# EVALUATION OF PUMP MAINTENANCE PERFORMANCE USING OVERALL EQUIPMENT EFFECTIVENESS AND SIX BIG LOSSES

**Halima Tus'sadiah[1], Afif Fawa Idul Fata[2], Priyo Ari Wibowo[3]**
[1,2,3]Sekolah Tinggi Teknologi Wastukancana, Purwakarta, Indonesia
Email: sadiahth18@gmail.com

**Abstract**

Equipment reliability is an essential factor in maintaining production continuity and operational efficiency in manufacturing industries. Frequent failures of Pump 402 and Pump 502 at PT XYZ resulted in increased downtime and reduced production performance. This study aimed to evaluate maintenance effectiveness using the Overall Equipment Effectiveness (OEE) method and identify the dominant causes of equipment losses through the Six Big Losses approach. A quantitative descriptive method was employed using maintenance reports, downtime records, production data, operating hours, and machine maintenance data collected during the observation period. OEE was calculated based on three performance indicators, namely Availability, Performance, and Quality, while Six Big Losses analysis was used to determine the major sources of equipment inefficiency. The results indicated that the average OEE value was below the world-class standard of 85%, suggesting that maintenance performance still requires improvement. Reduced Speed Losses and Equipment Failure Losses were identified as the dominant contributors to productivity losses. The primary causes included bearing damage, mechanical seal leakage, shaft misalignment, and failures of internal pump components. Based on these findings, improvements are recommended through strengthening preventive maintenance programs, conducting periodic equipment inspections, improving spare-part management, and standardizing maintenance procedures. These recommendations are expected to reduce downtime, improve equipment reliability, and enhance overall production performance.

***Keywords:*** *Overall Equipment Effectiveness, Six Big Losses, Preventive Maintenance, Equipment Reliability, Manufacturing Industry.*

## A. INTRODUCTION

Maintenance plays an essential role in ensuring equipment reliability, production continuity, and operational efficiency in manufacturing industries. An effective maintenance system minimizes machine failures, reduces downtime, and supports companies in achieving production targets while maintaining product quality. Consequently, manufacturing companies increasingly implement systematic maintenance strategies to improve equipment performance and competitiveness (Fathurohman & Fathurohman, 2025; Wahyudi et al., 2023).

At PT XYZ, Pump 402 and Pump 502 are critical supporting equipment in the production process. The operational performance of these pumps directly affects production continuity because unexpected failures may interrupt production activities and reduce productivity. Based on maintenance records, several operational problems such as equipment failures, excessive downtime, and reduced operating speed were observed during the production period. These conditions indicate that maintenance activities have not yet achieved optimum equipment effectiveness and require further evaluation (Wibowo & Padilah, 2023; Tifani et al., 2022.).

Overall Equipment Effectiveness (OEE) is one of the most widely used performance indicators for evaluating equipment effectiveness. OEE integrates three key indicators, namely Availability, Performance, and Quality, to provide a comprehensive assessment of equipment performance. According to (Wahyudi et al., 2023), OEE enables companies to measure equipment effectiveness quantitatively and identify operational losses that reduce productivity. In addition, Six Big Losses analysis is commonly used together with OEE to identify the dominant factors causing equipment inefficiency (Sobandi & Kosasih, 2014).

Several previous studies have demonstrated the effectiveness of OEE in evaluating manufacturing equipment. Ahdiyat & Nugroho (2022) and Dita et al. (2025) reported that OEE analysis successfully identified major productivity losses and assisted companies in establishing maintenance priorities. Likewise, Ahdiyat & Nugroho (2022) reported that OEE analysis successfully identified major productivity losses and assisted companies in establishing maintenance priorities. Furthermore, Dipa et al. (2022) and Febriani et al. (2025) concluded that systematic maintenance based on OEE contributes to higher equipment reliability and improved production efficiency. demonstrated that the integration of Overall Equipment Effectiveness and Six Big Losses effectively identified the dominant sources of productivity losses and supported the development of more effective maintenance improvement strategies. In addition, Primula & Hamdy (2023) concluded that systematic maintenance evaluation contributes to improving equipment reliability and operational efficiency. Although OEE has been widely applied in manufacturing industries, previous studies have generally focused on production machines, packaging equipment, or machining processes. Limited research has specifically evaluated the maintenance effectiveness of industrial pumps using an integrated approach combining OEE, Six Big Losses, Fishbone Diagram, and 5W+1H. Therefore, further research is required to determine the dominant productivity losses affecting pump performance and to formulate practical maintenance improvement strategies (Primula & Hamdy, 2023)

This study evaluates the maintenance effectiveness of Pump 402 and Pump 502 at PT XYZ using the Overall Equipment Effectiveness (OEE) method. Subsequently, the Six Big Losses approach is employed to identify the dominant productivity losses, while the Fishbone Diagram is used to determine the root causes of equipment performance degradation. Finally, the 5W+1H method is applied to formulate systematic maintenance improvement recommendations. The findings are expected to support PT XYZ in improving maintenance performance, reducing production losses, and increasing equipment effectiveness.

## B. METHODS

This study employed a quantitative descriptive research design to evaluate the maintenance effectiveness of Pump 402 and Pump 502 at PT XYZ. The study integrated the Overall Equipment Effectiveness (OEE) method with Six Big Losses, Fishbone Diagram, and 5W+1H analyses to evaluate equipment performance, identify dominant productivity losses, determine the root causes of equipment failures, and formulate maintenance improvement recommendations. This integrated approach has been widely applied in maintenance evaluation because it provides a systematic framework for improving equipment reliability and production efficiency (Ihsan, 2026; Lukman et al., 2025)

The research was conducted at PT XYZ using secondary data obtained from the maintenance department during the observation period from July to December 2025. The collected data consisted of loading time, planned downtime, unplanned downtime, operating time, production output, ideal cycle time, maintenance history, equipment failure records, and production quality reports. These data were obtained from company operational documents and maintenance reports, which were subsequently verified to ensure data accuracy and consistency (Suyatmo, 2023; Wahid et al., 2022).

The research procedure consisted of five sequential stages. The first stage involved collecting operational and maintenance data related to Pump 402 and Pump 502. The second stage consisted of calculating the Availability, Performance, and Quality values to obtain the Overall Equipment Effectiveness (OEE). The third stage involved calculating the Six Big Losses to determine the dominant productivity losses affecting equipment performance. The fourth stage was the identification of the root causes of the dominant losses using the Fishbone Diagram, which classified the causes into Machine, Man, Method, Material, and Environment factors. Finally, maintenance improvement strategies were formulated using the 5W+1H method to support continuous improvement of the maintenance system (Kurniawan, 2013; Febriani et al., 2025).

The Overall Equipment Effectiveness (OEE) was calculated using three performance indicators: Availability, Performance, and Quality. Availability represents the proportion of actual operating time compared with the planned production time. Performance measures the operating speed of the equipment relative to its designed capacity, while Quality indicates the proportion of products that satisfy the required quality specifications. The multiplication of these three indicators produced the Overall Equipment Effectiveness value, which was then compared with the world-class benchmark to evaluate maintenance performance (Rofid et al., 2024; Wardhani, 2022).

To identify the dominant productivity losses, the Six Big Losses method was employed by calculating the percentage contribution of each loss category. Subsequently, the dominant loss category was analyzed using the Fishbone Diagram to identify its root causes. Based on these findings, maintenance improvement recommendations were developed through the 5W+1H approach to provide practical corrective actions for reducing productivity losses and improving equipment effectiveness. This analytical framework enables maintenance managers to prioritize improvement programs according to the most critical maintenance problems (Kurniawan, 2018; Sobandi & Kosasih, 2014).

The research findings were analyzed descriptively by comparing the calculated Overall Equipment Effectiveness values with the international performance standard of 85%. The results of the Six Big Losses, Fishbone Diagram, and 5W+1H analyses were then integrated to formulate maintenance improvement strategies for Pump 402 and Pump 502 at PT XYZ. Since this study utilized only company operational data without involving human participants, ethical approval and informed consent were not required.

## C. RESULTS AND DISCUSSION

### 1. Overall Equipment Effectiveness (OEE)

The Overall Equipment Effectiveness (OEE) calculation was conducted to evaluate the effectiveness of Pump 402 and Pump 502 based on three main indicators, namely Availability, Performance, and Quality. The monthly OEE calculation results are presented in Table 1 below:

**Table 1 Overall Equipment Effectiveness (OEE) of Pump 402 and Pump 502**

| Month | Availability (%) | Performance (%) | Quality (%) | OEE (%) |
|---|---|---|---|---|
| July | 99% | 85.98% | 99.95% | 85% |
| August | 97% | 86.75% | 99.91% | 84.25% |
| October | 91% | 89.97% | 99.23% | 81.10% |
| November | 90% | 90.48% | 98.39% | 80.04% |
| December | 90% | 90.48% | 98.83% | 80.40% |
| **Average** | **93%** | **89%** | **99%** | **82%** |

Source: Research Data (2025)

The results show that the average OEE value of Pump 402 and Pump 502 was 82.29%, which was below the world-class benchmark of 85%. This indicates that the equipment had not yet achieved the expected level of effectiveness. Although the Quality value was relatively high at 99.26%, the lower Performance value of 88.73% contributed to the reduction in overall equipment effectiveness.

The finding is comparable with the study by Ariyah et al. (2022), which applied OEE to evaluate the efficiency of a batching plant and demonstrated that OEE could identify the performance gap between actual equipment operation and the expected level of effectiveness.

However, the result differs from Seiichi (1988) and Wibowo & Padilah (2023), who reported an OEE value of 89.28% for a Length Adjustment Line 3 machine. Their equipment had achieved the world-class benchmark, whereas Pump 402 and Pump 502 in the present study achieved only 82.29%. This difference indicates that equipment effectiveness is strongly influenced by the operating conditions, maintenance practices, and types of losses occurring in each production system.

Therefore, the OEE result indicates that improvement efforts should focus primarily on the Performance component and the losses responsible for reducing operating efficiency.

**2. Availability Analysis**

Although the Overall Equipment Effectiveness (OEE) analysis provides an overview of equipment performance, it does not specifically identify the sources of productivity losses. Therefore, the Six Big Losses method was applied to determine the dominant factors affecting the effectiveness of Pump 402 and Pump 502. The calculation results for each loss category are presented in Table 2.

**Table 2 Availability**

| Month | Loading Time (Hours) | Downtime (Hours) | Operational Time (Hours) | Availability (%) |
|---|---|---|---|---|
| July | 550 | 3 | 547 | 99% |
| August | 502 | 7 | 495 | 97% |
| October | 524 | 24 | 500 | 91% |
| November | 476 | 24 | 452 | 90% |
| December | 476 | 24 | 452 | 90% |
| **Average** | | | | 93% |

Source: Research Data (2025)

The average Availability was 91.14%. The lowest Availability occurred in November 2025, indicating that downtime and equipment failures had a greater effect during this period. The decrease in Availability was associated with recurring equipment problems, including bearing damage, mechanical seal leakage, shaft misalignment, and failures of internal pump components.

The result can be compared with the study by Wahid et al. (2022), which obtained an Availability value of 88.66% for the Chenyueh machine. The Availability value in the present study was higher, indicating that Pump 402 and Pump 502 had better equipment availability during the observation period. However, both studies demonstrate that downtime remains an important factor affecting equipment effectiveness.

This finding is also supported by (Aditya & Syaifullah, 2025; Ebeling, 1997), who reported that equipment effectiveness was affected by breakdown losses and idle time. The comparison indicates that although the equipment types were different, equipment downtime remained an important factor in determining equipment effectiveness.

The Availability value of 91.14% indicates that Pump 402 and Pump 502 were generally available for operation, although downtime still affected equipment performance. This result can be compared with the study by Maulana & Yusyama (2023), which analyzed bearing damage on a centrifugal water pump using Failure Mode and Effect Analysis (FMEA). Their study identified bearing failure as one of the important failure modes that required attention in pump maintenance. In the present study, bearing wear was also identified as one of the causes associated with reduced pump performance. The similarity between the two studies indicates that bearing condition is an important factor in maintaining the reliability and availability of centrifugal pump equipment. However, the previous study focused on failure-risk identification using FMEA, while the present study evaluated the effect of equipment losses on overall effectiveness using OEE and Six Big Losses.

**3. Performance Analysis**

The Performance Rate was calculated to evaluate the operating speed of Pump 402 and Pump 502 compared with their designed operating capacity. The calculation was based on the ratio between the actual production output and the theoretical production capacity during the operating time. The monthly Performance Rate values are presented in Table 3.

**Table 3 Performance**

| Month | Production Output (Month) | Ideal Cycle Time (Hours) | Operating Time (Hours) | Performance Rate (%) |
|---|---|---|---|---|
| July | 39192 | 0.012 | 547 | 85.98% |
| August | 35784 | 0.012 | 495 | 86.75% |
| October | 37488 | 0.012 | 500 | 89.97% |
| November | 34080 | 0.012 | 452 | 90.48% |
| December | 34080 | 0.012 | 452 | 90.48% |
| **Average** | | | | 89% |

Source: Research Data (2025)

The average Performance value was 88.73%. This value was lower than the Availability and Quality indicators, indicating that the main problem was related to the ability of the pumps to maintain their ideal operating performance.

The lower Performance value was associated with several equipment conditions, including bearing wear, shaft misalignment, mechanical seal leakage, and deterioration of internal components. These conditions did not always cause complete equipment stoppage but could reduce the operating speed and efficiency of the pumps.

A comparison with Wahyudi et al. (2023) shows that their study obtained an average OEE of 78.17%, with Idling and Minor Stoppages of 16.85% and Reduced Speed Losses of 7.85%. In contrast, the present study obtained a higher overall OEE but a substantially higher Reduced Speed Losses value. This difference indicates that the dominant losses can vary depending on equipment characteristics and operating conditions.

Therefore, improving the Performance indicator should become a major maintenance priority for Pump 402 and Pump 502.

**4. Quality Analysis**

The Quality Rate was calculated to determine the proportion of products meeting the required quality standards during the observation period. The calculation results are presented in Table 4.

**Table 4 Quality**

| Month | Production Output (Month) | Reject | Quality |
|---|---|---|---|
| July | 39192 | 18 | 99.95% |
| August | 35784 | 32 | 99.91% |
| October | 37488 | 289 | 99.23% |
| November | 34080 | 550 | 98.39% |
| December | 34080 | 400 | 98.83% |
| **Average** | | | 99.70% |

Source: Research Data (2025)

Table 4 presents the monthly Quality Rate of Pump 402 and Pump 502. The average Quality Rate reached 99.70%, indicating that almost all products met the company's quality requirements. The consistently high-Quality Rate demonstrates that product defects had only a minor effect on equipment effectiveness during the observation period.

Compared with the Availability and Performance indicators, the Quality Rate remained relatively stable throughout the observation period. This finding suggests that product quality was well maintained despite fluctuations in equipment performance. Consequently, quality losses were not identified as the primary contributor to the decrease in the OEE value.

This finding supports the study by Laysa (2023), which concluded that high Quality Rate values indicate effective production quality control, while overall equipment effectiveness is more strongly affected by Availability and Performance losses.

## 5. Six Big Losses Analysis

To identify the major sources of productivity losses affecting Pump 402 and Pump 502, the Six Big Losses method was applied. This analysis classified equipment losses into six categories to determine which factors contributed most significantly to the reduction in Overall Equipment Effectiveness (OEE). The calculation results are presented in Table 5

**Table 5 Six Big Losses Analysis**

| Month | Equipment Failure Losses | Set Up and Adjustment Losses | Idling and Minor | Reduced Speed Losses | Defect Losses | Yield Scrap Losses |
|---|---|---|---|---|---|---|
| July | 0.54% | 0.95% | 1.05% | 14% | 0.04% | 0% |
| August | 1.39% | 1.04% | 1.05% | 14% | 0.08% | 0% |
| October | 4.58% | 1.09% | 1.06% | 14% | 0.66% | 0% |
| November | 5,04% | 0.92% | 1.06% | 14% | 1.39% | 0% |
| December | 5,04% | 1.20% | 1.06% | 14% | 1.01% | 0% |
| **Average** | **2.17%** | **1.04%** | **1.06%** | **14%** | **0.63%** | **0%** |

Source: Research Data (2025)

Shows that Reduced Speed Losses contributed the highest percentage among the six categories of equipment losses. This result indicates that the pumps frequently operated below their designed operating speed, which significantly reduced production efficiency despite maintaining relatively high Availability and Quality values.

The dominance of Reduced Speed Losses suggests that the equipment remained operational but was unable to consistently achieve optimum performance. Based on maintenance records, this condition was associated with bearing wear, shaft misalignment, mechanical seal leakage, and deterioration of internal pump components. These factors gradually reduced pump efficiency and increased production losses.

The findings are consistent with Fathurohman & Fathurohman (2025), who reported that speed losses are one of the major contributors to reduced equipment effectiveness. Similarly, (Laysa, 2023) concluded that identifying dominant losses through the Six Big Losses approach enables companies to prioritize maintenance improvement more effectively.

To determine the maintenance priority, the Six Big Losses results were further analyzed using the Pareto principle, as illustrated in Figure 1.

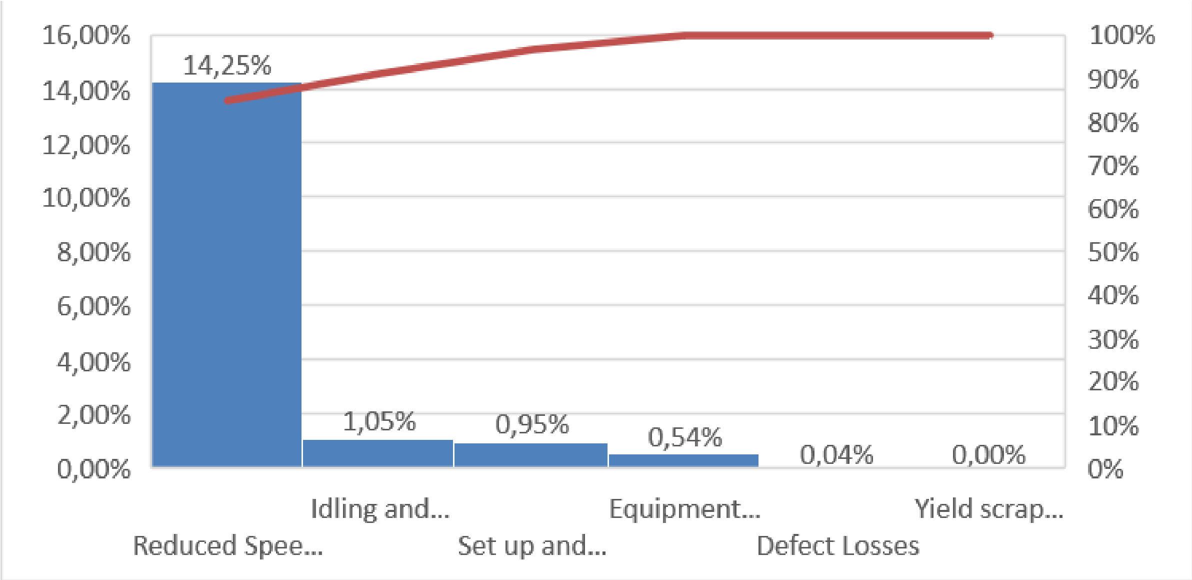


**Figure 1 Pareto Chart**

Figure 1 illustrates that Reduced Speed Losses accounted for the largest proportion of total productivity losses compared with the other five loss categories. According to the Pareto principle, improvement efforts should first concentrate on reducing Reduced Speed Losses because it contributes the greatest impact on the reduction of equipment effectiveness. By minimizing speed-related losses, the Overall Equipment Effectiveness (OEE) of Pump 402 and Pump 502 is expected to improve significantly.

### 6. Root Cause Analysis

To determine the factors contributing to the occurrence of Reduced Speed Losses, a root cause analysis was conducted using the Fishbone Diagram. The analysis results are presented in Figure 2.

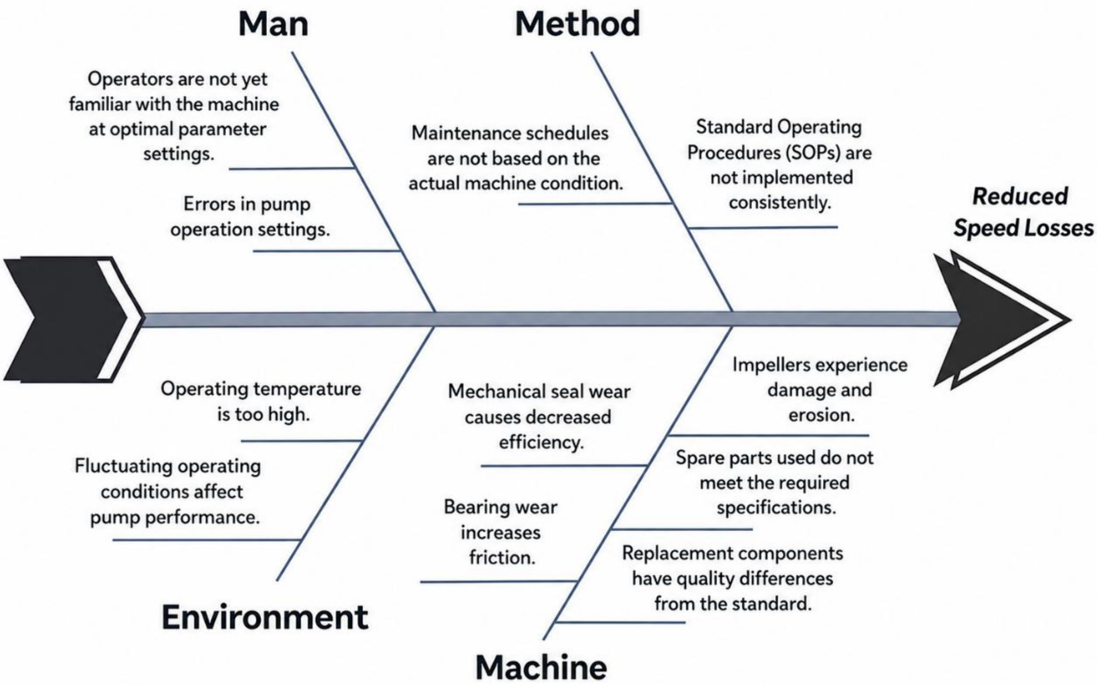


**Figure 2 Fishbone Diagram of Reduced Speed Losses in Pump 402 and Pump 502**

Figure 2 indicates that Reduced Speed Losses were influenced by factors related to Machine, Method, Man, Material, and Environment. The most dominant causes were bearing wear, shaft misalignment, and delayed replacement of worn components, and preventive maintenance activities that had not been fully optimized. These findings indicate that systematic maintenance planning and periodic inspections are essential to improve equipment performance and reduce productivity losses.

The results are in agreement with Wibowo & Padilah (2023), who stated that identifying root causes using the Fishbone Diagram facilitates the development of effective maintenance improvement strategies.

In addition, Setiawan et al. (2025) applied Pareto and Fishbone analysis to investigate defects in automotive components. Their study supports the use of these tools for prioritizing problems and identifying their underlying causes. In the present study, however, the Fishbone analysis was focused on equipment performance losses rather than product defects.

**7. Maintenance Improvement Recommendation**

Based on the root cause analysis, several maintenance improvement strategies were proposed using the 5W+1H method. This approach was applied to develop systematic corrective actions by defining the problem, the purpose of the improvement, the implementation method, the responsible personnel, the implementation location, and the execution schedule. The proposed maintenance improvement plan is presented in Table 6.

**Table 6 Maintenance Improvement Recommendations Using the 5W+1H Method**

| Problem | What | Why | Where | When | Who | How |
|---|---|---|---|---|---|---|
| Reduced Speed Losses due to bearing wear | Periodic bearing inspection | To prevent excessive wear | Pump 402 & Pump 502 | Monthly | Maintenance Department | Preventive maintenance according to SOP |
| Mechanical seal leakage | Replace damaged mechanical seals | To reduce leakage and downtime | Pump 402 & Pump 502 | During scheduled maintenance | Maintenance Technician | Component replacement following maintenance standards |
| Shaft misalignment | Perform shaft alignment | To maintain optimum pump performance | Pump 402 & Pump 502 | Every maintenance schedule | Maintenance Department | Alignment using appropriate measuring instruments |
| Shaft misalignment | Perform shaft alignment | To maintain optimum pump performance | Pump 402 & Pump 502 | Every maintenance schedule | Maintenance Department | Alignment using appropriate measuring instruments |

Table 6 summarizes the proposed maintenance improvement strategies developed using the 5W+1H approach. The recommendations focus on strengthening preventive maintenance, performing routine inspections of critical pump components, improving spare-part management, and ensuring timely replacement of damaged components. Implementing these actions is expected to reduce Reduced Speed Losses, improve equipment reliability, and increase the Overall Equipment Effectiveness (OEE) of Pump 402 and Pump 502.

These findings support the studies of Fathurohman & Fathurohman (2025), and Wahyudi et al. (2023), which emphasized that structured maintenance planning and continuous monitoring contribute significantly to improving equipment effectiveness and operational performance.

## D. CONCLUSION

This study evaluated the maintenance effectiveness of Pump 402 and Pump 502 at PT XYZ using the Overall Equipment Effectiveness (OEE) and Six Big Losses methods. The results showed that the average OEE value was 82.00%, which was below the world-class benchmark of 85%, indicating that the equipment had not yet achieved optimum effectiveness. The Six Big Losses analysis identified Reduced Speed Losses as the dominant source of productivity loss, indicating that the pumps frequently operated below their designed operating speed due to mechanical and maintenance-related factors.

Root cause analysis using the Fishbone Diagram revealed that Reduced Speed Losses were mainly influenced by machine condition, maintenance methods, personnel performance, spare-part management, and operating environment. Based on these findings, maintenance improvement strategies were developed using the 5W+1H approach, including strengthening preventive maintenance, performing routine inspections, improving spare-part availability, and replacing worn components promptly. These recommendations are expected to reduce productivity losses, improve equipment reliability, and increase the Overall Equipment Effectiveness (OEE) of Pump 402 and Pump 502.

This study was limited to maintenance data collected from Pump 402 and Pump 502 during the observation period. Future research is recommended to evaluate the implementation of the proposed maintenance improvements over a longer period and to integrate predictive maintenance, condition monitoring, or reliability analysis to further enhance maintenance performance in manufacturing industries.

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