

PAPER • OPEN ACCESS

## Optimization preventive maintenance of equipment production on palm oil mill

To cite this article: Ina Siti Hasanah and Ratih Wulandari 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **505** 012155

View the [article online](#) for updates and enhancements.



**IOP | ebooks™**

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the **collection** - download the first chapter of every title for free.

## Optimization preventive maintenance of equipment production on palm oil mill

<sup>1</sup> Ina Siti Hasanah

<sup>2</sup> Ratih Wulandari

<sup>1,2</sup> Industrial Engineering Departement, Faculty of Industrial Technology University Gunadarma  
Jl. Margonda Raya no.100, Depok, Jawa Barat, Indonesia

[inash@staff.gunadarma.ac.id](mailto:inash@staff.gunadarma.ac.id)

[ratih\\_wulandari@staff.gunadarma.ac.id](mailto:ratih_wulandari@staff.gunadarma.ac.id)

### ABSTRACT

Maintenance is an important issue that must be considered, especially in the agroindustry company. This paper is to identify and prioritize the most critical component in the production of palm oil using FMEA, and schedule maintenance with optimal total cost of maintenance. RPN obtained score from the highest to the lowest to be scheduled maintenance that is a component of the worm screw press machine, V-belt thresher drum equipment, V-belt separator clarification equipment, steel cable sling tracklier equipment, door seals equipment sterilizer, wheel lorry with ad on lorry equipment, V-belt boiler, screw pn clarification separator equipment, friction pad clarification separator equipment and V-belt equipment at the seed stasion. Optimization of the total cost of maintenance is the reliability level of 90% at a cost Rp. 131.443.940,2/year. Scheduling maintenance can save as much as 47,4% compared to no maintenance scheduling.

### 1. INTRODUCTION

Maintenance is all action or a combination of the various activities carried out in order to maintain or restore an equipment/ machinery on conditions acceptable to earer (Ricardo et all, 2009; Adolfo C., 2007; Ebeling EC, 1997). Maintenance has become the common issues and important faced by the industry and is one of the factors that determine the productivity of the industry.

Sharma et al. (2008) conducted a study that FMEA (Failure Mode and Effect Analysis) to identify and prioritize the causes of failure in a system. FMEA is a method that can be used to identify the critical components that have failed resulting in undesirable events such as loss of production. The goal is to determine and prioritize the potential failure modes by counting each RPN (Risk Priority Number) which may have detrimental effects on a system.

Combination of Petri net and techniques FMECA (Failure Mode Effects and Criticality Analysis) is a new solution for modeling complex industrial system reliability (Bertolini, M., et al. 2006). Fuzzy modeling FMECA can calculate the index of fuzzy failure mode, by using Mamdani type fuzzy inference mode and implications min max aggregation (Zafiropoulos and Dialynas, 2005).

Maintenance system plays an important role in achieving corporate goals. It is instrumental in reducing equipment downtime, improve quality and increase productivity. Election strategy improper system maintenance can affect the company's operating budget for unplanned maintenance costs will reduce the productivity and profitability (Shyjith et al. 2008). Operating budget especially plant maintenance costs and component costs are very high when compared to machines other processing costs (Pahan, 2008). It can be seen from the average percentage of the cost of care palm oil mill equipment PKS X from 2006-2010, 30.21% is almost close to the average cost of processing palm oil at 31.88%. The average percentage of the costs incurred for the maintenance



of equipment in 2010 amounted to 46.04% of the total cost of palm oil processing. Because of the magnitude of the maintenance costs, the maintenance of the system is needed so that maintenance costs can be reduced.

According Kurniawan (2006), a total investment of palm oil mills Rp. 103.73 billion for the PKS with installed capacity by 60 tonnes FFB / hour. The total investment is higher than the average cost of maintaining the equipment PKS X 24% of the total investment of PKS. Production equipment maintenance budget submitted to PKS X fell in stages ie 3 months in a year so that necessary preventive maintenance scheduling optimal production equipment at minimum cost.

Ebeling (1997), perform preventive maintenance on 90% reliability rate. PKS X wants preventative maintenance on 75%. This study aims to identify and define the components of the most critical production equipment in the production of palm oil millers X. The next goal is to schedule the maintenance component of the cost of maintaining the optimum.

## 2. METHOD

This study uses secondary data and primary data. Primary data were collected through interviews to obtain information about the scheduling of maintenance activities of the field supervisors, maintenance chief, head of production, plant managers, and maintenance staff.

Secondary data is data that is used all kinds of production equipment used, the components of the equipment used, the failure interval, and time replacing failure components. Goodness of fit test methods used to examine the distribution of component failures that are suitable for the equipment used. Bartlett's Test is used to test the exponential distibusi, Mann's test was used for testing the Weibull distribution, and the Kolmogorov Smirnov Test was used to test the normal and lognormal distributions. Having obtained a suitable distribution of failure, then the value of MTTF (Mean Time To Failure) and MTTR (Mean Time To Repair) can be calculated by the following formula (Ebeling, 1997; Ricardo et al, 2009):

### 1. Distribusi Eksponensial

$$MTTF = MTTR = \frac{1}{\lambda} \quad (1)$$

$$R(t) = e^{-\lambda t} \quad (2)$$

### 2. Distribusi Weibull

$$MTTF = MTTR = \theta \left( 1 + \frac{1}{\beta} \right) \quad (3)$$

$$R(t) = e^{-(t/\theta)^\beta} \quad (4)$$

### 3. Distribusi Normal

$$MTTF = MTTR = \mu \quad (5)$$

$$R(t) = 1 - \Phi \left( \frac{t - \mu}{\sigma} \right) \quad (6)$$

### 4. Distribusi Lognormal

$$MTTF = MTTR = t_{med} e^{s^2/2} \quad (7)$$

$$R(t) = 1 - \Phi \left( \frac{1}{s} \ln \frac{t}{t_{med}} \right) \quad (8)$$

To prioritize the most critical component FMEA method is used to determine the risk priority number (RPN) to perform the necessary corrective actions to prevent failures. Ben Power et al. (2009) using a numerical scale ranging from 1 to 10 to rank the severity of the failure rate, the possibility of failure modes and the possibility of failure is detected. Scale used ranges from 1 to 10, where 1 indicates very low scale and high scale 10 states. Higher RPN values are given higher priority than the lower value of the RPN. RPN is calculated by multiplying the rate of failure severity (S), the possibility of failure (O = Occurrence) and the probability of failure is detected (D = Detection) to determine the risk level of a process, as follows:

$$RPN = S \times O \times D \quad (9)$$

According to Sharma and Sharma (2010), Severity is related component failure effects mean time between repair (MTTR) of each component, Occurrence rate of failure is derived from the average time between failures (MTTF) of each components. Detection is the quantification of control that makes a failure can be detected and

the results obtained from the interviews with the head of engineering maintenance section. Scheduling method based on the failure replacement intervals specified level of reliability. If the lognormal distribution component replacement intervals failure to the reliability level R:

$$t_R = t_{med} e^{s(-\Phi^{-1}(R))} \quad (10)$$

If the weibull distribution component replacement intervals failure to the reliability level R:

$$t_R = \theta \left( -\ln(R) \right)^{1/\beta} \quad (11)$$

Reliability of the system after preventive maintenance is as follows (Ebeling, 1997):

$$R_m(t) = R(T)^n \times R(t-nT) \quad (12)$$

where :

$R_m(t)$  = reliability of systems with preventive maintenance

$n$  = number of maintenance

$t$  = time

$T$  = time interval preventive replacement

$R(T)^n$  = probability of reliability to  $n$  intervals

$R(t-nT)$  = probability of reliability for time  $t-nT$  of the last preventive maintenance actions.

Calculation of the total cost of preventive maintenance is as follows (Jardine, 2001):

$$\text{Total cost} = \frac{\{C_p \times R(t_p)\} + \{C_f \times (1 - R(t_p))\}}{\{t_p \times R(t_p)\} + \{t_f \times (1 - R(t_p))\}} \quad (13)$$

In this study calculates the total cost of maintenance for all components in order to obtain optimal maintenance costs, ie

$$\text{Minimization: Total cost} = \sum_{i=1}^n \frac{\{C_{pi} \times R(T_{pi})\} + \{C_{fi} \times (1 - R(T_{pi}))\}}{\{T_{pi} \times R(T_{pi})\} + \{t_{fi} \times (1 - R(T_{pi}))\}} \times T_{pi} \times k_{pi} \quad (14)$$

with constraints:  $0 < R(T_{pi}) < 1$

$C_{pi}, C_{fi}, t_{fi}, T_{pi} > 0$

$i = 1, 2, 3, \dots, n$

where :

$C_{pi}$  = cost of preventive cycles in the  $i$ -th component

= (cost technician  $\times$   $t_{pi}$  + of  $i$  component costs)

$C_{fi}$  = cost of failure cycles in the  $i$ -th component

= (cost technician  $\times$   $T_{fi}$  + of  $i$  component cost + cost of lost production  $\times$   $T_{fi}$ )

$t_{fi}$  = value of the  $i$ -th component MTTF

$T_{pi}$  = time interval preventive maintenance on the  $i$ -th component

$R(t_{pi})$  = probability of the expected reliability of the  $i$ -th component

### 3. RESULTS AND DISCUSSION

Based on analysis OEE (Overall Effectiveness Equipment Corporation), there are ten component in its eight equipment which experiencing mischief at months August. Components-component which experiencing mischief the said is components screw worms press machine, V-belt equipment thresher drums, V-belt equipment clarification separator, cables sling fertilizer equipment tracklier, seal has door equipment sterilizer,, wheel truck with a peace be at equipment lorry, V-belt boiler, screw pn equipment clarification separator, Friction pad equipment clarification separator and V-belt equipment on the station seeds.

The first step is to choose the preventive maintenance scheduling which components will be prioritized for scheduled, using FMEA (Failure Mode and Effect Analysis). Rating occurrence is the quantification of the level of failure events derived from the MTTF and the scale used ranges from 1-10. Rating of severity is the quantification of the level of impact due to the occurrence of failure associated MTTR and scale used ranges from 1-10 (Pande, et al. 2000). From the calculation of RPN values obtained from the highest to the lowest that will be scheduled maintenance that worm screw press machine, V-belt thresher drum equipment, V-belt separator clarification equipment, steel cable sling peralatan tracklier, seal stew door sterilizer equipment, wheel dolly + lori as equipment, V-belt boiler, screw pn clarification separator equipment, friction pad separator clarification equipment and appliances on the V-belt seed station.

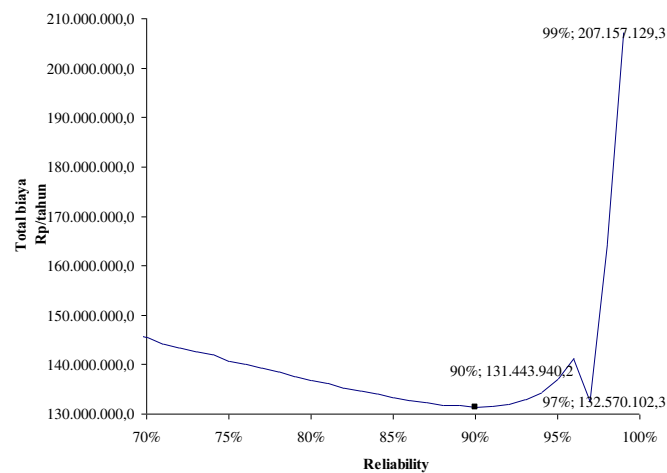
**Table 1.** Costs of failure and Cost Prevention in a single cycle

| component              | technician cost<br>(Rp/hour) | Production loss cost<br>(Rp/hour) | component cost (Rp) | $T_f =$<br>MTTR<br>(hour) | $t_p$<br>(hour) | failure cost,<br>$C_f$ (Rp) | preventive cost, $C_p$ (Rp) |
|------------------------|------------------------------|-----------------------------------|---------------------|---------------------------|-----------------|-----------------------------|-----------------------------|
| Screw worm             | 10.000                       | 525.000                           | 100.000             | 6,53                      | 6               | 3.592.471,2                 | 160.000                     |
| V-belt thresher drum   | 10.000                       | 525.000                           | 50.000              | 5,57                      | 5               | 3.027.335,6                 | 100.000                     |
| V-belt separator       | 10.000                       | 525.000                           | 200.000             | 6,03                      | 6               | 3.426.456,3                 | 260.000                     |
| Kabel sling baja       | 10.000                       | 525.000                           | 150.000             | 4,75                      | 4               | 2.690.742,3                 | 190.000                     |
| Seal pintu rebusan     | 10.000                       | 525.000                           | 425.000             | 4,31                      | 4               | 2.728.243,4                 | 465.000                     |
| Roda lori+as           | 10.000                       | 525.000                           | 150.000             | 5,26                      | 5               | 2.965.437,5                 | 200.000                     |
| V-belt boiler          | 10.000                       | 525.000                           | 250.000             | 6,14                      | 6               | 3.533.562,5                 | 310.000                     |
| Screw pn separator     | 10.000                       | 525.000                           | 970.000             | 2,74                      | 2               | 2.436.865,1                 | 990.000                     |
| Friction pad separator | 10.000                       | 525.000                           | 2.840.000           | 4,40                      | 4               | 5.196.573,7                 | 2.880.000                   |
| V-belt stasiun biji    | 10.000                       | 525.000                           | 92.000              | 6,42                      | 6               | 3.526.351,8                 | 152.000                     |

Calculation of total cost of maintenance prior to preventive maintenance for one year shown in Table 2. Based on Table 1 and Table 2, the components are calculated the total cost of preventive maintenance on a variety of levels of reliability to obtain the optimal total cost of maintenance for the 10 components. Calculation of total maintenance costs with the help of MS Excel. In Figure 1 can be seen the total cost of preventive maintenance is the most optimal reliability level 90% at a total cost of preventive maintenance Rp 131443940.2 per year.

**Table 2.** Calculation of Total Failure Cost before preventive maintenance for one year

| component              | $a_{tr} =$<br>MTTF<br>(hour) | $C_f$ (Rp)  | $T_f =$<br>MTTR<br>(hour) | $k_r$ | $T_c$ (Rp/jam) | expectation cost<br>(Rp) | Total failure<br>cost/year/<br>(Rp/year) |
|------------------------|------------------------------|-------------|---------------------------|-------|----------------|--------------------------|------------------------------------------|
| Screw worm             | 1.071,1                      | 3.592.471,2 | 6,53                      | 8,2   | 3.333,6        | 3.570.709,8              | 29.201.981,7                             |
| V-belt thresher drum   | 1.818,4                      | 3.027.335,6 | 5,57                      | 4,8   | 1.659,7        | 3.018.098,9              | 14.539.355,7                             |
| V-belt separator       | 1.485,7                      | 3.426.456,3 | 6,03                      | 5,9   | 2.297,0        | 3.412.603,7              | 20.121.559,9                             |
| Kabel sling baja       | 1.185,9                      | 2.690.742,3 | 4,75                      | 7,4   | 2.260,0        | 2.680.009,6              | 19.797.436,7                             |
| Seal pintu rebusan     | 1.193,2                      | 2.728.243,4 | 4,31                      | 7,3   | 2.278,2        | 2.718.435,5              | 19.956.946,8                             |
| Roda lori+as           | 2.580,9                      | 2.965.437,5 | 5,26                      | 3,4   | 1.146,7        | 2.959.403,2              | 10.044.825,3                             |
| V-belt boiler          | 1.955,5                      | 3.533.562,5 | 6,14                      | 4,5   | 1.801,3        | 3.522.506,9              | 15.779.490,3                             |
| Screw pn separator     | 452,2                        | 2.436.865,1 | 2,74                      | 19,4  | 5.357,1        | 2.422.177,0              | 46.927.940,4                             |
| Friction pad separator | 1.494,2                      | 5.196.573,7 | 4,40                      | 5,9   | 3.467,5        | 5.181.300,0              | 30.375.399,6                             |
| V-belt stasiun biji    | 709,6                        | 3.526.351,8 | 6,42                      | 12,3  | 4.925,0        | 3.494.736,5              | 43.143.013,0                             |
| Total                  |                              |             |                           |       |                |                          | 249.887.949,6                            |

**Figure 1.** The total cost for the ten components of preventive maintenance for one year

Scheduling maintenance for the ten components at the level of 90% reliability can save as much as 47.4%. After the scheduled preventive maintenance then the costs that affect the total cost of maintenance for the ten components of the sensitivity analysis. Parameter sensitivity analysis conducted by engineers and component

costs. The increase in the cost parameters technician will decrease by 50% to 88% level of reliability with optimal total cost for all 10 components of Rp 135,567,151.30 per year. When the parameters of the component costs increased by 16%, the rate dropped to 88% reliability with optimal total cost of maintenance for the 10 components of Rp 140935405.4 per year.

The decline parameter technician costs by 37% would raise the level of reliability of 97% to the total cost of maintaining optimal for the 10 components of Rp 128361802.5 per year. When the parameters of the component costs reduced by 13%, the rate increased to 97% reliability with optimal total cost of maintenance for the 10 components of Rp. 123649800.8 per year.

#### 4. CONCLUSION

FMEA can be used to identify failures in the components and calculate the value of the RPN to prioritize components. Priority consecutive components namely the worm screw press components, parts v-belt on drum thresher, v-belt component in the separator, the component cables on tracklier steel slings, components of the sterilizer door seals, wheel dolly + components as the lorry, the component v -belt on the boiler, screw pn component in the separator, the component separator and friction pad on the v-belt components on seed station. Preventive maintenance scheduling can improve the reliability of the components. Worm screw components scheduled preventative maintenance every 617 hours, the component v-belt on drum thresher every 755 hours, the component separator v-belt at every 727 hours, the components of steel cable sling on tracklier every 651 hours, the door seal components sterilizer every 328 hours , components wheels and axles on lorry lorries every 604 hours, v-belt components boiler every 662 hours, the component separator screw pn at every 452 hours, the separator pad friction components every 1,483 hours and v-belt component on the boiler station every 119 hours. At the 90% level of reliability, maintenance scheduling the 10 components can save costs for companies operating budgets of 47.4%. Increase in the cost parameters technician will decrease by 50% to 88% level of reliability. Decrease in the cost parameters technicians will increase by 37% reliability rate of 97%. If the parameters of the component costs increased by 16%, the rate drops to 88% reliability. When the parameters of the component costs decreased to 13%, the rate increased to 97% reliability.

#### 5. REFERENCES

- [1] Adolfo C. 2007. The Maintenance Management Framework: Models and Methods for Complex Systems Maintenance. Springer Series in Reliability Engineering.
- [2] Ben-Daya, M., Duffuaa, S.O., Raouf, A., Knezevic, J., Ait-Kadi, D. 2009. Handbook of Maintenance Management and Engineering. 1<sup>st</sup> Edition. Springer.
- [3] Bertolini, M, Bevilacqua, M., Mason, G. 2006. Reliability design of industrial plants using Petri nets. *Journal of Quality in Maintenance Engineering*. **Vol.12 No.4**. pp.397-411.
- [4] Ebeling, E., C. 1997. An Introduction to Reliability and Maintainability Engineering. Mc.Graw Hill, Singapore.
- [5] Jardine. 2001. Maintenance Excellence Optimizing Equipment Life Cycle Decisions. Marcel Dekker. Inc.
- [6] Kurniawan Ambar. 2006. Biaya Investasi Industri Kelapa Sawit. Potensi dan Peluang Investasi Industri Kelapa Sawit di Indonesia. Pusat Penelitian Kelapa Sawit. Medan.
- [7] Pahan, Iyung. 2008. Panduan Lengkap Kelapa Sawit. Cet.5. Jakarta: Penebar Swadaya.
- [8] Pande, P.S., Neuman, R.P., Cavanagh, R.R. 2000. The Six Sigma Way: How GE, Motorola, And Other Top Companies Are Honing Their Performance. Mc Graw-Hill. New York.
- [9] Riccardo M., Alberto R. 2009. Maintenance for Industrial Systems. Springer. London.
- [10] Sharma, R., Kumar, D. and Kumar, P. 2008. Predicting uncertain behavior of industrial system using FM - A practical case, *Applied Soft Computing*, **Vol. 8 No. 1**, pp. 96-109.
- [11] Sharma, R.K, Sharma P. 2010. System failure behavior and maintenance decision making using, RCA, FMEA and FM. *Journal of Quality in Maintenance Engineering*, **16.1**. p.64-88
- [12] Shyjith K., Ilangkumaran K., Kumanan S. 2008. Multi criteria decision making approach to evaluate optimum maintenance strategy in textile industry. *Journal of Quality in Maintenance Engineering*, **Vol.14 No.4**, p.375-386.
- [13] Zafiroopoulos, E.P., Dialynas, E.N. 2005. Reliability prediction and failure mode effects and criticality analysis (FMECA) of electronic devices using fuzzy logic. *The International Journal of Quality & Reliability Management*. **Vol.22, Iss.2/3**, 183-201.

## Authors' background

| Your Name                        | Title*              | Research Field          | Personal website                        |
|----------------------------------|---------------------|-------------------------|-----------------------------------------|
| <b>Ina Siti<br/>Hasana<br/>h</b> | <b>Lectur<br/>e</b> | <b>Maintenanc<br/>e</b> | <b>inash@staff.gunadarma.ac.<br/>id</b> |
|                                  |                     |                         |                                         |

\*This form helps us to understand your paper better, **the form itself will not be published.**

\*Title can be chosen from: master student, Phd candidate, assistant professor, lecture, senior lecture, associate professor, full professor