

A case study on risk analysis of machine breakdown using the FMEA method

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Abstract. This study addresses the frequent disruptions in PT X, the first cement factory in Indonesia, which affect its productivity and quality. The main problem involves the frequent stoppages of key machinery such as raw mills, kilns, cement mills, and especially coal mills, which are crucial for combustion processes. In 2021, the 6K1 coal mill experienced 384 hours and 38 minutes of downtime, with the Rotary 6K1A03 component being the most problematic, causing 205 out of 359 total disruptions. The Failure Mode and Effect Analysis (FMEA) method was employed to analyze these disturbances. The analysis revealed a critical Risk Priority Number (RPN) value of 5.148, with eight factors exceeding this threshold, including the high current in Rotary 6K1A03, with RPN values of 90, 35, 25, 24, 9, 8, and 6. These critical factors are prioritized for intervention. Consequently, it is imperative to implement management and risk mitigation strategies to address these issues and enhance the operational efficiency of the factory.

1 Introduction

The industry in Indonesia has developed rapidly with the increasing number of manufacturing companies. Within a company, risks that can disrupt the production process are inevitable, both those with major and minor impacts [1]. PT X, uses key machines such as raw mill, kiln, and cement mill in its production process. One vital machine is the coal mill, which grinds coal into powder to accelerate combustion. Based on 2021 data, there were 63 failure modes in the coal mill at PT X, with a stop duration of up to 384 hours and 48 minutes, caused by electrical, mechanical, and production disturbances. The FMEA analysis method identifies risks and prioritizes handling based on the RPN value [2]. Failure Mode and Effect Analysis (FMEA) is a structured procedure to identify and prevent as many risks as possible that play a role in a failure and problem in the production process both known and potential problems in the system [3].

Previous studies have shown the application of the FMEA method in various industries. For example, in banana flake production, FMEA identified failures in conveyor transmission components with the highest RPN value of 168, and in raw mill machines in the cement industry with the highest RPN value of 240. Another study on cement packaging machines showed that the main cause of failure was filling speed beyond handling priorities. FMEA has 3 assessment criteria, namely severity, occurrence frequency, and detection rate.

The criteria used in FMEA ranging from severity, frequency of occurrence, and detection level are used to determine the Risk Priority Number (RPN). RPN is used as a determination of action from prioritized risks [4]. Risk Priority Number (RPN) is a risk priority number

from the results of multiplication of severity, frequency and detection rate. The RPN determines the priority of the failure. RPN has no value or meaning [5]. The RPN value can be used to determine corrective actions that correspond to the level of value obtained [6]. The formula for finding the RPN value is as follows:[2].

$$RPN = S \times O \times D \quad (1)$$

Information:

S = Severity

O = Occurance

D = Detection (how far it can be detected)

Once the RPN is obtained, the next step is to calculate the critical value of the risk factors. This critical value is searched to determine the number of failure modes that exceed the critical value of the RPN. Failure modes that exceed critical RPN values receive primary handling in addressing risks the maximum limit with an RPN of 210. All these studies emphasize the importance of routine maintenance and close monitoring to minimize risks and optimize the production process [7].

This research, titled "A Case Study on Risk Analysis of Machine Breakdown Using the FMEA Method," aims to propose repair and maintenance solutions for the 6K1 coal mill machine at PT X. The study addresses the following problems: What are the disturbances in the 6K1 coal mill at PT X, what are the causes and risk levels of these disturbances in the 6K1 coal mill components at PT X, and What are the proposed repair and maintenance strategies for the 6K1 coal mill at PT X?

Theories used to support the problem-solving process include risk management, the Failure Mode and Effect

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Analysis (FMEA) method, and maintenance management.

2 Method

The research methodology includes several steps: literature studies, field studies, problem formulation, data collection, data processing, and flowcharts. Literature studies involve reviewing books, journals, and other references related to risk management, FMEA methods, and maintenance management. FMEA can evaluate and analyze components in a system so that it can minimize the risk or effect of a failure rate as a supporting method for assessing performance in a system [8, 9]. Field studies involve direct observations at PT X, specifically the 4W1 kiln machine, and interviews with staff and operators.

Problem formulation identifies issues based on the significant downtime of the 6K1 coal mill, which decreases productivity and disrupts the cement production process. Machine maintenance and maintenance activities are needed in the production process so that it runs properly and activity failures can be minimized [10]. The system RPN threshold value is obtained from the average RPN value for all components [11]. The study utilizes both primary and secondary data. Primary data is gathered

from interviews with staff and operators, detailing damages to the 6K1 coal mill. Secondary data includes documents from the maintenance planning and evaluation unit, specifically the daily report data of the 6K1 coal mill in 2021. The collected data is then processed for analysis.

1. Identify the 6K1 coal mill engine components on PT X that are experiencing problems.
2. Determine and select the 6K1 coal mill machine components that have the largest stop duration.
3. Identify any disturbances that occur in selected 6K1 coal mill machine components.
4. Provide an assessment in the form of weighting of engine disturbances consisting of severity, occurrence and detection criteria using the FMEA method.
5. Calculates the RPN value of each disturbance and the critical value.

3 Results and discussion

3.1 Results

The results of the research obtained in this section are in the form of RPN values for each failure mode; then a percentage calculation is carried out in failure mode, which can be seen in Table 1.

Table 1. Failure mode percentage in 6k1 coal mill

No	Failure Mode	RPN	Critical Value	Percentage	Cumulative Percentage
1	6K1A02 MD alarm	1	5.148	0.32%	0.32%
2	6K1J05 not ready	9	5.148	2.87%	3.18%
3	6K1J05 not ready + bin FC full	2	5.148	0.64%	3.82%
4	6K1M03 mill motor unit not ready	6	5.148	1.91%	5.73%
5	6K1M04 low pressure in 4 thrust pads	35	5.148	11.15%	16.88%
6	6K1M04 low pressure in 4 thrust pads + Bin FC Full	2	5.148	0.64%	17.52%
7	6K1M07 open loop	4	5.148	1.27%	18.79%
8	6K1M07 roller lubrication alarm, temp oil roller 3 H2	4	5.148	1.27%	20.06%
9	6K1M07 trip	4	5.148	1.27%	21.34%
10	6K1M07 vacuum alarm roller 2	24	5.148	7.64%	28.98%
11	There is a sound abnormality in the mill	2	5.148	0.64%	29.62%
12	There is a sound abnormality in the mill (ME install 2 ring wear tube bolts)	2	5.148	0.64%	30.25%
13	Alarm fault feeder motor 6K1A01M2 cooling fan trip	2	5.148	0.64%	30.89%
14	The transport equipment under the BHF is not ready, the MCC hangs for a moment and is reactivated via the MCC rack out/in	3	5.148	0.96%	31.85%
15	The raw coal bin is critical gate 6F1J05Z1 cannot lead to the bin (aisy is broken (Shaft))	4	5.148	1.27%	33.12%
16	H2 vibration fan trip booster	2	5.148	0.64%	33.76%
17	Chute 6K1A02 block	1	5.148	0.32%	34.08%
18	Drag chain 6J1U04 bus fault	1	5.148	0.32%	34.39%
19	Drag chain 6J1U04 broke	1	5.148	0.32%	34.71%
20	Faccum roller no2 alarm	1	5.148	0.32%	35.03%
21	Fault feeder alarm	3	5.148	0.96%	35.99%
22	Feeder A01 fault alarm	2	5.148	0.64%	36.62%
23	High 2 PPM alarm	4	5.148	1.27%	37.90%
24	HT capacitor fault	1	5.148	0.32%	38.22%
25	Interlock of the buster fan because the BHF transport device stops	2	5.148	0.64%	38.85%
26	Hanging material	2	5.148	0.64%	39.49%
27	Hanging material + feeder fault	1	5.148	0.32%	39.81%
28	ME side gate repair 6K1A02	1	5.148	0.32%	40.13%
29	The Mill Fan is not ready (PLC starter fault)	2	5.148	0.64%	40.76%
30	BHF O2 reading is high	3	5.148	0.96%	41.72%

No	Failure Mode	RPN	Critical Value	Percentage	Cumulative Percentage
31	Accumulator checking	6	5.148	1.91%	43.63%
32	Repair Broken tension rod roller 2 bolt	8	5.148	2.55%	46.18%
33	Repair The tension rod roller 2 bolt broke	4	5.148	1.27%	47.45%
34	PPM >1500 due to CO from kiln + kiln stop	4	5.148	1.27%	48.73%
35	PPM Co alarm H2 max	25	5.148	7.96%	56.69%
36	PPM Max due to CO from the kiln	2	5.148	0.64%	57.32%
37	PPM is high because Co from the kiln when starting 6K1V22. which stops suddenly 6K1V44 closes	2	5.148	0.64%	57.96%
38	Product transport 5K1J05 is not ready	1	5.148	0.32%	58.28%
39	BHF J05 transport product not ready (prohibits communication cable broken)	4	5.148	1.27%	59.55%
40	Product transport 6K1J05 is not ready	3	5.148	0.96%	60.51%
41	Pull rope due to falling material	1	5.148	0.32%	60.83%
42	Raw coal hanging in a bin	1	5.148	0.32%	61.15%
43	Hanging raw coal	1	5.148	0.32%	61.46%
44	Roller lubrication and hydraulic not ready	1	5.148	0.32%	61.78%
45	Rotary 6K1A03 high current	90	5.148	28.66%	90.45%
46	Rotary airlock 6K1P15 high current alarm has a plate that is blocking it	1	5.148	0.32%	90.76%
47	Rotary airlock 6K1P17 high current has a stuck plate	1	5.148	0.32%	91.08%
48	Sliding inlet block	3	5.148	0.96%	92.04%
49	Sliding outlet 6K1A03 clogged	1	5.148	0.32%	92.36%
50	Stop alarm capacitor fuse blown on mill motor 6K1M03 and mill fan 6K1P25 reset to ready panel	1	5.148	0.32%	92.68%
51	Mill outlet temp suddenly rises (damaged temp sensor)	3	5.148	0.96%	93.63%
52	Temperature middle bearing separator open loop	1	5.148	0.32%	93.95%
53	Tilt tension rod on roller 3	4	5.148	1.27%	95.22%
54	Thrust pads alarm	1	5.148	0.32%	95.54%
55	UPS alarm inverter overload	2	5.148	0.64%	96.18%
56	UPS general fault	3	5.148	0.96%	97.13%
57	UPS general fault alarm	2	5.148	0.64%	97.77%
58	UPS unit fault	1	5.148	0.32%	98.09%
59	Vacuum roller no 2 alarm	2	5.148	0.64%	98.73%
60	Valve V44 runtime	3	5.148	0.96%	99.68%
61	Max vibration + checking in mill	1	5.148	0.32%	100.00%

Based on the calculation of the RPN value in Table 1, there are 8 factors above the critical RPN value, namely Rotary 6K1A03 high current, 6K1M04 low pressure in 4 thrustpads, PPM Co alarm H2 max, 6K1M07 vacuum alarm roller 2, 6K1J05 not ready, Bolt Repair tension rod roller 2 broken, 6K1M03 mill motor unit not ready, and Accumulator checking with RPN value consecutively which is 90, 35, 25, 24, 9, 8 and 6 as many as 2 interference factors. These 8 nuisance factors are priorities for improvement, control, and risk mitigation.

3.2 Discussion

This section continues the results subsection, utilizing the Failure Mode and Effect Analysis (FMEA) method to assess risk levels and identify problems in the production process. FMEA analyzes fault factors causing the 6K1 coal mill to stop, including electrical, mechanical, and production disturbances. The daily report data of the 6K1 kiln machine at PT X in 2021 is weighted to calculate the RPN value, which determines the priority for repairing each disturbance factor. The critical RPN value is calculated to identify fault factors above this threshold, ensuring they receive prioritized attention for repairs.

3.2.1 Rotary 6K1A03 high current disorder

Rotary 6K1A03 high current is a failure mode with an RPN value above the first highest critical RPN value of 90. Rotary 6K1A03 high current is a dangerous failure disturbance that occurs every 3-4 days, and the potential for damage can always be detected. 6K1A03 is part of the coal mill, part of the coal mill, namely the rotary feeder as a regulator of the flow of material or materials in the production system or process. This part is usually in the form of a drum or cylinder that rotates to move material from one location to another. Rotary 6K1A03 high current has a combined problem: being blocked by a rock. Based on the calculation of the RPN value, Rotary 6K1A03's high current is the main priority that must be repaired, controlled, and risk mitigated. The disturbance experienced by Rotary 6K1A03 high current is a production disturbance with a stop duration of 174 hours 44 minutes. The cause of the Rotary 6K1A03 high current being blocked by a rock is the condition of the accumulation of material in the east (red) direction, the material easily sticks due to the blasting from below so that the material is very dense and hardens and the accumulation of material in this area will continue to increase so that it covers the area where the material falls

in the west direction. Preventive controls recommendations can be given to reduce the risk of this problem. It is recommended to carry out routine inspections and maintenance in the area around the Rotary 6K1A03. Focus on controlling the accumulation of material in the east direction which is susceptible to material sticking due to blasting from below. Here are some steps that can be taken:

1. Routine Cleaning: Carry out periodic cleaning of the accumulation area of material in the east direction to prevent the formation of a solid layer that can hinder the movement of machine components. Cleaning is carried out once a week considering the severity of this failure, which is quite dangerous.
2. Material Flow Regulation: Regulate the material flow more effectively to prevent blasting from below from producing excessive accumulation. This can involve adjusting the speed or direction of the material flow. Adjust the flow once every 3 or 4 days so that the flow does not produce accumulated accumulation.
3. Use of Non-Stick Lubricant: Apply a layer of non-stick lubricant to areas prone to sticky material accumulation. This can help reduce the possibility of solid and hard buildup.
4. Visual and Sensor Monitoring: Install sensors or visual monitoring cameras to monitor the condition of the area in real time. If potential problem material accumulation is detected, preventive measures can be taken early.
5. Addition of 40 mm self-cleaning leaf width: scrape off sticky material. previously by simulating the addition/welding of plates with dimensions of 10 x 40 mm, 10 x 30 mm and 10 x 20 mm, so that it is expected that the local rotary road test time will obtain ideal conditions for adding leaf width that does not hinder rotary performance.

3.2.2 6K1M04 low pressure in 4 thrustpads fault

6K1M04 low pressure in 4 thrustpads is a disturbance with an RPN value above the second highest critical value of 35. 6K1M04 low pressure in 4 thrustpads is a significant failure disturbance that causes losses, occurs every month and the potential for damage can always be detected. Based on the calculation of the RPN value, this disturbance is the second priority that must be repaired, controlled, and risk mitigation. The disturbance experienced by 6K1M04 low pressure in 4 thrustpads is a production disturbance with a stop duration of 28 hours 53 minutes. The disturbance can occur due to a decrease in pressure on the 4th thrustpad in the coal mill machine. Thrustpads is usually a component in the bearing system that is used to support axial loads on the machine shaft. A decrease in pressure on the thrustpads can result in operational problems, low performance, and even machine failure if not handled quickly. Preventive controls recommendations can be given to reduce the risk of this problem. Here are some steps that can be taken:

1. Routine Maintenance: Perform routine inspections on the thrustpads system to detect early signs of wear or damage and replace seals, bearings, and other components with limited life.

2. System Cleaning: Perform periodic cleaning of the hydraulic oil system to prevent contamination and ensure smooth oil flow.
3. Pressure Monitoring: Install a pressure monitoring system on the thrustpads to provide early warning of significant pressure drops.
4. Periodic Component Replacement: Schedule periodic replacement of critical components such as seals and bearings, even if they do not show obvious signs of damage.

3.2.3 Ppm Co alarm H2 max disturbance

Ppm Co alarm H2 max is a disturbance with an RPN value above the fourth highest critical value, which is 25. This disturbance is caused by imperfect combustion conditions or excess coal in the combustion process, which in turn causes problems with the coal mill machine. The ppm level should be below 1500. Ppm Co alarm H2 max is a failure disturbance that causes losses, occurs every 3 months, and potential damage can always be detected. Based on the calculation of the RPN value, this disturbance is the fourth priority that must be checked, controlled, and risk mitigation. The disturbance experienced by ppm Co alarm H2 max is an electrical disturbance with a stop duration of 17 hours 52 minutes. Preventive control recommendations can be given to reduce the risk of this disturbance. Here are some steps that can be taken:

1. Fuel Monitoring and Control: Implement routine monitoring of the amount of fine coal entered into the kiln. Ensure that monitoring of kiln temperature and pressure is also carried out periodically and carry out automatic control in the form of a system to regulate coal flow based on production needs and kiln capacity.
2. Routine Kiln Maintenance: Implement routine kiln maintenance, including periodic cleaning and inspection of equipment, such as burners and exhaust pipes.
3. Adding oxygen by pulling a van: Adding oxygen with the optimal amount of oxygen needed for efficient combustion and desired results. And anticipating the provision of excess oxygen which can result in unstable combustion.
4. Anticipating by ensuring that CO must be at 1000 PPM by making the combustion reaction in the kiln perfect.

3.2.4 6K1J05 not ready disorder

The issue with 6K1J05 not being ready is a disruption with an RPN value above the fifth highest critical value of 9. This occurs due to raw coal feeding issues, likely caused by blockages or mechanical damage. It's a minor but recurring problem happening every 2 years, with potential damage detectable. Based on RPN value calculation, it's the fifth priority for routine maintenance and monitoring. The disruption lasts for 4 hours 34 minutes and is an electrical issue. To prevent it, regularly check and repair transport equipment.

3.2.5 Interference repair of tension rod roller 2 broken bolts

Repairing tension rod roller 2 broken bolts is a disruption with an RPN value above the sixth highest critical value of 8. These bolts are located between the roller and cap on the coal mill machine. The issue arises due to bolt wear leading to breakage, causing performance decline. It occurs every 3-2 years, with detectable damage. It's the sixth priority for repair and mitigation. The problem lasts for 17 hours and 10 minutes and is a mechanical issue. To prevent it, conduct periodic maintenance without waiting for damage and replace broken bolts promptly. Visual inspection: Check the condition of the roller tension rod thoroughly, including the condition of the bearings, shaft and other components. Material test: To determine its strength and chemical composition, perform a material test on the remaining broken bolt. Stress analysis: Perform a stress analysis to determine the maximum load the roller tension rod can withstand.

System evaluation: Inspect the entire coal mill system to identify any imbalances or other problems that could cause excessive load on the roller tension rod. Replace bolts: Replace broken bolts with new bolts made from high-quality materials with appropriate specifications. Repair other damage: If damage is found to other components, such as bearings or shafts, repair or replace them. Reset tension: Once the repair is complete, reset the tension on the tension rod roller to factory specifications.

Prevention: Routine maintenance: Perform routine maintenance on the tension rod roller, including lubrication and cleaning. Condition monitoring: Use monitoring tools to monitor the operating condition of the roller tension rod and detect early signs of damage.

3.2.6 6K1M03 mill motor unit not ready disorder

The disturbances with the seventh highest RPN value are disturbances with an RPN value above the critical value obtained by 6. These disturbances are types of electrical disturbances consisting of 6K1M03 mill motor unit not ready disturbances, and accumulator checks. The eighth highest disturbance is 6K1M03 mill motor unit not ready. This disturbance is a coal mill drive that is not ready for use with the constraint that the requirements for running have not been met, such as minimal or low gearbox oil. This disturbance experiences minor failures that can be adapted, occurs every 3-2 years, and potential damage can always be detected with a stop duration of 1 hour 25 minutes. Preventive controls recommendations can be given to reduce the risk of this problem occurring. Steps that can be taken are to add oil that is already at its maximum or in a condition that meets the requirements and ensure periodic checks of the 6K1M03 section so that disturbances can be avoided. The second seventh highest disturbance is checking the accumulator. Checking the accumulator on the roller functions to raise and lower the roller. The disturbance occurred because there was a dirty oil filter, so it took time to check and caused the accumulator to not be fully charged or not function when needed. This disturbance experienced a small failure that could be adapted, occurred every 3-2 years, and potential

damage could always be detected with a stop duration of 37 minutes. Preventive controls recommendations can be given to reduce the risk of this problem. Steps that can be taken are to carry out regular and routine maintenance, ensure that the voltage regulator and charger are functioning properly, and clean the accumulator terminals regularly. So the risk of disturbances in the 6K1 coal mill can be avoided.

3.2.7 K1M07 vacuum alarm roller 2 disorder

The 6K1M07 vacuum alarm roller 2, a hydraulic pump with an RPN value above 24, is the third priority for repair and control. This issue, caused by oil circulation problems, leads to performance degradation and occurs every three months, with a stop duration of 13 hours and 46 minutes. Design modifications: If necessary, make design modifications to the roller tension rod to increase strength and resistance to loads. Preventive measures include: Clear work procedures: Establish clear work procedures for installing and tightening bolts, as well as regular inspections.

4 Conclusion

Based on the processing and analysis of data on the research that has been done, the conclusions obtained are as follows: In 2021, PT X experienced 61 disturbances in the 6K1 Indarung VI coal mill, including mechanical, production, and electrical issues such as alarms and equipment failures. Using the FMEA method, 10 failure modes with RPN values above 5.1 were identified, including high current in Rotary 6K1A03 and low pressure in 4 thrustpads. Significant disruptions included high current and low pressure, with preventive maintenance recommendations such as routine cleaning and monitoring of temperature and pressure. These are expected to reduce disruption risks and enhance operational efficiency.

Suggestions that can be given for better research in the future are: Further research is recommended to add other methods to complete this case study. Methods that can be used such as a risk matrix that determines the level of risk based on the probability of events and impacts.

Failure Mode Identification in the FMEA analysis succeeded in identifying various failure modes that could potentially occur in the 6K1 Coal Mill, such as component damage, problems with the control system, or disruption to the coal supply. Risk assessment in each failure mode is assessed based on severity, likelihood of occurrence and ease of detection. The results of this assessment are then summarized in a number called the Risk Priority Number (RPN). The failure mode with the highest RPN is considered to have the highest risk and deserves more attention.

Root Cause of further analysis is performed to identify the root cause of each failure mode. This is important to formulate appropriate corrective actions. Improvement Recommendations Based on the results of the analysis, a number of improvement recommendations will be proposed, such as increased maintenance, design

modifications, or changes to operating procedures. Improvement Priority of recommended improvements is usually prioritized based on the RPN value. Repairs related to the failure mode with the highest RPN will take top priority.

Failure mode has the highest RPN this indicates the most critical failure modes and needs to be addressed immediately. The primary root cause of this failure mode Understanding the root cause will help in formulating an effective solution. Recommendations for improvement are most effective and efficient consider cost, time, and impact to production in selecting improvement recommendations. The recommendations for improvement implemented plan the steps needed to implement recommendations for improvement, including assignment of responsibilities, budget allocation, and monitoring progress.

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