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Implementation of Total Productive Maintenance on Frame Welding Machine Maintenance Using the Overall Equipment Effectiveness (OEE) Method at PT Electronics Components Indonesia

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Abstract:- PT. Electronics Components Indonesia manufactures capacitors and focuses on enhancing productivity and operational efficiency of the frame welding machines through effective maintenance. This study employs a quantitative method to analyze the Overall Equipment Effectiveness (OEE) values, including availability, performance efficiency, and rate of quality, as well as conducting a Six Big Losses analysis. The results indicate that the average availability reached 97.83%, with a significant decrease in August due to downtime. Performance efficiency remained consistently above 90%, although higher product output tended to reduce efficiency. The rate of quality was stable and high, reflecting improvements in production processes and quality control. The average OEE value reached 88%, exceeding the global standard of 85%. To further enhance the effectiveness of the frame welding machines, suggested improvements include operator training, regular performance evaluations, attention to operator well-being, selection of high-quality raw materials, updating SOPs, regular preventive maintenance, improving workplace safety, and investing in backup energy systems. In conclusion, the improvements implemented successfully enhanced the performance and operational quality of the frame welding machines.

Keywords:- *Frame Welding Machine, Overall Equipment Effectiveness (OEE), Total Productive Maintenance (TPM).*

I. INTRODUCTION

In every industrial sector, particularly in manufacturing, the smooth running of production processes is essential for achieving company goals. Machinery and production equipment are crucial elements supporting the continuity of manufacturing operations. To compete in the global industrial market, companies must enhance machine efficiency to meet production targets. Efficiency becomes the primary focus in product generation; a machine is considered efficient if it can produce output according to the predetermined schedule. The more efficient the machine operation, the more likely production targets will be achieved, ultimately yielding profits for the company. Maintenance can be defined as a critical activity that supports the production process, aiming to maintain or preserve the quality of equipment so that it remains functional and ready for use [1]. Maintenance activities are essential for caring for and sustaining the quality of equipment or machinery to ensure optimal operation, consistent with its initial condition, and to improve machine performance [2]. Intensive evaluation and maintenance are necessary to optimize machine utilization and enhance machine effectiveness.

PT Electronics Components Indonesia, a company producing capacitors, recognizes the importance of machine maintenance in manufacturing to boost productivity and operational efficiency, particularly for frame welding machines, which play a key role in the production process. The frame welding machine transfers capacitors from the carrier bar to the frame and then welds them onto the frame. Therefore, increasing the operational efficiency and availability of the frame welding machine is crucial to achieving higher productivity goals. Based on the calculation of the effectiveness of the frame welding machine before implementing Total Productive Maintenance (TPM), the Overall Equipment Effectiveness (OEE) was 64%. The Mean Time Between Failures (MTBF) was 7.10 hours per month, and the Mean Time To Repair (MTTR) was 0.30 hours per month. Since the OEE value is below the optimal target of 85%, improvements are necessary to enhance productivity. Enhancing the productivity of the frame welding machine can be achieved through effective machine maintenance. This maintenance is a focal point in applying Total Productive Maintenance (TPM). Implementing TPM in the maintenance of frame welding machines can reduce losses due to unexpected downtime, optimize preventive maintenance, and ensure that machine performance is always at its best.

Total Productive Maintenance (TPM) is an innovative maintenance approach aiming to optimize equipment effectiveness, eliminate breakdowns, and encourage autonomous maintenance by operators through daily activities involving the entire workforce [3]. To achieve these goals, preventive and predictive maintenance are necessary. Implementing TPM principles is vital to minimizing machine disruptions. TPM benefits include maintaining factories and machinery in optimal condition, enabling operators to perform minor repairs, and allowing maintenance staff to focus on

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more serious issues. The main challenge in implementing transformative methods like TPM lies in changing the fundamental behavior or culture of a company. Although difficult, a cultural transformation toward continuous improvement is a highly rewarding investment for the company [2]. With a culture of continuous improvement, employees will have the awareness and commitment to maintain and enhance machine performance with the skills provided by the company. From the issues mentioned above, Overall Equipment Effectiveness (OEE) is an approach used to measure the effectiveness of equipment utilization. Thus, this study is titled "Implementation of Total Productive Maintenance on Frame Welding Machine Maintenance Using the Overall Equipment Effectiveness (OEE) Method at PT Electronics Components Indonesia.".

II. LITERATURE REVIEW

A. Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) originated from preventive production and maintenance practices in America and later moved to Japan, where it evolved into the Japanese system now known as TPM. The philosophy was developed by Dr. W. Edward Deming, who emigrated to Japan after World War II and employed data-driven decision-making to control product quality. Data-driven decision-making was also used for quality control activities related to production.

The first company to implement TPM was Nippondenso Corp., founded by Seiichi Nakajima. Nippondenso successfully applied TPM as recommended by the Japanese Institute of Plant Engineering (JIPE). Following this success, Nakajima wrote various books and articles in the late 1980s and early 1990s, popularizing and advocating for TPM.

TPM represents a close collaboration between maintenance and the entire production organization, aiming to improve production quality, reduce waste, lower production costs, enhance equipment performance, and develop an overall maintenance system in manufacturing companies. The comprehensive concept of TPM includes five main elements:

- Establishing a preventive maintenance (PM) system to extend the lifespan of machines or equipment.
- Implementing TPM across various departments, including engineering, production, and maintenance.
- Maximizing the overall effectiveness of machines or equipment.
- Involving all levels of management and production employees in the implementation of TPM.

Developing the PM-based maintenance system utilizing motivation management.

B. Overall Equipment Effectiveness (OEE)

According to Atikno and Purba (2022) in their journal "Improve The Work Effectiveness With Overall Equipment Effectiveness (OEE) As The Basis For Optimizing Production," Overall Equipment Effectiveness (OEE) is a method that measures the overall effectiveness of machines or equipment, evaluating production processes and product quality. By addressing key factors such as availability, performance efficiency, and quality rate, OEE helps companies enhance performance by identifying areas needing improvement. OEE is a comprehensive measure identifying the productivity level or output of machines and operations from a theoretical perspective. This assessment is crucial for evaluating and improving methods to increase machine or equipment productivity. Low OEE values often stem from inadequate preventive and corrective maintenance and high defect rates and speeds.

➢ *The Mathematical Formula for OEE is:*

$$OEE = Availability \times Performance\ Efficiency \times Rate\ of\ Quality\ Product$$

- *Steps for Calculating OEE*

- *Availability*

Availability refers to the machine's readiness to operate, crucial for assessing maintenance success. The standard indices for machine availability include:

- *Loading Time:*

This is the planned operational time for the machine, calculated as:

$$Loading\ Time = Available\ Time - Planned\ Downtime$$

Downtime Available Time is the total time production is available in a day, and Planned Downtime is scheduled for preventive maintenance or other pre-planned maintenance tasks.

- *Downtime:*

The time during which the machine is not producing output due to maintenance, including breakdowns and setup adjustments. It is calculated as:

$$Downtime = Breakdown + Setup\ Adjustment$$

- *Operation Time:*

The total operational time of the machine in a workday, calculated as:

$$Operation\ Time = Loading\ Time - Downtime$$

- *Availability Calculation:*

$$Availability = \left(\frac{Loading\ Time - Downtime}{Loading\ Time}\right) x100\%$$

- *Performance*

Performance measures the operational speed and efficiency, comparing the actual output to the ideal cycle time. Important factors include:

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- *Operation Speed Rate:*

The ratio of the machine's actual speed to its ideal speed, usually measured in units per minute.

- *Output:*

The production result from the machine over a specific period.

- *Performance Calculation:*

$$Performance = \left(\frac{Output\ Product}{Operation\ Time\ x\ Operation\ Speed\ Rate}\right) x100\%$$

- *Quality*

The Rate of Quality Product is the ratio of good products to the total processed products, considering the following:

- *Output:*

The total number of processed products.

- *Number of Defects:*

Includes reduced yield (damages during setup and adjustment) and reject and rework components.

- *Quality Calculation:*

$$Quality = \left(\frac{Output - (Reduced\ Yield + Reject\ \&\ Rework)}{Outpit}\right)$$

C. *Six Big Losses*

Activities and actions implemented in Total Productive Maintenance (TPM) do not only focus on preventing machine or equipment breakdowns and minimizing downtime [4]. Numerous factors can lead to losses due to low machine or equipment efficiency. The low productivity of machines or equipment, causing losses for the company, is often due to ineffective and inefficient usage, identified by six major factors known as the six big losses [5]. Efficiency measures how well resources are used in the production process to generate output, comparing actual performance against established standards [6]. Effectiveness, on the other hand, measures the degree to which the production system achieves its output goals, based on the actual output ratio to planned output. In today's competitive environment, measuring production systems solely based on output quantity can be misleading, as it neglects the critical characteristics of efficiency, effectiveness, and capacity.

Maximizing the efficient use of machines or equipment means optimizing their performance effectively and efficiently. According to Saiful et al. (2014), the goal of calculating the six big losses is to assess the overall equipment effectiveness. These six big losses include:

- **Equipment Failure:** Losses due to productivity decline and quality defects caused by equipment failure.
- **Setup and Adjustment Losses:** Losses incurred from downtime and defects during the setup for the next production item.
- **Idling and Minor Stoppages:** Losses caused by temporary disruptions or machine stoppages during production.
- **Reduced Speed:** The difference between the designed speed and the actual operational speed.
- **Reduced Yield:** Losses during the initial production phase until the machine reaches a stable condition.
- **Quality Defects and Rework:** Losses from defective products and rework due to malfunctioning production equipment.

III. METHODOLOGY

This study employs a quantitative research approach, leveraging documentation data. The purpose of using quantitative methods is to present detailed results, specific procedures, and clearly formulated hypotheses. This method allows for the systematic collection and analysis of numerical data, enabling objective measurement and evaluation of the research outcomes. Through this quantitative approach, the research provides an accurate and detailed depiction of the investigated phenomenon. Several key instruments are utilized in this research. First, a camera is employed to capture standard time data, enabling precise and detailed data collection that facilitates the analysis of the time required for each activity. Second, Microsoft Excel is used to process various collected data. Excel is highly beneficial for calculating and analyzing the availability rate, performance rate, quality rate, Overall Equipment Effectiveness (OEE), and Six Big Losses. By using Excel, data can be systematically organized, accurately calculated, and thoroughly analyzed to gain a comprehensive understanding of operational efficiency and effectiveness. This combination of camera and Excel usage ensures that the collected and processed data has high accuracy and reliability, supporting the research's objective of solving problems or testing hypotheses.

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➢ *The Research Design is Illustrated as Follows:*

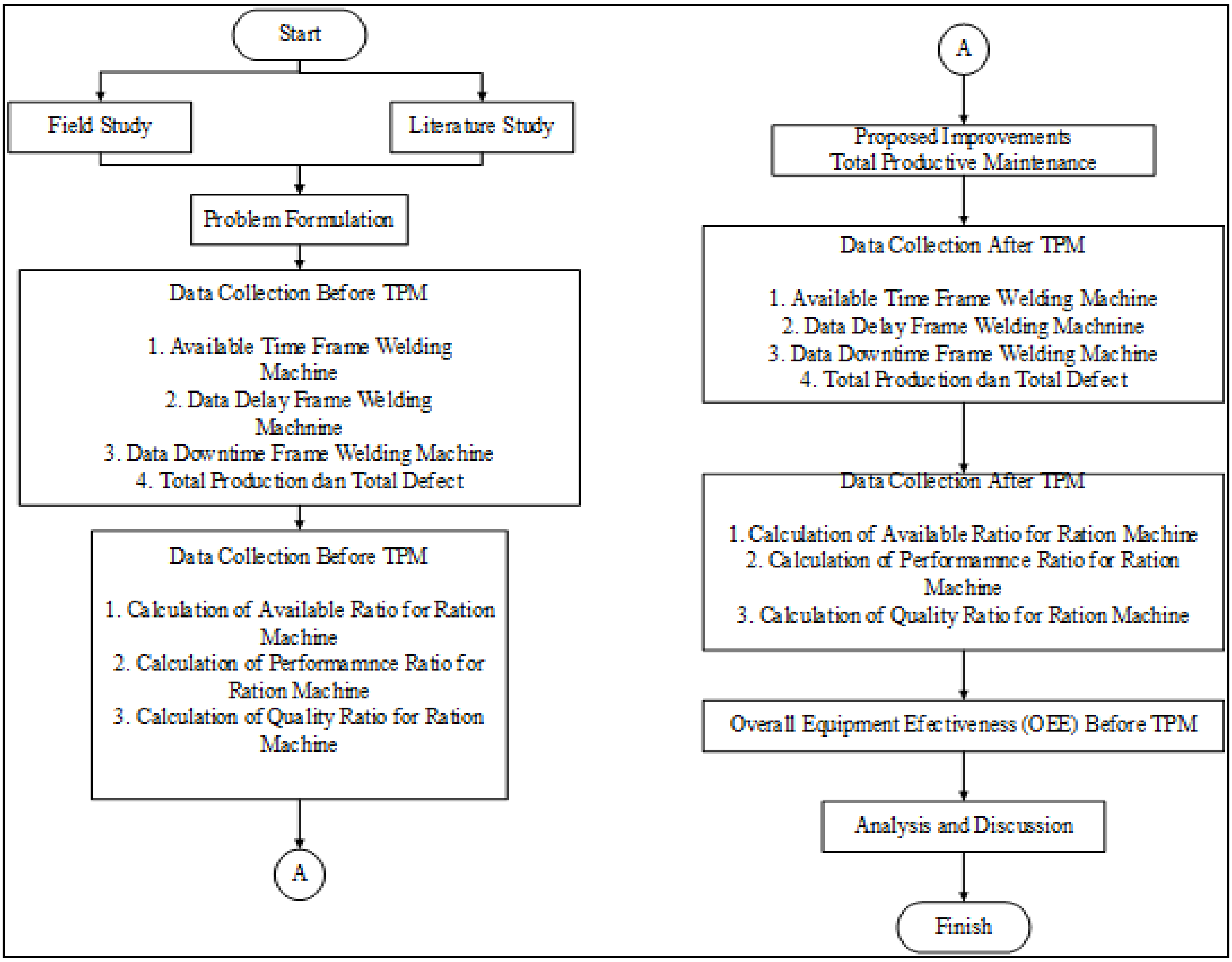

Fig 1 Design is Illustrated

The study is divided into two main parts, before TPM and after TPM. Before TPM, data collection involves recording the available time of the Frame Welding machine, delay data, downtime data, and total production and defects. Ratio calculations for availability, performance, and quality are then performed. OEE is calculated by multiplying these three ratios. After TPM, similar data is collected, and ratios and OEE are recalculated to assess the effectiveness of TPM in improving machine performance. Additional steps include field studies to observe machine conditions, literature reviews to understand TPM and OEE concepts, problem formulation to determine the research focus, and proposing improvements based on analysis results to enhance OEE.

Data collection encompasses primary and secondary data. Primary data is obtained from direct observations and interviews with machine operators at PT. Electronics Components Indonesia. Secondary data is sourced from company documents, including downtime, planned downtime, setup time, delay data, production output, and workforce and working hours. Data collection techniques involve systematic interviews with company management, production managers, and machine operators, field observations, and literature studies to gather relevant information. The research analyzes the performance of Frame Welding machines at PT. Electronics Components Indonesia. The population consists of all Frame Welding machines at the company, and the sample is taken from recorded data on output, reject, and downtime over one year. This data provides insights into production effectiveness, error rates, and downtime.

The collected data will be processed using the Overall Equipment Effectiveness (OEE) method, following these steps: calculating availability as the ratio of operation time to loading time, performance efficiency as the ratio of the quantity of products produced to the available operation time, and quality rate as the ratio of good products to the total processed products. OEE is then calculated to measure machine effectiveness. After OEE calculation, Six Big Losses are calculated, including downtime losses, speed loss, and defect loss. Evaluation and problem-solving proposals are then made based on the analysis to improve OEE. The proposed method involves calculating the baseline OEE value for the Frame Welding machine before improvement, conducting root cause analysis using a fishbone diagram, performing Pareto analysis to identify dominant breakdowns, and proposing machine maintenance improvements based on TPM concepts. These improvements include autonomous maintenance, planned maintenance, predictive maintenance, and preventive maintenance. TPM improvements are then implemented on the Frame Welding machine, OEE is recalculated post-TPM implementation, and the OEE values before and after improvements are compared to conclude the effectiveness of TPM in improving machine OEE.

To test the proposed Total Productive Maintenance (TPM) method, the baseline OEE value of the Frame Welding machine is calculated before TPM implementation. TPM is implemented on the Frame Welding machine for 12 months, including autonomous, planned, predictive, and preventive maintenance activities. Monthly OEE values are measured during TPM implementation to monitor improvements. Savings from improved OEE are calculated by reducing six big losses, waste, and defects. This process will determine the significant impact of TPM on improving Frame Welding machine effectiveness and its financial benefits to the company.

IV. RESULT

A. Measurement of Availability Ratio

The Availability Ratio is a metric indicating the utilization of available time for machine or equipment operation. This metric uses data such as machine working time, planned downtime, and various forms of other downtime (failures and repairs, setup, and adjustment). The appendix provides the percentage of daily downtime for January to December. The formula used to calculate the Availability Ratio is as follows:

$$Loading\ Time = Available\ Time - Planned\ Downtime$$

$$Loading\ Time = 28170 - 120$$

$$Loading\ Time = 28050\ minutes$$

To gather information about Availability, the next step after obtaining Loading Time data is to calculate Downtime. Downtime consists of machine breakdown time and setup and adjustment time. Below is the downtime data collection result along with an example calculation for January:

$$Downtime = Breakdown + Setup\ Adjustment$$

$$Downtime = 630 + 145$$

$$Downtime = 775$$

After obtaining Loading Time and Downtime data, the availability value can be calculated. An example calculation of the availability of the frame welding machine for January is as follows:

$$Availability = \left(\frac{Loading\ Time - Downtime}{Loading\ Time}\right) \times 100\%$$

$$Availability = \left(\frac{28050 - 775}{28050}\right) \times 100\%$$

$$Availability = 97\%$$

By performing the same calculations for the following months using the same method, the availability values of the Frame Welding machine from January 2023 to December 2023 are as follows:

Table 1 Measurement of Availability

Month	Loading Time (min)	Downtime (Min)	Operation Time (Min)	Availability (%)
January	28050	775	27275	97
February	27900	925	26975	97
March	28365	460	27905	98
April	28149	676	27473	98
May	28320	505	27815	98
June	28605	220	28385	99
July	28200	625	27575	98
August	27471	1354	26117	95
September	28122	703	27419	98
October	28020	805	27215	97
November	28443	382	28061	99
December	28611	214	28397	99

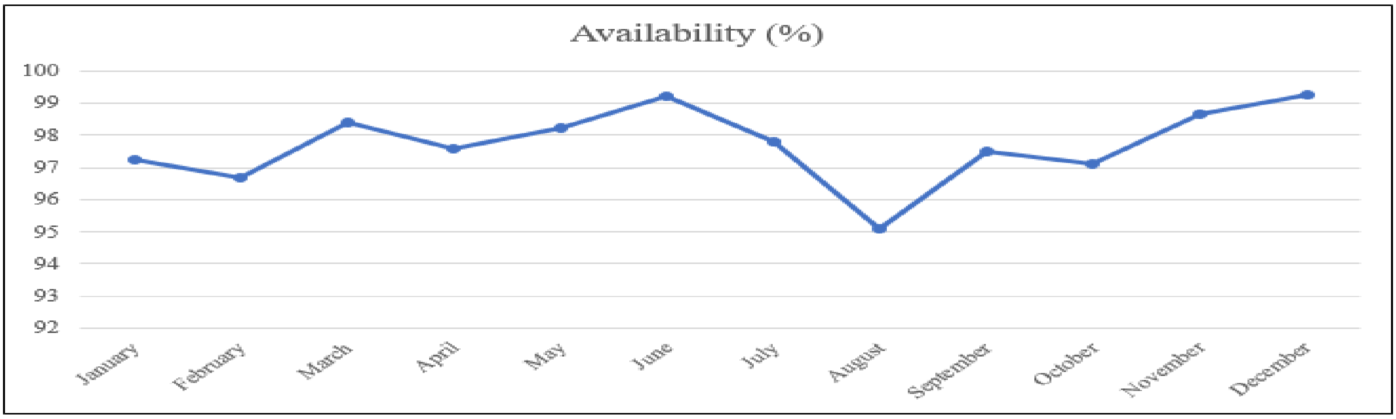

Fig 2 Graph Availability

The analysis of Overall Equipment Effectiveness (OEE) availability is a crucial step in evaluating the operational efficiency of a production facility. The table of OEE availability calculations shows consistency and fluctuations that provide valuable insights into the performance of the frame welding machine G4A-A71, size TQC-D3LM, over the studied period. Throughout the observed year, machine availability remained relatively stable from month to month, with an average availability of 97.83%. This indicates that maintenance management and operational planning are generally effective. However, special attention is required for months with high downtime, such as August, where machine availability significantly dropped to 95%. Data reveals that total downtime in August reached 1,354 minutes, primarily due to machine breakdowns accounting for 1,209 minutes. The trend of increased availability in certain months, such as June, November, and December, suggests that improvement efforts or changes in operations had a positive impact. For instance, in June, availability reached 99%, the highest of the year, due to a drastic reduction in downtime to just 220 minutes, mainly because of low machine adjustment time.

Conversely, months with availability below target, like August and October, highlight areas needing further improvement. In October, downtime increased to 805 minutes, with machine breakdowns contributing 660 minutes. The impact of machine repairs and maintenance on availability is also notable. Months with low downtime indicate effective machine maintenance and repair processes. Nevertheless, there is still room for efficiency improvement. Analyzing the OEE availability trend over the observed period offers a broader perspective on overall operational performance. This analysis is a valuable tool for management to identify areas for improvement to enhance machine availability, ultimately boosting productivity and overall efficiency in the production environment.

B. Measurement of Performance Ratio

The Performance Ratio indicates the efficiency of equipment in producing goods. The data used to measure this ratio includes Output, Actual Cycle Time, and Operating Time (Loading Time, Breakdown Time, and Setup Adjustment Time). The formula used to calculate the Performance Ratio is as follows:

$$Performance = \left(\frac{Operation\ Time \times Operation\ Speed\ Rate}{Output\ Product}\right) \times 100\%$$

$$\text{Performance} = \left(\frac{1715026}{27275 \times 0.5}\right) \times 100\%$$

$$Performance = 79\%$$

Using a similar calculation procedure, the Performance Efficiency values from January 2023 to December 2023 have been calculated, and the results are listed in the following table:

Table 2 Measurement of Performance Ratio

Month	Production quantity/Pcs	Ideal Time Cycle Time (Min)	Operation Time (Min)	Performance Effiency (%)
January	1715026	0,5	30975	90
February	1537388	0,5	28975	94
March	1537571	0,5	27905	91
April	1532380	0,5	27473	90
May	1075291	0,5	27815	88
June	1694141	0,5	30385	90
July	1588927	0,5	29575	93
August	1435432	0,5	26117	91
September	1495362	0,5	27419	92
October	1454860	0,5	27215	88
November	1531459	0,5	28061	92
December	1449735	0,5	28397	98

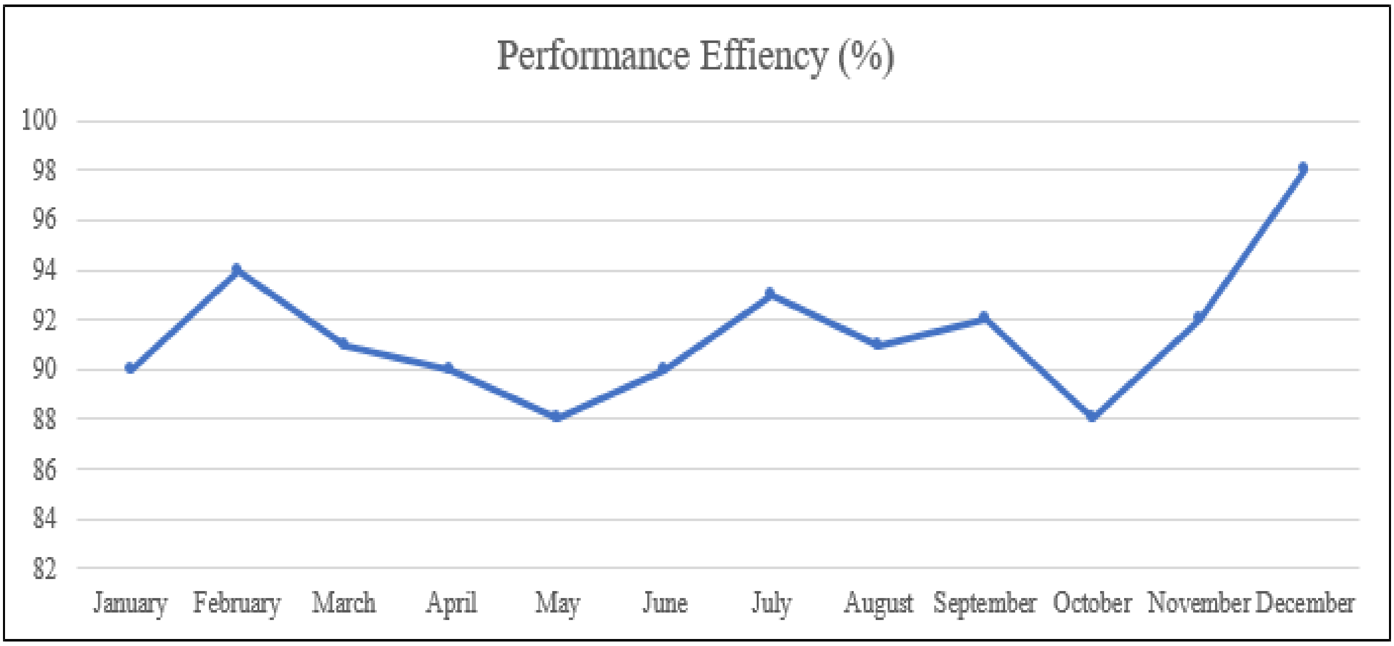

Fig 3 Graph Performance Efficiency

The analysis of Performance Efficiency from the provided OEE data offers insights into the operational efficiency of the equipment in producing goods. From the Performance Efficiency calculations, several key points can be observed:

➢ *Consistency of Efficiency:*

The performance efficiency of the frame welding machine G4A-A71, size TQC-D3LM, generally remained consistent month to month, with most months showing Performance Efficiency values above 90%. This indicates that the production process is running well overall, despite minor fluctuations.

➢ *Impact of Cycle Time:*

The efficiency of the frame welding machine is influenced by the actual cycle time used in the calculations. Months with lower cycle times tend to have higher Performance Efficiency values. For instance, December showed a high value of 98%, which may indicate improvements in the production process or more efficient settings.

➢ *Impact of Output:*

Although the machine's performance efficiency is primarily calculated based on Operation Time and Operation Speed rate, the product output also plays a crucial role. Months with higher production output tend to have lower Performance Efficiency values, as seen in January with a value of 90%. This suggests a trade-off between the quantity of production and the time spent maintaining efficiency.

➢ *Efficiency Improvements:*

There were notable increases in the performance efficiency of the frame welding machine in certain months, such as February and July, with values reaching 94% and 93%, respectively. These improvements could be due to enhancements in the production process, optimized machine settings, or better operational time management.

➢ *Improvement Trends:*

Over the year, there is a trend of improving performance efficiency for the frame welding machine, indicating ongoing efforts to enhance operational efficiency and optimize production processes.

By reinforcing this analysis with available data, such as production quantity, actual cycle times, and operation times, a clearer understanding of the factors affecting equipment performance efficiency is achieved. This comprehensive view aids in identifying ways to further improve operational efficiency and overall performance in the production environment.

C. Measurement of Quality Ratio

The Quality Ratio reflects the ability of equipment to produce products that meet standards. The data used to measure this ratio includes Output, Reduced Yield, and Rework. The formula for calculating the Quality Ratio is as follows:

$$Quality = \left(\frac{output - (Reduced\ Yield + Reject\ \&\ Rework)}{Output}\right) \times 100\%$$

$$Quality = \left(\frac{1715026 - 27234}{1715026}\right) \times 100\%$$

$$Quality = 98\%$$

Using a similar calculation procedure, the Rate of Quality values from January 2023 to December 2023 have been calculated, and the results are listed in the following table:

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Table 3 Measurement of Quality ratio

Month	Production quantity/Pcs	Reject/Pcs	Rate of Quality (%)
January	1715026	27234	98,41
February	1537388	25076	98,37
March	1537571	20568	98,66
April	1532380	20187	98,68
May	1075291	10519	99,02
June	1694141	14366	99,15
July	1588927	14206	99,11
August	1935432	18678	99,03
September	1995362	19956	99,00
October	2154860	23411	98,91
November	2131459	22879	98,93
December	2049735	22643	98,90

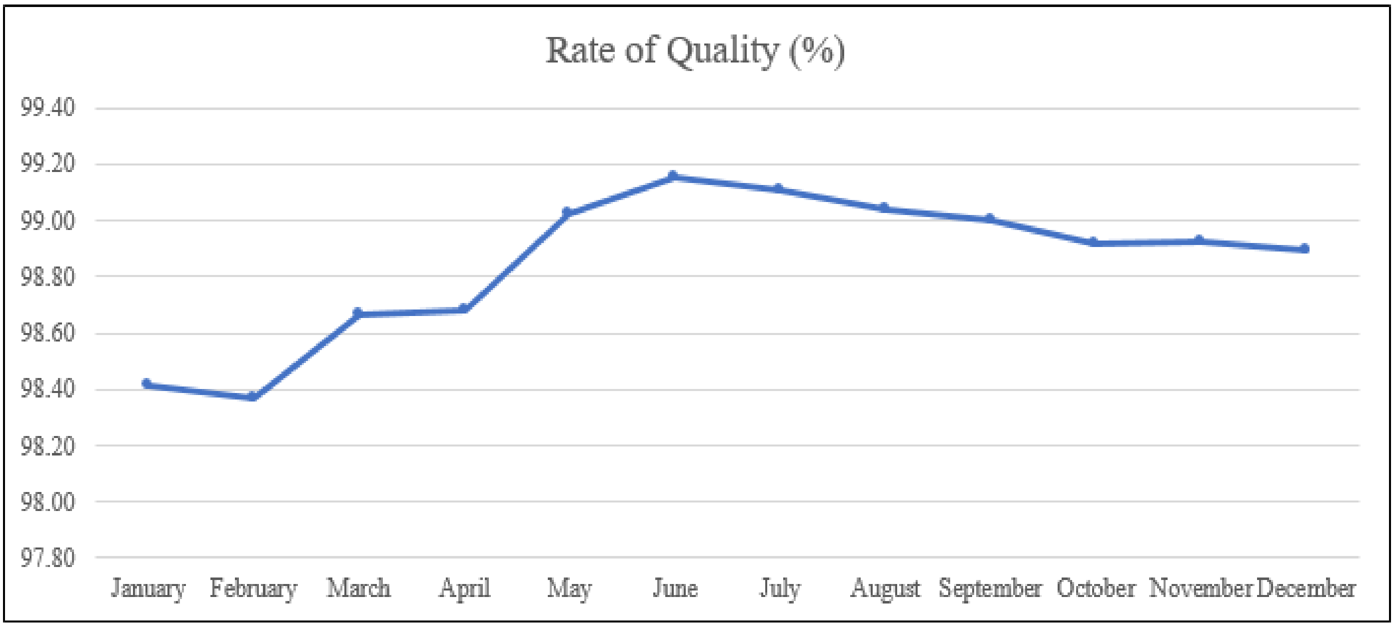

Fig 4 Graph Rate of Quality

The analysis of the Rate of Quality data provides insights into the equipment's capability to produce 6TPE150MAZB capacitors according to established standards. The data indicates a stable quality rate from month to month, with relatively minor variations. For example, in June, out of a total production of 1,694,141 pieces, only 14,366 pieces needed rework or were rejected, resulting in a quality rate of 99.15%. Similarly, in May, the quality rate reached 99.02%, with only 10,519 out of 1,075,291 pieces needing rework or rejection. Reducing rework and defective products is crucial for improving the product quality rate. For instance, in January, despite having 27,234 pieces needing rework or rejection out of a total production of 1,715,026 pieces, the quality rate was still 98.41%. There is a trend of increasing quality rates in certain months such as May, June, and July. In July, the quality rate reached 99.11%, with only 14,206 out of 1,588,927 pieces needing rework or rejection. Despite fluctuations in production volume, the quality rate remained consistently high. For instance, in August, with a production volume of 1,935,432 pieces, the quality rate was 99.03%, with only 18,678 pieces needing rework or rejection.

Although the overall quality rate is high, there are months where the quality rate slightly decreased, such as October and November. This indicates areas for potential improvement in the production process or quality control measures to consistently ensure optimal quality levels. By evaluating the Rate of Quality data, management can identify areas for improvement to enhance overall product quality. This can include enhancements in the production process, adoption of new technologies, or further development of quality control programs. Consequently, the company can maintain or even enhance its reputation in the market.

D. Measurement of OEE

After calculating the values for Availability, Performance Efficiency, and Rate of Quality for the frame welding machine at PT. Electronics Components Indonesia, the next step is to calculate the Overall Equipment Effectiveness (OEE) to evaluate the effectiveness of the machine's usage. The mathematical formula for OEE is as follows:

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$$OEE = Availability \times Performance\ Efficiency \times Rate\ of\ Quality$$

Using this formula, the OEE value provides a comprehensive overview of how effectively the frame welding machine is utilized at PT. Electronics Components Indonesia, considering availability, performance efficiency, and the quality rate of production.

➢ *For January, the Calculation of the Overall Equipment Effectiveness (OEE) is as Follows:*

$$OEE = 97\% \times 79\% \times 98\%$$

$$OEE = 75.04\%$$

Thus, the calculation of Overall Equipment Effectiveness (OEE) up to December 2023 is shown in the following table:

Table 4 Measurement of OEE

Month	Availability (%)	Performance Effiency (%)	Rate of Quality (%)	OEE	limit OEE
January	97%	90%	98%	86%	85%
February	97%	94%	98%	89%	85%
March	98%	91%	98%	87%	85%
April	97%	90%	98%	86%	85%
May	98%	88%	99%	85%	85%
June	99%	90%	99%	88%	85%
July	97%	93%	99%	89%	85%
August	95%	91%	99%	86%	85%
September	97%	92%	98%	87%	85%
October	97%	90%	98%	86%	85%
November	98%	92%	98%	88%	85%
December	99%	98%	98%	95%	85%

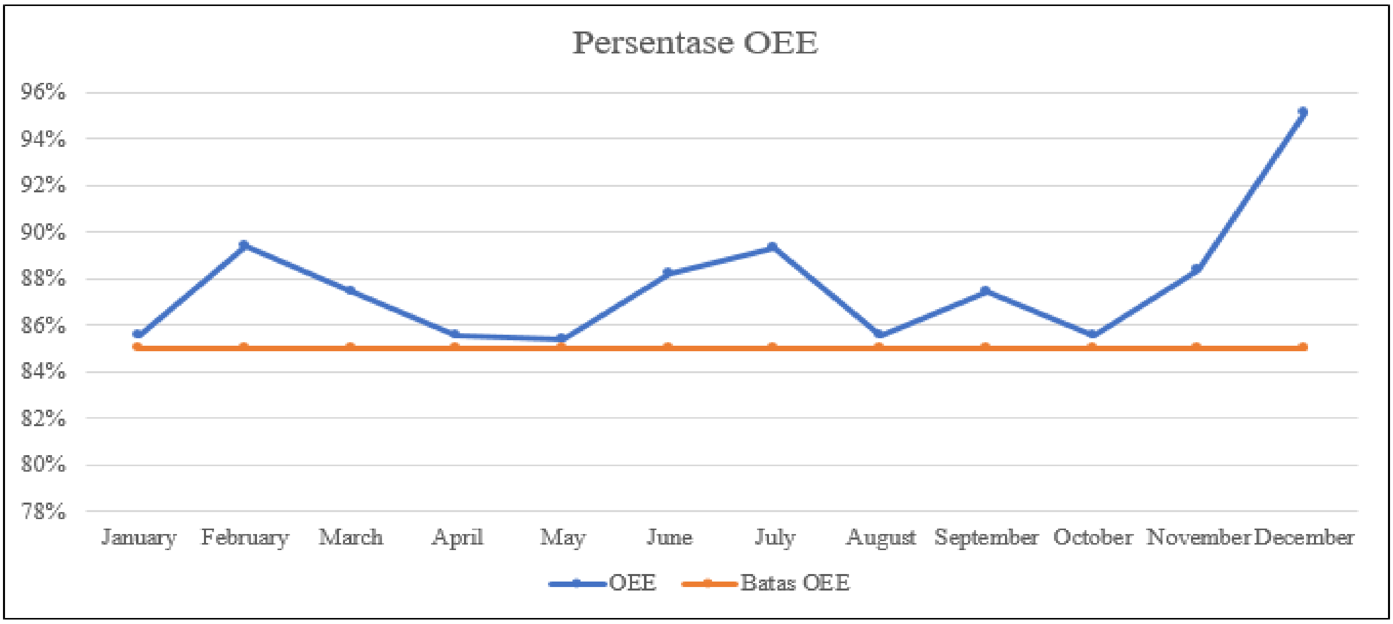

Fig 5 Graph OEE

The analysis of the Overall Equipment Effectiveness (OEE) data provides insights into the effectiveness of the frame welding machine G4A-A71, type size TQC-D3LM, at PT. Electronics Components Indonesia. Key points and supporting data from the study are as follows:

➢ *Performance Consistency:*

The OEE values are generally stable from month to month, with only minor variations. Despite slight fluctuations, the OEE consistently remains above the target threshold of 85%. For example, in December, the OEE reached 95%, indicating excellent performance.

➢ *Impact of Availability:*

Availability significantly influences the OEE value. Months with higher availability tend to have better OEE values. For instance, in June and December, the availability reached 99%, contributing to higher OEE values.

➢ *Impact of Performance Efficiency:*

Performance Efficiency also significantly affects OEE. Months with higher performance efficiency generally show better OEE values. For example, in February, the Performance Efficiency reached 94%, contributing to an increase in OEE to 89%.

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➢ *Impact of Quality Rate:*
The product quality rate affects the OEE as well. Months with higher quality rates tend to have better OEE values. For example, in May, the Quality Rate reached 99%, contributing significantly to an OEE value of 85%.

➢ *Achievement of Targets:*
Although the overall OEE values generally exceed the target threshold of 85%, there are a few months where the OEE slightly falls below this target. This indicates potential areas for improvement to consistently achieve or exceed the set target.

By reinforcing the analysis with the research data used in calculating OEE, such as Availability, Performance Efficiency, and Quality Rate values, we can better understand the factors influencing the effectiveness of the frame welding machine. This understanding helps management identify areas for improvement to enhance overall operational performance and efficiency.

V. CONCLUSION

Based on the research findings, several conclusions can be drawn. Firstly, the average availability rate of 98% indicates excellent maintenance performance due to minimal machine downtime. The performance and quality rates, at 91% and 98% respectively, show that machines rarely experience breakdowns and that the production process aligns with company standards. Secondly, the average Overall Equipment Effectiveness (OEE) calculated was 88%, surpassing the global standard of 85%. This indicates that performance and quality aspects of machine operations have been optimized, contributing to the high OEE. Lastly, to maintain production line effectiveness, it is recommended to implement structured training programs and regular performance evaluations to enhance operator skills. Additionally, focusing on the physical and mental well-being of operators can reduce fatigue and stress. Ensuring high-quality and consistent raw materials through strict supply chain management practices and regular quality audits is also crucial. Updating and standardizing clear Standard Operating Procedures (SOPs) will improve product quality consistency. Enhancing preventive maintenance through regular scheduling and periodic inspections can prevent unexpected machine failures. Finally, improving workplace safety and mitigating harmful external environmental influences, such as increased safety monitoring and investment in backup energy systems, are essential steps to ensure continuous operational efficiency.

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