Effectiveness Analysis of *Pelletizer Machine* Using *Overall Resource Effectiveness* (ORE) And *Failure Mode and Effects Analysis* (FMEA) Methods at PT Multi Energi Biomassa

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ABSTRACT

PT MEB is a manufacturing company engaged in producing and marketing renewable energy. The product is called wood pellets. The problem that often occurs at PT MEB is that the production target has not been achieved according to the target set by the company. One of the causes is that there are frequent disturbances in the performance of the pelletizer machine. The pelletizer machine is a wood pellet printing machine. Damage to the pelletizer machine can cause the production process to be disrupted, thereby reducing the amount of output produced. This study aims to analyze the causes of the decreased effectiveness of the pelletizer machine so that it can give improvement solutions to increase its effectiveness. This research uses Overall Equipment Effectiveness (OEE), Overall Resource Effectiveness (ORE), and Failure Mode and Effect Analysis (FMEA) methods. The results showed that the OEE and ORE values of the pelletizer machine from May 2020 to August 2021 were obtained on average at 25.93% and 19.63%, where these results were below the world-class standard (≥85%). From the results of the calculation of the six significant losses, the dominant factors that affect the effectiveness of the machine are reduced speed losses by 64%, breakdown losses by 19%, and idling and minor stoppage losses by 10%. Based on these results, an FMEA analysis was carried out and found that the RPN results for reduced speed losses and breakdown losses were 384, while the RPN value for idling and minor stoppage losses was 392. The corrective action that needs to be done is to carry out routine inspections of the engine and replace engine parts that are not working correctly.

Keywords: *Machine Effectiveness, Overall Equipment Effectiveness, Overall Resource Effectiveness, Six Big Losses, Failure Mode and Effect Analysis.*

1. INTRODUCTION

The wood pellet industry in Indonesia has enormous opportunities due to the availability of abundant sources of raw materials obtained from sawdust waste in the wood industry. Therefore, the demand for wood pellets as an alternative energy source is currently increasing. This is due to the use of conventional energy resources is dwindling because it cannot be renewed. So that many industries produce alternative renewable energy sources and one of them is wood pellets. However, the use of wood pellets in Indonesia is not too much, even though Indonesia has several wood pellet mills and one of them is PT Multi Energi Biomass (MEB).

PT MEB is a manufacturing company engaged in the production and marketing of renewable energy, where the product is called wood pellets or wood pellets wood pellets. The raw material used to produce wood pellets is sawdust from the wood industry. The production target at PT MEB is 30,000 tons per year. However, based on actual data, currently PT MEB only produces an average of 10,000 tons of wood pellets per year. This is due to frequent disturbances in engine performance. The problem that occurred at PT MEB was that there was damage to the pelletizer machine which resulted in the production process stopping.

The pelletizer machine is a machine for printing wood powder into wood pellets. This machine is a production machine that is the main key for the company in producing wood pellets. If the pelletizer machine is damaged, then all production processes cannot run. Where PT MEB has three pelletizer machines, if one of the three machines is damaged then both machines can be used. However, this can cause waiting times during the packaging process. These problems can be seen in Figure 1. about pelletizer machine downtime chart.

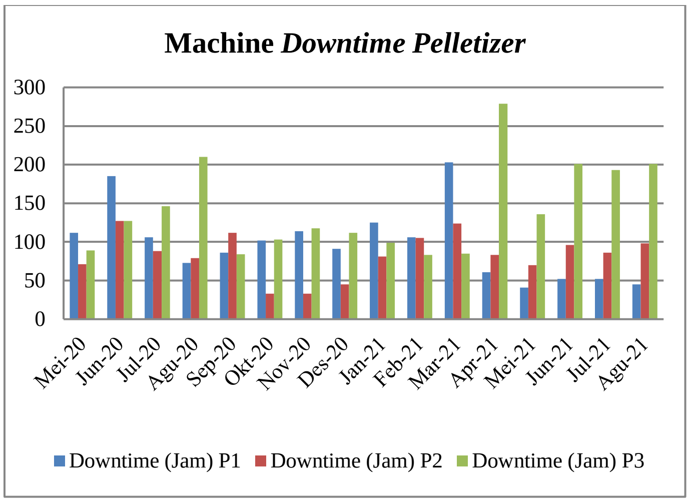

Figure 1. Pelletizer Machine Downtime Graph

Based on Figure 1. downtime the highest was in April 2021, namely on the pelletizer three machine (P3) of 279 hours. Then followed by pelletizer machine one (P1) with the highest downtime in March 2021 at 203 hours and on pelletizer machine two (P2) the highest downtime was in June 2020 at 127 hours. Based on these problems, to analyze the problems that occur in the pelletizer machine, a study was carried out using the Overall Equipment Effectiveness (OEE), Overall Resource Effectiveness (ORE) and Failure Mode and Effects Analysis (FMEA) methods.

OEE is a method that can be used to measure engine effectiveness based on the measurement of three main ratios, namely availability, performance efficiency, and rate of quality [1]. ORE is a manufacturing performance measurement factor that has been developed with the aim of providing a more in-depth evaluation than OEE by considering resources including the availability of humans, machines, materials, and methods [2]. FMEA is used after obtaining factors that affect failure or disability with the aim of obtaining which factors require further treatment using the Risk Priority Number (RPN) value. This study aims to analyze the causes of the decreased effectiveness of the pelletizer machine so that repair solutions can be given to increase the effectiveness of the machine.

2. METHODS

1. Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a method that describes the effectiveness and performance level of a machine or equipment [3]. The ultimate goal of OEE is to maximize the effectiveness of the machine or equipment [4]. OEE measurement is based on three factors, namely the provision of machinery and equipment (availability rate), the level of effectiveness and ability of the machine or equipment in producing a product (performance rate), and the ability of the machine or equipment to produce products that meet the standards (quality rate). The formula for calculating the OEE method can be seen as follows:

$$\text{OEE} = \text{Availability rate} \times \text{Performance rate} \times \text{Quality rate}$$

a. Availability Rate

Availability rate is an indicator used to show the level of reliability of a machine or equipment. The formula for calculating the availability rate is as follows:

$$\text{Availability rate} = \frac{\text{Operating Time}}{\text{Loading Time}} \times 100\%$$

$$\text{Availability rate} = \frac{\text{Loading Time} - \text{Downtime}}{\text{Loading Time}} \times 100\%$$

Information:
Operating Time = Operating time
Loading Time = Preparation time
Downtime = Time not working

b. Performance Efficiency Ratio

Performance efficiency is the ratio of the quantity of product produced multiplied by the ideal cycle time to the time available for the production process (operation time). To calculate the value of performance efficiency, the following formula is used:

$$\text{Performance Efficiency Ratio} = \frac{\text{Processed Amount} \times \text{Ideal Cycle Time}}{\text{Operation Time}}$$

Information:
Precessed Amount = Number of products
Ideal Cycle Time = Machine's ideal cycle time

c. Rate of Quality Product

Rate of Quality Product is the ratio of a good product (good product) in accordance with the product specifications that have been determined to the number of products processed. Calculation of rate of quality product data used is total product data processed with defect amount data, with the following formula:

$$\text{Quality Ratio} = \frac{\text{Processed amount} - \text{Defect amount}}{\text{Processed amount}} \text{x } 100\%$$

Information:
Defect amount = number of rework or defective products

d. Overall Equipment Effectiveness (OEE) Value Standard

The OEE value standard according to JIPM (Japan Institute of Plan Maintenance) introduced by Hakjima is the benchmark international standard for OEE value. The effectiveness standard of OEE value according to JIPM can be seen in Table 1.

Table 1. Standard OEE Value According to JIPM

OEE	World Class
Availability Rate	90%
Performance Efficiency Ratio	95%
Quality Rate	99%
OEE	85%

According to Hansen (2001) the OEE method can be categorized into the following provisions:

- If the OEE value is < 65%, then the OEE value is not accepted
- If the OEE value is 65-75%, then the OEE value can be said to be sufficient with the conditions and there must be an increase every quarter.
- If the OEE value is 75-85%, then the OEE value can be interpreted as very good and continues to the world-class level (≥ 85%).

2. Overall Resource Effectiveness (ORE)

Overall Resource Effectiveness (ORE) is a new methodology useful for overcoming losses associated with individual resources (human, machine, material, method) [2]. The loss factors evaluated by ORE are as follows:

a. Readiness (R)

Readiness is a calculation based on the total time when the system is not ready to carry out operations due to planned downtime which is still being prepared or planned activities. The readiness calculation formula is as in the following formula.

$$\text{Planned Production Time} = \text{Total Time} - \text{Planned Downtime}$$

$$\text{Readiness} = \left(\frac{\text{Planned Production Time}}{\text{Total Time}}\right)$$

Information:
Total time = Shift time or period decided by management

b. Availability of Facility (A_f)

Availability of facility or the availability of this facility relates to the total time the system is not operating due to facility downtime. The formula for calculating availability of facility is as follows.

$$\text{Loading t} = \text{Planned production time} - \text{facilities downtime}$$

$$\text{Availability of facility} = \left(\frac{\text{Loading time}}{\text{Planned production time}}\right)$$

c. Changeover Efficiency (C)

Changeover Efficiency is a measurement related to the total time when the system is not operating due to setup and adjustments. It shows the ratio of operating time to loading time. The formula for calculating changeover efficiency is as follows.

$$\text{Operation time} = \text{loading time} - \text{set up and adjustment}$$

$$\text{Changeover Efficiency (C)} = \left(\frac{\text{Operations Time}}{\text{Loading Time}}\right)$$

d. Availability of Materials (Am)

Availability of material is a calculation based on the total time in which the system does not operate due to material shortages. Availability of material is a comparison between running time and operation time. The formula for calculating availability of material is as follows.

$$\text{Running time} = \text{Operation time} - \text{Material shortages time}$$

$$\text{Availability of Material} = \left(\frac{\text{Running Time}}{\text{Operation Time}}\right)$$

e. Availability of Manpower (Amp)

Availability of manpower is a calculation based on the total time in which the system does not operate due to the absence of an operator. Availability of manpower is a comparison between actual running time and running time. The formula for calculating availability of manpower is as follows.

$$\text{Actual running time} = \text{Running time} - \text{Waktu operator absen}$$

$$\text{Availability of Manpower} = \left(\frac{\text{Actual Running Time}}{\text{Running Time}}\right)$$

f. Performance Efficiency (P)

Performance efficiency is a calculation of the total time by using the operator efficiently, where the time used in producing the product is the actual running time. Performance efficiency is a comparison between earned time and actual running time. The formula for calculating performance efficiency is as follows.

$$\text{Earned time} = \text{Cycle time/unit} \times \text{Quantity produced}$$

$$\text{Performance of Efficiency (P)} = \left(\frac{\text{Earned Time}}{\text{Actual Running Time}}\right)$$

g. Quality Rate (Q)

Quality rate is the level of product quality produced by the company, which is a comparison between the quality of parts accepted and the quality of parts produced. Quality rate is the ratio of the number of parts received to the number of parts produced. The formula for calculating the quality of rate is as follows.

$$\text{Quantity of parts accepted} = \text{Quantity produced} - \text{Quantity rejected}$$

$$\text{Quality Rate (Q)} = \left(\frac{\text{Quality of parts accepted}}{\text{Quality of parts produced}}\right)$$

h. Overall Overal Resource Effectiveness

Overall Resource Effectiveness (ORE) is a measure of the overall effectiveness of the manufacturing system (resources). ORE is generated from the results of measurements of readiness (R), availability of facility (Af), changeover efficiency (C), availability of material (Am), availability of manpower (Amp), performance efficiency (P), and quality rate (Q). The ORE calculation formula is as follows.

$$\text{ORE} = \text{R} \times \text{Af} \times \text{C} \times \text{Am} \times \text{Amp} \times \text{P} \times \text{Q} \times 100\%$$

3. Six Big Losses

Measurement of the productivity of six big losses is an activity that focuses on preventing damage to machines/equipment and minimizing downtime of machines or equipment. The low productivity of machines or equipment that causes losses to the company is often caused by the use of machines or equipment that is not effective and efficient. In increasing the effectiveness of facilities, it can be measured by six big losses, namely [5]:

a. Equipment Failure Loss

Damage to machines or equipment causes losses because the machine does not operate and does not produce output. It can be calculated by the following formula.

$$\text{Equipment Failure} = \frac{\text{Total breakdown time}}{\text{Loading time}} \times 100\%$$

b. Set-up and Adjustment

Set-up and adjustment caused by the installation and adjustment where the setup time and adjustment time in the production process. It can be calculated by the following formula.

$$\text{Setup and Adjustment Loss} = \frac{\text{Total setup and adjustment}}{\text{Loading time}} \times 100\%$$

c. Idling and Minor Stoppage

Losses due to operating without materials or due to a momentary stop arise if external factors cause a machine/equipment to stop repeatedly or the machine/equipment to operate without producing a product. It can be calculated by the following formula.

$$\text{Idling and Minor Stoppages} = \frac{\text{Nonproductive time}}{\text{Loading time}} \times 100\%$$

d. Reduced Speed Loss

The decrease in production speed occurs when the actual operating speed is lower and the designed machine speed operates at normal speed. The decline in production speed was caused, among other things, by:

- The designed machine speed cannot be achieved due to changes in the type of product or material that are not in accordance with the machine/equipment used.
- The production speed of the machine/equipment decreases because the operator does not know what the normal speed of the machine/equipment is actually.
- Production speed is intentionally reduced to prevent machine/equipment problems and higher product quality.

$$\text{Reduced Speed Loss} = \left(\frac{\text{Actual production time} - \text{Ideal operation time}}{\text{Loading time}}\right) \times 100\%$$

e. Process Defect Loss

Process defect loss is caused by defective products due to reprocessed product work. The resulting defective products will result in material losses, reduced production quantities, additional costs for rework, and increased production waste. It can be calculated by the following formula.

$$\text{Process Defect Loss} = \frac{\text{Ideal cycle time} \times \text{Rework}}{\text{Loading time}} \times 100\%$$

f. Reduce Yield Loss

Reduced yield loss is the loss of time and material that occurs during the time required by the machine/equipment to produce a new product with a predetermined product quality. In other words, reduced yield loss is caused by the presence of raw materials or products that do not meet specifications in accordance with company standards. It can be calculated by the following formula.

$$\text{Reduced Yield Losses} = \frac{\text{Ideal cycle time} \times \text{Scarp}}{\text{Loading time}} \times 100\%$$

4. Cause and Effect Diagram

Cause-and-effect diagrams are known as fishbone diagrams, which were introduced by Prof. Kaoru Ishikawa in 1943. This diagram is useful for analyzing and finding factors that significantly influence in determining the quality characteristics of work output. In addition, this diagram is useful for finding the real causes of a problem. An example of the use of cause and effect diagrams can be seen in Figure 2.

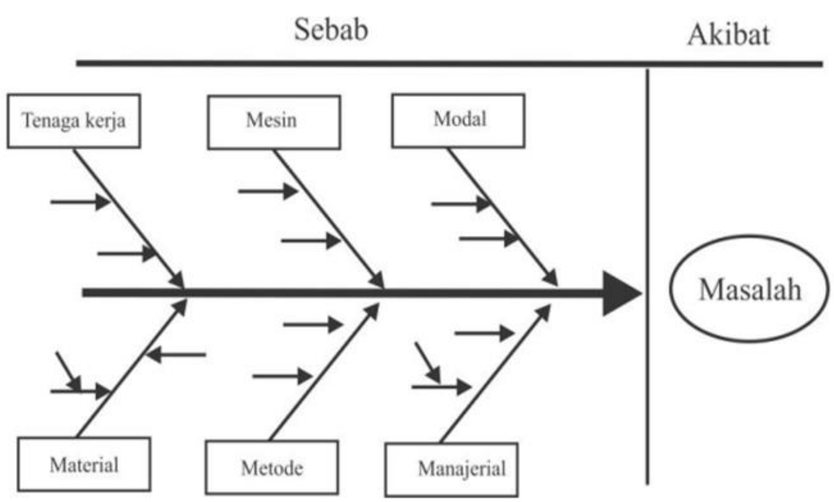

Figure 2. Cause and Effect Diagram

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5. Failure Mode and Effect Analysis (FMEA)

FMEA is conducted to analyze potential errors/failures in the system, and the identified potentials will be classified according to the magnitude of the potential failure and its effect on the process. FMEA is able to design processes that are free of waste and minimize errors and failures [6].

- Calculating the Value of the Risk Priority Number (RPN)

Risk Priority Number is a number that states the priority scale for quality risk which is used as a guide for planning actions. RPN is the product of severity, occurrence, and detection.

$$\text{RPN} = \text{Severity} \times \text{Occurance} \times \text{Detection}$$

The RPN number ranges from 1 to 1000, where the higher the RPN value, the more risky the process is to produce a product with the desired specifications.

3. RESULTS AND DISCUSSION

1. OEE calculation

OEE multiplies three factors, namely availability rate, performance efficiency, and quality rate.

Table 2. OEE Value May 2020 – August 2021

Bulan	*Availability Ratio (%)*	*Performance Ratio (%)*	*Quality Ratio (%)*	OEE
Mei-20	41,42%	60,94%	96,52%	24,36%
Jun-20	48,09%	59,63%	95,56%	27,41%
Jul-20	51,22%	64,32%	97,78%	32,21%
Agu-20	50,52%	69,22%	99,26%	34,71%
Sep-20	58,62%	57,70%	99,03%	33,50%
Okt-20	60,53%	39,22%	98,30%	23,34%
Nov-20	66,97%	15,13%	84,37%	8,55%
Des-20	79,82%	20,85%	94,67%	15,75%
Jan-21	34,26%	84,30%	92,61%	26,75%
Feb-21	55,40%	48,81%	92,02%	24,88%
Mar-21	61,19%	57,59%	98,59%	34,74%
Apr-21	61,56%	57,05%	99,31%	34,87%
Mei-21	44,79%	40,28%	88,93%	16,04%
Jun-21	24,65%	124,32%	90,06%	27,60%
Jul-21	76,04%	32,96%	94,15%	23,60%
Agu-21	54,81%	51,64%	94,05%	26,62%
Rata-Rata				25,93%

Based on the results of data processing, it was found that the average OEE value in May 2020 - August 2021 was 25.93%, which was still below the world-class standard value of >85%. This is influenced by the availability rate, performance ratio, and rate of quality values which are still below the established standard.

Table 3. Average OEE Value of Pelletizer Machine May 2020 – August 2021

Faktor OEE	Hasil	Standar JIPM
Availability Ratio	54,37%	90%
Performance Ratio	55,25%	95%
Quality Ratio	94,70%	99%
OEE	25,93%	85%

2. ORE calculation

ORE multiplies seven factors, namely readiness, availability of facility, changeover efficiency, availability of material, availability of manpower, performance efficiency, and quality rate.

Table 4. ORE Value May 2020 – August 2021

Bulan	R	Af	C	Am	Amp	P	Q	ORE
Mei-20	95,37%	98,06%	95,05%	92,92%	90,58%	23,68%	96,52%	17,10%
Jun-20	94,44%	96,86%	93,94%	95,70%	95,06%	26,64%	95,56%	19,90%
Jul-20	97,22%	97,14%	97,06%	97,98%	87,63%	31,76%	97,78%	24,44%
Agu-20	95,19%	98,04%	94,00%	100,00%	88,09%	32,77%	99,26%	25,13%
Sep-20	96,30%	98,04%	94,00%	97,87%	92,61%	32,24%	99,03%	25,68%
Okt-20	97,04%	98,82%	94,06%	100,00%	90,32%	22,84%	98,30%	18,29%
Nov-20	98,15%	98,10%	97,09%	100,00%	90,40%	9,88%	84,33%	7,04%
Des-20	97,41%	98,82%	94,06%	100,00%	97,89%	16,13%	94,67%	13,53%
Jan-21	96,67%	96,97%	90,63%	93,10%	93,09%	27,50%	92,60%	18,75%
Feb-21	97,22%	98,10%	97,09%	93,60%	92,31%	26,08%	92,01%	19,20%
Mar-21	94,44%	98,04%	94,00%	95,74%	96,00%	32,79%	98,59%	25,86%
Apr-21	95,37%	98,06%	95,05%	97,92%	92,77%	33,10%	99,31%	26,54%
Mei-21	96,30%	98,04%	94,00%	100,00%	85,96%	17,16%	88,94%	11,64%
Jun-21	96,30%	96,97%	90,63%	92,18%	95,01%	29,05%	90,06%	19,39%
Jul-21	97,04%	96,95%	97,06%	100,00%	95,15%	24,20%	94,15%	19,80%
Agu-21	97,22%	97,14%	97,06%	100,00%	87,07%	28,92%	94,39%	21,79%
Rata-Rata								19,63%

Based on the results of data processing, it was found that the average value of ORE in May 2020 - August 2021 was 19.63% which is still below the world-class standard, which is >85%. These results are influenced by the performance of efficiency and quality rate factors, where the results are below 99% and 95%. While the results of the other five factors are above 90%.

Table 5. Average Pelletizer Machine ORE May 2020 – August 2021

Faktor ORE	Hasil	Standar ORE
Readiness	96,36%	90%
Availability of Facility	97,76%	90%
Changeover Efficiency	94,67%	90%
Availability of Material	97,31%	90%
Availability of Manpower	91,87%	90%
Performance of Efficiency	25,92%	95%
Quality Rate	94,72%	99%
ORE	19,63%	85%

3. Calculation of Six Big Losses

Six big losses analysis aims to determine which losses are the most dominant in influencing the low effectiveness of the machine. Based on the results of the percentage of total time loss from each of the six big losses , it was found that the factor that most influenced the effectiveness of the pelletizer machine was reduced speed losses with a total percentage of 64%, followed by breakdown losses of 19% and idling and minor stoppage losses of 10%.

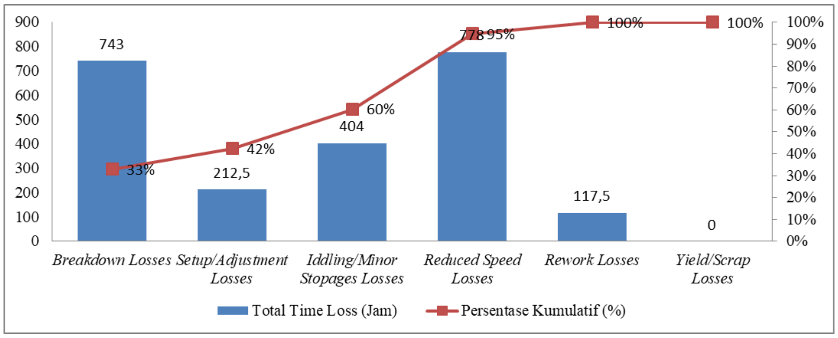

Figure 3. Percentage of Six Big Losses Pelletizer Machines May 2020 – August 2021

4. Cause and Effect Analysis

The causal diagram analysis was carried out on the most dominant losses, namely reduced speed losses, breakdown losses, and idling and minor stoppage losses.

a. Cause and Effect Diagram of Reduced Speed Losses

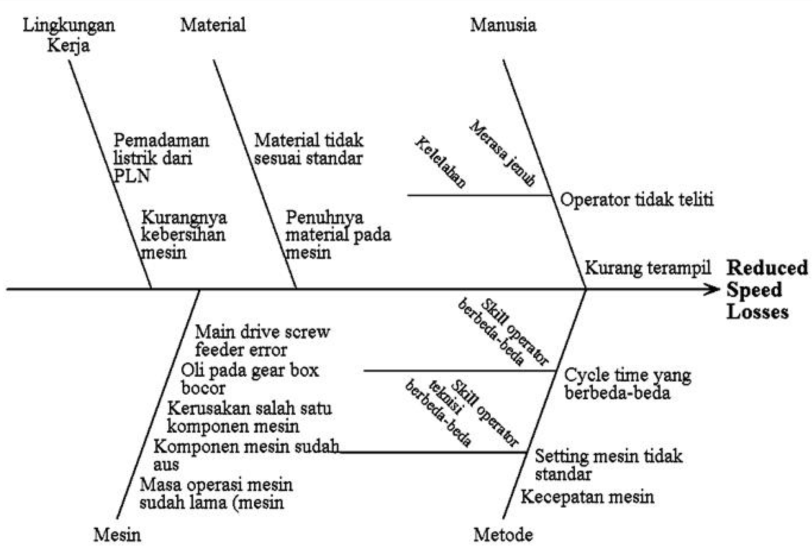

Figure 4. Cause and Effect Diagram of Reduced Speed Losses

b. Cause and Effect Diagram of Breakdown Losses

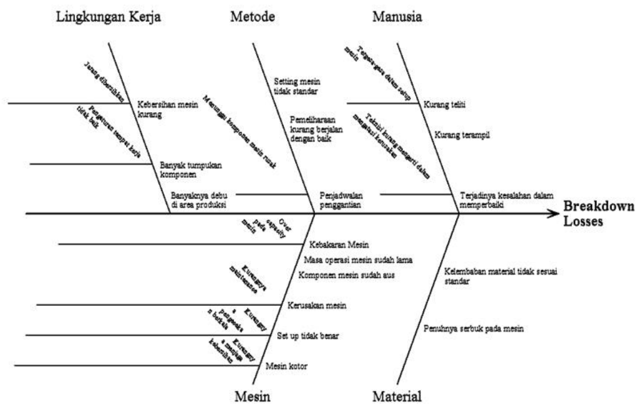

Figure 5. Cause and Effect Diagram of Reduced Speed Losses

c. Cause and Effect Diagram of Idling and Minor Stoppage Losses

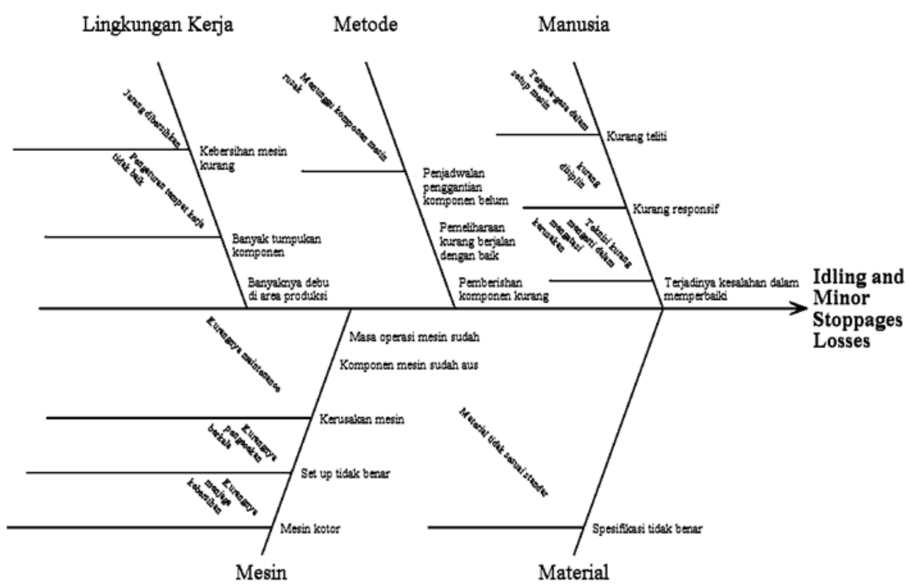

Figure 6. Cause and Effect Diagram of Idling and Minor Stoppage Losses

5. FMEA Analysis

FMEA is a method to identify and analyze potential failures and their consequences which aims to plan the production process well and can avoid production process failures and unwanted losses. From the results of the RPN calculation which multiplies the severity, occurrence, and detection values, it is found that the cause of the high losses in reduced speed losses and breakdown losses is the long operating period of the machine with a total RPN value of 384. While the cause of the high idling and minor stoppage losses is engine damage with the total value of the RPN is 392. Table 6. is factors causing failure based on the RPN value on reduced speed losses, breakdown losses, and idling and minor stoppage losses.

Table 6. Factors Causing Failure Based on RPN Value

No	Jenis Kegagalan	Bagian Kegagalan	Faktor Kegagalan	*Severity*	*Occurance*	*Detection*	RPN	Mode Potensi Kegagalan	Penyebab Potensial Kegagalan	*Recommended Action*	*Responsibility & Target Completion Date*
1	*Reduced Speed Losses*	Mesin	Masa operasi mesin sudah lama	8	8	6	384	Produksi produk mesin lama dan mesin sering rusak	Mesin yang digunakan merupakan mesin bekas dan beberapa *part* tidak berfungsi sebagaimana mestinya	1. Perusahaan mengganti *part* mesin yang sudah tidak berfungsi dengan *part* mesin yang baru. 2. Perusahaan melakukan pemeliharaan secara rutin (berkala) terhadap mesin.	Produksi sesuai target perusahaan
2	*Breakdown Losses*	Mesin	Masa operasi mesin sudah lama	8	8	6	384	Produksi produk mesin lama dan mesin sering rusak	Mesin yang digunakan merupakan mesin bekas dan beberapa *part* tidak berfungsi sebagaimana mestinya	1. Perusahaan mengganti *part* mesin yang sudah tidak berfungsi dengan *part* mesin yang baru. 2. Perusahaan melakukan pemeliharaan secara rutin (berkala) terhadap mesin sehingga dapat menjaga mesin tetap berfungsi.	Produksi sesuai target perusahaan
3	*Idling and Minor Stoppage Losses*	Mesin	Kerusakan mesin	8	7	7	392	Produksi menuurun	Kurangnya *maintenance* berkala terhadap mesin	1. Perusahaan melakukan perawatan preventif terhadap mesin seperti melakukan inspeksi, perbaikan kecil, pelumasan dan penyetelan sehingga mesin selama beroperasi terhindar dari kerusakan. 2. Perusahaan juga melakukan perawatan secara rutin dengan membuat jadwal perawatan terhadap mesin.	Menjaga mesin beroperasi dalam kondisi prima

4. CONCLUSION

Based on the results of research and data processing, several conclusions can be drawn as follows:

1. From the results of the OEE and ORE calculations for the pelletizer machine in May 2020 - August 2021, the average was 25.93 % and 19.63%, respectively. Based on these results, it can be concluded that the OEE and ORE values of the pelletizer machine are still below the world class standard (≥85%).
2. Based on the results of the percentage of total time loss from each of the six big losses, three dominant factors that affect the effectiveness of the pelletizer machine were found , namely reduced speed losses with a total percentage of 64%, followed by breakdown losses of 19% and idling and minor stoppage losses of 10 %. From these results, an FMEA analysis was carried out by calculating the RPN, it was found that the cause of the high losses in reduced speed losses and breakdown losses was the long operating period of the machine with a total RPN value of 384. While the cause of the high idling and minor stoppage losses was engine damage with a total RPN value. amounted to 392.
3. The corrective action that needs to be taken by the company based on the FMEA analysis is to carry out routine inspections and maintenance of the machine and replace the machine part that is considered not functioning with a new machine part.

SUGGESTION

As a result of this research, some suggestions can be given as follows:

1. To improve engine performance, the company should carry out periodic inspections so that the performance of existing machines can always be monitored and improved.
2. For the next researcher, they can design a maintenance system for the pelletizer machine with the factor of the machine operating period being long and often damaged, so that they can evaluate the performance of the machine.
3. For the next researcher who conducts research in the same field in order to carry out the application and further observations of the recommended actions and conduct an analysis by simulating the cost level loss.

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