ANALISIS OVERALL EQUIPMENT EFFECTIVENESS DALAM PENERAPAN TOTAL PRODUCTIVE MAINTENANCE PADA MESIN FLOW MIXER DI PT ASI

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Abstract

Improving machine productivity and effectiveness is a crucial factor in maintaining the competitiveness of manufacturing companies. One approach to improving equipment performance is Total Productive Maintenance (TPM), with Overall Equipment Effectiveness (OEE) as the primary indicator. This study aims to analyze the effectiveness of the Flow Mixer machine at PT ASI's Mold Shop Department based on its OEE value, which comprises availability, performance, and quality. It also identifies the dominant factors causing low machine effectiveness using the Six Big Losses approach. The research data were obtained from production data, planned and unplanned downtime, the number of defective products, and machine operating time during September–November 2025. The calculation results show that the Flow Mixer machine's OEE values were 66% (September), 68% (October), and 68% (November), respectively, which are still below the world-class OEE standard of 85%. The main factors influencing the low OEE are breakdowns and process defect loss. Improvement proposals are based on the eight pillars of TPM, which focus on improving machine maintenance, operator skills, and standardizing work procedures. Implementation of the proposed improvements in December resulted in an increase in the OEE value to 72%. The results of this study demonstrate that consistent TPM implementation can improve the effectiveness of the Flow Mixer machine and the productivity of the production process.

Keywords: Total Productive Maintenance, Overall Equipment Effectiveness, Six Big Losses, Flow Mixer, Machine Productivity

INTRODUCTION

In the modern industrial world in any field, increasing productivity and effectiveness are key factors in maintaining a company's competitiveness. When every machine or equipment is in a ready-to-use condition, its capabilities must be maintained and improved by implementing a planned, regular, and controlled maintenance program. In addition, human resource capabilities need to be adjusted to achieve the desired goals. Ineffective machine use results in low machine productivity, which is certainly a loss for the company. Machine effectiveness is the ability of a machine or equipment to produce products according to the target time, the number of products produced, and the desired quality (Siswanto et al., 2023).

Machines that are used repeatedly must be accompanied by good and appropriate machine maintenance activities, with the aim of avoiding a decrease in machine function during operation and also to avoid total machine damage (breakdown). In order for the machine to always be in prime condition, maintenance is needed as an optimization of the components and machine systems, such as by implementing Total Productive Maintenance (TPM) (Anthony, 2019).

TPM focuses on maximizing the performance of all equipment with all involvement from operators to managers, and the main goal of implementing TPM is to minimize the occurrence of defects and breakdowns to zero defects and zero breakdowns (Dewi, 2022). TPM is not only focused on how to optimize the productivity of equipment or supporting materials, but also pays attention to how to increase the productivity of workers or operators who will later take control of the equipment and materials. In essence, Total Productive Maintenance (TPM) is a periodic maintenance management approach that aims to achieve the maximum effectiveness limit of equipment/machines through the comprehensive involvement of all employees who have become a work culture that emphasizes minimizing damage, increasing machine reliability, and the active participation of all parties in maintaining and increasing productivity (Purwanto et al., 2024)(Samadhiya & Agrawal, 2024).

Total Productive Maintenance (TPM) needs to be implemented continuously to maintain the effectiveness and reliability of the machine. PT ASI is a company that produces various bathroom equipment such as faucets, showers, bathtubs, toilets, and other accessories. In the Mold Shop Department, one of the machines used is a Flow Mixer that functions to mix plaster material and water to produce a slurry liquid as a raw material for molding. This machine is capable of producing around 40 molds per day and plays a vital role in the smooth production process. However, in its operation, the machine often experiences problems such as downtime, substandard production speeds, and defective products. These conditions can reduce machine effectiveness and company productivity, so it is necessary to measure machine performance through the implementation of TPM in the production system (Suliantoro et al., 2017).

The achievement of Overall Equipment Effectiveness (OEE) in the implementation of Total Productive Maintenance (TPM) is characterized by two main aspects, namely quantitative and qualitative. The quantitative aspect is related to increasing operational time and machine productivity, while the qualitative aspect focuses on reducing defective products and improving product quality (Prasmoro & Ruslan, 2020). The OEE value describes the level of machine effectiveness based on production output and defect rates. Low machine effectiveness is generally influenced by six loss factors known as the Six Big Losses, namely breakdown, setting and adjustment, small stop, reduced speed, startup reject, and production reject (Nursanti & Susanto, 2014)(Prabowo et al., 2020).

Previous studies have widely applied OEE as a tool to measure machine effectiveness and identify productivity losses, However, most of these studies are limited to general manufacturing equipment and do not specifically analyze the effectiveness of Flow Meter machines or similar systems with complex material flow charateristics. In addition, some studies focus only on OEE measurement without in depth analysis of root causes using supporting tools such as Six Big Losses classification.

In pratice, damage to the Flow Mixer machine, such as jammed moyno pump that disrupts fluid flow or a malfunction plaster mixer impeller, can significantly hinder the production process. These conditions lead to decreased production output and reduced OEE value (Aziz & Feriadi, 2026). Therefore, there is a need for a more comprehensive analysis that only measures machine effectiveness using OEE but also identifies the root cause of inefficiencies through the Six Big Losses approach.

This study aims to fill this gap by evaluating the implementation of TPM on the Flow Mixer machine through OEE measurement based on availability, performance, and quality as well identifying the dominant factors causing low effectivess. The results are expected to provide a more specific and applicable basis for determining corrective actions ot improve machine performance and production productivity (Wahid, 2020)(Triwardani et al., 2013).

Although TPM has been widely used to improve machine effectiveness, a comprehensive evaluation of the Flow Mixer machine's performance in the mold production process at PT ASI has not yet been conducted using the Overall Equipment Effectiveness (OEE) approach and Six Big Losses analysis (Puspita & Widjajati, 2021), (Rizkia et al., 2015), (Muhammad Nanda Ali Waket & Moh. Jufriyanto, 2025).

The propose of this study is to analyze the implementation of Total Productive Maintenance (TPM) on the Flow Meter machine at PT. ASI, Mold Shop Department, through the measurement of Overall Equiment Effectiveness (OEE), which includes availability, performance, and quality aspect. Furthermore this study aims to identify the factors contributing to low machine effectiveness based on the Six Big Losses analysis, determine the dominant causes, and propose improvement recommendations to enhance machine effectiveness and production productivity.

METHOD

The data used in this study includes production volume, production time, machine breakdown time, repair data, and product quality. The data was collected for three months in 2025: September, October, and November..

Location and Time of Research

This research was conducted at PT. ASI, during September, October, and November, in the Mold Shop Department area. The Mold Shop Department produces Cast Molds that will be used by the Cast Shop Department for the production process. In its production process, the Mold Shop Department uses a Flow Mixer machine, this machine functions to mix water and plaster which will later be poured into the prepared mold. The research period was carried out with a focus on collecting machine operational data (Karmilawati et al., 2021).

Method of collecting data

Data collection in this study was conducted through observation and documentation. Observations were conducted by recording machine downtime, setup time, and production time. Meanwhile, documentation was conducted by collecting production reports, machine failure records, and product quality data (Tammya & Herwanto, 2021).

Data types and sources

The data used in this study consists of primary and secondary data obtained from the production activities of the Flow Mixer machine. The dependent variable in this study is the Overall Equipment Effectiveness (OEE), which reflect the level of machine effectiveness (Tobe et al., 2018). Meanwhile, the independent variable include machine operating time, downtime, production output compared to production targets, and defective product rates (rejects), which represent the component of availability, performance, and quality.

In addition, data related to the Six Big Losses factors are used to identify the main causes of reduced machine effectiveness. Theses variables are analyzed to determine their influence on the OEE value and to provide a basis for evaluating the implementation of Total Production Maintennace (TPM) (Asprilla, 2020).

Method flowchart.

This research method explains the stages and procedures used to analyze the effectiveness of the Flow Mixer machine at PT ASI. The research stages include data collection, data processing, and analysis using the Overall Equipment Effectiveness (OEE) method to identify factors causing low machine performance.

Research flowchart

The research was conducted using several stages of procedures that had previously been conceptualized and depicted in a flow diagram/flowchart.

Figure 1 explains the research process flow as follows: 1) Problem Identification: Identifying problems that affect the overall effectiveness value (OEE) that occurs in the machine and any obstacles that occur in the production process. 2) Data Collection: Data collection uses qualitative methods by conducting interviews, observations, and documentation. 3) OEE Calculation.

a) Perhitungan OEE dilakukan berdasarkan:
   - Input = Operate Time, loading time, plan downtime, obstacles, product capacity, product repair, good product, work hour efficiency, ideal cycle time, standard cycle time.
   - Output = Availability, Performance, Quality, OEE. An OEE of 85% can be considered world-class, and this figure is the benchmark for the OEE standard. If the OEE calculation results are below standard, the problem needs to be identified again.

b) The calculation of Six Big Losses is done based on
   - Input=Equipment Failure (Breakdown Loss), Setup and adjustment loss, Idling and minor stoppages, Reduced speed loss, Process defect loss, Reduced Yield.
   - Output = The highest number in each factor that influences the size of the OEE value and recommendations for improvement

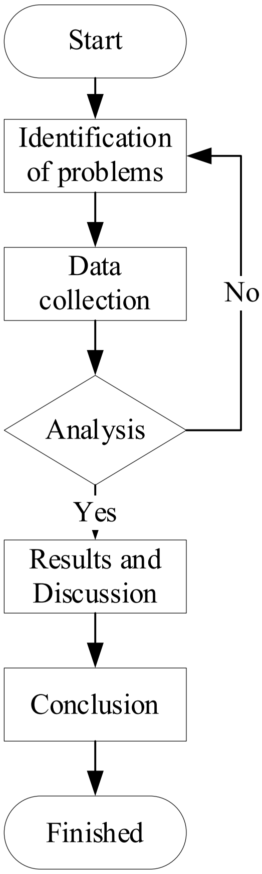

Figure 1. Research Flowchart

RESULTS

In the process, there are several problems that occur in the Flow Mixer machine, including: a) Downtime due to mechanical damage (worn bearings, damaged motors, or leaks in the seals). b) Impeller rotation instability which causes suboptimal mixing. c) Decreased energy efficiency due to excessive friction or worn components. d) Mixing quality does not meet standards, which results in a high number of defective products. e) Mono Pump jams which cause operators to have to wait to start production.

In addition, there are also several obstacles that disrupt the production process, thus impacting the low effectiveness value (OEE). a) Dead hoist: The hoist is used to lift production goods in the cast after they have hardened. b) Low air pressure: Air pressure is used to shoot production goods that are still in the cast to facilitate lifting and minimize cracks in the production goods.

Factors that influence OEE

From the observations, several factors influence the OEE value: a) Availability: Downtime on a flow mixer can affect productivity. For example, a lump of plaster that settled during the mixing process caused the machine to malfunction on October 8th, taking 178 minutes. b) Performance: With the same productivity time, production capacity is reduced. For example, many employees were sick on November 12th, resulting in only half the production target. c) Quality: This factor depends on production capacity and the quantity of good products. A large production capacity and a high-quality product mix will increase the quality value..

Factors that influence the value of availability, performance, quality

When measuring machine performance using the Overall Equipment Effectiveness (OEE) method, six major loss categories (Six Big Losses) are recognized that can reduce equipment effectiveness. These losses consist of breakdown loss and setup/adjustment loss, which impact availability. Furthermore, idling and minor stoppage loss, as well as reduced speed loss, affect the performance rate. Process defect loss and startup loss impact the quality rate. Identifying these six types of losses is crucial for understanding the source of machine performance decline in the production process.

Documentation

The data used in this study were obtained from various sources related to production and machine maintenance activities. This data includes machine damage and repair reports recorded daily, monthly, and annually. Furthermore, production productivity reports for the same period were used to analyze production process performance. This study also utilized standard documents and production operational procedures as references in understanding the workflow. Other supporting data included information on the availability of spare parts used in the machine repair process. Visual documentation in the form of photographs during the research process was also collected to support the analysis of machine conditions and the production process. Furthermore, this study also identified several cast mold models produced as objects of study in the production process.

Month to Date (September, October, November)

Working time data represents the total working hours for each month in minutes, presented in Table 1. Based on Table 1, in September was recorded at 23,930 minutes and increased to 27,480 minutes in October. This increase indicates an increase in production activity or additional operating hours during that period. However, in November, working time decreased to 23,360 minutes. This variation in working time between months indicates fluctuations in the intensity of the production process during the observation period. **Table *3*** represents the accumulation of working time data from each month in minutes.

Table 1. Total working time.

Month	Working Time (minutes)
September	23.930
October	27.480
November	23.360

A. Plan Down Time Shift 1 and shift 2

Planned Downtime is the total planned downtime in minutes for each month. Based on Table **2**, *planned downtime in September was recorded at 4,680 minutes and increased to 4,860 minutes in October. This increase indicates additional maintenance activities or scheduled machine downtime. In November, planned downtime decreased to 4,500 minutes, indicating a reduction in planned machine downtime. Variations in downtime can affect the level of machine availability in the production process.*

Table *4* shows the accumulated planned downtime for each month in minutes.

Table 2.Total planned downtime.

Month	Plan Downtime (minutes)
September	4.680
October	4.860
November	4.500

B. Loading time shift 1 and shift 2

Loading time is the working time reduced by planned downtime. Table 3 shows the monthly loading time values expressed in minutes. **Table *5*** shows the machine loading time values for each month during the observation period in minutes. Loading time in September was recorded at 19,240 minutes and increased to 22,620 minutes in October. However, in November, it decreased to 18,860 minutes. This variation in loading time indicates changes in machine operating time, which can affect the productivity level of the production process.

Table 3. Total loading time.

Month	Loading Time (minutes)
September	19.240
October	22.620
November	18.860

C. Unplanned Downtime Shift 1 and shift 2

Based on data on machine operational disruptions during the observation period, several incidents were recorded that caused downtime in the production process. In September, a disruption occurred on September 29 in the form of a hoist failure that caused the machine to stop for 73 minutes. In October, two disruptions were recorded: on October 8, a flow mixer jam that caused downtime of 178 minutes, and on October 20, a water reservoir leak that resulted in a production stoppage for 89 minutes. Meanwhile, in November, a disruption occurred on November 4 in the form of a power outage that caused a production stoppage for 15 minutes.

Operate time

Table *4* presents machine operating time data for each month during the observation period in minutes. Operating time in September was recorded at 19,430 minutes and increased to 22,620 minutes in October. However, in November, it decreased to 18,860 minutes. This change in operating time indicates fluctuations in production activity that can affect the effectiveness of machine use. **Table *6*** shows the accumulated total operating time for each month in minutes

Table 4. Total operate time.

Month	Operate Time (minutes)
September	19.430
October	22.620
November	18.860

E. Production capacity

Table 5 shows the production volumes produced each month during the observation period. Production in September was recorded at 1,653 units and increased to 2,078 units in October. However, production decreased to 1,450 units in November. This fluctuation in production volume indicates variations in production activity influenced by machine operating hours and production process conditions

Table 5. Total production capacity.

Month	Production Capacity (pcs)
September	1.653
October	2.078
November	1.450

F. Repair product

Table 6 shows the number of products repaired during the observation period. In September, 282 products were repaired, increasing to 316 in October. However, in November, the number of repaired products decreased to 226. This change in the number of repaired products indicates variations in the quality of the production process, which can be influenced by machine operating conditions, process parameters, and production levels in each period.

Table 6. Total repair products.

Month	Product Repair (pcs)
September	282
October	316
November	226

G. Total delay shift i and shift II

Table *7* presents the total delays that occurred in the production process each month during the observation period. The total delay in September was recorded at 4,753 minutes and increased to 5,127 minutes in October. However, in November, it decreased to 4,515 minutes. This variation in total delay indicates changes in the level of operational disruption that can impact the effectiveness of the production process.

Table 7. Total delay time.

Month	Total Delay (minutes)
September	4.753
October	5.127
November	4.515

H. Working Hour efficiency (effective employee working time)

Table 8 shows the level of work-hour efficiency for each month during the observation period. Work-hour efficiency was recorded at 80% in September, then increased to 82% in October. However, in November, there was a slight decrease to 81%. Overall, work-hour efficiency values were in the range of 80–82%, indicating that the utilization of work time in the production process was relatively stable.

Table 8. Total working hour efficiency.

Month	Working hour efficiency
September	80%
October	82%
November	81%

I. Cycle time standard

Table 9 shows that the standard cycle time in September was 11.6 minutes/unit and decreased to 10.8 minutes/unit in October. However, in November, the cycle time increased to 13.0 minutes/unit, indicating potential inefficiencies or disruptions in the production process during that period. The time required to produce one unit of goods.

Table 9. Total standard cycle time.

Month	Standard cycle time (minutes/unit)
September	11,6
October	10,8
November	13,0

J. Ideal cycle time

The fastest time to produce one unit of goods. Based on Table 10, the ideal cycle time in September was 9.3 minutes/unit and decreased slightly to 9.0 minutes/unit in October. However, in November, it increased to 10.5 minutes/unit. This change indicates variations in production process conditions that affected the ideal cycle time during that period.

Table 10. Ideal total cycle time.

Month	Cycle time ideal (Minutes/Unit)
September	9,3
October	9,0
November	10,5

Table 10 demonstrates a comprehensive approach, focusing not only on technical improvements to the machine but also on aspects of human resources, work methods, materials, and the environment. Implementation of these proposed TPM-based improvements is expected to reduce process defect loss, improve product quality, and contribute directly to a sustainable increase in the Flow Mixer machine's Overall Equipment Effectiveness (OEE).

Availability calculation
The availability value, the following calculation needs to be done:

$$\text{Availability} = \frac{\text{Operating Time}}{\text{Loading Time}} \times 100\% \quad (1)$$

1. Availability September
$$\text{Availability} = \frac{19.240}{19.167} \times 100\% = 99\%$$
2. Availability October
$$\text{Availability} = \frac{22.620}{22.353} \times 100\% = 99\%$$
3. Availability November
$$\text{Availability} = \frac{18.860}{18.860} \times 100\% = 100\%$$

The Availability value in September is 100%. Using the same calculation method as above, the Flow Mixer machine availability value for September, October, and November is obtained as shown in Table 11.

Table 11. Availability of Flow Mixer Machines in September, October, November.

Month	Operating Time (minutes)	Loading Time (minutes)	Availability (%)
September	19.240	19.167	99%
October	22.620	22.352	99%
November	18.860	18.860	100%

Table 11 summarizes the data presented to determine the Availability value for the three predetermined months. Although the Flow Mixer machine's availability during the September–November period was very high (99%–100%), it was not yet able to produce an optimal Overall Equipment Effectiveness (OEE) value. This condition indicates that the main problem with machine effectiveness does not lie in the availability aspect, but rather is more influenced by the machine's performance (performance efficiency) and product quality (rate of quality). Therefore, the next analysis focuses on identifying the factors that influence the low performance and quality values, so that a more targeted improvement strategy can be formulated through the Total Productive Maintenance (TPM) approach

K. Performance calculation

This calculation is carried out to determine the machine performance value based on the machine output in actual time against operating time and taking into account the ideal cycle time.

$$Performance = \frac{\text{Production Capacity} \times \text{Ideal Cycle Time}}{\text{Operation Time}} \times 100\% \quad (2)$$

1. Performance September
$$\text{Performance} = \frac{1.653 \times 9{,}3}{19.167} \times 100\% = 80\%$$
2. Performance October
$$\text{Performance} = \frac{2.078 \times 9{,}0}{22.620} \times 100\% = 82\%$$
3. Performance November
$$\text{Performance} = \frac{1.450 \times 10{,}5}{18.860} \times 100\% = 81\%$$

The Performance value in September is 80%. Using the same calculation method as above, the Flow Mixer machine Performance value for September, October, and November is obtained as shown in
Table *12*.

Table 12. Results of performance calculations during September, October, November.

Month	Production capacity	Ideal Cycle Time	Operation Time	Performance
September	1.653	9,3	19.167	80%
October	2.078	9,0	22.620	82%
November	1.450	10.5	18.860	81%

Table *12* is the calculation result, the performance value obtained in September was 80%, October 82%, November 81%

Rate of Quality Calculation

This calculation refers to the difference between the number of defective products and the total number of products. The Flow Mixer machine's Product Quality Rate for September, October, and November is as follows:

$$Rate\ of\ Quality = \frac{Good\ produk}{Total\ output} \times 100\% \quad (3)$$

1. Rate of Quality September
   $Rate\ of\ Quality$ September $= \dfrac{1.368}{1.653} \times 100\% = 83\%$
2. Rate of Quality October
   $Rate\ of\ Quality$ October $= \dfrac{1.760}{2.078} \times 100\% = 85\%$
3. Rate of Quality November
   $Rate\ of\ Quality$ November $= \dfrac{1.224}{1.450} \times 100\% = 84\%$

Using the same calculation method as above, the Rate of Quality Product value for the Flow Mixer machine was obtained during September, October, November, Table 13:

Table 13. Results of rate of quality calculations during September, October, November.

Month	Input jenis plaster		Total Output	Good Produk	Quality %
	Plaster Noritake	Plaster Sanicast			
September	1.221	432	1.653	1.368	83%
October	2.036	672	2.078	1.760	85%
November	970	480	1.450	1.224	84%

Table 13. The rate of quality values during the September–November period ranged from 83%–85%. The lowest quality value occurred in September (83%), then increased in October (85%), and decreased slightly in November (84%). This fluctuation indicates that product quality is not yet stable from month to month. The increase in quality values in October indicates temporary improvements in the production process, both in terms of process parameter settings and operator skills. However, the decline again in November indicates that these improvements are not yet consistent or sustainable. There are still significant levels of defective products compared to total output, indicating that process defect loss remains the primary cause of low quality.

Calculation of overall equipment effectiveness (OEE)

The Flow Mixer machine's OEE value in September–November was in the range of 66%–68%. Despite very high availability (99%–100%), the OEE value was not optimal because it was still influenced by relatively lower performance (80%–82%) and rate of quality (83%–85%). This indicates that the main problem with machine effectiveness is not machine availability, but rather the unstable production process speed and the still quite high level of defective products. Therefore, increasing OEE needs to be focused on improving process performance and product quality, not just reducing machine downtime.

$$\text{OEE} = \text{Availability} \times \text{Performance} \times \text{Rate of Quality} \quad (4)$$

1. $\text{OEE September} = 99\% \times 80\% \times 83\% = 66\%$
2. $\text{OEE October} = 99\% \times 82\% \times 85\% = 68\%$
3. $\text{OEE November} = 100\% \times 81\% \times 84\% = 68\%$

Table 14. Results of OEE calculations for flow mixer machines in September, October, November.

Month	Availability (%)	Performance Efficiency (%)	Rate of Quality (%)	OEE (%)
September	99%	80%	83%	66%
October	99%	82%	85%	68%
November	100%	81%	84%	68%

Based on Table 14, the Flow Mixer machine's Overall Equipment Effectiveness (OEE) value during the September–November period showed a relatively small but not yet significant increase. The OEE value was recorded at 66% in September, then increased to 68% in October, and remained relatively stable at 68% in November. This value is still far below the world-class OEE standard of 85%, indicating that the Flow Mixer machine's effectiveness is not optimal and still requires continuous improvement efforts.

L. December Production

Production data includes input of plaster types, total output, and non-defective products. Table *15*. Based on Table 15, the Flow Mixer machine's production performance in December showed an increase in production quality compared to previous months. Total material input consisted of 1,442 units of Noritake plaster and 460 units of Sanicast plaster, with a total production output of 1,902 units. Of this total output, 1,708 units of good product were obtained, resulting in a rate of quality of 89%. This 89% quality value indicates a significant decrease in the number of defective products compared to the September–November period, which was previously in the range of 83%–85%. This increase in quality indicates that the proposed improvements implemented, particularly to the process defect loss factor, are beginning to have a positive impact on the stability of the slurry mixing process and the quality of the resulting molds.

Table 15. Production report in December.

Month	Plaster type input		Total Output	Good Produk	Quality %
	Plaster Noritake	Plaster Sanicast			
December	1442	460	1.902	1.708	89%

M. OEE (Overall Equipment Effectiveness) analysis results.

Based on **Table *16***, the Overall Equipment Effectiveness (OEE) value of the Flow Mixer machine in the September–November period shows a relatively stable trend but is still below the world-class OEE standard of 85%. The OEE values were 66% in September, 68% in October, and 68% in November, respectively. This indicates that the effectiveness of the Flow Mixer machine is still not optimal and requires continuous improvement efforts. From the results of **Table *16***, the analysis that has been carried out, the OEE value in December increased by 4%. This analysis will be maintained and further developed so that productivity and effectiveness values remain within the desired standards.

Table 16. Results of OEE analysis.

Month	Availability (%)	Performance Efficiency (%)	Rate of Quality (%)	OEE (%)
September	99%	80%	83%	66%
October	99%	82%	85%	68%
November	100%	81%	84%	68%
December	100%	82%	89%	72%

DISCUSSION

Problems identified in the Flow Mixer machine—such as downtime due to mechanical failure (worn bearings, damaged motors, leaking seals), unstable impeller rotation, jammed mono pumps, and inconsistent mixing quality—indicate that process disruptions do not only originate from the technical aspects of the machine, but also from supporting production factors (hoist failure and low air pressure). This condition has a dual impact: (1) reducing the machine's effective operating time (availability), and (2) reducing the stability of the slurry mixing process, which leads to an increase in defective products (quality).

Non-machinery problems such as hoist failures and low tire pressure also increase operator waiting time, which directly reduces production performance. These findings reinforce the point that improving machine effectiveness requires more than just focusing on maintenance, but requires a systemic approach encompassing supporting equipment, work methods, and operational discipline.

Data on working time, planned downtime, loading time, and unplanned downtime show that most downtime comes from planned downtime, while unplanned downtime is relatively small but has a significant impact on smooth production (for example, the Flow Mixer jam and water reservoir leak in October). Although unplanned downtime is not large in cumulative terms, these events are critical because they occur during core processes, thus triggering production queues and potential reductions in mixing quality due to the stop-start process.

The decrease in production capacity in November (1,450 units) compared to October (2,078 units) indicates that human resource factors and operational constraints also impacted output, despite relatively adequate operating hours. This is reflected in the increased standard cycle time in November (13.0 minutes/unit), indicating process slowdowns due to operational disruptions and/or work inefficiencies.

A very high availability value (99%–100%) indicates relatively good availability of the Flow Mixer machine. This means that the machine is frequently ready for use. However, high availability does not automatically result in high OEE. This indicates that the primary issue with effectiveness is not the frequency of machine availability, but rather the quality of the process during operation and the actual production rate. Therefore, the focus of improvement is no longer simply reducing downtime, but rather increasing process stability and output quality.

The performance value (80%–82%) indicates that the actual production speed is still below the machine's ideal potential. This is consistent with field findings such as impeller rotation instability, hoist obstruction, and limited labor at certain times. Despite relatively high operating times, output is not optimal due to minor stoppages, operator waiting time, and reduced speed loss. Therefore, performance improvements need to be focused on reducing frequent minor disruptions, standardizing operating parameters, and improving workflow in the Mold Shop area.

The quality score for the September–November period (83%–85%) indicates a relatively high level of defective products. This unstable quality is in line with findings of problems with the inhomogeneous slurry mixing process, loose cast mold conditions, and variations in process parameter settings. Defective products not only reduce quality but also increase the workload (rework/repair), thus indirectly impacting performance and resource efficiency. Therefore, process defect loss is a dominant factor that needs to be prioritized in the improvement program.

The OEE value, which is in the range of 66%–68%, indicates that the Flow Mixer machine's effectiveness is still below world-class standards (85%). The combination of high availability with relatively low performance and quality suggest that the primary issue lies in process effectiveness during machine operation rather than machine availability. This finding is consistent with previous studies, which indicate that performance and quality losses are often the dominant contributors to low OEE values in manufacturing systems.

The increase in the quality score to 89% in December indicates that proposed improvements, particularly those targeting process defect loss, have begun to show a significant impact. Improvements in critical component maintenance, process parameter standardization, and ehanced operator competency contributed to more stable slurry mixing and reduced defective products. Similar improvements have also been reported in previous studies. Where TPM implementation succesfully reduced defect rates and improved overall production quality.

The improvement in quality is further reflected in the increase of the OEE value to 72% in December. Athough this increase has not yet reached the world-class standard, the upward trend demonstrates that the TPM-based improvement approach is effective and feasible for continued implementatio. From a practical perspective, these results can be applied as a reference for maintenance management in optimizing machine performance, particulary by focusing on reducing process losses and improvng operational consistency.

For future reasearch it is recommended to integrate additional analytical methods, such as predictive maintenance or advanced statistical analysis, to further enhance machine effectiveness. Moreover, similar studies can be conducted on different types of machine or production systems to validate the generalizability of the findings and to achieve more comprehensive optimization of OEE performance.

CONCLUSION

Based on the result of this study, the OEE value of the Flow Mixer machine was found to be in the range of 66%-68%, which is below the world-class standard, indicating suboptimal machine performance. The main finding of this study shows that the low effectiveness is primarily caused by breakdown loss and process defect loss, with performance and quality factors being more dominant than availability. The analysis using Six Big Losses reveals that the root cause are related to machine condition, operator competence, maintenance methods, materials, and work environments. The implementation of TPM, particulary through autonomous maintenance, planned maintenance, and operator training, has proven to improve machine performance, as indicated by the increase in OEE to 72%. There result confirm that a consistent TPM approach is effective in improving machine effectiveness and can be applied as a strategy to enhance production productivity.

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