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Enhancing Overall Equipment Effectiveness in Indonesian Automotive SMEs: A TPM Approach

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ABSTRACT

In the dynamic landscape of the automotive industry, operational efficiency is a pivotal factor for sustained growth. This study delves into the intricacies of enhancing manufacturing operations, mainly focusing on the blowing machines at RMA Ltd, a key player in the Indonesian automotive SME sector. The primary objective is to optimize Overall Equipment Effectiveness (OEE) by implementing a Total Productive Maintenance (TPM) approach. The Indonesian automotive sector, vital to national economic growth, needs help maintaining optimal production efficiency. This study centres on the blowing machines at RMA Ltd's Plant 7, emphasizing the need to address breakdowns, particularly in the blowing machine, which has been identified as the primary source of production losses. A comprehensive research methodology is outlined, beginning with an extensive literature review on TPM and OEE. The study then focuses on the Indonesian automotive SME sector, with RMA Ltd as the primary research subject. Data collection involves an initial survey to assess the current state of blowing machines, encompassing OEE, Six Big Losses, and other relevant factors. Post-implementation of improvements, the study reveals substantial enhancements in OEE. Availability rates increased (93.19%), Performance Efficiency improved (84.84%), and Quality Rate remained consistently high (98.41%). The calculated OEE rose from 67.42% to an impressive 77.80%. Noteworthy reductions in Six Big Losses, particularly in breakdowns, setup losses, and reduced speed losses, validate the efficacy of TPM implementation. This research introduces a novel approach by integrating socialization strategies, detailed work instructions, and proactive maintenance practices. Through a comprehensive research methodology, including an initial survey and post-implementation analysis, this study demonstrates significant OEE improvements of 11%. The findings underscore the novelty of this research in emphasizing the importance of holistic TPM implementation strategies in enhancing manufacturing operations within the Indonesian automotive SME sector. Furthermore, this study provides actionable insights for SMEs in the Indonesian automotive sector, highlighting the relevance of TPM in achieving operational excellence and competitive advantage. Ultimately, this research contributes a valuable blueprint for SMEs seeking to navigate the complexities of the automotive industry, offering a roadmap to optimize manufacturing operations and thrive in a competitive market.

1. INTRODUCTION

In an era of intense industrial competition, operational efficiency is critical for companies, especially in Indonesia's rapidly growing automotive sector [1, 2]. The main focus of this article is to improve the effectiveness of blowing machines at RMA Ltd to achieve optimal Overall Equipment Effectiveness (OEE). With support from the automotive component sector, the automotive industry plays a vital role in national economic growth [1, 3-6]. As an automotive component manufacturer, RMA Ltd faced the challenge of improving the OEE of the blowing machine, which is a critical element in the production of door covers. Maintenance data showed that the blowing machine had a significant breakdown rate, with the highest percentage among other machines in RMA Ltd's Plant 7.

As reported by Singh et al. [7], previous research showed that implementing Total Productive Maintenance (TPM) can improve the OEE of production machines. By adopting this approach, RMA LTD is expected to address the issue of machine effectiveness, particularly on the blowing machine. As observed by Edward [8], the implementation of TPM in the manufacturing industry can positively contribute to machine performance. In the case of Toba Pulp Lestari Ltd, the emphasis on OEE helped identify and reduce production losses. Duraisamy et al. [9] emphasised that SMEs can achieve operational excellence by implementing TPM. Although the company's size differs, the TPM concept remains relevant to improve production efficiency and effectiveness.

The case study from Zulfikar et al. [10] at ABC Ltd shows that OEE evaluation and Six Big Losses analysis can help identify the root causes of problems and guide improvements. This case is consistent with the concept of Lean Manufacturing, as discussed by Ondra [11]. Guritno and Cahyana [12] reported an increase in OEE after implementing TPM with an Autonomous Maintenance (AM) approach [8]. These measures have also proven successful in the case of TPM implementation at Wahana Tunas Utama Rucika Ltd. The application of TPM to packaging machinery, as in the study Saputra and Rady [13], shows the importance of OEE in improving productivity. With OEE evaluation, companies can identify factors that affect machine performance, as described by Martomo and Laksono [14].

The Lean Manufacturing approach, as proposed by Sandy and Wathoni [15], can be the foundation for OEE measurement. In the pharmaceutical industry, OEE is an effective tool for monitoring and improving production efficiency. A lightweight TPM model that suits the needs of SMEs, as proposed by Xiang and Chin [16], can guide the implementation of TPM at RMA Ltd. This research shows that TPM can be adopted effectively without burdening companies with significant investments [17, 18]. As a step towards aligning with international standards, RMA Ltd needs to adopt Lean Manufacturing and TPM methods. This step will help achieve the desired OEE level and improve the company's competitiveness in the global automotive market.

This study aims to investigate the potential of implementing TPM with a Lean Manufacturing approach to improve blowing machine OEE at RMA Ltd. By detailing blowing machine defect cases, measuring OEE, and implementing TPM-based improvement measures, the research endeavours to achieve optimal production performance and support the growth of the automotive industry in Indonesia. While the primary focus is on the blowing machines at RMA Ltd's Plant 7, the insights gained from this study hold broader implications for the Indonesian automotive SME sector. By elucidating the synergies between TPM and Lean Manufacturing principles in enhancing blowing machine OEE, this research offers transferable insights and methodologies applicable to similar contexts within the Indonesian automotive SME sector. Through a nuanced understanding of the challenges and opportunities encountered by RMA Ltd, this study aims to contribute to operational excellence and competitiveness within the wider Indonesian automotive industry.

However, despite the abundance of literature advocating for TPM and Lean Manufacturing principles, more research is still needed, focusing on their integration within the Indonesian automotive SME sector, particularly in the context of blowing machines. This gap underscores the need for a tailored approach to address the specific challenges faced by SMEs like RMA Ltd, where blowing machine breakdowns pose significant obstacles to achieving optimal production efficiency.

2. METHOD

In the preliminary phase, an in-depth literature study will be conducted to thoroughly understand the concept of Total Productive Maintenance (TPM) and its application in improving Overall Equipment Effectiveness (OEE) in various industries. The main focus will be on the problems and challenges commonly faced in the manufacturing industry, especially in production machinery. After the initial understanding, the next step is to establish the scope of the study. This process will include identifying small and medium-sized automotive companies (SMEs) in Indonesia as research subjects.

2.1 Data collection

Before TPM implementation, an initial survey will be conducted to obtain data on the conditions and problems associated with blowing machines in each SME automotive company [13, 19]. Data regarding OEE, Six Big Losses, and other factors affecting machine performance will be collected [20-22]. Once the data is collected, a preliminary OEE analysis will be conducted to evaluate the effectiveness level of the packaging-making machine. Identify the Six Big Losses that are most significant in the context of the SME automotive industry in Indonesia [10, 23, 24].

The door cover is one of the constituent parts of a car, the basic material of which is plastic. This component is located on the inside of the car door. Its function is to prevent water from entering the wall of the car door. The name of the machine is film blowing machine (SJ-H55/1000), the beginning of the machine at RMA LTD in 2015. The location of the cover door can be seen in Figure 1.

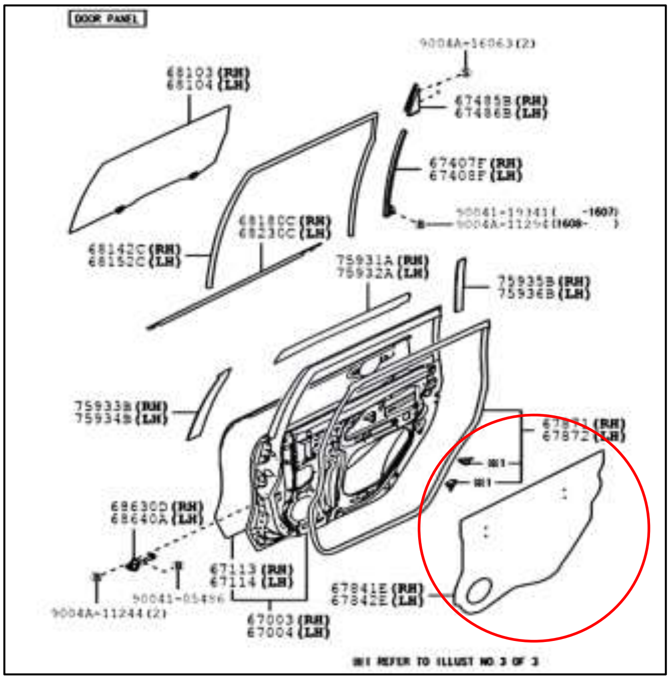

Figure 1. Location of cover door

2.2 Analysis of current condition

Based on the findings of the initial analysis, a TPM training programme will be designed. It covers the steps of TPM implementation, with an emphasis on preventive maintenance, directed improvement, and employee engagement [1, 19]. After the design of the training programme, the TPM implementation phase will begin in each company. Careful monitoring of changes in the machine's Availability Rate, Performance Rate, and Rate of Quality will be conducted periodically [13, 25, 26].

2.3 Design and implementation of TPM

Data from TPM implementation will be statistically analysed to evaluate significant changes in machine performance. Factors determining the success or obstacles in TPM implementation will be identified. The findings will be compiled in a report with graphs, tables, and in-depth analyses. Specific recommendations will be provided to improve engine OEE in the SME automotive industry. As a final step, the findings and recommendations will be discussed and validated with relevant parties in each SME automotive company, ensuring the sustainability and validity of the research results.

Moreover, a detailed elucidation of the blowing machines and their operational significance within the manufacturing process is warranted. The blowing machines, specifically the film blowing machine (SJ-H55/1000), serve as instrumental apparatuses in the production cycle of door covers, a fundamental component in automotive manufacturing. These machines play a crucial role in the extrusion of plastic film, which subsequently contributes to the fabrication of door covers essential for preventing water ingress into car doors. Additionally, it is imperative to critically evaluate any underlying assumptions guiding the study and their potential implications on the research outcomes and their generalizability. Assumptions concerning machine maintenance schedules, operational parameters, and levels of employee engagement may significantly influence the efficacy of TPM implementation and subsequent enhancements in OEE metrics. By meticulously examining these assumptions, this study endeavours to fortify the reliability and applicability of its findings across the Indonesian automotive SME sector.

3. RESULT AND DISCUSSION

3.1 Result of data collection

3.1.1 Working hour of blowing machine

Working hour is the overall time that shows the number of working hours used for the production process. RMA Ltd operates for 5 working days a week, this research was conducted only on shift 1. In September and November 2022 there was overtime, each month 2 times overtime. The overtime time is 1 hour 30 minutes. The working hour data of the blowing machine in September 2022-November 2022 can be seen in Table 1.

Table 1. Working hour data of blowing machine

Month	Total Working Hour (min)	Actualised Working Hour (min)
Sep	11,620	10,951
Oct	10,920	10,288
Nov	11,620	10,962

3.1.2 Planned downtime of blowing machine

Planned downtime is data showing the machine downtime the company has planned for scheduled maintenance or other management activities. Routine activities before carrying out the production process at RMA Ltd are gymnastics and briefing, then continued with the preparation time for operator preparation to run the machine after the production process has been completed, followed by cleaning activities to clean the work area and scrap from the production process. The scheduled time may change or not be the same and is flexible according to needs. The planned downtime data of the RMA Ltd blowing machine can be seen in Table 2.

3.1.3 Breakdown time of blowing machine

Breakdown time is data that shows the time of disruption to the machine so that the machine must be repaired immediately, even though the machine is operating. Then, the machine stops operating for a while. RMA LTD blowing machine breakdown time data can be seen in Table 3.

3.1.4 Setup and adjustment time of blowing machine

Setup and adjustment time shows the time it takes for the machine to start operating to produce new components, such as setting up a machine or changing moulds or dies. RMA Ltd's blowing machine setup and adjustment data can be seen in Table 4.

Table 2. Planned downtime of blowing machine

Month	Planned Downtime (min)				Total (min)
	Exercise	Briefing	Prepare	Cleaning	
Sep	219	114	226	110	669
Oct	209	106	212	105	632
Nov	220	110	220	108	658

Table 3. Breakdown time of blowing machine

Month	Breakdown Time (min)					Total (min)
	Broken Filters	Dynamo Burns	Broken Heater	Perforated Octopus Hose	Broken Bolts	
Sep	110	619	-	-	-	729
Oct	135	-	355	-	-	490
Nov	117	-	-	214	229	560

Table 4. Setup and adjustment data of blowing machine

Month	Setup and Adjustment Time (min)
Sep	518
Oct	541
Nov	567

In the production process, products are good, and some products have defects that must be rejected or repaired. The production data of the RMA LTD blowing machine can be seen in Table 5. In addition, the performance of the blowing machine (Table 6) also needs to be considered to assess the ideal output produced.

Table 5. Production data of blowing machine

Month	Actual Output (pcs)	Scrap (pcs)	Repair/Rework (pcs)
Sep	58,811	589	257
Oct	61,395	520	233
Nov	60,591	1,002	470

Table 6. Performance data of blowing machine

Month	Performance				
	Operating Time (min)	Production Target (pcs)	Actual Output (pcs)	Ideal Cycle Time (min)	Actual Cycle Time (min)
Sep	9,664	71,675	58,811	0.12	0.17
Oct	9,257	68,656	61,395	0.12	0.15
Nov	9,835	72,943	60,591	0.12	0.16

3.2 Data processing

The data collected during the research at RMA LTD will then be processed, namely calculating the availability rate, performance efficiency, quality rate, OEE, and six significant losses carried out on the blowing machine. Availability rate is a ratio that shows the utilisation of time available for machine or equipment operation activities expressed as a percentage, for example, the calculation of availability rate in September 2022 (Eq. (1)). The availability rate percentage for September 2022-November 2022 can be seen in Table 7.

$$Availability\ Rate = \frac{Operating\ Time}{Loading\ Time} \times 100\% = \frac{10{,}900\text{-}1247}{10{,}900} \times 100\% = 88.56\% \quad (1)$$

Table 7. Calculation of availability rate

Month	Loading Time (min)	Downtime (min)	Operating Time (min)	Availability (%)
Sep	10,900	1,247	9,653	88.56%
Oct	10,288	1,031	9,257	89.98%
Nov	10,962	1,127	9,835	89.72%

Performance efficiency is a ratio that shows the ability of equipment or machinery to produce products expressed in percentages, for example, the calculation of performance efficiency in September 2022 (Eq. (2)). The percentage of performance efficiency for September 2022-November 2022 can be seen in Table 8.

$$Performance = \frac{Processed\ Amount \times Ideal\ Cycle\ Time}{Operating\ time} \times 100\% = \frac{58{,}811 \times 0.12}{9{,}653} \times 100\% = 73.11\% \quad (2)$$

Table 8. Calculation of performance efficiency

Bulan	Operating Time (min)	Cycle Time (min)	Total Production (pcs)	Performance (%)
Sep	9,653	0.12	58,811	73.11%
Oct	9,257	0.12	61,395	79.59%
Nov	9,835	0.12	60,591	77.28%

The quality rate calculation is a ratio that shows the ability of a machine to produce products that meet standards and is expressed as a percentage, for example, the calculation of the quality rate in September 2022 (Eq. (3)). The quality rate percentage for September 2022-November 2022 can be seen in Table 9.

$$Quality\ Rate = \frac{Processed\ Amount - Defect\ Amount}{Processed\ Amount} \times 100\% = \frac{58{,}811\text{-}(589+257)}{58{,}811} \times 100\% = 98.56\% \quad (3)$$

Table 9. Calculation of quality rate

Month	Total Production (pcs)	Scrap (pcs)	Repair/Rework (pcs)	Finished Good (pcs)	Quality (%)
Sep	58,811	589	257	57,965	98.56%
Oct	61,395	520	233	60,642	98.77%
Nov	60,591	1,002	470	59,119	97.68%

The OEE calculation is based on the availability, performance, and quality values obtained; for example, the OEE calculation in September 2022 (Eq. (4)). The OEE percentage for September 2022-November 2022 can be seen in Table 10.

$$\begin{aligned} \text{OEE} &= Availability\ Rate \times Performance\ Efficiency \times Quality\ Rate \\ &= 88{,}56\% \times 73{,}11\% \times 98{,}56 \\ &= 63{,}81\% \end{aligned} \quad (4)$$

Table 10. Calculation of OEE

Month	Availability (%)	Performance (%)	Quality (%)	OEE (%)
Sep	88.56%	73.11%	98.56%	63.81%
Oct	89.98%	79.59%	98.77%	70.73%
Nov	89.72%	77.28%	97.68%	67.72%
Average	89.42%	76.66%	98.34%	67.42%

The calculation of six big losses aims to see what losses occur in the production process, resulting in less effectiveness. The calculation of six big losses consists of breakdown losses, set-up and adjustment losses, reduced speed losses, idling and minor stoppages, rework losses, and reduced yield.

Breakdown losses are a visible cause of loss because the damage will impact the machine, which will not produce output, for example, the calculation of breakdown losses in September 2022 (Eq. (5)). The percentage of breakdown losses for September 2022-November 2022 can be seen in Table 11.

$$\begin{aligned} \textit{Breakdown Losses} &= \frac{\textit{Total Breakdown Time}}{\textit{Loading Time}} \times 100\% \\ &= \frac{729}{10{,}900} \times 100\% = 6.69\% \end{aligned} \tag{5}$$

Table 11. Calculation of breakdown losses

Month	Total Breakdown Time (min)	Loading Time (min)	Breakdown Losses (%)
Sep	729	10,900	6.69%
Oct	490	10,288	4.76%
Nov	560	10,962	5.11%
Average			5.52%

Setup and adjustment losses are caused by the preparation of a long production process due to waiting for the arrival of materials and machine settings, for example, the calculation of setup and adjustment losses in September 2022 (Eq. (6)). The percentage of setup and adjustment losses for September 2022-November 2022 can be seen in Table 12.

$$\begin{aligned} &\textit{Setup \& Adjust Losses} \\ &= \frac{\textit{Total Setup \& Adjustment Time}}{\textit{Loading Time}} \times 100\% \\ &= \frac{518}{10{,}900} \times 100\% = 4.75\% \end{aligned} \tag{6}$$

Table 12. Calculation of setup and adjustment losses

Month	Setup and Adjustment Times (min)	Loading Time (min)	Setup and Adjustment (%)
Sep	518	10,900	4.75%
Oct	541	10,288	5.26%
Nov	567	10,962	5.17%
Average			5.06%

Reduced speed losses are caused by a decrease in engine speed in carrying out its operations or the engine does not work optimally, for example, the calculation of reduced speed losses in September 2022 (Eq. (7)). The percentage of reduced speed losses for September 2022-November 2022 can be seen in Table 13.

$$\begin{aligned} &\frac{\textit{Operating Time (Ideal Cycle Time} \times \textit{Result Processed)}}{\textit{Loading Time}} \\ &\times 100\% = \frac{9{,}959 - (0.12 \times 58{,}811)}{10{,}900} \\ &\times 100\% = 26.62\% \end{aligned} \tag{7}$$

Table 13. Calculation of reduce speed losses

Month	Actual Production Time (min)	Loading Time (min)	Ideal Cycle Time (min)	Total Production (pcs)	Reduced Speed (%)
Sep	9,959	10,900	0.12	58,811	26.62%
Oct	9,037	10,288	0.12	61,395	16.23%
Nov	10,132	10,962	0.12	63,336	23.09%
Average					21.98%

Idling and minor stoppages cause the production process to stop for no more than five minutes but with a fairly frequent stoppage frequency, which can also be called machine idle time or non-productive time; for example, the calculation of idling and minor stoppages in September 2022 (Eq. (8)). The percentage of idling and minor stoppages for September 2022-November 2022 can be seen in Table 14.

$$\begin{aligned} &\frac{\textit{(Total Target} \times \textit{Total Production)} \times \textit{Ideal Cycle Time}}{\textit{Loading Time}} \\ &\times 100\% = \frac{(71{,}675 \times 58{,}811) \times 0.12}{10{,}900} \\ &\times 100\% = 14.16\% \end{aligned} \tag{8}$$

Table 14. Calculation of idling and minor stoppages

Month	Total Target (pcs)	Total Production (pcs)	Ideal Cycle Time (min)	Loading Time (min)	Idling and Minor Stoppages (%)
Sep	71,675	58,811	0.12	10,900	14.16%
Oct	68,656	61,395	0.12	10,288	8.47%
Nov	72,943	63,336	0.12	10,962	10.52%
Average					11.05%

Rework losses are caused by the production process producing defective products, and the defective products produced result in material losses, reduced quantities that have been produced, increased production waste, and require costs for rework, for example, the calculation of rework losses in September 2022 (Eq. (9)). The percentage of rework losses for

September 2022-November 2022 can be seen in Table 15.

$$Rework\ Losses = \frac{Ideal\ Cycle\ Time \times Product\ Rework}{Loading\ Time} \times 100\% = \frac{0.12 \times 257}{10{,}900} \times 100\% = 0.28\% \tag{9}$$

Table 15. Calculation of rework losses

Month	Rework (pcs)	Loading Time (min)	Ideal Cycle Time (min)	Reject Losses (%)
Sep	257	10,900	0.12	0.28%
Oct	233	10,288	0.12	0.27%
Nov	470	10,962	0.12	0.51%
		Average		0.36%

Reduced yield is a loss that arises during the production process, resulting in products that do not meet the standards due to the production process not yet reaching a stable condition, for example, the calculation of reduced yield in September 2022 (Eq. (10)). The percentage of reduced yield for September 2022-November 2022 can be seen in Table 16.

$$Reduced\ Yield = \frac{Ideal\ Cycle\ Time \times Product\ Scrap}{Loading\ Time} \times 100\% = \frac{0.12 \times 589}{10{,}900} \times 100\% = 0.65\% \tag{10}$$

Table 16. Calculation of reduced yield

Month	Scrap Product (pcs)	Loading Time (min)	Ideal Cycle Time (min)	Reject Losses (%)
Sep	589	10,900	0.12	0.65%
Oct	520	10,288	0.12	0.61%
Nov	1,002	10,962	0.12	1.10%
		Average		0.78%

3.3 OEE and six big losses analysis

The Pareto chart of the six big losses can be seen in Figure 2. The calculation of the six big losses that have been accumulated shows that reduced speed losses are the largest type of losses that occur.

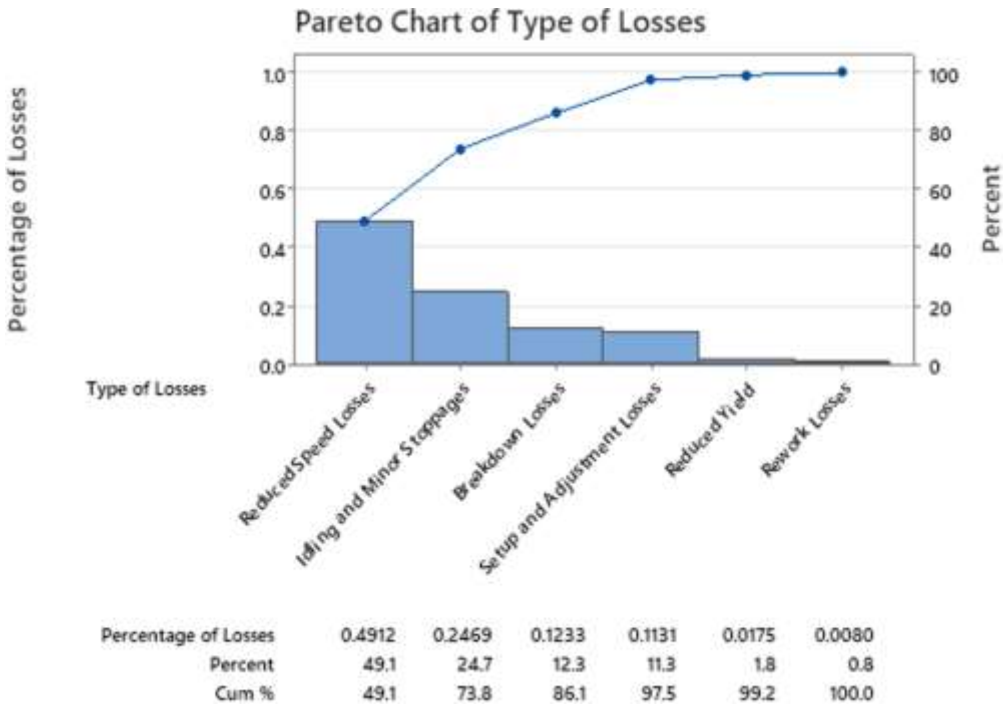

Figure 2. Pareto chart of six big losses

Analysis of OEE calculations is carried out in order to determine the level of effectiveness of the use of blowing machines in September 2022-November 2022 (Table 17). This OEE measurement uses average data from September 2022 to November 2022, namely by multiplying the availability value, performance efficiency value, and quality rate value.

Table 17. Percentage of OEE value

Category	Average OEE Value
Availability Rate (%)	89.42%
Performance Efficiency (%)	76.66%
Quality Rate (%)	98.34%
OEE (%)	67.42%

The OEE value of the calculation for three months made the average result of 66.42%, and the lowest category is performance efficiency, which is 75.54%. The explanation is as follows:

1) Availability rate data obtained from the calculation of its average of 89.42%. This value can already be categorised as quite good; what affects this value is the availability time used during operation, namely operation time and loading time, besides that the availability rate value will be a good category if the number of breakdown times can be minimised because the more damage will result in the higher the availability rate value.
2) Performance efficiency data obtained from the average calculation of 76.66%. This value cannot be categorised as good and must be increased again; what affects this

value is the availability time for the process to operate the resulting output and the ideal cycle time. This calculation of the amount of output does not match the time spent during the production process, so the value obtained can be categorised as not good.

3) The quality rate data obtained from the average calculation is 98.34%. This value is categorised as good; what affects this value is the amount of production and the number of defective products. The defective parts that occur can be categorised as not affecting production results because the quality rate value is good.
4) The OEE value is obtained from the product of the three factors, a value of 66.42%. This value still needs improvement because it is far from the standard set by Japan Institute of Plant Maintenance (JIPM), which is 85%. This value can be low because performance efficiency provides a small value that impacts the OEE value. Small performance efficiency is caused by the amount of production that fails to meet the target.

Analysis of six big losses aims to determine what factors affect the low effectiveness of blowing machines. The relationship between OEE and six big losses has an inversely proportional relationship. If the OEE value is low, it will result in a high value of six big losses, and vice versa. Based on the results of the calculations that have been carried out, the factor that causes the low OEE value occurs in performance efficiency. The results of the calculation of six big losses and the percentage order for September 2022-November 2022 can be seen in Table 18.

The six big losses for three months are calculated using the average. The results obtained reduce speed losses with the highest value, affecting the value of the actual production time, actual production quantity, ideal cycle time, and loading time. The value that most affects the low reduced speed losses is the time spent not following the output obtained, and the ideal cycle time that has been determined with the actual cycle time is different and slower.

Table 18. Percentage of six big losses

Type of Losses	Average Losses (%)	Percentage Losses (%)
Reduced Speed Losses	21.98%	49.12%
Idling and Minor Stoppages	11.05%	24.69%
Breakdown Losses	5.52%	12.33%
Setup and Adjustment Losses	5.06%	11.31%
Reduced Yield	0.78%	1.75%
Rework Losses	0.36%	0.80%

The next stage is to analyse the results of the most dominant type of losses in the calculation of six big losses, namely reduced speed losses, using Fishbone diagrams in order to find out the root causes of the problems that cause the dominant losses, look for any factors that cause reduced speed losses. The factor is sought for the cause of the problem and to find out the root of the problem. Making this Fishbone diagram results from discussions with operators and maintenance staff. The fishbone diagram for reduced speed losses can be seen in Figure 3.

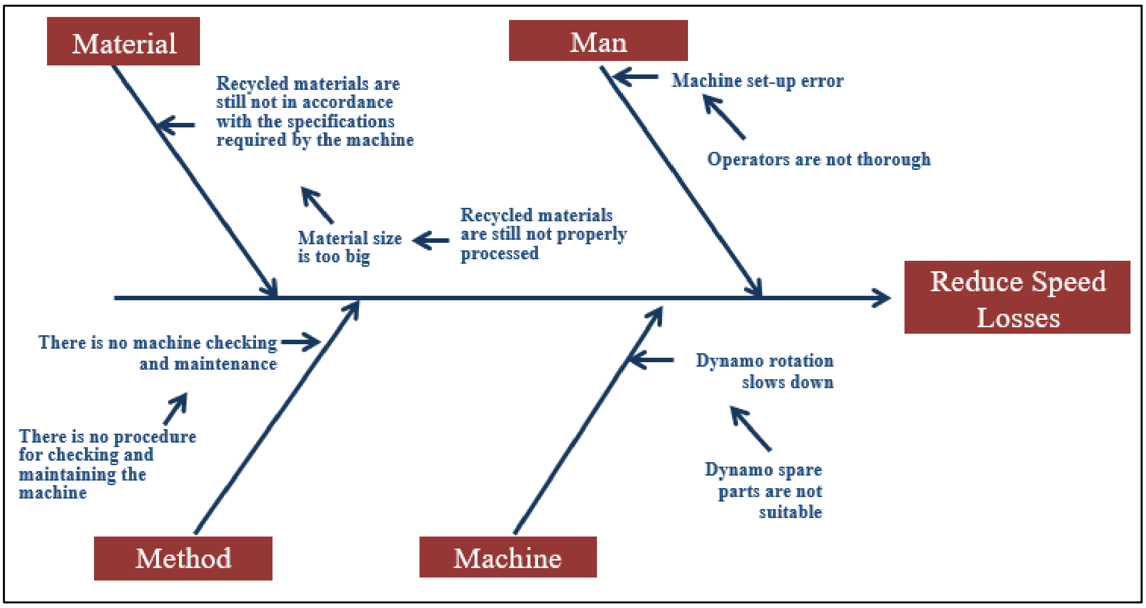

Figure 3. Fishbone diagram of reduce speed losses

Four factors cause reduced speed losses (Figure 3) to be the most dominant losses: humans, materials, methods, and machines. The explanation of each factor is as follows:

(1) Man

The problem is the operator makes machine setup errors. This problem happens because the operator is not careful.

(2) Material

The material factor, which is the problem, is that the recycled material needs to follow the machine's specifications. This problem happens because recycled material processing still needs to be corrected, so the plastic beans produced from recycled processing are quite large.

(3) Method

The method factor that is a problem is that machine checking and maintenance do not exist because there is no definite procedure.

(4) Machine

The machine factor that is a problem is that the replacement dynamo spare parts need to match the specifications. The previous dynamo caught fire, so the company had to look for a replacement dynamo. The production process needs to run smoothly, and the machine is reduced in speed.

After the factors that affect reducing speed losses are successfully mapped, a 5W + 1H analysis is made. 5W + 1H analysis is carried out to bring up the resolution of the problems that have been analysed in the Fishbone diagram. Each factor in the Fishbone diagram will be sought for problem-solving so that the problems can be resolved. The 5W+1H analysis of reduced speed losses can be seen in Table 19.

Table 19. 5W+1H analysis

Factor	Causes	Why	What	Where	When	Who	How
		Why does it need to be fixed?	**What is the improvement plan?**	**Where Is the improvement done?**	**When is the repair done?**	**Who is in charge?**	**How does it work?**
Man	Less thorough	To avoid process errors	Re-conduct socialisation	Blowing machine at RMA Ltd	Dec 2022	Supervisor plant 7	Provide re-socialisation for machine setting procedures and make work instructions so as not to forget again.
Material	Recycled materials have not been properly processed	To match the specifications	Make provisions for material size	Blowing machine at RMA Ltd	Dec 2022	Production division	Make adjustments to material sizes in accordance with machine specifications.
Method	There is no procedure for checking and maintaining the machine	In order to extend the usability of the machine, and the machine is not easy to experience breakdowns so that the production target is achieved	Make a check sheet for checking and maintaining the machine	Blowing machine at RMA Ltd	Dec 2022	Operator of the blowing machine	Checking and maintaining the machine regularly, one of which is by making a check sheet.
Machine	Dynamo spare parts are not suitable	In order to prevent machine damage	Make a list of standard machine spare parts	Blowing machine at RMA Ltd	Dec 2022	Production division	Make a standard list for machine spare parts so that if there is a purchase of spare parts, there is no error.

3.4 Improvement implementation

3.4.1 Socialising and making work instructions

This improvement was made because the operator needed to set up the machine correctly. With the supervisor re-socialising the operator to do the machine setup for each type of part, the operator is expected to avoid making mistakes again. The socialisation done by the supervisor can be seen in Figure 4.

Figure 4. Socialisation by supervisor

Making work instructions is the next stage so machine setup errors do not occur again. The goal is for operators to see the procedures and rules for each type of cover door for machine setup. The impact is that operators find it easier to do machine setup so that the goods produced follow the standards and the course of the production process follows the target. Based on the data, the number of operators making machine setup errors in September 2022-November 2022 occurred 3 times, and after the improvements seen in December 2022-February 2023, there were no such errors. In the work instructions, there are standard blowing machine spare parts so that there are no errors in purchasing and installing machine spare parts. Work instructions for the blowing machine can be seen in Figure 5.

3.4.2 Material standardisation

This improvement is done so that operators pay attention to the material used in the machine. Materials that do not follow the standard will quickly damage the filter part of the machine, adding machine breakdown time to repair the filter so that the production process time will be disrupted. The use of recycled materials for the subcover consists of 20%-25% original plastic seeds, the rest recycled plastic seeds, and 100% recycled plastic seeds for plastic packing.

Improvements were made because the size of the recycled material was enormous, so the machine filter was damaged twice a month. After regular checks and paying attention to the standard size of the material, damage to the machine filter occurred once a month. This recycled material aims to reduce costs, so its characteristics must be improved for the size to be appropriate, as in Figure 6.

Figure 5. Example of work instruction for blowing machine (in Bahasa)

Figure 6. Material standard of blowing machine

3.4.3 Improvement of check sheet creation

This improvement is carried out in the hope that the blowing machine will not easily experience breakdowns and that production targets are achieved if the problem can be resolved, it will have an impact on the availability value and performance efficiency value because it is related to the breakdown time and the amount of production produced, before implementing the check sheet, the calculation of Mean Time To Repair (MTTR), Mean Time Before Failure (MTBF), Mean Time To Failure (MTTF) is carried out.

$$\begin{aligned} \text{MTTR} &= \frac{Total\ Downtime}{Number\ of\ Failures} \times 100\% \\ &= \frac{1{,}779}{14} \times 100\% = 127.07 \text{ minutes} \end{aligned} \tag{11}$$

Based on the MTTR calculation (Eq. (11)) that has been carried out, the average time required for repair when damage or problems occur is 127.07 minutes.

$$\begin{aligned} \text{MTTF} &= \frac{Total\ Downtime}{Number\ of\ Failures} \times 100\% \\ &= \frac{28{,}745}{13} \times 100\% = 2{,}211.15 \text{ minutes} \end{aligned} \tag{12}$$

Based on the MTTF calculations that have been carried out, the average time the machine can operate before the subsequent damage occurs is 2,211.15 minutes, in the case of the dynamo checked for 3 months. The replacement of the dynamo is carried out for 5 years due to the infrequent frequency of damage, for the engine filter is replaced for 2 weeks once due to the frequency of damage 1 month 2 times.

$$\begin{aligned} \text{MTBF} &= \frac{Total\ Downtime}{Number\ of\ Failures} \times 100\% \\ &= \frac{28.745}{1} = 28{,}745 \text{ minutes} \end{aligned} \tag{13}$$

Based on the MTBF calculations that have been carried out, the average time the machine can operate before the next damage occurs is 28,745 minutes.

3.5 Impact of improvement

3.5.1 OEE after improvement

The OEE value is calculated again after the improvement implementation. The OEE value is expected to change for the better because the increase in the OEE value means that the implementation provides good results. The calculation for OEE after the implementation of improvements is as follows:

(1) Availability rate after improvement

There is an increase in the availability rate after improvement because implementing improvements reduces machine breakdown time. The data from the availability rate after improvement can be seen in Table 20.

(2) Performance efficiency after improvement

After improvement, performance efficiency increases because the machine is more controlled with reduced damage and TPM or machine checking. Hence, the resulting output is better after improvement. The data from performance efficiency after repair can be seen in Table 21.

(3) Quality rate after improvement

There is a not-too-far increase in the quality rate after improvement because the previous value is good. The data from the quality rate after improvement can be seen in Table 22.

(4) Overall Equipment Effectiveness (OEE)

The calculation results for the average OEE value after improvement have increased from 67.42% to 77.80% (Table 23). This value has increased because each factor has increased, and the improvements that have been implemented affect the OEE value.

Table 20. Availability rate after improvement

Month	Loading Time (min)	Downtime (min)	Operating Time (min)	Availability (%)
Dec	10,718	752	9,966	92.98%
Jan	10,708	817	9,891	92.37%
Feb	9,754	564	9,190	94.22%
Average of Availability Rate				93.19%

Table 21. Performance efficiency after improvement

Month	Operating Time (min)	Ideal Cycle Time (min)	Production Target (pcs)	Total Production (pcs)	Performance (%)
Dec	9,966	0.12	73,748	70,753	85.19%
Jan	9,891	0.12	73,193	70,012	84.94%
Feb	9,190	0.12	68,006	64,631	84.39%
Average of Performance Efficiency					84.84%

Table 22. Quality rate after improvement

Month	Total Production (pcs)	Scrap (pcs)	Repair/Rework (pcs)	Finished Good (pcs)	Quality %
Dec	70,753	581	643	69,529	98.27%
Jan	69,828	698	295	68,835	98.58%
Feb	64,631	701	349	63,581	98.38%
Average of Quality Rate					98.41%

Table 23. OEE Value after improvement

Month	Availability (%)	Performance (%)	Quality (%)	OEE (%)
Dec	92.98%	85.19%	98.27%	77.85%
Jan	92.37%	84.94%	98.58%	77.35%
Feb	94.22%	84.39%	98.38%	78.22%
Average	93.19%	84.84%	98.41%	77.80%

3.5.2 Six big losses after improvement

(1) Breakdown Losses

The value of breakdown losses has decreased due to reduced damage time with the improvements that have begun to be implemented. The calculation of breakdown losses after the implementation of improvements can be seen in Table 24.

Table 24. Breakdown losses after improvement

Month	Total Breakdown Time (min)	Loading Time (min)	Breakdown Losses (%)
Dec	137	10,718	1.28%
Jan	210	10,708	1.96%
Feb	62	9,754	0.64%
Average			1.29%

(2) Setup and adjustment losses after improvement

The value of setup and adjustment losses has decreased because the loading time value has improved with reduced damage time, even though no overtime is added to have a good loading time. The calculation of setup and adjustment losses after improvement can be seen in Table 25.

Table 25. Setup and adjustment losses after improvement

Month	Setup and Adjustment Times (min)	Loading Time (min)	Setup and Adjustment (%)
Dec	615	10,718	5.74%
Jan	607	10,708	5.67%
Feb	502	9,754	5.15%
Average			5.52%

(3) Reduce speed losses after improvement

The value of reduced speed losses has decreased because the actual production time has become better, the loading time has become better, and the amount of production has increased from before. The calculation of reduced speed losses after improvement can be seen in Table 26.

(4) Idling and minor stoppages after improvement

The value of idling and minor stoppages has decreased because the production amount is close to the target amount, and the loading time is improving. The calculation of idling and minor stoppages after improvement can be seen in Table 27.

Table 26. Reduce speed losses after improvement

Month	Ideal Production Time (min)	Loading Time (min)	Ideal Cycle Time (min)	Total Production (pcs)	Reduced Speed (%)
Dec	10,027	10,718	0.12	70,753	14.33%
Jan	9,909	10,708	0.12	70,012	14.08%
Feb	9,192	9,754	0.12	64,631	14.72%
Average					14.38%

Table 27. Idling and minor stoppages after improvement

Month	Total Target (pcs)	Total Production (pcs)	Ideal Cycle Time (min)	Loading Time (min)	Idling and Minor Stoppages (%)
Dec	73,748	70,753	0.12	10,718	3.35%
Jan	73,193	70,012	0.12	10,708	3.57%
Feb	68,006	64,631	0.12	9,754	4.15%
Average					3.69%

(5) Rework losses after improvement

The value of rework losses has decreased because the loading time has improved so that the rework products produced do not affect the value of rework losses. The calculation of rework losses after improvement can be seen in Table 28.

Table 28. Rework losses after improvement

Month	Rework (pcs)	Loading Time (min)	Ideal Cycle Time (min)	Reject Losses (%)
Dec	643	10,718	0.12	0.72%
Jan	295	10,708	0.12	0.33%
Feb	349	9,754	0.12	0.43%
Average				0.49%

(6) Reduce yield after improvement

The value of reduced yield increased from the results before the improvement because the scrap product increased from before. However, it is still categorised as good enough and does not dominate. The calculation of reduced yield after improvement can be seen in Table 29.

Table 29. Reduced yield after improvement

Month	Product Scrap (pcs)	Loading Time (min)	Ideal Cycle Time (min)	Reject Losses (%)
Dec	581	10,718	0.12	0.65%
Jan	698	10,708	0.12	0.78%
Feb	701	9,754	0.12	0.86%
Average				0.77%

3.5.3 MTTR, MTTF, MTBF after improvement

(1) MTTR after Improvement

Based on the data after improvement, the calculation for MTTR is obtained. There are 6 failures after improvement, with a total downtime of 409 minutes. The average time required to make repairs when damage or problems occur is 68.17 minutes. This value is better because of the decreased downtime and decreased damage frequency.

(2) MTTF after Improvement

Based on the data after improvement, the calculation for MTTF, the average time for the machine to operate after repair before damage occurs for the following spare part to be replaced is 7261.75 minutes. This value is obtained from 4 failures with a total operation time of 29,047 minutes. This value is increasing because the production time is improving, and the frequency of damage for items that must be replaced is reduced.

(3) MTBF after Improvement

Based on the data after improvement, the calculation for MTBF, the average time the machine can operate after repair before damage occurs for the next repairable spare part, is 29,047 minutes. This value has increased because production time is used better, and the damage frequency to repairable items is reduced.

3.6 Discussion

The company increased the OEE value of the blowing machine by implementing improvements, namely making check sheets, making material adjustment marks, re-socialising, providing work instructions, and making material lists. This improvement increased the OEE value percentage because the breakdown time was reduced. The machine speed had started to improve, so the resulting output increased from the previous month, and availability increased due to reduced breakdown time. A comparison of OEE values before and after the implementation of improvements can be seen in Table 30.

Table 30. Comparison of OEE before improvement and after improvement

Parameter	Before Improvement	After Improvement
Availability	89.42%	93.19%
Performance Efficiency	76.66%	84.84%
Quality Rate	98.34%	98.41%
OEE	67.42%	77.80%

To contextualise the results obtained from RMA Ltd further, we will compare the OEE values we obtained with the benchmark OEE values in the automotive manufacturing industry in Indonesia. According to available industry data, the average OEE value in the Indonesian automotive industry is around 60% to 70% [5, 19, 27-30] Thus, the OEE improvement results from 67.42% before improvement to 77.80% after improvement implementation at RMA Ltd. show a significant improvement consistent with the industry standard. In addition, it will compare international trends in the automotive manufacturing industry. Based on the literature, developed countries such as Japan and Germany have OEE values that tend to be higher, reaching 80-85%. Nonetheless, the OEE improvement of 10.38 percentage points that we achieved is an achievement worth considering in the context of Indonesia's growing automotive manufacturing industry.

In analysing the key results, it is important to consider the context of the Indonesian automotive industry and compare it with international trends. The increase in OEE from 67.42% to 77.80% following the implementation of improvements at RMA Ltd. demonstrates significant progress in operational efficiency. However, it should be noted that OEE values in the Indonesian automotive industry are still below the global average, highlighting the potential to improve operational performance in this sector further. Developed countries such as Japan and Germany have achieved higher OEE levels in the international context, reflecting a more mature approach to production management and equipment maintenance. Therefore, while recognising our positive achievements, the company must continue to pay attention to global best practices and implement them consistently to remain competitive in an increasingly competitive automotive market. Thus, while improving OEE is a positive step, it is important to continue pursuing international standards to achieve long-term excellence in the Indonesian automotive industry.

A comparison of the six big losses in Table 31 found that some values have decreased, but some have increased slightly. The highest losses are still reduced speed losses, but the numbers have decreased from the previous ones. The number is improving because the improvements made have a better impact, the number of damage has decreased, and the number of production has increased.

In addition, the MTTR, MTTF, and MTBF values are calculated again to determine the average time to repair the machine, and the average from one damage to the subsequent damage can be determined. A comparison of MTTR, MTTF, and MTBF values can be seen in Table 32.

Table 31. Comparison of six big losses before and after improvement

Type of Losses	Before Improvement	After Improvement
Breakdown Losses	5.52%	1.29%
Setup and Adjustment Losses	5.06%	5.52%
Reduced Speed Losses	21.98%	14.38%
Idling and Minor Stoppages	11.05%	3.69%
Rework Losses	0.36%	0.49%
Reduce Yield	0.78%	0.77%

Table 32. Comparison before and after improvement in MTTR, MTTF, and MTBF

Type of Losses	Before Improvement (min)	After Improvement (min)
MTTR	127.07	68.17
MTTF	2,211	7,262
MTBF	28,745	29,047

Comparison in Table 32. shows that there is a reasonably good improvement, the average time to repair decreases and the average time from one damage to the subsequent damage has increased, meaning that the improvement makes a good impact. The value becomes better because the damage time decreases and the frequency of damage decreases, so the MTTR, MTTF, and MTBF values improve.

4. CONCLUSIONS

In summary, the study has shed light on the transformative potential of Total Productive Maintenance (TPM) in optimising manufacturing operations, particularly within the Indonesian Automotive SME sector. The research has provided valuable insights into enhancing operational efficiency through a comprehensive analysis of Overall Equipment Effectiveness (OEE) and identifying key areas for improvement using the Six Big Losses framework. The first improvement implemented is to re-socialise the problems that occur. Then, socialisation results in the making of work instructions. The second is to adjust the material's size following the machine's specifications. The third is to check and maintain the machine regularly, one of which is by making a check sheet whose checking time is determined from the calculation of MTTR, MTTF, and MTBF from the results of the MTTF calculation, it shows that the period of checking the machine using a check sheet is for 3 days, while for the calculation of MTBF, checking is carried out for 4 days. The last is to make a standard list of machine spare parts so there is no error if spare parts are purchased. The previous OEE value was 67.42%. After the improvement, the value became 77.80%, up 11% from the previous OEE. The damage to the blowing machine from other machines before the improvement was 35.13%. After the improvement, it decreased to 22.09%. The significant increase in OEE from 67.42% to 77.80% following the implementation of targeted TPM interventions underscores the efficacy of such strategies in driving performance improvements. These findings contribute to the theoretical understanding of TPM and offer practical implications for SMEs in the automotive industry looking to enhance their competitiveness.

Moreover, it is crucial to acknowledge the limitations of this study to provide a balanced perspective. While the implemented interventions have yielded substantial improvements in OEE and machine reliability, it is essential to recognise that the findings are based on a single case study within the Indonesian automotive sector. Future research endeavours could benefit from conducting comparative studies across multiple SMEs or industries to generalise the effectiveness of TPM practices further. Additionally, exploring the long-term sustainability of the improvements and potential barriers to TPM implementation would enrich our understanding of its broader implications.

In addition, this study has significant implications for policy and practice in the Indonesian automotive sector. By demonstrating the tangible benefits of TPM implementation on operational efficiency and engine reliability, policymakers and industry stakeholders are encouraged to encourage adopting TPM practices among SMEs. Companies can also provide supportive policies, such as incentives or resources for TPM training and implementation, facilitating widespread adoption and fostering a culture of continuous improvement within the sector. In addition, collaboration between government agencies, industry associations, and academic institutions can foster innovation and knowledge exchange to advance Indonesia's automotive industry's global competitiveness.

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