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Application of Overall Equipment Effectiveness and Failure Mode Efffect and Criticality Analysis Methods to Improve Machine Performance Effectiveness

Muchammad Aldiansyah[1], Evi Yuliawati[2], Nur Rahmawati[3*], Dian Trihastuti[4]

[1,2]Jurusan TeknikIndustri, FakultasTeknologiIndustri,
Institut TeknologiAdhi Tama Surabaya
[3]Program StudiTeknikIndustri, FakultasTeknik,
UniversitasPembangunanNasional ”Veteran” JawaTimur
[4]Program StudiTeknikIndustri, FakultasTeknik,
UniversitasWidya Mandala Surabaya

nur.rahma.ti@upnjatim.ac.id

***Abstract*— PT XYZ is a company that produces hot rolled coils (HRC) steel products. One of the machines used in the process is a rough mill machine in the milling process. The problem is downtime on the rough mill machine that disrupts the production process time. The purpose of this study is to determine the value of the effectiveness of the machine, find the largest losses that affect the value of the effectiveness of the machine, identify the cause of the biggest losses and provide recommendations for improvement steps. The methods used are overall equipment effectiveness (OEE), six big losses, and the failure mode effect and criticality analysis (FMECA). The results show that the average OEE value of PT XYZ is 80%,but this value was still not following the ideal standard. By identifying the six big losses, the most significant losses are reduced speed losses, with a total percentage value of 86% and an average time lossof 5,020minutes. FMECA results obtain three components that cause the biggest losses: the engine motor, gearbox, and spindle. Recommendations for improvement include making and setting schedules, implementing predictive maintenance and preventive maintenance on rough mill machines, and regularly checking and replacing component spare parts.**

***Keywords*: Machine effectiveness, FMECA, OEE, Six big losses**

I. INTRODUCTION

Machines are equipment or tools with energy conversion (Tang et al., 2018) that greatly help and simplify human work (Dellermann et al., 2019). Machines exist in almost every human life, from home to the workplace (Sadowski, 2020). On the production floor, the role of machines, especially production machines, is vital (Ding et al., 2019). Equipment or machines that do not perform optimally can cause the production process to stop (Christi and Yuliawati, 2020). Therefore, maintenance of the machine needs to be carried out so that the production process in the company can run smoothly and increase the machine's effectiveness(Cachada et al., 2018). Maintenance itself is a series of activities in which it is related to how to maintain all systems on equipment or tools so that they can continue to work as expected(Setiawan et al., 2019) and (Manik, 2018).

PT XYZ is a company engaged in manufacturing that produces HRC steel products. The raw material is billet (raw steel). The manufacturing process includes several processes: cutting, burning, grinding, finishing/thinning material, and rolling or packaging. In the process of making HRC products, several machines are also used, one of which is a rough mill machine in the grinding process. The problem faced by PT XYZ at this time is the frequent downtime or downtime on

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the rough mill machine, so the production process time is disrupted. Downtime on rough mill machines does not affect product quality but the machining process time required in a cycle of the product production process. According to (Pontiana and Singgih, 2021), equipment or machinery is said to be good if it has a downtime percentage value of less than 3%. In contrast, the percentage of downtime on the rough mill machine has an average value of 5.12%. Therefore, it is essential to choose the correct method to increase effectiveness and provide recommendations for improvements to the rough mill machine.

The Overall Equipment Effectiveness (OEE) method was chosen to calculate the effectiveness of the rough mill machine and analyze the most significant or influential losses with the six big losses (Herry et al., 2018). Overall Equipment Effectiveness (OEE) is an instrument that can be used to identify the level of productivity of equipment or performance facilities (Rusman et al., 2019). OEE is a method that describes the product of six big losses on machines or facilities. The OEE method can help measure by involving three factors: availability, performance, and quality. The OEE method has the main objective, namely tool to measure the performance of the maintenance system. This method indicates the availability of equipment or machine, production efficiency, and the quality of the output of facilities or equipment (machines). The six big losses strongly influence the OEE of a system. Six big losses are activities carried out to prevent disruptions in facilities or equipment and minimize downtime in a facility or equipment. Six big losses consist of 6 categories: equipment failure or breakdown loss, set-up and adjustment losses, idle and minor stoppage, reduced speed, defects in the process, and reduced yield (Rozak et al., 2019). This research employs the failure mode effect and criticality analysis (FMECA) method to identify the cause of the biggest losses. Then, propose recommendations for corrective measures to increase the effectiveness of the rough mill machine (Prabowoand Sulistyowati, 2020). FMECA method is often used in determining the failure rate of each component and identifying overall problems that can minimize or eliminate factors that affect the production process both in the process and the equipment (Suharjo et al., 2019). FMECA is an integration of two methods, namely Failure Mode and Effect Analysis (FMEA) and CA (Criticality Analysis) (Wang et al., 2022). FMEA is an engineering method used to define and recognize problems, errors, and some of the systems, designs, processes, or services before a product or service is received by consumers (Safaatand Fatimah, 2022). While CA is a method to identify critical analysis by assessing and classifying the risk of system failure, the chance and severity of each failure are grouped into several categories at the specified criticality analysis value (Hegdeand Rokseth, 2020).

OEE and FMECA are methods that are often used in previous research. The OEE method has been applied to analyze the effectiveness of line production machines (Tsarouhas, 2019; Dobra and Jósvai, 20210; Lakho et al., 2020). FMECA has been widely applied in several systems, such as wind turbine systems (Wang et al., 2021) and railway systems(Catelani et al., 2021). The integration model of FMECA with the OEE framework has been proposed by (Sassanelli et al., 2021). In contrast, the combination of the two methods has also been able to overcome the problems that occur in reducing the system's effectiveness(Antonius, 2021)and (Kristian et al., 2021).

II. METHODOLOGY

The research method there are several stages, as follows:

A. Data Collection Stage

At this stage, the data sources used include (1) primary data involving a general description or profile of PT XYZ, identification of rough mill machines, production processes of HRC (hot rolled coil) products, and how rough mill machines work. (2) Secondary data includes data on operating time/work hours of rough mill machines, data on the number of HRC products produced, data on machine downtime, data on set-up and adjustments, and data on defects on HRC products. Secondary data was taken from July 2020 to December 2020.

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Table 1. Rough mill machine downtime data from July to December 2020

No	Month	*Downtime* (m)	Percentage of *Downtime* (%)
1	July	245	2,78
2	August	515	3,8
3	September	782	5,6
4	October	1057	6,9
5	November	681	4,4
6	December	1207	7,26
	Total	4487	30,74
	Average	747,83	5,12

Table 2. Operation time dan loading time 2020

No	Month	*Operation time* (m)	*Loading time* (m)	*Planned downtime* (m)	Working days (days)
1	July	31.315	31.560	120	22
2	August	31.645	32.160	960	23
3	September	11.278	12.060	2.340	10
4	October	31.103	32.160	960	23
5	Nopember	40.419	41.100	660	29
6	December	38.153	39.360	960	28
Average		30.652	31.400		

Table 3. Set up and adjustment and breakdown time 2020

No	Month	*Set up and adjust rough mill* (m)	*Breakdown time rough mill* (m)
1	July	120	125
2	August	240	275
3	September	360	422
4	October	388	669
5	November	320	361
6	December	480	727
	Average	318	430

B. Data Processing

`In the initial data processing, the OEE calculation will be carried out with the following equation [19]:

OEE = *Availability rate* × *Performance rate* × *Quality rate* ……………… (1)

The second is to calculate the six big losses to analyze losses that affect the effectiveness of the machine.The six big losses include equipment failure or breakdown losses, set-up and adjustment losses, idle and minor stoppage, reduced speed losses, processed defect losses, and reduced yield losses. It uses equations (2)-(7) to calculate the equipment failure or breakdown losses.

Equipment failure or breakdown = downtime/loading time ×100% …(2)

The equation for Set up and adjustment losses is as follows:

Set up and adjustment losses = set up and adjustment time/loading time×100% ………….(3)

The equations for Idle and minor stoppage losses are as follows:

Idle and minor stoppage losses = non productive time/loading time×100% ………... (4)

The Reduced speed losses equation is as follows:

Reduced speed losses = operating time − (ideal cycle time×output)/loading time …….(5)

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The equation for Processed defect losses is as follows:

Processed defect losses = (ideal cycle time×total defect amount)/loading time×100% ………………………..(6)

The equation for Processed defect losses is as follows:

Reduced yield losses = (number of initial defectsproduksi×ideal cycle time)/loading time×100% …….. (7)

The third stage identifies the causes of the biggest losses using the failure mode effect and criticality analysis (FMECA) method. FMECAcombines failure mode and effect analysis (FMEA) and criticality analysis (CA) and provides recommendations for corrective steps. In the FMECA method, the severity, occurrence, and detection values will be determined, whereas the RPN value will be obtained bymultiplying the three parameters. After getting the RPN results, the level of criticality analysis will determine the most significant value, whether it is included in the acceptable, tolerable, and unacceptable categories for that component. Based on that and recommendations for corrective steps are given. The following is a rating table for severity, occurrence, and detection values, namely:

Table 4. Severity Rating

Consequence	Criteria	Scale
No effect	There is no effect of the failure mode on print quality	1
Minimal repercussions	The quality characteristics are not compromised	2
Little effect	As a result, little to the quality	3
The result is small	Quality suffers minor hiccups	4
Enough effect	The failure resulted in some dissatisfaction with the quality	5
Enough effect	Failure causes discomfort	6
The consequences are big	Print quality is not satisfactory	7
Extreme	Print quality is very unsatisfactory	8
Serious	Potentially adverse effects on molding	9
Very risky	The effect on the failure mode is fatal to quality	10

Table 5. Occurance Rating

Consequence	Criteria	Scale
Almost never	Indicates no failures	1
Seldom	The probability of failure is extremely rare	2
Very small	The probability of failure is minimal	3
a little small	Several possible failures	4
Low	There is a possibility of failure	5
Currently	Moderate probability of failure	6
High Enough	The likelihood of failure is relatively high	7
High	A high number of possible failures	8
Very high	A very high number of possible failures	9
Almost certainly	Failure is almost certain	10

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Table 6. Detection Rating

Consequence	Criteria	Scale
Almost certainly	Controls can definitely bedetected	1
Very high	control almost certainly detects	2
High	controls have a high chance of being detected	3
High Enough	controls may detect high enough	4
Currently	Controls may detect moderate	5
Low	low detect control	6
A little	control has a slightly slight chance of detection	7
The least	control has very little chance to detect	8
Seldom	Control may not detect	9
Almost	Undetectable	10

Criticality analysis assesses and classifies the risk of system failure, the chance of failure, and the severity of each failure in several categories at a specified value. The following is a criticality analysis table (Yssaad et al., 2014):

Table7. Criticality

CRITICALITY		*Risk of Hazard*
Degree of Criticality	*Value*	
Minor	0 - 30	*Acceptable*
Medium	31 - 60	*Tolerable*
High	61 - 180	
Very high	181 - 252	*Unacceptable*
Critical	253 – 324	
Very critical	≥ 324	

III. RESULT AND DISCUSSION

The first stage of data calculation is the OEE value by multiplying the availability, performance, and quality rates. Table 8shows the OEE value from July to December 2020.

For example, the calculation of the average OEE value in July 2020 is as follows:

OEE = Availability rate × Performance rate × Quality rate

OEE = 99%×86%×97% = 82%

Table 8. Overall Equipment Effectiveness (OEE) Result

No	Month	*Availability*	*Performance*	*Quality*	OEE
1	July	99%	86%	97%	82%
2	August	98%	85%	96%	81%
3	September	94%	66%	96%	59%
4	October	97%	110%	97%	104%
5	November	98%	79%	98%	76%
6	December	97%	85%	98%	80%
	Average	97%	85%	97%	80%

The OEE standard value set by the company must comply with a world-class standard of 85%. Based on Table 8, it can be seen that the lowest OEE value is 59%, which occurred in September 2020. Table 8 shows that the OEE value reached the company's ideal standards in October 2020at 104%. In comparison, the OEEs of other months are still below the criteria. Moreover, the average OEE value on a rough mill machine is 80%, which is still less than the ideal standard according to World-class standards.Thusit is necessary to carry out further identification by calculating six big losses.

The second stage is to determine the biggest losses by calculating six big losses from the average OEE value results that still do not meet the standard. Table 9 shows the six big

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loss percentage values from July 2020 to December 2020.

Table 9. Six Big Losses

No	Month July	*Six Big Losses* (%)					
		Equipment Failure	*Set up and Adjustment losses*	*Idling and Minor Stoppage*	*Reduced Speed*	*Process Defect*	*Reduced Yield*
1	August	0,4%	0,4%	1,2%	14%	3%	0%
2	September	0,9%	0,7%	4,6%	14%	3.3%	0%
3	October	3,5%	3%	25,9%	32%	2.5%	0%
4	November	2,1%	1,2%	6,3%	10%	3%	0%
5	December	0,9%	0,8%	3,3%	20%	1.5%	0%
6	Month	1,8%	1,2%	5,5%	15%	2%	0%
	Average	2%	1,2%	7,8%	14%	3%	0%
	Total	9,6%	7,3%	46,7%	86%	15%	0%

Based on the results in Table 10, the largest time losses were obtained in the rough mill machine, namely reduced speed losses with a total lost time of 30,120 minutes with an average of 5,020 minutes.

The third stage identifies the cause of the biggest losses from the six big losses with FMECA. Determination of severity rating criteria (S), occurrence (O), and detection (D) from the results of brainstorming with the company, namely maintenance technicians on rough mill machines. The following is a table for calculating the FMECA method, namely, as follows:

Table10. Total Time Losses and Six Big Losses

No	Six big losses	Total time losses rough mill (m)	Average time losses rough mill (m)
1	Equipment failure	2.592	430
2	Set up and adjust losses	1.900	318
3	Idling and minor stoppage	10.529	1.755
4	Reduced speed losses	30.120	5.020
5	Process defect losses	4.678	780
6	Reduced yield losses	0	0

Table1. FMECA Result

No	Component	Failure Mode	Failure Effect	Failure cause	Criticality (C)				Degree Of criticality	Risk Of Hazard
					S	O	D	RPN		
1	Guide	The size of the guide is not as specified	Crash material cannot enter	The selection of guides is not as needed	5	4	7	140	High	Tolerable
		Guide entry porous	The material broke and had to be welded	The guide is damaged and failed due to too long use	5	5	6	150	High	Tolerable
		Broken exit guide	Material exits through the line	Components wear out	6	5	3	90	High	Tolerable
				Broken guides must be re-welded	5	4	6	120	High	Tolerable
2	Motor	The motor drive fails to function, so it cannot operate	The machine can not run	Electrical current problem	8	9	2	144	High	Tolerable
				Engine component failure	9	10	4	360	Very Criticality	Unacceptable
				Incorrect machine activation code	6	4	5	120	High	Tolerable

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No	Compo	Failure Mode	Failure	Failure cause	Criticality (C)				Degree	Risk
3	Gearbox	There was a miss alignment between the gear and the engine motor	The steering gearbox is loud and noisy	The gearbox is wearing out	9	9	3	243	Very high	Unacceptable
				loose fixing bolts or gearbox screw	5	7	4	140	High	Tolerable
4	Spindel	A jam occurs, and it stops suddenly	Roll can not run	The spindle components are worn	7	7	4	196	Very high	Unacceptable
				babet spindle down or dropped	6	6	4	144	High	Tolerable
5	Roll	Experiencing a missed roll	The material does not enter the guide entry	The tip of the material is bent so that it catches on the guide	7	6	4	168	High	Tolerable
				Broken roll	7	4	4	112	High	Tolerable
6	Layar	Broken and worn out	So that the material is out of line	The age of use is too long	5	4	6	120	High	Tolerable
				Materials go fast	5	5	6	150	High	Tolerable
7	Temperature heater	The engine temperature is too hot	The engine has overheated	The temperature sensor is broken	5	5	6	150	High	Tolerable
				Hot room temperature	4	4	7	112	High	Tolerable

Based on the hazard risk in Table 11, corrective steps should be determined for components with RPN values in the category unacceptable. The corrective actions include three recommendations. (1) The first recommendation is for motor failure function. The root cause of the failure is too long usage time and oil leak into the rotor. After discussion with the management, it is found that maintenance techniciansmust make and set a schedule for routine maintenance, especially for engine components that often have problems. Besides, clean the oil that leaksfromthe motor so that it does not spill over to other components. (2) The second recommendation is related to the failure of the engine gearbox component. The root cause of the failure is the excessive use of gears, which erodes due to excess material load. The corrective steps that should be taken after discussing with the company, namely maintenance technicians on the failed component, are implementing periodic and continuous predictive maintenance, carrying out routine checks, and replacing gearbox gears. (3) The third recommendation is related to the spindle component, jamming, and sudden stopping, which has an impact that the spindle component's experience of wear and tear. The root cause of the failure is the engine working time that exceeds the limit, the presence of dust or dirt adhering to the spindle components, and the negligence operator in component checking. Corrective steps that should be taken after discussing with the company, namely maintenance technicians on the failure component are implementing preventive maintenance activities when scheduling maintenance activities on spindle components as well as checking and replacing component spare parts regularly and providing training or training to all machine operators both new employees and existing employees.

IV. CONCLUSION

From the research conducted, it was concluded that the results of calculations using the OEE method, namely the average OEE value of 80%, still do not meet the ideal standard according to world-class for OEE, which is 85%. Therefore, it is necessary to identify the cause of the decrease in the effectiveness of the rough mill machine. From the analysis of the six big losses, the results are obtained, namely the losses that

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have an impact, which is in the category of speed losses, namely reduced speed losses with an average percentage of 14% and a total percentage value of 86%, total time losses (lost time) caused by reduced speed losses in July 2020 to December 2020 amounted to 30,120 minutes with an average time loss of 5,020 minutes. FMECA identification results show three components of failure: the engine motor, gearbox, and spindle. This is based on RPN values that are included in the Unacceptable category. Recommendations for improvements obtained results, namely engine motor components with motor drive failure modes fail to function so that they cannot operate,resulting in engine components' failure. There are three corrective steps recommended. The firstis making and setting schedules for routine maintenance, especially on machine components that are often problematic, and cleaning oil that leaks on the motor so it doesn't spill over to other components.The second recommendation is to regularly implement regular and continuous predictive maintenance, checking and replacing gearboxes. The third recommendation is to regularly implement preventive maintenance, especially when performing maintenance on the spindle. The maintenance procedure should include regularly checking and replacing component spare parts and providing training to all machine operators, both new and permanent employees.

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