

Investigation of Reliability and Optimization of Maintainability of Drying Unit Equipment in a Building Materials Industry

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Abstract - This study investigates the reliability and optimization of maintainability of Drying Unit equipment in a building materials manufacturing industry. The analysis is based on real operational and maintenance data collected during the period 2019–2025 and is conducted within the Reliability–Availability–Maintainability (RAM) framework. Quantitative evaluation was performed using key reliability indicators such as Time to Failure (TTF), Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), and Availability. Statistical analysis included the application of the Kaplan–Meier non-parametric survival estimator and Weibull distribution fitting for modeling the time-to-failure behavior of critical subsystems. The comparative assessment of parametric and non-parametric approaches enabled the identification of subsystems with reduced reliability and increased failure rates.

The results revealed variability in life-cycle behavior among subsystems and differentiated hazard rate trends, leading to documented proposals for maintenance policy redesign. The proposed strategy focuses on reducing unplanned downtime, improving MTBF, and decreasing MTTR through targeted preventive and condition-based maintenance actions. The study provides practical recommendations for enhancing maintenance management practices in industrial drying systems.

Keywords: Reliability, Maintainability, Availability, Weibull Distribution, Kaplan–Meier, RAM Analysis, Industrial Maintenance.

I. INTRODUCTION

Modern industrial environments are characterized by increased demands for competitiveness, quality, and sustainability. Ensuring continuous equipment operation is a critical success factor, particularly in high-intensity production systems. Maintenance is no longer viewed as a supporting function but as a strategic activity directly influencing cost efficiency, product quality, and operational reliability.

The Drying Unit constitutes a core component of the production process in the building materials industry. Its continuous operation under demanding thermal and mechanical conditions necessitates systematic monitoring of reliability and performance. This study focuses on analyzing the failure behavior of individual subsystems and developing proposals for maintenance optimization.

II. THEORETICAL FRAMEWORK

Reliability is defined as the probability that a system performs its intended function without failure for a specified time under stated conditions. Maintainability refers to the ability to restore a system to operational status within a predefined time interval. Availability is a combined measure of reliability and maintainability within the RAM framework.

The primary indicators used in this study include MTTF, MTBF, MTTR, and Availability. Survival analysis enables estimation of the probability of failure-free operation, while the hazard function describes the failure rate over time.

The Kaplan–Meier method provides a non-parametric estimation of the survival function, whereas the Weibull distribution is widely applied for parametric modeling of failure data. The Weibull shape parameter k determines the failure mechanism, while the scale parameter λ determines the time scale of the distribution and influences the expected lifetime of the system.

III. METHODOLOGY

The research is based on failure and repair data collected during the period 2019–2025. Data were categorized by subsystem, including Burner System, Mechanical Drive Equipment, Electrical Equipment, and Gearmotor.

Time to Failure (TTF) and Time to Repair (TTR) were calculated for each subsystem.

Statistical analysis was conducted using the Kaplan–Meier method to estimate survival curves and Weibull distribution fitting to calculate shape and scale parameters. The comparison of parametric and non-parametric approaches provided a comprehensive evaluation of system reliability behavior and supported evidence-based conclusions.

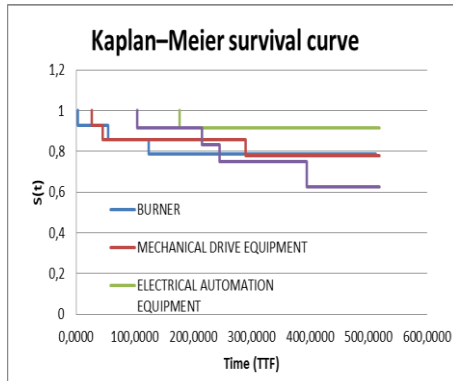


Figure 1. Kaplan–Meier survival curve

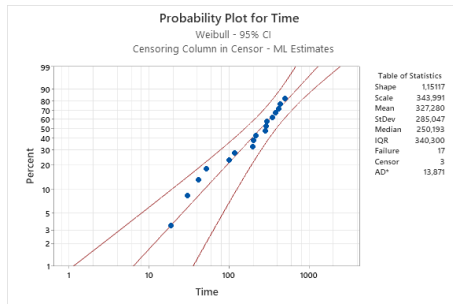


Figure 2. Weibull probability plot with 95% confidence interval for failure time

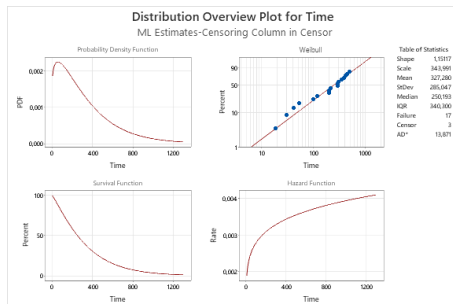


Figure 3. Summary plot of the fitted Weibull distribution (ML estimates) for failure time

IV. RESULTS

The analysis revealed differentiated failure behaviors among subsystems. In certain cases, an increasing hazard function was observed, indicating wear-out mechanisms and aging effects. In other cases, a decreasing trend suggested early-life failures.

System availability remained at relatively high levels; however, improvement potential was identified through revision of preventive maintenance intervals and implementation of predictive maintenance techniques.

V. CONCLUSIONS AND RECOMMENDATIONS

The study highlights the importance of systematic maintenance data analysis in industrial environments. The application of statistical reliability tools enhances failure prediction capability and supports optimal resource allocation.

It is recommended to strengthen predictive maintenance practices, implement condition monitoring systems, and integrate ISO 55000 asset management principles into the overall equipment management strategy.

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