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Analysis of Machine Performance with Calculations Overall Equipment Effetiveness on Packing Line Automation Machine

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A B S T R A C T

This study continues the previous practical work, emphasizing the importance of machine maintenance, problem improvement, and production facility maintenance to maintain quality and productivity. The maintenance team aims to find the right system to reduce machine breakdowns and maintenance costs. Automation, such as the Automated Packing Line, was chosen to optimize production with minimal labor. This study analyzes the effectiveness of automation machines in the Packing Line area and evaluates the role of labor in continuous improvements to calculate Overall Equipment Effectiveness (OEE). Results show that the OEE of the traying machine in the Automated Packing Line is 79%, still below the standard of 85%. After improvements were made, the OEE value increased to 87%

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INTRODUCTION

The advancement of technology in the industrial world has led the cosmetics industry to use automation-based machines in the production chain to be more effective and efficient. This is the background for PT. Hoyu Indonesia to implement automation in the powder line packing production area. Currently, the Production Department of PT. Hoyu Indonesia is facing a decline in performance in the powder line packing production area, caused by several factors.

The OEE (Overall Equipment Effectiveness) method and continuous improvement are essential to achieving satisfactory production operations as planned. To obtain accurate OEE calculations, machine or equipment maintenance in automation systems is required in the manufacturing industry. This maintenance ensures optimal operation, allowing OEE calculations to meet the production targets, one of which is by performing maintenance on the machines and equipment.

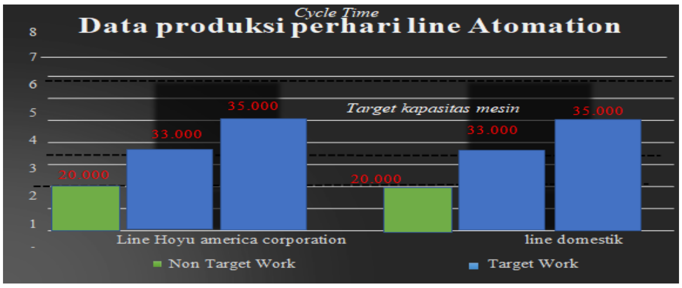

Figure 1. Daily Target Graph for Automation Line
Source: PT. Hoyu Indonesia Documentation (2021)

Based on the graph above, the production data on the company's automation line shows a daily production target of 33,000 pcs/day, with the machine capacity being 35,000 pcs/day. However, the lowest daily production output reached only 20,000 pcs/day, which resulted in the company failing to meet the monthly production target. In the first six months of 2021, the production output did not meet the target set by the company, leading to the inability to fulfill 100% of customer demand. The calculation of the target achievement ratio for January is as follows: The calculation of the target achievement ratio for the following months is shown in the production data in Table 1.

Table 1. Production Data for 2021

Production Data for 2021			
Month	Production Output (Pcs)	Target (Pcs)	Ratio
Januari	649,840	792,000	82%
Februari	658,640	792,000	83%
Maret	684,540	792,000	86%
April	678,890	792,000	86%
Mei	655,450	792,000	83%
Juni	665,665	792,000	84%
Total	**3,993,025**	**4,752,000**	

Source: PT. Hoyu Indonesia Documentation (2021)

Figure 2. Production Output Data for 2021
Source: PT. Hoyu Indonesia Documentation (2021

In Figure 2, it can be seen that in the previous year, the monthly hair dye production activities carried out by PT. Hoyu Indonesia did not reach the predetermined targets. The company set a target of 792,000 pcs per month. However, the production output during the first six months of 2021 failed to meet this target.

The smooth running of the production process requires the support of well-functioning machines and equipment. However, the Automation line faced challenges, such as frequent breakdowns or machine troubles, which led to suboptimal machine performance. Therefore, the readiness of production machines is crucial for production activities. With well-maintained machines, the products produced will meet the quality standards and targets set. However, what often occurs is negligence in machine maintenance, where maintenance is only performed after damage has occurred during production, leading to wastage.

The hair dye production process on the Automation line involves eight stages: washing, labeling, traying, gloving, leafleting, boxing, dozening, and cartoning. Among the eight machines used in the hair dye production process, some machines frequently experience issues, which disrupt the smooth production process and reduce machine productivity due to corrective maintenance activities that cause line stoppages. The machine downtime data is shown in Table 2.

Table 2. Machine Downtime Data for the Period of January – June 2021

Month	Washing Machine	Labeling Machine	Traying Machine	Gloving Machine	Leafleting Machine	Boxing Machine	Dozzen Machine	Cartoning Machine	Total (Minute)
JAN	60	145	1740	245	150	60	30	30	**2460**
FEB	45	140	1380	45	120	120	40	45	**1935**
MAR	120	180	1050	120	90	40	0	60	**1660**
APR	80	40	1095	125	40	0	45	40	**1465**
MEI	60	90	1410	45	160	40	30	40	**1875**
JUNI	80	50	1440	180	125	30	60	60	**2025**
Total	**445**	**645**	**8115**	**760**	**685**	**290**	**205**	**275**	**11420**

Source: Data Processing (2023)

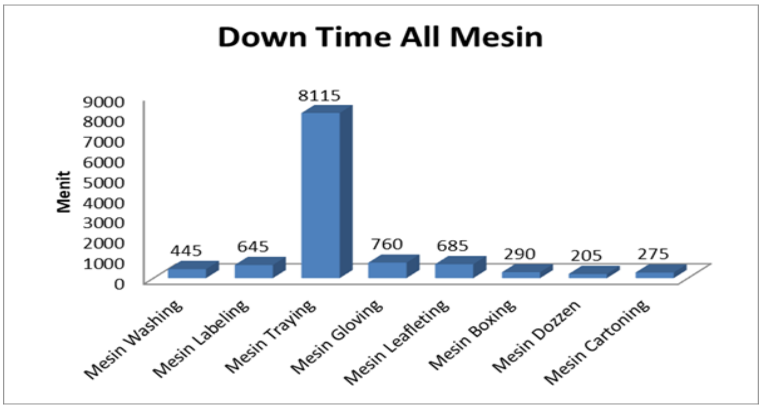

Figure 3. Machine Downtime Graph for Automation Line
Source: Data Processing (2023)

As shown in Figure 3, the total downtime in 2021 amounted to 11,420 minutes, equivalent to 190 hours. Based on the graph in Figure 2, the highest downtime occurred on the traying machine, with a downtime of 8,115 minutes. Therefore, based on the above data, the focus of this study will be on the traying machine.

The traying machine is designed to facilitate the packaging process of trays, containers, or box-shaped products. This machine has a total of 4 lanes and a production capacity of approximately 73 pcs/minute. Based on field findings, several main issues were identified in the tray machine sub-area, including tray trouble (product container), glove insert overload (overloaded bottle capacity), back take out (improper glove placement), and bottle rotary (bottles falling and not properly placed). These issues caused downtime due to machine stoppages for troubleshooting. Table 3 shows the data on issues with the traying machine during the period from January to June 2021.

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Table 3. Data on Traying Machine Issues in 2021

Types of Damage to the Tray Design Machine in 2021			
Month	**Date**	**Type of Damage**	**Repair Time (Minutes)**
Januari	02-Jan	trouble tray (wadah dari prodak)	120
Januari	03-Jan	trouble tray (wadah dari prodak)	120
Januari	04-Jan	trouble tray (wadah dari prodak)	120
Januari	07-Jan	glove insert (sarung tangan)	90
Januari	08-Jan	trouble tray (wadah dari prodak)	180

Januari	10-Jan	overload (kelebihan kapsitas botol)	60
Januari	12-Jan	back take out (peletakan gelove yang tidak sempurna)	120
Januari	13-Jan	trouble tray (wadah dari prodak)	180
Januari	18-Jan	trouble tray (wadah dari prodak)	120
Januari	20-Jan	glove insert (sarung tangan)	60
Januari	23-Jan	bottle rotary (botol jatuh dan tidak sempurna)	90
Januari	26-Jan	trouble tray (wadah dari prodak)	180
Januari	27-Jan	trouble tray (wadah dari prodak)	180
Januari	29-Jan	trouble tray (wadah dari prodak)	120
Februari	03-Feb	glove insert (sarung tangan)	120
Februari	04-Feb	glove insert (sarung tangan)	60
Februari	07-Feb	trouble tray (wadah dari prodak)	180
Februari	09-Feb	bottle rotary (botol jatuh dan tidak sempurna)	120
Februari	10-Feb	trouble tray (wadah dari prodak)	180
Februari	11-Feb	trouble tray (wadah dari prodak)	180
Februari	12-Feb	trouble tray (wadah dari prodak)	180
Februari	19-Feb	back take out (peletakan gelove yang tidak sempurna)	120
Februari	23-Feb	overload (kelebihan kapsitas botol)	120
Februari	27-Feb	trouble tray (wadah dari prodak)	120
Maret	01-Mar	trouble tray (wadah dari prodak)	120
Maret	05-Mar	overload (kelebihan kapsitas botol)	90
Maret	09-Mar	back take out (peletakan gelove yang tidak sempurna)	120
Maret	10-Mar	trouble tray (wadah dari prodak)	180
Maret	19-Mar	overload (kelebihan kapsitas botol)	90
Maret	21-Mar	trouble tray (wadah dari prodak)	120
Maret	22-Mar	trouble tray (wadah dari prodak)	180
Maret	26-Mar	trouble tray (wadah dari prodak)	150
April	05-Apr	back take out (peletakan gelove yang tidak sempurna)	45
April	08-Apr	trouble tray (wadah dari prodak)	180
April	10-Apr	trouble tray (wadah dari prodak)	120
April	14-Apr	trouble tray (wadah dari prodak)	180
April	16-Apr	overload (kelebihan kapsitas botol)	90

April	18-Apr	trouble tray (wadah dari prodak)	120
April	20-Apr	glove insert (sarung tangan)	60
April	23-Apr	trouble tray (wadah dari prodak)	180
April	28-Apr	trouble tray (wadah dari prodak)	120
Mei	02-May	overload (kelebihan kapsitas botol)	90
Mei	05-May	back take out (peletakan gelove yang tidak sempurna)	90
Mei	08-May	trouble tray (wadah dari prodak)	180
Mei	10-May	trouble tray (wadah dari prodak)	120
Mei	12-May	trouble tray (wadah dari prodak)	180
Mei	13-May	trouble tray (wadah dari prodak)	120
Mei	20-May	overload (kelebihan kapsitas botol)	90
Mei	23-May	trouble tray (wadah dari prodak)	180
Mei	26-May	trouble tray (wadah dari prodak)	180
Mei	28-May	trouble tray (wadah dari prodak)	180
Juni	02-Jun	trouble tray (wadah dari prodak)	180
Juni	10-Jun	overload (kelebihan kapsitas botol)	90
Juni	14-Jun	back take out (peletakan gelove yang tidak sempurna)	90
Juni	16-Jun	trouble tray (wadah dari prodak)	120
Juni	17-Jun	trouble tray (wadah dari prodak)	120
Juni	19-Jun	glove insert (sarung tangan)	90
Juni	21-Jun	trouble tray (wadah dari prodak)	180
Juni	22-Jun	trouble tray (wadah dari prodak)	120
Juni	25-Jun	trouble tray (wadah dari prodak)	150
Juni	26-Jun	glove insert (sarung tangan)	120
Juni	28-Jun	trouble tray (wadah dari prodak)	180
	Total waktu *breakdown* mesin *traying* pada *line automation*		**8115**

Source: PT. Hoyu Indonesia Documentation (2021)

From Table 3, it can be seen that issues with the traying machine occur frequently, with the longest machine downtime being 180 minutes per day or 3 hours per day. In contrast, the standard downtime for the automation line is 8 hours per month. Given the issues observed, the author will analyze the performance of the traying machine using the Overall Equipment Effectiveness

(OEE) method and conduct improvements using the Failure Mode and Effects Analysis (FMEA) method.

The aim of this study is to analyze the performance of the traying machine using the OEE method. After determining the OEE value for the traying machine, improvements will be made to minimize the downtime of the traying machine.

LITERATURE REVIEW

A. Maintenance

Maintenance is an activity carried out in an industry to maintain or enhance the operational capacity of machinery during the production process. A machine used continuously will experience wear and tear, hence maintenance is necessary. Optimal maintenance should be performed continuously and periodically to ensure that machines function at their best (Kurniawan, 2013).

Maintenance is the activity of preserving or keeping factory facilities/equipment in good working condition and performing necessary repairs or adjustments/replacements to ensure a satisfactory operational state as planned (Assauri, 2016). Maintenance encompasses activities aimed at keeping equipment systems functioning properly (Heizer et al., 2017). From various definitions, it can be concluded that maintenance is an activity performed to maintain and care for all equipment and facilities to ensure they function properly over time.

The primary goals of maintenance are defined as follows:

(1) To extend the useful life of assets
(2) To ensure optimal availability of equipment for production and achieve maximum return on investment
(3) To ensure operational readiness of all equipment required in emergencies
(4) To ensure the safety of personnel using the equipment (Daryus, 2008)

Further goals of maintenance include:

(1) Ensuring production capability meets production plans
(2) Maintaining quality at appropriate levels to meet product requirements and uninterrupted production activities
(3) Helping to reduce excessive wear and deviations and preserving invested capital
(4) Achieving the lowest possible maintenance costs by performing maintenance activities effectively and efficiently
(5) Avoiding maintenance activities that could jeopardize worker safety.
(6) Establishing close cooperation with other key functions of the company to achieve the company's main goals: maximizing return on investment and minimizing total costs (Assauri, 2016)

B. Functions of Maintenance

The function of maintenance is to extend the economic life of machines and production equipment, ensuring that they are always in optimal condition and ready for use in the production process. The benefits of good maintenance for machinery are as follows:

(1) Equipment and production facilities can be used for a long time
(2) Production processes run smoothly

(3) Minimizing the risk of severe damage to machines and equipment during production
(4) Ensuring that production equipment operates stably, with good process control and quality management
(5) Preventing total damage to machines and production equipment.
(6) Ensuring normal raw material consumption when equipment is functioning well (Agus, 2002)

C. Types of Maintenance

There are two types of maintenance:

(1) Preventive maintenance, also known as proactive or overhaul maintenance, involves activities to prevent unexpected failures and identify conditions that could lead to operational issues. Properly planned preventive maintenance can prevent failures or breakdowns, as operational failures can lead to total production stoppage.
(2) Corrective maintenance, also known as breakdown maintenance, involves activities carried out after a failure or malfunction to restore equipment to proper functioning (Agus, 2002).

D. Preventive Maintenance

Preventive maintenance (PM) is crucial for supporting production facilities classified as "critical units." This technique involves inspecting equipment to predict potential failures. Preventive maintenance is scheduled and typically periodic, involving tasks such as inspection, repair, replacement, cleaning, lubrication, and adjustment (Kurniawan, 2013).

Preventive maintenance aims to prevent unexpected damage and ensure that production facilities remain in a ready state for operation at all times (Agus, 2002).

By implementing preventive maintenance, companies can minimize severe damage to assets. The benefits include:

(1) Reducing the need for major overhauls
(2) Lowering the likelihood of large-scale repairs
(3) Reducing repair/replacement costs
(4) Minimizing defective products
(5) Reducing spare parts inventory
(6) Minimizing extra wage costs due to machine downtime (overhaul)
(7) Lowering unit production costs

Preventive maintenance requires routine and periodic inspections and services. There are two types:

(1) Routine maintenance involves regular activities such as cleaning, lubrication, checking oil levels, and warming up machines before operation.
(2) Periodic maintenance involves maintenance activities performed at set intervals.

Preventive maintenance processes include:

(1) Recording and managing data on maintenance, failures, and equipment use (basic equipment analysis).
(2) Performing all predictive activities, including inspections, measurements, part quality checks, lubrication analysis, temperature, vibration, noise, and recording predictive data for trend analysis.

(3) Minor repairs (30 minutes), with a focus on productivity.
(4) Documenting conditions requiring special attention, with potential failure risks.
(5) Scheduling and performing instructed repairs.
(6) Using failure frequency and severity to improve the PM task list.
(7) Training and upgrading the PM system (Kurniawan, 2013).

E. Corrective Maintenance

This activity is also commonly referred to as repair or corrective action. Such activities typically cannot be planned in advance as they can only be addressed after a malfunction occurs. Sometimes, repairs may be delayed or postponed. Corrective maintenance (CM) involves activities performed after a machine or production facility experiences damage or disruption, rendering it unable to function or produce effectively (Kurniawan, 2013).

Corrective maintenance focuses on repairing after damage has occurred, allowing production facilities and equipment to be used again, thus ensuring that the production process resumes smoothly and returns to normal. If a company only engages in corrective maintenance, there is an inherent uncertainty in the smooth operation of production facilities and equipment, which can lead to effects that hinder production if unexpected damage or disruptions occur.

Corrective maintenance may appear cheaper than preventive maintenance (PM), but costs can escalate when production is halted due to damage. Moreover, repair and maintenance costs increase when damage occurs. Thus, corrective maintenance is reactive, addressing issues only after they arise, rather than analyzing and preventing potential problems. Preventive maintenance should be intensified to avoid higher costs associated with corrective actions. For expensive and critical production machines, PM is significantly more beneficial than CM.

Corrective maintenance can be measured using MTTR (mean time to repair), which includes several activities typically divided into three groups:

(1) Preparation time, which involves finding personnel for the job, traveling, ensuring equipment is ready, and testing.
(2) Active maintenance time, which is the time required to perform the actual repair, including reviewing repair charts before starting and verifying that the issue has been resolved, possibly including post-repair documentation.
(3) Delay time (logistic time), which is the time spent waiting for components needed for repair (Kurniawan, 2013).

F. Total Productive Maintenance (TPM)

TPM is a method used to enhance machine productivity through equipment maintenance. Historically, the TPM concept was pioneered by Seichi Nakajima in the 1960s and became part of lean manufacturing to eliminate waste. Total productive maintenance (TPM) is a maintenance system involving all elements, from top management to frontline employees, including production operators, developers, marketers, and administrators. Operators are not only responsible for operating machines but also for maintaining them. TPM is an innovative approach to maintenance aimed at optimizing equipment effectiveness, reducing or eliminating sudden breakdowns, and enabling autonomous maintenance by operators (Prabowo & Agustiani, 2017). TPM aims to maintain machines and equipment in optimal condition. Achieving this goal requires both preventive and predictive maintenance. Applying TPM principles can minimize machine damage. Common machine issues include dirt, missing nuts and bolts, infrequent oil changes, leaks, unusual noises, and excessive vibration (Saipudin, 2019).

G. Human Resource Management

The implementation of total preventive maintenance involves applying eight pillars that must be addressed by all company elements for successful TPM implementation, including:

(1) Autonomous maintenance, which assigns routine maintenance responsibilities to operators, such as cleaning machines, checking machine completeness and functions, and inspecting machines for vibrations and noises. This approach fosters high ownership among operators, enhances their knowledge of the equipment, and helps identify potential damage before it worsens.

(2) Planned maintenance involves scheduling maintenance tasks based on past damage ratios or predicted damage levels. If no production schedule is available, line managers will list machine damages, and maintenance teams will replace parts, inspect, and adjust settings. Planned maintenance helps reduce sudden damage and better control component damage levels.

(3) Quality maintenance addresses quality issues by ensuring equipment can detect and prevent errors during production. This capability ensures the production process reliably meets specifications, reducing product failures and production costs.

(4) Focused improvement involves forming workgroups to proactively identify problematic machines or equipment and propose improvements. These groups may also identify talented employees to support company performance targets.

(5) Early equipment management utilizes experiences from previous repairs and maintenance to ensure new machines achieve optimal performance quickly. This pillar aims to achieve optimal performance for new equipment as soon as possible, given the need for production adjustments to meet company standards.

(6) Training and education are essential to address knowledge gaps when implementing TPM. Lack of knowledge about equipment can lead to damage and reduced productivity, harming the company. Training and documentation help operators or engineering teams learn and apply maintenance practices.

(7) Safety, health, and environment require workers to operate in a safe and healthy environment. This pillar mandates companies provide a safe and healthy environment, free from hazardous conditions, including providing personal protective equipment. The goal is to achieve an "accident-free" workplace.

(8) TPM in administration involves spreading TPM concepts to administrative functions, ensuring that all organizational members, including administrative staff (planning, purchasing, and finance), share a common understanding and perception of TPM (Saipudin, 2019).

H. Benefits of Total Productive Maintenance (TPM)

One of the main benefits and objectives of TPM is to increase factory and equipment productivity through a simple investment in maintenance. By investing in equipment maintenance, losses due to equipment failure can be minimized. There are six losses that can be prevented, commonly referred to as the "six big losses":

(1) Breakdown losses caused by the equipment
(2) Set-up and adjustment losses
(3) Minor stoppage losses
(4) Speed losses
(5) Quality defect and rework losses
(6) Yield losses

The first two losses affect equipment availability, the third and fourth losses affect equipment efficiency, and the fifth loss relates to a decline in quality (Prabowo & Agustiani, 2017).

I. Overall Equipment Effectiveness (OEE)

OEE is a comprehensive measure that identifies the productivity and theoretical performance level of machines/equipment. This measurement is crucial for determining areas that need improvement in terms of productivity and efficiency, and for identifying bottlenecks in the production line. OEE also serves as a tool for evaluating and improving methods to ensure increased productivity of machine/equipment usage (Saipudin, 2019).

OEE is expressed as the ratio of the actual output of equipment compared to the maximum output of the equipment under optimal performance conditions. OEE is based on the measurement of three main ratios: availability (A), performance efficiency (PE), and rate of quality product (ROQP) (Suliantoro et al., 2017).

OEE is a measure of the overall effectiveness of equipment to evaluate how well equipment performs. It is also used as a tool to enhance company productivity and as a decision-making step. OEE is a method used in TPM programs to maintain equipment in ideal condition by eliminating the six big losses (Ihsan & Azizi, 2017).

J. Formula for Overall Equipment Effectiveness (OEE)

The mathematical formula for Overall Equipment Effectiveness (OEE) is formulated as follows:

OEE = Avalibility x Performance Efficiency x Quality Product x 100%

Figure 4. OEE Standard Values

Based on an award presented by the Japan Institute of Plant Maintenance, the ideal OEE conditions are as follows:

(1) Availability ratio > 90%.
(2) Performance efficiency > 95%.
(3) Rate of quality product > 99%.

According to the benchmarks for the three parameters in the OEE calculation, the ideal minimum OEE value is 85%.

1. Availability Ratio

Availability is a comparison that illustrates the utilization of available time for the operation of machines or equipment. Availability is used to calculate downtime losses, which account for any instances where the machine cannot operate during the available process time. The formula used to measure the availability ratio is: (a) Operation Time. (b) Working Time. (c) Downtime.

Availability ratio can be calculated using the formula:

$$\text{Availability ratio} = \frac{\text{Loading Time Downtime}}{\text{Loading Time}} \times 100\%$$

Working Time is the available time per day or per month minus the planned machine downtime. Working Time = Total Availability – Planned Downtime. Planned downtime is the amount of machine downtime for maintenance (scheduled maintenance) or other management activities. Operation time is the result of subtracting Working Time from machine downtime (nonoperation time). In other words, operation time is the available operating time (availability time) after subtracting machine downtime from the total planned availability. Machine downtime is the time when the machine should have been used, but due to equipment failures or malfunctions, no output is produced. Downtime includes machine stoppages due to equipment failures, die replacements, setup and adjustment procedures, and other issues.

2. Performance Efficiency

Performance ratio is a comparison that describes the ability of equipment to produce products. The performance ratio is used to calculate speed losses, which include any factors causing effective time loss in the production process, such as incorrect machine operation, non-standard materials (requiring frequent re-settings), component wear, and operator errors. There are three factors needed to calculate the performance efficiency ratio:

(a) Ideal Cycle Time
(b) Processed Amount
(c) Operation Time

The performance efficiency ratio can be calculated using the following formula:

$$\text{Performance Efficiency} = \frac{\text{Processed Amount x Ideal Cycle Time}}{\text{Operation Time}} \times 100\%$$

3. Rate of Quality Product

The Rate of Quality Product is the ratio of the number of good products to the total number of products processed. It measures the proportion of products that meet quality standards against the total products produced. Therefore, the rate of quality product is calculated using the following two factors:

(a) Processed Amount (Total number of products processed)

(b) Defect Amount (Number of defective products)

The rate of quality product can be calculated using the following formula:

$$\text{Rate of Quality Product} = \frac{\text{Process Amount x Defent Amount}}{\text{Processed Amount}} \text{ x } 100\%$$

4. Six Big Losses

In a company, there are several losses related to equipment, commonly referred to as the six big losses. These six big losses are categorized into three types:

(a) Downtime losses. Breakdown losses or equipment failures are undesirable malfunctions of machines or equipment that cause losses to the company due to decreased output, wasted time, or product rejects. Examples of equipment failures include downtime losses, waiting for support factors, lack of operators, and shift changes. Set-up and adjustment losses refer to losses incurred due to set-up activities, including adjustments for switching to the next type of product for the subsequent production process. This includes set-up time for materials on machines, material shortages, operator shortages, major adjustments, and warm-up time.

(b) Speed losses. Idling and minor stoppages losses occur due to brief machine stoppages, machine jams, or idle machine time. These losses are usually short-lived and do not require extensive personal maintenance. Reduced speed losses arise when the actual process speed is below the optimal speed of the machine, leading to suboptimal production performance.

(c) Defect losses. Process defects are losses caused by defective products. Product defects result in material waste, reduced production quantity, increased production waste, and additional time required for reworking defective products. Reduced yield losses or start-up losses are losses of time and materials that occur during the production process due to unstable operating conditions, improper handling and installation of machines, or operator unfamiliarity with the production process (Prabowo & Agustiani, 2017).

5. Fishbone

Fishbone is a strategy developed by Kaoru Ishikawa to distinguish the state and logical outcomes of a problem. The backbone of the fishbone diagram represents the current issue, while the branching lines represent the causes of difficulties, typically categorized into individuals, materials, equipment, management, and environment. The fishbone diagram is valuable for quality improvement as it illustrates the main drivers of various issues in an organized manner (Lighter & Fair, 2000).

The fishbone diagram is a graphical representation that depicts the relationship between problems or outcomes and the factors causing them (Heizer et al., 2005). Based on these definitions, it can be concluded that the fishbone diagram is a tool that illustrates the graphical relationship between problems or outcomes and their causes, aiding in problem-solving analysis.

K. Failure Mode and Effect Analysis (FMEA)

FMEA is a qualitative risk analysis method aimed at helping select design alternatives with high reliability and potential safety, ensuring that all foreseeable failure modes and their impacts on operational success have been considered. It involves listing potential failures, identifying their impacts, developing initial criteria for major testing plans and designs, creating system checklists for qualitative reliability and availability analysis, and documenting for future reference to analyze field failures. It also assists in comparing designs and setting maintenance priorities (Saipudin, 2019).

The Risk Priority Number (RPN) is a critical indicator for determining appropriate corrective actions for failure modes. RPN is used by many FMEA procedures to estimate risk using three criteria:

(a) Severity of effects
(b) Occurrence of causes
(c) Detection of causes

The RPN is the product of the severity, occurrence, and detection ratings. This number indicates the ranking or order of deficiencies in the system design.

L. Previous Research

To support this research, several previous studies using Overall Equipment Effectiveness (OEE) methodology are referenced, including:

(1) Mardian et al. (2022) found that the average OEE for a steamer machine was 82.19%, below the JIPM standard of ≥85. The six big losses showed breakdown losses of 6.08%, set-up & adjustment losses of 5.21%, idling minor & stoppage losses of 21.42%, reduced speed losses of 1.48%, process defect losses of 5.04%, and zero reduced yield. FMEA analysis indicated the highest RPN for the fire adjust switch part change was 175. Improvements were suggested using autonomous maintenance methods with steps including CILT, methods, machines, measurements, and environment (Mardian et al., 2022).

(2) Ariyah (2022) concluded that the OEE for the Batching Plant machine was 80.45%, while the international OEE standard is 85%, indicating a need for improvement. The priority for improvement was the performance or efficiency of the machine in producing concrete, as performance was the lowest factor affecting the OEE, with planned reports at the end of maintenance activities (Ariyah, 2022).

(3) R. F. Prabowo et al. (2020) reported that the OEE for grinding machines in July–August 2019 averaged 90.73%, still below the JIPM standard with a quality ratio averaging 98.54%. The study used Total Productive Maintenance (TPM) based on OEE values to improve equipment effectiveness and eliminate major losses known as the six big losses (Prabowo & Agustiani, 2017).

(4) Karmilawati et al. (2021) used a fishbone diagram to analyze downtime caused by dirty dies, which led to reduced pressure on the moulding machine due to residue blocking. After repairs with a pneumatic roadless cylinder, performance improved to 95.32%, and OEE increased to 85%, meeting world-class standards (Karmilawati et al., 2021).

(5)Pahmi Hamda (2018) analyzed Total Productive Maintenance (TPM) using OEE and cause-and-effect diagrams for improvement suggestions. The OEE for the extruder machine was 37.129%, with availability at 94.618%, performance at 39.321%, and quality at 99.845%. Proposed improvements included preventive maintenance according to schedule, enhancing marketing management to reduce machine downtime, and ensuring active spare part procurement to minimize machine issues (Pahmi, 2018).

METHODOLOGY

This research was conducted at PT. Hoyu Indonesia, a Japanese company specializing in hair dye manufacturing located in the KIIC area. The object of this research includes daily maintenance data and production quality from August 2021 to September 2021, obtained from the Line Powder Production department at PT. Hoyu Indonesia. The types of data used in this research are divided into two categories: (1) Primary data. Data obtained not directly from company information but from other sources, including information from various books and scientific journals related to the research. (2) Secondary data. Data obtained directly from the research object through interviews and direct observations with trusted personnel managing various aspects of the operations.

The data collection techniques employed in this study include: (1) Field study: The author conducted on-site observations to gather data and view the production line at PT. Hoyu Indonesia. The collected data includes: (a) General company data, such as the company's history and location. (b) Production data for 2021. (c) Machine downtime data on the packing line automation. (d) Working time data on the powder production line. (e) Machine quality data used in the packing line automation. (2) Interviews. This technique involves direct interviews with employees who are directly related to the research issues. (3) Questionnaires. Researchers provide a set of questions related to the ongoing study to employees who serve as respondents. (4) Literature review. This method involves obtaining information from various sources such as reference books, journals, and other resources relevant to the research.

Methodology. The collected data is processed to be usable for research. The data processing stages in this research involve analyzing the data using the Overall Equipment Effectiveness (OEE) method: (1) Availability ratio. Availability is the ratio of operation time to working time. To calculate machine availability, the following values are needed: (a) Operation Time, (b) Working Time, (c) Downtime.

The Availability Ratio can be calculated using the formula:

$$A = \frac{\text{Loading Time Downtime}}{\text{Loading Time}} \times 100\%$$

Performance Efficiency Ratio is a ratio that describes the ability of equipment to produce goods. Three factors are needed to calculate the performance efficiency ratio:

(a) Processed Amount
(b) Ideal Cycle Time
(c) Operation Time

The Performance Efficiency Ratio can be calculated using the following formula:

$$PE = \frac{\text{Processed Amount X Ideal Cycle Time}}{\text{Operation Time}} \times 100\%$$

Rate of quality product is the ratio of the number of good products to the total number of products processed. Thus, the Rate of Quality Product is calculated using two factors:

(a) Processed Amount (Number of products processed)
(b) Defect Amount (Number of defective products)

The Rate of Quality Product can be calculated using the following formula:

$$ROPQ = \frac{\text{Processed Amount X Defect Amount}}{\text{Processed Amount}} \times 100\%$$

Overall Equipment Effectiveness (OEE). The mathematical formula for Overall Equipment Effectiveness (OEE) is:

OEE=Availability×Performance Efficiency×Quality Product×100%

Six big losses. To address various losses related to equipment in a company, the Six Big Losses concept is used. These losses are categorized into three types:

(1)Downtime losses. Breakdown losses or equipment failure, setup and adjustment losses.
(2)Speed losses. Idling and minor stoppages losses, reduced speed losses.
(3)Defect losses. Process defects, reduced yield losses, or startup losses.

The Pareto Diagram is used to analyze a phenomenon to determine the priorities and dominant factors in analyzing and addressing the issue. The Pareto Principle, also known as the 80/20 rule, means that 20% of problems have an impact of 80%. Therefore, to address a problem, such as in production activities, the Pareto Diagram helps identify the dominant factors first, rather than addressing all problems simultaneously.

The Fishbone Diagram is a tool that illustrates the relationship between a problem or effect and the factors causing the problem. It helps in analyzing and resolving issues by identifying potential causes.

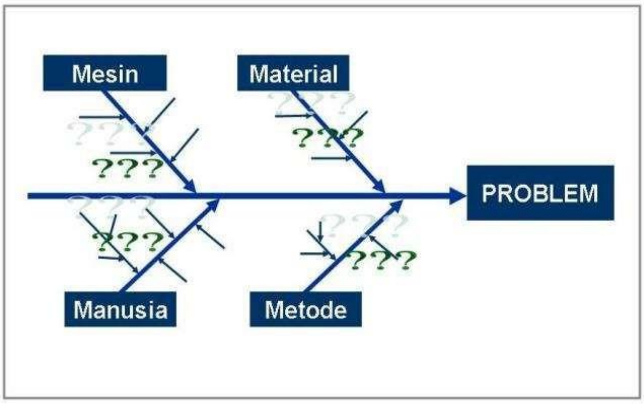

Figure 5. Diagram Fishbone
Source: (Jay Heizer & Render, 2005)

Failure Mode and Effects Analysis (FMEA). The purpose of conducting FMEA is to assist in selecting alternative designs with high reliability and safety potential, ensuring that all foreseeable failure modes and their impact on system operational success have been considered. It involves listing potential failures and identifying their impacts.

In creating an FMEA, the Risk Priority Number (RPN) is a critical indicator used to determine appropriate corrective actions for failure modes. RPN is used by many FMEA procedures to assess risk using the following three criteria:

(1)Severity of effect (Severity)
(2)Occurrence of cause (Occurrence)
(3)Detection of cause (Detection)

This study begins with a literature review by searching for sources such as books and journals. Following this, problem identification is conducted through field studies, including observation, interviews, and questionnaires. Data needed for this research, such as machine working hours, machine downtime, and production data for 2021, is then collected.

After gathering the necessary data, the next step is to process the data using the Overall Equipment Effectiveness (OEE) method in the following sequence:

(1)Availability ratio
(2)Performance efficiency
(3)Rate of quality product
(4)OEE value

From the OEE values obtained, an analysis is performed to determine the causes of suboptimal machine performance using the Six Big Losses method. The dominant causes are identified using the Pareto Diagram and then analyzed using the Fishbone Diagram and FMEA.

Once the root causes of suboptimal machine performance are identified, improvements are made to address these causes, leading to the results and conclusions of the study. The detailed reasoning is illustrated in the flowchart below.

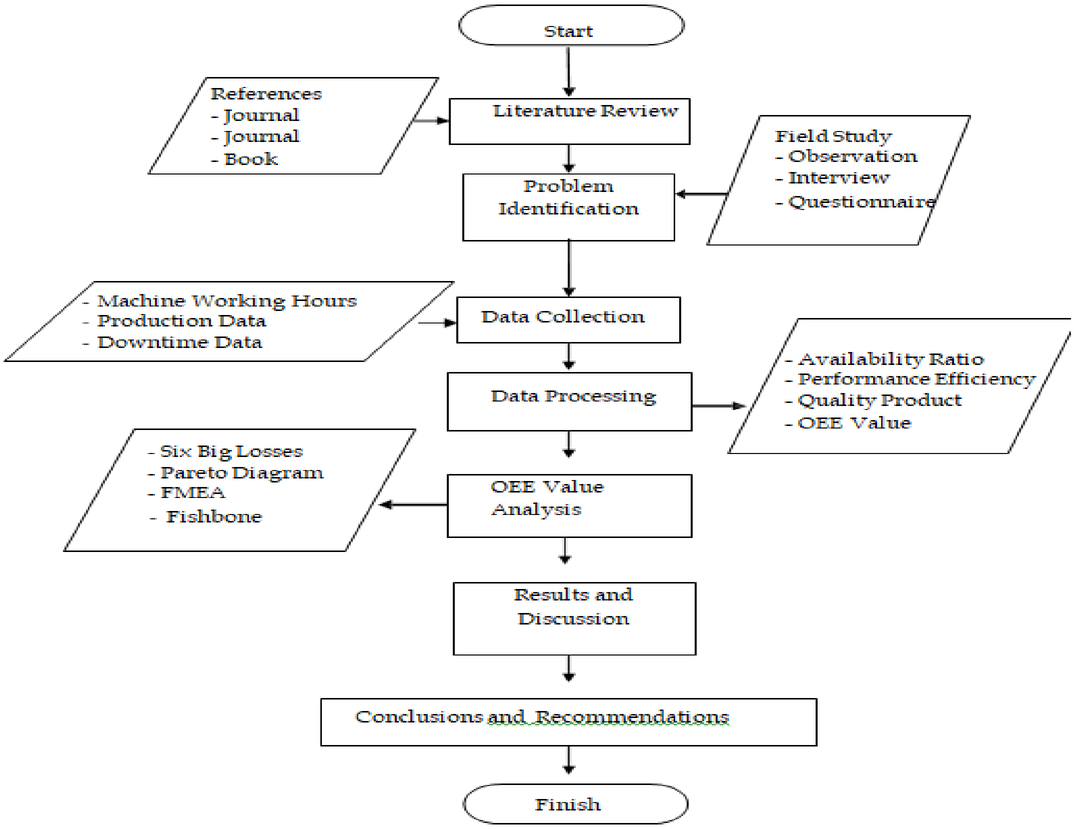

Figure 6. Framework

RESULT AND DISCUSSION

The following table shows the repair times for tray takeout troubles on the traying machine over the past 6 months.

Table 4. Repair Time Data Due to Tray Takeout Troubles

Month	Repair Time Due to Tray Takeout (Minutes)
Januari	1320
Februari	840
Maret	750
April	900
Mei	1140
Juni	1050
Total	6000

Source: Data Processing (2022)

After the repairs were made by modifying the addition of an air gun, changing the tray design to a zig-zag pattern, and adding a machine cover, the issues related to equipment & failure losses and idling and minor stoppages losses were eliminated. It can be assumed that the downtime due to tray takeout data was removed. The downtime after accounting for the repair time due to tray takeout is shown in Table 5.

Table 5. Downtime Data After Repairs

Downtime Data for 2021 Without Tray Takeout Issues				
Month	Working Time (Minutes)	Planned Downtime (Minutes)	Breakdown (Minutes)	Operating Time (Minutes)
Januari	11520	480	420	10620
Februari	11520	480	540	10500
Maret	11520	480	300	10740
April	11520	480	195	10845
Mei	11520	480	270	10770
Juni	11520	480	390	10650

Source: Data Processing (2022)

Based on the data above, the availability ratio measurement was then conducted after the repairs, as shown in the following calculations:

$$Availability\ Ratio = \frac{11.520-(480+420)}{11.520}\ x\ 100\% = 92\%$$

The complete calculations are shown in the following table:

Table 6. Availability Ratio After Repairs

Month	***Loading Time* (Minute)**	***Operation Time* (Minute)**	**AR %**
Januari	11520	10620	92%
Februari	11520	10500	91%
Maret	11520	10740	93%
April	11520	10845	94%
Mei	11520	10770	93%
Juni	11520	10650	92%
Rata-Rata			**93%**

Source: Data Processing (2022)

Table 6 shows the results of the availability ratio calculations after repairs for each month, where the average availability ratio obtained is 93%.

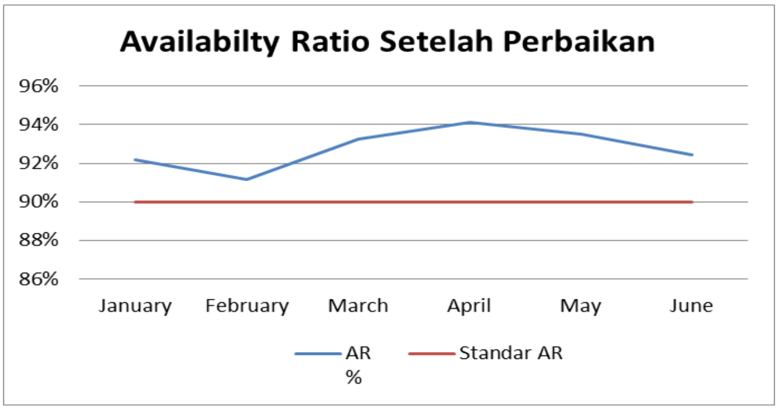

Figure 7. Availability Ratio After Repairs
Source: Data Processing (2022)

From Figure 7, the availability ratio after repairs is above the standard, indicating that the improvements made have achieved an ideal availability ratio. Next, the OEE value was calculated after the repairs, with the calculation for January as follows: OEE = 92% x 97% x 99% = 88%. The results of the calculations for the following months can be seen in Table 7.

Table 7. OEE Calculation Results After Repairs

Value OEE				
Month	Availability Ratio (After) %	Performa Efficiency %	Rate Of Quality Product %	OEE %
Januari	92%	97%	99%	88%
Februari	91%	94%	99%	85%
Maret	93%	95%	99%	87%
April	94%	94%	99%	88%
Mei	93%	94%	99%	87%
Juni	92%	96%	99%	88%
Rata-Rata	**93%**	**95%**	**99%**	**87%**

Source: Data Processing (2022)

Table 7 shows that the OEE value after repairs is 87%, indicating that the OEE value after repairs has exceeded the standard OEE value of 85%. This means that with the modifications made, the tray machine is now operating at an ideal performance level. Next, a comparison was made between the pre-repair and post-repair conditions.

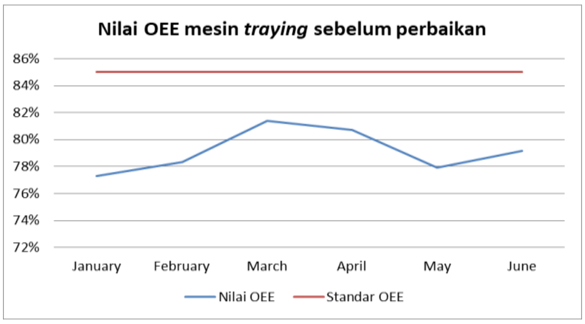

Figure 8. OEE Value Graph of Tray Machine Before Repairs
Source: Data Processing (2022)

Figure 8 illustrates the graph of the OEE value before repairs. Each month, the performance of the tray machine was not at an ideal level, with an average OEE value of 79%.

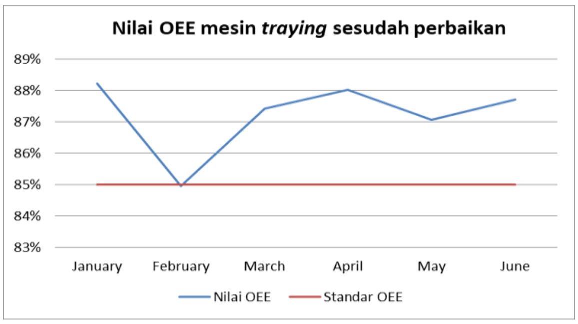

Figure 9. OEE Value Graph of Tray Machine After Repairs
Source: Data Processing (2022)

Figure 9 shows the graph of the OEE value after repairs. There is a significant improvement in the OEE value after repairs, with an average OEE value of 87%. This indicates that the modifications, including the installation of an automatic lubrication system, have improved the performance of the tray machine to an ideal level.

CONCLUSION AND RECOMENDATION

Based on the research results, the conclusions are as follows: (1) The OEE value of the tray machine on the packing line automation was 79%, which did not meet the OEE standard of 85%, indicating that the tray machine was not operating ideally in the previous period. (2) Analysis using the six big losses identified that equipment & failure losses and idling and minor stoppages losses accounted for a total percentage of 75.4%. (3) FMEA analysis identified the root cause of the problem as issues with tray takeout, leading to modifications to minimize tray takeout problems. Following these improvements, the tray machine's performance is now at an ideal level with an OEE value of 87%.

Recomendation

Based on the conclusions, the recommendations are: (1) PT. HI should measure the performance of all machines used in the production process to determine whether they are operating at an ideal condition or not. (2) PT. HI should pay attention to the condition and maintenance of machines used in the production process to ensure they operate at an ideal condition and provide optimal productivity.

FURTHER STUDY

For further study, it would be valuable to explore the Integration of Predictive Maintenance with OEE Analysis on Packing Line Automation Machines. This research could focus on incorporating advanced predictive maintenance techniques, such as machine learning and real-time monitoring, to forecast potential machine failures before they occur. By predicting when and where breakdowns are likely to happen, it’s possible to schedule maintenance more effectively, reducing unexpected downtime and improving the overall OEE. Additionally, this study could examine the impact of predictive maintenance on reducing specific loss categories identified in the OEE analysis, such as equipment failures and minor stoppages. The goal would be to develop a predictive model that not only improves machine uptime but also optimizes maintenance schedules to sustain and enhance the performance of automated packing lines. This approach could lead to more efficient operations, cost savings, and higher productivity, making it a critical area for future research.

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