Preventive Maintenance Scheduling for Shifter Machine in Flour Mills

Wahyukaton

Industrial Engineering Department, Engineering Faculty, Universitas Pasundan
Jl. Setiabudi 193 Bandung, West Java, Indonesia
wahyukaton@unpas.ac.id

Abstract. PT. Indofood Sukses Makmur Tbk, Divisi Bogasari Flour Mills is one of biggest food factory especially for producing flour. In this flour mills division has several machines which are composed from several components, so that the maintenance division has to keep all the machines in a good performance. The factory has three shifter machines which were composed 3 critical components which are motor, bearing, and shifter and they were experienced 133 breakdowns in the last 6 months in 2019. The maintenance was conducted by determining a Mean Time to Failure (MTTF) value and conducted a preventive maintenance. The calculations result showed for 3 critical components were motor has a replacement interval time at 781 hours (day 98th) with the availability value was 0,99914, bearing has a replacement interval time at 994 hours (day 124th) with the availability value was 0,999255, and shifter has a replacement interval time at 575 hours (day 72nd) with the availability value was 0,998729.

Keywords: preventive maintenance, MTTF, breakdown, replacement, interval, availability

1. Introduction
Maintenance concept is a set of various maintenance interventions (corrective, preventive, condition-based, etc.) and the general structure in which these interventions are brought together. Developing an appropriate maintenance concept is important because of the high direct and indirect costs and because of the operational impact maintenance [1]. Preventive maintenance is an activity to maintain facilities and to fix it, to do a need adjustments or replacements to achieve production process to meet the plan [2]. Preventive maintenance is a combination of all technique, administration actions including monitoring to make sure the systems are properly functioned [3].

PT. ISM Tbk., Bogasari Flour Mills Division has three shifter machines which were composed 3 critical components which are motor, bearing, and shifter and they were experienced 133 breakdowns in the last 6 months in 2019. Figure 1 shows that the critical component from the shifter machine can be determined that there are 3 critical components which are sitter, motor, and bearing. The objectives of this paper are to find the optimum replacement interval time for critical components, and to find the availability value.
2. Methods
Preventive maintenance is an important element of a maintenance activity and within a maintenance department it normally accounts for a significant proportion of the overall maintenance activity. Preventive maintenance is the care and servicing by maintenance personnel to keep facilities in a satisfactory operational state by providing for systematic inspection, detection, and correction of incipient failures either before their development into major failures or before their occurrence [4,5].

There are many objectives of performing preventive maintenance including improving capital equipment’s productive life, reducing production losses caused by equipment failure, minimizing critical equipment breakdowns, and improving the health and safety of maintenance personnel [6].

This research was constructed as follow,

2.1 Determining Critical Component.
This step has been done by constructing a pareto diagram as shown in Figure 1, that there are 3 critical components.

2.2 Calculating Time to Failure (TTF).
Time to Failure can be calculated by the time component has been repaired until that component will experiencing a failure.

![Pareto Diagram for Shifter Machine Failure](image)

**Figure 1. Pareto Diagram for Shifter Machine Failure**

| No | Date       | Machine No | TTF (Hrs) |
|----|------------|------------|-----------|
| 1  | 21/01/2010 | 1252-KLK0-SF | 0.00      |
| 2  | 01/02/2010 | 1252-KLK0-SF | 88.00     |
| 3  | 08/02/2010 | 1252-KLK0-SF | 56.00     |
| 4  | 03/01/2012 | 1252-KLK0-SF | 5552.00   |
| 5  | 19/04/2012 | 1252-KLK0-SF | 856.00    |
| 6  | 27/06/2012 | 1252-KLK0-SF | 552.00    |
| 7  | 17/09/2012 | 1252-KLK0-SF | 656.00    |
| 8  | 05/11/2012 | 1252-KLK0-SF | 392.00    |
| 9  | 27/05/2013 | 1252-KLK0-SF | 1624.00   |
| 10 | 09/09/2013 | 1252-KLK0-SF | 840.00    |
| 11 | 28/10/2013 | 1252-KLK0-SF | 392.00    |
| 12 | 24/11/2013 | 1252-KLK0-SF | 216.00    |
| 13 | 03/03/2014 | 1252-KLK0-SF | 792.00    |
| 14 | 06/05/2014 | 1252-KLK0-SF | 512.00    |
| 15 | 18/11/2014 | 1252-KLK0-SF | 1568.00   |

| No | Date       | Machine No | TTF (Hrs) |
|----|------------|------------|-----------|
| 16 | 28/05/2015 | 1252-KLK0-SF | 1528.00   |
| 17 | 24/11/2015 | 1252-KLK0-SF | 1440.00   |
| 18 | 08/01/2016 | 1252-KLK0-SF | 360.00    |
| 19 | 08/03/2016 | 1252-KLK0-SF | 480.00    |
| 20 | 16/02/2017 | 1252-KLK0-SF | 2760.00   |
| 21 | 20/03/2017 | 1252-KLK0-SF | 256.00    |
| 22 | 14/07/2017 | 1252-KLK0-SF | 928.00    |
| 23 | 18/09/2017 | 1252-KLK0-SF | 528.00    |
| 24 | 16/10/2017 | 1252-KLK0-SF | 224.00    |
| 25 | 29/01/2018 | 1252-KLK0-SF | 840.00    |
| 26 | 27/02/2018 | 1252-KLK0-SF | 232.00    |
| 27 | 27/05/2018 | 1252-KLK0-SF | 712.00    |
| 28 | 14/10/2018 | 1252-KLK0-SF | 1120.00   |
| 29 | 04/03/2019 | 1252-KLK0-SF | 1128.00   |
| 30 | 24/05/2019 | 1252-KLK0-SF | 648.00    |
2.3 Goodness of Fit Test.
A simulation software ARENA was used in this test. The smallest error will determine the fit of the distribution. After several tests using ARENA, the result is all failures are fit to Weibull Distribution.

| Table 2. Bearing Failure Data |
|-----------------------------|
| No | Date       | Machine No | TTF (Hrs) |
| 1  | 14/05/2010 | 1252-KLK0-SF | 0.00 |
| 2  | 30/04/2011 | 1252-KLK0-SF | 2808.00 |
| 3  | 09/06/2011 | 1252-KLK0-SF | 320.00  |
| 4  | 20/06/2011 | 1252-KLK0-SF | 88.00  |
| 5  | 04/09/2013 | 1252-KLK0-SF | 6456.00 |
| 6  | 22/11/2013 | 1252-KLK0-SF | 632.00  |
| 7  | 18/07/2014 | 1252-KLK0-SF | 1904.00 |
| 8  | 30/10/2014 | 1252-KLK0-SF | 832.00  |
| 9  | 25/01/2015 | 1252-KLK0-SF | 696.00  |
| 10 | 30/01/2015 | 1252-KLK0-SF | 40.00  |

| No | Date       | Machine No | TTF (Hrs) |
| 11 | 02/04/2015 | 1252-KLK0-SF | 496.00 |
| 12 | 27/05/2015 | 1252-KLK0-SF | 440.00 |
| 13 | 09/08/2015 | 1252-KLK0-SF | 592.00 |
| 14 | 27/10/2015 | 1252-KLK0-SF | 632.00 |
| 15 | 07/04/2016 | 1252-KLK0-SF | 1304.00 |
| 16 | 22/07/2016 | 1252-KLK0-SF | 848.00 |
| 17 | 20/10/2016 | 1252-KLK0-SF | 720.00 |
| 18 | 03/12/2016 | 1252-KLK0-SF | 352.00 |
| 19 | 24/02/2017 | 1252-KLK0-SF | 664.00 |
| 20 | 19/07/2017 | 1252-KLK0-SF | 1160.00 |
| 21 | 05/05/2019 | 1252-KLK0-SF | 5240.00 |

| Table 3. Shifter Failure Data |
|-----------------------------|
| No | Date       | Machine No | TTF (Hrs) |
| 1  | 22/02/2010 | 1252-KLK0-SF | 312 |
| 2  | 02/04/2010 | 1252-KLK0-SF | 120 |
| 3  | 17/04/2010 | 1252-KLK0-SF | 952 |
| 4  | 03/01/2012 | 1252-KLK0-SF | 5008 |
| 5  | 17/09/2012 | 1252-KLK0-SF | 2064 |
| 6  | 14/01/2013 | 1252-KLK0-SF | 952 |
| 7  | 28/02/2013 | 1252-KLK0-SF | 360 |
| 8  | 01/06/2013 | 1252-KLK0-SF | 744 |
| 9  | 21/06/2013 | 1252-KLK0-SF | 160 |
| 10 | 15/01/2014 | 1252-KLK0-SF | 1664 |
| 11 | 11/04/2014 | 1252-KLK0-SF | 688 |
| 12 | 22/05/2014 | 1252-KLK0-SF | 328 |
| 13 | 08/06/2014 | 1252-KLK0-SF | 136 |
| 14 | 14/06/2014 | 1252-KLK0-SF | 48 |
| 15 | 02/09/2014 | 1252-KLK0-SF | 640 |
| 16 | 29/12/2014 | 1252-KLK0-SF | 944 |
| 17 | 21/02/2015 | 1252-KLK0-SF | 432 |
| 18 | 29/03/2015 | 1252-KLK0-SF | 288 |
| 19 | 30/04/2015 | 1252-KLK0-SF | 256 |
| 20 | 28/05/2015 | 1252-KLK0-SF | 224 |
| 21 | 09/07/2015 | 1252-KLK0-SF | 336 |
| 22 | 12/09/2015 | 1252-KLK0-SF | 520 |
| 23 | 08/10/2015 | 1252-KLK0-SF | 208 |
| 24 | 12/02/2016 | 1252-KLK0-SF | 1016 |

| No | Date       | Machine No | TTF (Hrs) |
| 25 | 24/03/2016 | 1252-KLK0-SF | 328 |
| 26 | 16/04/2016 | 1252-KLK0-SF | 184 |
| 27 | 17/05/2016 | 1252-KLK0-SF | 248 |
| 28 | 19/09/2016 | 1252-KLK0-SF | 1000 |
| 29 | 14/11/2016 | 1252-KLK0-SF | 448 |
| 30 | 05/08/2017 | 1252-KLK0-SF | 2112 |
| 31 | 31/08/2017 | 1252-KLK0-SF | 208 |
| 32 | 04/11/2017 | 1252-KLK0-SF | 520 |
| 33 | 11/11/2017 | 1252-KLK0-SF | 56 |
| 34 | 04/12/2017 | 1252-KLK0-SF | 184 |
| 35 | 29/01/2018 | 1252-KLK0-SF | 448 |
| 36 | 19/02/2018 | 1252-KLK0-SF | 168 |
| 37 | 22/02/2018 | 1252-KLK0-SF | 24 |
| 38 | 27/02/2018 | 1252-KLK0-SF | 40 |
| 39 | 13/03/2018 | 1252-KLK0-SF | 112 |
| 40 | 27/05/2018 | 1252-KLK0-SF | 600 |
| 41 | 06/06/2018 | 1252-KLK0-SF | 80 |
| 42 | 11/06/2018 | 1252-KLK0-SF | 40 |
| 43 | 11/08/2018 | 1252-KLK0-SF | 488 |
| 44 | 13/08/2018 | 1252-KLK0-SF | 16 |
| 45 | 12/09/2018 | 1252-KLK0-SF | 240 |
| 46 | 30/09/2018 | 1252-KLK0-SF | 144 |
| 47 | 02/11/2018 | 1252-KLK0-SF | 264 |
| 48 | 21/05/2019 | 1252-KLK0-SF | 1600 |
Figure 2. Goodness of Fit test Result for Motor Component

Figure 3. Goodness of Fit test Result for Bearing Component

Figure 4. Goodness of Fit test Result for Shifter Component
2.4 Calculating Mean Time to Failure (MTTF).

To do this calculation, first it has to find the parameters for the distribution which was done by goodness of fit test, then using the equation of Weibull Maximum Likelihood Estimator (MLE) as follows.

The first derivation of likelihood function for Weibull distribution is to find a parameter \( \beta \) [6]

\[
g(\beta_j) = \left( \sum_{i=1}^{r} t_i^\beta \ln t_i \right) + (n-r)n t_i^\beta \ln t_i = 0
\]

To solve the equation, another method is used, Newton-Rhapson method to solve the equation

\[
\beta_{j+1} = \beta_j - \frac{g(\beta_j)}{g'(\beta_j)} \quad \text{where} \quad g'(x) = \frac{dg(x)}{dx}
\]

The equation can be solved by integration method to find \( \beta_j \) value that is maximum to closing 0. The first derivation is

\[
g'(\beta_j) = \left( \sum_{i=1}^{r} t_i^\beta \ln t_i \right) + \left( \sum_{i=1}^{r} t_i^\beta \right) - \frac{n}{\beta}
\]

The \( \beta_j \) value is \( \beta = b \), can be found by least square curve fitting. The parameter is:

\[
\theta = \left[ \frac{1}{r} \left( \sum_{i=1}^{r} t_i^\beta \right) + (n-r)n t_s^\beta \right]^{\frac{1}{\beta}}
\]

| No | Component | Distribution | Parameter | MTTF |
|----|-----------|--------------|-----------|------|
| 1  | Motor     | Weibull      | \( \beta = 940.6896 \) \( \theta = 1.21825 \) | 781.5047 |
| 2  | Bearing   | Weibull      | \( \beta = 0.952320 \) \( \theta = 953.3532 \) | 974.5278 |
| 3  | Shifter   | Weibull      | \( \beta = 0.997097 \) \( \theta = 574.4680 \) | 575.1772 |

2.5 Determining Component Replacement Interval, Optimum Replacement, Availability Value.

The Age-Replacement Strategy was used in this step. Calculating the component age from the first time it is installed until this component will having breakdown [6]. If within the determined interval there is no failure, the component is still need to be replaced, this will be the objective of Preventive Maintenance. The availability value can be calculated by these equations,

\[
F(t_p) = 1 - e^{-\left( \frac{t_p}{\theta} \right)^\beta}
\]

\[
R(t_p) = e^{-\left( \frac{t_p}{\theta} \right)^\beta}
\]

\[
M(t_p) = \frac{t_p}{F(t_p)}
\]

\[
D(t_p) = \frac{R(t_p)+F(t_p)}{t_p R(t_p)+M(t_p)+F(t_p)}
\]

\[
A(t_p) = 1 - D(t_p)
\]

| Component | \( F(t_p) \) | \( D(t_p) \)_min | \( A(t_p) \) |
|-----------|--------------|-----------------|-------------|
| Motor     | 0.636306     | 0.00085796      | 0.999142    |
| Bearing   | 0.629508     | 0.00074471      | 0.999255    |
| Shifter   | 0.631392     | 0.00127044      | 0.998729    |
3. Result and Discussion
After calculation of all parameters of preventive maintenance were done, then the reliability of 3 critical components were compared for before and after preventive maintenance was conducted, and the results are as shown on these figures,

**Figure 5.** Reliability Comparison for Motor Before and After Preventive Maintenance

**Figure 6.** Reliability Comparison for Bearing Before and After Preventive Maintenance

**Figure 7.** Reliability Comparison for Shifter Before and After Preventive Maintenance
Figure 3 shows that reliability value after preventive maintenance is less than reliability value before maintenance. This means that motor component has to be replaced immediately in order to maintain the good performance of the machine.

Figure 4 and Figure 5 show that the value of reliability before and after preventive maintenance are relatively equal. This means that the components are in good performance.

From all preventive maintenance parameters which have been calculated, it is possible to scheduling the components replacement interval, for motor component is in 781 hours or on the day of 98th, the optimum replacement interval for bearing component is in 994 hours or on the day of 124th, and the optimum replacement interval for shifter component is in 557 hours or on the day of 72nd.

| Component | Duration (Days) | Start | Finish |
|-----------|----------------|-------|--------|
| Motor     | 98             | Nov-19| Mar-20 |
| Bearing   | 124            | Dec-19| Apr-20 |
| Sifter    | 72             | Jan-20| Mar-20 |

**Figure 8. Gantt Chart for Scheduling Optimum Replacement Interval for 3 Critical Components**

4. Conclusion

Based on the values of preventive maintenance parameters, the optimum replacement interval for motor component is in 781 hours or on the day of 98th, with availability 0.999142. Suppose the component starts on November 2019 then it will be scheduled to be replaced on March 2020. The optimum replacement interval for bearing component is in 994 hours or on the day of 124th, with availability 0.999255. Suppose the component starts on November 2019 then it will be scheduled to be replaced on April 2020. The optimum replacement interval for shifter component is in 557 hours or on the day of 72nd, with availability 0.998729. Suppose the component starts on November 2019 then it will be scheduled to be replaced on February 2020.

5. References

[1] Pophaley, Mahesh, Krishna Vyas, Ram, 2010. Plant maintenance management practices in automobile industries: A retrospective and literature review. *Journal of Industrial Engineering and Management*, pp. 512-541

[2] O’Connor, P. D. T., and Kleyner, A. 2011. *Practical Reliability Engineering, Design for Reliability, 5th Edition*. (New York: John Wiley & Sons).

[3] Basri, E. I. Abdul Razak, I.H., Ab-Samat H., and Komaruddin S., 2017. Preventive Maintenance Planning: A Review. *Journal of Quality in Maintenance Engineering*, 23(2), 114-143, doi: 10.1108/JQME-04-2016-0014

[4] Dhillon, B. S. 2006. *Maintainability, Maintenance, and Reliability for Engineers*. Taylor & Francis Group, Boca Raton FL.

[5] Campbell, J., Jardine, A. K. S., and McGlynn, J. 2010. *Asset management excellence: optimizing equipment life-cycle decisions*. In Dekker Mechanical Engineering.

[6] Ebeling, Charles, 1996. Charles Ebeling - *An Introduction To Reliability and Maintainability Engineering*, McGraw-Hill.