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Application of Failure Mode and Effect Analysis (FMEA) for Defect Reduction: A Case Study on Scratch Defects in Oil Separator Parts in Machining Line

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A B S T R A C T

This study addresses the problem of significant defect rates on Oil Separator Parts in machining line, especially focusing on scratch defects. The defect rate reached 0.495%, exceeding the company's target of 0.1%. In the approach using FMEA, potential failure modes were identified and rated based on Risk Priority Number to plan corrective actions. Effort and Impact Analysis was used to analyze the most effective action recommendations. Implementation of the 5S methodology was selected as the improvement solution, which focused on workplace organization, maintenance, and cleanliness. The results were positive, with the number of defects decreasing dramatically from 540 to 67 units in July 2023, and the defect rate dropping from 0.495% to 0.145%. Although the company's quality targets have not been fully achieved, the FMEA approach and 5S implementation have been shown to significantly improve production quality and reduce defects. This study proves that this approach has the potential to address complex quality issues, although further challenges may be required to achieve the final goals set.

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1. INTRODUCTION

In the fast-growing automotive industry, achieving the highest quality standards is a key goal for every company. Intense competition forces manufacturers to not only innovate in product development but also in production process improvement to produce products with high quality and optimal efficiency. One of the widely used tools in this endeavor is Failure Mode and Effect Analysis (FMEA), which has proven to be very effective in identifying and addressing potential failures in the production process. In this context, this study discusses the application of FMEA as a highly relevant and useful tool to reduce defects in Oil Separator Parts in the company's machining line. Although Oil Separator Parts are one of the key components in the automotive industry, the company was facing serious challenges related to defects in the form of scratches on the product. It is important to understand that scratch defects can have a significant impact on product quality and customer satisfaction. Therefore, effective and efficient measures are required to address this issue. This study attempts to explain how FMEA is used as a tool to identify and analyze failure modes that could potentially cause scratches in Oil Separator Parts, as well as the effects of such failures.

The company has been facing serious challenges in its efforts to reduce the product defect rate, which is currently far from its target of 0.1%. This study provides an in-depth case study illustrating how FMEA was used to identify failure modes, evaluate their potential impact, and design appropriate corrective actions to reduce scratches on Oil Separator Parts. The results of this case study are expected to provide valuable insights into how tools such as FMEA can be effectively used in identifying and addressing quality issues in the automotive manufacturing industry. In addition, this study will also highlight the importance of risk management and continuous improvement in achieving high-quality targets and maximum customer satisfaction. Through rigorous analysis and proper implementation of corrective actions, the company hopes to achieve the highest quality standards in the production of Oil Separator Parts.

2. LITERATURE REVIEW

The use of quality management tools and approaches has become a key factor in maintaining competitiveness and customer satisfaction (Sumasto, Arliananda, Imansuri, Aisyah, & Pratama, 2023; Sumasto, Arliananda, Imansuri, Aisyah, & Purwojatmiko, 2023) in various industries. In this context, it is important for companies to continuously adapt to the changing environment and adopt product innovation and standardization of production processes. Several tools have been applied to achieve this goal, one of which is the PDCA (Plan-Do-Check-Act) cycle, the 5S (Seiri, Seiton, Seiso, Seiketsu, Shitzuke) method, and the 5W2H (5 Whys + 2 Hows) method. The combination of these tools made a significant impact on the production process, with up to a 10% increase in available time by operators (Neves et al., 2018). The concept of lean manufacturing highlights the importance of eliminating waste in the production process. One of the wastes that can be addressed with the lean approach is 'Waiting' and 'Motion'. In a study in the plastic bag manufacturing industry, the implementation of 5S strategies successfully reduced the usage time and waiting time which led to an increase in operational efficiency of up to 18% (Shahriar et al., 2022). In the healthcare industry, implementing lean approaches such as 5S can have an impact on productivity. Studies in hospital medical record units show that the application of 5S work attitudes has a positive relationship with worker productivity and can help overcome problems such as the accumulation of leftover documents and incorrect distribution (Millenia et al., 2023).

Meanwhile, in the manufacturing industry, the application of lean manufacturing including 5S can also have a positive impact on productivity, production costs, and product quality (Neves et al., 2018; Sumasto, Akbar, et al., 2023; Sumasto, Riyanto, Pratama, Imansuri, & Putri, 2023; Tarigan & Budiman, 2021). The use of this approach in the tire industry successfully improved the efficiency of tool switching, reduced material wastage, and better resource utilization (Suresh Kumar & Syath Abuthakeer, 2012). Risk management is also an integral part of the quality management approach. Studies in the automotive industry show that the implementation of the Failure Mode and Effect Analysis (FMEA) method can identify potential failures and their impacts, resulting in significant improvements to the production process and a reduction in product defects (Febriana et al., 2020; Iska Aprilia Wardhani et al., 2022; Kholil, 2023; Novianti & Rochmoeljati, 2023; Pérez-Pucheta et al., 2019; Solihudin et al., 2023; Sumasto, Satria, et al., 2022; Sumasto, Nugroho, Purwojatmiko, Wirandi, Imansuri, et al., 2023; Wahjudi & Cahyadi, 2022; Wahjudi & Projesa, 2021). FMEA is used to identify defect-causing factors, analyze risks, and design effective corrective actions to improve production quality and productivity (Sumasto, Nugroho, Purwojatmiko, Wirandi, Imansuri, et al., 2023). In addition, FMEA has also been used in various sectors, such as the automotive industry, manufacturing, and the food industry. The application of FMEA in reducing potential failures and defects in products can help optimize production processes, improve efficiency, and minimize costs (Dewi et al., 2013; Sharma et al., 2019; Sumasto, Safril, et al., 2022; Sumasto, Maharani, Purwojatmiko, Imansuri, & Aisyah, 2023; Tarigan & Budiman, 2021; Zuniawan, 2020). In various industries, including manufacturing, risk investigation through FMEA and lean manufacturing approaches such as 5S has made a positive impact in addressing issues of efficiency, product defects, and production costs. By identifying the causal factors and impacts of potential failures, companies can design appropriate corrective actions to improve quality, productivity, and customer satisfaction..

3. RESEARCH METHOD

In the initial stage of the study, historical data relating to defects in Oil Separator Parts components will be collected. This data will include information on the type and number of defects in June 2023. The collected data will be analyzed using the Pareto Chart to identify the dominant defects (Sumasto, Satria, et al., 2022; Sumasto, Maharani, Purwojatmiko, Imansuri, & Aisyah, 2023). These defects will be ranked based on their frequency and impact on overall product quality.

The next step is to form a multidisciplinary team, consisting of the production supervisor, production leader, and engineering team. This team will lead the Failure Mode and Effect Analysis (FMEA). This stage involves identifying potential failure modes in the Oil Separator Parts machining process that can cause scratch defects. Each identified failure mode will be rated based on severity, occurrence, and detection using a predefined scale (Kholil, 2023; Solihudin et al., 2023; Zuniawan, 2020). The team will design possible preventive and corrective actions to reduce the risk of failure and scratch defects.

Proposed preventive and corrective actions will be evaluated using the Effort and Impact Analysis method. Actions that deliver significant results with reasonable effort will be identified as "quick win" actions (Sumasto, Safril, et al., 2022). These actions will be the focus of the initial implementation. The recommended preventive and corrective actions will be implemented in the production environment. This may include changes in machining processes, personnel training, or the use of new tools. Implementation will be done carefully and recorded properly..

After implementation, production quality will continue to be monitored regularly. New production quality data will be collected and compared with historical data before the implementation of the preventive measures. This aims to ensure the effectiveness of the measures taken. In the final stage of the study, the results of the FMEA analysis, countermeasure implementation, and performance evaluation will be thoroughly evaluated. The dominant defects after implementation will be analyzed to see a decrease in frequency.

4. RESULT AND DISCUSSION

Based on historical defect data in the first week of June 2023 at Oil Separator Parts in the Machining Line, 6 types of defects were obtained. These types of defects are scattered in 12 position points (Fig. 1. and Fig. 2.).

Fig. 1. Defect position for point 1 to 6

Fig. 2. Defect position for point 7 to 12

Oil Separator Parts has a production target of 216,000 units/month. Based on historical data in June, the defect rate for the product is 0.495% and has not met the target of 0.1%. Scratch defects dominate with a total of 540 occurrences (Fig. 3.). This indicates that scratch defects are a major issue that needs to be addressed as they account for 50.5% of the total defects. Improvements in machining methods or process changes aimed at reducing or eliminating scratches can have a significant impact on product quality. Besides that, defect rate in Oil Separator Parts. The Focus Group Discussion (FGD) process was conducted as the first step in identifying and analyzing problems related to defects in the Oil Separator Part (Figure 4.). The FGD involved a four-person engineering team, each with more than ten years of experience in their respective fields. The team consisted of a Production Manager, a Manufacturing Supervisor, a Process Engineer, and a Mechanical Engineer. The diverse participation of the team members provided a comprehensive insight into various aspects of the manufacturing process.

In the FGD, each team member provided their views and experiences on the problems in the Oil Separator Part. The discussion was guided by several structured questions to ensure that all relevant aspects were explored. The existence of excess work elements as a problem in the Manpower factor was identified by the Manufacturing Supervisor who directly manages the production line. The Production Manager also provided insight into issues related to previous work that needed to be thoroughly cleaned up, contributing to the defects.

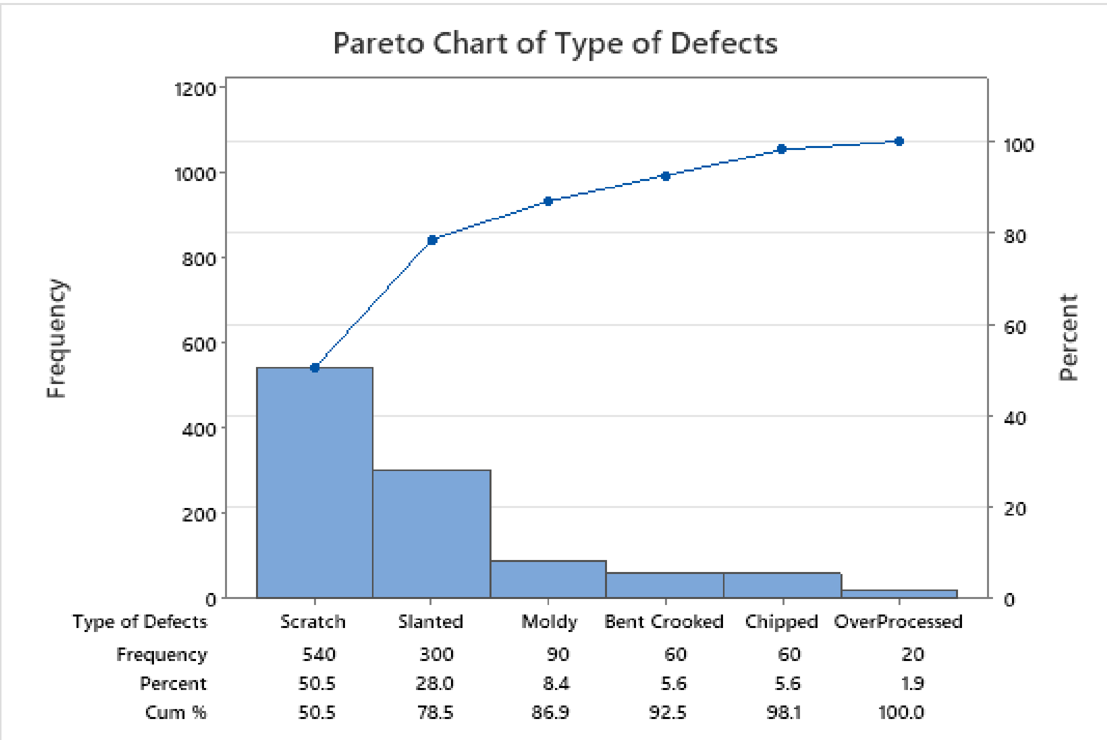

Fig. 3. Pareto chart of type of defects of Oil Separator Parts

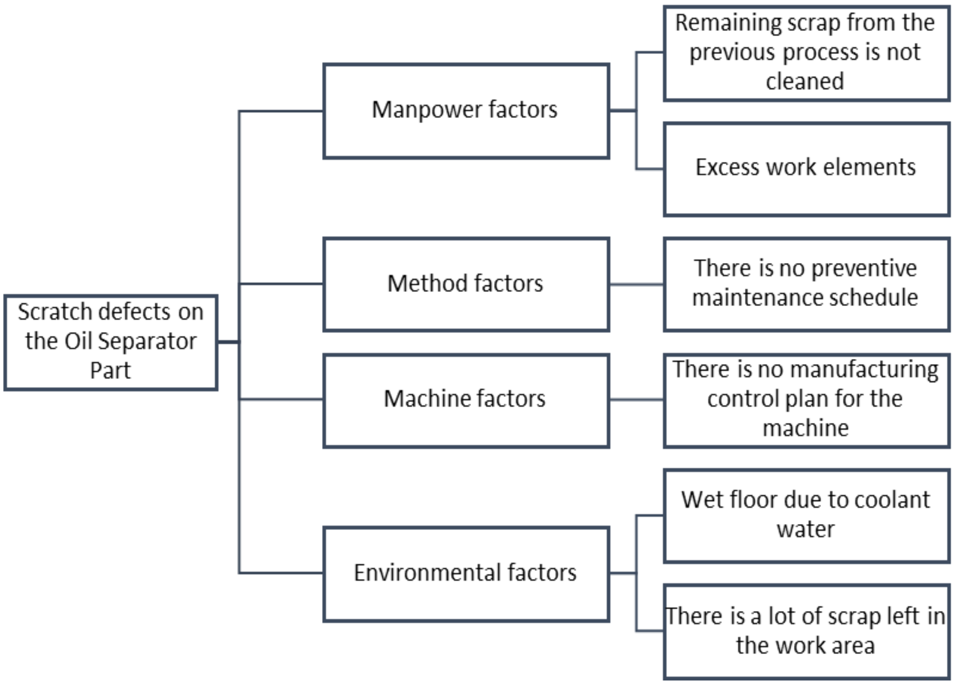

Fig. 4. Tree diagram of defect scratch
(Source: result of focus group discussion, 2023)

In the Method Factors segment, the Process Engineer revealed that the absence of a preventive maintenance schedule was a contributing factor to the occurrence of defects. The discussion on Machine Factors involved an explanation from the Machine Technician, who identified that the absence of a manufacturing control plan for the machine also contributed to the occurrence of defects.

Environmental factors were discussed in depth with the involvement of all team members. The Production Manager shared that the wet floor condition due to cooling water was an essential factor in the defects. In addition, the Manufacturing Supervisor and Machine Technician noted that the large amount of leftover materials in the work area also negatively impacted product quality. By conducting structured FGDs and involving a diverse team, we can gain in-depth information about the problems that occur in the Oil Separator Part manufacturing process. The discussion results then became the basis for applying Failure Mode and Effect Analysis (FMEA) to identify, assess, and reduce the risk of defects in the product.. To be able to see the impact and level of risk that may occur due to these failures, it is analyzed using Failure mode effect analysis (FMEA). The risk level criteria in the FMEA analysis used start from severity (Table 1.), occurrence (Table 2.), detection (Table 3.), and risk priority number (RPN) criteria values formulated by the Engineering Team and by the Supervisor of the production department.

Table 1. Scale number of severity

Scale	Effect	Criteria: Severity of Effect
1	Never	Failure has no effect
2	Rarely	Failure has little effect
3	Quite Frequently	Failure has impact and is quite critical
4	Frequently	Failure is very impactful and critical
5	Very Frequently	Failure is very costly and critical

Source: data processing, 2023

Table 2. Scale number of occurance

Scale	Effect	Criteria: Occurance of Effect
1	Never	Minor or avoidable failures
2	Rarely	A failure that can be overcome and has no effect
3	Quite Frequently	Failures are not a significant amount
4	Frequently	Significant failure
5	Very Frequently	Unavoidable failure

Source: data processing, 2023

Table 3. Scale number of detection

Scale	Effect	Criteria: Detection of Effect
1	Certain	Problems can be detected immediately
2	Easy	Problems are detected after they occur
3	Quite difficult	Problems that occur are unlikely to be detected and resolved
4	Difficult	Problems that occur may not be detected and resolved
5	Very difficult	Problems that occur cannot be detected and resolved

Source: data processing, 2023

FMEA analysis of the problem of scratch defects in oil separator parts is carried out using the small group discussion method with competent sources, namely production operators, production supervisors, and engineering teams. The team formulated the impact/impact of failure, and causal factors, and currently using a potential scratch defect control tool found in Figure 4. The results of the discussion of the Severity (S), Occurance (O), and Detection (D) scale values can be seen in Table 4.

Table 4. Results of FMEA of scratch defect in oil separator parts

Potetial Failure	Effects of Failure	Effect Factor	Current Control	Value S	Value O	Value D	RPN	Recommendation Action
Remaining scrap from the previous process is not cleaned	Contamination of Subsequent Processes, Quality Defect, and Safety Concern	Process Conditions and Cleaning Process	Not Available	3	4	1	12	Implementation of Visual Management with Check Sheets in the previous process and Making SOPs
Excess work elements	Reduced Productivityand Quality Decline	Non-compliance with Standards and quality of work	Not Available	3	4	2	24	Making Work Instructions and Socializing SOPs
There is no preventive maintenance schedule	Increased Equipment Downtime, Loss of Product Quality, and	Age and Condition of Equipment, History of Previous Machine	Preliminary report about machine breakdown	4	4	2	32	Creating a preventive maintenance schedule

Potetial Failure	Effects of Failure	Effect Factor	Current Control	Value			RPN	Recommendation Action
				S	O	D		
	Operational Inefficiency	Breakdowns, and Technical Complexity						
There is no manufacturing control plan for the machine	Inconsistent Product Quality and Higher Scrap and Rework Rates	The precision of the production method and the complexity of the manufacturing process	Not Available	3	3	1	9	Making manufacturing control plans for machines
Wet floor due to coolant water	Safety Concerns and Product Contamination	Compliance with Safety Standards and operational efficiency	Not Available	2	2	2	8	Addition of inspection in 5S schedule
There is a lot of scrap left in the work area	Increased Safety Hazards and Quality Concern	Waste Management System and Process Quality	Not Available	2	2	2	8	Making gutters between machines to accommodate scrap

(Source: result of focus group discussion, 2023)

Based on the FMEA results (Table 4.), the highest RPN is obtained, which is 32. There is no preventive maintenance schedule. However, in terms of production that is directly related to customer satisfaction, a quick win with minimal investment is required. To get a quick win, Effort & Impact Analysis is used (Table 5).

The approach of using the Effort & Impact Matrix after obtaining the results from FMEA can help in identifying and prioritizing improvements that can deliver significant results with relatively low effort. This approach makes it possible to focus on improvements that provide immediate benefits (quick wins) by considering the level of effort required and the resulting impact.

Table 5. Effort and impact analysis

No	Recommendation Action	Effort	Implementation Effort	Impact	Solution Impact
1	Implementation of Visual Management with Check Sheets in the previous	Current Process Analysis, Visual Concept Development, Check Sheets Development, Process Assessment,	3	Consistency and Uniformity, Reducing the Risk of Failure, Increasing Operational	3

No	Recommendation Action	Effort	Implementation Effort	Impact	Solution Impact
	process and Making SOPs	Employee Training, and Validation.		Efficiency, and Improving Product Quality.	
2	Making Work Instructions and Socializing SOPs	Current Process Analysis, Visual Concept DevelopmentWork Instruction Development, Process Assessment, and Socializing	3	Improved Compliance with Procedures, More Consistent Product Quality, and Improved Operational Efficiency	3
3	Creating a preventive maintenance schedule	Assessment of Risks and Priorities, Identification of Relevant Equipment and Machinery, Planning of Maintenance Frequency, Determination of Maintenance Measures, and Quality Improvement.	3	Increasing Equipment Reliability, Reducing Downtime and Interruptions, Increasing Production Efficiency, Reducing Maintenance Costs, and Improving Product Quality.	4
4	Making manufacturing control plans for machines	Identification of Relevant Machines and Processes, Assessment of Risks and Priorities, Analysis of Current Processes, Identification of Required Controls, Development of Procedures and Work Instructions, and Testing and Validation.	3	Product Quality Improvement, Defect and Failure Reduction, Consistency Improvement, and Production Efficiency Improvement.	3
5	Addition of inspection in 5S schedule	Understanding of 5S Principles, Development of Inspection Guidelines, Distribution of Inspection Tasks, Implementation of Inspections, and Continuous Improvement.	1	Increasing the Application of 5S Principles, Increasing Operational Efficiency, Increasing Safety, Increasing Product Quality, Reducing Production Disturbances, and Improving the Work Environment.	4
6	Making gutters between machines to accommodate scrap	Identification of suitable designs, mapping of production areas, planning for the transfer of remaining production,	2	Reducing Production Leftovers, Increasing Production Efficiency, Increasing Work	4

No	Recommendation Action	Effort	Implementation Effort	Impact	Solution Impact
		procurement of materials and equipment, measurement and installation, and measurement of effectiveness.		Environment Cleanliness, Better Waste Management, Increasing Safety, and Increasing Environmental Awareness.	

(Source: result of focus group discussion, 2023)

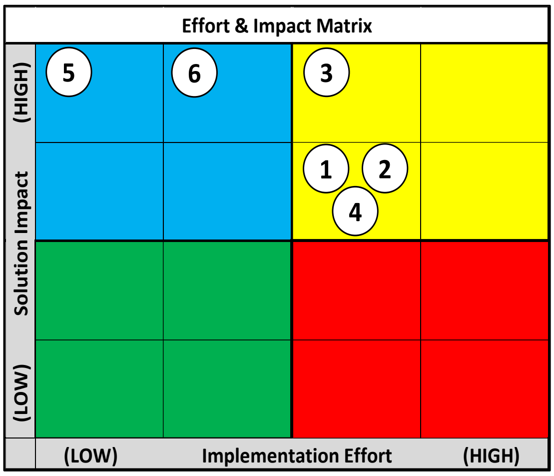

Fig. 5. Effort and impact matrix

Based on the results of the Effort and Impact Matrix (Figure 5), it was found that to get a quick win, the implementation of the fifth and sixth recommendation action points is required. As for the first, second, third, and fourth points, it is still questionable whether the implementation of the recommendation action is worth the effort that will be made. The analysis leads to the implementation of the fifth recommendation action because it has a lower effort than the sixth point.

The addition of inspection in the 5S schedule in the Oil Separator Parts production process has a significant impact (Table 6.). Implementation of improvements was carried out in July 2023. The implementation results showed that there was an improvement in quality as seen from the decrease in the number of defects (Table 7). Scratch defects decreased from 540 units to 67 units in July 2023. In addition, not only scratch defects decreased but also other defects. The impact of the improvement made the total defect from 1070 units to 314 units. Based on the improvement results, defects in Oil Separator Parts decreased from 0.495% to 0.145%. Although the results of the improvement still cannot meet the target, the results of the FMEA and 5S implementation have a positive impact on the production of Oil Separator Parts.

Table 6. 5S implementation

Before 5S Implementation	After 5S Implementation
Seiri	
	
Seiton	
	
Seiso	
	
Seiketsu	

Before 5S Implementation	After 5S Implementation
	
Shitsuke	
	

Table 7. Comparison after improvement

Types of Defect	Before Improvement	After Improvement
Scratch	540	67
Slanted	300	103
Moldy	90	65
Bent Crooked	60	41
Chipped	60	33
Over Processed	20	5
Total	**1070**	**314**

5. CONCLUSION

This study aims to solve the problem of high defect rates on Oil Separator Parts in the machining line, especially the scratch defect problem which is the main cause. The high defect rate on Oil Separator Parts, which reached 0.495%, far exceeded the company's target of 0.1%. In the course of the research, the main problem was identified and focused on improving scratch defects which accounted for 50.5% of the total defects in June 2023. Through the Failure Mode and Effect Analysis (FMEA) approach, the research team successfully identified potential failure modes that can cause scratch defects in Oil Separator Parts. Risk evaluation using the RPN (Risk Priority Number) method helps determine which corrective actions are the main focus based on severity, occurrence, and detection. The results of the FMEA and RPN analysis open up opportunities for recommendation actions to improve product quality. The assessment of recommendation actions using Effort and Impact Analysis allows the identification of actions that provide significant results with reasonable effort, known as "quick win" actions.

In this case, the implementation of 5S (Simplify, Straighten, Scrub, Standardize, Sustain) was selected as the corrective action based on the results of the Effort and Impact Analysis. The results of the 5S implementation were very positive, where the number of defects in Oil Separator Parts was drastically reduced from 540 units to 67 units in July 2023, or from a rate of 0.495% to 0.145%. Although the company's target has not been fully achieved, the results of the implementation of FMEA and 5S have proven their positive impact on the production of Oil Separator Parts in defect reduction. The success in reducing the number of defects is a significant step in the effort to improve product quality and approach the set target. Overall, this research provides clear evidence that the application of FMEA approach and 5S implementation can result in significant improvement in defect reduction in Oil Separator Parts. However, further research and a holistic approach may be required to achieve the quality targets desired by the company.

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