Analysis of Overall Equipment Effectiveness on Production Machines Using Autonomous Maintenance

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Abstract

Maintenance is an important thing to do in a company to support the running of the production process. The research was conducted at a company operating in the electrical industry. This company is a manufacturing company that produces ceramic insulators. Based on the results of research that has been carried out, there are problems with downtime. To increase the productivity of machine performance, it is necessary to measure machine performance, namely by using the Total Productive Maintenance (TPM) concept. In using the Total Productive Maintenance concept, the Overall Equipment Effectiveness value and Six Big Losses analysis are calculated. The aim of this research is to determine the level of machine effectiveness and the causes of ineffective machine performance in the production process. Once the level of engine performance and its causes are known, suggestions for improvements can be made to improve the level of effectiveness of engine performance. Based on the analysis that has been carried out, the machine that has the largest downtime is the extruder machine. Based on the results of the calculations that have been carried out, the average OEE value is 51.970%, with the largest factor being the performance efficiency value of 61.489% and the largest six big losses value being reduced speed losses of 33.421%.

Keywords
Overall Equipment Effectiveness, Maintenance, Six Big Losses and Total Productive Maintenance.

1. Introduction
The manufacturing industry is a field that is developing very rapidly, especially in Indonesia. Various manufacturing companies compete with each other to be the best. Manufacturing companies must also have advantages compared to their competitors to increase customer satisfaction which has a positive impact on the company. To support optimal production processes, routine maintenance and repairs are very necessary to maximize the production process. When the machines used by the company run well and damage rarely occurs, then of course the production target will be achieved and the company will not experience losses (Vital and Lima 2020).

Maintenance or what is usually called upkeep is an important aspect that must be paid attention to and carried out as the production process progresses. Small errors resulting from maintenance negligence can develop into a big problem and can result in losses if the company does not pay attention to maintenance (Shaker et al. 2022). This company is a manufacturing company that produces ceramic insulators that has been around since 1971. This company has various types of different machines at each work station. To determine machine performance, downtime is needed for calculations. In the company, there are 3 machines that have the largest downtime, namely the filter press, extruder and wad mill. The selection of data used to determine machine performance refers to downtime and is taken from the largest amount of time, namely on the extruder machine.

At this company, machine performance measurements have not yet been implemented against its production targets. One way to overcome this is by implementing Total Productive Maintenance or TPM, which is a maintenance system that aims to maximize machine performance so that it becomes more effective and efficient. The Overall Equipment Effectiveness OEE method is to determine machine performance and also the Six Big Losses method to find the main factors of 6 problems that make machine work not optimal.

Based on the existing problem formulation, the aim of the research carried out is to determine the level of effectiveness of the production machines found at this company, find out what are the causes of ineffective performance of production machines this company, and provide suggestions and appropriate repair solutions to increase the productivity and effectiveness of the production machine performance located at this company.

2. Literature Review

The development of the manufacturing industry, which is currently full of competition, forces companies to maintain their performance so as not to lag behind other companies (Cheah et al. 2020). The world of manufacturing industry has a system for applying machines, labor, equipment and raw materials to be transformed into a product that has selling value. Production machines and equipment are the main resources that cannot be separated from the overall resource system owned by the company (Baig et al. 2013). Machines are tools that determine success in making products to simplify the production process. Machine performance will determine the quality of the product produced. (Singh et al. 2018). Basically, a machine also has a lifespan. As a machine ages, its performance will decrease and in time it will die. Please note that the life of the machine can be extended by carrying out routine maintenance and carrying out preventive maintenance. Prevention efforts require indicators as a basis for carrying out prevention and making appropriate decisions. (Beatrix et al. 2020).

3. Methods

Research was carried out by conducting field studies and literature studies. Field studies are carried out by direct research, interviews with related parties, and also direct observation of the companies studied. Literature studies are carried out by conducting literacy using written references such as journals, books, theses and readings related to maintenance to serve as a basis for thinking in writing the thesis. The data collection carried out included primary data and secondary data. Primary data collection was obtained through direct interviews with parties related to the research topic being conducted. Primary data collected includes company operational time, production systems, and machine working time. Secondary data collection was obtained through historical company recap data. Secondary data collected includes machine downtime, machine setup time, production volume, number of defects, cycle time, and production targets.

Data processing is carried out with the aim of converting the data that has been obtained into the required information which will later be useful to help the analysis process. The first data processing carried out was calculating the OEE value to determine the level of effectiveness of machine performance in the company. The OEE calculation includes the value of availability, performance efficiency, and rate of product quality. From the calculation results, it can be seen whether the resulting value is in accordance with the standard or not. After carrying out the OEE calculation, the six big losses calculation is carried out to find out the largest type of losses. Then it is continued with Pareto diagram analysis, fault tree analysis, and failure mode effect analysis.

4. Data Collection

The data obtained is in the form of historical machine data, namely downtime, setup time, and production quantities. The data taken is data from September 2022 to August 2023. The following is the company's historical data in monthly form.

Table 1. Historical machine data

No.	Month	Production Quantity (Pcs)	Downtime (Minutes)	Setup (Minutes)
1.	September 2022	27421	831	330
2.	October 2022	26337	886	315
3.	November 2022	26685	712	330
4.	December 2022	28164	924	300
5.	January 2023	28791	801	330
6.	February 2023	27916	793	300
7.	March 2023	26737	756	330
8.	April 2023	29024	842	270
9.	May 2023	29407	944	315
10.	June 2023	28295	719	300
11.	July 2023	27882	877	300

No.	Month	Production Quantity (Pcs)	Downtime (Minutes)	Setup (Minutes)
12.	August 2023	28323	835	330

In Table 1, you can see the amount of production, downtime and setup time from September 2022 to August 2023. The average production amount is 27,915 and for downtime the average value is 826 minutes. Meanwhile, the average setup time is 312 minutes.

5. Results and Discussion

Based on the field studies that have been carried out, information was obtained regarding the company's operational time, production system, machine working time, and historical machine data. There are 3 machines at this company which have the highest downtime compared to other machines, namely the filter press, extruder and wad mill machines. Based on the company's historical data, it can be concluded that the machine that will be analyzed using overall equipment effectiveness (OEE) calculations is the extruder machine. The selection of machines to be analyzed was taken based on consideration of the greatest downtime compared to filter press and wad mill machines.

This company have 5 working days. However, each month has a different number of working days because there are different holidays. In one day, the company has 8 hours of work with 1 hour of rest starting at 07.00 to 16.00.

5.1 Straight Pass

Straight pass data is data that shows the number of ceramic insulator products that do not experience defects and are ready for shipping through the final inspection stage. Straight pass data consists of production numbers, straight passes, and number of rejects (Supriatna et al. 2020). The following is straight pass data in Table 2.

Table 2. Straight pass data

Month	Production (Pcs)	Reject (Pcs)	Straight Pass (Pcs)	% Straight Pass
September 2022	27421	772	26649	97.185%
October 2022	26337	801	25536	96.959%
November 2022	26685	829	25856	96.893%
December 2022	28164	739	27425	97.376%
January 2023	28791	665	28126	97.690%
February 2023	27916	710	27206	97.457%
March 2023	26737	614	26123	97.704%
April 2023	29024	826	28198	97.154%
May 2023	29407	783	28624	97.337%
June 2023	28295	832	27463	97.060%
July 2023	27882	681	27201	97.558%
August 2023	28323	759	27564	97.320%

In Table 2, you can see the straight pass value from September 2022 to August 2023. The average straight pass value obtained is 97,308%. Straight pass data is also used to calculate the rate of quality product.

5.2 Overall Equipment Effectiveness

In processing OEE data, calculations are carried out for availability values, performance efficiency, and rate of product quality (Singh et al. 2018). The following are the results of calculating the overall equipment effectiveness value in Table 3.

Table 3. Data value of overall equipment effectiveness

Month	Availability	Performance Efficiency	Rate of Product Quality	Overall Equipment Effectiveness
September 2022	87.435%	56.568%	97.185%	48.068%
October 2022	86.383%	57.613%	96.959%	48.254%
November 2022	88.723%	54.251%	96.893%	46.638%
December 2022	85.429%	65.412%	97.376%	54.415%
January 2023	87.760%	59.175%	97.690%	50.732%
February 2023	86.988%	63.674%	97.457%	53.980%
March 2023	88.247%	54.650%	97.704%	47.120%
April 2023	85.291%	75.021%	97.154%	62.165%
May 2023	85.726%	64.822%	97.337%	54.089%
June 2023	87.869%	63.892%	97.060%	54.491%
July 2023	85.988%	64.336%	97.558%	53.970%
August 2023	87.392%	58.458%	97.320%	49.718%

In the calculations that have been carried out, the calculation results show an average availability of 86.936%, performance efficiency of 61.489%, and rate of product quality of 97.038%. Based on world class standard values, it can be seen that the value that has the largest range with world class standards is performance efficiency with a minimum standard of 95% (Wudhikarn 2016). And the average OEE value is 51.97%, which indicates that the machine effectiveness value at this company is still below the established international standard, namely 85%.

5.3 Six Big Losses

In the six big losses, there are 6 types of losses that cause machine performance to be less than optimal and efficient. Six big losses are divided into three main categories based on the type of loss, namely downtime losses, speed losses, and quality/defect losses (Chikwendu and Chima 2018). After calculating the value of the six big losses, the calculation results are converted into graphical form. The following is a graph of the calculation of the value of the six big losses which can be seen in Figure 1.

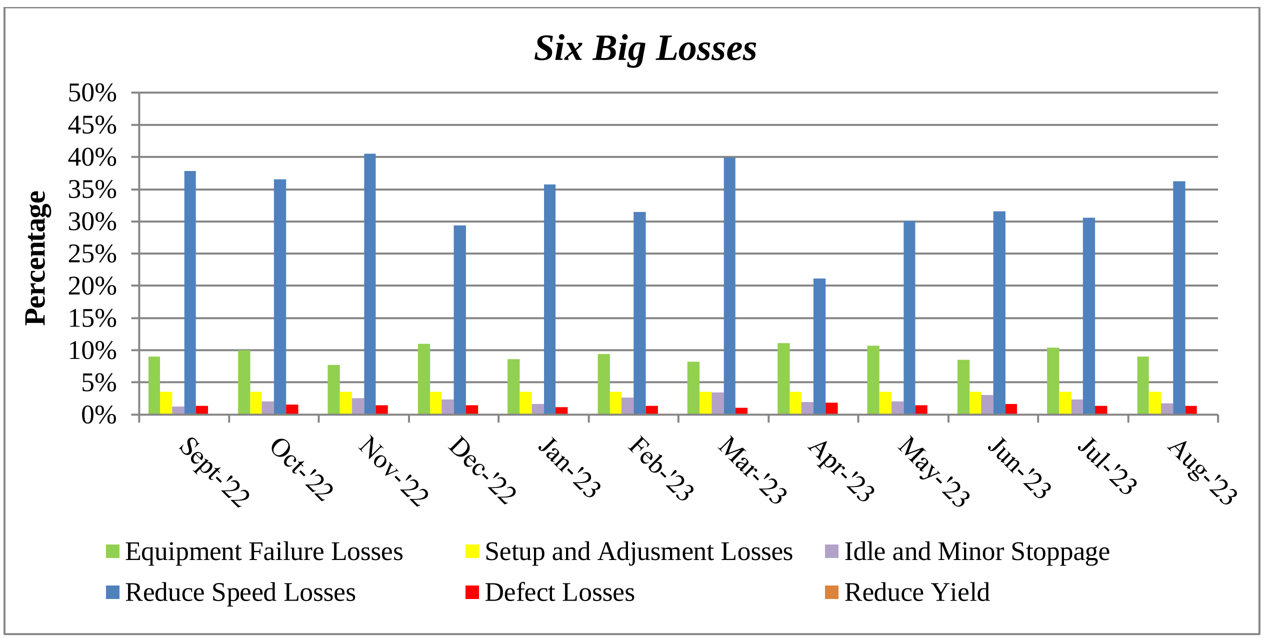

Figure 1. Chart of six big losses

In the graph of the six big losses values, it can be seen that the largest losses value is reduced speed losses with an average value of 33.421%. The next largest loss value is equipment failure losses with a value of 9.493%, setup and adjustment losses with a value of 3.571%, idle and minor stoppage with a value of 2.271%, defect losses with a value of 1.44% and the smallest value is reduce yield with a value 0%.

5.4 Pareto Chart

On the Pareto diagram, you can see the order of losses starting from the largest to the smallest. The Pareto diagram can be seen in Figure 2.

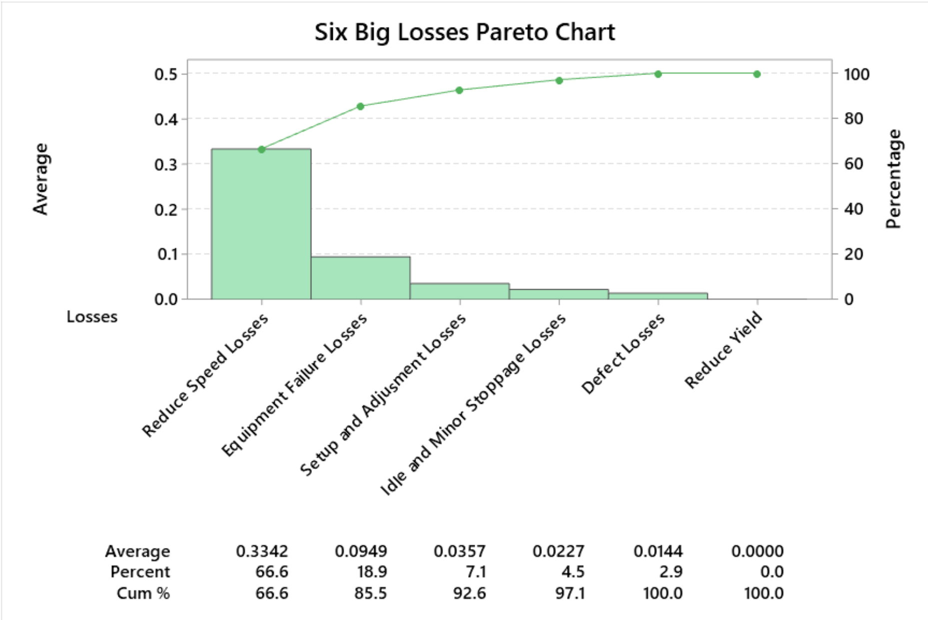

Figure 2. Pareto diagram of six big losses

Based on the Pareto diagram above, there are the sequence of the six big losses from largest to smallest. The biggest types of losses are reduce speed losses and equipment failure losses. And there is also a cumulative percentage of each losses.

5.5 Fault Tree Analysis

Fault tree analysis is an analytical tool used to interpret in the form of a graph or tree the factors that cause failure or error in a system and show the causal relationship of a case (Baig et al. 2013). The following is an FTA based on the six big losses in Figure 3 and Figure 4.

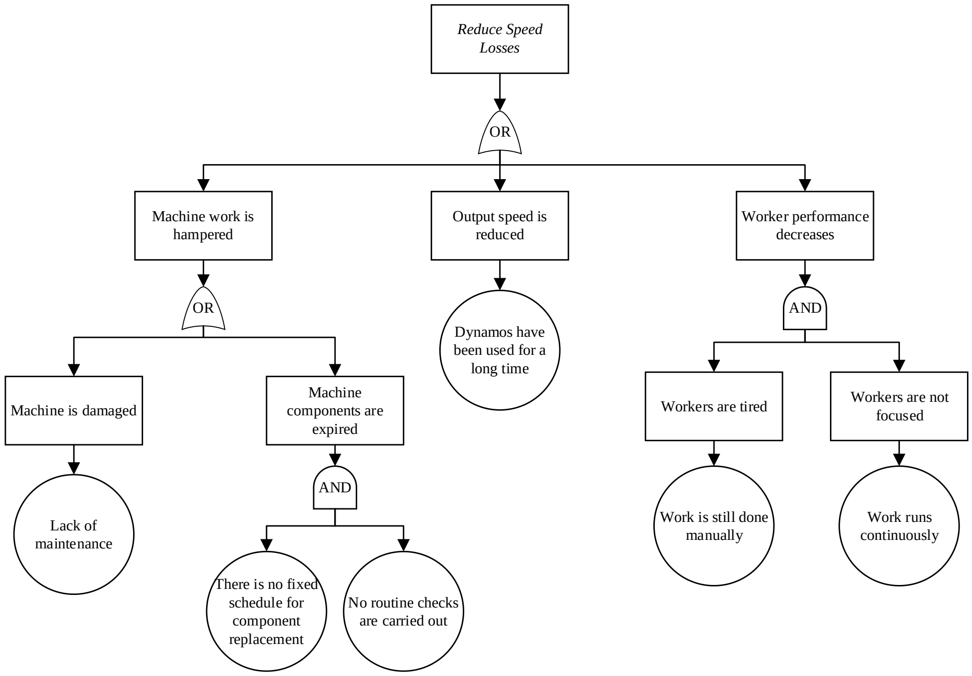

Figure 3. Fault tree analysis of reduces speed losses

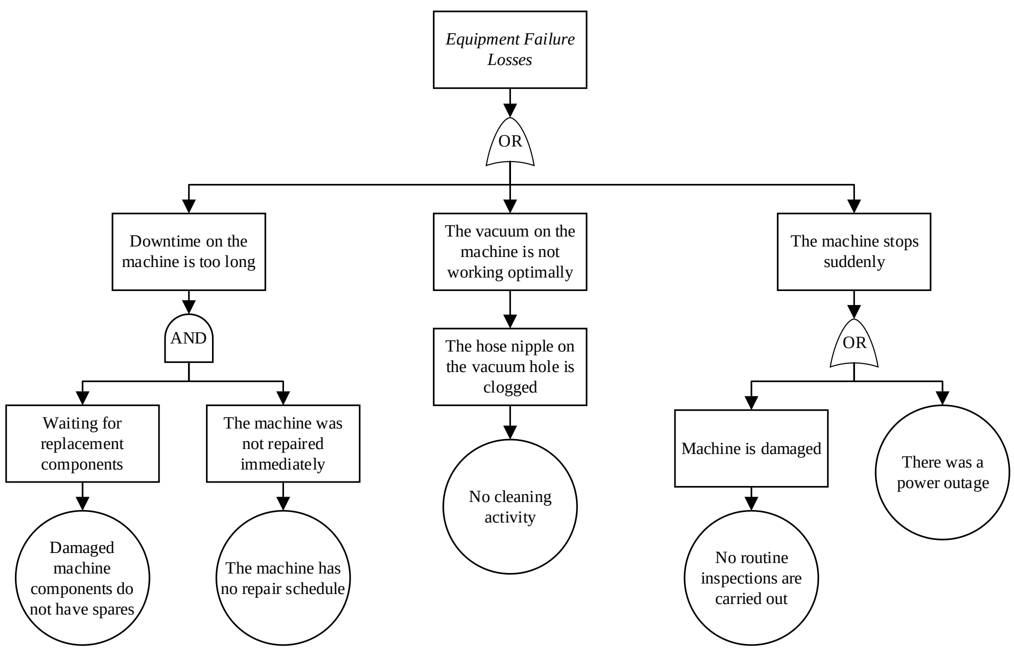

Figure 4. Fault tree analysis of equipment failure losses

In the fault tree analysis that has been carried out, the root cause of each problem can be seen. The OR gate indicates that only one of the underlying causal factors occurs and is not related. Meanwhile, the AND gate indicates that the underlying causal factors occur simultaneously and are interrelated. In reduce speed losses, there are 3 main causing factors, first, the machine's work is hampered, the output speed of the machine is reduced, and worker performance decreases. Meanwhile, in equipment failure losses, the main causes are the downtime on the machine being too long, the vacuum on the machine not working optimally, and the machine stopping suddenly.

5.6 Failure Mode Effect Analysis (FMEA)

FMEA is a method or tool used to analyze potential failures in a production. FMEA aims to analyze potential risks that may occur in equipment, work processes, or work systems (Liu et al. 2019).After analyzing using fault tree analysis to find out the causes of the highest losses, FMEA analysis is carried out to analyze the risks that have the highest potential. FMEA analysis can be seen in Table 4.

Table 4. FMEA causes of extruder machine failure

Process Name	Identity Number	Failure Mode	Effects of Failure	Causes of Failure	Criticism			RPN	Action
					S	O	D		
Reduce Speed Losses	1.1	Machine work is hampered	Production speed decreases	Components on the machine are worn	7	6	4	168	Replacing components on the machine
	1.2	The output speed of the machine is reduced	Production target not achieved	The dynamo is old	5	5	4	100	Replace the dynamo according to its lifespan
	1.3	Worker performance decreases	Workers are not focused	Workers experience fatigue	4	7	3	84	Provides a comfortable resting place
Equipment Failure Losses	2.1	*Downtime* on the machine too long	The production process is hampered	The machine was not repaired immediately	4	6	4	96	Scheduling maintenance on machines
	2.2	*Vacuum*the machine is not working optimally	There is excess air content	*Nipples*the hose on the vacuum hole is clogged	5	4	3	60	Schedule hose nipple cleaning
	2.3	The machine stops suddenly	Machine work becomes unproductive	The machine is damaged	6	7	3	126	Scheduling routine service on machines

After carrying out FMEA analysis, the RPN values were found for 6 failure modes on the extruder machine. In the FMEA table above, you can see the highest to lowest causes of failure. There are 3 causes of failure with the highest RPN value, namely the machine's work is hampered with an RPN value of 168, the machine stops suddenly with an RPN value of 126, and the output speed of the machine is reduced with an RPN value of 100.

5.7 Autonomous Maintenance Improvements

Autonomous maintenance is a machine maintenance concept that involves machine operators as users to carry out basic maintenance. The implementation of autonomous maintenance aims to directly involve the machine operator as the person responsible for machine maintenance, which in turn is expected to increase productivity and reduce downtime (Workineh and Iyengar 2014). To date, this company implement preventive maintenance and corrective maintenance. Preventive maintenance is machine maintenance that is scheduled within a fixed time period. Meanwhile, corrective maintenance is machine maintenance carried out after the machine is damaged (Hung et al. 2017). Procedure carried out on this company for carrying out maintenance on machines is still relatively unstructured and existing machine maintenance procedures are still unclear. Proposed improvements regarding the problems found in this company focuses on the TPM autonomous maintenance pillar. The suggestions that will be given are SOP for autonomous maintenance, gantt chart, maintenance implementation schedule, and work orders.

The scope of maintenance carried out by operators is carrying out light maintenance and repairs such as cleaning machines, inspections, lubrication, machine monitoring, and other things related to production machines. The SOP in this proposed improvement aims to maximize the effectiveness of maintenance activities and prevent fatal damage which causes losses for the company, as well as reducing downtime.

The Gantt chart on the proposed improvements provided aims to plan machine care and maintenance activities and also monitor maintenance activities that have been carried out. By using a Gantt chart, operators who are monitoring maintenance activities will immediately fill in information related to the machine being repaired, starting from the timeline, the name of the machine being repaired, to the time needed to repair the machine.

The final improvement proposal is to create work orders for machine maintenance activities. Work orders are useful for making it easier to record handling of problems on machines which can be filled in manually by staff or operators in the field. This work order is a sign that the machine is damaged and must be repaired immediately or just carry out light maintenance to prevent fatal damage which can increase downtime.

6. Conclusion

Based on the analysis that has been carried out, the average OEE value from September 2022 to August 2023 is 51.97%, which means that this value is still at world class standards and indicates that maintenance activities are not yet optimal. In calculating the six big losses, the highest value was obtained for reducing speed losses with a value of 33.421%. There are several factors that cause low OEE values, especially on extruder machines. Some of the machine work is hampered, the machine stops suddenly, and the output speed of the machine is reduced. By providing proposals for improvements with autonomous maintenance, it is hoped that the effectiveness of the machine will increase, thereby triggering production performance to meet production targets.

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Biographies

Theo Richard is a student at Industrial Engineering Department of Tarumanagara University. He was born in July 2002. With his spirit, he decided to write an industrial engineering journal. He started his college at Tarumanagara University in 2020. He likes to do some research and literature reviews from the books and journals.

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