

Research Article

FMEA-Based Preventive Maintenance Strategy for Airlock Systems Material Handling at PT XYZ

Erlangga E. Taruna^{1*}, Rusindiyanto²¹ Universitas Pembangunan Nasional "Veteran" Jawa Timur, Indonesia 1; e-mail : erlanggackatarunaa@gmail.com² Universitas Pembangunan Nasional "Veteran" Jawa Timur, Indonesia 2; e-mail : rusindiyanto.ti@upnjatim.ac.id

* Corresponding Author : Erlangga E. Taruna

Abstract: The continuous operation of airlock machines in wheat milling facilities plays a critical role in the material handling system, especially in the transfer of grain from ships to silo storage. At PT XYZ, the airlock machine has been identified as the equipment with the highest frequency of downtime over a three-month observation period, leading to significant disruptions in production flow and increased corrective maintenance costs. This study aims to analyze the failure modes of the airlock machine using the Failure Mode and Effect Analysis (FMEA) method and to develop preventive maintenance recommendations based on the highest Risk Priority Number (RPN) values. The research adopts a quantitative descriptive approach, involving field observations, interviews with maintenance personnel, historical breakdown analysis, and machine technical documentation review. The FMEA results indicate that the seal, gear, and bearing are the most critical components, with RPN values of 224, 210, and 192, respectively. These components are prioritized for preventive actions such as regular seal replacement, scheduled lubrication, gear inspections, and motor monitoring. Simulation of the proposed maintenance strategy demonstrates a 66.7% reduction in downtime, from 18 hours to 6 hours per month, and a 43.7% reduction in total maintenance costs, from Rp 9,034,500 to Rp 5,087,500 monthly. These results validate the effectiveness of the FMEA method in identifying risk-prone components and optimizing maintenance planning. It is recommended that PT XYZ institutionalize periodic FMEA updates and establish a cross-functional analysis team to continuously monitor and improve equipment reliability.

Keywords: Airlock Machine; FMEA; Preventive Maintenance; Risk Priority Number.

Received: June 07, 2025

Revised: June 21, 2025

Accepted: July 05, 2025

Published: July 07, 2025

Curr. Ver.: July 07, 2025



Copyright: © 2025 by the authors.

Submitted for possible open

access publication under the

terms and conditions of the

Creative Commons Attribution

(CC BY SA) license

[\(https://creativecommons.org/licenses/by-sa/4.0/\)](https://creativecommons.org/licenses/by-sa/4.0/)<https://creativecommons.org/licenses/by-sa/4.0/>

1. Introduction

Large-scale wheat milling companies such as PT XYZ manage highly complex material handling processes, particularly in the jetty and silo areas, which rely heavily on continuously operating mechanical equipment to transfer tons of wheat (Sulistiyono & Saifuddin, 2024). One of the most critical components in this system is the airlock machine, which functions as a pressure valve—enabling the transfer of granular materials from one pressure zone to another without losing airflow or pressure (Susilo & Widijati, 2024). This machine ensures a stable flow while preventing atmospheric contamination within the silo, thereby maintaining an efficient and safe transfer system (Setiyawan, 2021).

Based on observations conducted over the past three months, the airlock machine recorded the highest downtime compared to other equipment such as blowers, separators, and weighers (Praja & Onde, 2025). This high frequency of downtime disrupts the smooth transfer of wheat from the ship to the silo, causes fluctuations in material flow, triggers unplanned stock accumulation, interferes with operational continuity, and leads to significant corrective maintenance costs (Kurniawan & Wawan, 2022). Similar conditions have been reported in the application of FMEA in cement and palm oil milling plants, where downtime

in conveyors or elevators was identified as a major source of failure and recommended as a priority for maintenance action (Yaqin, et al., 2022).

Therefore, a systematic approach is required to analyze equipment failures and assess their impact quantitatively (Filz, Langner, Herrman, & Thiede, 2021). One of the most appropriate methods is Failure Mode and Effect Analysis (FMEA), which has been widely applied to evaluate potential failures in various processing industries such as batching plants, compressors, and raw mills (Romere & Laseinde, 2021). Through FMEA, potential failure modes in the airlock machine—such as seal degradation, pressure imbalance, valve mechanism damage, and bearing wear—can be identified and assessed using the Risk Priority Number (RPN), which incorporates severity, occurrence, and detection factors (Behnia, et al., 2023).

The next step is to develop maintenance recommendations based on FMEA results, including preventive actions such as periodic seal replacement, optimal lubrication, pressure recalibration, ultrasonic bearing inspection, and modular maintenance strategies to minimize downtime (Pasaribu, et al., 2021). Previous studies have shown that implementing FMEA-based recommendations can reduce downtime in critical equipment by 30–50%, while significantly improving Overall Equipment Effectiveness (OEE) (Jurewicz, et al., 2023).

2. Research Method

The object of this research is the airlock machine located in the Jetty and Silo Department of PT XYZ. This machine is used to transfer wheat continuously and in a closed system from the ship into the silo storage unit. The machine operates in a harsh environment characterized by high dust levels, elevated air pressure, and continuous operational demands. Due to these extreme conditions, the airlock is categorized as a critical component in the material handling process, particularly because any malfunction in this machine can significantly disrupt the smooth flow of wheat from unloading vessels to the storage silos.

This study employs a descriptive quantitative approach, with a series of systematic steps designed to capture both qualitative insights and quantitative measurements. The data collection process was carried out through several methods, including direct field observation and real-time monitoring of the machine in operation, interviews with maintenance technicians and department supervisors to gather practical insights, a documentation review of historical breakdowns and maintenance records, as well as an in-depth analysis of the airlock's technical specifications and operational manuals. The core analytical tool used in this study is the Failure Mode and Effect Analysis (FMEA) method. The FMEA process began with the identification of critical components within the airlock system. Once identified, each component was analyzed for potential failure modes that could occur under current operating conditions. For each failure mode, three main parameters were assessed: the severity of the impact, the frequency of occurrence, and the ability to detect the failure in advance. These parameters were then used to calculate the Risk Priority Number (RPN), which serves as a numerical index for prioritizing maintenance actions. Based on the RPN values obtained, preventive maintenance recommendations were formulated, aimed at reducing the likelihood of future failures and improving overall equipment reliability.

This study is based on several general assumptions to ensure consistency in analysis. There are two units of airlock machines operating alternately in the field. The observation period for this research spans three months, during which data on machine performance and failures were collected. On average, the airlock machine experienced six downtime incidents per month, with each incident lasting approximately three hours. The cost of corrective maintenance for each failure was estimated at Rp 1,500,000 per incident, whereas the cost for conducting preventive maintenance was significantly lower, estimated at Rp 500,000 per cycle. The main components observed throughout this study include the seal, motor, bearing, gear, and rotor, which are considered the most failure-prone parts and directly affect the performance and reliability of the airlock machine.

3. Results and Discussion

3.1. Identification of Components and Failure Modes in the Airlock Machine

The first step in the FMEA process is to identify the critical components of the airlock machine along with the possible failure modes, root causes, and the potential effects of those failures on system performance. The identification was carried out through a combination of

field observation, historical maintenance data, and technical specification analysis. The results are presented in Table 1.

Table 1. Identification of Airlock Components, Failure Modes, Causes, and Effects

Component	Failure Mode	Cause	Failure Effect
Seal	Worm or Leaking	Abrasion, aging	Air leakage, pressure loss
Motor	Burned Out	Overload, electrical issue	Machine stops rotating
Bearing	Jammed, worn	Lack of lubrication	Excessive friction, overheating
Gear	Wear	Contaminant, poor lubrication	Uneven rotation
Rotor	Misalignment	Wear or mechanical deformation	Vibration, damage to other components

The table above shows that each component has a specific failure mode with clear causes and effects that could disrupt the airlock's performance. These findings are essential for prioritizing risk and establishing suitable maintenance strategies.

3.2. FMEA Assessment

After identifying the failure modes, each is assessed using the FMEA method by assigning scores to Severity (S), Occurrence (O), and Detection (D). These scores are then multiplied to produce the Risk Priority Number (RPN) for each failure mode. The higher the RPN value, the higher the priority for implementing preventive measures. The results of the FMEA assessment are presented in Table 2.

Table 2. FMEA Assessment Results for Airlock Machine Components

Component	Failure Mode	Severity (S)	Occurrence (O)	Detection (D)	RPN (SxOxD)
Seal	Worn/Leaking	8	7	4	224
Motor	Burned Out	9	5	3	135
Bearing	Jammed	8	6	4	192
Gear	Wear	7	6	5	210
Rotor	Misalignment	6	5	5	150

From the table above, it is evident that the seal has the highest RPN score (224), followed by the gear (210), and the bearing (192). These three components are identified as having the highest potential risk of failure and should therefore be prioritized for preventive maintenance interventions. Focusing on these components will likely have the most significant impact on reducing overall downtime and improving the reliability of the airlock system.

3.3. Maintenance Action Recommendations

Based on the results of the FMEA analysis, several preventive maintenance strategies are proposed for the critical components of the airlock machine. These recommendations are designed to reduce the likelihood of failures with high Risk Priority Number (RPN) and to improve the overall equipment effectiveness (OEE). The proposed maintenance actions, intervals, and descriptions for each key component are summarized in Table 3.

Table 3. Recommended Preventive Maintenance Actions for Airlock Components

Component	Maintenance Strategy	Interval	Description
Seal	Preventive replacement	Every 200 operating hours	Prevents leakage due to wear and aging
Motor	Electrical current monitoring	Weekly	Detects overload potential before critical failure
Bearing	Scheduled lubrication	Every 100 hours	Prevents excessive friction and overheating
Gear	Visual inspection and lubrication	Every 150 hours	Prevents deformation and progressive wear
Rotor	Rebalancing/alignment	Every 6 months	Maintenance rotational balance and reduces vibration

The table indicates that each component requires a specific maintenance approach tailored to its failure mode. The seal, having the highest RPN, should be replaced preventively at regular intervals to avoid performance degradation due to leakage. The motor requires frequent current monitoring to detect early signs of overload, while the bearing demands consistent lubrication to avoid thermal buildup and seizing. Meanwhile, gears benefit from combined visual inspections and lubrication to control wear and misalignment. Lastly, the rotor should undergo rebalancing or alignment checks every six months to maintain mechanical stability and avoid vibration-induced damage. Implementing these targeted preventive actions is expected to significantly reduce unplanned downtime, extend component lifespan, and improve the reliability and performance of the airlock system as a whole.

3.4. Implementation Impact

To estimate the potential benefits of implementing the recommended preventive maintenance strategies, a cost and downtime simulation was conducted based on the average conditions observed during the three-month monitoring period. The simulation compares key operational parameters before and after the implementation of FMEA-based recommendations. The results are summarized in Table 4.

Table 4. Simulated Impact of FMEA-Based Maintenance Implementation

Parameters	Before FMEA	After Recommendation	Description
Average downtime/month	18 hours	6 hours	Prevents leakage due to wear and aging
Corrective maintenance cost/month	Rp 9,034,500	Rp 3,011,500	Detects overload potential before critical failure
Preventive maintenance cost/month	Rp 0	Rp 2,076,000	Prevents excessive friction and overheating

Total maintenance cost/month	Rp 9,034,500	Rp 5,087,500	Prevents deformation and progressive wear
Rotor	Rebalancing/alignment	Every 6 months	Maintenance rotational balance and reduces vibration

The simulation results show a significant reduction in both downtime and total maintenance costs after implementing the FMEA-based recommendations. Average monthly downtime drops from 18 hours to just 6 hours, indicating improved equipment availability and operational continuity. Although there is an increase in preventive maintenance costs (from Rp 0 to Rp 2,076,000), this investment is offset by a substantial reduction in corrective repair costs—down by approximately 66%. Overall, the total monthly maintenance expenditure is reduced by more than Rp 3.9 million, highlighting the cost-effectiveness of a preventive, risk-based maintenance strategy. These findings support the adoption of FMEA as a proactive tool in maintenance planning for critical machinery in continuous processing systems.

4. Conclusions

This study confirms that the application of the Failure Mode and Effect Analysis (FMEA) method is an effective and structured approach for identifying potential failure modes in critical equipment, specifically the airlock machine used in the Jetty and Silo Department of PT XYZ. The airlock, which plays a crucial role in the closed transfer of wheat from ships to storage silos, operates under high mechanical stress, dusty environments, and continuous pressure differentials. Through systematic identification and assessment of component-level failures—including seal leakage, bearing seizure, gear wear, motor burnout, and rotor imbalance—this study successfully quantifies risk using the Risk Priority Number (RPN), integrating severity, occurrence, and detection ratings.

The results show that the seal, gear, and bearing are the most failure-prone components, with the highest RPN values of 224, 210, and 192, respectively. These components significantly contribute to equipment downtime and pose risks to process continuity and operational reliability. In response, targeted preventive maintenance strategies were proposed based on FMEA outcomes, including periodic replacement, routine inspections, scheduled lubrication, current monitoring, and alignment checks. Simulated implementation of these preventive actions shows a substantial reduction in average monthly downtime by 66.7%, from 18 hours to 6 hours. In parallel, total maintenance costs decreased by approximately 43.7%, from Rp 9,034,500 to Rp 5,087,500 per month. While preventive maintenance introduces planned expenditure (Rp 2,076,000/month), the long-term benefits far outweigh the costs through minimized corrective interventions and increased operational stability. This underscores the importance of transitioning from reactive to proactive maintenance, particularly in large-scale industrial operations that rely on uninterrupted material handling systems.

In light of these findings, it is strongly recommended that PT XYZ adopt FMEA as a core component of its maintenance strategy. This includes forming a multidisciplinary FMEA team involving personnel from maintenance, production, engineering, and quality control to ensure holistic analysis and alignment with operational goals. Furthermore, the company should institutionalize routine FMEA updates every 6 to 12 months, or upon the introduction of new equipment, significant process changes, or emerging failure patterns. Continuous refinement of failure analysis and maintenance planning is essential to achieving long-term reliability, cost efficiency, and operational excellence. Future studies are encouraged to integrate complementary techniques such as Root Cause Analysis (RCA), Reliability-Centered Maintenance (RCM), or condition monitoring technologies to further strengthen predictive capabilities and extend equipment life cycles in high-demand industrial settings.

References

- [1] R. Ardiansyah, D. Widyaningrum, and M. Jufriyanto, "Upaya perawatan peralatan bengkel alat berat PT. BMI dengan metode FMEA," *Jurnal Sains dan Teknologi*, 2023.
- [2] F. Behnia, H. Ahmadabadi, and M. Mirhassani, "Developing a fuzzy optimized model for selecting a maintenance strategy in the paper industry: An integrated FGP-ANP-FMEA approach," *Expert Systems with Applications*, 2023.
- [3] M.-A. Filz, J. Langner, C. Herrman, and S. Thiede, "Data-driven failure mode and effect analysis (FMEA) to enhance maintenance planning," *Computers in Industry*, 2021.
- [4] D. Jurewicz, M. Drabowska, A. Burduk, D. Medynski, J. Machado, and P. Motyka, "Implementation of Total Productive Maintenance (TPM) to improve overall equipment effectiveness (OEE) - Case study," *ISPEM*, 2023.
- [5] Kurniawan and Wawan, "Perbaikan kualitas menggunakan metode Failure Mode and Effect Analysis dan Fault Tree Analysis pada produk Punch Extruding Red di PT. Jaya Mandiri Indotech," *Jurnal Ilmiah Ekonomi dan Bisnis*, 2022.
- [6] I. Pasaribu, D. A. Ritonga, and A. Iewan, "Analisis perawatan (maintenance) mesin screw press di pabrik kelapa sawit dengan metode Failure Mode and Effect Analysis (FMEA) di PT. XYZ," *JITEKH*, 2021.
- [7] Praja and Onde, "Corrective maintenance pada PC AFTN merk," *Jurnal Informatika dan Teknik Elektro Terapan*, 2025.
- [8] M. D. Romere and O. Laseinde, "Optimization of condition-based maintenance strategy prediction for aging automotive industrial equipment using FMEA," *Procedia Computer Science*, 2021.
- [9] Setiyawan, "A systematic literature review of Total Productive Maintenance on industries," *Performa: Media Ilmiah Teknik Industri*, 2021.
- [10] W. A. Sulistiyono and J. Saifuddin, "Pengendalian kualitas dengan metode Failure Mode and Effect Analysis (FMEA) pada pembongkaran bahan baku impor di PT X," *SAMMAJIVA: Jurnal Penelitian Bisnis dan Manajemen*, 2024.
- [11] D. D. Susilo and E. P. Widjijati, "Proposed preventive maintenance of air screw compressor machine using Failure Mode and Effect Analysis and Modularity Design methods at PT XYZ," *IJIEM*, 2024.
- [12] Yaqin, Arianto, and Siahaan, "Studi perawatan berbasis risiko sistem pelumasan mesin induk KM Mabur dengan pendekatan FMEA," *Sitekin*, 2022.