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Total Productive Maintenance (TPM) Implementation Plan on the Topper TNL-85a Machine for Turning Process Effectiveness at PT AMRW

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ABSTRACT (10PT)

PT AMRW is a company engaged in the manufacturing industry to produce various sanitation products. One of its departments is the molding department that produces molds, tools, and jigs where the process mostly begins with the turning process using the Topper TNL-85A machine. However, the current machine performance is not optimal due to downtime, not achieving production targets, and delays in product availability so that overtime is required. The three objectives of this study are to determine the value of machine effectiveness using the overall equipment effectiveness (OEE) method, to determine the types of losses that cause machine losses based on the six big losses (SBL), and to provide improvement suggestions to improve the machine's OEE value based on the 8 pillars of total productive maintenance (TPM). Using a descriptive quantitative method, after knowing the losses that occurred, an analysis was carried out to find the root cause using a fishbone diagram before making improvement suggestions. The results of this study found that the machine's OEE value was 73.3% and the SBL was 26.7%. The biggest losses are 11.7% reduction speed losses because the machine has not reached its ideal cycle time, 7% breakdown losses due to machine failures that still occur quite frequently, and 6.8% set-up and adjustment losses due to the setup and adjustment process taking too long. The proposed improvements are based on the eight pillars of TPM, where one root cause uses one of the pillars that best suits the needs.

1. Introduction

The manufacturing industry currently has a significant contribution to Indonesia's economy, amounting to 19.8% [1]. The rapid development of the manufacturing industry today has led companies to compete in terms of both the quantity and quality of their production [2]. When companies can improve quality and meet production quantities, it will impact sales by increasing consumer trust [3]. The need for equipment and machines that can work effectively to complete production accurately, at low cost, and with high product quality, as these three factors are essential components for the success of the manufacturing industry [4]. Therefore, to achieve this, each stage of the production process and the necessary resources must be in a ready-to-use condition, both in terms of capacity, capability, and precision, so that the process runs smoothly and demand can be met.

PT AMRW is a company engaged in the manufacturing industry, producing various bathroom fixtures such as faucets, showers, and the like. The production process at PT AMRW begins with three different processes depending on the raw materials used, namely forging, injection molding, and casting. Although they require different machines, all three processes need basic mold in their production. The molding department is

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dedicated to producing molds, jigs, and tools that will be used by the production department. One of the machines used by the molding department is the CNC Lathe machine, specifically the Topper TNL-85A, which functions for initial turning. However, this machine has a high downtime value. Downtime is the time spent when the machine stops working and is not producing [5].

The high value of downtime can cause losses for the company due to the lack of production. Downtime can be caused by a decrease in machine performance, damage to parts within the machine, and poor-quality spare parts [6]. The production output of a company will increase when machine maintenance and regular machine usage are performed [7]. As in research [8], the OEE value results for Yasda machines in 2016-2018 were 76%, 92% and 85%. The reason OEE was still below world class standards was due to waiting for products from previous operations, operators carrying out other operations, unexpected maintenance, unexpected meetings and planned maintenance. Another study found an OEE value of 70.14% for a cutting machine. This was influenced by performance and quality, concluding that machine analysis significantly impacts performance and requires further improvement [9]. Another study found an OEE value of 61.94%. One factor contributing to the low OEE value was the low performance value, at 68.29%. The dominant factor causing the decrease in machine effectiveness was reduction speed losses, with a value of 42.38% [10].

Machine analysis is necessary to determine the condition of the machine using the Overall Equipment Effectiveness (OEE) method. The decline in machine productivity can lead to six types of losses (six big losses) that require regular maintenance [11]. There are three types of maintenance: predictive, preventive, and corrective maintenance, all of which are included in the 8 pillars of TPM. Since the Total Productive Maintenance (TPM) method aligns with the kaizen principle and is crucial for achieving goals, the company uses Total Productive Maintenance (TPM) to reduce production costs and enhance product value [12]. The objective of this research is to determine the OEE value of the machine, identify the loss factors that cause a decrease in production time, and provide improvement suggestions based on the eight pillars of TPM.

2. Method

This research is a type of quantitative study with a descriptive approach, which involves the use of numerical data that illustrates the performance of the machine so that it can be processed and analyzed statistically. The data needed to perform measurements using the Overall Equipment Effectiveness (OEE) and Six Big Losses (SBL) methods are operating time, loading time, ideal cycle time, process amount, defect amount, and downtime that occur. This data is classified as primary data because it was obtained directly from the company, where the observation sample is the Topper TNL-85A machine at PT AMRW in the Molding Department.

Overall Equipment Effectiveness

Downtime or machine non-working time is divided into two, namely planned downtime and unplanned downtime. Planned downtime is the condition where the machine is not working because it is undergoing scheduled repairs that have been set [13]. Unplanned downtime occurs when the machine is not working and needs repairs during production, often causing losses to the company. In this study, the unplanned downtime used as initial data consists of setup and adjustment time during the production process as well as machine breakdown time.

Overall equipment effectiveness is a method commonly used by companies to measure machine performance to understand the effectiveness as well as the issues with the machines and equipment. The OEE value categories according to Nakajima (1998) in [14] are established in five classes, show in Table 1.

The OEE value is obtained from the multiplication of its three main metrics, namely the rate of quality product (Q), performance efficiency (P), and availability (A), where the minimum global standard OEE value is ≥ 85%.

$$OEE\ (\%) = Avaibility\ \times Performance\ \times Quality \quad (1)$$

Table 1. OEE Value Category

Value	Category	Explanation
OEE < 65%	Low	The existence of economic losses and very low competitiveness requires immediate improvement.
65% ≥ OEE > 75%	Standard Company	Economic losses and low competitiveness, immediate improvement is needed.
75% ≥ OEE > 85%	Moderate	The company is moving towards world-class status. The presence of fewer economic losses and slightly lower competitiveness. The need for improvement so that the OEE value > 85%.
85% ≥ OEE > 95%	World-Class Company	Join a world-class company with strong competitiveness.
OEE ≥ 95%	Leading Company	A fast system with no production downtime.

a. Availability portion of the OEE metric represents the percentage of scheduled time that the operation is available to operate. Another way of saying this is that the Availability is a percentage of time a machine is available to produce parts. The Availability metric is a pure measurement of Uptime that is designed to exclude the effects of Quality, Performance, and Scheduled Downtime Events [15]. For the standard availability, it is ≥ 90%.

$$Availability = \frac{Available\ Time}{Scheduled\ Time}\ x\ 100\% \quad (2)$$

b. Performance or the desired performance of a machine or tool is the standard machine speed without any decrease compared to the actual speed, with a standard performance level of 100%. Ideal cycle time is the time set to process one product. Processed amount is the number of products processed. Operating time is the time the machine operates. For performance, the standard is ≥ 95%.

$$Performance = \frac{Processed\ ammount\ x\ ideal\ cycle\ time}{Operating\ Time}\ x\ 100\% \quad (3)$$

c. Quality is determined by comparing the products that pass the quality test with the actual production amount. Processed amount is the quantity produced by the machine. Number of defects is the number of defects in the products produced by the machine. Quality has a standard of ≥ 99%.

$$Quality = \frac{Processed\ amount - number\ of\ defect}{Processed\ ammount}\ x\ 100\% \quad (4)$$

From the three main matrices according to world-class standards, if the final OEE value has not reached 85% or one of the three values has not reached the value in the table above, then improvements need to be made [11], [16].

Six Big Losses

Six big losses are a group of problems that often occur in machines, causing losses due to low efficiency. By Nakajima (1988), the six groups of losses are [17]:

1. Breakdown losses: Losses caused by machine damage that require repair or replacement of damaged components are also known as equipment failure losses.

$$BL = \frac{Breakdown\ Time}{Loading\ Time}\ x\ 100\% \quad (5)$$

2. Setup and adjustment losses: that is, when the setup or preparation process of the machine is carried out, production losses do not occur.

$$SAL = \frac{Setup\ and\ Adjustment\ Time}{Loading\ Time}\ x\ 100\% \quad (6)$$

3. Idle and minor stoppage losses: During production minor stops can occur; these events are considered to be difficult or too expensive to record. This loss includes the time of all the activities that can not be tracked [18].

$$IMSL = \frac{ideal\ cycle\ time\ x\ total\ output}{Loading\ Time} \quad (7)$$

4. Reduced speed losses: When machines run slower than their ideal cycle time, the result is lost productivity. This performance loss is often overlooked, yet it can account for substantial hidden waste across a shift or production cycle.

$$RSL = \frac{operating\ time - (Ideal\ cycle\ time\ x\ Total\ proceesd\ amount)}{Loading\ Time}\ x\ 100\% \quad (8)$$

5. Defect losses: losses due to products not meeting quality standards.

$$DL = \frac{Ideal\ Cycle\ Time\ x\ Defect\ Amount}{Loading\ Time}\ x\ 100\% \quad (9)$$

6. Reduce yield: Quality loss due to producing defective products from the moment the machine is turned on until production stabilises.

$$RY = \frac{Ideal\ Cycle\ Time\ x\ Yield}{Loading\ Time}\ x\ 100\% \quad (10)$$

Fishbone Diagram

The graphic method called the fishbone diagram uses lines and symbols shaped like fish bones to show cause-and-effect relationships [19]. This diagram is one of the basic 7 tools used to categories the root cause of problems according to the influencing factors, namely 4M+1E (machine, man, material, method, and environment). The fishbone diagram is used in this research to analysis and identify the root cause of the 4M+1E factors that lead to machine downtime.

Total Productive Maintenance

Total productive maintenance is a method aimed at reducing unplanned maintenance with the goal of improving the efficiency of production activities in various aspects [20]. This maintenance method not only focuses on machines and tools but also on human resources because humans are the executors [21]. If this method is applied correctly, quality, productivity, and costs will increase. The main objective of this method is no damage, no loss, no accidents. If damage can be eliminated, it will result in improved equipment performance and labour productivity, which in turn will reduce costs and decrease the amount of existing inventory. By improving the performance of existing machines and tools, this reduces costs [14]. The foundational concept used is the eight pillars of TPM, show in figure 1.

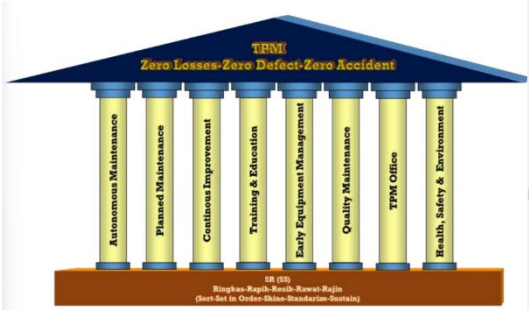


Fig. 1. TPM Pillar

1. Autonomous Maintenance, which means operators are trained to perform daily maintenance and foster a sense of responsibility in using and preventing damage by cleaning machines, inspecting, adding oil, and so on [20].
2. Planned Maintenance, a routine planned maintenance such as monthly, quarterly, or annual, and is a preventive as well as reactive measure [21].
3. Quality Maintenance, maintaining quality by ensuring that the machines and equipment used are in good condition and ready to control product failures and minimise production costs [22].
4. Focused Improvement, an improvement aimed at increasing the effectiveness of equipment, processes, and the overall factory. This improvement is comprehensive, involving the identification, quantification, and elimination of existing losses.
5. Early equipment management, or maintenance prevention, is the repair based on existing experience to ensure the machine operates optimally [23].
6. Training and education are pillars of improvement by providing training or education to employees or operators so that they can make decisions quickly based on documents and maintenance steps they have learned [24].

7. Safety, health, and environment, maintenance by ensuring the creation of a safe work environment to prevent accidents and injuries [18].
8. TPM in administration, improvement by introducing the principles of TPM comprehensively to the company's administration so that all organisational participants (the company) have the same perspective and understanding [25].

3. Results and Discussion

The data used in this research are downtime data and production data, here is the machine downtime data for each month in minutes.

Table 2. Downtime January – June 2024

Month	Breakdown time (minute)	Setup and adjustment (minute)	Planned Downtime (minute)	Total Machine Downtime (minute)
January	767	723	260	1.750
February	451	414	160	1.025
March	304	242	210	756
April	632	498	140	1.270
May	611	619	160	1.390
June	163	397	225	785

By knowing the monthly downtime data, OEE and SBL calculations can be performed to determine the effectiveness level and identify the largest loss factors. Here is the production data for the TNL-85A topper machine, which can be seen in Table 3.

Table 3. Production Data January – June 2024

Month	Machine operating time (minute)	Loading time (minute)	Operating time (minute)	Actual cycle time (minute)	Ideal cycle time (minute)	Processed amount (pcs)	Defect amount (pcs)	Production Target (pcs)	Number of working days
Jan	6.960	5.977	5.210	25,01	23,87	175	1	179	16
Feb	8.700	8.126	7.675	38,92	34,05	184	0	187	20
Mar	7.830	7.378	7.074	46,04	34,54	147	0	149	18
Apr	6.960	6.322	5.690	34,64	32,76	148	0	150	16
May	8.700	7.921	7.310	59,88	47,76	111	0	112	20
June	9.135	8.513	8.350	34,48	30,14	228	0	231	21

Machine working time is the optimal time the machine operates in one month. Obtained from the daily working time (435 minutes) multiplied by the number of working days. Because this machine produces different types of products in varying quantities, its cycle time also varies. The idle cycle time is obtained by calculating the weighted cycle time of each type multiplied by the production quantity and divided by the total production quantity for that month.

Overall Equipment Effectiveness (OEE)

The OEE calculation is performed to determine the performance value of the Topper TNL-85A machine in terms of performance, availability, and the quality it produces. The calculations for availability, performance, and quality are carried out separately and then multiplied to obtain the OEE value. Table 4 shows the OEE calculation results of the machine for the period from January to June 2024.

Based on the OEE calculations in Table 4, it is known that the OEE value of the machine from January to June 2024 ranges between 66.9% - 80.7% and has an average OEE of 73.3%, which has not yet reached the global standard value of 85%. Therefore, improvements are needed, and the causes of the losses must be identified to enhance the machine's effectiveness.

Table 4. OEE Calculation

Month	Availability	Performance	Quality	OEE
January	87,2%	80,2%	99,42%	69,5%
February	94,4%	81,6%	100%	77,1%
March	95,9%	71,8%	100%	68,8%
April	90%	85,2%	100%	76,7%
May	92,3%	72,5%	100%	66,9%
June	98,1%	82,3%	100%	80,7%
Average	92,98%	78,9%	99,90%	73,3%

The failure to achieve the OEE value is caused by downtime that still exceeds the predetermined limits, as well as low-performance values due to not meeting production targets and cycle times being greater than the ideal cycle time planned. The performance value of 78.9% is still far below the minimum value of 95%, indicating that improvements are needed to enhance machine effectiveness to maintain the smoothness of every production process in the company.

Six Big Losses

After knowing the OEE value of the machine, an SBL calculation is performed to determine the types of losses that occur. Knowing the calculation results and the causes of the largest losses, it makes it easier for the company to make improvements to increase machine effectiveness based on the existing problems. Here are the results of the calculations for each type of loss.

Table 5. SBL Calculation January – June 2024

Month	Breakdown losses	Setup and adjustment	Reduce speed losses	Idle & minor stoppage	Defect losses	Reduce yield	Amount
Jan	12,8%	12,1%	3,3%	1,6%	0.4%	0.2%	30,4%
Feb	5,6%	5,1%	11%	1,3%	0%	0%	23,0%
Maret	4,1%	3,3%	22,9%	0,9%	0%	0%	31,2%
April	10%	7,9%	4,4%	1%	0%	0%	23,3%
Mei	7,7%	7,8%	17%	0,6%	0%	0%	33,1%
Juni	1,9%	4,7%	11,6%	1,1%	0%	0%	19,3%
Average	7,0%	6,8%	11,7%	1,1%	0,1%	0,0%	26,7%
Percentage	26,3%	25,5%	43,8%	4,1%	0,2%	0,1%	100%

Based on Table 5, it is known that the highest SBL value is in May at 33.1% and the lowest in June at 19.3%. After determining the value of each type of loss each month, the average for each type and the total percentage were calculated. Thus, the average SBL value is 26.7%, and the highest loss factor can be identified using a Pareto diagram as shown in Figure 2.

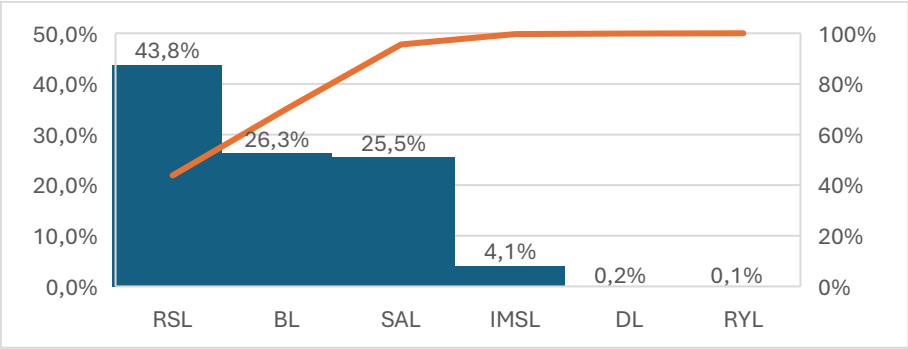


Fig. 2. Pareto diagram SBL

Based on Figure 2, it is known that the highest cause of losses is reduce speed losses at 43.8% or an average of 11.7% because the feeding process takes longer due to softer chips, making it difficult to cut the material or the available raw material, which is not of the correct size. The next significant cause is breakdown losses at 26.3% or 7%, where the high losses are caused by the long machine setup time according to the operator's ability. In one day, several changes between types of objects are made, requiring time to reset according to their type. Setup and adjustment at 25.5% or an average of 6.8%, where sudden machine failures cause the machine to stop and become non-operational. The damages that occur are not always the same; some of the damages that have occurred in the past few months include spindle errors, alarm errors, and shifts in the machine's center point. Idle & minor stoppage rank fourth at 4.1% or an average of 1.1% of the total. Defect losses still exist, although their percentage is 0.2% and reduce yield is 0.0%.

Fishbone Diagram

Fishbone diagram or cause-and-effect diagram illustrates the issues that cause losses in the machine. There are three loss factors with the highest values, namely breakdown losses (BL), setup adjustment losses (SAL), and reduce speed losses (RSL). There are five factors that influence losses, namely 4M+1E (method, man, machine, material, and environment). Figure 3 is a fishbone diagram of the Topper TNL-85A machine.

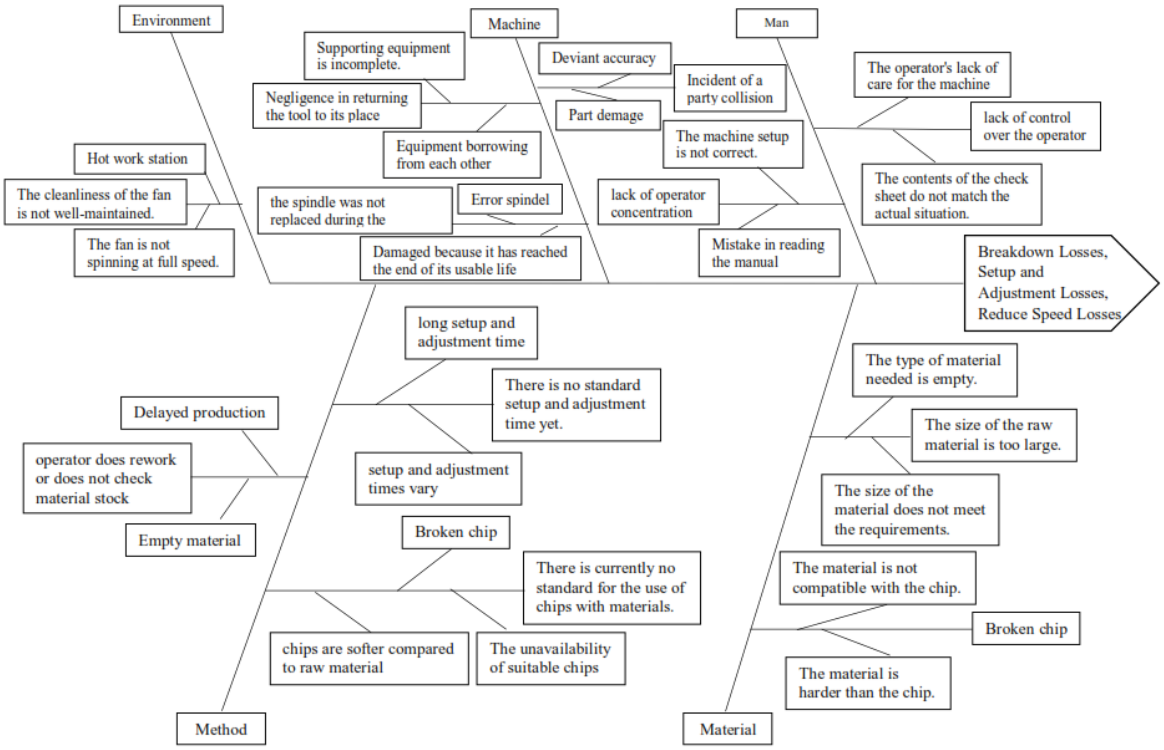


Fig. 3. Fishbone diagram BL, SAL and RSL

Based on Figure 3, it is known that the man factor (human) has two root causes, namely lack of concentration and lack of control over the operator. The machine factor includes three issues: part collision incidents, negligence in returning tools to their proper places, and the spindle not being replaced during monthly maintenance. The environmental factor is the high temperature due to the lack of cleanliness of the fan. The material factor has two root causes, namely the material size being too large and broken chips. The method factor has three root causes, namely the operator performing rework, the absence of chip usage guidelines for the material, and the lack of setup and adjustment time standards.

Total Productive Maintenance

Based on the analysis of the top 3 (three) losses using the fishbone diagram, improvement recommendations were made based on the 8 pillars of TPM. The training & education improvement pillar is used in the man aspect to address the lack of operator concentration that leads to incidents. The planned maintenance pillar is used for machine issues, necessary to prevent machines from operating in unsafe conditions. The TPM in administration pillar is used in the man aspect to conduct regular inspections of operators.

The Focused Improvement pillar is used in the aspects of machine, material, and method for setting up standard setup times in the method, chip usage in the material, and tool return in the machine. The Autonomous Improvement pillar is used in the aspect of the machine so that operators can be disciplined and handle machine problems promptly. The Early Equipment Management pillar is used in the aspect of material to ensure chip usage is correct from the beginning of the planning. The quality maintenance pillar is used in the method aspect to control stock and performance to eliminate rework. The safety & environment pillar is used for issues related to a hot environment. In this study, all 8 existing TPM pillars are included in the improvement proposal for PT AMRW.

4. Conclusion

Based on the discussion results, it is known that the OEE value of the Topper TNL 85A machine is 73.3%, which has not yet reached the minimum world standard value of 85%, thus requiring improvement. The machine's SBL value is 26.7%, with its three highest losses being reduce speed losses at 11.7%, breakdown losses at 7%, and setup and adjustment losses at 6.8%. The proposed improvements are based on the eight pillars of TPM, namely autonomous maintenance, planned maintenance, quality maintenance, focused improvement, early equipment management, training and education, safety and environment, and TPM in administration, where one root cause uses the pillar most suitable for the needs.

Declarations

Author contribution.
Rizqi Wahyudi: Conceptualization, methodology, data analysis, manuscript review, and editing
Aqyla Muqsitha: data collection, data analysis, and write original draft.
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