An Evaluation of the Effectiveness and Reliability of the Machines Using the Overall Equipment Effectiveness (OEE) and Reliability Analysis Methods at the Tea Leaf Processing Plant PT. Perkebunan Nusantara IV Unit Bah Butong

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Abstract. The Tea Leaf Processing Plant PT. Perkebunan Nusantara IV Unit Bah Butong is an industry that motion in the tea leaf processing. The process of production is supported by a number of interdependent machines and tools to achieve optimal productivity. The problem is that frequent machine failure is considered to be interfering with the production process resulting from maintenance's un-maximum. Thus need evaluation of the effectiveness and reliability of machines in order to maximize maintenance in order to reduce machine failure. The purpose of this study is to know the value of the effectiveness production engine by calculating the value of the Overall Equipment Effectiveness (OEE), identifying the effectiveness of the engine by measuring six big losses, calculating the reliability of the engine by adding analysis and improving the maintenance schedule to improve engine efficiency, and predicting OEE's values after maintenance repairs were made. The value of this journal is expected to be an input to companies to know the value of the effectiveness machines and the reliability of the entire machine system if maintenance is done according to the recommended MTTF maintenance program.

1. Introduction

A common problem facing every manufacturing industry is that of repairing the machinery of production. This is an unavoidable problem, because of the failure of the production engine, both small scale, medium, and severe scale. This problem, it can result in disruptions of production performance by a lapse in production time and certainly lead to the company’s financial cost. Therefore, it is better that regular maintenance of the production engine before damage is done to the production process[1]. Maintenance is the conception of all activities necessary to maintain or maintain the quality of facilities/machines in order to function properly as conditions initially did. Further Ebeling (1997) defines maintenance as a form of activity that is carried out in order to achieve the item that returns or keeps it in working condition. Performance measurement is crucial to a company benchmark for corporate objectives[2]. Performance measures are also crucial for the management of companies as the parameters for achieving or not the target of the company. Doing this means that there is a monitoring process, which involves control and improving the performance of employees or production machines[3].
Production at the tea leaf processing plant PT. Perkebunan Nusantara IV Unit Bah Butong is still referred to as an obstacle that interferes with the production of machines. During this time the company has applied a corrective maintenance to address the disorder, where repairs are made after the engine breaks down. Moreover, the company has never measured the value of its effectiveness in the production line to see how far the production of machines could go. Here is the data table for the 2018 production of machines:

Table 1. Data of production failure of 2018 period in the tea leaf processing plant PT. Perkebunan Nusantara IV unit Bah Butong

| Months     | Working Days | Old Machine Used (Hour) | Downtime Machine (Hour) | Total Damage |
|------------|--------------|-------------------------|-------------------------|--------------|
| January    | 26           | 468                     | 29                      | 51           |
| February   | 23           | 368                     | 30                      | 67           |
| March      | 25           | 450                     | 32                      | 65           |
| April      | 24           | 408                     | 24                      | 57           |
| May        | 24           | 432                     | 33                      | 64           |
| June       | 22           | 352                     | 35                      | 54           |
| July       | 26           | 520                     | 14                      | 54           |
| August     | 25           | 375                     | 9                       | 48           |
| September  | 24           | 288                     | 18                      | 57           |
| October    | 27           | 432                     | 37                      | 60           |
| November   | 25           | 375                     | 11                      | 54           |
| December   | 25           | 400                     | 20                      | 59           |
| **Total**  | **296**      | **4868**                | **292**                 | **690**      |

Based on Table 1 it is concluded that the machines suffer more than twice the average amount of damage a day. Thus, it needs to maximize maintenance in order to reduce engine failure and improve the reliability of production machines.

According to Nakajima, there are six equipment losses that cause low performance from machines and equipment. Those six losses, which constitute the three types of six big losses, that is the availability of time consists of breakdown losses in equipment and adjustment (sets up and adjustment losses). Engine performance, consisting of idle and minor stoppages and low operating speed. Quality of the product consists of the quality defect and reduced yield losses [4].

Reliability is the probability of a system performing according to the function required in a given period of time. The accumulated value of a system is usually expressed in probability, with a score of R (Reliability) between 0-1. Value of 0 says the system is failing. Whereas the value of 1 indicates the system conditions can run as expected without any damage [5].

2. Literature Review

Maintenance is the conception of all activities necessary to maintain or maintain the quality of facilities/machines in order to function properly as conditions initially did. Ebeling defines treatment as a form of activity in which it achieves outcomes that return items or maintain them in regular working conditions.

Overall Equipment Effectiveness (OEE) it was a total measurement of the performance associated with the characteristic of the productivity and culture process. OEE's measurements show how well companies use their resources included equipment, labor and ability to satisfy consumers. The aim of OEE is to measure the performance of a maintenance system, by using this method it is known for the availability of machines/equipment, production efficiency (performance), and the quality of production/equipment output [6].

\[
\text{OEE} (%) = \text{Availability} (%) \times \text{Performance rate} (%) \times \text{Quality rate} (%)
\]  

(1)
The availability of machines represents the ratio of operation time to the loading time of a machine. Then availability can be calculated as follows.

\[
\text{Availability} = \frac{\text{Available Time} \times \text{Downtime}}{\text{Available Time}} \times 100\% \tag{2}
\]

The performance rate is a measure of the efficiency of a machine running the production process. Three important factors in counting performance rate are the ideal cycle time, greater amount and operation time. Then the spectacle can be counted as follows.

\[
\text{Performance} = \frac{\text{Operating Speed Rate}}{\text{Net Operating Rate}} \times 100\% \tag{3}
\]

Quality rate is a good quality ratio of the number of products that are processed. The formula is very helpful in disposing of the quality of the production process.

\[
\text{Quality Rate} = \frac{\text{Processed Amount} - \text{Defect Amount}}{\text{Processed Amount}} \times 100\% \tag{4}
\]

According to Seichi Nakajima, the company's OEE ideal condition is availability > 90%, performance efficiency > 95%, quality rate > 99 % and OEE > 85%.

Reliability or accuracy or may be defined as probability that a component/system will inform a function that is needed in a given period of time when used in operating conditions. Reliability theories can be used to predict when parts on a machine will malfunction, so they can determine when should be done with care, replacement, and provision of components [7].

This research was conducted at PT. Perkebunan Nusantara IV Bah Butong Unit located on Jl. Besar Sidamanik, Sidamanik, Simalungun Regency, North Sumatra Province, Indonesia. Research time is done starting June 2019 - August 2019.

3. Methodology
Based on its nature, it has been classified as a descriptive research, one that attempts to project a systematic and factual solution of a current problem. Research aims to evaluate the effectiveness of machines with overpowering equipment appliances (OEE) and improve engine efficiency by designing repairs for maintenance programs using reliability analysis approaches.

The variables used in this study are as follows:

- Dependent Variables
  - Value of engine effectiveness
  - Causes of Machine Failure
  - Engine reliability value

- Independent variable
  - Time Breakdown (Damage) Machine
  - Time of Setup
  - Time Available Time
  - Production Data
  - Corrective Repair Time
  - Machine Damage Intervals

The research was carried out in several stages beginning with the identification of problems to produce conclusions. The research design is detailed steps in research to produce the desired model. The steps of the research process can be seen in Figure 1.
4. Result and Discussion

The research engine consists of 13 types of Open Top Roller (OTR), Double Indian Burblekaker Netehrland (DIBN), Press Cup Roller (PCR), Rotor Vane (RV), Fluid Bed Dryer (FBD), Two Stages Dryer (TSD), Middleton machine, Nissan machine, Vibro machine, Jackson machine, Van Der Meer machine, and Roll Press Paper Sack (RPPS) machine. Data gathered from the company starts in January - December 2018, that is machine breakdown, machine setup, available time, total product processed, total scrap, total actual production time, interval damage and machine repairs time.

4.1. Actual Overall Equipment Effectiveness (OEE) Counting Analysis

Based on data processing obtained value availability, performance efficiency and rate of quality product averaged 99.15%, 83.92% and 99.96% each one. The value of Overall Equipment Appliances (OEE) is 83.17%.

4.2. Actual Six Big Losses Accounting Analysis

Based on calculating the breakdown loss value of average machine is 0.30 percent. The largest breakdown loss value in vibro 5 machine rate of 0.42 percent. The setup and adjustment loss value average machine amounts to 0.55 percent. The largest setup and adjustment loss amount to OTR 1, OTR 3, OTR 7, PCR 1, PCR 3 and PCR 4 with a setup and adjustment loss value rate of 1.07%. Idling and minor stoppages of machine average 4.70%. The largest idling and minor stoppages on FBD 2 and FBD 4 with idling and minor stoppages 7.74%. The reduced speed average value is 11.25%. The largest reduced speed value is in the Middleton 2 machine with an increased value-speed of 19.72%. The rework loss of the machine was at a 0.0% value due to the absence of product impairment in the company. The yield/scrap loss machine value average rate 0.00%. The largest yield/scrap loss remained on the Silencing 1 and silencing 2 machine value a yield/scrap loss is 0.01%.

4.3. The Machine Maintenance Schedule Analysis

Distribution pattern testing is done using Minitab software 16. Here's a recapitulation pattern of interval distribution of overall machine damage:

\[ \text{Figure 1. Steps of the research process} \]
Table 2. The MTTF machine value

| Machine   | Distribution | MTTF Value |
|-----------|--------------|------------|
| OTR 1     | Weibull      | 33 Day     |
| OTR 2     | Normal       | 14 Day     |
| OTR 3     | Lognormal    | 29 Day     |
| OTR 4     | Lognormal    | 22 Day     |
| OTR 5     | Normal       | 25 Day     |
| OTR 6     | Normal       | 43 Day     |
| OTR 7     | Normal       | 24 Day     |
| OTR 8     | Weibull      | 36 Day     |
| DIBN 1    | Lognormal    | 24 Day     |
| DIBN 2    | Lognormal    | 26 Day     |
| PCR 1     | Lognormal    | 14 Day     |
| PCR 2     | Weibull      | 19 Day     |
| PCR 3     | Lognormal    | 16 Day     |
| PCR 4     | Normal       | 53 Day     |
| PCR 5     | Normal       | 15 Day     |
| PCR 6     | Normal       | 22 Day     |
| PCR 7     | Weibull      | 53 Day     |
| RV 1      | Normal       | 21 Day     |
| RV 2      | Normal       | 17 Day     |
| FBD 1     | Lognormal    | 14 Day     |
| FBD 2     | Lognormal    | 14 Day     |
| FBD 3     | Lognormal    | 19 Day     |
| FBD 4     | Normal       | 21 Day     |
| TSD 1     | Lognormal    | 19 Day     |
| TSD 2     | Weibull      | 15 Day     |
| TSD 3     | Weibull      | 18 Day     |
| Midleton 1| Lognormal    | 18 Day     |
| Midleton 2| Weibull      | 20 Day     |
| Nissan 1  | Normal       | 21 Day     |
| Nissan 2  | Normal       | 25 Day     |
| Nissan 3  | Normal       | 21 Day     |
| Nissan 4  | Lognormal    | 31 Day     |
| Van De Meer 1 | Lognormal | 29 Day |
| Van De Meer 2 | Normal   | 30 Day |
| Van De Meer 3 | Weibull   | 30 Day |
| Van De Meer 4 | Normal   | 35 Day |
| Jackson 1 | Lognormal    | 18 Day     |
| Jackson 2 | Weibull      | 59 Day     |
| Siliran 1 | Normal       | 36 Day     |
| Siliran 2 | Lognormal    | 32 Day     |
| Siliran 3 | Lognormal    | 32 Day     |
| Vibro 1   | Lognormal    | 35 Day     |
| Vibro 2   | Normal       | 26 Day     |
| Vibro 3   | Weibull      | 24 Day     |
| Vibro 4   | Normal       | 25 Day     |
| Vibro 5   | Weibull      | 25 Day     |
| RPPS      | Normal       | 47 Day     |
From the table above it can be seen that OTR 2, PCR 1, FBD 1, and FBD 2 have the lowest MTTF for 14 days and Jackson 2 has the highest MTTF during 59 days.

4.4. The Machine Repair Time Analysis

Selected distribution patterns are conducted using Minitab Software 16. Here are the parameters calculated for the selected distribution pattern, hence the MTTR value for the machine:

| Machine | Distribution | MTTR Score |
|---------|--------------|------------|
| OTR 1   | Lognormal    | 88 Minute  |
| OTR 2   | Normal       | 35 Minute  |
| OTR 3   | Lognormal    | 67 Minute  |
| OTR 4   | Lognormal    | 65 Minute  |
| OTR 5   | Weibull      | 54 Minute  |
| OTR 6   | Weibull      | 87 Minute  |
| OTR 7   | Normal       | 33 Minute  |
| OTR 8   | Lognormal    | 78 Minute  |
| DIBN 1  | Weibull      | 46 Minute  |
| DIBN 2  | Normal       | 51 Minute  |
| PCR 1   | Lognormal    | 43 Minute  |
| PCR 2   | Normal       | 55 Minute  |
| PCR 3   | Lognormal    | 75 Minute  |
| PCR 4   | Lognormal    | 94 Minute  |
| PCR 5   | Weibull      | 44 Minute  |
| PCR 6   | Normal       | 55 Minute  |
| PCR 7   | Weibull      | 89 Minute  |
| RV 1    | Lognormal    | 50 Minute  |
| RV 2    | Weibull      | 43 Minute  |
| FBD 1   | Lognormal    | 39 Minute  |
| FBD 2   | Lognormal    | 36 Minute  |
| FBD 3   | Weibull      | 49 Minute  |
| FBD 4   | Normal       | 57 Minute  |
| TSD 1   | Weibull      | 42 Minute  |
| TSD 2   | Weibull      | 39 Minute  |
| TSD 3   | Weibull      | 50 Minute  |
| Midleton 1 | Weibull   | 43 Minute  |
| Midleton 2 | Lognormal | 38 Minute  |
| Nissan 1 | Weibull      | 47 Minute  |
| Nissan 2 | Lognormal    | 65 Minute  |
| Nissan 3 | Lognormal    | 58 Minute  |
| Nissan 4 | Weibull      | 71 Minute  |
| Van De Meer 1 | Weibull | 41 Minute  |
| Van De Meer 2 | Weibull | 85 Minute  |
| Van De Meer 3 | Lognormal | 84 Minute  |
| Van De Meer 4 | Weibull | 91 Minute  |
| Jackson 1 | Weibull      | 50 Minute  |
| Jackson 2 | Weibull      | 73 Minute  |
| Siliran 1 | Weibull     | 73 Minute  |
| Siliran 2 | Normal       | 61 Minute  |
| Siliran 3 | Lognormal    | 54 Minute  |
| Vibro 1  | Normal       | 104 Minute |
It is seen from the table above that the RPPS engine has the smallest MTTR of 22 minutes and the Vibro 1 has the largest MTTR of 104 minutes.

### 4.5. The Machine’s Reliability Value Analysis on A Maintenance Schedule

The machine's reliability on a test maintenance schedule is used to determine the magnitude of the machine by the time the proposed maintenance schedule is done.

Table 4. Value increased reliability engineering

| Machine   | Value Reliability (R(tp)) | Value Increased Reliability |
|-----------|---------------------------|-----------------------------|
| OTR 1     | 63.27%                    | 63.27%                      |
| OTR 2     | 46.38%                    | 91.85% (7 Day)              |
| OTR 3     | 48.96%                    | 92.24% (8 Day)              |
| OTR 4     | 38.74%                    | 90.68% (6 Day)              |
| OTR 5     | 50.50%                    | 50.50%                      |
| OTR 6     | 49.67%                    | 90.27% (3 Day)              |
| OTR 7     | 50.19%                    | 50.19%                      |
| OTR 8     | 63.22%                    | 63.22%                      |
| DIBN 1    | 42.02%                    | 90.27% (11 Day)             |
| DIBN 2    | 40.59%                    | 90.90% (8 Day)              |
| PCR 1     | 46.57%                    | 94.37% (9 Day)              |
| PCR 2     | 62.85%                    | 62.85%                      |
| PCR 3     | 50.00%                    | 91.63% (21 Day)             |
| PCR 4     | 49.49%                    | 90.73% (18 Day)             |
| PCR 5     | 50.54%                    | 50.54%                      |
| PCR 6     | 51.52%                    | 51.52%                      |
| PCR 7     | 63.29%                    | 63.29%                      |
| RV 1      | 50.32%                    | 50.32%                      |
| RV 2      | 48.38%                    | 91.24% (5 Day)              |
| FBD 1     | 40.84%                    | 92.58% (5 Day)              |
| FBD 2     | 36.54%                    | 93.77% (3 Day)              |
| FBD 3     | 37.28%                    | 90.75% (5 Day)              |
| FBD 4     | 49.04%                    | 90.13% (4 Day)              |
| TSD 1     | 37.06%                    | 92.47% (4 Day)              |
| TSD 2     | 63.58%                    | 63.58%                      |
| TSD 3     | 64.33%                    | 64.33%                      |
| Midleton 1| 52.16%                    | 52.16%                      |
| Midleton 2| 62.91%                    | 62.91%                      |
| Nissan 1  | 50.00%                    | 50.00%                      |
| Nissan 2  | 48.81%                    | 90.15% (6 Day)              |
| Nissan 3  | 50.55%                    | 50.55%                      |
| Nissan 4  | 45.38%                    | 93.51% (25 Day)             |
| Van De Meer 1 | 51.99%              | 51.99%                      |
| Van De Meer 2 | 44.65%              | 91.08% (28 Day)             |
| Van De Meer 3 | 63.26%              | 63.26%                      |
Van De Meer 4 50.49% 50.49%  
Jackson 1 73.81% 73.81%  
Jackson 2 63.14% 63.14%  
Siliran 1 49.77% 90.58 % (11 Day)  
Siliran 2 43.78% 90.38 % (19 Day)  
Siliran 3 40.37% 91.45 % (11 Day)  
Vibro 1 41.27% 90.23 % (15 Day)  
Vibro 2 50.65% 50.65%  
Vibro 3 63.38% 63.38%  
Vibro 4 50.63% 50.63%  
Vibro 5 63.53% 63.53%  
RPPS 50.61% 50.61% 

Can be seen from the table above that OTR 2, OTR 3, OTR 4, OTR 6, DIBN 1, DIBN 2, PCR 1, PCR 3, PCR 4, RV 2, FBD 1, FBD 2, FBD 3, FBD 4, TSD 1, Nissan 2, Nissan 4, Van Der Meer 2, Silencing 1, Silencing 2, Silencing 3, and Vibro 1 are a machine that has enhanced reliability. The reliability value of the OTR 2 machine maintenance schedule for every 7 days of use was 0.9185, and further for each machine. OTR 6 and FBD 2 have the smallest MTTF value of 3 days at a reliability value of 90.27 % and 93.77 % and Van De Meer 2 has the largest MTTF value of 28 days at 91.08 %. Data processing is needed to predict when a machine will fail so that the maintenance of a company can determine when maintenance should take place, but such measures are not fully applied to the company.

4.6. The Reliability Value Analysis of the Entire Mechanical System

The machine in the company is set up with a series and parallel configuration. The reliability of the entire mechanical system is meant to identify the reliability of the machinery viewed as a whole. The machine consists of 12 subsystems that were initially calculated parallel configurations. Then is calculated configuration of the series from subsystems 1 to subsystems 13. The overall product of an actual machine system is 77.83 %. The overall product of the proposed machine system is 85.82 %.

4.7. Overall Equipment Effectiveness (OEE) Projections Analysis

After calculations of the actual Overall Equipment Effectiveness (OEE) were made according to the company's data, then calculated the value of MTTR and MTTF each machine from interval frequency data machine damage and machine repair times and was calculated the reliability of the machine.
Obtained maintenance program schedules of each machine, then calculated the value of Overall Equipment Effectiveness (OEE). Here is the recapitulation of the value of Overall Equipment Effectiveness (OEE). The proposed Overall Equipment Effectiveness (OEE) value a total machine is 85.43%.

4.8. The Six Big Losses Projections Analysis
Once the OEE counts on a projection, then it counts the value of Six Big Losses projection. The value of Six Big Losses projection, it is found that three losses analysed have been minimized after using the maintenance program schedule of breakdown losses, idling and minor stoppages and reduced speed. The actual value breakdown rate is 0.30% and the correct breakdown rate is 0.25%. Idling and minor stoppages ‘actual value is 4.70% and idling and minor stoppages projection is 2.44%. The actual increased speed value is 9.40% and the projected speed value is 9.33%.

5. Conclusion
The conclusion of this research there are four the average value of Overall Equipment Effectiveness (OEE) the machine was 83.17 %. The smallest OEE is on Vibro 4’s 74.39 % machine and the largest is on DIBN 2’s 94.46 % machine. The Effect of the decrease in the effectiveness of the production machine seen by six big losses with an average breakdown losses rate of 0.30 %, setup losses averaged 0.55 %, idling and minor stoppages averaged 4.70 %, reduced speed average of 11.25 %, rework loss average of 0.00 % and a yield/scrap loss average of 0.00 %. The overall value of the mechanical engineering system is 77.83% and after maintenance schedule improvements, machine reliability increased by 85.81 %. OEE’s prediction for improvement of the maintenance schedule is 85.43 %.

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