 13 | Pipe Support                     |              |              |              |              |              |       |
| 14 | Limit Switch VS                  |              |              |              |              |              |       |
| 15 | Coupling Chain                   |              |              |              |              |              |       |
| 16 | Chamfer VS                       |              |              |              |              |              |       |
| 17 | Bleed Pipe                       |              |              |              |              |              |       |
| 18 | Cylinder Chute                   |              |              |              |              |              |       |
| 19 | Packing Steam Inlet              |              |              |              |              |              |       |
| 20 | Hydraulic Gate                   |              |              |              |              |              |       |
| 21 | Coupling Arch Breaker            |              |              |              | 1            | 1            | 2     |
| 22 | Arch Support Pipe                |              |              |              | 2            |              | 3     |
| 23 | Arch Breaker Holder              |              |              |              |              |              |       |
| 24 | Auger Hanger                     | 4            | 4            |              | 2            |              | 10    |
| 25 | Arch Breaker Blade               | 2            |              |              |              |              |       |
| 26 | Pipe                             |              |              |              |              |              |       |
| 27 | Conveyor Auger                   | 2            |              |              | 1            |              | 3     |
| 28 | Steam Strainer                   |              |              |              |              |              |       |
| 29 | Umbrella Pipe Holder             |              |              |              |              |              |       |
| 30 | Auger Coupling Chain             |              |              | 3            | 1            | 4            |       |
| 31 | Steam Pipe (in top of Arch Breaker) |              |              |              | 1            |              |       |
| 32 | Arch Breaker Chain               |              |              |              | 1            |              | 1     |
| 33 | Arch Breaker Blade               |              |              |              |              | 1            |       |
|    | Auger Blade                      |              |              |              |              |              |       |
|    | Total                            |              |              |              |              |              | 82    |

The result of the pareto diagram of engine damage with the principle of 80%-20% shows that there are five sterilizer machines that often suffer loss up to a cumulative percentage of 80%. Data on the frequency of critical engine component damage can be seen in Table 3.
Table 3. Time Interval Data for Critical Components of Sterilizer Machine Damage

| No. | Machine Name | Sterilizer 1 (days) | Sterilizer 2 (days) | Sterilizer 3 (days) | Sterilizer 4 (days) | Sterilizer 5 (days) |
|-----|--------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| 1.  | Sterilizer 1  | 79                  | 14                  | 166                 | -                   | -                   |
| 2.  | Sterilizer 2  | 36                  | 14                  | 2                   |                     |                     |
| 3.  | Sterilizer 3  | 81                  | 44                  | 35                  |                     |                     |
| 4.  | Sterilizer 4  |                     |                     |                     |                     |                     |
| 5.  | Sterilizer 5  |                     |                     |                     |                     |                     |

The time interval data for bottom liner component damage is then sorted, and the distribution test (goodness of fit) is done using EasyFit software. Distribution test results will show the data parameters used for the MTBF (mean time between failure) component. Distribution test results will show the data parameters used for the calculation of the MTBF (mean time between failure) part, as shown in Figure 2.

Figure 2. Test Results for Data Distribution of Interval Time Damage of Bottom Liner Components

The goodness of fit results above indicates that the chosen distribution is an Exponential distribution with a Chi-Squared index of 0.12449. Parameters for the distribution of time interval data for Bottom Liner components can be seen in Figure 3.

Figure 3. Parameters of Distribution of Interval Time Damage Data for Bottom Liner Components

\[ \lambda = 0.02174 \] with value 0.02174 is obtained as parameter. MTBF (mean time between failure) calculations based on the exponential distribution are as follows.

\[
MTBF = \frac{1}{\lambda} = 57.47126 \approx 57 \text{ days}
\]

The MTBF calculation (mean time between failure) indicate that the bottom liner component must be treated with components such as checking the condition of the weld or the possibility of a fault every
57 days. Then the reliability of the bottom liner component is calculated at the time of treatment as follows.

\[ R(t) = e^{-\lambda t} \] (2)

Component reliability calculation results show that the bottom liner component has a reliability of 0.2896 or 28.96% at the time of treatment.

4. Conclusions
The conclusions that can be obtained from this study are:
- Discussion of the problem carried out is the proposed preventive maintenance improvements by calculating the mean time between failures on the bottom liner component of the sterilizer machine, which indicates that maintenance must be carried out every 57 days.
- The percentage of component reliability at the time of treatment is 0.2896 or 28.96%.

References
[1] Corder A S 1988 Maintenance Management Techniques (London: McGraw-Hill)
[2] Taheri A, Lazakis I and Turan O 2014 Integration of Business and Technical Aspects of Reliability and Maintenance ICMT
[3] Kay E 1976 The effectiveness of preventive maintenance International Journal of Production Research 14(3) P 329–344
[4] Corder A S 1976 Maintenance Management Techniques (London: McGraw-Hill)
[5] Gallimore K F and Penlesky R J 1988 A Framework for Developing Maintenance Strategies Production and Inventory Management Journal 29(1) p 16
[6] Dhillon B S 2002 Engineering Maintenance A Modern Approach (New York: CRC Process LLC)
[7] Jardine A K S 2006 Maintenance, Replacement and Reliability (Boca Raton: Taylor & Francis Group)
[8] Ebeling C E 1997 Introduction to Reliability and Maintainability Engineering (London: McGraw-Hill)
[9] Maukar A L, Sosodoro I W and Adiprabowo R 2016 Scheduling Preventive Maintenance on Auto Rooting Machines at Toys Manufacturer Company Jurnal Rekayasa Sistem Industri 5(1) pp 26-30
[10] Sembiring N, Panjaitan N and Angelita S 2018 Design of Preventive Maintenance System Using the Reliability Engineering and Maintenance Value Stream Mapping Methods in PT XYZ IOP Conf Series: Material Science and Engineering 309(1) p 012218
[11] Sembiring N and Batubara Y P 2019 The Spare Part Maintenance of Cake Breaker Conveyor with Reliability Centered Spares Method IOP Conference Series: Materials Science and Engineering 523(1) p 012079