Maintenance Policy for Korin Filling Machines Using Overall Equipment Effectiveness (OEE) and Markov Chain

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Abstract. The aim of this study is to measure the performance effectiveness, determine component replacement, and maintenance schedule for Korin filling machines that often experience downtime. The downtime can cause the performance of the machine to decline so that the production process does not run optimally, the product operating time decreases from the time of the targeted operation. This study used two methods, Overall Equipment Effectiveness (OEE) is a method used to measure the effectiveness of overall machine performance by measuring Availability, Performance, and Quality Level factors, meanwhile, Markov Chain is a method used to determine preventive maintenance schedules to obtain optimal time and costs for important components. The results of the Overall Effectiveness of Equipment on the Korin Filling machines are decreased. The value of the performance factor is at the lowest value. The results of the Markov Chain method yielded a machine maintenance schedule every five days.

1. Introduction

As stated by Kurniawan, maintenance is an activity carried out in the industry to maintain or increase the carrying capacity of a machine during the production process [1]. Production machines that are used continuously will experience a decrease so maintenance is needed. Care is needed to maintain the quality and the system so that it can function properly as in the initial conditions. The maintenance must be carried out continuously and on target, then the quality of the machine will be maintained and the life of the machine can be maximized.

PT. IKAFOOD PUTRAMAS is a food company that produces spices and sauces known as "Kokita". Production activities consist of nine production lines. Line 5 (Korin Filling Machine) has the biggest downtime. That happens because maintenance and repairs are done if there is downtime during production. Korin Filling Machines often experience sudden downtime during the production process. If this happens, the performance of the machine will decrease so that the production process does not run optimally, i.e. the product operating time is reduced from the targeted operating time. In addition, there is an irregular maintenance schedule. This is related to the effectiveness of the use of machines that are still not optimal. According to Aghezaff, technical problems in parts of the machine that often suffer damage can suddenly slow down the production process [2].

Nakajima introduced the concept of TPM (Total Productive Maintenance), whose aim is to improve and maintain equipment efficiency [3]. According to Muchiri et. al in the TPM, most of the research involved OEE (Overall Equipment Effectiveness) measures related to maintenance [4]. As stated by Noon, OEE measurement method is useful to know the performance of a machine or equipment and as a material consideration for the decision to maintain its production activities and reduce losses from machines or equipment of production [5]. OEE measurements are expected to show the level of readiness, performance, and quality of the machines used in production. This OEE method consists of 3 factors, namely Availability, Performance, and Quality. In addition to measuring the machine's utility, if any machine is damaged, it is necessary to schedule machine maintenance and
calculate the maintenance costs. According to Subagyo et.al, Markov Chain is a mathematical technique commonly used for modeling various business systems and processes. The Markov Chain method is used to find out the estimated maintenance costs and machine maintenance schedules [6].

The aim of this study is to measure the utility of the machine with the Overall Equipment Effectiveness (OEE) method and analyze the causes of downtime on the machine as well as determining the schedule of replacement of a component, maintenance costs with the Markov Chain method.

2. Method

This research was conducted in Line 5, Korin Filling machine in January to April 2018, at PT IKAFOOD PUTRAMAS.

2.1 Calculates the OEE value

- Availability, which consists of Damages and Regulations / Adjustments.

Butar-butar et.al introduces availability as a determinant that considers expenditures available for carrying out production activities using machinery or equipment [7]. To find availability value using available time data, planned downtime, breakdown time, and set up time. After the data is available the processed meal used the following equation.

\[
\text{Availability} = \frac{\text{Operation time}}{\text{Loading time}} \times 100\%
\]

- Performance, which consists of Small Stops and Slow Running.

Butar-butar et.al argues that performance is a comparison that shows a machine's ability or performance to produce a product. [7]. To calculate the value of performance efficiency requires data cycle time, operation time, and total production data. For performance, efficiency calculations can use the following equation.

\[
\text{Performance} = \frac{\text{processed amount} \times \text{ideal cycle time}}{\text{operation time}} \times 100\%
\]

- Quality, which consists of Startup Defects and Production Defects

Butar-butar et.al argues that the level of quality is a comparison that illustrates the ability of machines to produce products according to company standards.[7]. The calculation of a rate of product quality requires production data such as good product and total reject. To calculate the rate of a quality product, we can use the following equation.

\[
\text{Rate of Quality} = \frac{\text{Processed amount} - \text{Defect amount}}{\text{Processed amount}}
\]

- Calculates OEE Value can use this following equation.

\[
\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Rate of Quality}
\]

Nakajima said that the ideal condition for each value was based on his experience, Availability value must be > 90%, Performance value > 95%, and Quality Value > 99%. The specified OEE ideal value must be greater than 85% [2].

2.2 Markov Chain

Jardine argued that Markov Chain is a limited stochastic process in which probabilistic for the future depend on existing protection in the present conditions [8]. The following items must be calculated in the Markov chain method as follows [7]: Calculate of the machine status transition probability, the transition matrix 1, the transition matrix 2, maintenance costs and determination of machine maintenance schedules.

The classification of damage to calculate the transition value of a Markov Chain process, in this problem, then the machine system will be grouped according to the conditions of damage. The conditions agreed here is the level of engine readiness when carried out maintenance by the machine.
How to determine this condition by periodically checking. When the machine is turned into four, it is as follows:

1. Good Conditions (G) are conditions where the machine can be in accordance with the provisions of the company that has been approved, such as the state of the new machine and the machine does not depend on damage during the production process. This condition is called status 1.
2. Mild Damage Condition (MD) is a place where the machine can operate well, but sometimes a small damage occurs. This condition is called status 2.
3. Medium Damage Condition (MoD) is a condition where the machine can be used but with an alarming condition. The agreed condition is a process that can be carried out but when the production process can be stopped. This condition is called status 3.
4. High Damage Conditions (HD) are conditions where the machine cannot be used to run so that the production process stops. This condition is called status 4.

3. Results and Discussion

3.1 Overall Equipment Effectiveness Method

The value of overall equipment effectiveness is influenced by three factors: availability, performance, and rate of quality. The followings are the results of the calculation of the three factors and the OEE value itself.

1. \[ Availability = \frac{147}{204} \times 100\% = 72.22\% \]
2. \[ Performance = \frac{889 \times 0.11}{147} \times 100\% = 66.37\% \]
3. \[ Rate of Quality = \frac{2667 - 587}{2667} \times 100\% = 78.00\% \]
4. \[ OEE = 72.22\% \times 66.37\% \times 78.00\% = 37.39\% \]

Performance values have the lowest value compared to the availability value and the rate of quality value. The low-performance value is caused due to downtime when the engine is producing, thereby, reducing the operation time of the Korin Filling machine. The determination of the most critical downtime is done by sorting downtime which has the highest influence on the production performance of the machine. The data used in determining critical downtime is the frequency of component replacement data that often occurs on three Korin Filling machines during January-April 2018. The most frequently damaged component, namely the Heat. The OEE value of the Korin Filling Machine is very small at 37.39%. According to Bamber, to increase the OEE value requires solid teamwork involving all lines, namely operation, maintenance, and management of manufacturing equipment and resources [9].

3.2 Markov Chain Method

Performance is the lowest value it is because maintenance is not carried out regularly and machine maintenance schedules are not yet available. Hence, the next step is to determine the proposed treatment by doing the replacement time of the heater component on the Korin Filling machine using the Markov Chain method so that maintenance on the machine can be done regularly. Following are the Markov Chain method steps:

- Step 1 : Calculate of the machine status transition probability, it can be seen in Table 1.
### Table 1. Matrix probability of machine status transition

| Month   | G/G | G/MD | G/MoD | G/HD | MD/MD | MoD/MoD | MD/HD | MoD/MoD | MoD/HD | HD/G |
|---------|-----|------|-------|------|-------|---------|-------|---------|--------|------|
| January | 0   | 1/2  | 0     | 0    | 0     | 1/5     | 0     | 1/2     | 0      | 0    |
| February| 0   | 0    | 0     | 0    | 0     | 0       | 1/2   | 0       | 0      | 0    |
| March   | 0   | 0    | 0     | 0    | 1/5   | 2/5     | 0     | 0       | 0      | 0    |
| April   | 0   | 0    | 0     | 1/2  | 1/5   | 0       | 0     | 0       | 0      | 0    |
| **Total** | **0** | **0.50** | **0** | **0.50** | **0.40** | **0.40** | **0.20** | **0.50** | **0.50** | **1** |

- Step 2: Calculate of the transition matrix 1, it can be seen in Table 2 and Table 3.

### Table 2. Matrix transition matrix 1, Korin Filling machines (Po).

|   | G  | MD | MoD | HD |
|---|----|----|-----|----|
| 1 | 0  | 0.50 | 0    | 0.50 |
| 2 | 0  | 0.40 | 0.40 | 0.20 |
| 3 | 0  | 0    | 0.50 | 0.50 |
| 4 | 1  | 0    | 0    | 0    |

Table 2 shows the Korin Filling machine that experiencing high damage in the status 4. Table 3 shows the opportunity (P29) for the Korin Filling machine under some conditions.

### Table 3. Matrix probability of Filling Korin Machine (Po)

| Step-n | Probability |
|--------|-------------|
|        | G           | MD          | MoD         | HD           |
| P(29)  | 0.2857      | 0.2381      | 0.1905      | 0.2857       |

- Step 3: Calculate of the transition matrix 2, can be showed in Table 4. and Table 5. Table 4 shows the calculation of transition probability matrix 2 (selected) Korin Filling machine with condition P₁ (Corrective maintenance at status 4 and preventive maintenance at status 3).

### Table 4. Matrix transition matrix 1, Korin Filling machines (P1).

|   | G  | MD | MoD | HD |
|---|----|----|-----|----|
| 1 | 0  | 0.50 | 0    | 0.50 |
| 2 | 0  | 0.40 | 0.40 | 0.20 |
| 3 | 0  | 0    | 0    | 0   |
| 4 | 1  | 0    | 0    | 0   |

Table 5 shows a probability (P25) of Korin Filling machines if corrective maintenance is carried out on status 4 and preventive maintenance on status 3.
Table 5. Matrix probability of Filling Korin Machine (P1)

| Step-n | Probability |
|--------|-------------|
| P(25)  | 0.1818      |
|        | 0.4545      |
|        | 0.1818      |
|        | 0.1818      |

- Step 4 : Calculate of total maintenance costs
  
  A. The calculation of company’s maintenance costs

  Corrective maintenance costs = corrective maintenance time × cost of corrective downtime
  
  = 11.25/12 × Rp 262,500
  
  = Rp. 246,093.75/day

  Preventive maintenance costs = preventive maintenance time × preventive downtime costs
  
  = 6/12 × Rp 256,250
  
  = Rp. 12,625/day

  Total Cost = Corrective maintenance costs + Preventive maintenance costs
  
  = Rp. 246,093.75 + Rp. 12,625
  
  = Rp. 255,718.75/day

  B. The calculation of maintenance cost, condition P₁ (Tc₁):

  Corrective maintenance costs = corrective maintenance time × cost of corrective downtime
  
  = 11.25/12 × Rp 262,500
  
  = Rp. 246,093.75/day

  Expectation costs = steady state probability × cost of corrective downtime
  
  = 0.2857 (0) + 0.2381 (0) + 0.1905 (0) + 0.2857 (Rp 246,093.75)
  
  = Rp. 70,308/day

  C. The calculation of maintenance cost, condition P₁ (Tc₂):

  Expectation cost = (steady state probability × preventive downtime cost) + (steady state probability × cost of corrective downtime)
  
  = 0.1818 (0) + 0.4545 (0) + 0.1818 (Rp. 12,625) + 0.1818 (Rp. 246,093.75)
  
  = Rp. 47,035/day

- Step 5 : Determination of machine maintenance schedules.

  The decision for the chosen maintenance costs is Tc₂, so the maintenance schedule for the Korin Filling machines by replacing Heater component is:

  \[
  \text{Schedules of maintenance is : } \frac{2 \text{ hours}}{11.25 \text{ hours}} \times 26 \text{ days} \approx 4.6 \text{ days} \approx 5 \text{ day}
  \]
4. Conclusion
Preventive and corrective maintenance methods must be carried out optimally, in order to extend the life of the machine and produce optimum product quality. In addition, machine monitoring, replacement of small components, and filling out reports on engine conditions are regularly carried out. According to Tanuhardja, to determine time carry out preventive maintenance for equipment requires information about when the equipment will reach a failed or damaged condition [10]. As stated by Winata the transition of equipment from good condition to fail cannot be the exact time is known, but information about the likelihood of the transition occurring at any given time is based on the function of the damage [11]. The proposed plan for replacing critical components and proper maintenance of the Korin Filling machine is to use preventive maintenance policies with replacement times of the Heater component every 5 days and the maintenance costs are Rp. 47,035 per day.

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