Journal of Management and Innovation Entrepreneurship (JMIE)
Volume 3, No 1 – Oktober 2025
e-ISSN : 3026-6505

IMPLEMENTATION OF KAIZEN TO REDUCE SETUP AND ADJUSTMENT DOWNTIME ON ROTOR PRODUCTS WITH THE DMAIC METHOD

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Received: 19-08-2025	Revised: 14-09-2025	Approved: 20-10-2025

ABSTRACT

In the industrial sector, production process efficiency plays a crucial role in reducing costs and enhancing productivity. This study aims to minimize downtime caused by Setting tool activities on the Rotor machining 5A OP 20 line at an air compressor manufacturing company. The approach combines the continuous improvement philosophy of Kaizen with the structured DMAIC (Define, Measure, Analyze, Improve, Control) methodology from Six Sigma. Data revealed that Setting tool activities contributed to 3.08% of total downtime, exceeding the company's target of 2.00%. Through primary and secondary data collection and quantitative analysis, this research identified several root causes, including suboptimal tool lifetime, inappropriate Cutting Parameters, and the absence of standardized operating procedures. Interventions were carried out by improving tool specifications, developing SOPs, conducting operator training, and visualizing production data. As a result, downtime was reduced by 27.7%, tool lifetime increased by 10%, and estimated Cost Savings reached IDR 41,654,021 .81 per year. Beyond technical achievements, the study demonstrates that cross-functional collaboration and active employee involvement in the Improvement process foster a more efficient, adaptive, and sustainable work culture. The integration of Kaizen principles supported by the DMAIC framework proves to be an effective strategy for enhancing operational efficiency and achieving comprehensive cost reduction in the manufacturing sector.
Keywords: *Kaizen, DMAIC, Downtime, Cost Reduction*

INTRODUCTION

In the era of global competition, the manufacturing industry is required to continuously improve efficiency to overcome challenges such as material price volatility, rising labor costs, and pressure on productivity (Sari, 2023). One of the key indicators in measuring production performance is Overall Equipment Effectiveness (OEE), which includes three main elements: availability, performance, and quality (Pratama & Hidayat, 2024). Among the factors that influence availability, downtime is the most crucial aspect, especially downtime due to setup and adjustment activities. A study by Afrilian et al. (2025) shows that setup time can contribute up to 20% of total downtime in the precision components industry. This is reinforced by a report by Agustin et al. (2025) which highlights that setup efficiency is one of the keys to reducing machine downtime and increasing output.

A similar phenomenon was also observed in the AC compressor manufacturing company where this study was conducted, where setup and adjustment tool activities contributed 4.58% of downtime, far exceeding the company's target of 3.50%. From downtime data for the period July to December 2024, it can be seen that the Setting Tool activity was the primary contributor to the downtime discrepancy, with actual downtime at 3.08% compared to the target of 2.00%, resulting in a gap of 1.08%. Meanwhile, Model Setting and Program Setting activities met the company's targets. High setup time not only has an impact on reducing equipment effectiveness, but also results in increased production costs due to decreased output per working hour, the use of unproductive labor during the setup process, and increased tool change frequency which has an impact on machine utilization.

To address this issue, this study applies a combined approach between the Kaizen philosophy and the DMAIC (Define, Measure, Analyze, Improve, Control) method from Six Sigma. The DMAIC method was chosen because it offers a structured, data-driven improvement framework and focuses on reducing process variability (Wijaya, 2024). DMAIC is effective in identifying root causes through statistical analysis and is able to produce sustainable solutions compared to temporary fixes. Meanwhile, Effendy (2024) emphasized the involvement of all organizational elements, particularly operators, in the process of identifying improvement opportunities and implementing solutions incrementally. Kaizen implementation has also been shown to reduce waste and increase productivity in manufacturing lines through a low-cost, employee-driven approach (Herlambang & Natsir, 2023).

The combination of Kaizen and DMAIC has been widely used in various previous studies and has been proven effective in reducing setup time and operational costs (Putra & Susanto, 2024). In this context, DMAIC provides a data-driven scientific approach, while Kaizen strengthens the aspects of employee engagement and a culture of continuous improvement. The correlation between reduced setup time and cost reduction is very clear. A study by Martono (2024) showed that every 1% reduction in downtime can result in a 3–5% increase in productivity, as well as operational cost savings of up to tens of millions of rupiah, depending on production capacity. Therefore, reducing setup time by 1.08% on the rotor machining line is expected to have a significant impact on reducing production costs and increasing the company's competitiveness.

RESEARCH METHODS

This research is an applied research with a quantitative descriptive approach that aims to identify and reduce downtime due to tool setting activities on the Rotor machining line 5A OP20. The descriptive approach is used to describe the actual conditions systematically, while the quantitative approach is used to measure the impact of implementing improvements through the DMAIC method and the Kaizen philosophy. The data used consists of primary and secondary data. Primary data was obtained through direct observation on the production floor, recording tool setting times before and after repairs, as well as interviews and brainstorming with operators and technicians. Meanwhile, secondary data includes downtime reports, time setting monitoring for the last three months, as well as references from internal company documents and related scientific literature studies. Data collection was conducted through direct observation of the tool setup process to record time and detect potential waste. Semi-structured interviews based on the 5W1H (Five Things to One) were used to gather information from field workers, complemented by brainstorming sessions to identify obstacles and develop improvement proposals. Historical downtime documentation, production reports, and work standards were also collected as a basis for analysis. The collected data was then processed and analyzed using various methods, including calculating average tool setup times, visualizing trends in graphical form, Pareto analysis to identify the largest contributors to downtime, and root cause analysis using fishbone diagrams. The improvement process was carried out through the DMAIC stages, which include Define, Measure, Analyze, Improve, and Control.

The research steps are designed systematically and structured to ensure that any improvement recommendations are based on valid and objective data. In addition to reactively solving downtime issues, this study also emphasizes the importance of finding the root cause to produce sustainable solutions. The evaluation was conducted by comparing before and after improvements, including changes in average setup time, tool change frequency, and estimated downtime costs. Cost efficiency was analyzed based on the total production time savings after the improvements were implemented.

RESULTS AND DISCUSSION

To ensure targeted improvements, several *Critical to Quality* (CTQ) aspects were established based on internal customer needs and company standards. The following is a table of CTQs for this study:

Table 1.
Critical to Quality (CTQ) *Settings tool Rotor machining* 5A OP 20

No	Customer Needs (Voice of Customer)	Critical to Quality (CTQ)	Target
1	*tool setting* process is fast and consistent.	*tool setting* time per cycle	271.8 seconds (4.53 minutes)
2	*Lifetime Tool* optimal according to supplier specifications	Minimum *Tool Lifetime* before replacement	≥ 200 products
3	Minimal production *downtime due to tool changes*	*Tool* change frequency as low as possible	Adapted to life *time standards*
4	Operators understand and follow work procedures	Consistency of working methods between operators	100% according to procedure

The table above shows the results of the *Critical to Quality* (CTQ) identification based on customer needs *(Voice of Customer)* in the *Rotor machining area* 5A OP 20. Several important aspects that are the focus of improvement include a maximum *tool setting time* of 271.8 seconds or 4.53 minutes per cycle, a minimum *tool lifetime* of 200 products before replacement, the lowest possible *tool replacement frequency according to life time standards* , and consistency of work methods between operators must reach 100% according to established procedures.

Table 2.
Comparison of Actual Time and Standard *Setting tool*

Parameter	Actual Value	Company Standards	Frequency/ *time* s	Information	Judgment
Average *Tool Setting Time*	271.83 seconds	271.8 seconds	128	According to standards	Okay
Fastest *Setting* Time	260 seconds	271.8 seconds	85	Below standard	Okay
Longest *Setting* Time	285 seconds	271.8 seconds	15	Above standard	*Defect*

The table above shows the results of *tool setting time measurements* during the *tool change process* on the 5A OP20 *Rotor machining* . The average *setting time* was recorded at 271.83 seconds , which is still in accordance with the company standard of

271.8 seconds. The fastest time achieved was 260 seconds, which occurred 85 times, indicating that the process was mostly running efficiently.

Visualization of the average *downtime* for 6 months, the following shows the actual against the target and the difference for each month:

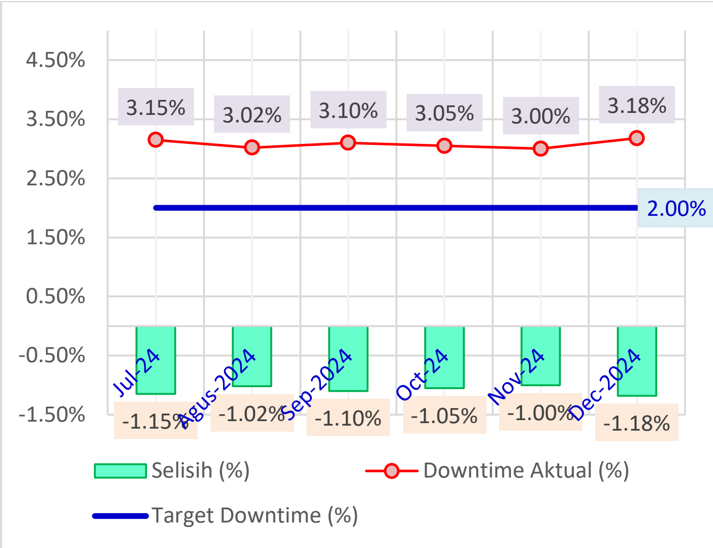

Figure 1. Graph of Actual and Target *Downtime* and Difference Each Month

Analysis of the frequency of tool settings during one month of production shows that several types of tools experience a fairly high rate of replacement.

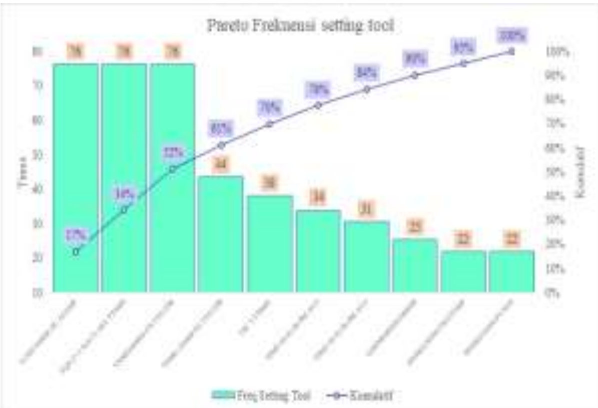

Figure 2. Pareto frequency *Setting* tool *Rotor machining* 5A OP 20

These results serve as a reference for prioritizing improvements, namely by evaluating the use of *tools* that contribute significantly to *downtime* and costs, so that they can be significantly reduced.

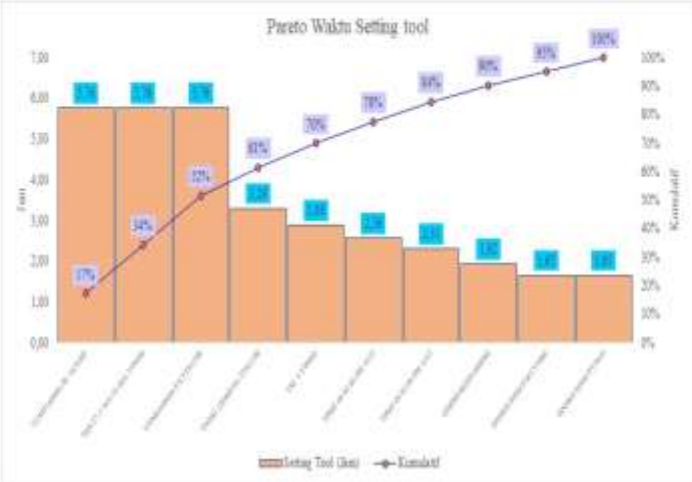

Figure 3. Pareto time *setting tool* area *Rotor machining* 5A OP 20

Based on the Pareto diagram of *tool setting time* , it can be seen that the top three *tools* , namely VCMT160408-SU AC820P, TQS 27-3 56-0 35-40A TT9080, and VNMG160404-FX TT8125B, contribute the largest *setting time* , reaching 52% cumulatively. This condition indicates that most of the downtime is only caused by a small number of *tool types* . When five As subsequent *tools* are added, the cumulative figure rises to 90%, reinforcing the importance of focusing on the *tools* with the greatest impact. *Thus* , improvements directed at these priority *tools* will significantly impact the overall efficiency of the production process.

Table 3.
Expense *cutting* cost analysis *tool* s/ month

No	*Tool* Name	Price / Pcs	*Tool* Change Freq	*Cutting Edge*	Consume /Month	Expense/Month
1	VCMT160408-SU AC820P	Rp. 102,000.00	76	2	38	Rp. 3,892,575.00
2	TQS 27-3 56-0 35-40A TT9080	Rp. 98,000.00	76	3	25	Rp. 2,493,283.33
3	VNMG160404-FX TT8125B	Rp. 86,000.00	76	2	38	Rp. 3,281,975.00
4	TNMG 220408 FG TT8125B	Rp. 96,000.00	44	3	15	Rp. 1,395,657.14
5	TSC 5 TT9080	Rp. 78,000.00	38	3	13	Rp. 992,225.00
6	TPMT 09 02 08-PM 4315	Rp. 89,000.00	34	3	11	Rp. 1,006,359.26
7	TPMT 09 02 08-PM 4315	Rp. 85,000.00	31	3	10	Rp. 865,016.67
8	GDFMS4020N-040DM	Rp. 86,000.00	25	2	13	Rp. 1,093,991.67
9	DNMG130504 FM CT3000	Rp. 94,000.00	22	2	11	Rp. 1,024,935.71
10	DNMG130504 PV3010	Rp. 92,000.00	22	2	11	Rp. 1,003,128.57
	Total		**444**		**185**	**Rp. 17,049,147.35**

Based on the calculation results in the *tool usage cost table* , the total monthly expense for *tool replacement needs* in the *Rotor machining process* OP 20 reached Rp 17,049,147.35, which when added up becomes Rp 204,589,768.25 per year. The three *tools* with the largest cost contributions are VCMT160408-SU AC820P (Rp 3.89 million /month), VNMG160404-FX TT8125B (Rp 3.28 million/month), and TQS 27-3 56-0 35-40A TT9080 (Rp 2.49 million/month). The three tools together contributed almost 55% of the total monthly cost, reflecting significant financial pressure from the *cutting usage side.* This condition indicates that there is a concentration of costs on a small number of tool types *, so* that Pareto analysis becomes an important basis for determining cost control priorities.

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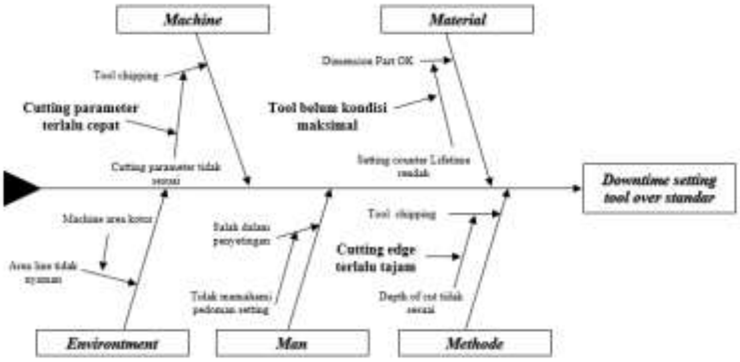

Figure 4. *Downtime* fishbone diagram *Settings tool* over standard

Based on the analysis results that have been carried out, the factors causing the problem of high *tool change frequency* can be classified into five main aspects, namely *the Machine aspect* (machine), Material (material/ *tool*), Method (work method), Man (operator), and *Environment* (work environment). This classification is arranged to systematically map the source of the problem, thus facilitating the identification of the most dominant root causes of increased *downtime due to tool setting* activities . The analysis results show that the high *tool change frequency* is caused by five main aspects. In the Machine aspect, *tool chipping* and the selection of *cutting speeds* that are too high are found, which accelerates *tool wear* . From the Material side, some inserts look good visually but experience micro wear, plus the counter *lifetime setting* is too low. The Method aspect includes inappropriate cutting depth and *cutting design.* too sharp *edge .* In terms of human factors, there were operator *setting errors and inconsistencies in following SOPs. Meanwhile, in terms of the environment* , dirty machine areas and an un-ergonomic workspace slowed down the *tool change process* . All of these factors directly contributed to increased *downtime.*

Table 4.
Comparison of lifetime before and after the 1st repair

***Tool* Name**	***Lifetime* current condition**	**After Life *time* - Up**	**Improvement**
VNMG160404-FX TT8125B	200	220	10%
TQS 27-3 56-0 35-40A TT9080	200	220	10%

lifetime condition has been increased from 200 pcs/ *edge* to 220 pcs/ *edge* . The 10% increase *in Tool Lifetime* is the target agreed upon after conducting trials and regular *monitoring* . Although *the tool* is capable of achieving increases of up to 15%, the company sets a safety limit of 10% to maintain process stability and avoid the risk of quality degradation. Results of Activities The last one can increase *the lifetime* from 200 pcs/ *edge* to 500 pcs/ *edge.* This means it can increase 150% from the previous condition. Here is a comparison of *the lifetime* before and after repair:

Table 5.
Comparison of lifetime before and after the 3rd repair

Front face finish process	Before (VCMT 160408SU)	After (VBMT 160408 FX)	Improvement
Life *time*	200	500	150%

The Control stage is the final step in the DMAIC method which aims to ensure consistent and sustainable improvements in the Setting tool process on Rotor machining 5A OP 20 by implementing a control system that monitors and standardizes the process continuously. Several control efforts carried out include the implementation of the SOP for Standardizing Setting tools which contains systematic work steps, standard cutting tool parameters, and maximum time for each Setting activity; the use of a tool change monitoring checklist by operators as control documentation that can be reviewed by the production team; periodic evaluation of tool lifetime which shows an increase in average tool life of up to 10-150% after the implementation of improvements; as well as strict monitoring of the consistency of cutting parameters such as spindle speed, feedrate, and depth of cut to avoid tool damage due to inappropriate parameters. All of these steps are designed to maintain the quality and effectiveness of the Setting tool process continuously.

The DMAIC approach provides a systematic way of thinking in solving problems. The *Define* stage is used to identify *downtime . Tool setting* is one of the most impactful factors on production performance. Next, *the Measure phase* is conducted to measure *tool setting duration* and determine a performance baseline *before* repairs. *The Analyze* phase revealed that the high frequency of *insert tool replacements* was the primary cause of *downtime* . Based on these findings, improvements were made at the *Improve stage* by increasing *the Tool Lifetime* , adjusting cutting parameters, and compiling more effective work SOPs. Finally, the *Control phase* ensures that improvement results are consistently maintained through operator training and visualization of work information in the field. This entire process demonstrates how a structured and continuous approach can produce improvements that not only impact technical aspects but also provide tangible benefits to overall work efficiency. After a series of corrective actions were carried out, including increasing *tool lifetime* , adjusting machine parameters, modifying *tool design* , and improving operator competency, re-measurements were conducted to evaluate the effectiveness of the improvements. These measurements focused on two main aspects: the duration of *downtime* due to the *tool setting process* and the level of *tool durability* during operation. The results of these measurements are presented in Table 4.15, which compares the conditions before and after the improvements. This data is expected to provide a comprehensive picture of the impact of the improvements on increasing production process efficiency.

Table 6.
***Downtime* Results *Settings tool* and Lifetime *Tool* Before & After**

Parameter	**Before**	**After**	**Percentage of change**
Downtime Setting tool	3.08%	2.23%	27.7%
Lifetime Tool	200	220 and 500	10% and 150%
Tool Change	444/month	385/month	13.29%

Parameter	Before	After	Percentage of change
Frequency			
Estimated *Cost Savings*	Rp204,589,768.25 / Year	Rp162,935,746.44 / Year	20.36%

$$Downtime\ \text{Reduction} = \frac{(17.29-12.78)}{17.29} x100\% = 27.7\ \%\ (7)$$

Kaizen and DMAIC -based improvements on the *tool setting process* . The 150% increase *in tool lifetime is a notable achievement, as it successfully reduced the pressure on tool setting activities* , which were previously performed routinely and frequently. This directly contributed to a decrease in *tool changeover frequency* from 444 to 385 times per month, representing an 86% increase in efficiency. Adjusting machine parameters also positively contributes to machining process stability. These changes contribute to reducing the risk of *tool* chipping and minimizing potential *defects* in the final product. Thus, all the improvement efforts that have been implemented have been proven to contribute directly to increasing operational efficiency while maintaining the consistency of the quality of production results.

The impact of improvements on *cost reduction* is as follows:

1. Production Time Efficiency: *Downtime* decreases, production capacity increases without additional overtime costs.
2. *Tooling* Cost Savings : *Tool Lifetime* increases, need to purchase *Insert Tools* decreases.
3. Improved Product Quality: *Defects* are reduced, scrap and rework costs can be reduced.

Measured and sustainable implementation *of Kaizen has made a real contribution in reducing operational costs and increasing the efficiency of the production process in the Rotor machining area* OP20 . Simultaneously, *downtime* due to *tool setting* has also decreased significantly, indicating that the work process has become more stable, efficient, and has minimal disruption. The economic implications are no less significant: the estimated cost of *tool usage* has decreased from Rp204,589,768.25 to Rp162,935,746.44 per year, resulting in a cost efficiency of 20.36%. This achievement strengthens the evidence that the improvement approach is not only technically effective, but also has a direct impact on the company's cost performance. The combination of strengthening technical, managerial, and operational aspects is the main key to the success of this program in supporting the goal of sustainable *cost reduction . The following is a summary table in the estimated cost* reduction:

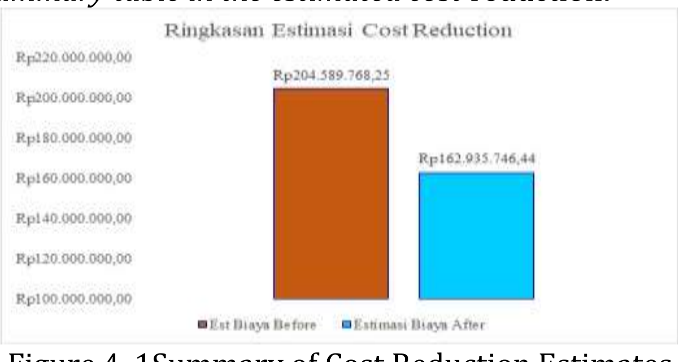

Figure 4. 1Summary of Cost Reduction Estimates

Based on the results of the analysis of three types *of cutting The tools* with the largest cost contribution in the *Rotor machining process* OP 2**0,** namely VCMT160408-SU AC820P, VNMG160404-FX TT8125B, and TQS 27-3 56-0 35-40A TT9080, were improved by replacing the insert specifications and adjusting the cutting parameters. These improvements resulted in increased *tool lifetime, where* the VCMT inserts that were originally used were replaced by VBMT inserts with a lifetime increase of 150%, while VNMG and TQS experienced an increase of 10% each. This improvement resulted in a reduction in the need for *tool replacement* , which directly reduced the monthly *tool usage cost.* Before the improvement, the total monthly cost of the three *tools* was Rp9,668,935. After the improvement, the monthly cost decreased to approximately Rp6,808,267. Thus, the estimated *cost reduction* resulting from the improvement in *tool usage* reached Rp41,654,021.81 per year. This figure reflects the actual cost efficiency (*real cost savings*) because it comes from the reduction in the number of *tool purchases due to the increased tool* lifespan .This finding aligns with Kholil's (2023) research, which showed that the combined application of Lean and DMAIC can reduce *defects* by up to 60% through improved layout and inspection procedures. Although the focus of his research was on product defects, the principle of improving process efficiency remains relevant to this study. Furthermore, Dramowicz & Cyplik's (2018) research also demonstrated that combining DMAIC and PDCA can accelerate production cycle times, similar to the efficiency improvements achieved *in the Setting tool in this study.*

27.7% reduction *in downtime also supports the findings of Kartika (2020) regarding the implementation of Lean Kaizen* which can increase production line productivity by reducing non-value-added activities. Thus, the results of this study strengthen the evidence that the combination of the DMAIC method and *Kaizen principles* can be implemented effectively to increase efficiency, reduce *downtime* , and realize *cost reduction* in the *tool setting process* in the 5A OP 20 *Rotor machining line* .Overall, DMAIC-based improvements and the *Kaizen approach* showed significant results in increasing the efficiency *of the Setting tool* . This proves that the application of the concept of data-driven continuous improvement can produce real cost and time savings in the production line. With the achievement of a 27.7% reduction in *downtime and an* annual cost efficiency of Rp41,654,021.81, the research objectives to reduce *the Setting tool time* and increase cost efficiency can be realized.

CONCLUSION

The application of the Kaizen concept combined with the DMAIC method has been proven to be effective in reducing setup and adjustment downtime on the 5A Rotor machining line by reducing downtime from 3.08 % to 2.23% or a decrease of 27.7%. Improvements were made through increasing tool lifetime, adjusting cutting parameters, preparing SOPs, operator training, and visualizing work information so that the process becomes faster, more stable, and more efficient. A significant impact was seen in efficiency and cost reduction, with tool lifetime increasing from 200 to 220 and 500 products per side, tool replacement frequency decreasing by 86%, and cost savings reaching Rp41,654,021.81 per year with increased work time efficiency without additional overtime hours.

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