

Research Article

Reliability and Maintenance Performance Analysis of a 1600-ton Press Machine Using MTBF, MTTR, KPI, and Downtime Indicators

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Abstract

This study presents a comprehensive analysis of the reliability and maintenance performance of a 1600-ton press machine in refractory production using an innovative inverse KPI model. Key metrics—including Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR), a specially formulated Key Performance Indicator (KPI), and total downtime—were systematically evaluated over a 24-month observation period (June 2023-May 2025). The methodology involved the meticulous collection of monthly operational data, failure events, and repair logs. Time-series analysis was employed to identify trends and correlations between the implemented proactive maintenance strategies and equipment performance metrics. The inverse KPI, defined as $KPI = (MTTR / MTBF) \times 100$, proved to be a highly effective tool for performance tracking. The results demonstrate a remarkable 75% reduction in total downtime by mid-2024, correlating directly with a significant increase in MTBF and a decrease in the KPI value. A temporary performance anomaly in early 2025 was investigated and linked to an unforeseen component failure, highlighting the importance of continuous monitoring. The findings conclusively demonstrate the efficacy of a data-driven, proactive maintenance approach, providing a practical and transferable framework for enhancing industrial asset management. This study underscores the substantial benefits of applying systematic reliability engineering principles to optimize performance in traditional industrial settings.

Keywords

Reliability Engineering, Maintenance Performance, MTBF, MTTR, Downtime Analysis, Industrial Equipment, Press Machine, Predictive Maintenance

1. Introduction

In the competitive landscape of industrial manufacturing, equipment reliability serves as a cornerstone for achieving operational excellence, cost efficiency, and sustainable productivity. High-tonnage press machines, particularly those employed in metal forming and refractory production, represent critical assets whose performance directly impacts pro-

duction output, product quality, and overall plant efficiency. Unplanned downtime in such machinery can result in significant financial losses, disrupted supply chains, and increased maintenance costs. Thus, the implementation of effective maintenance strategies is not merely optional but essential for modern manufacturing enterprises. This study investigates the

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reliability and maintenance performance of a 1600-ton press machine operating in a refractory manufacturing environment. Over a 24-month observation period, we tracked and analyzed key reliability metrics—Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), a specially formulated Key Performance Indicator (KPI), and total downtime—to evaluate the efficacy of maintenance practices and identify areas for improvement. The primary objectives of this research are:

- 1) to assess the trends in reliability indicators over time;
- 2) to correlate maintenance activities with performance metrics;
- 3) to propose a practical framework for maintenance optimization; and
- 4) to contribute a real-world case study to the existing body of knowledge in industrial maintenance engineering.

2. Literature Review

"The evolution of maintenance strategies from reactive to proactive and predictive approaches has been well-documented in industrial engineering literature [11]. The foundational principles of Reliability-Centered Maintenance (RCM), as formalized by Moubray [6], provide a critical framework for function-oriented maintenance, which has become a cornerstone of modern asset management." Reliability-Centered Maintenance (RCM), introduced by Moubray [9], emphasizes the criticality of function-oriented maintenance and has become a cornerstone in asset management. Similarly, Total Productive Maintenance (TPM), pioneered by Nakajima [10], focuses on maximizing equipment effectiveness through proactive and preventive measures involving all employees. Mean Time Between Failures (MTBF) and Mean Time to Repair (MTTR) are foundational metrics in reliability engineering. MTBF measures the average operational time between consecutive failures, serving as an indicator of reliability, while MTTR quantifies the average repair time, reflecting maintainability. Numerous studies have utilized these metrics to assess equipment performance and guide maintenance decisions [8, 10]. In addition to these traditional metrics, Key Performance Indicators (KPIs) are increasingly used to benchmark maintenance efficiency. While KPIs can be defined in various ways, this study adopts an inverse KPI formulation— $KPI = (MTTR/MTBF) \times 100$ —where lower values indicate better performance. This approach aligns with the principles of efficiency and continuous improvement and has been implicitly supported in works by Al-Najjar [1] and Eti et al. [5], who highlighted the economic benefits of proactive maintenance. Recent advancements in predictive maintenance [4, 13] and Industry 4.0 technologies have further expanded maintenance management tools. Notably, Paez Advincula [8] emphasized the role of operational reliability engineering in business development. However, practical implementation in tradi-

tional industries remains challenging, underscoring the need for case studies like this. "Foundational works by Dhillon [2] and Mobley [5] have established frameworks for maintenance metrics, while Nakajima [7]'s TPM methodology emphasizes total employee involvement in equipment care."

3. Methodology

3.1. Data Collection

Monthly operational and maintenance data were collected from a 1600-ton press machine at the Mehrgodaz Refractories Factory over a 24-month period (June 2023 to May 2025). The data included: - Operational hours - Failure events - Repair times - Downtime records All dates were converted from the Persian calendar to the Gregorian calendar to ensure consistency and ease of interpretation. "Data collection protocols followed established standards in reliability engineering [3, 12], ensuring consistency and reproducibility."

3.2. Performance Indicators

The following indicators were calculated on a monthly basis:

MTBF (Mean Time Between Failures): Calculated as total operational hours divided by the number of failures.

MTTR (Mean Time to Repair): Calculated as total repair time divided by the number of repairs. KPI (Key Performance Indicator): Defined as $(MTTR / MTBF) \times 100$.

Downtime: Total non-operational time due to failures and repairs, recorded in minutes.

3.3. Data Analysis

Time-series analysis was employed to visualize trends and identify patterns or anomalies in the data. Descriptive statistics were used to summarize the central tendencies and variabilities of the metrics. Additionally, correlation analysis was conducted to examine relationships between the indicators.

4. Case Study: The 1600-ton Press Machine

The subject of this study is a 1600-ton hydraulic press machine used in the production of refractory bricks. The machine operates under high mechanical stress and requires regular maintenance to ensure optimal performance. Prior to the observation period, the maintenance strategy was primarily corrective. However, starting in early 2023, a shift toward preventive and proactive maintenance was initiated, including scheduled inspections, component replacements, and operator training programs.

5. Results and Analysis

5.1. MTBF Trend

MTBF values showed a remarkable upward trend, increasing from 4.93 hours in June 2023 to a peak of 24.25

hours in August 2024 (Figure 1). This improvement indicates a significant enhancement in machine reliability, likely attributable to the preventive maintenance measures implemented. A slight decline was observed in early 2025, suggesting the need for ongoing optimization.

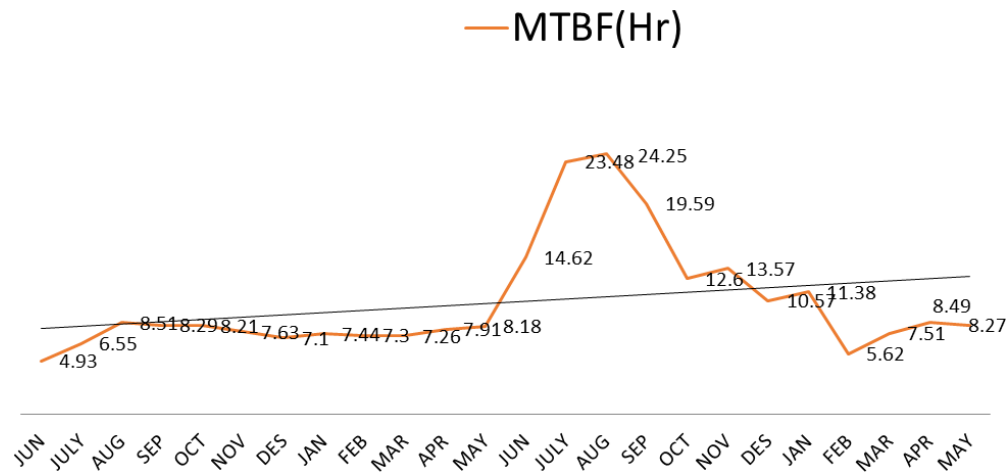


Figure 1. MTBF Trend Over Time.

5.2. MTTR Trend

MTTR values remained relatively stable throughout the period, ranging between 0.4 and 1.39 hours (Figure 2). The

lowest MTTR (0.4 hours) was recorded in July 2023, while the highest (1.39 hours) occurred in April 2025. The stability in MTTR suggests consistent repair processes, though opportunities for further reduction exist through improved spare parts management and technician training.

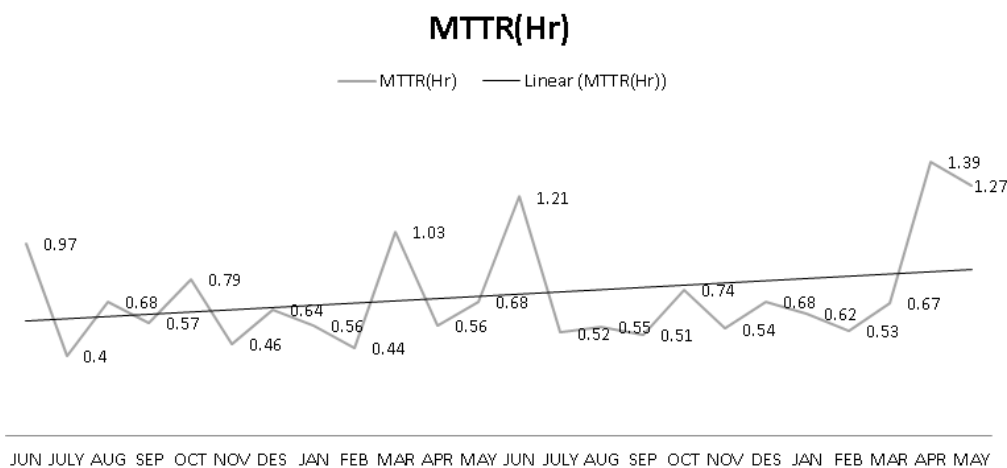


Figure 2. MTTR Trend Over Time.

5.3. KPI Trend

The KPI trend mirrors the improvement in MTBF, decreasing from 25.4% in June 2023 to 7.69% in August 2024

(Figure 3). This inverse relationship validates the use of KPI as an efficiency indicator. A notable spike in KPI (24.53%) was observed in February 2025, coinciding with a major failure event that required extensive repairs.

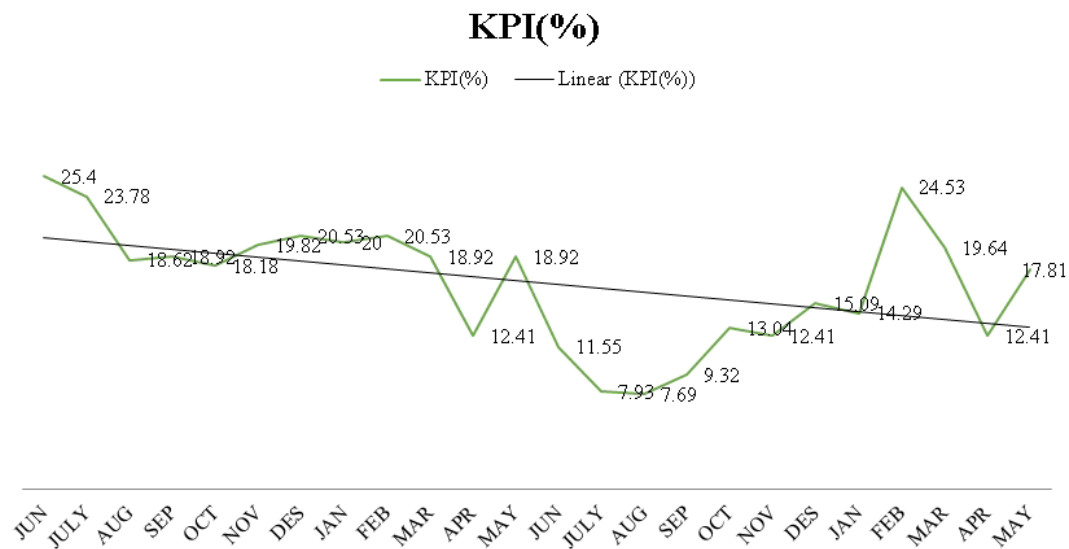


Figure 3. KPI Trend Over Time.

5.4. Downtime Trend

Total downtime decreased dramatically from 7365 minutes

in June 2023 to under 1000 minutes in July and August 2024 (Figure 4). This reduction aligns with the improvements in MTBF and KPI, underscoring the positive impact of reliability-focused maintenance strategies.

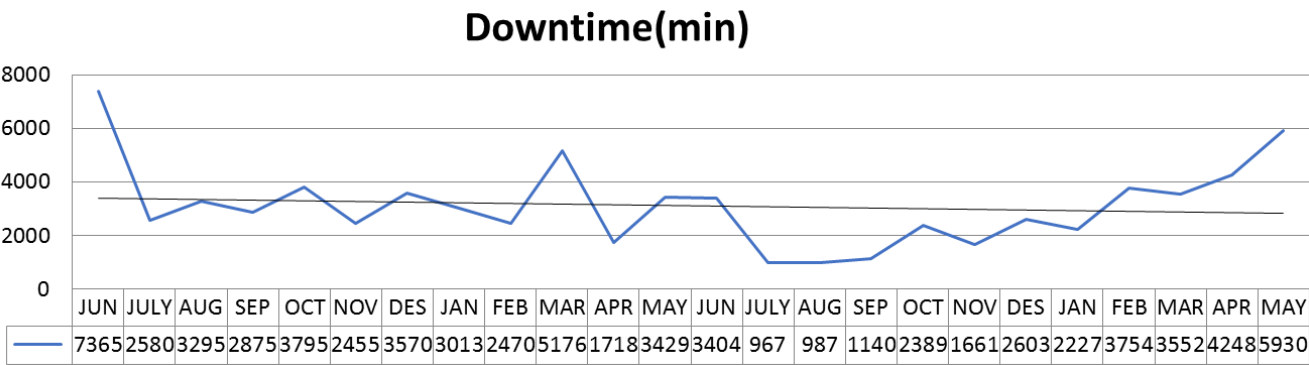


Figure 4. Downtime Trend Over Time.

6. Discussion

The results clearly demonstrate the effectiveness of proactive maintenance interventions in enhancing the reliability and performance of the press machine. The strong inverse correlation between MTBF and KPI confirms the validity of the chosen performance model. The notable improvement in mid-2024 can be attributed to a series of scheduled overhauls, timely component replacements, and enhanced operator training programs. The anomaly in February 2025, characterized by a spike in KPI and downtime, highlights the vulnerability of even well-maintained systems to unforeseen failures. This event may have been caused by a combination of factors, including component fatigue, operational error, or

external conditions. It underscores the importance of continuous monitoring and adherence to maintenance protocols. The stability of MTTR throughout the study period indicates that repair procedures were well-established and efficiently executed. However, the variability in MTTR values suggests that there is still room for improvement, particularly through the adoption of predictive tools and better inventory management. "The stability in MTTR values aligns with findings from Wireman [12], who noted that standardized repair procedures can reduce time-to-repair by up to 40%."

7. Implications for Industry

This study offers several practical implications for industrial engineers and maintenance managers:

Performance Benchmarking:

The inverse KPI model provides a straightforward yet powerful tool for tracking and benchmarking maintenance efficiency.

Resource Allocation:

Trends in MTBF and downtime can inform decisions regarding resource allocation, spare parts inventory, and preventive maintenance scheduling.

Cost Management:

Reducing downtime directly translates into higher production capacity and lower operational costs.

Methodological Transferability:

The approach used in this study can be applied to other critical assets across various manufacturing sectors.

8. Limitations

This study is based on a single case study, which limits the generalizability of the findings. Factors such as operator skill variability, environmental conditions, and production load fluctuations were not explicitly controlled for in the analysis. Future research should incorporate these variables into multivariate models to provide a more comprehensive understanding.

9. Future Work

Future research directions include:

- 1) Developing predictive maintenance models using artificial intelligence and machine learning algorithms.
- 2) Conducting comparative analyses across multiple machines or production lines.
- 3) Performing cost-benefit analyses of different maintenance strategies.
- 4) Integrating real-time sensor data for continuous reliability monitoring.
- 5) Exploring the impact of human factors and organizational culture on maintenance performance.

10. Conclusion

The reliability and maintenance performance of the 1600-ton press machine improved significantly over the 24-month study period, as evidenced by increased MTBF, reduced downtime, and lower KPI values. The inverse KPI model proved to be an effective tool for performance tracking. The findings underscore the value of data-driven maintenance management and provide a practical framework for industrial engineers seeking to enhance asset reliability and operational efficiency. By adopting proactive, reliability-centered maintenance strategies, manufacturing enterprises can achieve substantial cost savings and productivity improvements.

Abbreviations

KPI	Key Performance Indicator
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair

Author Contributions

Pejman Moemenishahraki is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares that there are no conflicts of interest regarding the publication of this paper.

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