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Analysis of sag mill machine performance using overall equipment effectiveness (OEE) and failure model and effects analysis (FMEA) method

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ABSTRACT

The mining company uses a variety of grinding machines to process minerals, whereas the most common type of machine is the Semi-Autogenous Grinding SAG Mill machine. This machine is employed for the mining process of hard rock as raw material into gold, copper, and silver. However, the SAG Mill machines are often broken, even suddenly not working, with an average loss time of 97.30 hours which impacts a decrease in efficiency and production quality of up to 40%. It can cause losses that do not reach the production target. This research aims to measure the effectiveness of the SAG Mill machine and determine the failure using the OEE and FMEA methods. The results showed that the SAG Mill machine is still under standardized based on the Japan Institute of Plant Maintenance (JIPM), which is 85%. The FMEA method and RPN value apply to analyze downtime losses, and idling is the loss that highly affects the effectiveness of SAG Mill machines. Recommendations for the company are to increase the number of equipment that aims to prolong the machine's age and accelerate production. This research contributes to another solution to help maintenance managers by measuring the effectiveness and determining the failure of the SAG Mill machine

INTRODUCTION

The mining industry is inseparable from heavy machinery or the main production machine. The outcome between current domestic enterprises and new entrants, the organization gains access to a more competitive market environment to maintain and expand its respective market shares [1]. So it must develop and optimize the production process, quality control, and quality management [2]. This work's discovery of issues related to various additive manufacturing techniques is noteworthy [3]. The goal is to create items at a profit by utilizing an effective maintenance system that helps enhance availability by minimizing machine downtime [4].

Mining companies use a variety of grinding machines to process minerals. The most common type of machine is the SAG Mill [5]. SAG Mill uses semi-autogenous grinding in the coal and ores process due to their strong applicability, large capacity, and low consumption to grind certain media [6]. The filling level is a significant parameter of the SAG Mill, as it affects both the processing capacity of the Mill and the operation costs and stability [7]. Overcapacity and long continuous operation, big problems will occur when the machine stops suddenly and causes downtime. This machine suddenly stops making the target product quality often not achieved, disrupts the production process, and harms the company. Those problem causes the production effect to decrease until the production output is 40% with an average downtime of 97.30 hours, and a decrease in company profits and reduced machine efficiency. The SAG Mill engine is the core engine used by the company for further production. Analyzing machine efficiency as the value of machine availability during the production process, effective machine performance in producing products, and the level of product quality produced by the machine are necessary. The results of the machine efficiency will be used as the implementation of preventive maintenance to prevent time loss in the future.

Total Productive Maintenance is a planning system that helps businesses improve the quantity and quality of their production by examining the effectiveness of their machinery, equipment, processes, and people [8]. TQM uses as the alternative solution to maintenance implementation [9]. Overall Equipment Effectiveness (OEE) is one of the methods used to improve the status and effectiveness of the production process. The OEE requires identifying the source of the problem from the most common and important sources of production losses and fixing it. [10] Total Productive Maintenance (TPM) has been introduced in Japan to help solve system maintenance problems by giving operators and employees more responsibility [11]. To structure it coordinately, TQM aims to bring production and maintenance functions through good work practices, teamwork, and continuous improvement. The Japan Institute of Plant Maintenance (JIPM) has proposed an eight-pillar plan for improving TPM implementation that will substantially increase labor productivity through controlled maintenance, reduced maintenance costs, and reduced production stoppages and downtimes [12].

Based on previous research conducted by Sakti (2019) [13] aims to develop a computerized database system to help measure the OEE calculation so it can help the company knows their real-time machine performance. The system contributes to automating the process of OEE calculation and identifies the losses associated with equipment effectiveness. Failure mode and effect analysis (FMEA) uses to identify the losses that highly decrease the effectivity. According to previous research by Beatrix (2021) [14], The OEE applies to determine the effectiveness of systems and manufacturing processes, such as availability, performance, and quality and is also used to measure machine effectiveness. This study aims to measure the effectiveness of the Stretch Blow machine at PT. X by calculating the Overall Equipment Effectiveness (OEE) value. Stretch Blow Machine is one of the machines used in the production process of plastic bottles. These machines often suffer damage making targets and not achieving product quality. According to research by Pholmeyer (2022) [15], the study presents an approach for a data-driven failure risk assessment validated on real-world process data of a nonwoven production line. In this approach, association rule mining applies to continuous processes for producing highly interpretable results in the primary causes of failures. The result of this paper is a method for an interpretable risk assessment in continuous production processes. By using OEE and FMEA in live production, causes of failures can be detected and interpreted. Based on previous research conducted by Wang (2021) [16]. The primary purpose of the FMEA in this paper is to identify potential effects and rank them according to their severity. Risk assessment in FMEA is to determine the risk level for each potency failure based on its ranking in terms of risk priority numbers (RPN).

The FMEA adopts an RPN model for prioritization of potential failure models. The classical method of criticality assessment yields RPN values that vary in the first half of the allowable range. [17]. To determine the relative importance of the identified failure modes and effects for the second analysis (criticality analysis), a quantitative index, Risk Priority Number (RPN), is calculated. Occurrence (O), severity (S), and detection (D) of a failure are the based point of RPN [18]. The engine efficiency, and the size of the ratio of the six elements of the six

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most losses equipment failure, set-up, and adjustments, idling and minor stoppages, reduced speed, scrap and rework, and startup losses [19].

The study aims to evaluate SAG Mill Machine performance using overall equipment effectiveness (OEE). The calculated variables can be analyzed as follows availability rate, performance rate, and quality rate to be expected. Therefore, FMEA can make suggestions to overcome the causes of productivity loss and improve the performance of the SAG Mill machine. This research contributes to another solution to help maintenance managers by measuring the effectiveness and determining the failure of the SAG Mill machine.

METHOD

1. Research Stage

The following is an explanation of the stages carried out in this research:

- Literature review and problem identification

A literature review is carried out to study theory and science. The production department carries out the preliminary survey directly, observing the production process from the raw to the finished material.

- Problem Formulation and Research Objectives

After studying the theory related to the problems found, the next step is the problem and setting research objectives.

- Data Collection

Data collection is collecting data needed in research through interviews, direct observation, or data already available at the research site.

- OEE Calculation

The data collected determines the value of availability, performance, and quality. After getting the availability, performance, and quality values, the next step is calculating the OEE value with the formula.

- JIPM

Comparing The OEE value with the Japan Institute of Plant Maintenance (JIPM). JIPM has been widely used throughout the world by a standard of 85%

- FMEA Calculation

The initial stage of FMEA processing is to identify the failure of the OEE category value that most significantly affects the effectiveness of the SAG Mill machine. After the failure is known, the effects and causes of the failure can be identified by determining the rating of severity, occurrence, and detection. Then the process is continued with the calculation of the RPN.

- Data Analysis and Discussion

The RPN values of some of the biggest failures are analyzed, then recommendations are given to repair the causes of failures that occur on the SAG Mill machine.

- Conclusions

At this stage, conclusions can be drawn from the research that has been done.

2. Overall Equipment Effectiveness (OEE) Method

Overall Equipment Effectiveness (OEE) is a method to be used as a metric measuring for application of the Total Productive Maintenance (TPM) program to maintain equipment in ideal condition by eliminating the Six Big Losses [20]. The OEE method discovers areas where productivity or machine efficiency needs to improve and measures machine effectiveness regarding equipment availability, performance effectiveness, and quality rate. Overall, manufacturing performance indicators represent a connecting point between manufacturing plants [21]. The OEE method used in this study is because OEE is the only method that can measure the effectiveness of the main engine for the company's production process based on the stop time of the machine. To identify the best OEE measuring systems, follow the four-step analysis and decision-making process below. These steps provide a helpful guide for selecting the best OEE measuring system.

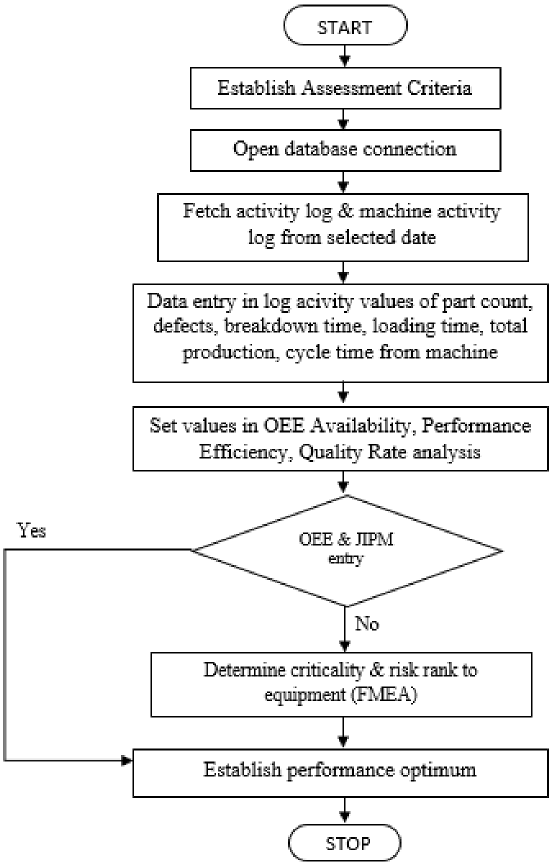

Figure 1. Input process output of OEE and FMEA

- Choose a pilot machine

To gain some initial experience with OEE, begin by choosing a pilot machine. In this research, the pilot machine is SAG Mill Machine. SAG Mill Machine is crucial in the manufacturing process that receives more work requests than it can handle, thus holding up the flow. Optimizing it will improve the overall process.

- Make sure your personnel has trained appropriately

To successfully introduce OEE, you should ensure that the response team knows how it works and its benefits. In addition to smoothing implementation, this will motivate your team to consistently take advantage of it for maximum results.

- Capture data

In the following, we show you the data that you will need to calculate the OEE factors:

a. Several good parts (good count): Good parts have no defects after the first pass and do not need to be reworked.
b. Several bad parts: Bad parts fall short of the required quality after the first pass. These parts can either be corrected by reworking them or discarded. The sum of good and bad parts equals the number of all produced parts, which can be used to calculate performance and quality. Bad parts can be captured similarly to the good parts.
c. Ideal cycle time: This is the theoretical minimum time required to manufacture one part. Multiplying the ideal cycle time by the planned production time yields the number of parts that could be produced, which is needed to calculate performance.
d. Planned production time: The OEE metric only considers losses caused during the planned production time. Consequently, it is essential to carefully define the planned stops left out of the account, like breaks, meetings, etc.

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e. Unplanned stops: Periods during which your machines do not produce as planned. The causes can include technical problems or a shortage of materials. The difference between planned production time and total unplanned stops equals actual production time, which reveals the availability loss.

- Calculate the OEE score and improve your processes

The results of OEE analysis can help find inefficiencies in a machine, as it will be easy to maintain errors. According to Wicaksono and Yuamita (2022) [22], OEE is calculated by obtaining the value of the availability of the machine, production equipment, and performance efficiency. It is as shown in equation 1 :

$$\text{OEE} = \left(\frac{\text{A}}{100} \text{x} \frac{\text{PE}}{100} \text{x} \frac{\text{QR}}{100}\right) \text{x } 100 \tag{1}$$

Where A is Availability, PE is Performance efficiency, and QR is Quality Rate. To find out the values of A, PE, and QR, respectively, the following calculations are listed below:

2.1. Availability rate

Availability is the machine's level of availability or readiness at any time. To calculate availability, we can use equation 2:

$$\text{Availability rate} = \frac{Operation\ Time}{Loading\ Time} \times 100\% \tag{2}$$

Operation time is the efficient time at which a machine operates. While loading time is the available time per day or month that has been reduced by planned downtime.

2.2. Performance rate

Performance Efficiency is the ratio of product quantity that has been made and then multiplied by the ideal cycle time to the time available for production. It shows in equation 3

$$\text{Performance efficiency} = \frac{Processed\ amount\ x\ ideal\ cycle\ time}{Operation\ Time} \times 100\% \tag{3}$$

Ideal cycle time is a cycle time of machine production that can be achieved in optimal conditions or does not experience obstacles during production and problems that cause the machine to stop

2.3. Quality rate

Quality rate is the ratio between good products that have qualified to the number of processed products. It shows in equation 4

$$\text{Rate of Product Quality} = \frac{Processed\ Amount - Defect\ Amount}{Processed\ Amount} \times 100\% \tag{4}$$

3. Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis is a technique to find weaknesses in a design, process, or system of a design, process or when the system is realized in the production phase. This technique aims to find the root cause of the problem. The failure effect describes the impact of the failure mode occurring [23]. The identification process of failure modes and failure effects is essential for improving performance and eliminating waste [24]. FMEA elements are built, which are used to support the analysis. Some FMEA elements are process function, potential failure mode, potential effects of failure, severity, potential cause, occurrence, current process control, detection, and risk priority number (RPN) [25]. The FMEA is a process used to identify and eliminate potential failures by assessing the criticality of the failure modes [26]. The criticality of the failure modes is evaluated using FMEA to select only the critical system-level failure modes [27]. There are failure analysis methods other than FMEA, namely RCA. The root-caused Analysis (RCA) method is employed to determine the central source of quality problems and solutions for solving problems using 5 W+1H [28]. The difference between FMEA and RCA is that FMEA uses for pre-failure analysis. RCA uses for post-failure analysis. Therefore, since the OEE value is a calculation of efficacy using SIX BIG losses used in FMEA, FMEA can be used with a Risk Priority Number (RPN), which identifies based on the severity of the failure. The most critical failures must be identified based on the failure's seriousness to determine the most critical errors. The steps on FMEA Method are as follows:

a. Identify potential failures that could occur in each process.
b. Identify the frequency of a problem that occurs.
c. Identify control systems
d. Calculate the RPN or Risk Priority Number with the formula
e. Establish some corrective measures

Calculating RPN's percentage and the cumulative percentage will decide the severity, occurrence, and detection score based on Suherman et. al [29] :

3.1. Calculating severity score

The severity score is an evaluation of the possible impact of a failure or defect. The function of severity score is to rank how serious the failure effect shows 1 as the lowest score and 10 as the highest. The rank and criteria of severity score is listed in Table 1.

Table 1. Calculating severity score

Rank		Criteria
1-2	Minor	It is unreasonable to suspect that this error's trivial nature could significantly affect products and services. Customers probably will not even notice the mistake
3-4	Low	Damage to a low degree due to the nature of this error will cause minimal disruption to the customer.
5-6	Moderate	A moderate level due to this error caused some dissatisfaction. This error may result in the need for unscheduled repairs and/or damage to the equipment
7-8	High	Not paying attention to security issues and or government regulations. May disrupt ongoing processes and/or services.
9-10	Very High	Disruption to ongoing processes and or services. 9 - 10 Very High damage rate when the fault affects the safety and involves violating government regulations

Source : Suherman et. al (2019) [29]

3.2. Calculate occurrence score

The occurrence score is the number of possible causes of failure occurs. Occurrence decides the rating according to an estimated frequent or cumulative failure caused by certain events. The occurrence score rate is 1 to 10, where 1 is the lowest and 10 is the highest. The occurance score and criteria is listed in Table 2.

Table 2. Occurrence score using number of failures

Ranking	Criteria
1-2	Very low/rare occurrence.
3-4	Occurrence at low probability.
5-6	Occurrence at a moderate/moderate probability level. The process is under statistical control with occasional errors, but not to a large proportion
7-8	Occurrence with a high probability of occurrence. The process is under statistical control with frequent errors.
9-10	Occurrence at a very high probability. Errors are almost certain (1 in 10).

Source : Suherman et. al (2019) [29]

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3.3. Calculate detection score

The detection level is to define a process control that will specifically detect the root cause of the failure. Detection is a measurement to control failures that can occur. The detection score rate is 1 to 10, where 1 is the highest and 10 is the lowest. The determination of detection score is listed in Table 3.

Table 3. Determination of detection score

Ranking		Criteria
1-2	Very High	The probability of a defective/damaged/wrong product or service is very small (1 in 10,000). Defects/damages will be clearly visible and ready to be detected. Lowest reliability/detectability at 99.99%
3-4	High	The probability of a defective/damaged/wrong product or service is low (1 in 5000, to 1 in 500). Lowest reliability/detectability at 99.8% level
5-6	Moderate	The probability of a defective/damaged/wrong product or service is moderate/tolerable (1 in 200, to 1 in 50). Lowest reliability/detectability at 98% level
7-8	Low	The probability of a defective/damaged/wrong product or service is high (1 in 20). Lowest reliability/detectability at 90% level
9-10	Very Lox	The probability of a defective/damaged/wrong product or service is very high (1 in 10). Usually, the goods are not checked or cannot be checked. Defects/damages/errors are often hidden and not visible during processing or servicing. Reliability/detectability at 90% level or lower.

Source : Suherman et. al (2019) [29]

RESULTS AND DISCUSSION

1. OEE Calculation

Calculate the score of availability, performance efficiency, and quality rate to know the OEE score :

1.1. Availability

Based on the availability rate calculation in equation 2, the results of the SAG Mill machine in January 2021 are as follows. Then, with the same equation, the calculation of avalaibility rate from January to December 2021 is presented in Table 4.

$$\text{Availability} = \frac{534}{744} \times 100\% = 74.32\ \%$$

Table 4. Availability from January to December 2021

Month	Machine Loading Time	Machine Operation Time	Machine Downtime	Availability (%)
January	744	551.69	131.517	74.32
February	672	575.04	97.017	85.41
March	744	343.21	345.767	46.23
April	720	524.81	160.3	72.77
May	744	674.3	39.25	90.59
June	720	695.96	1.817	96.52
July	744	544.3	193.7	73.25
August	744	723.99	16.083	97.17

Month	Machine Loading Time	Machine Operation Time	Machine Downtime	Availability (%)
September	720	689.68	9.983	95.69
October	744	714.43	15.65	95.96
November	720	625.48	85	86.94
December	744	663.85	71.433	89.51
		Average		83.69

From the result calculation of availability in Table 4, the lowest Availability value is in March 2021, which is 46.23%, which is lesser than the JIPM Standard, which is 85%. There is another percentage of months with a low result of availability, namely January at 74.32% and July at 73.25%. The highest Availability value was in August at 97.17%. The Availability values from January 2021 to December 2021 are 83.69% and less than ideal because the result is below 85%. The low Availability value on the SAG Mill machine can occur due to the short operation time of the machine.

1.2 Performance Efficiency

Based on the availability calculation in Equation 3, the results of calculating the Performance Efficiency value of the SAG Mill machine in January 2021 are as follows. Then, the same calculation formula to calculate the period January 2021 to December 2021 is listed in Table 5.

$$\text{Performance Efficiency} = \frac{1{,}402{,}834 \text{ x } 2.778}{551.69} \text{ x } 100\% = 70.64\%$$

Table 5. Performance efficiency from January to December 2021

Month	Production	Machine Time Operation	Ideal Cycle Time	Performance Efficiency (%)
January	1,402,834	551.69	2,778	70.64
February	1,668,072	575.04	2,778	80.59
March	953,564	343.21	2,778	77.19
April	1,348,307	524.81	2,778	71.38
May	1,902,054	674.3	2,778	78.37
June	2,536,841	695.96	2,778	99.98
July	1,641,859	544.3	2,778	83.80
August	2,540,040	723.99	2,778	97.47
September	2,451,020	689.68	2,778	98.74
October	2,537,484	714.43	2,778	98.68
November	2,151,150	625.48	2,778	95.55
December	2,234,807	663.85	2,778	93.53
		Total		104726.22
		Average		87.26%

The results of the Performance Efficiency calculation in Table 5, the lowest Performance Efficiency value in January 2021 is 70.64% and below the JIPM Standard, which is 85%. The highest Performance Efficiency value in June by 99.98%. Based on the table results, the average rate of quality product calculation for January 2021 to December 2021 is 87.26%.

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1.2. Quality Rate

Based on the availability calculation in Equation 4, the results of calculating the Quality Rate value of the SAG Mill machine in January 2021 are as follows. The same calculation formula to calculate the period January 2021 to December 2021 is listed in Table 6.

Processed Amount = 1,402,834
Defect Amount = 198.13

$$\text{Rate of Product Quality} = \frac{1402834-198.13}{1402834} \times 100\% = 98.69\%$$

Table 6. Quality rate from January to December 2021

Month	Production	Defect Products	Rate of Product Quality (%)
January	1,402,834	198.13	98.69
February	1,668,072	142.33	99.21
March	953,564	186.36	98.36
April	1,348.307	275.94	98.06
May	1,902,054	293.92	98.58
June	2,536,841	305.18	98.82
July	1,641,859	198.6	98.63
August	2,540,040	174.73	99.38
September	2,451,020	133.37	99.5
October	2,537,484	212.93	99.21
November	2,151,150	199.16	99.19
December	2,234,807	174.6	99.27
	Total		1186.9
	Average		98.90

The results of the calculation of the product quality rate are shown in Table 6. The Pareto diagram shows that all rates of quality value of the products in the January 2021-December 2021 period are at an average of 98.90%. All rates of product quality are above the JIPM standard of 85%.

1.3 Overall Equipment Effectiveness (OEE)

Based on the availability calculation in Equation 1, the results of the OEE method of the SAG Mill Machine in January 2021 are as follows, and the same calculation formula to calculate the period January 2021 to December 2021 is listed in Table 7:

OEE = (74.32 x 70.64 x 98.69) x 100% = 51.81%

Table 7. Overall equipment effectiveness (OEE) 2021

Month	Result			OEE (%)
	Availability	Performance Efficiency	Rate of Quality	
January	74.32	70.64	98.69	51.81
February	85.41	80.59	99.21	68.28
March	46.23	77.19	98.36	35.09
April	72.77	71.38	98.06	50.93
May	90.59	78.37	98.58	69.98
June	96.52	99.98	98.82	95.38
July	73.25	83.8	98.63	60.54

Month	Result			OEE (%)
	Availability	Performance Efficiency	Rate of Quality	
August	97.17	97.47	99.38	94.12
September	95.69	98.74	99.5	94.01
October	95.96	98.68	99.21	93.94
November	86.94	95.55	99.19	82.39
December	89.51	93.53	99.27	83.10
		Total		87963.35
		Average		73.30%

Based on Table 7, it can be seen that the largest OEE value on June 2021 was 95.38%, and the OEE value, the smallest was in March 2021 of 35.09%. The OEE value in table 7 is the OEE value for the period January 2021 to December 2021. The OEE value in the January, February, March, April, May, July, November, and December is still below the JIPM standard, which is 85%. The low OEE value is due to the availability of the low values. The SAG Mill machine's level of effectiveness is not yet effective from the JIPM (Japan Institute of Plant Maintenance) standard.

2. FMEA Method

An FMEA analysis is used to make improvements to avoid the cause of the problem and improve the production process in the future. The result of FMEA method in this study is shown in Table 8.

Table 8. Result of FMEA method

No.	Failure	Failure Mode	Failure Effect
1.	Equipment Failure (breakdown losses)	Power problem, there is a long lag time when running the machine. Electrical matter due to a short circuit in the engine motor	It needs additional short power, which takes time for the engine to be at minimum speed.
2.	Set-up and adjustment losses	Late production time	Stopped production time and not on time.
3.	Downtime Losses	Unexpected damage, such as sudden power failure, broken bearing, broken coil	Stopping time of the whole continuous production process and unable to carry out production due to machine downtime
4.	Idling and Mirror Stoppages	Engine Stops due to electrical or mechanical problems.	Reduces time effectiveness and machine availability; takes more time to run
5.	Reduced speed	The rotation is not optimal when running, and the speed does not reach the standard due to overload	At least the production results become slow, and the engine overheats
6.	Defect loss	The raw material is too hard	The Production results do not match the specifications.

The analysis result in the direct effects table are problems in the failure factor of the six big losses. The related causes and effects found in Downtime Losses and Idling and Mirror Stoppages cause extensive downtime or losses of time.

3. Risk Priority Number

A Risk Priority Number (RPN) is used to prioritize the improvements and analyze the failure of the SAG MILL machine. The result of RPN is shown in Table 9 as the circulation of RPN.

Table 9. Calculation of RPN

No.	Failure	S x O x D	RPN
1.	Equipment Failure (breakdown losses)	7 x 5 x 5	175
2.	Set-up and adjustment losses	5 x 6 x 6	180
3.	Downtime Losses	7 x 7 x 7	343
4.	Idling and Mirror Stoppages	6 x 7 x 7	294
5.	Reduced speed	6 x 5 x 6	180
6.	Defect loss	5 x 7 x 5	175

According to Krachangchan (2018) [1], OEE is an important measure of efficiency that is simple to use. They studied TPM and RCM implementation using Failure Modes and Effects Analysis (FMEA) to analyze the cause of a problem with machine breakdown and eliminate potential machine failures. From the RPN result, the primary cause of failure is downtime losses by 343. There are two categories of downtime losses on sawmill machines, Breakdown Loss and Planned Loss. Breakdown Loss can occur due to damage such as electrical, leaks in Knelson, Broken Bearings and Liners, broken coils, Hard Rocks that are difficult to destroy, and others. Planned Loss is a planned loss event such as an inspection that requires the machine to stop, a shutdown schedule, a schedule for changing bearings and liners, taking samples of incoming ore, inspecting the rotor machine on the SAG Mill, and others. So that it can cause production targets that are not as targeted, long-term shutdowns, long-term repairs, production stops for continuous processes, and delays in the delivery of goods. Based on research conducted by Tsarouhas (2019) [4], OEE is a metric that counters progress in improving the effectiveness and efficiency of a manufacturing process. The results of this study were discussed with the factory's management, who considered it very important and in the right direction to adopt and implement them.

Moreover, there are some indirect benefits, i.e., continuous maintenance and control of the equipment, enhanced quality of work life, reduced absenteeism, and enhanced communication in the workplace. Research shows the OEE method can be used for machine efficiency in continuous control of equipment, improving the quality of work life in preventive maintenance. Still, communication between workers is somewhat lacking because human error always occurs even though the analysis has been carried out. Recommendations that can be taken with the existing analysis can be made to increase the number of equipment that aims to make the machine age new so that it can accelerate production.

CONCLUSION

In this research, OEE and FMEA Methods are both used to identify the losses and failures of the equipment and manufacturing processes and make an improvement. Based on the results of the OEE calculation, the OEE value from January until December 2021 ranges from 35.09% to 95.38%. The respective OEE values for January are 51.81%, February 68.28%, March 35.09%, April 50.93%, May 69.98%, July 60.54%, November 83.39%, and December 83.10%. These values are still below the JIPM (Japan Institute of Plant and Maintenance) standard, which is 85%. The results of the FMEA analysis based on RNP calculations that affect the OEE value are due to Downtime Losses and Idling and Mirror Stoppages and have the biggest score of 343 and 294. It caused the Stopping time of the whole continuous production process and unable to carry out of production due to machine downtime. Having obtained the OEE results, the company can identify the losses, which mostly decrease the effectivity. Failure mode and effect analysis (FMEA) may be a tool to identify and prevent losses.

Further, the company may identify possible solutions for eliminating losses and improving production performance. Recommendations that can be made with the existing analysis can be made to increase the number of equipment that aims to make the machine age new so that it can accelerate production. For further research, the experts' opinions on failure modes can integrate with the uncertain environment, like linguistic terms, fuzzy theory, grey theory, and evidence theory. AHP, as the weighting determination method, is not convenient for determining the given research objects' weights; AHP can be adopted due to fewer pairwise comparisons, more consistent comparisons, and more reliable weights besides FMEA. Therefore, it is recommended for further research, recommendations on the application of OEE can be applied to the latest production technology with more than one machine and continuous production to obtain overall production efficiency.

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