GIJES
Greenation International Journal of Engineering Science
+62 81210467572 https://research.e-greenation.org/GIJES greenation.info@gmail.com
GREENATION RESEARCH
DOI: https://doi.org/10.38035/gijes.v4i3
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Analysis of Molding Machine Efficiency Using the Overall Equipment Effectiveness (OEE) Method and Six Big Losses to Reduce Product Defects at PT. XYZ

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Abstract: This study aims to evaluate the performance efficiency of molding machines using the Overall Equipment Effectiveness (OEE) method and to identify the main causes of production losses through the Six Big Losses approach and a Fishbone Diagram. The data used consist of machine operational records from January to June 2025. The findings show that the average OEE score is 63.08%, below the company's standard of 75%. The Six Big Losses analysis indicates that the largest losses are attributed to equipment failures, accounting for 63.45%, followed by reduced speed at 12.70% and idling and minor stoppages at 10.79%. In addition, the Fishbone analysis indicates that the main causes of low OEE are related to machine and personnel factors, including hydraulic system malfunctions, machine overheating, and extended setup times resulting from limitations in operator skills. The proposed improvements focus on implementing preventive maintenance, improving operator skills, and standardizing work procedures. Estimates suggest that these improvements could potentially increase the OEE value to 68.6%. The findings are expected to serve as a basis for improving machine effectiveness and production process efficiency.

Keywords: Fishbone Diagram, molding machine, machine efficiency, OEE, Six Big Losses

INTRODUCTION

One of the primary indicators of manufacturing process success is the efficiency of production equipment (Yazdi et al., 2018). Highly effective machinery can consistently follow production schedules, operate at its intended capacity, and produce goods that meet quality standards. Since gasket assembly products require a high degree of precision and durability, machine performance is critical in the rubber-based manufacturing industry (Adak et al., 2025). The Total Productive Maintenance (TPM) paradigm, which emphasizes preventive maintenance and continuous improvement of equipment effectiveness, is widely adopted by manufacturing companies to maintain and improve machine performance (Hardt et al., 2021).

Nevertheless, several operational challenges remain in its implementation, including excessive machine downtime, inconsistent production speeds, and defective products. These issues not only reduce productivity but also increase production costs and lower product quality (Rahul, 2013). One of the most widely used methods for evaluating machine performance is Overall Equipment Effectiveness (OEE). This method integrates three key indicators: Availability, Performance Efficiency, and Quality Rate. The resulting OEE value provides a comprehensive assessment of the actual condition of production equipment and the extent to which it is effectively utilized in the manufacturing process (Ng et al., 2020).

Furthermore, OEE analysis helps identify the primary sources of production losses, commonly known as the Six Big Losses, which represent the major forms of inefficiency in manufacturing systems. This study focuses on the molding machine used in the rubber gasket assembly production process at PT. XYZ.

The molding machine plays a crucial role in shaping products and ensuring the quality of the final output. Preliminary observations revealed several operational problems, including frequent machine downtime, inconsistent production speeds, and a defect rate exceeding the company's acceptable quality standard. These findings indicate that the machine is not operating at its optimal performance level and requires a more comprehensive evaluation.

Moreover, the absence of a structured performance evaluation and a systematic approach to identifying production losses limits the company's ability to establish effective improvement priorities. Without a clear understanding of the major sources of inefficiency, improvement initiatives may become less focused and ineffective. Therefore, integrating OEE analysis with the Six Big Losses framework and a root-cause analysis tool such as the Fishbone (Ishikawa) Diagram is essential to obtain a comprehensive understanding of the factors affecting machine performance.

Accordingly, this study aims to evaluate the effectiveness of the molding machine using the OEE method, identify the primary causes of production losses through the Six Big Losses framework, and determine their root causes using the Fishbone Diagram. Furthermore, this study proposes improvement strategies aimed at reducing product defects and enhancing overall machine performance. The findings are expected to provide practical insights for improving production efficiency and serve as a valuable reference for future research on manufacturing performance optimization.

Literature Review

Research Object

This study focuses on the molding machine used in the production of button gasket assemblies at PT. XYZ, a company operating in the rubber component manufacturing industry. The molding machine serves as the primary equipment for forming thermoplastic materials into finished products based on predetermined mold designs.

During the observation period from January to June 2025, the molding machine experienced a significant increase in downtime, while the reject rate of gasket assembly products exceeded the company's acceptable quality threshold.

Research Variables

The variables examined in this study are divided into two categories:

1) Independent Variable. An independent variable is an element that influences or causes changes in another variable (Petter et al., 2013). In this study, the independent variable is molding machine efficiency, evaluated through availability, performance efficiency, and quality rate as components of the OEE approach.

2) Dependent Variable. A dependent variable is a variable that changes or is influenced by another variable (Novera & Thomas, 2020). In this study, the dependent variable is the OEE value.

Research Stages

The investigation stages in this study are illustrated in the following research flowchart.
Figure 1. Research stages flowchart

Data Analysis Techniques

1) Availability (α). This measures the amount of time the machine actually operates compared with the total planned production time (Priyanto & Suhada, 2020).

$$\alpha = [(Ld - Dt) / Ld] \times 100\% \quad (1)$$

α = Availability; Ld = Loading Time; Dt = Downtime.

2) Performance Efficiency (β). This compares the actual machine speed with the ideal speed determined by normal output (Ummah & Dahda, 2022).

$$\beta = (Ct \times To / Ot) \times 100\% \quad (2)$$

β = Performance Efficiency; Ct = Cycle Time; To = Total Output; Ot = Operating Time.

3) Quality Rate (Q). This determines the proportion of products that are defect-free and acceptable.

$$Q = (Gp / To) \times 100\% \quad (3)$$

Q = Quality Rate; Gp = Good Product; To = Total Output.

4) OEE Calculation. The overall level of machine performance effectiveness in the production process is determined using the OEE calculation (Tammya & Herwanto, 2021).

$$OEE = \alpha \times \beta \times Q \quad (4)$$

α = Availability; β = Performance Efficiency; Q = Quality Rate.

Six Big Losses Analysis

The Six Big Losses approach is used in Total Productive Maintenance (TPM) to categorize and identify the six main causes of low machine effectiveness. These losses comprise equipment failure losses, setup and adjustment losses, idling and minor stoppage losses, reduced-speed losses, process defect losses, and reduced-yield losses. The purpose of this analysis is to identify the main causes of low Overall Equipment Effectiveness (OEE), so that appropriate improvement measures can be formulated (Iskandar & Padmakusumah, 2025).

Downtime Losses

This refers to periods that should be used for production but during which the equipment cannot perform production tasks effectively because of machine breakdowns or other problems (Silitonga et al., 2025).

1) Breakdown Losses. Losses caused by unexpected machine failures that prevent the machine from operating.

$$\text{Breakdown Losses} = (\text{Unplanned Downtime} / \text{Loading Time}) \times 100\% \quad (5)$$

2) Setup and Adjustment Losses. Time spent preparing the machine, such as changing molds, resetting the machine, and making initial production adjustments, results in setup and adjustment losses.

$$\text{Setup Losses} = (\text{Setup Time} / \text{Loading Time}) \times 100\% \quad (6)$$

Speed Losses

These occur when a machine operates at a speed below the ideal speed specified by its design. Two factors contribute to speed losses (Nur & Haris, 2019).

1) Idling and Minor Stoppage Losses. Losses occur when the machine is waiting or idle, including time associated with cleaning and rearranging.

$$\text{Idling and Minor Stoppage Losses} = (\text{Non-productive Time} / \text{Loading Time}) \times 100\% \quad (7)$$

2) Reduced Speed Losses. Losses occur when the actual operating speed is lower than the ideal operating speed.

Reduced Speed Losses = [Operating Time − (Ideal Cycle Time × Total Product)] / Loading Time × 100% (8)

Defect Losses

Defect losses refer to situations in which a machine fails to produce goods that meet established quality standards. There are two components associated with defect losses (Supriyati & Wiyatno, 2025).

1) Defects in Process. These are defects that arise during the manufacturing process.

Rework Losses = (Ideal Cycle Time × Rework) / Loading Time × 100% (9)

2) Reduced Yield Losses. Reduced-yield losses occur during the initial production phase, when the output has not yet met quality standards.

Scrap Losses = (Ideal Cycle Time × Scrap) / Loading Time × 100% (10)

Fishbone Diagram

A Fishbone Diagram is generally a graphical representation of data describing the causes of failures or nonconformities. The analysis extends to the most fundamental sub-factors contributing to a problem. Fishbone Diagram analysis is based largely on data collected subjectively through observation and analysis. Such data may originate from objective or subjective elements and may be quantitative or qualitative (Arfelli & Hapsari, 2023).

METHODS

Data Collection

Table 1. Working-day data

Day	Working hours	Shifts	Non-productive time
Monday	24 hours/day	3 shifts	Lunch break: 60 minutes
Tuesday	24 hours/day	3 shifts	Cleaning: 20 minutes
Wednesday	24 hours/day	3 shifts	Changing and heating the mold and its molding tool: 110 minutes
Thursday	24 hours/day	3 shifts	—
Friday	24 hours/day	3 shifts	—
Saturday	10 hours/day	2 shifts	—

This section presents working-day data as the basis for analyzing machine effectiveness. Non-productive time is classified as planned downtime and is taken into account when deducting the available time in the Availability calculation under the Overall Equipment Effectiveness (OEE) method.

Working Hours = Shifts × Operating Hours
Working Hours = (20 days/month × 24 hours/day)
Working Hours = 520 hours/month

Defective Product Data

Table 2. Defective product data

No.	Month	Production target	Actual production	Actual defects	Total production	Reject percentage
1	January	115,880	95,1650	15,8150	110,980	14.25%
2	February	115,910	95,170	15,840	111,010	14.26%
3	March	115,7850	95,160	15,7250	110,8850	14.18%
4	April	110,8650	90,3640	15,6010	105,9650	14.72%
5	May	110,780	90.37	15,510	105,880	14.64%
6	June	110,800	90,375	15,525	105,900	14.66%
	Total	680,080	556,604	94,016	650,620	14.45%

The number of defective products in gasket assembly production between January and June 2025 was 94,016 units, or 14.45% of total production. This high number of defective products resulted in considerable losses.

Downtime Data

Table 3. Downtime and planned downtime

Month	Planned downtime (hours)	Unplanned downtime (hours)
January	76	26
February	76	28
March	76	29
April	76	26
May	73	28
June	73	27
Total	450	164

The performance analysis is based on planned and unplanned machine downtime data. Planned downtime refers to periods scheduled by the company during which equipment is not operated, for example, for maintenance, setup, or production breaks. Meanwhile, unplanned downtime is determined through direct field observations and includes periods when the machine breaks down or stops functioning because of unexpected problems.

Available Time = Shifts × Working Hours

Loading Time = Machine Operating Time − Downtime per Month

Operating Time = Loading Time − Unplanned Downtime

Table 4. Available time, loading time, and operating time

Month	Available time (hours)	Loading time (hours)	Operating time (hours)
January	520	444	418
February	520	444	416
March	520	444	415
April	520	444	418
May	506	433	405
June	510	437	410
Total	3,096	2,646	2,482

This report describes the available time, loading duration, and operating hours of the molding machine from January to June 2025. Available time remained relatively stable at approximately 520 hours per month, while loading time was consistently 444 hours during the first four months, with a slight decrease in May and June due to changes in the downtime schedule. Operating time ranged from 405 to 418 hours, reflecting machine stoppages during production. In brief, the difference between loading time (2,646 hours) and operating time (2,482 hours) indicates recurring downtime that affects machine efficiency and the Availability metric in the OEE calculation.

RESULTS AND DISCUSSION

Availability Calculation Results

$$\alpha = (418 \text{ hours} / 444 \text{ hours}) \times 100\% \quad (1)$$

$$\alpha = 94.14\%$$

Table 5. Machine availability rate

Month	Operating time (hours)	Loading time (hours)	Availability rate
January	418	444	94.14%
February	416	444	93.69%
March	415	444	93.46%
April	418	444	94.14%
May	405	433	93.53%
June	410	437	93.82%
Average			93.79%

Performance Efficiency Calculation Results

$$\beta = (0.0030 \times 110{,}980 \text{ pcs} / 418 \text{ hours}) \times 100\% \quad (2)$$

$$\beta = 79.65\%$$

Table 6. Machine performance rate

Month	Cycle time (hours)	Total product	Operating time (hours)	Performance rate
January	0.0030	110,980	418	79.65%
February	0.0030	111,010	416	80.05%
March	0.0030	110,885	415	80.15%
April	0.0030	105,965	418	76.05%
May	0.0030	105,880	405	78.42%
June	0.0030	105,900	410	77.48%
Average				78.63%

Quality Rate Calculation Results

$$Q = [(110{,}980 \text{ pcs} - 15{,}815 \text{ pcs}) / 110{,}980 \text{ pcs}] \times 100\% \quad (3)$$

$$Q = 85.74\%$$

Table 7. Quality rate

Month	Total product	Rejected product	Quality rate
January	110,980	15,815	85.74%
February	111,010	15,840	85.73%
March	110,885	15,725	85.81%
April	105,965	15,601	85.27%
May	105,880	15,510	85.35%
June	105,900	15,525	85.33%
Average			85.53%

OEE Calculation Results

$$OEE = 94.41\% \times 78.69\% \times 76.61\% \quad (4)$$

$$OEE = 56.91\%$$

Table 8. OEE values

Month	α	β	Q	OEE
January	94.14%	79.65%	85.74%	64.29%
February	93.69%	80.05%	85.73%	64.29%
March	93.46%	80.15%	85.81%	64.27%
April	94.14%	76.05%	85.27%	61.04%
May	93.53%	78.42%	85.35%	62.60%
June	93.82%	77.48%	85.33%	62.02%
Average	93.79%	78.63%	85.53%	63.08%

Based on the evaluation of the machine from January to June 2025, the recorded average availability was 93.79%, performance reached 78.63%, and quality reached 85.53%. In addition, the average Overall Equipment Effectiveness (OEE) achieved was 63.08%. This figure was then compared with the company's OEE standard of 75%. The comparison between the actual OEE value and the company standard shows that machine performance remains below the desired target. This comparison is illustrated in the following graph. Figure 2. OEE value graph

Six Big Losses Calculation Results

Breakdown Losses

$$\text{Breakdown Losses} = (26 / 444) \times 100\% \quad (5)$$

$$\text{Breakdown Losses} = 5.8\%$$

Table 9. Breakdown losses

Month	Unplanned downtime	Loading time	Equipment failure losses
January	26	444	5.8%
February	28	444	6.3%
March	29	444	6.5%
April	26	444	5.8%
May	28	433	6.4%
June	27	437	6.1%
Average			6.15%

Setup and Adjustment Losses

$$\text{Setup Losses} = (44 / 444) \times 100\% \quad (6)$$

$$\text{Setup Losses} = 10\%$$

Table 10. Setup and adjustment losses

Month	Loading time	Setup and adjustment	Setup losses
January	444	44	10%
February	444	44	10%
March	444	44	10%
April	444	44	10%
May	433	43	10%
June	437	43	10%
Average			10%

Idling and Minor Stoppage Losses

$$\text{Idling and Minor Stoppage Losses} = (76 / 444) \times 100\% \quad (7)$$

$$\text{Idling and Minor Stoppage Losses} = 17\%$$

Table 11. Idling and minor stoppage losses

Month	Loading time	Planned downtime	Minor stoppages
January	444	76	17%
February	444	76	17%
March	444	76	17%
April	444	76	17%
May	433	73	16.85%
June	437	73	16.85%
Average			16.95%

Reduced Speed Losses

$$\text{Reduced Speed Losses} = [418 - (0.0030 \times 110{,}980)] / 444 \times 100\% \quad (8)$$

$$\text{Reduced Speed Losses} = 19.15\%$$

Table 12. Reduced speed losses

Month	Loading time	Operating time	Actual production	Cycle time	Reduced speed losses
January	444	418	110,980	0.0030	19.15%
February	444	416	111,010	0.0030	18.62%
March	444	415	110,885	0.0030	18.54%
April	444	418	105,965	0.0030	22.54%
May	433	405	105,880	0.0030	20.17%
June	437	410	105,900	0.0030	21.12%
Average					20%

Defects in Process

$$\textbf{Rework Losses} = (0.0030 \times 15{,}815) / 444 \times 100\% \quad (9)$$

$$\textbf{Rework Losses} = 10.68\%$$

Table 13. Defects in process

Month	Loading time	Cycle time	Actual rejects	Defect losses
January	444	0.0030	15,815	10.68%
February	444	0.0030	15,840	10.70%
March	444	0.0030	15,725	10.62%
April	444	0.0030	15,601	10.54%
May	433	0.0030	15,510	10.49%
June	437	0.0030	15,525	10.65%
Average				10.61%

Accumulated Six Big Losses Calculation

Based on the calculations, the most significant losses are caused by reduced speed, followed by idling and minor stoppages, process defects, equipment failures, and, finally, setup and adjustment losses. Therefore, the main source of losses in the production process is clearly the inefficient speed of the equipment. Consequently, the company should prioritize improving equipment efficiency so that it can operate at its maximum potential.

Table 14. Six Big Losses values

Losses	Total loss time	Percentage	Cumulative percentage
Equipment failure losses	2,646	63.45%	63.45%
Reduced speed losses	530	12.70%	76.15%
Idling and minor stoppages	450	10.79%	86.94%
Defect losses	282	6.76%	93.70%
Setup losses	262	6.28%	100%
Rework losses	0	0.00%	100%

Pareto Diagram Analysis

The Pareto Diagram of the Six Big Losses emphasizes that the distribution of production losses on the molding machine is highly concentrated and uneven. Equipment failure is the dominant contributor, accounting for 63.45% (2,646), indicating that most production downtime is caused by machine breakdowns. This dominance points to a serious machine reliability problem, making Availability the OEE component most affected.

Furthermore, reduced speed (12.70%) and idling and minor stoppages (10.79%) also contribute significantly to total losses. Cumulatively, these three factors account for 76.15%, reinforcing the Pareto principle that most losses originate from a small number of major causes. This situation indicates that, in addition to machine reliability issues, there are operational inefficiencies associated with reduced production speed and frequent short machine stoppages. These directly affect the Performance component of the OEE calculation.

Meanwhile, quality-related losses, such as defects (6.76%) and setup losses (6.28%), make relatively smaller contributions. Nevertheless, both factors still affect the Quality and Availability components, particularly if they are not managed continuously. The low contribution of rework losses (0%) indicates that the main problem does not lie in product reprocessing, but rather in machine operational disruptions.

From a production-system perspective, these results indicate that the main bottlenecks lie in the machine's technical condition and operational stability, rather than solely in output

quality. Therefore, improvement efforts should be focused and prioritize reducing equipment failures through enhanced machine reliability, followed by optimization of operating speed and reduction of minor stoppages.

The implications of these findings suggest that an effective OEE improvement strategy cannot be applied uniformly to all types of losses. Instead, the strategy must be based on priorities determined by each factor's contribution. By focusing improvements on the three main losses, the potential increase in OEE will be more significant than with a general, unfocused approach. This also underscores that integrating Pareto analysis and OEE is an effective method for determining improvement priorities in production systems.

Cause-and-Effect Diagram Analysis

The average Overall Equipment Effectiveness (OEE) score for the molding machine remains at 63.08%, below the company standard of 70%. The Pareto Diagram reveals that the largest loss is caused by equipment failure (63.45%), followed by reduced speed (12.70%) and idling and minor stoppages (10.79%). Further investigation using a Fishbone Diagram is therefore required to determine the underlying causes.

As illustrated in Figure 4, six main factors contribute to poor machine performance: man, machine, method, material, measurement, and environment. On the human side, limited operator skills and setup times of up to two hours per day contribute to increased non-productive time. The main machine-related problems are the high rate of equipment failure caused by hydraulic system leaks and machine overheating.

In terms of methods, inadequate tool-cleaning procedures and improper tool storage lead to residue accumulation, tool corrosion, and increased defects. Regarding materials, material contamination contributes to inconsistencies in product quality. In terms of measurement, the process becomes unstable because there are no machine-monitoring parameters. From the environmental perspective, uncontrolled temperature, humidity, and workplace cleanliness all affect machine performance.

Overall, the main causes of high losses and low OEE values are machine-related and human factors. Consequently, improvements should focus on enhancing machine reliability and operator competence. Figure 4. Fishbone (cause-and-effect) diagram

Proposed Improvements

Table 15. Proposed improvements based on Fishbone analysis

No.	Problem	Cause	Improvement action	Expected impact
1	High equipment failure rate	Engine and hydraulic system leaks and overheating	Implement preventive maintenance, conduct regular inspections of hydraulic systems, and optimize cooling systems	Improve availability and reduce downtime
2	Long setup time	Inexperienced operators and lack of standardized setup procedures	Train operators and standardize setup procedures	Reduce setup time and increase productive time
3	Dirty tools	Cleaning procedures are inadequate	Implement standard operating procedures (SOPs) for tool cleaning	Reduce defects caused by contamination
4	Corroded tools	Improper tool storage	Upgrade the tool-storage system in accordance with industry standards	Improve product quality and prevent corrosion

5	High product defect rate	Contaminated materials	Separate storage areas and improve material management	Increase the quality rate and reduce defects
6	Inconsistent machine performance	No machine-monitoring parameters are available	Use a daily checklist accompanied by temperature and pressure monitoring	Maintain process stability and improve performance
7	Workplace conditions are not conducive to productivity	Unregulated temperature, humidity, and hygiene	Improve cleanliness in the production area and control the working environment	Improve product consistency and machine performance

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The main issue addressed in this study is the suboptimal performance of the molding machine, as evidenced by high downtime, unstable production speeds, and the presence of defective products. This issue was analyzed using the Overall Equipment Effectiveness (OEE) method, which produced a value of 63.08%, still below the company standard of 70%. This result indicates that machine effectiveness has not been maximized and requires targeted improvements.

To identify the main sources of losses, a Six Big Losses analysis was conducted and visualized using a Pareto Diagram. The findings show that equipment failure (63.45%) is the dominant cause, followed by reduced speed (12.70%) and idling and minor stoppages (10.79%), with a combined contribution of 76.15%. These findings emphasize that most of the decline in machine performance is caused by major factors related to operational disruptions and machine reliability.

Furthermore, the Fishbone analysis shows that machine and human factors are the root causes. Technical disruptions, such as hydraulic system leaks and overheating, trigger a high rate of equipment failure, while limitations in operator competence result in longer setup times and increased non-productive time. Additional supporting factors, including methods, materials, measurement, and the environment, further exacerbate inefficiencies in the production system.

In conclusion, the low OEE value results from a complex interaction between interrelated technical and human factors. Therefore, improvement strategies should prioritize increasing machine reliability and operator competence in order to significantly reduce losses.

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