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Productivity Analysis Using Total Productive Maintenance and Overall Equipment Effectiveness (OEE) at PT. Automotive Manufacturing

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Abstract:- This study aims to analyze and improve productivity at PT Manufaktur through the Total Productive Maintenance (TPM) approach and measurement of Overall Equipment Effectiveness (OEE). The problem faced by the company is a significant decrease in productivity, reflected in the increase in machine downtime by 25%, product defect rates reaching 12%, and various losses in the production process which result in financial losses reaching Rp. 500 million per month. The research method used a quantitative approach with primary data collection through direct observation, interviews with operators and production supervisors, and secondary data in the form of production, maintenance, and quality control records during the period November 2023-October 2024. The analysis was carried out by calculating the OEE value based on three main components, namely Availability, Performance rate, and Quality rate, and identifying the implementation of the eight pillars of TPM using an assessment matrix and fishbone analysis. The results showed that the average OEE value was 77.94% (Availability 95.1%, Performance Rate 82.49%, Quality Rate 99.45%), still below the world class standard (85%). Losses are caused by breakdown losses (5%), defect losses (2%), setup and adjustment losses (3%), reduced speed losses (13%), and idling and minor stoppage losses (14%). Effective TPM implementation is recommended through autonomous maintenance, planned maintenance, quality maintenance, and focused improvement programs, with a target of increasing the OEE value to 86% within 12 months. This research also produced a comprehensive TPM implementation roadmap along with key performance indicators for continuous monitoring and evaluation.

Keywords:- *TPM, OEE, Six Big Losses, FMEA.*

I. INTRODUCTION

In the era of Industry 4.0 and intensifying global competition, manufacturing companies are required to continuously improve their productivity and operational efficiency while maintaining high product quality. Productivity is not only a key indicator in measuring company performance, but also a determining factor in maintaining competitive advantage and long-term business sustainability. PT. Manufaktur, as one of the companies engaged in the processing industry with a production capacity of 50,000 units per month, faces serious challenges in maintaining and improving its productivity amidst the complexity of the production process and dynamic market demands.

Total Productive Maintenance (TPM) is a holistic approach to maintenance management that aims to maximize the effectiveness of equipment and production processes through a comprehensive preventive maintenance system. TPM not only focuses on technical maintenance aspects, but also involves the transformation of organizational culture through the empowerment of all employees in an effort to increase productivity. The concept was first developed in Japan by Seiichi Nakajima and has proven effective in improving productivity in various global manufacturing industries. TPM is built on eight fundamental pillars: autonomous maintenance, planned maintenance, quality maintenance, focused improvement, early equipment management, training and education, safety, health and environment, and TPM in administrative departments.

Overall Equipment Effectiveness (OEE) is a key metric in TPM that measures equipment effectiveness based on three main parameters: availability, performance, and quality. OEE is a powerful tool in identifying areas that need improvement and measuring the impact of TPM program implementation on overall productivity.

➢ *The Problems faced by PT Manufaktur Include Several Interrelated Critical Aspects:*

- *Technical Aspects:*

✓ High machine downtime which reaches 20%-25% of the available production time
✓ Product quality variability with defect rate reaching 12%
✓ Various losses in the production process that reduce efficiency
✓ Non-optimization in machine capacity utilization

- *Management Aspects:*

✓ Maintenance system that is still reactive
✓ Lack of standardization in operation and maintenance procedures

- ✓ Limitations in performance data documentation and analysis system
- ✓ Suboptimal coordination between departments

- *Human Resource Aspects:*

- ✓ Limited operator competence in performing basic maintenance
- ✓ Resistance to work system change
- ✓ Lack of employee involvement in improvement programs
- ✓ Training needs that have not been met optimally

Preliminary data showed that the company experienced production losses of 15-20% and financial losses reaching Rp 500 million per month due to these various factors. This condition prompted the need for a comprehensive analysis of the effectiveness of the existing equipment and maintenance system implementation, as well as the development of a systematic and measurable improvement strategy.

- *This Research Aims to:*

- ✓ Analyze equipment effectiveness through OEE measurement and identify the six big losses that affect productivity.
- ✓ Evaluate existing TPM implementation using assessment matrix and gap analysis.
- ✓ Develop a comprehensive TPM implementation roadmap with timeline and targets..
- ✓ Formulate strategic and technical improvement recommendations to increase productivity.
- ✓ Design a monitoring and evaluation system to ensure the sustainability of the TPM program.

- *The Significance of this Research Lies in its Contribution to:*

- ✓ Providing a practical framework for TPM implementation in the manufacturing industry
- ✓ Developed a comprehensive OEE measurement and analysis model
- ✓ Generate best practices in maintenance management and productivity improvement
- ✓ Memberikan Provide empirical references for further research in the field of TPM and OEE

Through a systematic TPM approach and OEE measurement, it is expected that this research can provide a comprehensive picture of the actual productivity conditions and produce strategic recommendations for continuous improvement at PT Manufaktur. The results of this study are also expected to be a reference for other manufacturing industries in efforts to increase productivity through the implementation of TPM and OEE measurements, and contribute to the development of a body of knowledge in the field of maintenance management and industrial productivity.

II. RESEARCH METHODOLOGY

➢ *Total Productive Maintenance (TPM)*

Total Productive Maintenance (TPM) is an innovative approach to equipment maintenance that involves maintenance personnel and operators working in teams focused on eliminating equipment breakdowns and equipment-related defects. It is a systematic approach to improving production systems and quality by including all employees through moderate investment in maintenance (Agustiady & Cudney, 2016). Full support from all employees and top management is required for TPM to succeed. TPM is also a key aspect of a quality management system. TPM seeks to increase productivity by investing in proper maintenance to reduce losses. There are six preventable losses which are Breakdowns, Setup and adjustments, Idling, Minor stoppages, Quality, Rework.

➢ *Overall Equipment Effentiveness (OEE)*

Overall Equipment Effentiveness (OEE) is an indicator of overall equipment health and is the most commonly used measure of equipment performance. It is a measure of the percentage of time a piece of equipment produces a quality product (Agustiady & Cudney, 2016). OEE can dramatically affect productivity because it breaks down losses into clear categories, variability in OEE components, pinpointing areas that need further improvement, especially regarding downtime due to technical and maintenance issues (David Rakes, Muhammad Arif, Agus Setiawan, Kerina Putri Nasution & Yudi Prastyo, 2024). It also helps Lean teams target improvement activities accordingly. As you begin your TPM implementation, it is important to focus on the most critical equipment first.

➢ *Organizations should measure OEE for three main reasons:*

- To help prioritize improvement projects and reflect results
- To incorporate aspects of equipment utilization, operation, and quality
- To measure changes in capacity, productivity, and quality.

Calculating OEE must obtain the availability of equipment, the performance efficiency of the process and the rate of product quality with the formula (Agustiady & Cudney, 2016):

$$\text{OEE}(\%) = \textit{Availability (\%)} \times \textit{Peformance} (\%) \times \textit{Quality rate} (\%)$$

Availability ratio is a ratio that describes the utilization of time available for machine or equipment operation. The formula used by the Availability ratio is:

$$Availability = \frac{Operation\ Time}{Loading\ Time} \times 100\%$$

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➢ *Description:*

- Operating time: Length of equipment downtime (Loading timedowntime).
- Loading time: Available time minus planned equipment downtime (available time - planned downtime).

$$Ideal\ Cycle\ Time = 1 - \frac{Total\ Delay}{Avaiable\ Time} x\ 100\%$$

$$Waktu\ Siklus\ Ideal = \ cycle\ time\ x\ \%\ working\ hours$$

➢ *Description:*

- Processed amount: Total products processed or number of products produced
- Ideal cycle time: Ideal/minority cycle time
- Operating Time: Length of equipment downtime that is actually in operation (loading time-downtime)

Quality Ratio is a ratio that shows the ability of equipment to produce products in accordance with standards. The formula used for measuring this ratio is:

$$Rate\ Of\ Quality\ Product = \frac{Processed\ Amount - Defect\ Amount}{Processed\ Amount}\ x\ 100\%$$

➢ *Description:*

- Processed amount: Total products processed / number of products produced.
- Defect amount: The number of defective products produced.

➢ *Six Big Losses*

The purpose of calculating the six big losses is to determine the overall effectiveness value of Overall Equipment Effectiveness (Agustiady & Cudney, 2016). From this OEE value, steps can be taken to improve or maintain this value.

The six losses can be classified into three types:

➢ *Downtime Losses*

Downtime losses are the amount of production time that is lacking due to internal and external disturbances from both machine breakdowns, power failures and so on. The factors that cause breakdown time are machine damage or the heat of the machine/equipment.

- *Equipment Failures (Loss due to Equipment Breakdown)*

The cause of sudden machine stoppage causes losses, because the machine stops operating, so production is not maximized. The amount of machine effectiveness lost due to the breakdown losses factor can be calculated using the following formula:

$$Breakdowns\ Losse = \frac{\text{Total Breakdowns Time}}{\text{Loading Time}}\ x\ 100\%$$

Performance efficiency is a ratio that describes the ability of equipment to produce goods.

Performance efficiency can also be used as a measure of stability in a process in periods when the equipment is running at the following speeds:

$$Peformance\ Efficiency = \frac{Pr\ o\ cessed\ Amount\ x\ Ideal\ Cycle\ Time}{Operation\ time} x\ 100\%$$

- *Setup and AjusmentLosses*

Setup time is the production time required for one type of product including machine warm-up. The time required to setup the machine starts from the machine stops until it stops until it operates normally. The loss of effectiveness due to setup and adjustment Losses can be calculated by the formula:

$$Setup\ and\ Adjusment\ Losse = \frac{setup\ time}{Loading\ Time} x\ 100\%$$

➢ *Speed Loss*

Speed Loss can occur when the operation of the machine is not in accordance with its maximum specification speed. Speed Loss can occur due to wear and tear on the machine due to the amount of scrap attached to the machine. Factors that affect Speed Loss are:

- Idling and Minor Stoppages (Idling and minor stoppages losses) occur when the machine stops repeatedly due to external factors such as power outages, machine cleaning caused by tangled threads. If idling and minor stoppages occur frequently, the effectiveness lost due to idling and minor stoppages can be seen by using the formula:

$$Idling\ and\ minner\ stoppages = \frac{non\ produktive}{Loading\ Time} x\ 100\%$$

- Reduced Speed Losses i.e. losses due to machines not working optimally (decrease in operating speed) occur if the actual operating speed of the machine/equipment is less than the optimal speed or designed speed of the machine. formula:

$$Reduced\ Speed\ Losses = \frac{production\ time - (Ideal\ Cycle\ Time\ x\ Quantity\ product)}{Loading\ Time} x\ 100\%$$

➢ *Defect Loss*

Defect loss i.e. the occurrence of repetition of the production process and the presence of unused raw material waste, consisting of:

- Rework loss is a loss caused by defective products and reprocessed products. The resulting defective products will result in material losses, reducing production quantities. Rework losses include labor costs and the time required to process and rework or to repair defective products. formula:

$$Rework\ Loss = \frac{Ideal\ Cicle\ Time\ x\ Rework}{Loading\ Time} x\ 100\%$$

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- Reduced Yield Losses caused by unused materials or raw material waste. Formula:

$$Reduced\ Yield\ Losses = \frac{\text{Ideal Cicle Time Scrup}}{\text{Loading Time}} x\ 100\%$$

➢ *FMEA (Failure Mode and Effect Analysis)*

Used after obtaining factors that affect failure or defect with the aim of obtaining which factors require further handling. By looking at the Failure Mode and Effect Analysis (FMEA) analysis, potential causes that require immediate corrective action can be identified. The Risk Priority Number (RPN) value is obtained from the result of multiplying the Severity, Occurance, and Detection values, the highest RPN will be used as a proposal for corrective action. FMEA is usually carried out during the conceptual and early design stages of the system with the aim of ensuring that all possible failures have been considered and appropriate efforts to overcome them have been made to minimize all potential failures (Kevin A, 2001). FMEA is a systematic method of identifying and preventing problems that occur in products and processes (McDermott, 2009).

III. RESULTS AND DISCUSSION

➢ *Overall Equipment Effentiveness (OEE)*

Calculation results To find out the root of the problem in this study, downtime observations have been made on the band saw mill machine. The following are the types of downtime on the band saw mill machine, namely worn bearings, broken saws, missing saw teeth, reduced engine rotational speed and saw tooth wear.

- *Calculation of Availability Ratio*

Availability is the ratio of operation time, by eliminating equipment downtime, to loading time. the formula used to measure the availability ratio is the equation:

Table 1 Availability Ratio Calculation

Month	Loading Time (Hours)	Total Downtime (Hours)	Operating Time (Hours)	Availability Ratio (%)
Nov-23	166	7,5	158,5	95,5%
Dec-23	128	6,4	121,6	95%
Jan-24	174	7,9	166,1	95,5%
Feb-24	102	5,1	96,9	95%
Mar-24	103	5,5	97,5	94,6%
Apr-24	103	5,5	97,5	94,6%
May-24	14	0,6	13,4	95,7%
Jun-24	86	4,5	81,5	94,7%
Jul-24	94	4,8	89,2	94,9%
Aug-24	89	4,4	84,6	95,5%
Sep-24	78	4	74	94,8%
Oct-24	120	5,2	114,8	95,6%

From the table the highest availability calculation results are in May 2024 with a value of 95.7% and the lowest availability value occurs in March and April 2024 with a value of 94.6%. The results of the calculation of the average availability value for one year, namely in the period November 2023 to October 2024, obtained a value of 95.1%.

- *Calculation Performance Efficiency*

The calculation of performance efficiency begins with the calculation of ideal cycle time. Ideal Cycle Time is the ideal cycle time of the machine in cutting logs. In looking for effectiveness, the ideal time calculation must be done in the operating hours of a production, then the formula used is equation (3) can be seen in table 2

Table 2 Performance Efficiency Calculation

Month	Processed Amount (Pcs)	Waktu Siklus Ideal (Hours/Pcs)	Operation Time (Hours)	Performance Efficiency (%)
Nov-23	45.612	0,00289	158,5	83,17%
Dec-23	29.639	0,00342	121,6	83,36%
Jan-24	47.889	0,00289	166,1	83,32%
Feb-24	7.368	0,01096	96,9	83,34%
Mar-24	45.147	0,00180	97,5	83,34%
Apr-24	33.633	0,00242	97,5	83,47%
May-24	49.723	0,00209	13,4	74,21%
Jun-24	50.477	0,00134	81,5	82,99%
Jul-24	55.276	0,00134	89,2	83,03%
Aug-24	51.938	0,00135	84,6	82,89%
Sep-24	45.898	0,00134	74	83,11%
Oct-24	54.871	0,00173	114,8	82,68%

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From the table of OTC Robot Performance Efficiency calculation results above, the highest performance efficiency calculation results were obtained in April 2024 with a value of 83.47% and the lowest performance efficiency value occurred in May 2024 with a value of 74.21%. The results of the calculation of the average Performance Efficiency value for one year, namely in the period November 2023 to October 2024, obtained a value of 82.49%.

- *Rate of Quality Product calculation*

Rate of Quality Product Rate of Quality is a ratio that describes the ability of equipment to produce products that are in accordance with standards. The formula for finding the Rate of Quality value is shown in equation 7. The results of the Rate of Quality calculation from November 2023 to October 2024 are shown in Table 3.

Table 3 Rate of Quality Product Calculation

Month	Processed Amount (Pcs)	Total Deffect	Rate of Quality
Nov-23	45.612	258	99,43%
Dec-23	29.639	258	99,12%
Jan-24	47.889	255	99,46%
Feb-24	7.368	72	99,02%
Mar-24	45.147	340	99,24%
Apr-24	33.633	179	99,46%
May-24	49.723	156	99,68%
Jun-24	50.477	187	99,62%
Jul-24	55.276	81	99,85%
Aug-24	51.938	94	99,36%
Sep-24	45.898	272	99,40%
Oct-24	54.871	76	99,86%

Based on the calculation table above, the results of the quality rate calculation with the highest value are in October 2024 with a value of 99.86% while the lowest quality rate value is in February 2024 of 99.02%.

- *Calculation of Overall Equipment Effectiveness (OEE)*

To determine the overall effectiveness of the machine, the values of Availability Ratio, Performance Efficience and Rate Of Quality Product must first be obtained. The formula for finding the value of Overall Equipment Effectiveness is shown in equation 1. The results of the calculation of Overall Equipment Effectiveness from November 2023 to October 2024 are shown in Table 4.

Table 4 Calculation of Overall Equipment Effectiveness

Month	Availability Ratio (%)	Performance Efficiency (%)	Rate of Quality	OEE(%)
Nov-23	95,5%	83,17%	99,43%	78,97%
Dec-23	95%	83,36%	99,12%	78,49%
Jan-24	95,5%	83,32%	99,46%	79,14%
Feb-24	95%	83,34%	99,02%	78,39%
Mar-24	94,6%	83,34%	99,24%	78,24%
Apr-24	94,6%	83,47%	99,46%	78,53%
May-24	95,7%	74,21%	99,68%	70,79%
Jun-24	94,7%	82,99%	99,62%	78,29%
Jul-24	94,9%	83,03%	99,85%	78,67%
Aug-24	95,5%	82,89%	99,36%	78,65%
Sep-24	94,8%	83,11%	99,40%	78,31%
Oct-24	95,6%	82,68%	99,86%	78,93%

Based on the table of overall equipment effectiveness (OEE) calculation results above, the highest overall equipment effectiveness (OEE) value was obtained in January 2024 with a value of 79.14% and the lowest overall equipment effectiveness (OEE) value occurred in May 2024 with a value of 70.79%. The results of the calculation of the average overall equipment effectiveness (OEE) value for one year in November 2023 to October 2024 above obtained the results of the calculation of the overall equipment effectiveness (OEE) value of 77.94%.

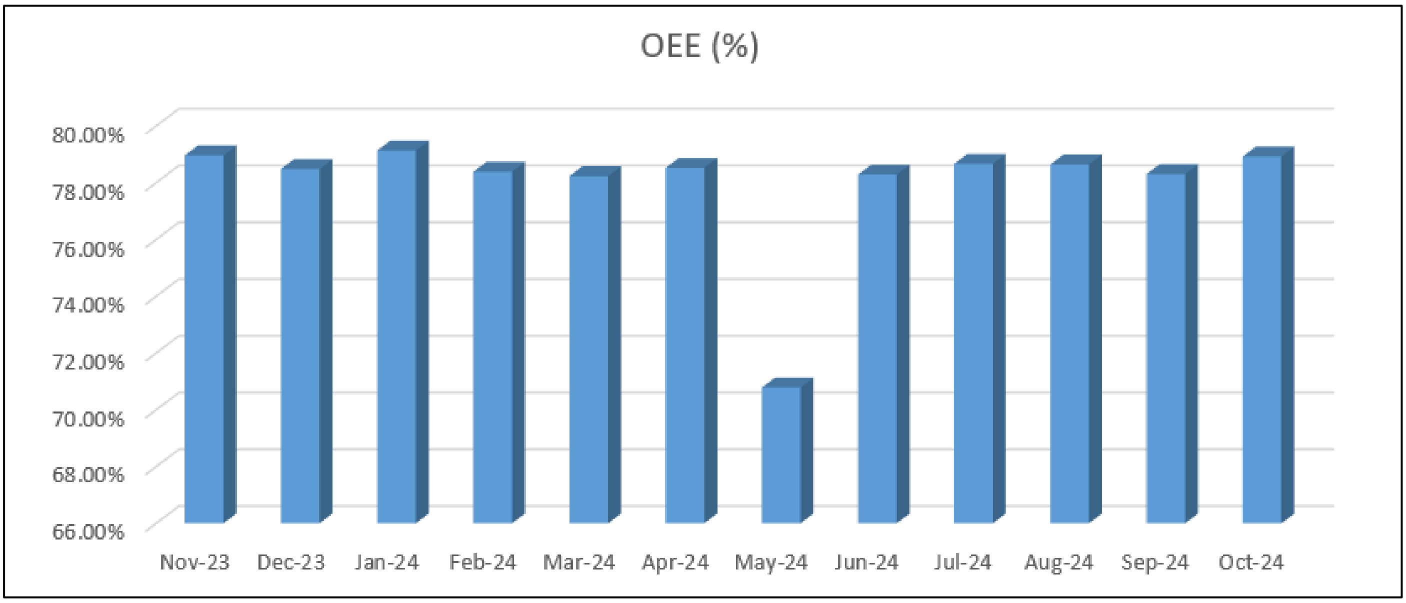

Fig 1 Overall Equipment Effectiveness (OEE)

➢ *Calculation Result Six Big Losses*

- *Breakdown Losses, set-up and Adjustment Dan Idling and Minor Stoppages*

The large percentage of lost machine effectiveness is caused by equipment failure. Factors that cause breakdown time are power cut-off and machine/equipment damage. In the calculation of set-up and adjustment, all data regarding the set-up time of the machine that is the object of research is required. To determine the percentage of lost machine effectiveness, the Set Up and Adjustment Losses calculation is carried out using the equation 9 formula, to determine the percentage of idling and minor stoppages factors in affecting machine effectiveness. Based on the machine delay data obtained, the factor that includes nonproductive time is spraying the machine. Idling and minor stoppage calculations using the formula equation 2.10. then the results are obtained as table 5.

Table 5 Results Breakdown Losses Dan set-up and Adjusment

Month	Total Breakdown (Hours)	Loading Time (Hours)	Breakdown Loss (%)	Total (Hours)	Set-up Adjusment Loss (%)	Cleaning Mesin (Hours)	Idling and Minor Stoppages (%)
Nov-23	7,5	166	4,52%	6,9	2,46%	1,8	1,14%
Dec-23	6,4	128	5%	7,5	2,27%	2,2	1,72%
Jan-24	7,9	174	4,54%	6,7	2,18%	2,1	1,21%
Feb-24	5,1	102	5%	7,4	2,36%	2,1	2,11%
Mar-24	5,5	103	5,34%	7,8	2,55%	2,1	2,03%
Apr-24	5,5	103	5,34%	7,9	2,57%	2,1	2,03%
May-24	0,6	14	4,28%	6,5	2,22%	1,9	13,57%
Jun-24	4,5	86	5,23%	7,4	2,12%	2,5	2,91%
Jul-24	4,8	94	5,11%	7,3	2,15%	2,4	2,55%
Aug-24	4,4	89	4,94%	7,3	2,40%	2,1	2,35%
Sep-24	4	78	5,13%	7,4	2,25%	2,3	2,95%
Oct-24	5,2	120	4,33%	6,6	2,31%	1,8	1,50%

- *Reduced Speed Losses, Rework losses dan Yield/scrap loss*

At this stage Reduced speed losses are losses due to reduced engine speed in operation so that the engine cannot work at the theoretical speed that has been designed. Reduced speed losses are calculated using the equation 11. Rework Losses. Factors categorized into defect losses are rework loss and yield/scrap loss. Rework losses are products that do not meet predetermined quality specifications even though they can still be repaired or reworked. This loss will certainly affect material stock and inefficient operating time. Rework losses are calculated using equation 12 and Yield/scrap loss to determine the percentage of yield/scrap loss factors that affect machine effectiveness. Calculation of yield/scrap loss using equation 13, the results obtained are as shown in table 6.

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Table 6 Calculation Reduced Speed Losses, Rework Losses Dan Yield/scrap loss

Month	Loading Time (Hours)	Idle Cycle Time (Hours /pcs)	Rework	Rework Loss (%)	Reduced Speed Time (Hours)	Reduced Speed Loss (%)	Scrap (pcs)	Scrap Loss (%)
Nov-23	166	0,00289	33,813	58,86%	17,7%	9,7%	0	0%
Dec-23	128	0,00342	40,014	69,12%	18,6%	10,6%	0	0%
Jan-24	174	0,00289	33,813	56,16%	18,2%	10,2%	0	0%
Feb-24	102	0,01096	128,232	77,86%	19,1%	11,1%	0	0%
Mar-24	103	0,00180	21,060	36,80%	20,2%	12,2%	0	0%
Apr-24	103	0,00242	28,314	66,52%	18,4%	10,4%	0	0%
May-24	14	0,00209	24,453	36,50%	18,8%	10,8%	0	0%
Jun-24	86	0,00134	15,678	24,42%	19,2%	11,2%	0	0%
Jul-24	94	0,00134	15,678	22,34%	19,5%	11,5%	0	0%
Aug-24	89	0,00135	15,795	23,95%	17,6%	9,6%	0	0%
Sep-24	78	0,00134	15,678	26,93%	19,7%	11,7%	0	0%
Oct-24	120	0,00173	20,241	29,18%	17,9%	9,9%	0	0%

➢ *Failure Mode and Effect Analysis (FMEA)*

Calculating the RPN (Risk Priority Number) Value, The risk priority number value is the value of the product of the severity, occurrence, and detection values of each failure that occurs. The RPN calculation formula is like equation 14 with an example of the calculation of risk priority, for example, for the type of failure breakdown losses caused by wire jams by controlling cleaning the wire line and disciplining operators in sorting raw materials. Severity is worth 8, Occurrence is worth 7, Detection is worth 8. By using equation 15, the RPN value is obtained: RPN = 8 x 7 x 8 => RPN = 448 the results of the calculation of the process with the full RPN value can be seen in table 7.

Table 7 Calculation RPN FMEA

Loss	Causes of failure in the process	S	Effects caused by failure	O	Controls performed	D	RPN
Breakdown Losses	Jig clamp broke	9	The result of oblique welding is not precise	9	Replace with a new jig clamp	7	567
	Loose jig	9	Perforated welds	9	Tightening loose jigs	9	729
	Dirty Roller Feeder	10	Porous welds	8	Cleaning Roller Feeder	9	720
Reduced Speed Losses	Reduced engine speed	7	Machines work longer to process products	8	Perform routine maintenance and periodic checks	5	280
	Old age of machine	7		8		5	280
	Wire lines often get stuck (dirty)	8	Porous welds	9		5	360

The results of the FMEA analysis show that the largest RPN value is 729 in breakdown losses for the type of failure of the jig stay harness loose, the value is obtained from the criteria for the occurrence of a reduction in the main function of 9, a medium level of frequency of 9 and detected causes rarely 9. Then the second largest is 720 in breakdown losses for the type of failure of the dirty roller feeder, the value is obtained from the criteria for the occurrence of loss of comfort of the main function of 10, a high level of frequency of 8 and detected causes of medium 9.

IV. CONCLUSIONS

➢ *The Conclusions that can be drawn from the Research Results in this Publication Manuscript are:*

- The effectiveness value of the machine is availability 95.1%, performance efficiency 82.49%, rate of quality 99.02% with OEE of 77.94%. The six big losses of the machine are Breakdown, with a total time loss of 71.2 hours with a percentage of 5%, Setup and adjustment with a total time loss of 64.8 hours with a percentage of 3%, Idling and Minor Stoppages, with a total time loss of 17.7 hours and a percentage of 14%, Reduced Speed, with a total time loss of 31.5 hours and a percentage of 13%, Process Defect, with a total time loss of 4.21 hours. and a percentage of 2.26%. and Yield / Scrap, with a total time loss of 0 hours. Losses are the main cause that affects the effectiveness of the machine. Based on the results of the above calculations, the losses that affect effectiveness are breakdown losses of 5% and reduced speed losses of 13%.
- Factors affecting machine performance are broke Jig clamp, Loose Jig, dirty Roller Feeder The highest risk of failure is RPN 729 in the breakdown losses category for the type of failure of Jig loose. The highest risk of failure in the reduced speed losses category is that the wire line is often jammed with an RPN value of 360.

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