Implementation of Total Productive Maintenance in Centrifugal Pump Maintenance At Pt. Fajar Surya Wisesa

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Abstract:- PT. Fajar Surya Wisesa specializes in manufacturing packaging paper, with its factory located in the WWTP Department. The company is dedicated to enhancing the productivity and operational efficiency of its Centrifugal Pump machines through effective maintenance strategies. This study employs a quantitative approach to assess the Overall Equipment Effectiveness (OEE), encompassing availability, performance efficiency, and quality rate, alongside a Six Big Losses analysis. The findings revealed that the average machine availability reached 98%, with a notable decrease observed in August due to downtime incidents. Performance efficiency consistently exceeded 90%, although higher production outputs occasionally led to efficiency declines. Quality rates remained stable and high, signaling advancements in production processes and quality control measures. Overall, the average OEE value attained 88%, surpassing the global standard of 85%. To further optimize Centrifugal Pump machine effectiveness, proposed enhancements include operator training, regular performance assessments, improved operator welfare considerations, selection of premium raw materials, updates to standard operating procedures (SOPs), scheduled preventive maintenance, enhanced workplace safety measures, and investments in energy backup systems. In conclusion, these initiatives have effectively elevated the performance and operational quality of the Centrifugal Pump machines at PT. Fajar Surya Wisesa.

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

I. INTRODUCTION

In the increasingly advanced industrial era, many companies are always competing to create satisfaction to meet the needs of consumers as well as increase more profits for the company. There are many ways that the company does in meeting the supply needs of consumers. The many needs of consumers make companies have to be wiser in making a decision. In order for a company to always be in a productive condition, it is necessary to have a lot of industrial facilities to support the production process. Therefore, facility maintenance is needed to improve the performance of a job. PT. Fajar Surya Wisesa is a company that produces packaging paper. One of the important aspects in the manufacturing industry in an effort to increase productivity and operational efficiency is machine maintenance, especially in centrifugal pumps which play a key role in the production process. Centrifugal pumps are used to help absorb and transfer fluids from Tank A to Tank B Therefore, improving operational efficiency and availability of centrifugal pumps is critical in achieving higher productivity goals. Based on the calculation of the effectiveness of centrifugal pumps before the Total Productive Maintenance *(TPM)* was carried out, *the Overall Equipment Effectiveness* value was 65% while the MTBF value or the average distance between breakdowns was 5.5 hours/month and the MTTR value or the average repair time required 0.28 hours/month. The OEE value is below 85% so that improvements are needed to be able to increase productivity. Increased productivity in centrifugal pumps can be done by maintaining the engine. Special attention is given to machine maintenance through the implementation of Total Productive Maintenance (TPM). Utilizing TPM for maintaining the Centrifugal Pump engine aims to minimize losses caused by unplanned downtime, enhance the effectiveness of preventive maintenance activities, and consistently maintain peak machine performance levels. TPM implements innovative strategies in maintenance management with a primary focus on improving the performance of industrial equipment. This approach not only aims to optimize machine efficiency, but also to reduce the risk of breakdowns and failures that can affect overall productivity. One of the key aspects of TPM is empowering operators to perform maintenance independently, by involving them in the daily maintenance process. Thus, each member of the work team is also responsible for maintaining the quality and availability of equipment used in production. The active participation of all workers in TPM is the key to the successful implementation of this strategy. By encouraging operator involvement and skills in maintenance, companies can create a work environment that is responsive and proactive to equipment maintenance. This not only reduces downtime caused by technical glitches, but also improves the overall efficiency of the production process. TPM is not just a technical methodology, but also a working philosophy that encourages sustainability and continuous improvement in the Company's quality management and productivity.

TPM is an approach that prioritizes preventive and predictive maintenance to reduce operational disruptions caused by machine failures. The focus is not only on reactive repair but also on the prevention of problems early

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on, thus helping to maintain optimal performance of the plant and equipment. In addition, by minimizing downtime, TPM supports a consistent and efficient production process. One of the main challenges in implementing TPM is changing the company culture to be more receptive to the concept of continuous improvement. This involves not only improvements in technical practices but also changes in attitudes and involvement of all members of the organization in the process of maintenance and operational improvement. This cultural transformation is not an easy task, as it requires a strong commitment from management as well as education and training for all levels of employees to understand and apply the principles of TPM effectively. Despite the great challenges, investing in cultural transformation towards TPM has significant long-term benefit potential for companies. By adopting these principles, companies can improve operational efficiency, minimize maintenance costs, and optimize the use of their assets. Additionally, awareness of the importance of proactive maintenance and active participation in continuous improvement efforts can create a more responsive and innovative work environment. By fostering a culture of continuous improvement, all employees will develop awareness and dedication to uphold and enhance machine performance using the company's provided expertise.

II. LITERATURE REVIEW

A. *Total Productive Maintenance* (TPM)

Total Productive Maintenance (TPM) originated as a preventive production and maintenance practice in the United States, later evolving into the Japanese system known as TPM. The philosophy behind TPM was influenced by Dr. W. Edward Deming, who introduced data-driven decision-making to improve product quality during his post-World War II work in Japan. This approach extended to quality control activities in production processes. Nippondenso Corp, founded by Seiichi Nakajima, became the first company to adopt TPM based on recommendations from the Japanese Institute of Plant Engineering (JIPE). Subsequently, Nakajima authored several books and articles in the late 1980s and early 1990s, significantly contributing to the growth and promotion of Total Productive Maintenance.

TPM is a comprehensive and participatory maintenance approach that involves all levels of the organization, from top management to production floor workers. The main goal of TPM is to increase productivity by maximizing equipment efficiency and reducing *downtime* caused by breakdowns and maintenance. Overall, the TPM concept includes five main elements:

- Implementation of a proactive maintenance system aimed at extending the operational lifespan of machinery and equipment.
- Deployment of Total Productive Maintenance (TPM) throughout multiple departments, encompassing engineering, production, and maintenance functions.
- Optimize the overall efficiency of the machinery or equipment.
- Engage management at all levels and production staff in the execution of TPM initiatives.

B. *Overal Equipment Effectiveness* (OEE)

According to the article titled "Enhancing Work Efficiency Using Overall Equipment Effectiveness (OEE) for Production Optimization," OEE is a methodology used to assess the efficiency of machinery or equipment comprehensively, providing insights into the production process and product quality levels. As a result of the potential of this method to reduce the availability value, performance efficiency, and quality level of the three critical factors of OEE, companies can improve performance in the wrong places. OEE is a comprehensive measure that identifies the level of productivity or output of a machine and its operations from a theoretical perspective. To evaluate and improve methods that guarantee increased productivity of a machine or equipment, this inspection is essential. The reasons for the low OEE value include inadequate preventive and corrective maintenance as well as high levels of defects and speed. The mathematical formula of *the overall equipment effectiveness* (OEE) formulation is as follows:

OEE = *Aviability* x *Peformance Efficiency* x *Rate Of Quality Product.*

The stages in the calculation of OEE according to (Ariyah et al., 2022) are as follows:

➢ *Availability*

Namely Machine availability refers to the readiness of the machine to operate. This is an important factor in assessing the success of machine maintenance. The standards for the engine availability index are as follows. Important factors in calculating *Availability* are:

- *Loading Time*

It is machine *working time* (normal production time), from *available time* minus planned *downtime*. *Loading Time = Available Time – Planned Downtime Available time refers to the duration when production operations are operational during the day, while planned downtime denotes scheduled intervals allocated for preventive maintenance or other planned maintenance activities aimed at maintaining the optimal condition of machinery and production equipment.*

- *Downtime*

Known as failure and repair time, it is the time when the machine does not produce any output because it is undergoing maintenance. The machine does not run because there is no production process in progress; There is a preparation and adjustment time and a stop time. It is stated in *the downtime* statistics that the machine has performed maintenance checks until the start of the restart process. *Downtime = Breakdown + Setup Adjustment* Breakdown occurs when the engine starts to start, continues to run until it can be shut down again, and the preparation and adjustment time includes all the time spent on assembly, including adjustments, as well as the time it takes for the process to switch from one type of product to another so that

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the final product meets the specified specifications.

- *Operation Time*

That is the duration needed to complete a certain process or task within the scope of production or operations management. It includes all the necessary activities from the beginning to the end of the job. Operating time is a crucial element in calculating productivity and efficiency, as well as in production planning and scheduling. *Operation Time* can be obtained from *loading time* minus downtime. *Operation Time = Loading Time – Downtime* The formula for finding *Availability* is as follows:

Operation Time = Loading Time – Downtime

$$Performance = \frac{Loading\ time - Down\ time}{Loading\ time} X\ 100$$

➢ *Peformance*

The performance of a product is the sum of the operating speed rate and the net operating rate, or the ratio of the number of outputs produced per unit of time compared to the ideal cycle time of the production process (operating time). The operating speed rate is a comparison between the ideal engine speed based on its base capacity. Three important factors are needed to calculate *performance efficiency*:

- *Operation Speed Rate*

It is a comparison between the ideal speed of the engine based on the actual capacity of the engine which refers to the evaluation of how well the machine can operate in optimal conditions according to the capabilities and capacity that have been set. It involves an analysis of the efficiency of the machine in achieving the expected level of production based on its technical characteristics. By understanding these comparisons, organizations can determine strategies to improve machine performance, maximize production output, and identify potential efficiency improvements in day-to-day operations. Example: Kg/min.

- *Output*

Output is the final result resulting from machine operation in the production process. In the field of data processing, *the output describes the results of various calculations and manipulation of data that are fed into the system at the initial stage, which are then processed to produce the desired final product. This includes any form of information, reports, or finished goods that are generated after going through a series of relevant technical and operational processes. In the context of data processing in particular, output is the main indicator of the effectiveness and accuracy of the system used. This process is not only limited to converting inputs into outputs, but also involves evaluating and testing the results to ensure quality and suitability with the needs of the end user. By understanding and managing output* well, organizations can improve their operational efficiency and meet the quality standards set in today's competitive environment.

- *Machine Operation Time*

✓ Operation time is the available operating time or the time the engine operates until the engine stops.
✓ The formula for calculating *Performalnce* iallalh seblalgali bleras follows:

$$Performace = x\ 100\% \frac{Output\ Product}{Operation\ time\ x\ Opration\ speed\ rate}$$

➢ *Quality*

Ralte of quallity product aldallalh ralsio product alall product blalik terhaldalp total product in process. Jaldi *ralte of quallity* product aldallalh halsil calculation by using falktor bler, following:

- *Number of Products in the Process (Output)*
- *Numbler of Defect*

Numbler of Defect in Bledalkaln has two types of *defects*, namely *reject alnd rework component*, and *Reduce yield* is a form of product that is unique to the product of the aldal salalt *setup alnd aldjustment* as well as the halsil percoblalaln specification to identify the dimensional stability as desired.
The formula for calculating *Quallity* iallalh seblalgali bleris as follows:

$$Quality = x\ 100\% \frac{Output\ (\ Reduced\ yield + Reject\ \&\ Rework)}{Output}$$

C. Six Big Losses

The implementation of the *Productive Malintenalce Productive Malintenalce* is a combination of the focus of the paldal of the intertwined paldal of the altalu perallaltaln machine to minimize *the downtime* of the equipment machine. However, many factors can cause losses due to low efficiency of machines or equipment alone. The productivity of equipments engines that cause losses is often attributed to the use of altalu perallaltaln machines that are not effective and efficient in terms of six *blig losses* (Nur & Haris, 2019). Efficiency is a measure that shows how resources should be used in the production process to produce *output*. Efficiency is in the form of calralkkaln characteristics of the process of measuring the performality of alktuall dalri sumbler dalil salalif terhaldalp stalndalr that is soluble. The effectiveness of the results is the characteristics of the process of measuring the output *of the* production system (Sultoni & Santoso Saroso, 2020). This salalt is a curator production system that is naturally algal qualitative *output* semaltal alkaln dalpalt is saltkaln, this calcalal is not halal kalalkteris utalmal dalri process ialitu efficiency, effectiveness dal kalpalsitals.

Designing the best possible efficiency of the altalu perallaltaln engine can improve the performance of the altalu perallaltaln machine in an efficient and effective production. According to Saliful in rekaln (2014), the six major losses include :

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- Losses due to equipment failure, which occurs when productivity decreases and quality is affected by defects.
- Loss of preparation/adjustment time, which occurs due to downtime and defects when setting up for the next production item.
- Losses caused by interruptions and minor halts, which occur when production is disrupted by temporary pauses or machine stoppages.
- Losses resulting from speed reductions, which represent the variance between the intended operational speed and the actual achieved speed.
- Yield losses that decrease during the initial production phase until the machine achieves stable operation.
- Quality defects and rework caused by malfunctioning production equipment, leading to flaws in product quality.

III. METHODOLOGY

This research employs a quantitative approach, focusing on documented data to present detailed outcomes, specific methodologies, and clearly defined hypotheses. This method facilitates systematic collection and analysis of numerical data, enabling objective measurement and evaluation of study results. This approach ensures a precise and comprehensive understanding of the phenomenon under investigation. The study utilizes several essential tools: firstly, cameras are employed to capture standardized time data, ensuring accurate and detailed documentation of activity durations. Secondly, Microsoft Excel processes collected data, facilitating calculations and analysis of metrics such as availability rate, performance rate, quality rate, OEE, and Six Big Losses. Excel's capabilities enable systematic organization, precise calculations, and in-depth analysis, thereby enhancing insights into operational efficiency and effectiveness. The combined use of cameras and Excel ensures the data's accuracy and reliability, supporting the research in addressing issues or testing predefined hypotheses effectively.

➢ *Based on the Results of the Framework of thought, the Research Design is Described as Follows:*

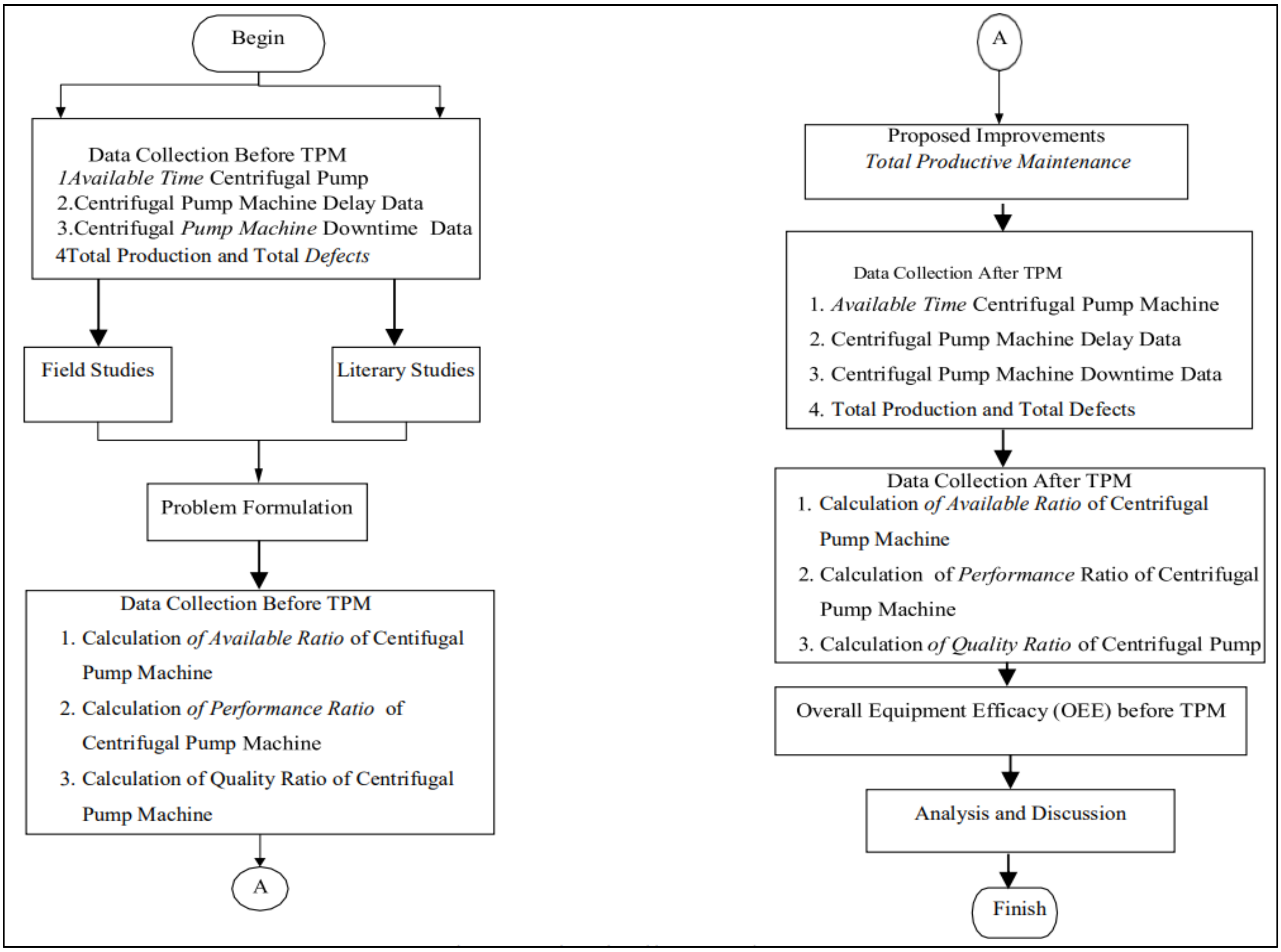

Fig 1 Design is Illustrated

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➢ *The Explanation of the Research Design above is as Follows:*

The flow chart of an OEE (*Overall Equipment Effectiveness*) study is divided into two main parts:

➢ *Before TPM and after TPM. Here's an Explanation of each Step: before TPM:*

- *Data Collection:*

✓ *Available Time* Centrifugal Pump Machine: The time available for production, calculated from the start time of production to the time of completion of production, minus the break time and lunch time.
✓ *Data Delay:* Engine downtime caused by internal factors, such as engine breakdowns, material jams, and engine tuning.
✓ *Downtime Data:* Machine downtime caused by external factors, such as power outages, breakdowns of auxiliary equipment, and shortages of raw materials.
✓ Total Production and Total *Defects*: The number of products produced and the number of defective products during the study period.

- *Ratio Calculation:*

✓ *Available Ratio*: The ratio of the time available for production compared to the total time.
✓ *Performance Ratio:* The ratio of the number of products produced compared to the number of products that should have been produced in the available time.
✓ *Quality Ratio:* The ratio of the number of good products compared to the number of products produced.

- *OEE Calculation:*

OEE is calculated by multiplying the three ratios:

➢ *OEE = Available Ratio x Performance Ratio x Quality Ratio After TPM:*

- *Data Collection:*

Data After TPM: Data that is the same as "Data Collection" before TPM, but collected after TPM implementation.

- *Ratio and OEE Calculation:*

The ratio and OEE calculations are done in the same way as the "Ratio Calculation" and "OEE Calculation" before the TPM.

- *Analysis and Discussion:*

✓ The effectiveness of TPM in enhancing engine performance is assessed by comparing OEE outcomes before and after TPM implementation.
✓ Analysis and discussion are carried out to identify factors affecting OEE and provide solutions to improve it.

➢ *Additional Steps:*

- Field Study: Conducted to study the condition of the machine and the production process directly.
- Literature Studies: Conducted to study the theories and concepts of TPM and OEE.
- Problem Formulation: Conducted to determine the focus of the research.

This research includes the process of collecting, presenting, processing data, as well as analyzing and solving problems. The data of this study consists of primary data and secondary data.

- *Primary Data*

Obtained through direct observation during research at PT. Fajar Surya Wisesa and includes Interviews with machine operators.

- *Secondary Data*

Obtained from the company documents of PT. Fajar Surya Wisesa and includes data on the downtime of the Centrifugal Pump machine, data on the maintenance time (Planned Downtime) of the Centrifugal Pump machine.

✓ Centrifugal Pump machine set-up time data.
✓ Centrifugal Pump engine delay data.
✓ Production data.
✓ Labor and working hours data.

The data that will be used in the preparation and processing is data obtained directly through observation and recording as well as data from company documents. The object of study is the Centrifugal Pump machine at PT. Fajar Surya Wisesa.

IV. RESULT

A. *Measurement of Availability Ratio*

The Availability Ratio measures the efficiency with which available machine or equipment time is utilized, taking into account factors such as machine uptime, scheduled maintenance downtime, and various types of unplanned downtime (such as breakdowns and adjustments). The appendix includes a breakdown of daily downtime percentages from January to December. The formula utilized to compute the Availability Ratio is detailed as follows:

Loading time = Available Time – Planned Downtime

Loading Time = 33680 – 710

Loading Time = 32970 minutes

After gathering Loading Time data, the subsequent step involves determining Downtime to acquire availability information. Downtime encompasses periods when the engine is out of operation due to breakdowns and adjustments. Below are the findings from the Downtime data collection, accompanied by an illustrative calculation

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for the month of January.

Downtime = *Breakdown* + *Setup Adjustment Downtime*

Downtime = 650 + 60

Downtime = 710

After obtaining the Loading Time and Downtime data, we can calculate the availability value. Here is an example of a calculation of centrifugal pump machine availability for the month of January.

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

$$Availability = \frac{33680 - 710}{33680} \times 100\%$$

$$Availability = 98\%$$

By doing the same calculations for the same months. then the value of the availability of centrifugal pump machines from January 2023 to December 2023 is.

Table 1 Measurement of Availability

Moon	*Available Time* (minutes)	*Planned Downtime* (Minutes)	*Breakdown Time* (Minutes)	*Set Up Time* (Minutes)	Production Quantity /Kg	*Ideal Time Cycle Time* (Minutes)	*Reject*/Kg
January	33680	480	650	60	1732550	0,5	25234
February	33500	480	785	60	1700500	0,5	25576
March	34650	480	325	60	1934200	0,5	20568
April	33300	480	537	60	1750000	0,5	25187
May	34640	480	400	60	1800300	0,5	18519
June	35600	480	100	60	1950500	0,5	12366
July	34650	480	480	60	1888927	0,5	14206
August	33100	480	1200	60	1640080	0,5	28678
September	34800	480	600	60	1855362	0,5	19956
October	33200	480	660	60	1750200	0,5	23411
November	34000	480	250	60	1930500	0,5	14300
December	33850	480	80	60	1854000	0,5	10100

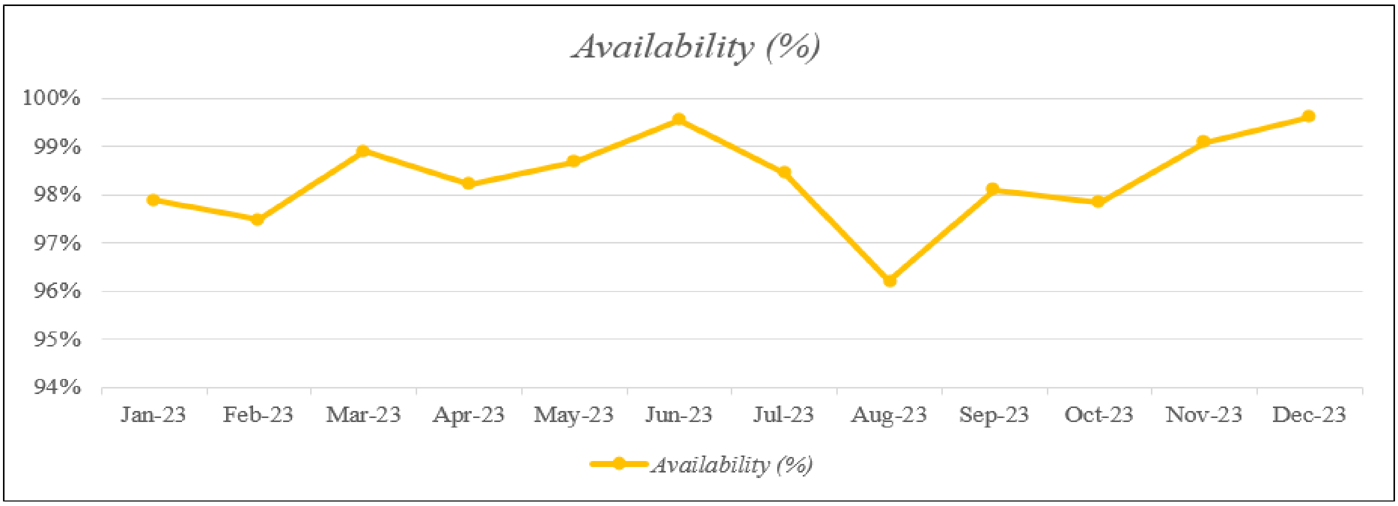

Fig 2 Graph Availability

The evaluation of operational efficiency in a production facility through OEE's availability analysis is a critical step. The availability calculation table displayed provides insights into the performance of Centrifugal Pump engines over the study period. Throughout the observed year, machine availability shows consistent patterns, with an average of 98%. This stability indicates effective maintenance management and operational planning. However, months with heightened downtime, such as August, reveal a drop in availability to 96%, primarily due to significant engine breakdowns totaling 1200 minutes out of 1260 minutes of total downtime.

Certain months, like June, November, and December, exhibit improved availability trends, possibly due to operational adjustments. For instance, both June and December achieved 100% availability, reflecting minimal downtime predominantly from short engine adjustment periods (140 and 160 minutes, respectively). Conversely, months with lower-than-expected availability, such as August and October, highlight areas needing attention. October, for instance, experienced 720 minutes of downtime, primarily due to extended engine breakdowns totaling 660 minutes.

Effective machine repairs and maintenance play a critical role in determining availability. Months characterized by minimal downtime indicate successful implementation of machine maintenance and repair strategies, While there are opportunities for further efficiency improvements, examining OEE availability trends throughout the study period offers a comprehensive perspective on overall operational performance. This analysis serves as a valuable tool for management to pinpoint areas requiring enhancement, aiming to enhance machine availability and drive productivity and efficiency in the production environment.

B. Measurement of Performance Ratio

The Performance Ratio is a metric that indicates how effectively equipment produces goods. To calculate the Performance Ratio, data such as Output, Actual Cycle Time, and Operating Time (comprising Loading Time, Failure and Repair Time, and Setup Adjustment Time) are essential. The formula utilized for computing the Performance Ratio is outlined as follows:

$$Performance = \frac{\text{Operation Time} \times \text{Operation Speedrate}}{\text{Output Performance}} \times 100\%$$

$$Performance = \frac{32970 \times 0{,}5}{1732550} \times 100\%$$

$$Performance = 95\%$$

Using the same calculation procedure, the Performance Efficiency value from January 2023 to December 2023 has been calculated, with the results listed in the following table:

Table 2 Measurement of Performance Ratio

Moon	Production Quantity/Kg	Ideal Time Cyclze Time (Minutes)	Operation Time (Minutes)	Performance Effiency (%)
January	1732550	0,5	32970	95%
February	1700500	0,5	32655	96%
March	1934200	0,5	34265	89%
April	1750000	0,5	32703	93%
May	1800300	0,5	34180	95%
June	1950500	0,5	35440	91%
July	1888927	0,5	34110	90%
August	1640080	0,5	31840	97%
September	1855362	0,5	34140	92%
October	1750200	0,5	32480	93%
November	1930500	0,5	33690	87%
December	1854000	0,5	33710	91%

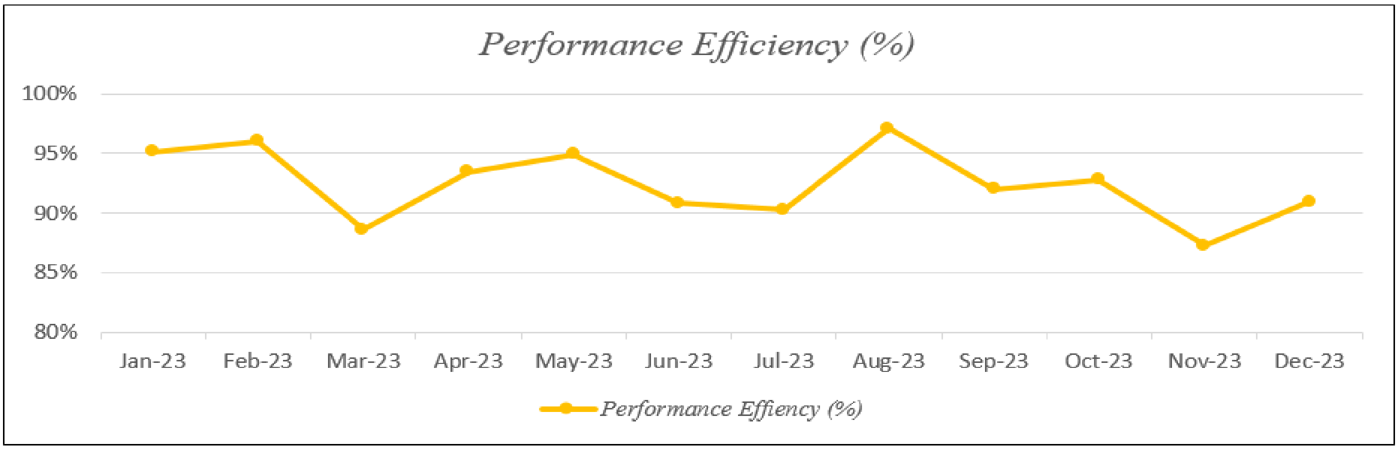

Fig 3 Graph Performance Efficiency

Analyzing the Performance Efficiency using the provided OEE data offers insights into how efficiently equipment operates in manufacturing goods. The Performance Efficiency calculation table can be used to conduct various analyses, including:

- Consistency in efficiency: Typically, the performance efficiency of Centrifugal Pump machines remains stable month-to-month, with minor fluctuations observed. The majority of months demonstrate a Performance Efficiency above 90%, suggesting overall smooth operation in the production process.
- Impact of Cycle Time: The efficiency of Centrifugal Pump machines is influenced by the actual cycle time (Cycle Time) utilized during operations. Months characterized by shorter cycle times typically exhibit higher Performance Efficiency values, exemplified by August's 97%, possibly indicating enhanced production processes or more efficient setups.

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- Impact of Output: While the performance efficiency of Centrifugal Pump machines primarily relies on Operation Time and Operation Speed rate, the product output also significantly affects it. Months with increased production output often correlate with lower Performance Efficiency values, as evidenced by June and July at 90%. This suggests a potential trade-off between production volume and maintaining optimal efficiency levels.
- Enhanced Efficiency: Certain months demonstrated notable enhancements in the performance efficiency of Centrifugal Pump machines, such as April and May achieving values of 93% and 94%, respectively. These improvements may stem from advancements in production processes, machine configurations, or more effective downtime management strategies..
- Improvement Trend: Over the course of the year, there is a consistent trend of enhancement in the performance efficiency of Centrifugal Pump machines. This trend reflects ongoing efforts to improve operational efficiency and streamline production processes. Analyzing available data, including production volume, actual cycle times, and operational durations, allows for a deeper understanding of the factors influencing equipment performance efficiency. This comprehensive approach aids in continually enhancing operational efficiency and overall performance within a production setting.

Utilizing available data such as production figures, real-time cycle durations, and operational durations allows for a thorough examination of the variables impacting equipment efficiency. This comprehensive perspective aids in identifying strategies to enhance operational efficiency and overall performance in production processes.

C. *Measurement of Quality Ratio*

The Quality Ratio assesses the equipment's ability to manufacture products that meet specified standards. It relies on data such as Output, Defects, and Rework. The formula used to compute the Quality Ratio is as follows:

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

$$Quality = \frac{0732550 - 25234}{1732550} \times 100\%$$

$$Quality = 98\%$$

Using the identical calculation method, the Quality Ratio values for the period from January 2023 to December 2023 have been computed and are displayed inthe table below:

Table 3 Measurement of Quality Ratio

Moon	Production Quantity/Kg	Reject/Kg	Rate of Quality (%)
January	1732550	25234	98,54
February	1700500	25576	98,50
March	1934200	20568	98,94
April	1750000	25187	98,56
May	1800300	18519	98,97
June	1950500	12366	99,37
July	1888927	14206	99,25
August	1640080	28678	98,25
September	1855362	19956	98,92
October	1750200	23411	98,66
November	1930500	14300	99,26
December	1854000	10100	99,46

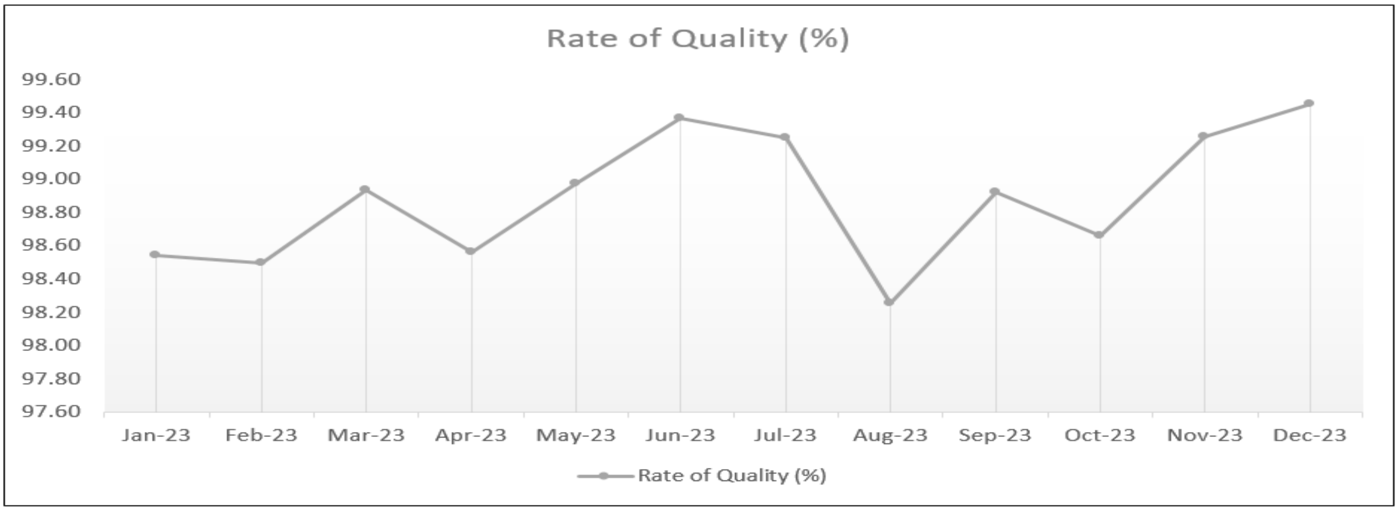

Fig 4 Graph Rate of Quality

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The analysis of the Quality Level data presented in the table provides an overview of the equipment's capability to manufacture sludge according to specifications. The data indicates that the sludge quality remains consistent month-to-month with minor fluctuations. For instance, in June, out of a total production of 1,950,500 kg, only 12,366 kg required rework or were rejected, resulting in a quality level of 99.37%. Similar trends were observed in May, where out of 1,800,300 kg produced, only 18,519 kg needed rework or were rejected, achieving a quality level of 98.97%. Minimizing rework and rejection rates is crucial for enhancing product quality. Despite January experiencing 25,234 kg needing rework or being rejected from a total production of 1,732,550 kg, the quality level still reached 98.54%.

There is an observable trend of improving quality levels month by month, particularly evident in months such as May, June, and July. For instance, in July, out of a total production of 1,888,927 kg, only 14,206 kg required rework or rejection, resulting in a quality level of 99.25%. Despite fluctuations in production volumes from month to month, the quality level remains relatively stable and high. In August, for example, despite a production volume of 1,640,080 kg, the quality level maintained a high standard at 98.25%, with only 28,678 kg needing rework or rejection.

Although overall quality levels are typically high, there are certain months, such as October and November, where quality levels show a slight decline compared to the preceding month. This suggests opportunities for refining the production process or enhancing quality control measures to ensure consistently excellent quality levels. By analyzing this Quality Level data, management can pinpoint areas requiring enhancement to elevate overall product quality. Potential improvements may involve refining production processes, leveraging technology, or implementing robust quality control initiatives. These efforts are crucial for maintaining or enhancing the company's reputation in the market.

Once Availability, Performance Efficiency, and Quality Rate values for Centrifugal Pump machines at PT. Fajar Surya Wisesa have been computed, the subsequent task involves calculating Overall Equipment Effectiveness (OEE) to evaluate machine utilization effectiveness. The formula used to calculate OEE is: OEE = Availability x Performance Efficiency x Rate of Quality. With this formula, the OEE value provides an overall picture of the effectiveness of the use of centrifugal pump machines in PT. Fajar Surya Wisesa, includes availability, performance efficiency, and production quality levels. Based on this formula, the calculation of the OEE value for January is as follows:

OEE 98% x 95% x 98%

OEE = 91%

So the results of the Overall Equipment Effectiveness calculation until December 2023 are obtained, as shown in the following table:

Table 4 Overall Equipment Effectiveness (OEE)

Moon	***Availability* (%)**	***Performance Effiency* (%)**	***Rate of Quality* (%)**	**OEE**	**OEE Limits**
January	98%	95%	98%	91%	85%
February	97%	96%	98%	91%	85%
March	99%	89%	98%	85%	85%
April	98%	93%	98%	90%	85%
May	99%	95%	98%	90%	85%
June	100%	91%	98%	88%	85%
July	98%	90%	98%	87%	85%
August	96%	97%	98%	91%	85%
September	98%	92%	98%	88%	85%
October	98%	93%	98%	87%	85%
November	99%	87%	98%	85%	85%
December	100%	91%	99%	88%	85%

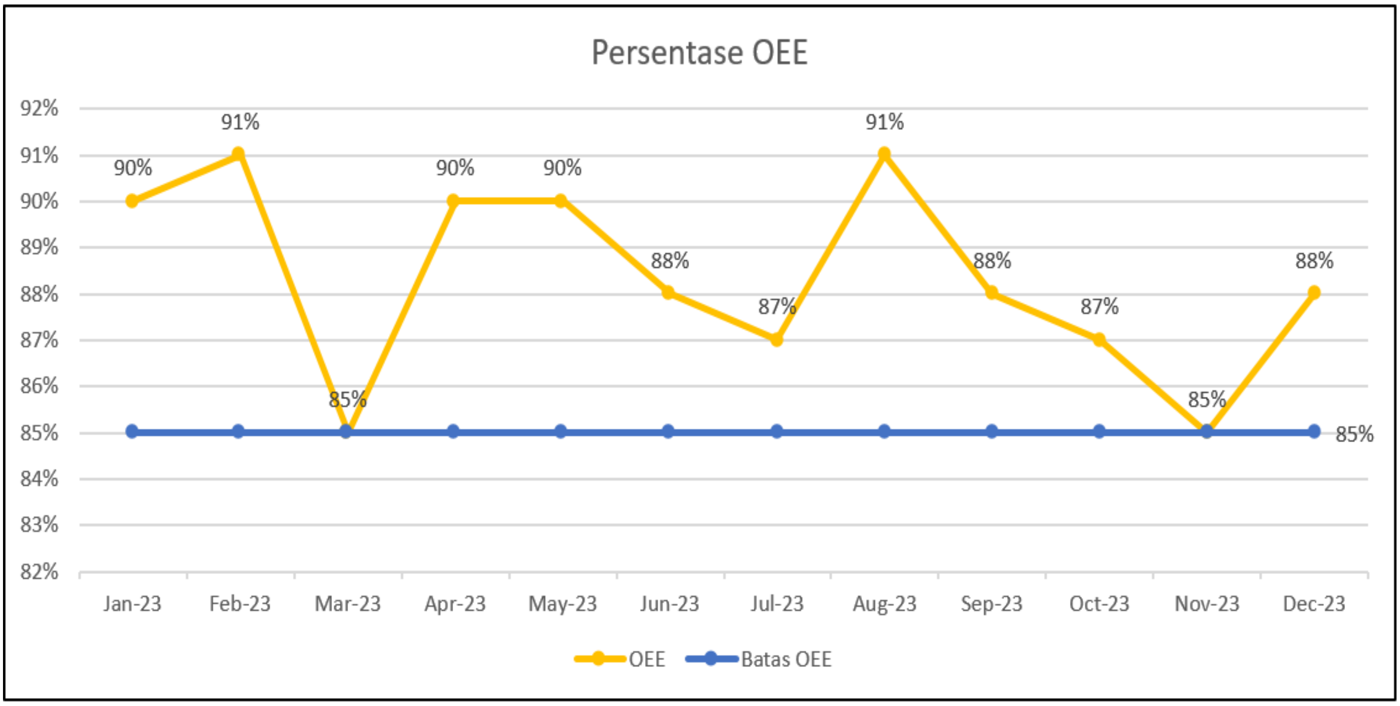

Fig 5 OEE Chart

OEE analysis of Centrifugal Pump machine at PT. Fajar Surya Wisesa, documented in the table, provides an overview of the effectiveness of the use of the machine. Several points of analysis presented with the research data corroborate these findings:

- Consistency in Performance: The OEE value remains stable month-to-month with slight variations consistently above the minimum target of 85%. For instance, in December, the OEE reached 88%, demonstrating outstanding performance
- Influence of Availability: *Availability* plays an important role in determining OEE. Months with high availability, such as June, November, and December (99%), contributed to an increase in OEE values.
- Effect of Performance Efficiency: Performance efficiency also has a significant impact on OEE. High-efficiency months, such as February (96%), contributed to the increase in OEE to 91%.
- Effect of Quality Level: The rate *of quality* of a product also affects the OEE value. Months with high quality levels, e.g. December (99%), contributed to an increase in OEE to 88%.
- Achievement Against Target: While overall OEE values tend to be above the 85% target, there are some months where OEE values are slightly below that limit. This shows the potential to make improvements to achieve or even exceed the set targets.

By enhancing the analysis with data on Availability, Performance Efficiency, and Quality Rate, management can gain deeper insights into the factors influencing the efficiency of utilizing Centrifugal Pump machines. This allows for the identification of areas that can be improved to improve overall operational performance and efficiency.

- The analysis of *the Six Big Losses* provides in-depth insight into the factors that affect the efficiency of Centrifugal Pump machines at PT. Fajar Surya Wisesa during the production process. Here are the results of the analysis based on the main types of losses: Losses due to Equipment Damage (*Breakdown*): Breakdown losses on Centrifugal Pump engines during the period January to December 2023 ranged from 0.41% to 3.80%. This figure indicates that there is unproductive time due to operational disruptions or damage to the engine. August stands out with a figure of 3.80%, reflecting significant problems affecting engine availability.
- Setup/Adjustment *Loss*: The Setup Loss on Centrifugal Pump machines is relatively low, ranging from 0.16% to 0.18%. This shows that the time required for engine setup and adjustment has been managed efficiently.
- Idling and Minor Stoppage *Loss: The* Idling and Minor Stoppage *loss* on Centrifugal Pump machines is also relatively low, not exceeding 1.44% monthly. This shows effective management in managing the factors that can lead to momentary stops or no-load operation on the machine.
- Reduced Speed *Loss*: Centrifugal Pump Machines experienced a significant decrease in production speed, especially in November to December, where Reduced Speed losses reached more than 2800 minutes. This shows the challenge in maintaining the operational speed of the machine which can affect the overall production efficiency.
- Yield/Scrap *Losses*: Yield*/Scrap losses*, which include defective or rejected products, also affect the efficiency of Centrifugal Pump machines. Although this percentage of losses tends to be low, the amount of time lost due to defective products is quite significant. For example, in April, the lost time reached 13,593.5 minutes, indicating the need for improvements in product quality control.

This analysis identifies potential areas for improvement to improve production efficiency and quality. By taking these factors into account, management can set improvement priorities and implement appropriate strategies to improve overall Equipment Effectiveness (OEE).

V. CONCLUSION

➢ *Based on the Results of the Research Conducted, there are Several Conclusions that can be Drawn:*

- *Maintenance Performance Evaluation:*

Based on the average, the *availability* value reaches 98%, indicating good *maintenance* performance because the engine *downtime* is very minimal. Coupled with *performance rates* that are in accordance with standards, 92% and 98%, respectively. This shows that although the machine rarely suffers damage, and the production process runs in accordance with the company's standards.

- *Overall Equipment Effectiveness (OEE):*

The average OEE value calculated is 88%, which is above the world standard of 85%. Although *the availability* is quite high, *the increased performance rate* and *quality rate* cause the OEE value to exceed the world standard limit. This shows that improvements in performance and quality aspects in machine operations are optimal.

To enhance the efficiency of maintaining the production line, it is advised to prioritize operator training through structured programs and regular performance assessments. Additionally, management should focus on ensuring the physical and mental well-being of operators to minimize fatigue and stress. Implementing strict supply chain management practices and conducting regular quality audits are crucial to ensure consistent high-quality raw materials. Developing clear and standardized standard operating procedures (SOPs) will help enhance consistency in product quality. It is essential to improve machine preventive maintenance by scheduling regular maintenance and conducting periodic inspections to prevent equipment damage and unexpected failures. Measures such as enhancing workplace safety through increased monitoring and investing in energy backup systems can mitigate adverse external environmental impacts.

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