ANALYSIS OF TOP MIRROR VISION BROKEN IN TSP (TEST SCAN PACK) MACHINE

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***Abstract*—Top Mirror Vision is a critical optical component in the Test Scan Pack (TSP) machine that affects inspection accuracy in semiconductor manufacturing. Damage to the mirror surface can reduce image quality and lead to inspection errors. This study aims to identify the root cause of Top Mirror Vision damage and develop an improvement to reduce its occurrence. A Fishbone Diagram and root cause validation were used to analyze the problem. The analysis identified direct contact between the air gun nozzle and the mirror surface during manual cleaning as the main cause of damage. To address this issue, a semi-automated cleaning system utilizing controlled airflow was designed and implemented. The results showed that the number of Top Mirror Vision broken incidents decreased from 7 cases to 0 cases, achieving a 100% reduction. The proposed system also improved cleaning consistency and inspection stability. Therefore, the semi-automated cleaning system proved to be an effective solution for reducing Top Mirror Vision damage in the TSP machine.**

Keywords: Top Mirror Vision, Fishbone Diagram, Root Cause Analysis, Semi-Automated Cleaning System, TSP Machine.

I. INTRODUCTION

In semiconductor manufacturing, maintaining product quality is essential to ensure reliability, consistency, and efficiency in production processes. High product standards require precise inspection systems to detect defects at an early stage. Automatic Optical Inspection (AOI) is widely implemented in manufacturing environments to perform non-contact inspection and ensure that products meet quality specifications [1][2]. The TSP (Test Scan Pack) machine integrates AOI technology to carry out inspection processes, where the accuracy of the inspection results is highly dependent on the condition of its optical components.

One of the critical optical components in the AOI system is the Top Mirror Vision, a replaceable mirror component that reflects and directs images toward the inspection camera. The condition of this component directly affects the clarity and accuracy of the captured images. Damage to the mirror surface, such as scratches, contamination, or cracks, can degrade image quality, resulting in misdetection, false rejection, or undetected defects that ultimately affect production quality [3][4]. Based on actual conditions in the production line, the Top Mirror Vision frequently experienced damage during operation. The damage was generally found in the form of cracks and contamination on the mirror surface. This condition was associated with the manual cleaning process using an air gun, where the nozzle position and cleaning distance depended entirely on the operator because no fixed nozzle position or distance control was provided. Consequently, the air gun nozzle could be positioned inconsistently and potentially come into contact with the mirror surface. As a result, the mirror required frequent replacement, leading to increased downtime and affecting the stability of the inspection process.

Top Mirror Vision broken is a defect that occurs in the mirror component of the TSP machine's visual inspection system. This mirror plays an important role in reflecting the product surface to the inspection camera; therefore, its condition directly affects the accuracy of inspection results. Damage to the mirror, such as cracks, scratches, or contamination, can reduce reflection quality and lead to unclear image capture, which impacts the system's ability to detect products accurately [1].

n this study, the defect analyzed focuses on the physical condition of the Top Mirror Vision, which can be classified into two categories: good and not good conditions. A good condition refers to a mirror that is clean, flat, and free from physical defects, allowing optimal reflection and stable inspection performance. The physical appearance of a Top Mirror Vision in good condition is shown in Figure 1. In contrast, a not good condition refers to a damaged mirror surface, such as cracks, scratches, or uneven areas caused by improper handling during cleaning or maintenance. The physical appearance of a damaged Top Mirror Vision is shown in Figure 2.

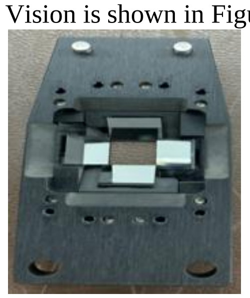


Figure 1. Physical Appearance of Top Mirror Vision in Good Condition

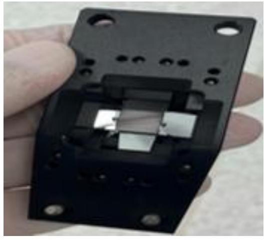


Figure 2. Physical Appearance of Top Mirror Vision in Broken Condition

The condition of the Top Mirror Vision directly affects the quality of the inspection image captured by the camera. When the mirror is in good condition, the reflected image remains clear and stable, allowing the inspection system to accurately detect and classify products. The inspection result obtained under this condition is shown in Figure 3. However, when the mirror surface is damaged, the reflection quality decreases, resulting in blurry images, noise, and inaccurate detection by the inspection system. This condition may lead to invalid rejects and reduced inspection reliability. The inspection result under a damaged Top Mirror Vision condition is shown in Figure 4.

Figure 3. Top Mirror Vision in Good Condition

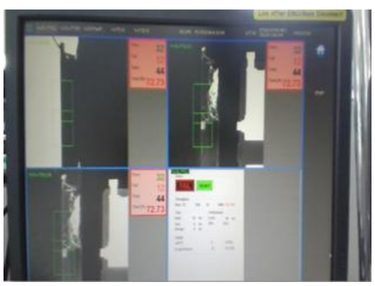


Figure 4. Top Mirror Vision in Broken Condition

Based on initial observation data, the number of Top Mirror Vision broken incidents was recorded across several inspection cameras within a single SRM machine used in the Test Scan Pack (TSP) process. One SRM machine consists of multiple inspection cameras, each utilizing a Top Mirror Vision component. The data shows that damage incidents occurred repeatedly on different cameras, indicating that the problem was not isolated but systematic in nature. Specifically, the highest number of incidents occurred in the VSSSPADPKG camera with 4 cases, followed by VSSL-FT(L) with 2 cases, and VSSL-FT(R) with 1 case. This distribution indicates that the issue affects multiple inspection points within the system. This condition represents the initial state of the system before root cause analysis and corrective actions were implemented, as shown in Figure 5. The detailed monitoring results of Top Mirror Vision broken incidents before implementation are presented in Table I.

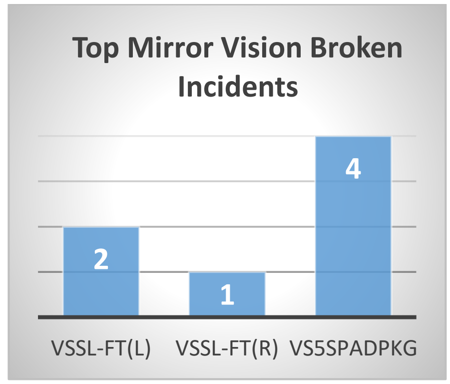


Figure 5. Data Before Top Mirror Vision Broken

TABLE I
TOP MIRROR VISION BROKEN INCIDENTS BEFORE IMPLEMENTATION

Month	WEEK	Number of Incidents
October 2025	Week 1	1
October 2025	Week 2	1
October 2025	Week 3	0
October 2025	Week 4	1
November 2025	Week 1	1
November 2025	Week 2	0
November 2025	Week 3	1
November 2025	Week 4	0
December 2025	Week 1	0
December 2025	Week 2	1
December 2025	Week 3	0
December 2025	Week 4	1
Total		7 Incidents

Proper maintenance and controlled handling of optical components are essential to maintain stable system performance and reduce failure rates. In industrial environments, a systematic approach is required to analyze problems, identify root causes, and develop effective corrective actions. Without proper analysis and improvement strategies, recurring issues may continue to affect production efficiency and product quality.

Therefore, this study aims to analyze the root cause of Top Mirror Vision damage in the TSP machine and propose an effective improvement in the cleaning process. The proposed solution focuses on the development of a semi-automated cleaning system designed to minimize human error, reduce direct contact with the mirror surface, and improve cleaning consistency. It is expected that this improvement will enhance inspection accuracy, extend component lifespan, and support overall production performance.

II. METHOD

A. Research Methodology Flowchart

This study applies a systematic approach to analyze the causes of Top Mirror Vision damage and develop an effective corrective action for the TSP machine. The methodology consists of several stages, including problem identification, data collection, root cause analysis, solution design, and evaluation. Each stage is conducted sequentially to ensure that the problem is thoroughly investigated and that the proposed solution addresses the identified root cause. The overall research flow used in this study is illustrated in Figure 6.

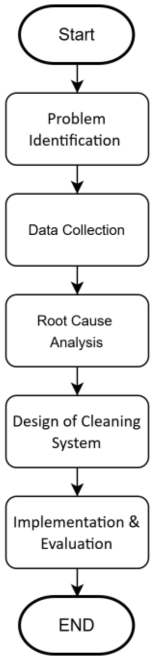


Figure 6. Research Methodology Flowchart

1. Problem Identification

The first stage is problem identification, which is conducted through direct observation in the production area. At this stage, recurring issues related to Top Mirror Vision damage are identified, including the frequency of occurrence and its impact on inspection performance. The observation focuses on the condition of the mirror surface and the cleaning practices performed by operators.

2. Data Collection

The second stage is data collection. Data is collected through observation, documentation, and discussions with operators and maintenance personnel. The collected data includes types of damage, cleaning methods used, frequency of cleaning, and operational conditions of the TSP machine. This data is used to support further analysis and to understand the main factors contributing to the problem.

3. Root Cause Analysis

The third stage is root cause analysis. Root Cause Analysis was conducted to verify the dominant cause before proposing the improvement [5]. In this study, the Fishbone Diagram method is used to systematically identify the possible causes of Top Mirror Vision damage. The analysis is categorized into several factors, such as Man, Method, Machine, and Material. This approach helps to determine the dominant factors contributing to the problem and provides a clear direction for improvement.

4. Solution Design

The fourth stage is solution design. Based on the results of the analysis, a semi-automated cleaning system is proposed to reduce direct contact between cleaning tools and the mirror surface. The system is designed to improve consistency in the cleaning process and minimize the risk of human error. The design focuses on ease of implementation, effectiveness, and compatibility with the existing TSP machine.

The proposed semi-automated cleaning system is designed to provide a controlled cleaning mechanism for the Top Mirror Vision. The system utilizes a regulated airflow to clean the mirror surface without direct physical contact. The nozzle position and airflow direction are adjusted to ensure uniform cleaning while maintaining a safe distance from the mirror surface. This design aims to eliminate the risk of mechanical impact caused by manual cleaning tools and to ensure consistency in the cleaning process. The system is developed with consideration of ease of use, safety, and compatibility with existing machine conditions.

5. Evaluation

The final stage is evaluation. The proposed solution is evaluated by comparing conditions before and after implementation. The evaluation focuses on improvements in mirror condition, reduction in damage occurrence, and enhancement of inspection performance. The results of this evaluation are used to determine the effectiveness of the proposed solution.

B. Fishbone Diagram

A Fishbone Diagram is a tool used to analyze problems by identifying possible causes in a structured and visual manner. A Fishbone Diagram was used to identify potential root causes contributing to Top Mirror Vision damage [6][7]. The diagram represents the problem as the head, while the contributing factors are categorized into several branches, such as Man, Method, Machine, Material, and Environment. This approach helps to systematically explore all possible causes and provides a clear overview of factors contributing to the problem.

In manufacturing industries, including semiconductor production, process failures often result from multiple interconnected factors. Therefore, the Fishbone Diagram is widely used to map relationships between causes and identify the most significant contributors. This method enables a comprehensive analysis and reduces the risk of overlooking important factors during problem identification.

Furthermore, the Fishbone Diagram serves as an initial step before conducting deeper analysis, such as root cause validation. By identifying all potential causes, the analysis can be narrowed down to the most relevant factors for further evaluation. This makes the Fishbone Diagram an effective and essential tool for analyzing process-related defects in industrial environments. The Fishbone Diagram used in this study is shown in Figure 7.

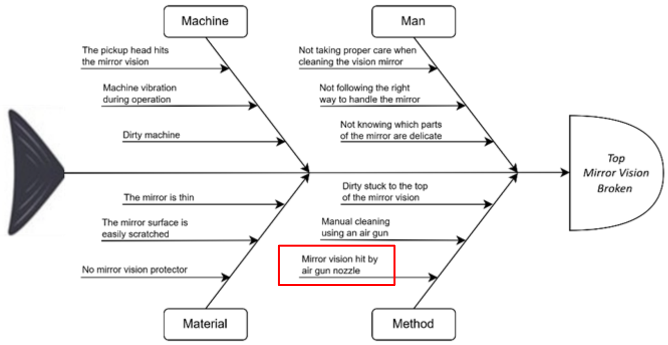


Figure 7. Fishbone Diagram of Top Mirror Vision Broken

C. Potential Root Cause Validation

After identifying potential causes using the Fishbone Diagram, a validation process is conducted to determine the most significant contributing factor. This validation is carried out through direct observation of the cleaning process in the production area, supported by collected data and documentation. The evaluation focuses on the condition of the mirror surface, patterns of damage, and the cleaning practices performed by operators.

The validation process also considers the frequency of damage occurrence across different inspection cameras and the consistency of the cleaning method applied. By analyzing these factors, less significant causes are eliminated, and the analysis is focused on the most relevant contributor to the problem. The validation results of each potential root cause are presented in Table II.

TABLE II
POTENTIAL ROOT CAUSE VALIDATION

Potential Root Cause	CURRENT CONTROL	Potential Root Cause (Y/N)
Not taking proper care when cleaning the vision mirror	Operators receive regular training on proper mirror handling	N
Not following the right way to handle the mirror	General operator training available	N
Not knowing which parts of the mirror are delicate	Basic machine briefing provided	N
The pickup head hits the mirror vision	Machine setting and mechanical limit available	N
Dirty machine	Regular cleaning schedule exists	N
Machine vibration during operation	Machine vibration is controlled through periodic preventive maintenance.	N
Dirty stuck to the top of the mirror vision	Cleaning performed periodically	N
Manual cleaning using an air gun	Air gun commonly used for cleaning	N
Mirror vision hit by air gun nozzle	No fixed nozzle position or distance control during manual cleaning	Y
The mirror is thin	Mirror specification follows standard	N
The mirror surface is easily scratched	Mirror material as per supplier standard	N
No mirror vision protector	Visual check during maintenance	N

Based on the validation results, the lack of a fixed nozzle position and distance control during manual cleaning was identified as the primary root cause. Since the nozzle position depended entirely on the operator, the nozzle could be positioned inconsistently and potentially enter the Top Mirror Vision area, increasing the risk of accidental contact with the mirror surface. This condition may result in physical damage, such as scratches or cracks, which can degrade inspection performance.

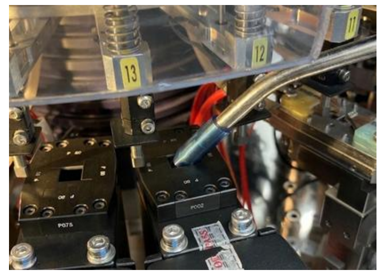


Figure 8. Air Gun Nozzle Inserted into the Top Mirror Vision Area During Cleaning

Figure 8 shows the manual cleaning process where the air gun nozzle was inserted into the Top Mirror Vision area to clean the mirror surface. Since no fixed nozzle position or distance control was provided, this cleaning method increased the potential risk of accidental contact with the mirror.

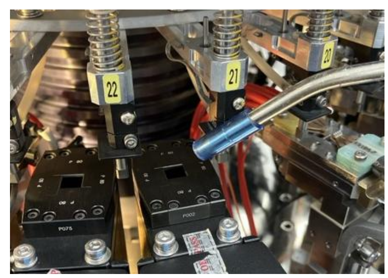


Figure 9. Air Gun Nozzle Positioned Outside the Top Mirror Vision Area During Cleaning

Figure 9 shows the manual cleaning process where the air gun nozzle remained outside the Top Mirror Vision area. This nozzle position reduced the possibility of accidental contact with the mirror surface during cleaning.

The One Point Lesson provides guidance on the manual cleaning procedure and instructs operators not to insert the air gun nozzle into the vision module. However, it does not define a specific nozzle-to-mirror distance or provide a physical positioning mechanism, resulting in operator-dependent nozzle positioning during the cleaning process.

D. Corrective Action

Based on the validation results, the identified root cause is the manual cleaning method using an air gun, which creates a high risk of direct contact between the nozzle and the mirror surface. Therefore, a corrective action is required to eliminate this risk and improve the reliability of the cleaning process.

The selected corrective action is the implementation of a semi-automated cleaning system to replace the manual cleaning method. This approach aims to minimize human error, prevent direct physical contact with the mirror surface, and ensure a more consistent and controlled cleaning process.

The proposed semi-automated cleaning system is designed to provide a safer cleaning mechanism for the Top Mirror Vision by utilizing regulated airflow to remove dust and contaminants without direct contact. The airflow direction and nozzle position are adjusted to maintain a safe distance from the mirror surface while ensuring effective cleaning.

In addition, the system is designed with a simple activation mechanism to improve ease of use and operational safety. This design ensures consistency in the cleaning process, reduces the risk of mechanical damage, and is compatible with existing TSP machine conditions. The proposed semi-automated cleaning system design is illustrated in Figure 10.

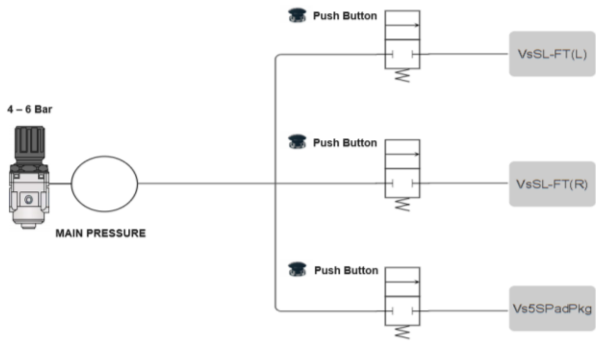


Figure 10. Semi-Automated Cleaning System Design

The system uses a 4–6 bar air pressure distributed to multiple inspection points. Each line is controlled by a push button to direct airflow to specific cameras. When activated, the airflow cleans the Top Mirror Vision without direct contact, ensuring a safer and more consistent cleaning process.

III. RESULT AND DISCUSSION

A. Implementation of Cleaning System

The semi-automated cleaning system was implemented on the TSP machine to replace the previous manual cleaning method, which had a high risk of direct contact with the Top Mirror Vision surface. The semi-automated cleaning system utilizes compressed air distributed through pneumatic tubing and operated using a push-button mechanism [8]. The system utilizes controlled airflow distributed through several inspection points using push button control valves. This implementation was designed to improve cleaning consistency, reduce operator-related risks, and minimize the possibility of physical damage during the cleaning process. The implementation of the semi-automated cleaning system on the TSP machine is shown in Figure 11.

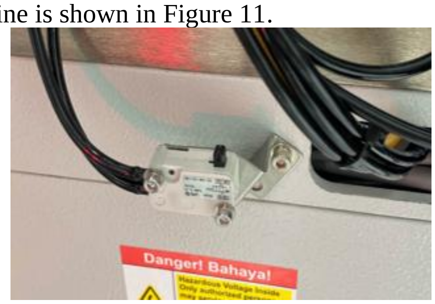
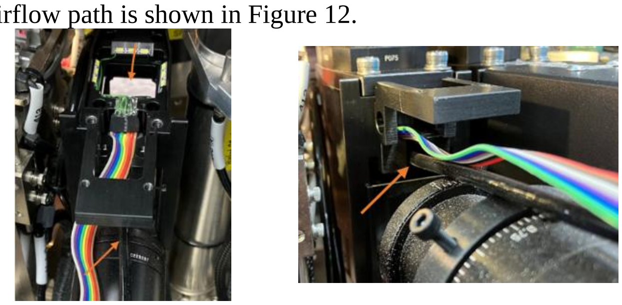


Figure 11. Implementation of Semi-Automated Cleaning System

To ensure a consistent cleaning process, the pneumatic tubing was routed and secured to provide a fixed airflow path toward the Top Mirror Vision. This fixed position eliminates the need for manual nozzle positioning, reducing operator dependency and minimizing the potential risk of accidental contact with the Top Mirror Vision. The fixed pneumatic airflow path is shown in Figure 12.



(a) Top View (b) Side View

Figure 12. Fixed Pneumatic Tubing Configuration for Top Mirror Vision Cleaning (a) Top View; (b) Side View

During operation, the operator activates the push button to release compressed air toward the Top Mirror Vision surface without direct contact. This mechanism allows contaminants on the mirror surface to be removed safely while maintaining a consistent cleaning process. The operation of the cleaning system using the push-button mechanism is shown in Figure 13.

Figure 13. Push Button Cleaning System Operation

B. Result After Implementation

After the implementation of the semi-automated cleaning system, data was collected to evaluate its effectiveness. The results show a significant improvement in the condition of the Top Mirror Vision.

Before implementation, Top Mirror Vision broken incidents were recorded on several inspection cameras due to direct contact during manual cleaning. However, after the implementation of the proposed system, the number of incidents decreased from 7 cases to 0 cases, resulting in a 100% reduction. The monitoring results after implementation are summarized in Table III.

TABLE III
TOP MIRROR VISION BROKEN INCIDENTS AFTER IMPLEMENTATION

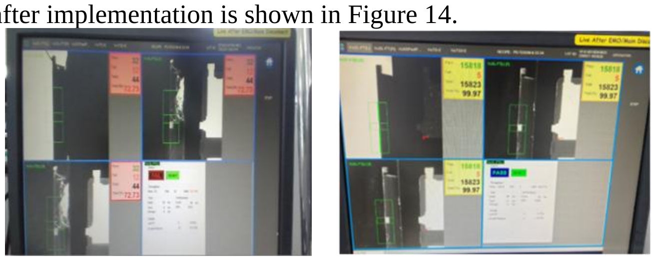
Month	WEEK	Number of Incidents
February 2026	Week 1	0
February 2026	Week 2	0
February 2026	Week 3	0
February 2026	Week 4	0
March 2026	Week 1	0
March 2026	Week 2	0
March 2026	Week 3	0
March 2026	Week 4	0
April 2026	Week 1	0
April 2026	Week 2	0
April 2026	Week 3	0
April 2026	Week 4	0
Total		0 Incidents

The implementation of the semi-automated cleaning system minimizes direct contact between the cleaning mechanism and the optical component, thereby improving inspection consistency and reducing the possibility of physical damage [9]. Before implementation, the cleaning process relied on direct operator handling using an air gun, as shown in Figure 11(a), which created a risk of contact between the nozzle and the mirror surface. After implementation, the cleaning process was performed using a push-button controlled airflow system, as shown in Figure 11(b), eliminating direct physical contact and improving cleaning consistency. The comparison of the cleaning process before and after implementation is shown in Figure 13.

(a) Before (b) After

Figure 14. Comparison of Implementation (a) before; (b) after

The improvement also affected the quality of the inspection results. Before implementation, the inspection image quality was less stable due to the condition of the Top Mirror Vision, as shown in Figure 12(a). After implementation, the inspection images became clearer and more stable, as shown in Figure 12(b), indicating that the mirror condition was maintained more effectively. The comparison of inspection results before and after implementation is shown in Figure 14.



(a) Before (b) After

Figure 15. Comparison of Implementation (a) before; (b) after

C. Discussion

The implementation of the semi-automated cleaning system successfully addressed the main root cause identified in the analysis process, namely direct contact between the air gun nozzle and the mirror surface during manual cleaning.

By replacing the manual method with a controlled airflow mechanism, the cleaning process became safer and more consistent. This improvement reduced the occurrence of mechanical damage and improved inspection stability.

The proposed improvement also reduces operator dependency by providing a more consistent and standardized cleaning process [10].

IV. CONCLUSION

This study successfully identified that the main cause of Top Mirror Vision damage in the TSP machine was the manual cleaning method using an air gun, which created a high risk of direct contact with the mirror surface. To address this issue, a semi-automated cleaning system was implemented using controlled airflow to eliminate direct physical contact during the cleaning process.

The implementation results showed that the number of Top Mirror Vision broken incidents decreased from 7 cases to 0 cases, achieving a 100% reduction. In addition, the system improved inspection stability and image quality, resulting in more reliable inspection performance. Therefore, the proposed semi-automated cleaning system proved to be an effective solution for reducing Top Mirror Vision damage and supporting stable production processes in the TSP machine.

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REFERENCES

[1] A. B. D. Al, R. M. Abu, and A. Mousavi, "A Review and Analysis of Automatic Optical Inspection and Quality Monitoring Methods in Electronics Industry," vol. 8, 2020, doi: 10.1109/ACCESS.2020.3029127.

[2] A. B. Goti, "Automated Optical Inspection (AOI) Based on IPC Standards," vol. 13, no. 03, pp. 26928–26947, 2025, doi: 10.18535/ijecs/v14i03.5052.

[3] Z. Ren, F. Fang, N. Yan, and Y. Wu, *State of the Art in Defect Detection Based on Machine Vision*, vol. 9, no. 2. Korean Society for Precision Engineering, 2022. doi: 10.1007/s40684-021-00343-6.

[4] Y. Du, J. Chen, H. Zhou, X. Yang, Z. Wang, and J. Zhang, "An automated optical inspection (AOI) platform for three-dimensional (3D) defects detection on glass micro-optical components (GMOC)," *Opt. Commun.*, vol. 545, no. July, p. 129736, 2023, doi: 10.1016/j.optcom.2023.129736.

[5] R. A. De Fretes, "ANALISIS PENYEBAB KERUSAKAN TRANSFORMATOR MENGGUNAKAN METODE RCA (FISHBONE DIAGRAM AND 5-WHY ANALYSIS) DI PT . PLN (PERSERO) KANTOR PELAYANAN KIANDARAT," vol. 16, no. 2, 2022.

[6] A. Page, S. H. Sakdiyah, N. Eltivia, and A. Afandi, "Journal of Applied Business , Taxation and Economics Research (JABTER) Root Cause Analysis Using Fishbone Diagram : Company Management Decision Making," vol. 1, no. 6, pp. 566–576, 2022, doi: 10.54408/jabter.v1i6.103.

[7] R. Arif and A. Gunawan, "Diagram Pareto dan Diagram Fishbone : Penyebab yang mempengaruhi Keterlambatan Pengadaan Barang di Perusahaan Industri Petrochemicals Cilegon Periode 2020-2022 Pendahuluan Landasan Teori," vol. 7, no. 1, pp. 1–10, 2023.

[8] "Basics of pneumatics -," *Educ. Resour. Effic. Manuf. Ind. EREMI*, 2022.

[9] A. Akundi and M. Reyna, "ScienceDirect ScienceDirect A Machine Vision Based Automated Quality Control System for Product Dimensional Analysis," *Procedia Comput. Sci.*, vol. 185, no. June, pp. 127–134, 2021, doi: 10.1016/j.procs.2021.05.014.

[10] A. Sioma, "applied sciences," *Vis. Syst. Prod. Qual. Control Syst.*, 2023.