

Implementation of Reducing Machine Downtime on Eco-Automotive Component Products Using the Quality Tools Approach

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Keywords:

Eco-filter, Machine downtime, Quality Tools, Engine failure, Continuous Improvement, Root cause analysis

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Received: 17 July 2024

Revised: 20 August 2024

Accepted: 29 September 2024



ABSTRACT

Awareness of the negative environmental impacts needs to be considered in all aspects of life, including the automotive industry. An eco-filter is not just a filter for automotive vehicles but a progressive step towards environmentally friendly mobility. Environmentally oriented products often face challenges in their production processes, including eco-filters, which have the highest machine failure rates compared to other products in this study. This research demonstrates that quality tools can help analyze and understand the causes of the highest machine downtime during repairs at one of Indonesia's largest automotive component manufacturers. The results show that the highest failure was due to replacing halogen heaters used to melt plastic caps. After analyzing the causes of failures and machine breakdowns, it was found that modifying the machine by installing a TVR to regulate the halogen power according to the ideal specifications is a solution to reduce machine downtime. The study shows that quality tools can be used not only to make improvements to enhance quality or productivity but also to reduce machine downtime, especially to improve machine reliability on eco-friendly products.

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1. INTRODUCTION

Environmental issues, sustainability, and occupational health and safety (OHS) have garnered global attention across various sectors, including the goods and services industry.

According to the UNEP-United Nations Environment Programme report, the use of natural resources has tripled in the past five decades, significantly contributing to pollution, waste, climate change, and biodiversity loss. Without immediate action, this will increase by

another 60% by 2060 [1]. High-quality products that prioritize environmental considerations are expected to address these factors, and automotive products that are environmentally sensitive must meet customer demands to become more environmentally friendly. Recent research indicates that eco-innovation practices combined with circular economy principles can enhance competitiveness in the automotive industry [2]

Filters are an essential component of automotive systems that also need to consider eco-innovation. Filters have two main functions: removing contaminants (typically solids) from fluids (water and gas) and separating one or more phases from a mixture [3]. Filters are needed to screen contaminants, innovation in automotive filter components involves developing eco-filters, a type of filter designed with environmental considerations in mind, reducing negative impacts when disposed of, facilitating recycling, and reducing carbon footprint and industrial waste. According to IATF 16949, additional quality tools such as the Production Parts Approval Process (PPAP) include specific Customer Specific Requirements (CSR) [4]. Tier 1 suppliers, often mandate permissible percentages of prohibited chemical substances in a product, typically outlined in IMDS or REACH regulations. However, companies still face challenges in finding suitable solutions due to limited knowledge and experience in sustainable eco-design development [5]. On the other hand, increasing demand for environmentally friendly products is causing higher industry complexity, where the necessary processes and materials do not match the available capabilities and experience.

In strategic flexibility, production or operational activities are the top priority, followed by financial capabilities, and then external relationships with the government or society [6]. Leadership approaches and crucial elements of effective management significantly also influence quality costs [7]. Guidance and direction from management are crucial, especially for the maintenance team [8]. In particular, maintenance management costs are frequently excluded from manufacturing expenses, even though they play a vital role in ensuring operational quality and efficiency. In the industry, continuous improvements related to productivity and quality

are often carried out using quality tools in problem-solving. Previous research applied lean concepts to packaging sealing lines in FMCG manufacturing in Indonesia and used quality tools with comprehensive line observations [9], recommending comprehensive observations to identify the main line that constitutes the company's Pareto problem.

The eco-filter consists of three simple components: the plastic cap, media, and inner liner. Plastic materials are needed to reduce waste and facilitate recycling in the plastic cap process. Previous research using quality tools for plastic materials has been conducted, but this process primarily focused on tooling mold adjustments to control temperature, pressure, and other factors in the product [10].

Another recent study on the use of quality tools was applied to reduce defects in the water dispenser industry, suggesting the use of other tools such as the Pareto diagram and 5W1H [11]. The three previous studies broadly explored production and quality improvements using quality tools, generally focusing on product enhancement.

Moreover, quality tools can also improve machine reliability. Research on applying quality tools to analyze machine improvements, particularly in pump machine testing in India, showed increased maximum production and minimized downtime due to machine failure. Therefore, reducing machine downtime can lead to increased productivity [12]

Summarizing previous research suggestions, this study uses quality tools to analyze and implement productivity improvements due to machine downtime on environmentally friendly automotive components by observing the entire line of a major automotive component manufacturer in Indonesia. The possibility of improving the company's level can be achieved by implementing lean maintenance within the company [13] Despite the increasing trend of customer transition from Internal Combustion Engine vehicles to Electric Vehicles and they need to do some diversification strategies to keep the company exist [14]. Large-scale automotive component companies with strong internal capabilities can still capture market share [15], as

the company in this case is one of the largest automotive component manufacturers in Indonesia. This is supported by considerations such as the still-low demand for EVs, the significant investment required for the transition, changes in the supply chain, and manufacturing technology [16], which are internal factors that encourage the existence of the current manufacturing conditions.

2. METHOD

In this research, the approach taken involves using the PDCA (Plan, Do, Check, Action) concept with the use of quality tools to address the primary issue related to the highest downtime of eco-filter machines. According to maintenance management tools, in addition to FMEA, other related tools that can be applied are quality tools such as Root Cause Analysis (RCA), Pareto Diagram, and Cause and Effect Diagram [17]. The 80/20 principle, also known as Pareto, can be implemented to solve various problems, where a significant portion of results or profits often stems from a small contribution, such as 20% of products or services generating 80% of total profits, or 20% of factors causing 80% of all customer complaints or issues [18]. Pareto is universally applicable across many domains, including economics, social society, and others [19].

The research was conducted at an automotive component company in Banten, Indonesia over a period of three months, involving observation, data collection, and problem analysis. Subsequently, implementation was carried out, and an analysis of the occurrences before and after the improvements was conducted to monitor the results over two weeks. Figure 1 provides a comprehensive overview of the steps taken during this research.

In this study, the first step involves iterating Pareto across all lines in the company and selecting the top line with 20% machine damage. Subsequently, an analysis of machines within that line identifies the machine number with the highest damage levels, followed by a breakdown of the types of damage occurring on that machine. Following the Pareto principle, these iterations focus on the highest 20% or more, assuming that 20% of machine downtime on that line represents potential disruptions to overall company productivity.

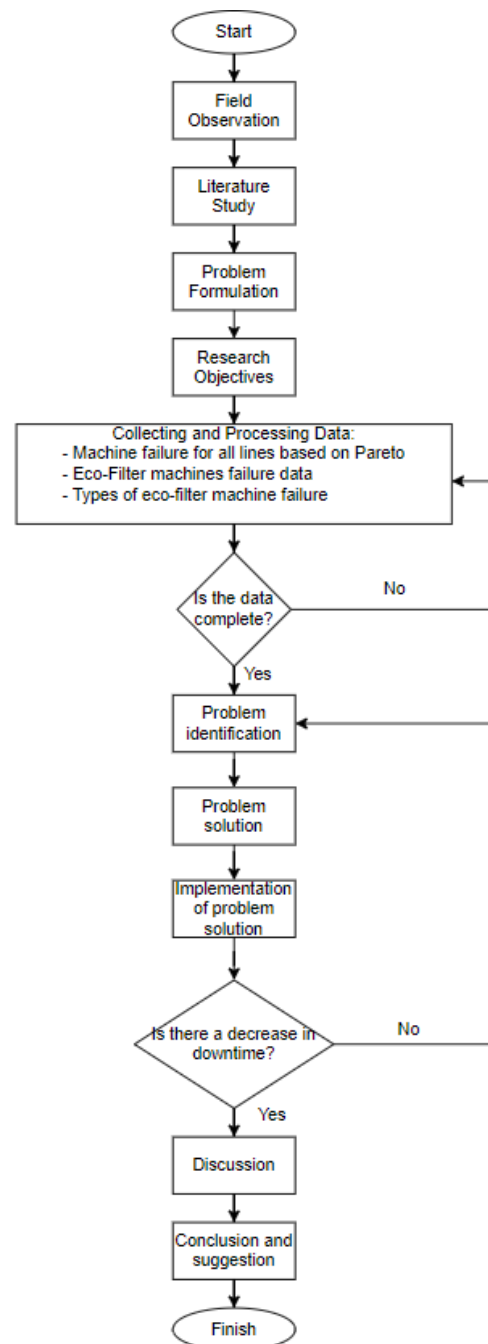


Fig. 1. Research Flow Scheme.

2.1 Data Analysis

Data analysis in this study was conducted through three iterations using Pareto diagrams to identify key details worthy of resolution, as they potentially contribute to 80% of total productivity-related barriers. The Pareto diagram was employed as an analytical tool to prioritize issues that have the greatest impact on productivity. By iterating three times, researchers ensured that the generated data was accurate, providing a more structured and clear overview of the most critical issues.

Figure 2 illustrates the data processing results related to the number of damages across all production lines at PT X based on Pareto analysis conducted over three months. This data encompasses various types of damages and their frequencies, sorted to highlight those occurring most frequently and significantly impacting productivity. Thus, this figure provides a comprehensive view of areas needing more attention for improvement. The findings of this analysis are expected to serve as a reference for decision-making efforts aimed at enhancing operational productivity at PT X.

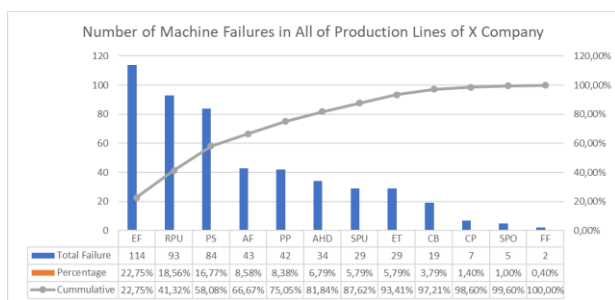


Fig. 2. Number of Machine Failures in All of PT X Production Lines.

The results of the first iteration of the Pareto diagram indicate that the highest number of damages at PT X occurred on the EF (eco-filter) line, with 114 instances of damage. This line is followed by RPU with 93 instances of damage and PS with 84 instances of damage. Other lines experienced machine damages totaling no more than 50 instances. From this analysis, it is clear that improvement efforts should focus on the 20% of occurrences that have the greatest impact on productivity, specifically on the EF line, which accounts for 22.75% of the occurrences.

The next step involves a second iteration by collecting damage data from all machines on the EF line. Pareto analysis is applied again to identify machines experiencing the highest damages.

The results of this second iteration are depicted in Figure 3, illustrating the types of machines with the highest frequency of damage. This analysis provides further insight into the primary causes of damage and assists in prioritizing specific repair needs on the EF line. This approach aims to enhance operational efficiency and significantly reduce machine downtime.

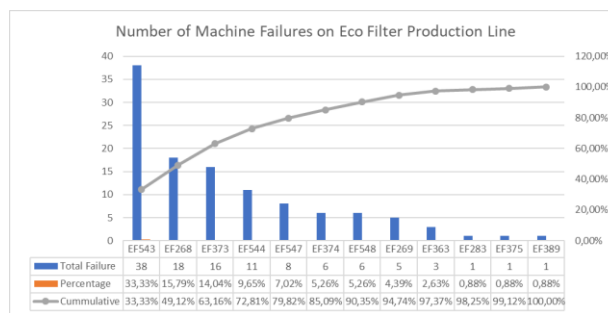


Fig. 3. Number of Machine Failures on EF Production Line.

From 114 instances of damage on the EF line, it was found that machine EF543 had the highest number of damages, totaling 38 occurrences over three months, accounting for 33.33% of the total. This analysis indicates that machine EF543 is the primary source of issues on the EF line and requires special attention in improvement efforts.

Next, after identifying the machine with the highest damages, the next step is to breakdown the types of failures occurring on machine EF543. This process involves collecting detailed data on various types of failures experienced by the machine and analyzing the frequency and causes of each type of failure.

The results of this analysis are presented in Figure 4, providing a visual overview of the distribution and characteristics of failures on machine EF543. By understanding the patterns and specific causes of damage, more effective and targeted repair strategies can be formulated, aiming to reduce the frequency of damages and enhance overall operational performance.

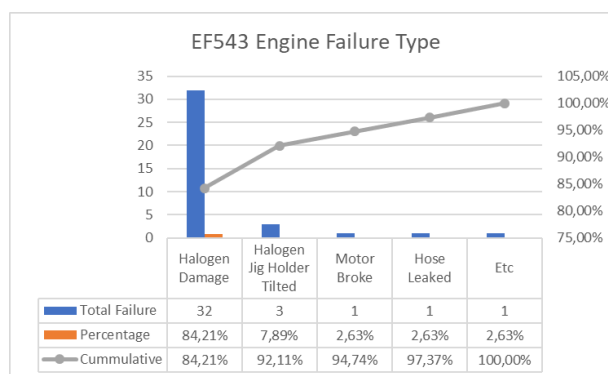


Fig. 4. EF543 of Machine Failure.

The final iteration involved identifying the source of damage on machine EF543 in the eco-filter line, revealing that more than half or nearly all of the damages on the machine were caused by halogen damage, occurring 32 times over a three-month period.

Repairing halogen damage requires approximately 15 minutes by the maintenance team. This time is quite significant considering the continuous production process on this line, where each product is produced every 33 seconds using double heads on jigs, as described in Equation 1.

$$Production\ loss\ (pcs) = \frac{Repair\ time\ (second)}{cycle\ time\ (\frac{second}{pcs})} \quad (1)$$

$$Production\ loss\ (pcs) = \frac{900\ second}{33\ \frac{second}{pcs}} = 54.5 \rightarrow 55\ pcs$$

2.2 Causal Analysis

The next stage in this research activity involves conducting a more in-depth data analysis. This analysis utilizes various proven quality tools [20], including circle diagrams, bar charts, run charts, cause-and-effect diagrams (Ishikawa Diagram), and flowcharts. The application of the cause-and-effect diagram is particularly crucial in unraveling the complexity of the analysis results, involving brainstorming sessions with supervisors and direct observation of the relevant production line.

From the detailed analysis, it was found that the primary cause of halogen damage is excessively high temperature, exceeding the machine's power capacity. This information is detailed and clearly presented in Figure 5, depicting the cause-and-effect relationship between high temperature and halogen damage. These findings provide deep insights into various factors contributing to operational issues on the production line, serving as a crucial basis for designing effective and timely repair strategies.

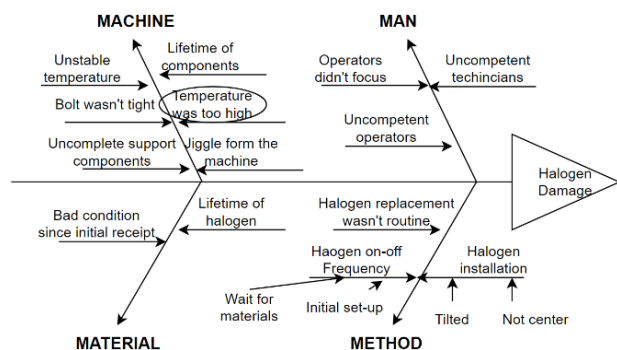


Fig. 5. Cause and Effect Diagram for Halogen Damage.

This analysis not only identifies the root cause but also underscores the importance of swift and targeted interventions to minimize downtime and maximize productivity. By thoroughly understanding the mechanisms of halogen damage, it is expected that the implemented repair measures will significantly enhance operational efficiency and production effectiveness at PT X.

The next step in analyzing the causes of high temperature involves referring to Equation 2, which describes the relationship between power and current. The definition of active power, being the average power corresponding to the original power transmitted by the load with the current and voltage it has, as explained by [21], serves as a crucial reference in these calculations.

Equation 2 helps determine the required current, by considering the machine specifications requiring 3000 watts of power, under AC 3-phase electrical network conditions with 220 volts of voltage.

$$IL = \frac{P}{3.VL.cos\ \emptyset} \quad (2)$$

IL = Network Current (ampere)
 P = Active Power (watt)
 VL= Network Voltage (volt)
 cos \emptyset = Power Factor

According to the result based on this calculation is:

$$IL = \frac{3000\ watt}{3.220\ volt. 0.8} = 5.6\ ampere$$

Based on field observations, the maximum current required should only be 5.6 amperes, but the power supplied to the halogen reaches 6.3 amperes, as illustrated in Figure 6. This condition clearly exceeds the machine's standard capacity, resulting in halogen damage occurring 32 times over three months on the EF543 machine.

These findings indicate that the discrepancy between the required current and the supplied power is the main cause of the problem, which needs immediate addressing to minimize damage and machine downtime, potentially disrupting operational efficiency.



Fig. 6. Current Conditions Supplied to EF543 Machine.

Field observations found that the current supplied to the machine exceeds the recommended specifications. Ideally, the machine should handle up to 3326 watts, but the actual specification only requires 3000 watts. This mismatch is a major factor causing repeated halogen damage, noted 32 times over three months on the EF543 machine.

To overcome this challenge, thorough improvements are needed to regulate the supplied current to match the actual power required by the machine. As an analysis method, the 5 Why approach depicted in Figure 7 was used. This approach helps identify the root cause of the problem with repetitive questions leading to deeper causes related to factors impacting this current mismatch.

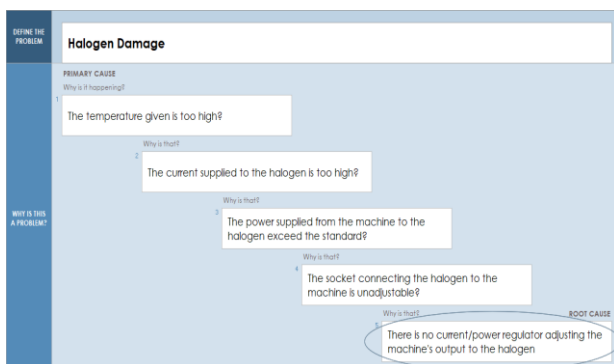


Fig. 7. 5 Why Analysis of Halogen Damage on EF543 Machine.

One technical solution that can be implemented is to modify the machine by installing a Thyristor Voltage Regulator (TVR). The TVR can be set to control the electrical current delivered to the machine according to the power requirements matching the specifications. By optimizing current settings through the TVR, is expected to reduce the risk of overheating and component damage to the halogen. This will not only increase the productivity

level of the production line but also extend the component's lifespan and reduce machine downtime. Overall, this approach is key to ensuring reliability and operational consistency in a dynamic industrial production environment.

2.3 Improvement Implementation

The previous analysis revealed that the supplied current was too large, and inconsistent with the machine's capacity, causing a high frequency of halogen replacements. To address this issue, the machine was modified by installing a Thyristor Voltage Regulator (TVR). The TVR allows power flow regulation by adjusting the voltage amplitude and phase angle, with adjustable longitudinal-transversal regulation.

The TVR installation on the EF543 machine can be seen in Figure 8. This step not only improves power flow regulation to reduce the load on the halogen but also increases overall energy efficiency. Using this technology is expected to optimize machine performance and reduce the risk of damage caused by unstable electrical currents. Additionally, TVR usage can increase equipment lifespan and reduce unexpected machine downtime, which in turn will boost productivity and operational reliability in a dynamic industrial environment.

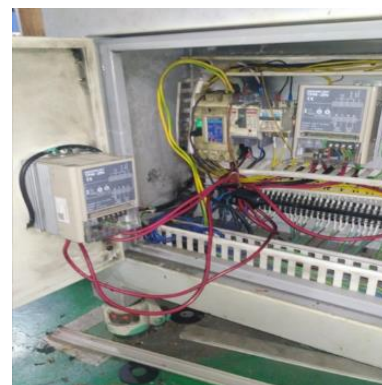


Fig. 8. TVR Installation Implementation on EF543 Machine.

Research results show that TVR usage allows load schedule alignment, and voltage level stabilization on a complex network with nodes having uneven loads, and creates optimal power flow distribution in the electrical system [22]. After the TVR installation, the current supplied by the machine can be adjusted within the range of 5 to 5.6 amperes, depending on the requirements and type of product produced. As the product size increases, such as diameter and plastic melting level, the current requirement also increases.

Figure 9 illustrates the results of TVR installation on the EF543 machine, showing the ability to regulate the current generated by the machine according to operational needs.

With this technology, it is expected to improve energy efficiency and machine operational reliability while reducing the risk of overheating and component damage. This approach not only contributes to overall machine performance enhancement but also supports environmental sustainability goals by optimizing resource usage efficiently in the context of dynamic industrial production, especially in the automotive sector.



Fig. 9. Current Supply Regulation Results Using TVR.

The TVR installation on the machine has been successfully implemented and demonstrated the ability to regulate the current according to the machine's required specifications. The next step is to monitor the results of the performed improvements.

This monitoring is necessary to ensure the machine can operate optimally and consistently according to expected standards after modification. By monitoring the improvement results, it can be evaluated whether the TVR usage is effective in optimizing current regulation and reducing potential problems related to overheating and component damage. This information is important to validate the technical success of TVR implementation and to determine further improvement steps needed to maximize machine efficiency and reliability in the long term.

3. RESULT AND DISCUSSION

The implementation has been carried out and monitored over a two-week period. Based on the collected data, there was a significant reduction

in machine damage and the number of halogen replacements required. Table 1 presents a comparison of results before and after the implementation, providing a clear picture of the positive impact of the improvement actions implemented.

Table 1. Comparison of Results Before and After Improvements.

Before Improvement		After Improvement	
Number of Breakdowns	Number of Halogens Replaced	Number of Breakdowns	Number of Halogens Replaced
7	9	3	5

Based on this research, a significant reduction in the number of machine damages and halogen replacement frequency was observed. The total damage count decreased by 57.2%, from 7 damage cases in two weeks to only 3 damage cases. Meanwhile, halogen replacements also decreased by 44.5%, from 9 units to 5 units needing replacement.

These findings confirm that the primary cause of failure in the EF543 machine is excessive temperature. Quality tools analysis revealed that the mismatch between the current and the machine's power capacity is the main cause of frequent halogen component damage. The results of the TVR installation on the EF543 machine, as carried out in this study, showed success in reducing machine damage levels by over 50% and decreasing the halogen replacement frequency. This not only results in significant cost efficiency but also improves productivity, noting an increase of 220 product units in two weeks.

TVR application can effectively regulate the electrical current supplied to the machine according to its operational needs, thus reducing the risk of overheating and component damage. Therefore, this step not only improves the machine's overall reliability and performance but also supports operational optimization goals in a dynamic industrial production environment.

Overall, the results of this study provide strong evidence that TVR technology as a machine modification solution can offer significant benefits in reducing machine damage, enhancing operational efficiency, and promoting sustainability in energy resource management in manufacturing industries.

4. CONCLUSION

The conclusions from this research are that eco-friendly products are indeed more difficult to control in terms of productivity, quality, and machine reliability. Quality tools, typically used as improvement tools to enhance productivity or quality, also provide solutions for maintenance.

In this research context, quality tools were successfully implemented to analyze and address machine downtime issues, particularly in the eco-filter production process in the automotive industry. In-depth analysis conducted with quality tools helped identify the main causes of machine downtime and provided a strong basis for making effective repair decisions. Implementing quality tools in this research proved that these tools are not only beneficial for improving quality and productivity but are also significant in enhancing machine reliability and reducing production downtime. Quality tools allow for more precise machine modifications, such as installing TVR to regulate power on halogens as per required specifications.

Thus, this research shows that quality tools are multifunctional, providing positive impacts not only on production aspects but also in maintenance, thereby supporting more efficient and environmentally friendly operations. By conducting an in-depth analysis and implementing the recommended actions in this research, it is expected that a 20% improvement in addressing the highest machine failure causes can lead to an 80% reduction in machine downtime frequency, both on the eco-filter line and throughout PT X. This step is key to optimizing operational reliability and overall production efficiency. By focusing on the primary causes of failure, it is evident that implementing quality tools can positively impact operational performance, reduce unexpected machine downtime, and increase consistency in managing machines and equipment in dynamic industrial environments like PT X, to produce high-quality, environmentally friendly, and eco-friendly products such as the eco-filter.

For future research, it is suggested to further explore the application of quality tools in various aspects of machine maintenance and different industries. Research can also focus on developing new methods or improving existing

quality tools to further enhance their effectiveness in identifying and addressing operational problems. Also, For the further consideration, automotive products especially those classified as OEM, are required to comply with regulations aligned with IATF 16949 standards, particularly the adjustments within the Production Part Approval Process (PPAP) when changes or modifications are proposed. A well-defined project management strategy is essential to address these changes and ensure the successful implementation of future improvements.

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