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# Failure Prediction Models using Vibration Data Motor and Gearbox: A Case Research in The Mining Industry PT Angsana Coal

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## ABSTRACT

PT Angsana Coal (PT AC) is a major coal mining company in South Kalimantan, Indonesia, which is a subsidiary of PT Energi Sinar Dunia Tbk under the Energi Mas Group. With a vision to be a leading energy provider, PT AC has increased its coal production from 6 million tons per annum (MTPA) in 2015 to 42 MTPA in 2023, with a target of reaching 54 MTPA through strategic expansion and infrastructure improvement. The company's operations prioritize sustainable resource management, advanced technology, and coal extraction efficiency. This study aims to evaluate the effectiveness of vibration analysis-based predictive maintenance implementation in improving Bunati system reliability, reducing downtime, and lowering maintenance costs. The research method includes historical data collection related to reactive maintenance and comparative analysis of system performance before and after the implementation of predictive maintenance. The results showed that PT AC's reactive maintenance strategy led to a significant increase in unscheduled maintenance downtime, peaking at 706.90 hours in 2018 due to frequent motor and gearbox breakdowns. The implementation of predictive maintenance is able to detect early signs of wear and tear, enabling timely intervention, thus improving system reliability, lowering downtime, and reducing overall maintenance costs. The implications of this study show that investment in monitoring tools, personnel training, and a robust data framework can improve PT AC's operational efficiency, support the achievement of production targets, and promote the sustainability of the energy industry.

**Keywords:** Predictive Maintenance, Vibration Analysis, Equipment Reliability, Downtime Reduction, Condition Monitoring, Maintenance Optimization.

## INTRODUCTION

The coal mining industry plays an important role in meeting global energy needs, especially in developing countries (Indrayani & Firdaus, 2024). As one of the main fossil energy sources, coal contributes significantly to power generation and various industrial sectors (Afin & Kiono, 2021). According to the International Energy Agency (IEA) report, the global demand for coal continues to increase, especially in the Asia-Pacific region which dominates the world's coal consumption

(Voller & Hastiadi, 2024). This is driven by the growing need for energy to support economic development and industrialization. However, the increase in coal production is also accompanied by various challenges, including the need to maintain operational sustainability, process efficiency, and environmental impact management (Hade Chandra Batubara et al., 2024).

In Indonesia, coal is one of the main export commodities that play an important role in the national economy (Hanif & Taufiq, 2023). As the third largest coal producer in the world, Indonesia has shown significant growth in its production capacity (Pahlevi et al., 2024). However, the industry is faced with major challenges in terms of operational reliability and equipment efficiency. Key equipment such as motors and gearboxes used in material handling systems play a crucial role in maintaining mine operations. Failure of this equipment can cause unscheduled downtime, lower production efficiency and increase maintenance costs. Therefore, the application of modern maintenance technologies such as predictive maintenance is an urgent need to address this issue.

PT Angsana Coal (PT AC), one of the largest coal mining companies in Indonesia, is located in South Kalimantan and is a subsidiary of PT Golden Energy Mines Tbk under the Sinar Mas Group. As one of the major players in the coal industry, PT AC has contributed significantly to Indonesia's status as a major global coal exporter. From 2015 to 2023, PT AC's coal production increased rapidly from 6 million tons per annum (MTPA) to 42 MTPA, with an ambitious target of reaching 54 MTPA in the coming years through expansion strategies and infrastructure improvements (Figure 1). To support this vision, PT AC has partnered with Bunati's material handling infrastructure improvement initiative to improve operational efficiency.

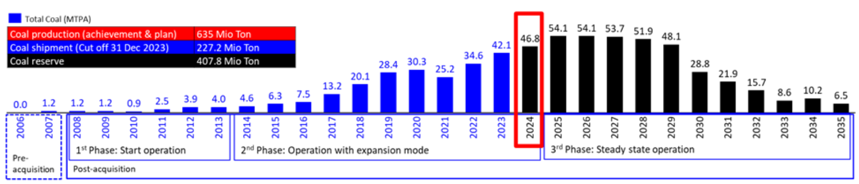


**Figure 1. PT Angsana Coal's Coal Production Target 2006-2036**

PT AC's mining activities emphasize sustainable resource management and the application of cutting-edge technology to maintain the sustainability and efficiency of the extraction process. However, a big challenge in this industry is ensuring reliable physical and mechanical availability of equipment, especially in the face of intense competition. Based on data from 2017 to 2024, the Physical Availability (PA) and Mechanical Availability (MA) indicators show a fluctuating trend (Figure 2). In the 2017-2020 period, both indicators experienced a significant decline due to the high frequency of damage to motors and gearboxes, indicating that the maintenance strategy implemented at that time was not effective enough.

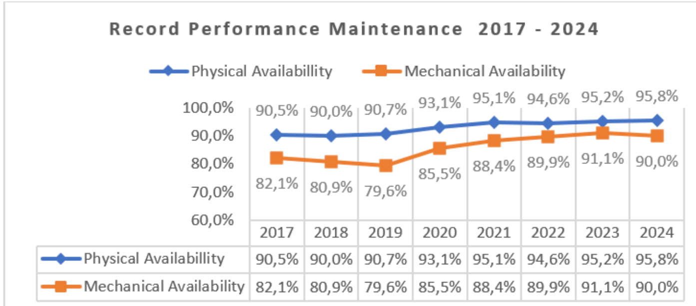


**Figure 2. Maintenance Track Record of PT Angsana Coal 2017-2024**

From 2021 to 2023, PT AC implemented a preventive maintenance approach, which succeeded in gradually improving MA and PA, but was not sufficient in addressing the underlying problems in motors and gearboxes. Therefore, in 2024, the company adopted a predictive maintenance strategy based on vibration analysis supported by digitalization. This strategy is expected to achieve the performance targets set by the Ministry of Energy and Mineral Resources (MEMR), which are PA and MA of at least 90%.

Despite a decrease in the frequency of breakdowns from 27 events in 2021 to only 6 events in 2024 (Figure 3), the amount of unscheduled maintenance time per event increased from 464.63 hours to 706.90 hours. This shows that although damage can be reduced, resolving each event takes longer due to the complexity of the problem. Therefore, the implementation of more proactive predictive maintenance technology is an urgent need to improve system reliability, reduce downtime, and optimize overall equipment performance.

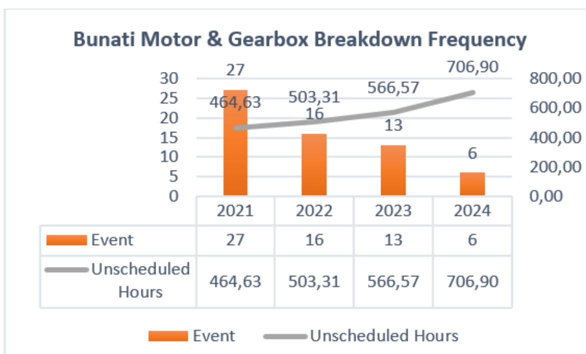


**Figure 3. Frequency and Duration of Unscheduled Maintenance on Bunati Motors and Gearboxes**

Previous studies, such as those conducted by (Ramadhan & Nurhidayat, 2022)and Kosmowski et al. (2023), have shown the urgency of transitioning from reactive to predictive maintenance approaches. (Ramadhan & Nurhidayat, 2022) applied the Reliability-Centered Maintenance (RCM) and FMECA methods to plan preventive maintenance intervals, whereas (Hatta et al., 2024) highlighted the role of big data-based predictive technologies and artificial intelligence in supporting maintenance planning in power plants. These findings confirm that predictive maintenance can be a more efficient solution in managing critical assets such as motors and gearboxes.

Similar research was conducted by (Jauhari, 2023) who utilized vibration analysis-based machine learning methods to predict failures in gearboxes in the manufacturing industry. This study shows that the integration of artificial intelligence algorithms with maintenance data can increase the accuracy of damage prediction by 92%, allowing companies to reduce downtime by 40%. These findings highlight how modern technology can have a significant impact on a company's operational efficiency.

In addition, research by (Kusumawati et al., 2017) explored the implementation of Internet of Things (IoT) in predictive maintenance in the mining industry. By using smart sensors to collect real-time data from motors and gearboxes, this study successfully demonstrated a 35% reduction in average repair time and a 30% increase in system reliability. These results underscore the importance of a robust data infrastructure and advanced analytics capabilities to support the implementation of predictive maintenance strategies.

Based on the above background, this research is unique in its application to the coal mining industry in Indonesia, focusing on the use of vibration analysis as the main method for predicting equipment failure. This research aims to develop a failure prediction model based on vibration data on motors and gearboxes in the Bunati system of PT Angsana Coal. The benefits of this research are expected to help the company reduce operational downtime, lower maintenance costs, and improve overall operational reliability and efficiency.

## RESEARCH METHOD

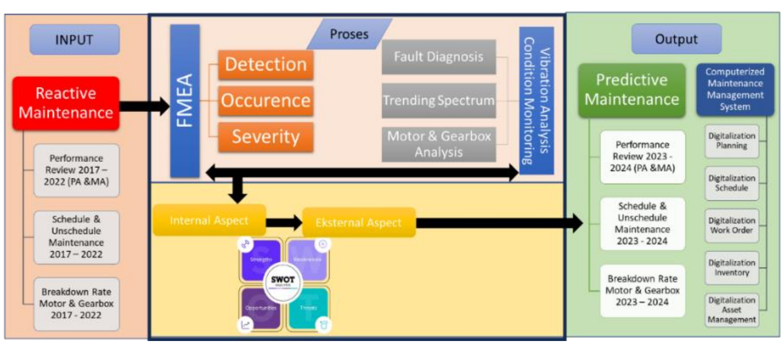


**Figure 4. Conceptual Framework**

Figure 5,This conceptual framework delineates the shift from reactive maintenance to predictive maintenance via a systematic approach using Failure Mode and Effects Analysis (FMEA) and condition monitoring methodologies. Historical data from 2017 to 2022, encompassing performance evaluations, both scheduled and unscheduled maintenance, and failure rates of motors and gearboxes, is employed to analyze maintenance trends and challenges. The procedure also encompasses sophisticated condition monitoring methodologies, including fault detection, trending spectrum analysis, and motor and gearbox evaluation, emphasizing vibration analysis for condition assessment. These instruments provide early defect identification and continuous asset health monitoring, promoting a proactive strategy.

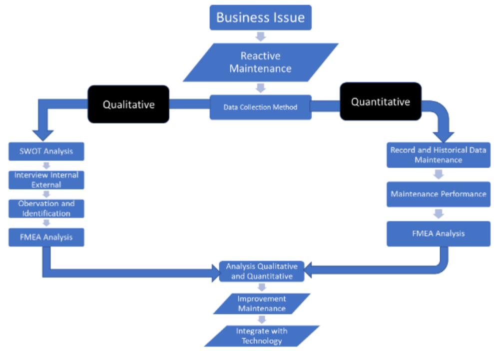


**Figure 5. Flowchart Data Research Method**

Figure 6 explain that The methodology for the research involves several structured steps. The essence of the predictive maintenance model entails the analysis of vibration data. Vibration sensors are positioned at critical locations on the motors and gearboxes to collect real-time data.

**Data Collection**

This Research methodology employs a synthesis of qualitative and quantitative data collecting to successfully solve maintenance challenges. Furthermore, Failure Mode and Effects Analysis (FMEA) is employed to qualitatively evaluate probable failure locations, offering insights into areas for enhancement in the maintenance process (Battirola Filho et al., 2017).

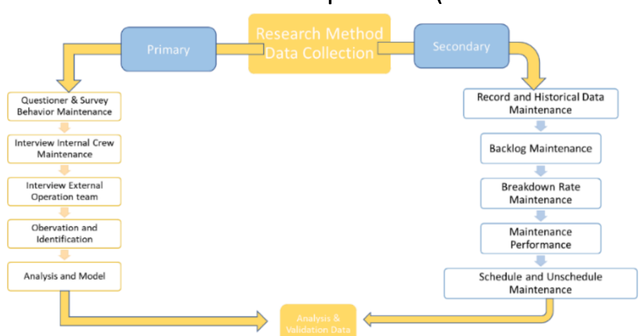


**Figure 6. Research Method Data Collection**

Figure 6 explain This data gathering strategy uses both primary and secondary sources to examine maintenance practices and performance. The Secondary Data technique emphasizes the analysis of pre-existing records and historical data. This include analyzing backlog maintenance data, failure rates, and maintenance performance metrics.

**Data Analysis**

In order to enhance maintenance techniques, data analysis research in this context thoroughly examines both quantitative and qualitative data. The analysis employs qualitative approaches, such as behavioral comparisons to a maturity model, alongside quantitative techniques like Failure Mode and Effects Analysis (FMEA), which detects risks and computes Risk Priority Numbers (RPN) to prioritize concerns (Resende et al., 2024).

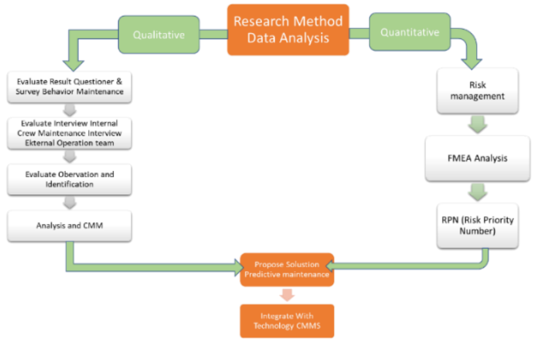


**Figure 7. Research Method Data Analysis**

Figure 7 explain This research methodology for maintenance strategy analysis employs both qualitative and quantitative data to assess and recommend enhancements. The qualitative method starts with the assessment of outcomes from questionnaires and surveys about maintenance habits. This involves reviewing interviews with internal maintenance personnel and external operations teams, along with observations to detect maintenance concerns.The Research computes the Risk Priority Number (RPN) for each failure, facilitating prioritizing according to risk levels.

***Qualitative Data***

The qualitative research methodology for formulating failure prediction models utilizing vibration data in motor and gearbox systems, specifically in a mining industry case Research such as PT Angsana Coal.

1) Observation: In this case Research, a researcher would spend time in the field at PT Angsana (Figure 9) Coal's mining site, observing the actual working conditions of the motors and gearboxes. Observations may include the physical setup, environmental factors (such as dust and temperature), and operational practices that could influence vibration levels.

**Figure 8. Inspection data Motor and Gearbox using tools**

2) Review of Maintenance Records and Historical Data: Qualitative analysis also involves examining historical maintenance records, repair logs, and failure reports to identify common

trends in equipment failures and the context surrounding them. These records reveal patterns that might not be immediately evident through quantitative analysis alone.

3) Document Analysis: Technical manuals, inspection checklists, and reports on past maintenance interventions are reviewed to understand the equipment's expected operational conditions and maintenance protocols (Guillén et al., 2016).

***Quantitative Data***

The quantitative research methodology for failure prediction models utilizing vibration data in motor and gearbox systems, specifically within the mining sector at PT Angsana Coal, emphasizes the systematic collection, analysis, and modeling of numerical vibration data to forecast potential equipment failures.

1) Vibration Data Acquisition (Figure 9): The foundation of quantitative analysis in this research method is the systematic collection of vibration data from the motors and gearboxes. This data is typically gathered using sensors (such as accelerometers or piezoelectric sensors) placed on critical points of the motor and gearbox assemblies.

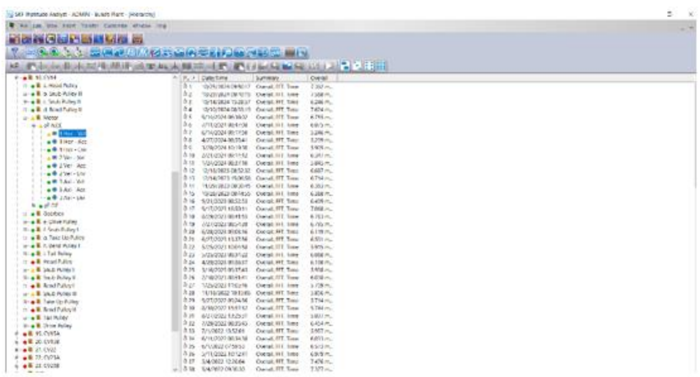

**Figure 9. Data Vibration Acquisition by software Analysis**

2) Data Preprocessing (Figure 10): Once collected, the vibration data undergoes preprocessing to remove noise and outliers, which could distort the analysis. Techniques like filtering and smoothing are applied to ensure that the data reflects actual vibration patterns rather than random fluctuations or sensor errors. This step ensures that the data is clean, accurate, and ready for meaningful analysis.

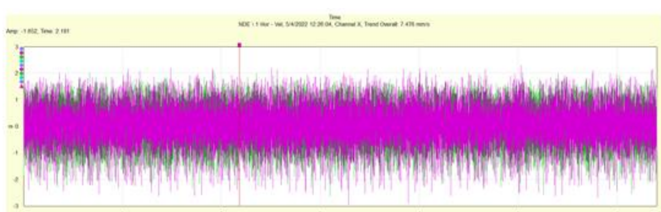

**Figure 10. Data Preprocessing Vibration Signal using Software Analysis**

3) Failure Mode and Effects Analysis (FMEA): FMEA is applied quantitatively to identify potential failure modes in the motor and gearbox based on vibration features. Each failure mode is

assessed for its likelihood and impact, and a Risk Priority Number (RPN) is calculated for each mode. Higher RPN values indicate higher-priority failure risks, guiding maintenance teams on which components to monitor more closely. This quantitative prioritization ensures that resources are focused on the most critical issues that could disrupt operations.

## RESULT AND DISCUSSION

### Define Problem

The Bunati conveying system relies on the motor and gearbox, which are essential for driving and regulating the conveyor belt's movement to provide effective coal transfer to barging points. The existing maintenance strategy, characterized by its reactive and planned nature, has resulted in unforeseen equipment malfunctions and operating inefficiencies.

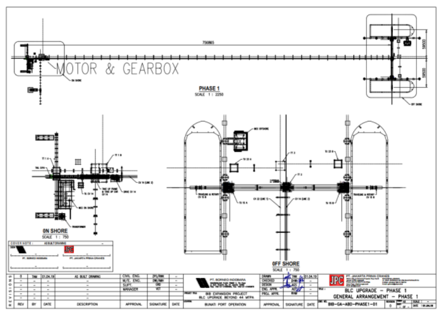


**Figure 11. General arrangement Conveyor System PT Angsana Coal**

Figure 11 explain The drawing illustrates both onshore and offshore sections of the conveyor. The onshore portion is located closer to the motor and gearbox, which initiates the conveyor's movement. The offshore section extends towards the loading or barging area, suggesting that this conveyor system is likely used for transporting bulk materials like coal to barges for shipping.

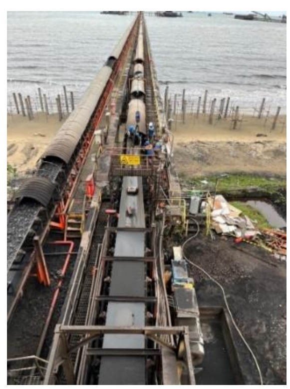

**Figure 12. Photo Motor and Gearbox Conveyor PT Angsana Coal**

Figure 12 Explain Existing photo of The motor and gearbox are vital elements in the structure of a conveyor since they facilitate the operation of the whole system. The motor supplies the necessary mechanical force to propel the conveyor belt, therefore assuring maximum efficiency in the transportation of Coal to Bargings. Conversely, the gearbox modifies the speed and torque generated by the motor to correspond with the operating specifics of the conveyor, such as synchronising the speed of the belt with the weight being transported. In the absence of a well-operating motor and gearbox, the conveyor would be unable to sustain ideal performance or may even cease to function.

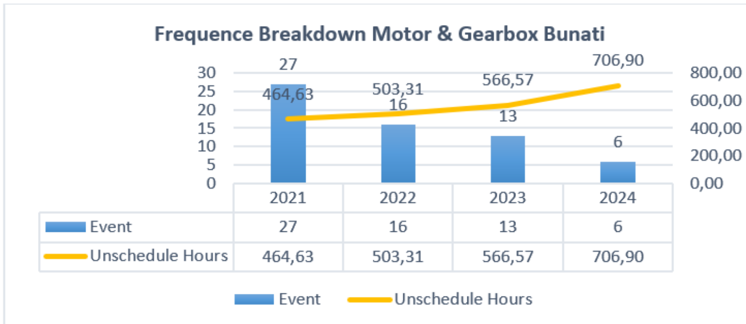


**Figure 13. Frequence Breakdown Motor and Gearbox PT Angsana Coal**

Figure 13 Explain that Frequency Breakdown Motor and Gearbox Bunati depicts the yearly breakdown incidents and unplanned downtime hours for the motor and gearbox inside the Bunati conveyor system from 2021 to 2024. In 2023, the trend persisted with 13 incidents and an increased downtime of 566.57 hours. By 2024, the event count decreased to 6, signifying an enhancement in maintenance methods. Nonetheless, despite the decrease in events, unscheduled hours persisted in increasing, culminating at 706.90 hours. This trend indicates that although the incidence of breakdowns has diminished, the severity or duration of each occurrence has increased.

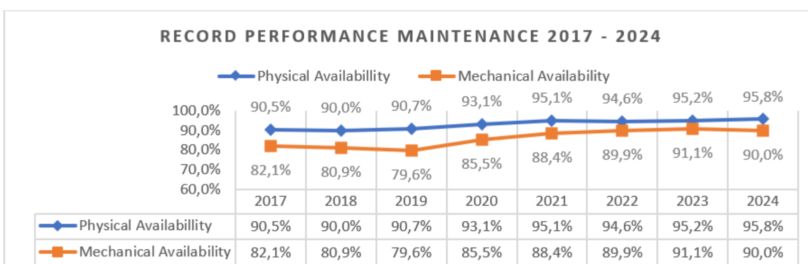


**Figure 14. Record Performance Maintenance PT Angsana Coal**

Based on the chart Figure 14, it is evident that the Physical Availability (PA) and Mechanical Availability (MA) values for Angsana Coal from 2017 to 2024 show a fluctuating trend. During the period from 2017 to 2020, both indicators experienced a significant decline, primarily due to frequent failures of motors and gearboxes.

**Measure**

Critical metrics such as uptime and vibration data are essential in assessing the maintenance performance of the motor and gearbox at PT Angsana Coal's Bunati plant. Reactive maintenance between 2017 and 2020 led to a sharp rise in unscheduled maintenance hours, peaking at 706.90 hours in 2018, highlighting the inadequacy of preventive measures. From 2021, the adoption of stricter preventive protocols reduced unscheduled maintenance hours significantly, from 503.31 hours in 2020 to 128.31 hours by 2024. This improvement, further supported by predictive maintenance and digitalization introduced in 2024, underscores a proactive approach to enhancing equipment reliability and operational efficiency.

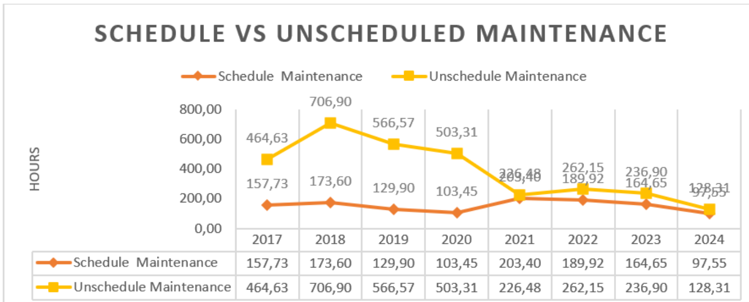


**Figure 15. Record Schedule and Unschedule Maintenance PT Angsana Coal**

Figure 15 explain PT Angsana Coal reactive maintenance strategy resulted in a significant increase in unscheduled maintenance hours between 2017 and 2020, reaching a peak of 706.90 hours in 2018 owing to frequent motor and gearbox failures. The scheduled maintenance hours over this period were consistently low, ranging from 157.73 to 173.60 hours. This suggests that the preventative measures used were inadequate in preventing machine failures. Unscheduled maintenance hours exhibited a distinct downward trend from 2021 to 2024, with a substantial decline from 503.31 hours in 2020 to 226.48 hours in 2021, and further decreasing to 128.31 hours by 2024.

a. Vibration Data Figure 17: Collect and analyze vibration data from the machinery to identify patterns that may indicate impending failures.

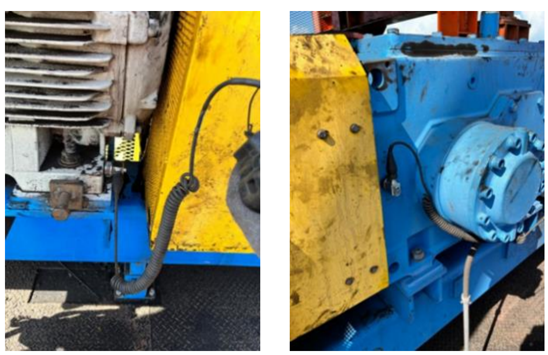

**Figure 16. Taking Vibration data Motor And Gearbox Using Tools**

**Tabel 1. Result Vibration Data Motor and Gearbox from 2020 – 2024**

| CV14 | Units | 1<br>Loading<br>31/07/2020 | 2<br>Loading<br>05/04/2021 | 3<br>Loading<br>24/04/2022 | 4<br>Loading<br>28/10/2023 | 5<br>Loading<br>27/04/2024 |
|---|---|---|---|---|---|---|
| Motor | mm/s | 5.77 | 7.179 | 12.819 | 6.388 | 5.761 |
| Gearbox | mm/s | 4.32 | 7.038 | 18.366 | 4.885 | 5.148 |

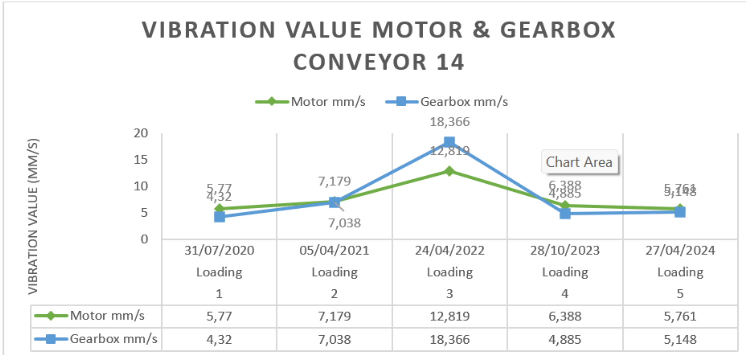


**Figure 17. Vibration Value Motor and Gearbox PT Angsana Coal**

Figure 17 explain The Bunati plant's CV14 unit motor and gearbox vibration data shows how predictive maintenance may reduce unexpected downtimes and production losses. Millimeters per second (mm/s) vibration levels are important indications of rotating equipment such motors and gearboxes, with greater values indicating imbalance, misalignment, or bearing wear. From 2020 to early 2021, the motor and gearbox vibration levels were low and consistent at 5.77 and 4.32 mm/s, respectively. However, in 2022, the motor reached 12.819 mm/s and the gearbox 18.366 mm/s, showing substantial mechanical faults that might cause massive failures if not corrected.

ISO 10816-3 defines vibration severity levels to determine if they are safe or need maintenance. On 24/04/2022 (Loading 3), the gearbox vibration reached 18.366 mm/s and the motor 12.819. The gearbox is likely in Zone D (Danger), requiring immediate repair, while the motor is in Zone C (Warning), indicating that maintenance should be scheduled to avoid future issues. The next tests (2023 and 2024) show a reduction in vibration, with the gearbox recording 4.885 mm/s and 5.148 mm/s and the motor 6.388 and 5.761.

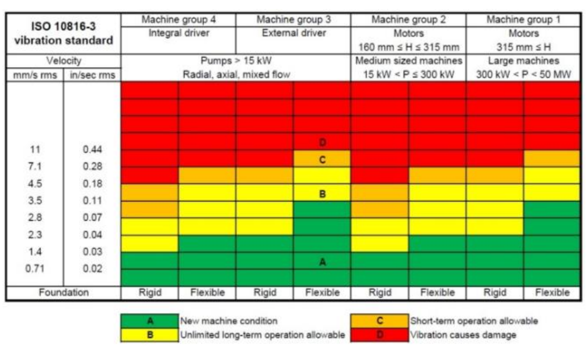


**Figure 18. ISO 10816-3 Standard Vibration Severity Level**

Figure 18 ISO 10816-3 provides guidelines for evaluating the vibration severity of machines with nominal power above 15 kW and nominal speeds between 120 rpm and 15,000 rpm. It focuses specifically on vibration measurements on the bearings of machines, categorizing machines by size and mounting type, and establishing acceptable vibration severity levels for safe and optimal operation.

1. Motor and Gearbox Classification: Machines are categorized into four groups based on power, size, and mounting type, including rigid and flexible mountings. The standard provides separate thresholds for each group to account for differences in structure and behavior.
2. Vibration Severity Levels: ISO 10816-3 specifies four vibration severity zones for machine operation:
   a) Zone A (Good): Vibration is within normal operating range; machine operation is acceptable.
   b) Zone B (Satisfactory): Vibration is slightly higher but still within acceptable limits; routine maintenance should be considered.
   c) Zone C (Warning): Increased vibration may impact machine life; maintenance should be scheduled, as continuous operation in this zone is not advisable.
   d) Zone D (Danger): Vibration is at a critical level, and immediate corrective action is necessary to avoid severe damage or machine failure.

b. Data Collection Tools Figure 20 : Utilize vibration sensors, CMMS data, and historical maintenance records to gather the necessary data.

**Figure 19. Collecting Vibration Data PT Angsana Coal**

**Analyze**

Analyze vibration data to detect anomalies or patterns that could predict failures. During the Analyze phase, the vibration data is examined to detect patterns or anomalies that may signal impending failures. For instance, the data reveals a significant spike in 2022, with motor vibration reaching 12.819 mm/s and gearbox vibration peaking at 18.366 mm/s. Such increases suggest underlying mechanical issues that could lead to equipment failure if left unaddressed. By analyzing these patterns, maintenance teams can identify specific periods of increased risk and determine the root causes of these anomalies, such as possible misalignment or component degradation.

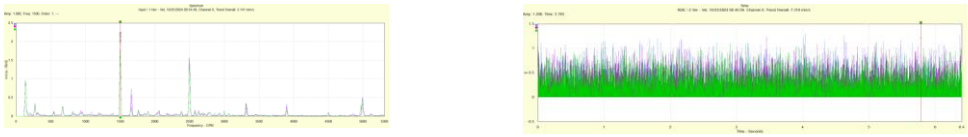

**Figure 20. Spectrum Vibration Motor and Gearbox**

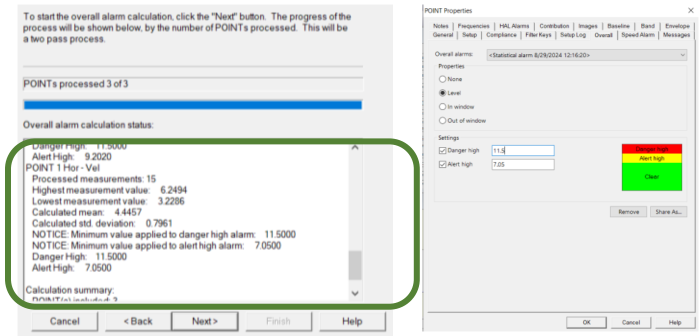


**Figure 21. Spectrum Analysis motor and Gearbox PT Angsana Coal**

Figure 20 and Figure 21 The analysis of vibration data for CV 14 (conveyor 14) indicates that the implementation of a strong predictive maintenance strategy is essential in order to avoid unforeseen equipment breakdowns and save downtime. Accurate determination of vibration levels is crucial since they provide an early indication of mechanical problems, and setting specific thresholds for action is imperative. Once the vibration level on conveyor 14 exceeds 7.05 mm/s, a warning alarm should be activated, indicating to the maintenance staff to make necessary preparations for impending problems. This preparedness includes verifying the availability of essential spare parts and ensuring that the team is prepared to promptly react in case the situation worsens. Once the vibration level surpasses 11 mm/s, it rises to a critical threshold indicating significant mechanical deterioration or impending catastrophic collapse. The use of this proactive strategy not only improves the dependability of equipment but also maximises operational effectiveness by avoiding expensive disruptions in production. By actively monitoring and promptly responding, the maintenance crew can effectively preserve the health of the conveyor system, therefore guaranteeing uninterrupted and seamless operation without any unforeseen interruptions by Figure 22.

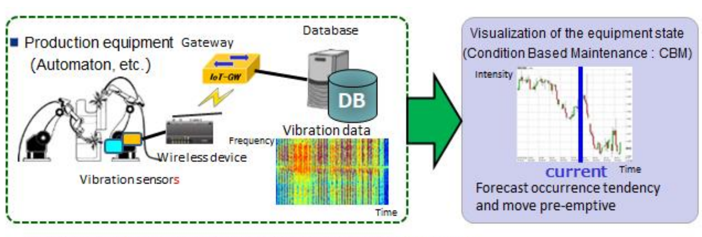


**Figure 22. Digitalization Spectrum Analysis method**

c. Perform Failure Modes and Effects Analysis (FMEA) to identify the most critical failure modes and their causes. Risk Assessment to Evaluate the risks associated with different maintenance strategies and the potential impact of implementing predictive maintenance.

Failure Mode and Effects Analysis (FMEA) for a motor and gearbox system, detailing each step according to the specified process in PT Angsana Coal:

1) Define Role: Identify the function of the motor and gearbox in the operation (e.g., part of a conveyor system for material handling).
2) List Supporting Assets: Note other assets (sensors, control systems, lubricants) that contribute to motor and gearbox performance.
3) Assign Unique ID: Give each motor and gearbox a unique identifier for analysis tracking.
4) Document Function and Failure Modes: Outline the function and potential failure modes (e.g., overheating, vibration) for each asset.
5) Assess Failure Impact: Describe the operational impact of each failure mode (e.g., conveyor shutdown).
6) Rate Severity: Use a severity chart to assign ratings based on impact.
7) Identify Causes and Frequency: List failure causes (e.g., lubrication, alignment issues) and assign a probability rating.
8) Record Current Controls and Detectability: List existing controls (e.g., maintenance, sensors) and assign detectability ratings.
9) Calculate and Evaluate RPN: Multiply severity, probability, and detectability ratings for the Risk Priority Number; mark high RPNs as "High Risk."
10) Implement Mitigations and Reassess: For high risks, add controls, assign responsibility, and recalculate RPN until risks reach acceptable levels.

**Severity Level Charts**

This severity level chart for FMEA categorizes the probable impacts of failure scenarios in a motor and gearbox system. It offers a scale ranging from 1 to 10 to evaluate the severity of each failure, with higher values signifying more significant repercussions. This is how these levels pertain to a motor and gearbox:

**Tabel 2. Severity Chart Level**

| Effect | SEVERITY of Effect | Ranking |
|---|---|---|
| **Catastrophic** | Very high severity ranking when a potential failure mode affects safe operation and/or involves noncompliance with regulations without warning | **10** |
| **Extreme** | Very high severity ranking when a potential failure mode affects safe operation and/or involves noncompliance with regulations with warning | **9** |
| **Very High** | Product/item inoperable, with loss of primary function | **8** |
| **High** | Product/item operable, but at reduced level of performance. Customer dissatisfied | **7** |
| **Moderate** | Product/item operable, but may cause rework/repair and/or damage to equipment | **6** |
| **Low** | Product/item operable, but may cause slight inconvenience to related operations | **5** |

| Effect | SEVERITY of Effect | Ranking |
|---|---|---|
| **Very Low** | Product/item operable, but possesses some defects (aesthetic and otherwise) noticeable to most customers | **4** |
| **Minor** | Product/item operable, but may possess some defects noticeable by discriminating customers | **3** |
| **Very Minor** | Product/item operable, but is in noncompliance with company policy | **2** |
| **None** | No effect | **1** |

1) Catastrophic (10): Failure severely compromises safety, risks harm, or breaks regulations without warning; requires immediate shutdown.
2) Extreme (9): Severe failure impacting safety or compliance, with some warning for emergency action.
3) Very High (8): Motor or gearbox inoperable, halting system function; major impact on production, minimal safety risk if protocols are followed.
4) High (7): Reduced performance, causing delays and dissatisfaction, e.g., slower or intermittent operation.
5) Moderate (6): Operational but needing repairs, rework, or minor damage control.
6) Low (5): Minor inconvenience or performance inconsistencies, no production halt.
7) Very Low (4): Minor defects, noticeable but non-critical to operations or satisfaction.
8) Minor (3): Defects evident to experts but minimal functional impact.
9) Very Minor (2): Fails internal standards, little effect on function.
10) None (1): No impact on performance or operation.

**Probability Level Charts**

The FMEA probability level chart categorizes the possibility of failure, spanning from "Remote" to "Very High." This aids in assessing the frequency of failures in the motor and gearbox system, which is essential for prioritizing maintenance and risk management strategies. This is how these levels pertain to a motor and gearbox:

**Tabel 3. Probability Chart Level**

| | | |
|---|---|---|
| **Very High: Failure is almost inevitable** | >1 in 2 | **10** |
| | 1 in 3 | **9** |
| **High: Repeated failures** | 1 in 8 | **8** |
| | 1 in 20 | **7** |
| **Moderate: Occasional failures** | 1 in 80 | **6** |
| | 1 in 400 | **5** |
| | 1 in 2,000 | **4** |
| **Low: Relatively few failures** | 1 in 15,000 | **3** |
| | 1 in 150,000 | **2** |
| **Remote: Failure is unlikely** | <1 in 1,500,000 | **1** |

1) Very High (10 - 9): A ranking of 10 or 9 suggests that failure is almost inevitable
2) High (8 - 7): For a high probability level, failure is frequent but not inevitable.

3) Moderate (6 - 4): Moderate probability implies occasional failures, with occurrences ranging from once in every 80 uses to once in every 2,000 uses.
4) Low (3 - 2): A low probability ranking means relatively few failures, such as one in every 15,000 to 150,000 uses.
5) Remote (1): A remote probability level implies that failure is very unlikely, with an occurrence rate of less than one in 1,500,000 uses.

**Detectability Level Charts**

The FMEA detection level chart categorizes the probability of identifying a failure mode or its cause prior to its manifestation as a problem, spanning from "Absolute Uncertainty" to "Almost Certain." This scale assesses the efficacy of existing controls in identifying probable problems within the motor and gearbox system, facilitating preventative measures. This is the application of the detection levels:

**Tabel 4. Detection Level Charts**

| Detection | Likelihood of DETECTION | Ranking |
|---|---|---|
| **Absolute Uncertainty** | Design control will not and/or can not detect a potential cause/mechanism and subsequent failure mode; or there is no design control | **10** |
| **Very Remote** | Very remote chance the design control will detect a potential cause/mechanism and subsequent failure mode | **9** |
| **Remote** | Remote chance the design control will detect a potential cause/mechanism and subsequent failure mode | **8** |
| **Very Low** | Very low chance the design control will detect a potential cause/mechanism and subsequent failure mode | **7** |
| **Low** | Low chance the design control will detect a potential cause/mechanism and subsequent failure mode | **6** |
| **Moderate** | **Moderate chance the design control will detect a potential cause/mechanism and subsequent failure mode** | **5** |
| **Moderately High** | **Moderately high chance the design control will detect a potential cause/mechanism and subsequent failure mode** | **4** |
| **High** | High chance the design control will detect a potential cause/mechanism and subsequent failure mode | **3** |
| **Very High** | Very high chance the design control will detect a potential cause/mechanism and subsequent failure mode | **2** |
| **Almost Certain** | Design control will almost certainly detect a potential cause/mechanism and subsequent failure mode | **1** |

1) Absolute Uncertainty (10): If detection is rated as 10, there is no design control in place to detect the motor or gearbox failure, meaning issues could occur without warning.
2) Very Remote (9): Detection rated as very remote indicates an extremely low chance of identifying a failure mode in the motor or gearbox.
3) Remote (8): A remote rating means there’s a small chance that existing controls will detect failures.

4) Very Low (7): With a very low detection rating, it's unlikely that failures in the motor or gearbox will be caught by current controls, but there is a slightly higher chance compared to remote levels.
5) Low (6): A low detection rating suggests a low likelihood of identifying failures, though there is some potential for detection.
6) Moderate (5): At this level, there is a moderate chance of detecting motor or gearbox failures
7) Moderately High (4): A moderately high detection rating means there's a reasonably good chance
8) High (3): A high detection rating indicates that there's a strong likelihood that existing controls,
9) Very High (2): With a very high rating, there is an excellent chance of detecting issues
10) Almost Certain (1): An almost certain detection level means that any potential cause of failure in the motor or gearbox is almost guaranteed to be identified before it can lead to an issue

This Failure Mode and Effects Analysis (FMEA) concentrates on the motor and bevel helical gearbox employed to operate the belt conveyor in the maintenance department of BLC. The research delineates probable failure mechanisms, including overheating, excessive vibration, misalignment, and wear in certain motor and gearbox components.

Department: Maintenance
Lokasi : BLC

Failure Mode Effect Analysis

| Sl.No. | Business / Service | Asset Name/ Spesific Part | Asset Number | Function | Potential Failure Mode(s) | Potential Technical Effect(s) of Failure | Potential Business Consequence(s) of Failure | Sev | Potential Cause(s)/ Mechanism(s) of Failure | | | Prob | Current Controls: Preventive Controls | Current Controls: Detective Controls | Det | RPN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Motor | | Penggerak Belt Conveyor | Motor Panas | Motor Rusak | Loss Production karena conveyor | 6 | Overload | Fan tidak optimal | N/A | 3 | Mempertahankan ampere dibawah 90% | Temperature Monitoring & Visual Inspection | 4 | 72 |
| | | | | | Bearing Motor Rusak | Motor tidak dapat berputar | Loss Production karena conveyor stop | 8 | Lubrikasi tidak optimal | kontaminasi | N/A | 3 | Relube Bearing | Vibration Monitoring | 6 | 144 |
| | | | | | Motor Overload | Motor Rusak | Loss Production karena conveyor stop | 6 | Muatan berlebihan | N/A | N/A | 3 | Mempertahankan ampere dibawah 90% | Memperhatikan load pada conveyor | 3 | 54 |
| | | | | | Vibrasi tinggi | Motor Rusak, Noise | Loss Production karena conveyor stop | 6 | Misalignment | Motor Unbalance | N/A | 3 | Vibration Monitoring | Vibration Monitoring | 8 | 144 |
| | | | | | Rotor Rusak | Motor Rusak, Noise | Loss Production karena conveyor stop | 6 | Misalignment | Motor Unbalance | N/A | 3 | Vibration Monitoring | Vibration Monitoring | 7 | 126 |
| | | Bevel Helical Gearbox | | Mengubah torsi dan kecepatan dari Motor Belt Conveyor | Teeth Gear Aus | Noise, Efisiensi berkurang | Pembelian Gearbox Baru | 8 | Kurangnya lubrikasi | Overload | N/A | 3 | Pengecekan level oli dan penambahan oli jika kurang | Vibration Monitoring | 6 | 144 |
| | | | | | Bearing Gearbox Rusak | Bearing tidak dapat berputar | Loss Production karena conveyor stop | 8 | Lubrikasi tidak optimal | kontaminasi | N/A | 3 | Relube Bearing | Vibration Monitoring | 3 | 72 |
| | | | | | Seal Aus | Oli bocor, lubrikasi berkurang | Cost penambahan oli dan pencemaran lingkungan | 5 | Instalasi tidak benar | kontaminasi | N/A | 5 | Pengecekan berkala seal gearbox | Visual Inspection | 2 | 50 |
| | | | | | Vibrasi Tinggi | Gearbox Rusak, Noise | Loss Production karena conveyor stop | 6 | Gear aus | Mechanical loosenes | N/A | 3 | Vibration Monitoring | Vibration Monitoring | 8 | 144 |
| | | | | | Misalignment | Vibrasi tinggi, Teeth Aus | Loss Production karena conveyor stop | 6 | Tidak dilakukan alignment | Mounting kendor | N/A | 3 | Vibration Monitoring | Vibration Monitoring | 8 | 144 |

**Figure 23. Failure Mode Effect Analysis Motor and Gearbox PT Angsana Coal**

The primary emphasis of the table is on Failure Mode Effect Analysis with vibration analysis, a method to identify problems such as misalignment, imbalance, or component defect in motors and gearboxes that operate belt conveyors. Excessive vibration in motors might suggest issues such as rotor unbalance or bearing wear. Upon multiplying the Severity, Probability, and Detection scores, the Risk Priority Number (RPN) is determined, which serves as an indicator of the level of urgency in resolving these concerns. High Reliability Provision Number (RPN) values, such as 144 seen in instances of misalignment and bearing failure, emphasise the importance of promptly implementing preventative actions to reduce risks and guarantee the dependability of the conveyor system.

Compare the performance of current maintenance practices with predictive maintenance models. Contrasting contemporary maintenance techniques with predictive maintenance models reveals notable disparities in efficiency, cost-effectiveness, and equipment dependability (West et al., 2024).

**Improve**

***Develop Solutions:***

Implementing predictive maintenance with vibration analysis is crucial for improving the reliability of the Bunati conveyor system. This approach allows early detection of wear in key components like the gearbox and motor, enabling timely interventions before major failures occur. Integrating this data into a Computerized Maintenance Management System (CMMS) enhances maintenance planning and scheduling based on real equipment conditions rather than fixed timelines (Jonassen, 2024). Figure 24 Integrate CMMS with vibration analysis data to enhance maintenance planning and scheduling.

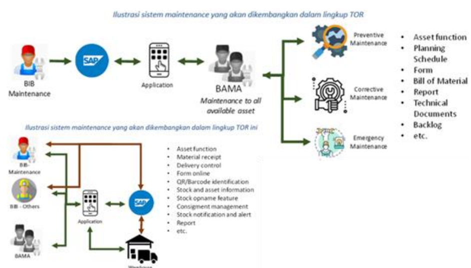


**Figure 24. Flowchart Computerized Maintenance Management System PT Angsana Coal**

Training is a critical component in transitioning to a predictive maintenance strategy. Maintenance personnel must be equipped with the skills to use vibration analysis tools and interpret the resulting data effectively. Training should cover the basics of vibration analysis, the operation of instruments like accelerometers and vibration meters, and proper data collection techniques. Additionally, team members should learn to analyze vibration spectra and time-waveform data to identify common issues such as misalignment, imbalance, bearing defects, and gear wear, ensuring efficient monitoring and maintenance of key equipment like motors and gearboxes.

**Control**

In the Control phase, a systematic methodology is essential to maintain the enhancements realized via predictive maintenance and to guarantee the enduring reliability of the Bunati conveying system. Ongoing surveillance is crucial.

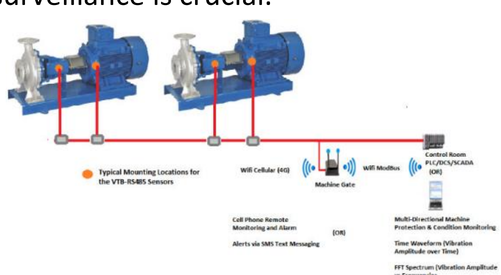


**Figure 25.Integration CMMS with Vibration data PT Angsana Coal**

Standardization in figure 25 is essential for ensuring consistency and efficiency in predictive maintenance operations. Formulating Standard Operating Procedures (SOPs) for executing vibration analysis and interpreting outcomes will direct the team through each phase, guaranteeing adherence to best practices in all maintenance activities. The predictive maintenance approach should be routinely evaluated and modified according to performance data and team feedback to facilitate continuous improvement. This method facilitates the enhancement of maintenance methods as new knowledge and technology develop.

## CONCLUSION

The research on predictive maintenance for motor and gearbox systems at PT Angsana Coal has demonstrated significant improvements in operational reliability and equipment longevity. By transitioning from a reactive and planned maintenance strategy to a predictive maintenance framework grounded in vibration analysis, PT Angsana Coal has successfully reduced the frequency and severity of unforeseen failures, leading to enhanced system performance and minimized downtime. The application of Failure Mode and Effects Analysis (FMEA) enabled the identification and prioritization of critical failure modes, such as bearing wear and misalignment, allowing for effective implementation of preventative measures. The results, including the substantial reduction in vibration levels post-maintenance interventions, highlight the effectiveness of predictive maintenance in stabilizing equipment functionality and achieving compliance with ISO 10816-3 standards. These findings confirm that predictive maintenance, supported by systematic analysis and targeted interventions, provides a reliable framework for optimizing equipment performance in mining operations.

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