ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

July 30, 2024

Analysis of Cut Size Paper Cutting Machine Performance Using Total Productive Maintenance Concept (Case Study: PT. RST)

Rolandi[a*], Anita Susilawati[a] and Ismet Hari Mulyadi[b]

[a)] *Mechanical Engineering Department, University of Riau, Indonesia*
[b)] *Mechanical Engineering Department, Faculty of Engineering, University of Andalas, West Sumatera, Indonesia*

* Corresponding author: rolandi7003@grad.unri.ac.id

Paper History

Received: 11-May-2024
Received in revised form: 19-June-2024
Accepted: 30-July-2024

PT. RST, a leading paper factory in Indonesia, prioritizes timely production by optimizing productivity, efficiency, and paper quality. This study assesses the reliability of the Cut Size (CS) paper cutting machine, which is enhanced through the implementation of Total Productive Maintenance (TPM) as a management philosophy to ensure high-efficiency operations. To evaluate machine performance, Overall Equipment Effectiveness (OEE) measurement was used. The data was collected from January to September 2023. Hence, an analysis was conducted to improve the performance of the CS machine. The average OEE value of 70.9% falls short of the target of 72%. This research aims to improve the performance of the CS machine through the TPM approach, focusing on the Focused Maintenance pillar. Using tools such as Pareto diagram, why-why analysis, fishbone diagram, and the 5W1H method, several sources of problems causing the decrease in OEE value will be identified and addressed.

KEYWORDS: *Total Productive Maintenance (TPM), Cut Size (CS), Overall Equipment Effectiveness (OEE).*

NOMENCLATURE

Av	Availability
LT	Loading Time
DT	Downtime
TAv	Time Available
PSD	Plan Shutdown
EqF	Equipment Failure
SL	Setup Losses
BD	Breakdown
PDT	Process Downtime
CgR	Change Roll
CgW	Change Wrapper
CgO	Change Order
CgS	Change Size
PE	Performance Efficiency
RSL	Reduced Speed Losses
DSp	Design Speed
OSp	Operation Speed
QR	Quality Rate
Dfp	Defect in Process
Df	Defect
Ru	Roll Used

1.0 INTRODUCTION

PT. RST, as one of the leading international-scale paper factories in Indonesia, which fulfilling global demand for paper, catering to the ever-growing market needs. Timely delivery of products is crucial for PT. RST, and the availability of these products heavily relies on the dependability of paper cutting machines, which directly influences productivity, efficiency, and paper quality. PT. RST utilizes the Total Productive Maintenance (TPM) concept as a management philosophy to ensure that production equipment and machines operate at high efficiency levels. Within the TPM concept, one method used for measuring machine performance is calculating the Overall Equipment Effectiveness (OEE) value, a critical indicator for evaluating machine performance in daily operations [1], [2].

OEE measurement is a significant method for assessing production machine performance, encompassing three interconnected factors: availability, performance, and quality. This method is used to determine how efficiently and productively a machine operates. During 2023, from January to September, the average OEE value generated by the CS paper cutting machines owned by PT. RST was 70.9%, as shown in Table 1 (PT. RST, 2023). Based on the average OEE value produced by the Cut Size machines, it appears that the TPM concept implemented by the Finishing Department is not optimal, as indicated by performance below the company's set target of 72% (PT. RST, 2023).

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers
Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

Table 1: The OEE CS Jan – Sept 2023 (PT. RST, 2023)

Month	OEE Cut Size (%)									
	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10
Jan	67,6	69,1	71,1	68,8	70,9	60,3	79,5	75,5	75,6	73,4
Feb	64,2	69,6	70,1	70,2	72,5	57,7	72,0	66,8	74,5	70,8
Mar	61,8	69,4	73,1	68,3	62,5	71,5	68,3	60,7	74,8	71,2
Apr	62,0	64,6	71,1	63,7	73,0	73,4	72,5	75,3	78,1	76,5
May	63,9	68,1	74,9	72,7	68,9	71,7	69,8	77,6	76,4	77,7
Jun	66,8	65,3	74,3	67,7	76,6	68,5	66,0	70,5	75,4	78,8
Jul	66,5	66,3	73,2	83,9	75,0	70,5	57,5	70,8	73,9	72,8
Aug	61,5	72,3	77,9	70,8	75,3	68,6	69,4	75,3	75,5	79,5
Sept	60,1	74,3	76,4	69,4	72,6	76,0	68,0	76,4	70,8	77,5
Avg	63,8	68,8	73,6	70,6	71,9	68,7	69,2	72,1	75,0	75,4
Avg#2	70,9									

This research is an expansion of a previous study [3] that also examined the effectiveness of CS paper cutting machines. The objective was to pinpoint potential sources of problems that could lower OEE values and devise action plans to eliminate and prevent issues affecting OEE through the TPM Focused Maintenance pillar. The OEE is a standard for measuring factory performance, introduced by Seiichi Nakajima in the early 1970s during his tenure at a Japanese factory maintenance institute. It is essential in production processes to maintain machine performance and availability. Higher values in these two variables theoretically lead to better product quality as well [4]. Nakajima [1] observed that world-class companies maintain high levels of availability, performance, and quality in their equipment, which are key components for achieving high OEE scores. World-class companies are renowned for having OEE scores of 85% or higher.

According to [5][6], the three OEE factors can be explained as follows:

- Availability: Measures the time used for business or personal operations in a day, comparing equipment loading and downtime.
- Performance Efficiency: Compares equipment speed during production with its maximum speed.
- Rate of Quality: Determines product quality by comparing production to the total material used.

The concept of six big losses, developed by Nakajima within TPM, categorizes productivity losses from an equipment perspective, addressing common causes of equipment-based productivity loss in manufacturing. According to Nakajima [1], the six big losses are as follows:

1. Equipment failure: Refers to scheduled production periods interrupted due to various reasons, including major equipment failures such as machines or tools malfunctioning or breaking down, hindering the smooth production process.
2. Setup and adjustment: The period during which equipment should be operating to produce goods but is hindered by a series of setup or other preparation activities.
3. Idling and minor stops: Periods when scheduled production equipment can be disrupted by various minor issues, including material feeding errors, material spills affecting machine performance, or incorrect settings affecting production outcomes.
4. Reduced speed: Any decrease in production process speed can result from various factors, ranging from equipment production issues, operator errors, to process defects themselves.
5. Process defects: Defects occurring in the manufacturing process can lead to significant waste, including wasted raw materials, rework, or generated waste.
6. Reduced yield: Product losses due to defects or issues during the manufacturing process can directly impact production efficiency and the quality of the final product.

Total Productive Maintenance (TPM) began development in the 1970s in Japanese companies and was later applied in US manufacturing industries. Maintaining equipment conditions that support production process execution is crucial in implementing production unit maintenance. The goal of productive maintenance is to achieve what Nakajima [1] refers to as profitable PM. Figure 1 illustrates the general development of maintenance methods.

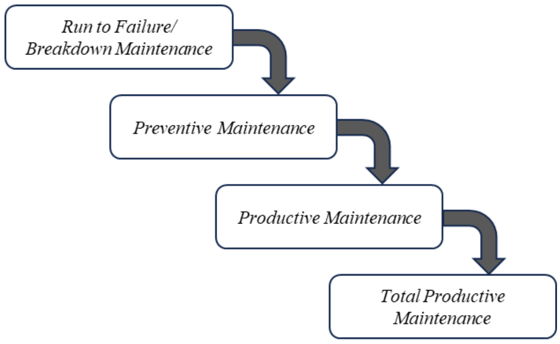

Figure 1: Maintenance methods development

TPM is a proactive approach that involves total participation from all employees within an organization to ensure continuous improvement of equipment and processes, focusing on eliminating all types of losses, including breakdowns, setup and adjustment times, downtime and minor stops, reduced speed, and defects. TPM also emphasizes the development of a culture of continuous improvement and overall equipment effectiveness (OEE) enhancement through the implementation of autonomous maintenance, planned maintenance, focused improvement, and other related activities [7].

The TPM is a holistic approach to equipment maintenance aimed at achieving flawless production by minimizing breakdowns and minor stops, creating a safe working environment, and emphasizing preventive and proactive maintenance to maximize equipment operational efficiency and involve everyone in the organization, from top management to production mechanics and support groups. TPM blurs the lines between production and maintenance roles by empowering operators to help maintain equipment, creating shared responsibility for equipment that encourages greater involvement by shop floor workers [8].

The TPM is a close cooperation between maintenance and the entire organization, aiming to improve production quality, reduce waste, lower production costs, enhance equipment capabilities, and develop the overall maintenance system in manufacturing companies. TPM activities and actions focus not only on preventing machine or equipment breakdowns and minimizing machine or equipment downtime but also address various factors that can lead to losses due to low

JOMAse | Received: 11-May-2024 | Accepted: 30-July-2024 | [(68) 2: 64-74]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

equipment efficiency, causing losses for the company [9], [10]. The TPM approach, as demonstrated in research conducted by Sahu & Mishra [11] at a steel factory, the study results indicated a significant improvement in equipment effectiveness and overall production rate after implementing TPM, while reducing defects and rework. Additionally, maintenance costs and repair time also decreased. Time wastage, such as downtime, reduced rework, and job rejection, could be successfully eliminated. Singh et al. [12] mentioned in their study on implementing TPM in an automotive company's machine workshop that TPM's success depends on various pillars like 5-S, Jishu Hozen, Planned Maintenance, Quality maintenance, Kaizen, Office TPM, and Safety, Health & Environment. OEE increased from 63% to 79%, showing productivity and product quality improvements.

A study on implementing TPM strategies to improve OEE in the jute industry in Bangladesh by Haider & Rafiquzzaman [13] found that equipment failure losses reduced by 14.84% through continuous improvement. Defect rates decreased by 19.45% through preventive action. Most importantly, OEE increased by 3.8% by enhancing productivity and product quality. However, the researched company faces many challenges. Their OEE (58.81%) is still significantly lower than the benchmark for world-class manufacturing OEE (85%). Nevertheless, this research, through TPM implementation, provides insights for companies to understand OEE issues and how to improve them.

To succeed in TPM using a comprehensive approach emphasizing synergy between maintenance and overall organizational effectiveness, there are eight fundamental pillars as seen in Figure 2. Each addresses specific aspects crucial for optimizing equipment, improving productivity, and fostering a culture of continuous improvement in the manufacturing environment. The eight pillars include focused maintenance, planned maintenance, autonomous maintenance, early management, quality maintenance, training and education, office TPM, and safety, health, & environment[14], [15], [16], [17]. Focused maintenance, also known as focused improvement, is a systematic problem-solving approach aimed at identifying and eliminating root causes of equipment-related losses. It is one of the eight common pillars supporting improvement goals in TPM [18], [19]. Focused improvement is a systematic approach to problem-solving aimed at identifying and eliminating sources of inefficiency, defects, and waste in manufacturing processes to achieve higher quality, productivity, and cost-effectiveness [20].

Kaizen is a management philosophy originating from Japan and is often considered the key to Japan's success in maintaining competitiveness in the global market. The term "Kaizen" comes from Japanese, consisting of two words: "kai" meaning change, and "zen" meaning good or better. Therefore, Kaizen, which translates to "continuous improvement" in Japanese, is a key concept in lean manufacturing. It involves making small, incremental changes to processes and systems to enhance efficiency, quality, and safety. Kaizen is a bottom-up approach that encourages all employees to identify and solve problems rather than relying solely on management decisions [21], [22], [23]. Masaaki [24] explains that one of the fundamental principles of Kaizen is the active participation of all employees in continuous improvement processes.

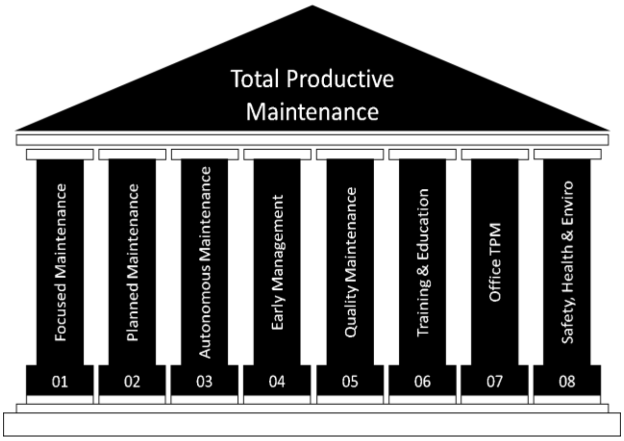

Figure 2: TPM pillars

In Kaizen, all employees are encouraged to actively participate in finding solutions to problems and improving performance. Additionally, Kaizen emphasizes the importance of using data and facts in decision-making, as well as the development of employees' skills and abilities.

The PDCA cycle (Plan-Do-Check-Act), as seen in Figure 3, also known as the Deming Cycle, is a fundamental principle of the scientific method based on the proposition of change, implementing change, measuring results, and taking appropriate action. The relationship between Kaizen and the PDCA concept is crucial. Kaizen, meaning "continuous improvement" in Japanese, focuses on implementing small changes every day that lead to significant improvements over time. The PDCA process supports both the principles and practices of continuous improvement and Kaizen [25], [26], [27], [28].

A Pareto diagram, also known as a Pareto chart, is a graphical representation of data that helps identify the most significant factors contributing to a problem or issue. The diagram aids in identifying the most significant factors contributing to a problem or issue, allowing businesses to focus resources on the aspects that have the greatest impact on the company. Pareto charts are useful in manufacturing settings for analyzing quality and defect data and can be used to pinpoint defects that need prioritization to achieve the greatest overall improvements [29], [30], [31]. While initially used for analyzing quality issues in manufacturing, Pareto diagrams can also be applied in various other contexts such as project management, customer service, and even strategic decision-making. Pareto diagrams can help identify areas where quality improvements will have the greatest impact, allowing for a more focused approach on crucial aspects, thereby achieving quality improvements more efficiently [32].

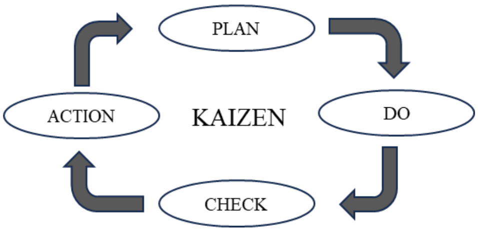

Figure 3: PDCA cycle

JOMAse | Received: 11-May-2024 | Accepted: 30-July-2024 | [(68) 2: 64-74]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers
Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

Fishbone analysis, also known as cause-and-effect diagrams or Ishikawa diagrams, is a visual tool used to identify and organize potential causes of a specific problem or effect. It is a structured approach that helps generate cause ideas for a problem and is often used in root cause analysis. The diagram resembles a fishbone, with the problem or effect placed at the fish's head and its causes extending to the left like fish ribs. Major causes branch off from the backbone, while additional branches indicate source causes. This diagram helps separate the content of an issue from its history and allows team consensus on the problem and its causes [33]. The steps in creating a fishbone diagram [34] are as follows:

- Agree on the problem statement (effect). The initial step in creating a fishbone diagram is to formulate a clear and detailed statement about the problem or effect being faced.
- Create main categories of causes and connect to the "fish backbone." After creating the problem statement, the next step is to create broad categories that could potentially cause the problem. For example, if using 5M/6M, this could mean man (human), machine, method, material, measurement, and if using 6M, environment could be added.
- Identify and list possible causes within each category, drawing small lines to represent sub-causes if needed.
- Here, each main category is further divided into sub-categories or specific possible causes. For example, under the human category, sub-categories could include inadequate training, workload overload, or lack of skills. Then, small lines (branches) are used to connect these sub-categories to the fish backbone.
- Analyze the diagram to identify potential causes of the problem. Once the entire diagram is filled with various possible causes, this stage involves in-depth analysis to identify the potential causes that may be the source of the problem.

After the causes have been identified, improvement steps can be tested, implemented, and then re-analyzed through an iterative process, making fishbone analysis not just a tool for identifying problems but also for delving deeper and addressing their underlying sources [31], [35].

The Why-why analysis is a simple investigation method developed by Sakichi Toyoda, the founder of Toyota Industries. This method aims to uncover the root cause of a problem by asking "why" repeatedly until reaching the fundamental source. This technique is based on the idea that by asking "why" repeatedly, one can understand the underlying cause of a problem rather than just addressing its symptoms [36]. The 5W1H method is a problem-solving technique that helps view ideas and problems from various perspectives. It is a question-and-answer method aimed at understanding problems better and finding their root causes. The abbreviation 5W1H stands for what, where, when, why, who, and how. This method is often used in brainstorming sessions to generate new ideas or find solutions to problems. It can also be used in project management to ensure all factors are considered before taking action. This method allows for understanding the situation by analyzing all aspects to identify the problem. By using the 5W1H method, teams can develop precise and effective solutions that address the underlying problem rather than just dealing with its symptoms [37].

2.0 METHODOLOGY

2.1 Data Collection

The analysis process in this study began by recalculating the OEE values of PT. RST using the Nakajima concept [1]. All data needed for the calculations were collected. The method used for data collection in this research involved conducting question-and-answer sessions with several experts in the CS paper cutting machine. Several parameters used in the OEE calculation are as follows:

- Time available: the time available to run the machine for production processes.
- Plan shutdown: planned downtime for maintenance or repair of equipment and machine components.
- Operating time: the time the machine is actively operating outside of planned downtime.
- Unplanned shutdown/breakdown: unplanned downtime due to equipment failure or disruption.
- Process downtime: downtime during the production process.
- Setting and adjustment time: time required to set up and adjust the machine for changes.
- Weekly cleaning: time spent cleaning the machine periodically.
- Fogging: downtime for eliminating all types of potentially falling insects entering the production process through fogging.
- Change roll: time required to change paper rolls.
- Change wrapper: time required to change product ream packaging.
- Change order: time required to change production orders.
- Change size: time required to change product size.
- Operating speed: the actual operating speed of the machine.
- Design speed: the maximum design speed of the machine.
- Net production: the net production output of the machine.
- Roll used: the number of paper rolls used in production.

2.2 Data Processing

The series of fundamental calculations is carried out to re-evaluate the values obtained by PT. RST in order to measure and evaluate the performance of the CS paper cutting machine involving six big losses as seen in Figure 3.

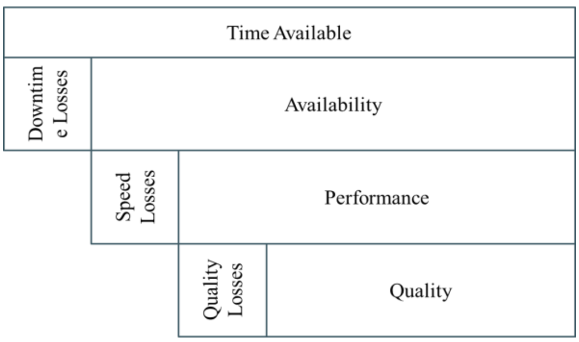

Figure 3: Six Big Losses Diagram

In line with Nakajima's concept [1], Equation 1 is used to calculate the availability value used by PT. RST, which involves time wasted due to equipment failure and setup and

JOMAse | Received: 11-May-2024 | Accepted: 30-July-2024 | [(68) 2: 64-74]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers
Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

adjustment losses. Furthermore, Equations 2 through 5 are sequentially used to calculate loading time, downtime, equipment failure, and setup losses.

$$Av \quad (1)$$

$$LT = TA - PSD \quad (2)$$

$$DT = EqF + SL \quad (3)$$

$$EqF = BD + PDT \quad (4)$$

$$SL = (CgR + CgW + CgO + CgS) \quad (5)$$

The total equipment failure/breakdown time calculation measures the total time when the machine experiences unplanned failures or damages, including downtime due to technical issues affecting production and stoppages due to errors in the production process. For the calculation of total setup and adjustment loss or setup losses, this study calculates the total time spent on each setup, material changeovers, machine adjustments before production, as well as time used for machine cleaning and insect elimination efforts through fogging at PT. RST. This is time that does not directly contribute to production and can affect machine availability.

In the context of performance efficiency calculation, in line with the concept of six big losses, it involves idling & minor stoppage and reduced speed losses in its calculations [1]. However, due to data collection at PT. RST being manual, and specifically for idling & minor stoppage, which would obviously keep operators busy recording such minor disruptions, it does not use calculations in time units but rather uses units of production speed in reams per minute.

To accommodate this limitation, this study only focuses on calculating reduced speed losses, along with several main causes of this speed loss. Equation 6 is used to calculate the value of production machine performance efficiency. Then, Equation 7 is used to calculate the value of the reduce speed losses that occur.

$$PE = 100\% - RSL \quad (6)$$

$$RSL = (DSp - OSp)/DSp \times 100\% \quad (7)$$

This calculation compares the actual operating speed of the machine with the design speed of the machine. Thus, this study will help identify to what extent the machine operates at the expected speed and whether there are differences between actual performance and expected performance due to various factors, both internal machine issues and external machine factors. This will enable understanding the factors affecting speed loss and assess its impact on operational efficiency.

In the process of calculating production quality on the CS paper cutting machine, it involves calculating Defect in process and reduced yield [1]. However, in the PT. RST environment, where no new products are produced, the reduced yield calculation is not applied in the OEE calculation process. Similarly, PT. RST does not use time units in quality rate calculations, but rather uses a calculation by comparing net production output with raw material used. Equation 8 is used for calculating the quality rate value and Equation 9 is used to calculate the value of defects that occur during the production process.

$$QR = 100\% - DfP \quad (8)$$

$$DfP = \quad \times 100\% \quad (9)$$

The defect in process calculation is an important aspect in assessing the production quality of the CS machine. This section calculates the amount of raw material (paper) lost due to defects or errors in the production process compared to the total amount of raw material used. Next, the results of the availability, performance efficiency, and quality rate calculations are combined for the OEE calculation. Equation 10 is used to calculate the OEE value generated by a production machine.

$$OEE = Av \times PE \times QR \quad (10)$$

3.0 RESULT AND DISCUSSION

3.1 The OEE Calculation

According to Equations 1 through 4, for the availability calculation, the values of availability for the CS machine during January to September 2023 based on the re-evaluation can be seen in Table 2. Similarly, as per Equations 6 and 7, for the performance efficiency calculation, the performance values for the CS machine based on the re-evaluation can be seen in Table 3. Following Equations 8 and 9 for the quality rate calculation, the quality rate values for the CS machine based on the re-evaluation can be seen in Table 4. Table 5 shows the OEE values for the CS machine owned by PT. RST based on the re-evaluation conducted in this study. The OEE value calculated by PT. RAK previously seen in Table 1 was 70.9%. However, the OEE value based on the re-evaluation using Nakajima's concept (1988) in Table 5 is 71.1%. The re-evaluation results in this study offer a new perspective on PT. RAK regarding machine efficiency calculation.

Table 2: The CS availability Jan-Sept 2023 (re-calculate)

Month	Cut Size Availability (%)									
	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10
Jan	82.2	86.8	86.1	79.7	77.0	81.1	88.6	85.4	84.0	82.9
Feb	83.4	90.2	89.3	80.1	80.6	80.0	83.7	82.6	82.0	79.5
Mar	80.0	91.7	88.7	81.3	81.0	86.5	82.9	80.5	83.9	82.5
Apr	81.4	85.7	82.6	76.3	81.5	83.4	85.9	83.6	85.1	85.2
May	81.3	86.3	91.4	81.1	80.0	84.9	83.2	85.8	83.0	84.3
Jun	82.1	84.6	88.4	85.6	80.2	81.9	77.7	82.7	82.2	83.5
Jul	83.7	84.8	85.9	86.7	81.3	82.8	75.2	82.0	77.9	77.1
Aug	78.8	92.4	90.2	84.1	80.5	82.0	81.8	84.2	81.0	83.5
Sept	80.6	95.5	88.6	81.1	81.0	83.5	84.0	84.0	79.7	83.6

Table 3: The CS performance Jan-Sept 2023 (re-calculate)

Month	Cut Size Performance (%)									
	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10
Jan	87.8	83.6	88.0	92.7	94.7	80.4	91.0	91.7	92.9	91.0
Feb	81.7	80.9	82.0	92.7	92.0	76.1	89.0	85.0	94.2	92.9
Mar	84.3	80.0	87.0	90.9	81.3	91.3	85.8	80.0	92.9	90.3
Apr	80.0	80.9	90.0	87.3	92.7	91.3	86.5	93.3	94.8	91.6
May	84.3	80.9	87.0	94.5	90.7	89.1	85.8	95.0	94.8	94.8
Jun	86.1	80.0	87.0	89.1	94.7	87.0	87.1	88.3	93.5	97.4
Jul	83.5	81.8	89.0	98.2	94.7	89.7	79.4	90.9	96.8	96.8
Aug	84.3	80.0	89.0	92.7	95.3	88.4	87.1	91.1	96.8	97.4
Sept	79.1	60.0	88.0	92.7	93.3	87.8	84.5	94.8	92.3	96.1

JOMAse | Received: 11-May-2024 | Accepted: 30-July-2024 | [(68) 2: 64-74]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers
Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

July 30, 2024

Table 4: The CS quality rate Jan-Sept 2023 (re-calculate)

Month	Cut Size Quality rate (%)									
	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10
Jan	94.2	95.3	94.1	93.2	98.0	94.1	98.6	96.8	97.6	97.5
Feb	94.5	95.5	96.7	94.7	98.0	94.5	96.8	95.1	96.6	96.0
Mar	91.9	94.6	94.6	92.8	96.4	94.7	96.1	94.5	95.8	95.8
Apr	95.0	93.2	95.6	96.2	96.8	96.5	98.1	96.7	96.7	98.2
May	93.6	97.7	94.3	95.0	96.6	94.7	97.8	95.5	97.6	97.7
Jun	95.7	96.5	96.4	94.7	97.7	96.4	97.3	96.8	98.0	96.8
Jul	95.3	95.7	96.4	98.8	97.8	95.2	94.1	95.4	97.9	97.4
Aug	93.3	97.7	97.2	96.6	98.3	94.5	97.6	98.3	96.6	97.8
Sept	95.2	129.6	98.0	93.8	96.9	94.8	96.6	96.6	96.8	97.0

Table 5: The CS of the OEE Jan-Sept 2023 (re-calculate)

Month	Cut Size OEE (%)									
	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10
Jan	68,0	69,2	71,3	68,9	71,5	61,4	79,4	75,8	76,1	73,5
Feb	64,4	69,7	70,8	70,3	72,6	57,5	72,1	66,7	74,7	70,9
Mar	62,0	69,4	73,0	68,6	63,5	74,8	68,4	60,9	74,7	71,3
Apr	61,9	64,6	71,1	64,0	73,1	73,5	72,9	75,5	78,0	76,6
May	64,2	68,2	75,0	72,8	70,1	71,7	69,7	77,9	76,8	78,0
Jun	67,6	65,4	74,2	72,3	74,1	68,6	65,9	70,7	75,4	78,7
Jul	66,6	66,4	73,7	84,1	75,3	70,8	56,2	71,1	73,7	72,7
Aug	62,0	72,3	78,0	75,3	75,4	68,4	69,5	75,4	75,7	79,6
Sept	60,7	74,3	76,4	70,5	73,3	69,4	68,6	77,0	71,2	77,9
Avg	64,2	68,8	73,7	71,9	72,1	68,5	69,2	72,3	75,1	75,5
Avg#2	71,1									

The study reveals that the difference stems from the allocation of machine downtime values, particularly related to weekly cleaning and fogging activities. The research found that PT. RAK included machine downtime for these activities in the non-allowed downtime category. However, it becomes intriguing when realizing that these activities are actually planned to be carried out every month as part of routine maintenance. The inaccurate placement of downtime values directly affects the machine availability calculation and certainly affects the obtained OEE value. Although there is a difference of 0.2% in the calculated OEE value, the average OEE result still falls short of the Company's target, which is set at 72%. This result illustrates the complexity of challenges faced by the Cut Size machine in achieving the expected efficiency level.

3.2 Finding Problematic Using Pareto Diagram

To identify the focus areas for improvement that can significantly impact OEE value, this research employs the Pareto diagram as the primary analytical tool. By utilizing the Pareto diagram, the research provides a visual perspective revealing the contribution of each Cut Size machine to the most noticeable OEE decrease. The Pareto diagram unveils information that enables researchers to identify which Cut Size machines contribute the most to the low OEE value. In Table 6, there are OEE gap values for each machine against the set target. The analysis of OEE gap values from each machine is done meticulously, and then, using the Pareto diagram as shown in Figure 4. It can identify the machines that contribute the most to the gap. The Pareto diagram allows the author to prioritize machines that require more attention in efforts to improve performance effectively.

By applying the 80-20 concept from the Pareto diagram, this research identifies the main focus on Cut Size machines that significantly contribute to the OEE value decrease, thus, in Figure 4, it is identified that CS1, CS6, and CS2 are the main focus that plays a role in influencing overall operational performance.

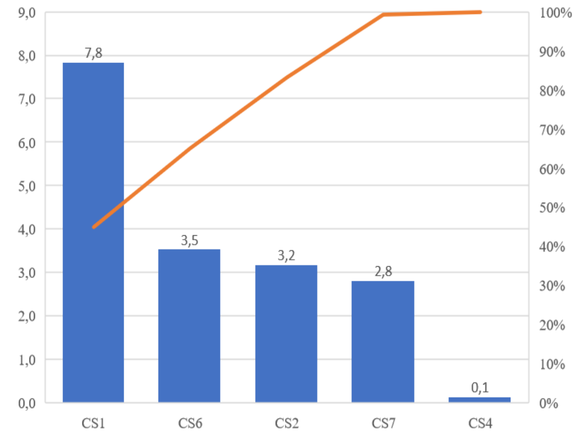

Figure 4: Pareto for OEE gap

The next step is to examine each parameter contributing to the low OEE value. The analysis of OEE parameters involves a comprehensive evaluation of several variables, including machine downtime, production speed, and quality level of production results. Table 7 shows some of these OEE value-forming parameters for CS1, CS6, and CS2 machines.

Table 6: Gap of CS's OEE

	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10
Average of OEE	64.2	68.8	73.7	71.9	72.1	68.5	69.2	72.3	75.1	75.5
Gap OEE	7.8	3.2	-1.7	0.1	-0.1	3.5	2.8	-0.3	-3.1	-3.5

Table 7: OEE parameters value of CS1, CS6 & CS2

	CS1	CS6	CS2
Availability	81.5	82.9	88.7
Performance	83.5	86.8	78.7
Quality	94.3	95.0	99.5

Continuing the in-depth analysis of OEE value-forming parameters on the selected Cut Size machines, findings emerge from this research. For CS1 machine, it is revealed that availability plays a role in decreasing the OEE value. A similar observation can be found in CS6 machine, where availability value becomes the main focus of the potential improvement area to optimize operational efficiency. Meanwhile, when highlighting CS2 machine, the analysis results show that performance value becomes the spotlight that significantly impacts the decrease in OEE value. The equipment failure plays a crucial role in decreasing availability value. Table 8 shows equipment failure data that occurred in CS1, and Table 9 shows equipment failure data that occurred in CS6 during January to September 2023. In Figure 5, it can be clearly seen that issues like bad folding carton, ream jam, and strapper problem are the main problems that decrease CS1 availability value. And in Figure 6, it can be clearly seen that issues like paper jam, bad folding wrapper, ream jam, sheet stacking out, and misalignment wrapper are the main problems that decrease CS6 availability value.

JOMAse | Received: 11-May-2024 | Accepted: 30-July-2024 | [(68) 2: 64-74]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

3.3 Finding the Root Causes Using Why-Why Analysis

The next step is the search for the root causes of each problem using the why-why analysis method. This process becomes a crucial step to detail more deeply and understand the fundamental reasons behind each problem affecting the performance of Cut Size machines. Involving collaboration from experienced teams in Cut Size machine operations, namely the Finishing Maintenance Head, Senior Mechanical Supervisor, Senior Mechanical Specialist, and Senior Process Engineer explored as far as possible every layer of problem causes. In Table 10, there's a list of issues that decrease the availability value for CS1 and CS6 based on the Pareto diagram, which can be seen in Figures 5 and Figure 6.

Each problem listed in Table 10 will be formulated together with the aforementioned experts using the why-why analysis method. From several machine problems causing a decrease in the availability value of machines CS1 and CS6, which were investigated using the why-why analysis method. The several problems leading to recommendations for periodic replacement activities were identified. Further information can be found in Table 11. All periodic component replacement activities should consider historical data on the replacement of each component to determine the optimal replacement time.

Table 8: Problem for equipment failure at CS1

Problem Identification	Time (hrs)	Problem Identification	Time (hrs)
Hairy corner	16.1	Sensor problem	5.5
Strapper problem	12	Error 40	2.7
Drive belt broken	9.9	Feeding conveyor problem	2.5
Bolt broken	3.4	Bad folding carton	58.9
Gripper broken	3.3	Ream jam	48.9
Bad cutting	3.2	Paper jam	21.8
Edge welding	3	Sheet stacking out	20.3
Bearing problem	3	Botom transfer fault	14.5
Drive problem	18.3	Label problem	6.5
Lifting table error	14.1	Strapper problem	5.7
Sheet counter error	14.1	Palletizer problem	5.3
Strapper problem	11.2	Misalignment wrapper	5.2
Machine can't start	7.4	Glue problem	5.2
Gripper error	5.7	Bad folding wrapper	4.6

Table 9: Problem for equipment failure at CS6

Problem Identification	Time (hrs)	Problem Identification	Time (hrs)
Bad cutting	18.4	Micromatik fault	2.9
Bolt broken	7.8	Paper jam	37.2
Bad fodling wrapper	6.5	Bad folding wrapper	31
Strapper problem	4.8	Ream jam	27.4
Folding sheet	3.9	Sheet stacking out	27.3
Torn sheet	3.7	Misalignment wrapper	23.9
Dragging teeth problem	3	Folding sheet	14.9
Gripper ream lost	2.7	Trim plug up	13.5
Separator finger problem	2.5	Wrapper jam	12.6
Width variation	8	Ectra glue	9.3
Central module not ready	7.2	Dirty bottom sheet	8.1
Fault chuck monitoring	6.6	Width deviation	8
CSW not synchrone	5.8	Bent corner	7.8
Backstand problem	5.5	Gripper ream lost	7.1
Mobil hopper problem	3.9	Edge welding	6.5

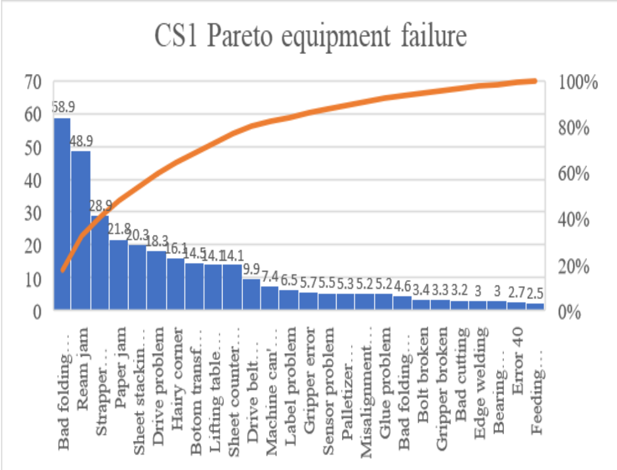

Figure 5: Pareto for equipment failure in CS1

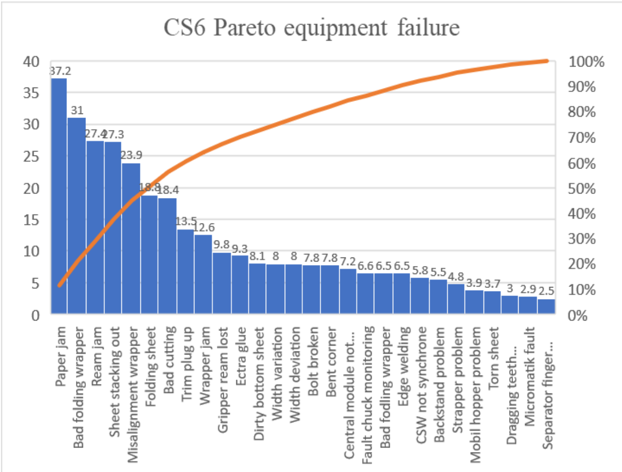

Figure 62: Pareto for equipment failure in CS6

Table 10: Problem listed

No	Problem description
1	Bad folding carton
2	Bad folding wrapper
3	Misalignment wrapper
4	Paper jam
5	Ream jam
6	Sheet stacking out
7	Strapper problem

Furthermore, from the investigation results using the why-why analysis method for machines CS1 and CS6, several issues leading to recommendations for periodic cleaning, checking, and tuning activities were found. Detailed information can be found in Table 12. All these recommended activities need to be published and socialized to all team members to be implemented optimally, so that the same problems do not occur again. For problems requiring additional action plans, further discussions are held to formulate the appropriate plan for problem resolution. Details regarding some of these issues can be seen in Table 13.

JOMAse | Received: 11-May-2024 | Accepted: 30-July-2024 | [(68) 2: 64-74]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

Table 11: List for periodic component replacement

No	Recommendations for periodic component replacement
1	Seal cylinder for folding bow carton
2	Oil seal for all gearbox
3	Roller for press overlapping
4	Drive wheel for transfer belt
5	Squaring device chain
6	Heater for strapper
7	Modul tensioner for strapper
8	Seal cylinder for strapper
9	Chamber shoe for collecting box

Table 12: List for regular maintenance activities

No	Recommended periodic cleaning/checking/adjusting
1	Regular schedule for pull off tape checks
2	Regular schedule for pull off tape bearing checks
3	Regular schedule for adding the lubrication
4	Regular schedule for chain cleaning
5	Regular schedule for cleaning/inspection of the press roller adjustment threads
6	Regular schedule for vacuum bar cleaning
7	Regular schedule for impeller cleaning (revise old schedule due to too long interval)
8	Regular schedule for machine belt tension checks
9	Regular schedule for strapper cleaning
10	Regular schedule for heater of strapper cleaning

3.4 Finding the Root Cause of CS2 Problems with the Fishbone Method

The use of the Fishbone diagram is an important step in detailing the sources of problems that occur in complex issues. Highlighting the decrease in OEE value on machine CS2 as seen in Table 7, the main problem identified is the performance efficiency of the machine. The decrease in performance efficiency is mainly caused by operating the machine at a speed below the design's intended speed. By categorizing each potential cause into categories such as human, method, material, machine, and environment, the Fishbone method provides a comprehensive view of the sources of problems. By exploring every possible cause in detail, ensuring there are no limitations in detailing the factors affecting CS2 machine performance.

Table 13: List of issues that require action plan

No	Problems that require action plan
1	There is no vacuum bar protection from glue splashes
2	The operator paid little attention to the process of installing the double tape and when the paper went under the nip roller
3	There are no instructions for adjusting the separating finger and gripper
4	There are no instructions for setting the strapper heater temperature

Table 14: List of major CS2 problems

No	Major problems
1	There are no written speed instructions for some conditions
2	Lack of supervision of operators
3	The operator does not provide the latest information on problems that occur
4	The decrease in speed is due to the need to measure the diameter of the paper roll still manually
5	Upgrade costs are expensive
6	There is no correct maintenance methods
7	The room temperature must be maintained

Figure 7 shows the Fishbone diagram created from collaboration among experts. Through the approach of the 5 main categories, namely human, method, material, machine, and environment, we can see several major problems that could potentially slow down the machine. This table shows problems from various aspects, which then become the focus for developing improvement plans to enhance machine performance. From the analysis with the Fishbone diagram, several root problems causing the main decrease in the speed of Cut Size machine CS2 can be identified. Detailed information about the main problems revealed through Fishbone analysis can be found in Table 14.

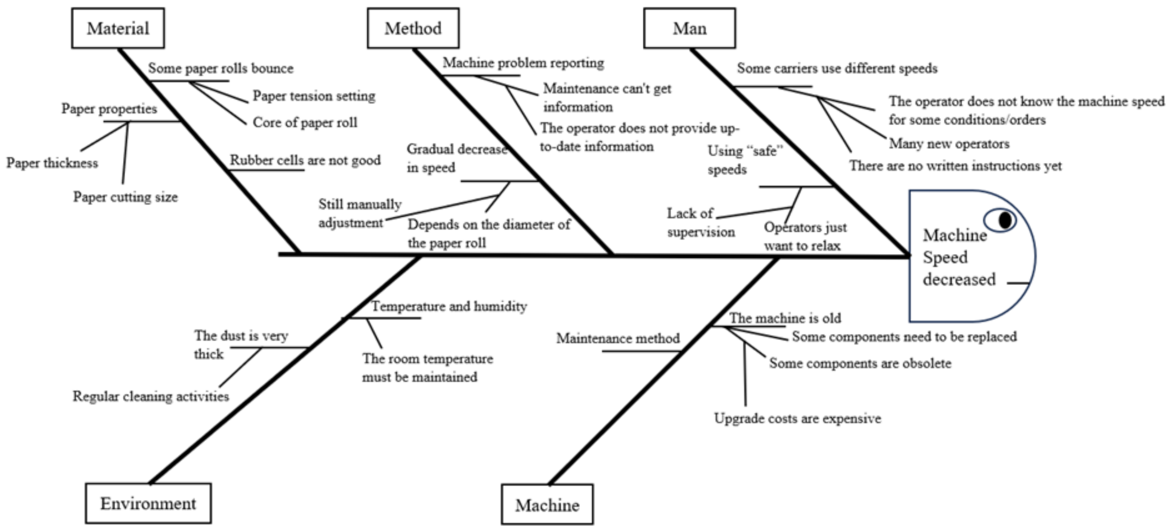

Figure 7: Fishbone diagram of CS2 speed reduction

JOMAse | Received: 11-May-2024 | Accepted: 30-July-2024 | [(68) 2: 64-74]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

July 30, 2024

Table 1615: Action plans for CS1 & CS6

No	What	Why	How/Action Plan	Where	When	Who
1	There is no vacuum bar protection from glue splashes	The type of glue used is a new type	Make a vacuum bar protector from glue splashes	Machine	April 2024	Technician
2	The operator paid little attention to the process of installing the double tape and when the paper went under the nip roller	There's a new operator	Create work instructions for checking new incoming paper	Office	April 2024	Senior Operator
3		Negligent because it has become a daily job	Read several shift work instructions again before starting work	Machine	April 2024	Operator
4	There are no instructions for adjusting the separating finger and gripper	Previously learned orally from generation to generation	Create work instructions for setting up the parting finger and gripper	Machine	April 2024	Senior Operator
5	There are no instructions for setting the strapper heater temperature	Previously it was arranged by an electrician, so there was wasted time waiting	Create work instructions for setting temperature by the operator	Machine	April 2024	Electrician

Table17: Action plans for CS2

No	What	Why	How/Action Plan	Where	When	Who
1	There are no written speed instructions for some conditions	So far, it has been based on verbal instructions passed down from generation to generation	Create speed lists based on conditions (paper properties, order type, etc.)	Office	April 2024	Senior Operator
2	Lack of supervision of operators	The shift supervisor controls all areas and there is no CCTV	Schedule surprise inspections by senior management	Office	April 2024	Senior Management
3	The operator does not provide the latest information on problems that occur	There is no urgent order to report the problem	Each operator must collect at least 2 abnormalities (although they may be the same problem because they have not been worked on)	Machine	Continue	Operator
4	The decrease in speed is due to the need to measure the diameter of the paper roll still manually	There is no program on the machine yet	Create a program that regulates speed reduction	Machine	June 2024	Electrical Specialist
5	Some electronic drives are no longer produced	Electronic devices have a cycle where they are no longer produced, and there are replacements	Mapping all electronic items and making upgrade plans carried out by the electric team	Office	Dec 2024	Electrician
6	There is no correct maintenance methods	The machine maker does not provide this type of maintenance in the manual book	Determine the type of treatment that is suitable	Office	Dec 2024	Maintenance
7	The room temperature must be maintained	There is an increase in room temperature because the cooling coil on the AHU (Air Handling Unit) has leaked	Make plans for cooling coil replacement	Office	May 2024	Technician

3.5 Determining Action Plan with 5W1H Method

Table 13 lists the identified problems with Cut Size machines CS1 and CS6, which require detailed action plan. Detailed analysis is then carried out for each problem using the 5W1H method. This method allows us to understand the essence of the problem by asking questions about what the problem is, why it occurs, how the improvement steps will be implemented, where the action plan will take place, when the implementation schedule is, and who is responsible for executing the action plan. Table 14 provides details of the action plans prepared to address the main problems that can affect the availability of machines CS1 and CS6. A similar process is also carried out for problems identified through the Fishbone diagram method, which can then be transferred into Table 16, affecting the performance of machine CS2. Furthermore, in Table 17 provides further details of the action plans prepared to address the main problems identified earlier, focusing on optimizing CS2 machine performance.

4.0 CONCLUSION

In order to identify the source of problems that could decrease the performance of the Cut Size machines owned by the Finishing Department, the research begins with recalculating the OEE value of these machines. An interesting difference was found in the calculation of the OEE value, especially regarding the inclusion of machine downtime for weekly cleaning and fogging activities. The Finishing Department included the machine downtime for these activities in the non-allowed downtime category, which affects the machine availability calculation and the overall OEE value. Although there was a 0.2% improvement in recalculating the OEE value of the Cut Size machines, the average OEE value obtained (71.1%) still falls short of the company's target set (72%).

Furthermore, in order to eliminate and prevent the recurrence of the same problems, by applying the focused maintenance pillar of TPM, through the 80-20 concept from the Pareto diagram, it was identified that CS1, CS6, and CS2

JOMAse | Received: 11-May-2024 | Accepted: 30-July-2024 | [(68) 2: 64-74]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers
Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

are the main focus areas affecting overall operational performance. Availability value plays a crucial role in reducing the OEE value for CS1 and CS6, while the performance value influences the decrease in OEE value for CS2. The Pareto diagram also reveals significant contributions from equipment failures in CS1 and CS6 that affect machine availability and OEE value.

Based the why-why analysis method, several recommendations for periodic component replacement and periodic maintenance activities were generated to help improve machine availability and OEE value. Additionally, by using the fishbone method and 5W1H, action plans were identified to address the identified problems, starting from component replacement to operator training, thereby reducing the likelihood of recurring problems in the future.

REFERENCES

[1] S. Nakajima, “Introduction to TPM: total productive maintenance. (Translation),” *Productivity Press, Inc., 1988,* p. 129, 1988.

[2] A. Tomlinson, “Introduction to the TPM,” *Smart Cards, Tokens, Security and Applications*, pp. 173–191, 2017.

[3] M. Ardi, A. Sutanto, and A. Susilawati, “Analysis of Effectiveness of Cut Size Line Machines Based on Total Productive Maintenance (TPM) and Analytical Hierarchy Process (AHP)-A Case Study,” *Journal of Ocean, Mechanical and Aerospace-science and engineering-*, vol. 67, no. 3, pp. 109–117, 2023.

[4] A. K. Gupta and R. K. Garg, “OEE improvement by TPM implementation: a case study,” *International Journal of IT, Engineering and Applied Sciences Research*, vol. 1, no. 1, pp. 115–124, 2012.

[5] S. Singh, J. S. Khamba, and D. Singh, “Analyzing the role of six big losses in OEE to enhance the performance: literature review and directions,” *Advances in Industrial and Production Engineering: Select Proceedings of FLAME 2020*, pp. 411–421, 2021.

[6] D. H. Stamatis, *The OEE primer: understanding overall equipment effectiveness, reliability, and maintainability*. CRC Press, 2017.

[7] I. P. S. Ahuja and J. S. Khamba, “Total productive maintenance: literature review and directions,” *International journal of quality & reliability management*, 2008.

[8] B. Steven, “Total Productive Maintenance: Proven strategies and techniques to keep Equipment running at peak efficiency,” *DOI*, vol. 10, p. 0071467335, 2013.

[9] S. Borris, *Total productive maintenance*. McGraw-Hill New York, 2006.

[10] R. Thorat and G. T. Mahesha, “Improvement in productivity through TPM implementation,” *Mater Today Proc*, vol. 24, pp. 1508–1517, 2020.

[11] S. Sahu and S. K. Mishra, “Overall Equipment Effectiveness Improvement of Annealing Furnace by Implementation of Total Productive Maintenance (TPM)-A Case Study.,” 2017.

[12] R. Singh, A. M. Gohil, D. B. Shah, and S. Desai, “Total productive maintenance (TPM) implementation in a machine shop: A case study,” *Procedia Eng*, vol. 51, pp. 592–599, 2013.

[13] M. M. N. Haider and M. Rafiquzzaman, “Implementation of Total Productive Maintenance in a Jute Bag Industry: a Case Study,” *Journal of Engineering Science*, vol. 14, no. 1, pp. 137–149, 2023.

[14] E. Y. T. Adesta, H. A. Prabowo, and D. Agusman, “Evaluating 8 pillars of Total Productive Maintenance (TPM) implementation and their contribution to manufacturing performance,” in *IOP conference series: materials science and engineering*, IOP Publishing, 2018, p. 012024.

[15] J. C. Meca Vital and C. R. Camello Lima, “Total Productive Maintenance and the Impact of Each Implemented Pillar in the Overall Equipment Effectiveness,” *International Journal of Engineering and Management Research*, vol. 10, 2020.

[16] H. A. Prabowo, Y. B. Suprapto, and F. Farida, “The evaluation of eight pillars total productive maintenance (TPM) implementation and their impact on overall equipment effectiveness (OEE) and waste,” *Sinergi*, vol. 22, no. 1, pp. 13–18, 2018.

[17] J. Singh and H. Singh, “Justification of TPM pillars for enhancing the performance of manufacturing industry of Northern India,” *International Journal of Productivity and Performance Management*, vol. 69, no. 1, pp. 109–133, 2020.

[18] S. Kunio and N. Seiichi, “TPM for supervisors.” Productivity Press, Portland, 1992.

[19] X. Sun, “Implementing a Total Productive Maintenance Approach into an Improvement At S Company,” 2018.

[20] J. M. Nicholas, “Competitive manufacturing management: continuous improvement, lean production, customer-focused quality,” *(No Title)*, 1998.

[21] D. Carnerud, C. Jaca, and I. Bäckström, “Kaizen and continuous improvement–trends and patterns over 30 years,” *The TQM Journal*, vol. 30, no. 4, pp. 371–390, 2018.

[22] M. Rossini, F. Audino, F. Costa, F. D. Cifone, K. Kundu, and A. Portioli-Staudacher, “Extending lean frontiers: a kaizen case study in an Italian MTO manufacturing company,” *The international journal of advanced manufacturing technology*, vol. 104, pp. 1869–1888, 2019.

[23] I. W. Rusdiana and D. Soediantono, “Kaizen and implementation suggestion in the defense industry: A literature review,” *Journal of Industrial Engineering & Management Research*, vol. 3, no. 3, pp. 35–52, 2022.

[24] I. Masaaki, “Kaizen: The key to Japan’s competitive success,” *New York, ltd: McGraw-Hill*, 1986.

[25] M. Dudin, E. Frolova, N. Gryzunova, and E. Shuvalova, “The Deming Cycle (PDCA) concept as an efficient tool for continuous quality improvement in the agribusiness,” *Asian Soc Sci*, vol. 11, no. 1, pp. 239–246, 2015.

[26] W. E. Deming, “Out of the crisis: Quality,” *Productivity and Competitive Position, Massachusetts, USA*, 1986.

[27] M. N. Dudin, O. O. Smirnova, N. V. Vysotskaya, E. E. Frolova, and N. G. Vilkova, “The deming cycle (PDCA) concept as a tool for the transition to the innovative path of the continuous quality improvement in production processes of the agro-industrial sector,” 2017.

[28] M. Jagusiak-Kocik, “PDCA cycle as a part of

JOMAse | Received: 11-May-2024 | Accepted: 30-July-2024 | [(68) 2: 64-74]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th July 2024. Vol.68 No.2

continuous improvement in the production company-a case study," *Production engineering archives*, vol. 14, no. 14, pp. 19–22, 2017.
[29] G. Karuppusami and R. Gandhinathan, "Pareto analysis of critical success factors of total quality management: A literature review and analysis," *The TQM magazine*, vol. 18, no. 4, pp. 372–385, 2006.
[30] S. Bajaj, R. Garg, and M. Sethi, "Total quality management: a critical literature review using Pareto analysis," *International Journal of Productivity and Performance Management*, vol. 67, no. 1, pp. 128–154, 2018.
[31] R. S. Raman and Y. Basavaraj, "Quality improvement of capacitors through fishbone and pareto techniques," *International Journal of Recent Technology and Engineering*, vol. 8, no. 2, pp. 2248–2252, 2019.
[32] M. S. Ab Talib, A. B. Abdul Hamid, and A. C. Thoo, "Critical success factors of supply chain management: a literature survey and Pareto analysis," *EuroMed Journal of Business*, vol. 10, no. 2, pp. 234–263, 2015.
[33] S. A. Kumar and N. Suresh, *Production and operations management*. New Age International, 2006.
[34] D. D. Shinde, S. Ahirrao, and R. Prasad, "Fishbone diagram: application to identify the root causes of student–staff problems in technical education," *Wirel Pers Commun*, vol. 100, pp. 653–664, 2018.
[35] M. Coccia, "The Fishbone diagram to identify, systematize and analyze the sources of general purpose Technologies," *Journal of Social and Administrative Sciences*, vol. 4, no. 4, pp. 291–303, 2018.
[36] M. Hassan and I. M. Jalaludin, "Application of why-why analysis to improve predictive maintenance strategy for injection molding machine," *Information Technology Journal*, vol. 15, no. 4, pp. 130–136, 2016.
[37] D. Little *et al.*, "Preclinical tendon and ligament models: Beyond the 3Rs (replacement, reduction, and refinement) to 5W1H (why, who, what, where, when, how)," *Journal of Orthopaedic Research®*, vol. 41, no. 10, pp. 2133–2162, 2023.

JOMAse | Received: 11-May-2024 | Accepted: 30-July-2024 | [(68) 2: 64-74]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085