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Scheduling Preventive Maintenance to Increase the Effectiveness of Injection Molding Machines Using the Overall Equipment Effectiveness Method at PT. Mah Sing Indonesia

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Abstract: *This study aims to evaluate the Overall Equipment Effectiveness (OEE) in a production environment from January to December 2023. Utilizing quantitative analysis, monthly OEE values were assessed, revealing significant variations. No month achieved the World Class OEE standard of 85%, with the highest value recorded in August (54%) and the lowest in December (35%). The average OEE for the period was approximately 44.67%, substantially below the established benchmark. The primary factor contributing to the low OEE was identified as the low Availability rate, leading to significant machine downtime. Following the implementation of a structured preventive maintenance schedule, machine downtime markedly decreased from 21,540 minutes to 1,464 minutes. Recommendations for moulding machine maintenance include weekly servicing outside production hours, during production halts, or after producing 260,000 units. For other machines, monthly, semi-annual, or annual maintenance schedules are proposed. The study concludes that proper preventive maintenance scheduling can significantly enhance OEE and reduce machine downtime, thereby improving overall production efficiency.*

Keywords: *Scheduling Preventive Maintenance, Overall Equipment Effectiveness, Six Big Losses.*

INTRODUCTION

In the era of increasingly global industrial competition and rapid technological development, industries continue to strive to improve the quality and quantity of their products. This creates a need to improve efficiency and effectiveness in the production process (Adenuga et al., 2022; Bonada et al., 2020; Quiroz-Flores & Vega-Alvites, 2022). The production process in the manufacturing industry tends to rely on machines as the backbone of its operations. However, intensive and sometimes over-capacity use can lead to deterioration in engine performance, reduced engine life, and even damage to engine components (Bakhtiar et al., 2019; Hardt et al., 2021; Nurprihatin et al., 2023). Machine breakdowns not only cause costly downtime but also require additional costs for component repairs or replacements (Moreira et al., 2020). Therefore, the main challenge for manufacturing companies is to run production processes effectively and efficiently, while minimizing disruptions due to machine breakdowns (Duffuaa et al., 2020; Farahani et al., 2022a; Lee et al., 2020). Machine failures can be caused by several factors, including the condition of the machine itself, human intervention, and environmental factors such as temperature, humidity, and workplace cleanliness (Farahani et al., 2022b; Hadiyat et al., 2022). To face these challenges, companies need to implement effective preventive maintenance strategies, improve training for machine operators, and pay attention to environmental factors that can affect machine performance (Alvira et al., 2015; Firmansyah et al., 2015; Khasanah et al., 2023; Mawson & Hughes, 2019).

Pranoto in (Nurjanah et al., 2023) highlights that losses due to engine damage are not only financial but can also threaten the safety of workers. This confirms that machine maintenance issues impact not only the company's operational and financial efficiency but also the safety of individuals involved in the production process (Hadisaputra & Hasibuan, 2022).

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The statement is about PT. Mah Sing Indonesia in maintaining the effectiveness of its injection molding machine production process. Although the company has nine injection molding machines, they often experience unexpected downtime, which can disrupt the smooth running of production. To overcome this problem, a multidisciplinary approach involving various aspects, such as human resources, technology, management, and capital, is needed (Li et al., 2021; Supriyadi et al., 2017). By involving all these elements in an integrated manner, the company can increase the effectiveness of the injection moulding process at PT. Mah Sing Indonesia, reducing downtime and increasing productivity overall.

The problem continues when the injection moulding machine is operating in the production line. This indicates the need for rescheduling maintenance so that the injection moulding process can run optimally. To overcome these challenges, it is important to understand the frequency data of injection moulding machine breakdowns during 2023. This data can be the basis for identifying possible breakdown patterns, evaluating maintenance needs, and designing more effective maintenance schedules to minimize downtime and maximize machine performance

RESEARCH METHODS

Research Venue and Object

This research was carried out at PT. Mah Sing Indonesia which is located in Parungmulya, Ciampel District, Karawang, West Java 41363, in the period of January 2023 to December 2023.

Data Collection

Data collection aims to collect the information needed to achieve the research objectives. The data collected consisted of primary and secondary data, which included:

1. Primary Data Primary data is data obtained directly from the source. Primary data collection was carried out through field observations and interviews with resource persons who are experts in their fields.
2. Secondary Data Secondary data is obtained from indirect sources such as literature studies, references, and company documents. This secondary data serves as supporting data for primary data.

   Data collected from primary and secondary sources include:

   a. Shift length.
   b. Downtime Molding.
   c. Total products.
   d. Product rework.
   e. Delay molding.
   f. Planned downtime.
   g. Molding damage criteria.

   Data Collection Methods Data is collected through the following three methods:

a. Observation Observation is a method of collecting data by making direct observations in the company.
b. Interview Interview is a method of data collection that is carried out through direct conversations with parties related to the problem being researched. The goal is to obtain the necessary information from the company.
c. Literature Studies Literature studies are literature studies that aim to provide a basis for thinking in research and solve problems that have been formulated. This study is carried out to obtain references in the form of theories or methods that are relevant to the research topic. Literature studies are used as the basis for basic theories and assumptions in the preparation of research.

RESULTS AND DISCUSSION

Availability Rate Calculation

Availability Rate is the ratio between Operating Time and Loading Time. The formula for calculating the Availability Rate is as follows:

$$\text{Availability Reate} = \frac{Operating\ Time}{Loading\ Time}\ 100\%$$

Here's a calculation of the Availability Rate value for January.

$$\text{Availability Rate} = \frac{Operation\ Time}{Loading\ Time} \text{ x } 100\%$$

$$= \text{x } 100\% \frac{108180}{208020}$$

$$= 52\%$$

The Availability Rate value that has been calculated for January to December 2023 can be found as follows:

Table 1. Availability Rate Injection Molding Calculation Data for January 2023 – December 2023

Moon	*Operation Time* (minutes)	*Loading Time* (minutes)	*Availability Rate* (%)
January	108180	208020	52%
February	132720	210840	63%
March	150420	233340	64%
April	64284	135840	47%
May	94274	194220	49%
June	76872	174840	44%
July	101153	196860	51%
August	1099929	191760	57%
September	99744	192540	51%
October	89064	182220	48%
November	62106	153600	40%
December	55536	150000	37%

Data Processing Sources 2024

Performance Calculation

Performance Rate is the reliability or ability of the machine/equipment to produce output based on gross product, Operating Time, and ideal cycle time. The formula for the Performance Rate is (Hasriyono, 2009):

$$\text{Performance Rate} = \frac{actual\ product}{Standart\ Product}\ x\ 100\%$$

Table 2. Performance Rate Calculation from January 2023 – December 2023

Moon	*Actual Product*	*Standard Product*	*Performance* (%)
January	41030	43170	95%
February	29538	39543	75%
March	35390	43156	82%
April	13059	15029	87%
May	36470	41159	89%
June	22030	22906	96%
July	36081	37204	97%
August	20865	21616	97%

Moon	*Actual Product*	*Standard Product*	*Performance* (%)
September	29816	30694	97%
October	23761	24690	96%
November	21636	22620	96%
December	22750	23496	97%

Data Processing Sources 2024

Quality Rate Calculation

Quality Rate is the ability of a machine to produce products that meet company standards based on output, good products, and rejected products. A rejected product is a damaged product.
Here is the Quality Rate calculation for January:

$$\text{Quality Rate} = \frac{\textit{Gross Product} - \text{Total } \textit{Reject}}{\textit{Gross Product}} \text{ x } 100\%$$

$$= \text{x}100\% \frac{224258-6645}{224258}$$

$$= 97\%$$

The results of the calculation of the Quality Rate value from January to December 2023 can be found in the following table:

Table 3. of the Quality Rate calculation for January to December 2023 is as follows:

Moon	*Gross Product* (unit)	Total *Reject*	*Quality Rate* (%)
January	224258	6645	97%
February	185151	5048	97%
March	209245	4934	98%
April	115642	3423	97%
May	181363	4541	97%
June	154157	3879	97%
July	180076	3815	98%
August	174273	4350	98%
September	176462	3506	98%
October	171579	3587	98%
November	169510	3989	98%
December	136382	3847	97%

Data Processing Sources 2024

Calculation of Overall Equipment Effectiveness (OEE) Value

Based on the three main factors in OEE, the overall equipment effectiveness (OEE) value can be calculated. The formula for determining the OEE value is (Nakajima, 1998):
OEE (%) = Availability Rate (%) x Performance Rate (%) x Quality Rate (%)
Here is the calculation of OEE values for January 2023:
OEE (%) = Availability Rate (%) x Performance Rate (%) x Quality Rate (%)
= 52% x 95% 97%
= 48%

The Overall Equipment Effectiveness (OEE) values from January to December 2023 can be found in Table 4. The table contains the results of the OEE calculation during the period.

Table 4. Calculation of Overall Equipment Effectiveness Value from January 2023 – December 2023

Moon	*Availability Rate* (%)	*Performance Rate* (%)	*Quality Rate* (%)	OEE (%)
January	52%	95%	97%	48%
February	63%	75%	97%	46%
March	64%	82%	98%	51%
April	47%	87%	97%	40%
May	49%	89%	97%	42%
June	44%	96%	97%	41%
July	51%	97%	98%	48%
August	57%	97%	98%	54%
September	51%	97%	98%	48%
October	48%	96%	98%	45%
November	40%	96%	98%	38%
December	37%	97%	97%	35%

Data Processing Sources 2024

Six Big Losses Calculation

1) Breakdown Losses

It is a comparison between the Total Breakdown Time and the Loading Time of an engine. The formula applied is (Hasriyono, 2009):

Breakdown Losses = x 100%$\frac{\text{Total } Breakdown\ time}{Loading\ Time}$

Here is the calculation of Breakdown Losses for January 2023:

Breakdown Losses = $\frac{16080}{208020}\ x\ 100\%$

= 7.73%

Data on Breakdown Losses from January to December 2023 is contained in the following table:

Table 5. Breakdown Losses Calculation in January 2023 – December 2023

Moon	Total *Breakdown Time*	*Loading Time*	*Breakdown Losses*
January	16080	208020	7,73%
February	19230	210840	9,12%
March	21270	233340	9,11%
April	12150	135840	8,94%
May	12600	194220	6,48%
June	12720	174840	7,27%
July	13110	196860	6,65%
August	10890	191760	5,67%
September	10500	192540	5,45%
October	11640	182220	6,38%
November	10740	153600	6,99%
December	11100	150000	7,40%
Total	162030	2224080	

Data Processing Sources 2024

2) Calculation of Set-up and Adjustment Losses

The formula used to calculate Set-up and Adjustment Losses is (Hasriyono, 2009):

$$\text{Set-up and Adjustment Losses} = \frac{\text{Total } Set{-}up\ and\ Adjustment}{Loading\ Time}\ x\ 100\%$$

$$Setup\ and\ Adjustment\ losses = \frac{Total\ Setup\ and\ Adjustment}{loading\ time}\ x\ 100\%$$

$$\text{Set-up and Adjustment Losses} = \frac{12190}{208020}$$

$$= 5.86\%$$

The results of the calculation of Set-up and Adjustment Losses from January 2023 – December 2023, are as follows:

Table 6. Calculation of Set-up and Adjustment Losses from January 2023 – December 2023

Moon	*Set-up Machine*	*Schedule Shutdown*	Total *Set-up and Adjustment*	*Loading Time*	*Set-up and Adjustment Losses (%)*
January	11190	1000	12190	208020	5,86%
February	10950	1000	11950	210840	5,66%
March	10470	1000	11470	233340	4,91%
April	8334	1000	9334	135840	6,87%
May	8841	1000	9841	194220	5,06%
June	9432	1000	10432	174840	5,965
July	11412	1000	12412	196860	6,30%
August	8070	1000	9070	191760	4,72%
September	7917	1000	8917	192540	4,63%
October	8151	1000	9151	182220	5,02%
November	8586	1000	9586	153600	6,24%
December	11820	1000	12820	150000	8,54%

Source: Data processing 2024

Diagram Pareto

By utilizing Pareto diagrams, major or major problems can be broken down into smaller parts, so that improvement efforts can be focused more effectively. The Pareto diagram shows that of the Six Big Losses, the most influential factor is Breakdown Losses. Here are the results of the Pareto diagram:

Table 7.Percentage of Pareto Breakdown Losses in January – December 2023

Moon	*Breakdown Losses*	Percentage (%)	Cumulative (%)
January	7,73	9%	9%
February	9,12	11%	20%
March	9,11	10%	30%
April	8,94	10%	40%
May	6,48	7%	47%
June	7,27	8%	55%
July	6,65	8%	63%
August	5,67	7%	70%
September	5,45	6%	76%
October	6,38	7%	83%
November	6,99	8%	91%
December	7,40	9%	100%
Total	87,19	100%	

Data Processing Sources 2024

Below is the Pareto Chart of Breakdown Losses for January – December 2023

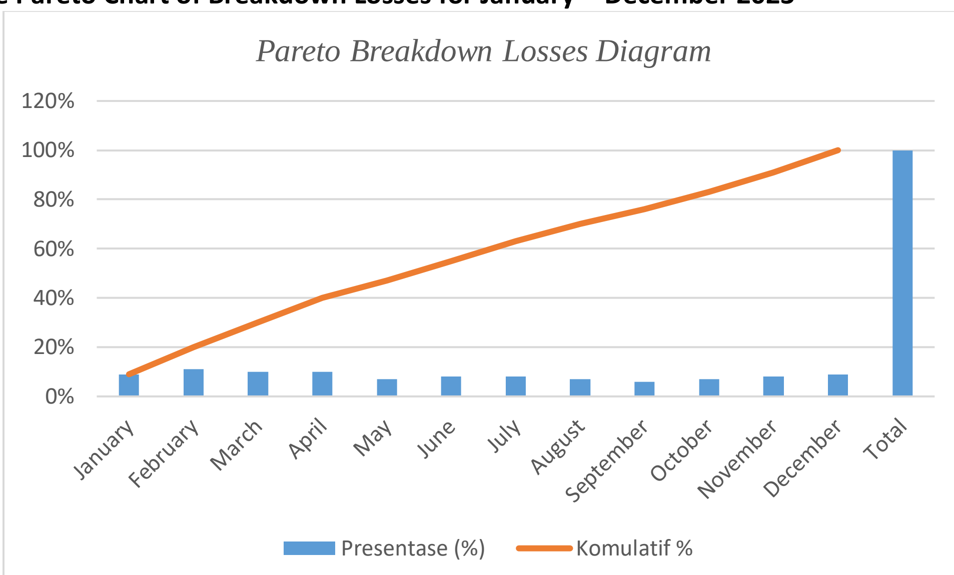

Figure 1. Pareto Breakdown Losses Diagram

Source: Data Processing 2024

Fishbone Diagram

Using a fishbone diagram, we can identify the root cause of the problem. Based on the pareto diagram above, the most significant factor is the loss due to damage. Therefore, it is necessary to carry out further identification to find out the cause of high losses due to damage. Here is a fishbone diagram for losses due to damage.

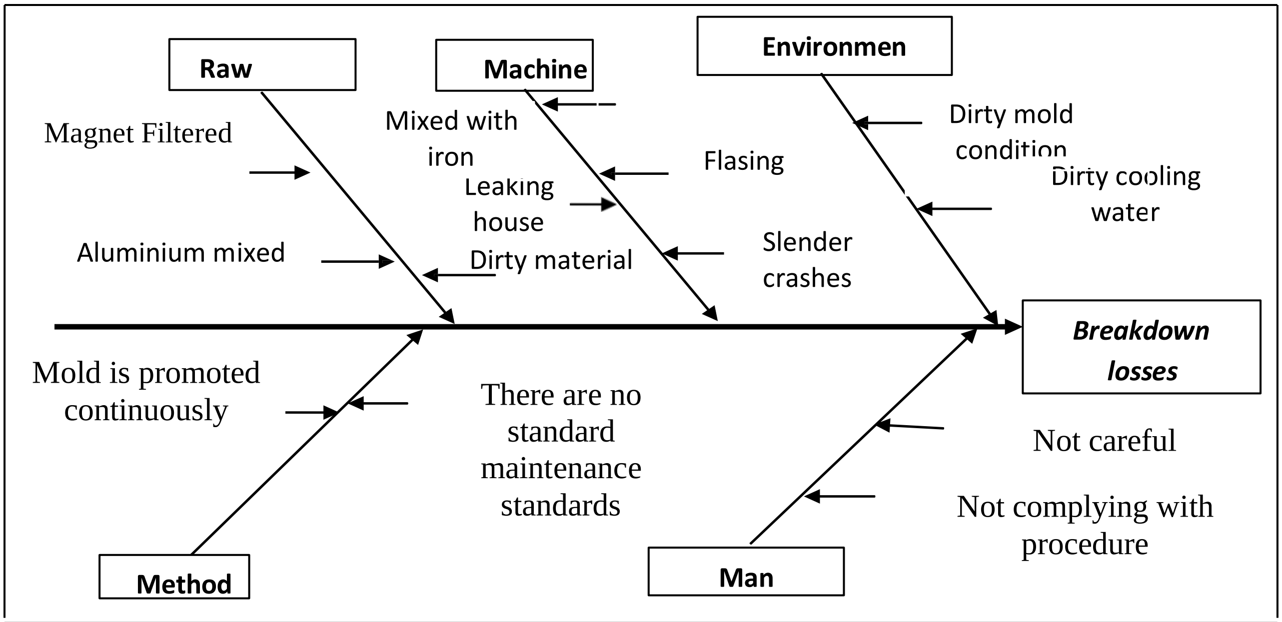

Figure 2. Fishbone Diagram

Table 8. Improvement Using 5W + 1H Breakdown Losses

No.	Factor	Machine	Method	Material	Man	Environment
1	What	Improving equipment inspection before starting the production phase	1. Improving the machine maintenance criteria." 2. Enhancing machine performance to be more reliable."	"Strengthening supervision to maintain the quality of raw materials."	1. Improving accuracy while performing tasks." 2. Increasing the level of vigilance while carrying out work."	"Improving the cleanliness of equipment and production areas."
2	Why	"To prevent machines from malfunctioning during operation (such as ejector jams, flashing, or hose leaks)."	"To ensure that maintenance activities are carried out in accordance with established regulations."	"To prevent machine components from being damaged."	1. So that employees are more careful when working. 2. So that employees are more alert when working.	To ensure that the production machine remains clean and dirt does not affect its performance.
3	Where	Operator section	Maintenance section	Qc section and Operator	Operator section and Maintenance	Operator section and Maintenance
4	When	Before starting production.	During the time before and after the production process.	Before starting production	Before and after the production process.	Before and after the production process
5	Who	Operator department	Maintenance departement	Qc departement and Operator departement	Operator departement and Maintenance departement	Operator departement and Maintenance departement
6	How	Providing instructions on proper machine operation at the	Providing training and guidelines on maintenance	Providing guidance on raw materials that meet	Providing pre-work guidance and training to enhance	Providing guidance on the significance of maintaining

No.	Factor	Machine	Method	Material	Man	Environment
		beginning of the production process.	according to regulations	established criteria.	responsibility and discipline in work.	machine cleanliness.

Data Processing Source 2024

Comparison Before Preventive Scheduling and After Preventive Maintenance Scheduling

The following shows a comparison before and after the scheduling of preventive maintenance performed on injection molding machines in table 4.23 as follows:

Table 9. Comparison Before and After Preventive Maintenance

Before *Preventive Maintenance*			After *Preventive Maintenance*		
Business Hours	*Machine* Downtime	Percentage	Business Hours	*Machine* Downtime	Percentage
209220	21540	10%	209220	1464	0,7%

Source: Data Processing 2024

Prior to the implementation of Preventive Maintenance, the company had a total of 209,220 hours of machine work. Of these, engine downtime was recorded at 21,540 hours, which means the downtime percentage was 10%. After the implementation of Preventive Maintenance, the total working hours of the machine remained at 209,220 hours. However, engine downtime was significantly reduced to just 1,464 hours, which was in line with the company's target of 0.7%. This shows that Preventive Maintenance is effective in reducing engine downtime, from 10% to only 0.7%, thereby improving the company's overall operational performance and efficiency.

CONCLUSION

Based on research and analysis carried out on the Injection Molding machine at PT. Mah Sing Indonesia, can be summarized as follows: The results of the calculation of the Overall Equipment Effectiveness (OEE) value for the period January to December 2023 show that the OEE value varies every month. Not a single month comes close to the World Class OEE standard of 85%. The highest OEE value was achieved in August with 54%, while the lowest value was achieved in December with 35%. The average Overall Equipment Effectiveness (OEE) value from January to December is around 44.67%. This result shows that the average OEE value per month is still far below the set standard, which is less than 85%. The main cause of the very low engine effectiveness, well below the Word Class standard of 85%, is the low Availability rate, which leads to high machine downtime. After running preventive maintenance scheduling, there was a very significant change in engine downtime. Initially, the engine downtime reached 21,540 minutes (10%), but after corrective actions, it dropped to just 1,464 minutes (0.7%).

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