talenta PUBLISHER

Jurnal Sistem Teknik Industri
Journal homepage: https://talenta.usu.ac.id/jsti



Continuous Improvement of Injection Moulding Systems Through the Integration of the A3 Problem-Solving Framework with a PLC-Based Magnetic Self-Cleaning Filter System in the Automotive Industry

Hibarkah Kurnia[*1], Dwi Indra Prasetya[1], Arif Nuryono[2], Asep Arwan Sulaeman[3], Rizki Hidayah[4]

[1]*Industrial Engineering Department, Faculty of Engineering, Universitas Pelita Bangsa, Jalan Inspeksi Kalimalang No. 09, Bekasi, West Java 17530, Indonesia*
[2]*Industrial Engineering Department, Faculty of Engineering, Universitas Bhayangkara Jakarta Raya, Jalan Raya Perjuangan Bekasi Utara, West Java 17121, Indonesia*
[3]*Informatic Engineering Department, Faculty of Engineering, Universitas Pelita Bangsa, Jalan Inspeksi Kalimalang No. 09, Bekasi, West Java 17530, Indonesia*
[4]*Industrial Engineering Study Program, Faculty of Engineering, Universitas Pelita Bangsa, Jalan Inspeksi Kalimalang No. 09, Bekasi, West Java 17530, Indonesia*
[*]Corresponding Author: hibarkah@pelitabangsa.ac.id

ARTICLE INFO

Article history:
Received 3 July 2026
Revised 20 August 2026
Accepted 30 October 2026
Available online 31 October 2026

E-ISSN: 2527-9408
P-ISSN: 1411-5247

How to cite:
H. Kurnia, Dwi Indra Prasetya, Arif Nuryono, Asep Arwan Sulaeman and Rizki Hidayah, "Continuous Improvement of Injection Moulding Systems Through the Integration of the A3 Problem-Solving Framework with a PLC-Based Magnetic Self-Cleaning Filter System in the Automotive Industry", *J. Sist. Tek. Ind.*, vol. 28, no. 4, pp. 256–269, October 2026.

ABSTRACT

Metal contamination in plastic resin is a critical issue in automotive injection moulding production systems. This contamination leads to product defects, check ring damage, cushion value instability, and high maintenance costs. This study aims to implement a continuous improvement approach using the A3 Problem-Solving method, centred on the design and implementation of a Programmable Logic Controller (PLC) based automated Preventive Magnetic Cleaning (PMC) system. This study addresses findings regarding design gaps in a PLC-based (Mitsubishi) self-cleaning magnetic filter system, integrated with the A3 problem-solving framework. The system automatically executes a cleaning cycle whenever material transfer occurs, thereby proactively preventing the magnetic shielding phenomenon without requiring manual intervention. The A3 framework was utilized to systematically identify the root cause via fishbone analysis, revealing the magnetic shielding phenomenon as the primary failure mechanism. As a technical solution, a neodymium magnet-based self-cleaning filter system was designed and installed on the auto-feed line of an 850T servo injection machine, controlled by a Mitsubishi PLC using ladder logic. Results demonstrated the elimination of manual cleaning interventions (2 hours/cycle), stabilization of cushion values from an average of 4.2 to 8.4 (within the standard range of 6–8), the capture of 100 grams of metal contaminants per week, and savings of IDR 47,000,000 in check ring replacement costs, with a payback period of 0.4–1.5 months. This study highlights the effectiveness of integrating lean management tools with automation technology as a sustainable continuous improvement strategy.

Keyword: A3 Problem-Solving, Continuous Improvement, Injection Moulding, Magnetic Self-Cleaning Filter, PLC Automation

ABSTRAK

Kontaminasi logam pada resin plastik merupakan masalah kritis dalam sistem produksi *injection moulding* otomotif. Kontaminasi ini menyebabkan cacat produk, kerusakan *check ring*, ketidakstabilan nilai *cushion*, dan tingginya biaya perawatan. Penelitian ini bertujuan untuk menerapkan pendekatan perbaikan berkelanjutan menggunakan metode pemecahan masalah A3, yang berfokus pada perancangan dan implementasi sistem *Preventive Magnetic Cleaning* (PMC) otomatis berbasis *Programmable Logic Controller* (PLC). Studi ini membahas temuan terkait celah desain pada sistem filter magnetik pembersih otomatis berbasis PLC (Mitsubishi) yang diintegrasikan dengan kerangka kerja pemecahan masalah A3. Sistem ini secara otomatis menjalankan siklus pembersihan setiap kali terjadi transfer material, sehingga secara proaktif mencegah fenomena *magnetic shielding* tanpa memerlukan intervensi manual. Kerangka kerja A3 digunakan untuk mengidentifikasi akar masalah secara berkala melalui analisis *fishbone*, yang mengungkap fenomena *magnetic shielding* sebagai mekanisme kegagalan utama. Sebagai solusi teknis, sistem filter pembersih otomatis berbasis magnet neodymium dirancang dan dipasang pada jalur pengumpanan otomatis (*auto-feed line*) mesin injeksi servo 850T, yang dikendalikan oleh PLC Mitsubishi menggunakan logika *ladder.* Hasil penelitian menunjukkan penghapusan intervensi pembersihan manual (2 jam/siklus), stabilisasi nilai *cushion* dari rata-rata 4,2 menjadi 8,4 (dalam rentang standar 6–8), penangkapan 100 gr kontaminan logam per minggu, serta penghematan biaya penggantian *check ring* sebesar Rp47.000.000, dengan periode pengembalian modal (*payback period*) antara 0,4 hingga 1,5 bulan. Studi ini menyoroti efektivitas integrasi perangkat manajemen *lean* dengan teknologi otomatisasi sebagai strategi perbaikan berkelanjutan yang andal.

Keyword: A3 Problem-Solving, Injection Moulding, Magnetic Self-Cleaning Filter, Otomasi PLC, Perbaikan Berkelanjutan

This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International.
http://doi.org/10.32734/jsti.v28i4.26330

1. Introduction

In the modern manufacturing ecosystem, plastic products have become integral components, replacing traditional materials such as glass, wood, and metal, particularly in the automotive sector [1]. Injection moulding is a primary production method that relies heavily on resin material quality and the stability of process parameters. It plays a crucial role in the production chain, particularly in manufacturing plastic components widely used for both vehicle interiors and exteriors [2]. This process is known for its ability to produce large volumes of products with high precision; however, it is also highly susceptible to various operational issues, such as product defects, machine downtime, and material contamination [3]. One of the key challenges in injection moulding systems is maintaining consistent product quality over the long term [4]. Material contamination, particularly by fine metal particles, is often the primary cause of defects such as black spots and flow marks, as well as a reduction in the product's mechanical strength.

These contaminants typically originate from the wear of machine components, material feeding systems, or the production environment. Consequently, employing magnets as filters within the material flow is a common solution for capturing these metal particles [5]. However, the effectiveness of the magnets depends heavily on their cleanliness; without routine and optimal cleaning, performance declines, and they can even become a source of new contamination. A critical challenge frequently encountered is metal contamination in the resin, which may stem from equipment degradation or the use of recycled material derived from internal waste [6]. These metal particles are abrasive and can damage vital components such as screws and barrels while also causing visual defects known as black dots. At PT. XYZ current contamination control relies on passive permanent magnets, which have significant limitations.

Preliminary data collected before corrective actions revealed several issues, including operational inefficiencies in the magnetic filter cleaning process; this manual task required two hours of labour from one worker, thereby disrupting production continuity. Furthermore, process instability led to fluctuating "cushion" values averaging 4.2 which fell below the ideal standard range of 6–8. This indicated backflow caused by micro-metal particles obstructing the check ring at the screw tip. Additionally, high costs were incurred due to premature component damage; the intensive cleaning process and check ring replacement entailed expenses amounting to IDR 47,000,000.

In many industries, the magnet cleaning process is still performed manually and based on a fixed schedule (time-based maintenance). This approach has several drawbacks, including imprecise cleaning timing (too early or too late), reliance on operators, and the absence of a system to monitor the magnet's actual condition. Consequently, the risk of failure in the material filtration system remains high, impacting both product quality and production efficiency. This study addresses the issue by applying a continuous improvement approach that integrates managerial and technical methods [7][8]. The A3 problem-solving method is used as a framework to systematically identify root causes in the field, ranging from analyzing the current situation to determining measurable countermeasures [9]. As a technical solution, Preventive Magnetic Cleaning (PMC) automation is implemented using a Programmable Logic Controller (PLC)-based magnetic self-cleaning filter system. The PLC is designed to control pneumatic actuators that automatically perform magnetic cleaning during every material transfer cycle, thereby eliminating the need for manual intervention [10].

In the context of continuous improvement, companies are required not only to resolve issues that arise but also to identify their root causes and prevent similar problems from recurring [11]. One widely used method in lean manufacturing practice is the A3 problem-solving method. This method is a systematic approach that emphasizes a comprehensive understanding of the problem, root cause analysis, and the development and implementation of sustainable solutions. By using the A3 format, the problem-solving process becomes more structured, transparent, and easy to communicate across teams [12]. The general framework of the A3 Problem Solving research method is illustrated in Figure 1.

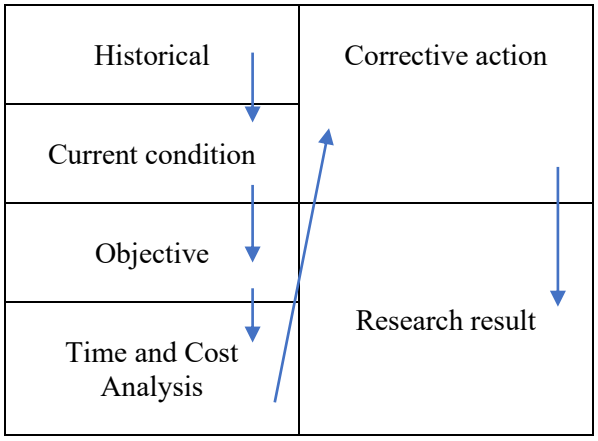


Figure 1. Research Framework for the A3 Problem-Solving Method

The application of the A3 method to improve the injection moulding system is expected to comprehensively identify the factors causing material contamination and the decline in product quality [13]. Furthermore, this method can assist in designing solutions that are not merely reactive but also preventive and sustainable. One potential solution is the development of a PMC automation system. By leveraging automation technology, the magnet cleaning process can be performed periodically based on actual conditions or specific parameters, thereby reducing reliance on manual intervention and enhancing system performance consistency. PMC automation also aligns with the concepts of smart manufacturing and Industry 4.0, wherein production processes are supported by smarter, integrated, and data-driven systems [14]. With this system in place, the company can monitor the condition of the magnets in real-time, determine the optimal cleaning schedule, and reduce the risk of material contamination. The impact extends beyond improved product quality to include reduced downtime, cost-efficient maintenance, and enhanced overall productivity [15].

Previous research on metal filtration systems in plastic manufacturing processes has generally focused on the technical aspects of enhancing magnetic performance. Wang et al. [16] Focusing research on optimizing magnetic flux density and separator geometry to maximize the capture efficiency of ferromagnetic contaminants. Cheng et al. [17] Developing a mathematical model to predict magnetic saturation capacity based on particle concentration in the material flow. Another study by Ghasemi et al [18] Proposing a multi-stage magnetic separator design to enhance contaminant capture selectivity.

However, there are three significant gaps in the existing literature. First, no research integrates PLC-based automated cleaning systems with real-time material transfer cycles; consequently, preventing contaminant accumulation still relies on human intervention. Second, problem-solving approaches in previous studies tend to be purely technical, lacking the integration of lean management methodologies such as A3 Problem-Solving that enable a systematic understanding of root causes from an operational perspective. Third, existing studies

rarely provide a comprehensive evaluation of financial impacts, including calculations of payback periods and long-term maintenance cost savings resulting from the implementation of automated filtration systems.

This study addresses this gap by designing a PLC-based (Mitsubishi) magnetic self-cleaning filter system integrated with the A3 Problem-Solving framework. The system automatically executes a cleaning cycle whenever material transfer occurs, thereby proactively preventing the magnetic shielding phenomenon without the need for manual intervention. Consequently, this research offers a dual contribution: a technical innovation in filtration system automation and a systematic managerial approach to continuous improvement. Optimization efforts for metal filtration systems in the industry generally remain focused on increasing magnetic flux density and modifying separator geometry to achieve maximum contaminant capture efficiency [16][17]. This research offers novelty through the integration of an automated control system. It involves the design and construction of a PLC-controlled magnetic self-cleaning filter system. The system automates the contaminant cleaning cycle in real-time based on material transfer duration, thereby preventing the accumulation of particles that cause magnetic shielding and maintaining optimal filtration performance without the need for manual cleaning intervention.

However, the implementation of automation-based solutions cannot be carried out without a deep understanding of existing conditions and the root causes of the issues at hand. Therefore, integrating the A3 Problem-Solving method with the development of automation systems represents a relevant and strategic approach [9]. The A3 method plays a role in systematically identifying and defining problems, while PMC automation serves as an innovative and sustainable solution implementation [19]. Based on the foregoing, this research focuses on the continuous improvement of the injection moulding system in the automotive industry through the application of the A3 Problem-Solving method and the development of PMC automation. The study aims to implement a continuous improvement approach using the A3 Problem-Solving method, integrated with the design and implementation of a PLC-based automated PMC system.

This research offers two primary contributions that provide added value to both the scientific community and the industry. First, from a technical perspective, it yields a prototype of a PLC-based magnetic self-cleaning filter system capable of eliminating the need for manual cleaning; the system utilises ladder diagram control logic adaptable to various injection moulding machine capacities. Second, from a managerial perspective, the research demonstrates the effectiveness of integrating the A3 Problem-Solving method as a systematic diagnostic framework for identifying the root causes of complex operational issues in an automotive manufacturing environment, while also showing that the lean thinking approach applies not only to manual process improvements but also serves as a foundation for decision-making regarding automation investments.

2. Method

This research methodology is designed to achieve continuous improvement in the injection moulding system by integrating A3 Problem-Solving with automated preventive magnet cleaning. The study employs an applied research approach based on an industrial case study, utilizing a combination of qualitative and quantitative analysis. The research was conducted at an automotive manufacturing facility in Cikarang over six months, with observations made before the improvements (February–April 2026) and following the improvements (May–July 2026). The research steps are outlined in Figure 2.

As illustrated in Figure 2, the study began with a business case analysis addressing the inefficiencies of manual cleaning which required 26 hours annually and the financial risks associated with critical asset damage. Root Cause Analysis (RCA) revealed that magnetic shielding and contaminant saturation were triggering mechanical malfunctions in the machine's check ring. This condition caused material backflow, destabilizing the cushion value to an average of 4.2 well below the company's operational standards. To achieve the desired future state, the study proposed replacing the passive system with an automated, PLC-based magnetic self-cleaning filter to maintain resin purity within the hopper. The solution incorporated an automated preventive maintenance strategy triggered during every transfer cycle to eliminate barrier layers on the magnet's surface. Implementation involved designing hardware using neodymium magnets and pneumatic actuators, alongside developing software in the form of a Mitsubishi PLC ladder diagram. The system was then integrated into the auto-feed line of an 850T servo-driven machine to eliminate human variability and stabilize production process parameters. Final measurements assessed operational time efficiency (zero manual interventions) and the effectiveness of metal contaminant capture, which reached 100 grams per week. Measurements also validated quality stability, with the cushion value improving to an average of 8.4, indicating that machine component functionality had been restored to optimal levels. This systematic methodology is expected to address

operational challenges while providing sustained financial protection against potential damage to high-value components.

3. Result and Discussion

This section will discuss the research results based on the methods used. The previous section explained that this study used the A3 problem-solving method, which is part of lean thinking, to reduce costs in an injection moulding system with automatic preventive magnetic cleaning in the automotive industry.

3.1. Business Care

In the plastic manufacturing industry, metal contamination in resin is a critical issue that can compromise product quality and accelerate the wear of machine components. At PT XYZ, the previous contamination control system relied on passive permanent magnets and was heavily dependent on manual intervention. This inefficiency not only disrupted production continuity but also posed workplace safety risks [20]. The maintenance costs for the plastic injection machine over the past three years are shown in Figure 3.

<table>
<tr><th>Business Care</th><th>Future State</th></tr>
<tr><td>1. Operational Inefficiency and Safety Risks: Current passive magnet systems rely heavily on inefficient manual cleaning, consuming significant technician time (approximately 26 hours annually).
2. Financial Losses due to Quality Degradation and Asset Damage: Incompletely filtered metal contamination leads to unstable cushion values (averaging 4.2 against a standard of 6–8) and premature damage to critical components such as screws, barrels, and check rings resulting in substantial repair and replacement costs.</td><td>1. Replacing the passive magnet system with an automatically operating Magnetic Self-Cleaning Filter.
2. Cleaning the magnet surface during every material transfer cycle prevents the accumulation of contaminant layers.
3. Utilizing a Mitsubishi PLC with ladder logic to automatically control the operational sequence.
4. Ensuring the purity of the resin material entering the hopper.
5. Implementing an automated preventive maintenance strategy to manage failure risks at an early stage.</td></tr>
<tr><th>Root Cause Analysis (RCA)</th><th>Action/Responsible/Due date</th></tr>
<tr><td rowspan="2">1. Accumulation of metal particles on the passive magnet surface, creating a barrier layer.
2. Periodic manual cleaning (once a week) causes the magnet to reach saturation between cleaning intervals.
3. Mechanical interference with the check ring: unfiltered micro-metal particles enter the machine and jam the check ring at the screw tip.
4. Abrasive damage to assets: the presence of unfiltered metal particles is abrasive, directly accelerating wear and physical damage to critical components such as the screw, barrel, and check ring.</td><td>1. Design and construction of a magnetic self-cleaning filter unit utilizing Neodymium magnets and pneumatic actuators to replace passive magnetic systems that require manual cleaning.
2. Implementation of a Mitsubishi PLC-based control system to automate the magnet cleaning cycle in real-time—based on material transfer duration—without interrupting the production process.
3. System integration into the machine's auto-feed line to eliminate operator involvement (0 MP) while maintaining the stability of quality parameters, such as cushion values and injection pressure.</td></tr>
<tr><th>Measurement</th></tr>
<tr><td></td><td>1. Operational time efficiency.
2. Contaminant capture effectiveness.
3. Quality stability (cushion value).</td></tr>
</table>

Figure 2. Research Steps

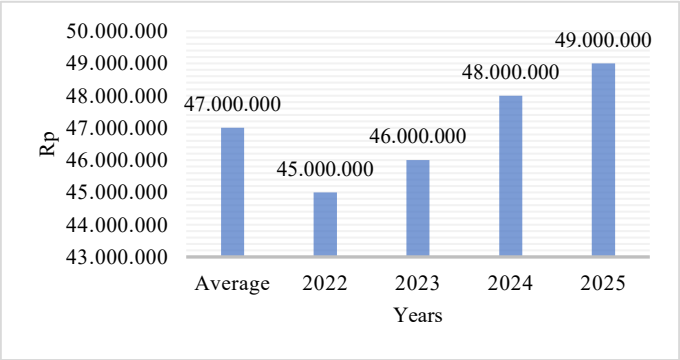


Figure 3. Maintenance Costs for Plastic Injection Machines

Based on Figure 3, the maintenance cost for the plastic injection machine including annual part replacements is IDR 47,000,000 per occurrence of backflow leakage caused by obstructing micro-metal particles, a situation that necessitates the use of a check ring at the screw tip. This upward cost trend indicates that, without systematic intervention, maintenance expenses will continue to place a significant burden on the company's operations. Observations made before the implementation of improvements yielded the data presented in Table 1.

Table 1. Observation of Problem Parameters

No	Activity Parameter	Remarks
1	Man-hour Efficiency	A single manual cleaning process for the magnetic filter requires two hours and the involvement of one operator (1 MP).
2	Quality Stability	The cushion value is unstable, averaging 4.2 a figure below the established operational standard (6–8).
3	Cost Burden	The cumulative cost for intensive cleaning and the replacement of check ring components damaged by contamination amounts to IDR 47,000,000.

As shown in Table 1, these three parameters are interconnected, forming a self-perpetuating cycle of issues. Man-hour inefficiencies lead to suboptimal cleaning frequencies, resulting in contaminant accumulation and process instability, which ultimately culminate in component damage and escalating maintenance costs. This cycle of problems provides a compelling justification for implementing systematic, preventive, and sustainable improvements. The condition of a fouled check ring requiring replacement is illustrated in Figure 4.



Figure 4. Nozzle disassembly process for check ring replacement

Figure 4 reveals a significant buildup of metal contaminants on the surface of the check ring. This condition causes mechanical interference in the form of material backflow during the injection phase. The impact is immediately evident in unstable cushion value fluctuations, as the contaminated check ring fails to seal properly, allowing resin to flow backward from the barrel toward the rear of the screw.

3.2. Root Cause Analysis

Following the nozzle disassembly process for check ring replacement (shown in Figure 4), the repair team concluded that the root cause was cushion instability resulting from magnetic shielding. The primary phenomenon involved was magnetic shielding, wherein an accumulation of metal particles on the magnet's surface formed a barrier layer that exponentially reduced the magnetic attractive force. Consequently, micro-sized metal particles bypassed the barrier and became trapped at the check ring located at the screw tip. This

caused material backflow during the injection phase, directly triggering fluctuations in cushion values and physical damage to the components. To address this, a team of seven maintenance experts held a troubleshooting meeting utilizing the Fishbone diagram method. During the meeting, a designated leader guided the analysis using the "5 Whys" technique, while the results of the Fishbone diagram analysis are presented in Figure 5.

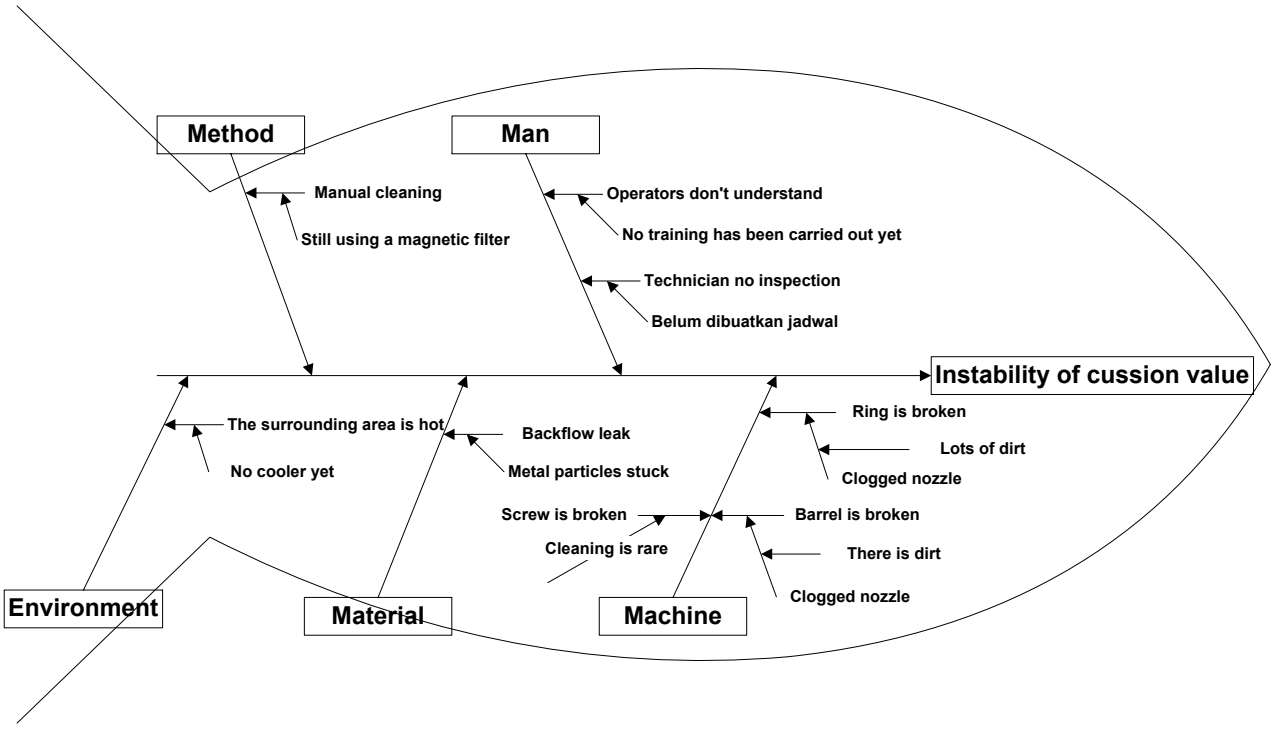


Figure 5. Fishbone diagram

Figure 5 displays a cause-and-effect analysis using the Ishikawa (Fishbone) diagram with four main categories of causes [21]. Regarding the "Man" category, it was found that operators did not understand the failure mechanisms of the magnetic shielding, and no training existed regarding the inspection of the magnetic filter's condition. In the "Method" category, cleaning schedules were not standardized and remained reactive. Under the "Machine" category, the barrel and screw exhibited abrasive wear caused by metal contaminants, and the nozzle was clogged. Regarding the "Environment" category, high ambient temperatures around the machine combined with the lack of a cooling system accelerated the rate of component degradation. These four categories synergistically contributed to the instability of the cushion value, which was the primary observed effect. Based on the RCA results, the components that sustained significant damage are summarized in Table 2.

Table 2. Damaged Components and Impact Analysis

No	Damage Part	Remarks
1		Manual magnetic filter: If the manual magnetic filter becomes fouled with metal contaminants, these particles will eventually migrate into the screw barrel.
2		Check ring: Metal particles accumulating on the magnetic filter can be carried into the screw barrel, leading to buildup on the check ring and causing backflow.

3.3. Future State

Based on the root cause analysis, the design and implementation of a PLC-based magnetic self-cleaning filter system are proposed. This system utilizes a Mitsubishi PLC to control pneumatic actuators that automatically clean the magnet during each material transfer cycle. The objective is to ensure the magnet

surface remains clean, thereby maintaining the magnetic flux at an optimal level for capturing contaminants, with a target average of 100 grams per week. The automation control panel featuring the Mitsubishi PLC is shown in Figure 6.



Figure 6. Automation control panel with Mitsubishi PLC

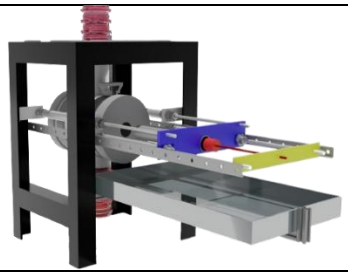
Figure 6 illustrates the automation control panel unit featuring a Mitsubishi PLC, which serves as the control brain for the entire system. The figure shows the control panel equipped with the Mitsubishi PLC, input/output (I/O) modules, and other supporting components. The panel is designed to integrate signals from cylinder position sensors with ladder logic that governs the operating sequence of the pneumatic actuators. The organized panel design facilitates easy maintenance and rapid troubleshooting in the event of system malfunctions.

System implementation involves two key aspects. On the hardware side, the unit is assembled using high-strength neodymium magnets, SMC pneumatic cylinders as actuators, and cylinder sensors for position feedback. On the software side, ladder logic is programmed into the PLC to manage delays and cleaning interruptions in real-time. The system is then integrated into the auto-feed line of an 850T servo-driven injection moulding machine.

3.4. Action

This section discusses the corrective measures to be implemented, including hardware fabrication, software development, and the integration of these components. Hardware assembly involves constructing the unit using neodymium magnets, SMC pneumatic cylinders, and cylinder sensors. Software development entails creating control logic via PLC ladder diagrams to manage delays and real-time cleaning interventions. Finally, the system is integrated by installing the device onto the auto-feed line of an 850T servo-type injection molding machine. Details regarding the pneumatic wiring configuration and automation filter unit components are provided in Table 3.

Table 3. Pneumatic Wiring Configuration and Automation Filter Unit Components

No	Automated Filter Unit Assembly	Remark
1		Unit illustration

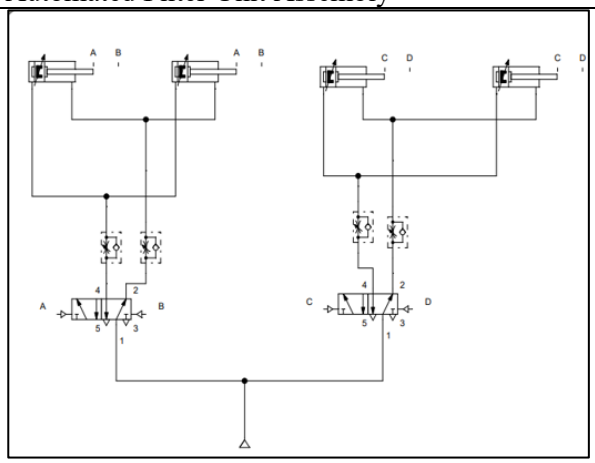
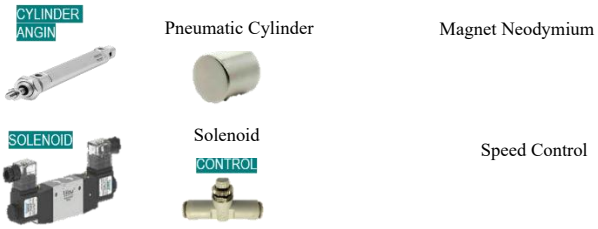
No	Automated Filter Unit Assembly	Remark
2		Wiring pneumatic
3		Automation filter unit

Table 3 presents the pneumatic wiring configuration and the automation filter unit assembly installed on the production system. It details the pneumatic system installation, which integrates the air compressor, solenoid valve, and SMC pneumatic cylinder into a unified circuit. The neat and protected wiring configuration ensures operational reliability within the hot and dusty production environment. The cleaning mechanism operates by driving a scraper linearly across the magnetic surface at the end of each material transfer cycle, thereby collecting contaminants adhering to the magnet into a collection bin that can be emptied periodically without halting the machine.

3.5. Measurement

Following the implementation of the automated system, an evaluation was conducted based on four key performance indicators. Table 4 summarizes the comparison of conditions before and after implementation for each indicator.

Table 4. Comparison of Results Before and After Implementation

No	Performance Indicators	Before Improvement	After Improvement
1	Cleaning Time (per cycle)	2 hours manual (1 person)	0 hours (automatic, 0 MP)
2	Total Hours/Year Lost	~26 technician work hours	0 hours (complete elimination)
3	Cushion Value (average)	4.2 (below the 6–8 standard)	8.4 (within standard range)
4	Contaminants Captured	Not measured (often saturated)	100 g per week
5	Check Ring Replacement Cost	IDR 47,000,000 per incident	Avoided (extended lifespan)
6	Investment Payback Period	-	0.4 – 1.5 months

Based on Table 4, the implementation of the automatic magnetic self-cleaning filter system successfully met all improvement targets established during the Future State phase. The complete elimination of wasted manual labour hours, the stabilization of cushion values within the standard range, and a significant reduction in maintenance costs serve as concrete evidence of the approach's effectiveness. Following the implementation of the automated system, the following results were achieved:

a. Elimination of Time Waste: The cleaning process operates fully automatically, eliminating the need for 2 hours of manual intervention and saving Rp 246,786 in man-hour costs per cycle.

b. Improved Process Capability: Cushion values stabilized, with the average rising to 8.4 falling within the

standard range and ensuring product dimensional accuracy.

c. Maintenance Cost Efficiency: Successfully extended the service life of the check ring, resulting in maintenance cost savings of Rp 47,000,000.

d. Financial Viability: The project offers a very rapid return on investment, with a payback period ranging from 0.4 to 1.5 months.

The integration of Lean Thinking and A3 Problem-Solving methods proved effective in transforming a wasteful manual process into an efficient automated system [22]. This automation not only provides financial protection against damage to company assets but also enhances the overall stability of the injection process [23]. The condition of the injection hopper before and after the installation of the automated filter unit is presented in Table 5.

Table 5 illustrates the condition of the injection hopper before and after the installation of the automated filter unit, visually demonstrating the system transformation that has taken place. The comparison clearly highlights a significant transformation in the filtration system. Before implementation, the injection hopper was equipped only with passive magnets lacking an automatic cleaning mechanism, making it susceptible to contaminant saturation. Following implementation, an automated filter unit was installed and integrated with the auto-feed line, featuring a pneumatic actuator system and a PLC control panel. This visual change represents a paradigm shift from a reactive, schedule-based cleaning approach to a preventive approach based on actual conditions. The results regarding filtering magnet strength and magnet condition are shown in Table 6.

Table 5. Condition of the Injection Hopper Before and After Installation of the Automated Filter Unit

No	Hopper Injection Conditions	Remarks
1		Hopper injection: Automated filter not yet installed.
2		Hopper injection after the installation of the automated filter unit.

Table 6. Results of Filter Magnet Strength and Magnet Condition Checks

No	Equipment Condition	Remark
1		Check ring unit
2		Checking filter magnet strength
3		The filter magnet is still in good condition

Table 6 presents the results of the filter magnet strength and condition checks, confirming that the magnets remained in optimal condition following the implementation of the automation system. These results verify that the automatic cleaning system operating during every material transfer cycle consistently maintains the cleanliness of the neodymium magnet surfaces. Magnetic strength measurements taken with a Gaussmeter showed stable values within the optimal operating range, demonstrating the successful elimination of magnetic shielding. This serves as technical confirmation that the implemented solution functions in accordance with the physical principles underlying its design.

3.6. Discussion with Previous Research

The findings of this study reinforce and complement existing research on magnetic filtration systems and continuous improvement in the manufacturing industry. The following systematic comparison identifies the position of this study's contribution within the existing body of literature. First, regarding the magnetic filtration system approach, the study by Wang et al.[16] Focusing on the geometric optimization of magnetic separators to enhance the capture efficiency of ferromagnetic particles in fluid flow, achieving an efficiency increase of up to 23%. Cheng et al. [17] Developing a mathematical model to predict magnetic saturation capacity based on particle concentration. Unlike the two aforementioned studies, which focused on magnet geometry design, this research addresses post-saturation operational issues specifically, preventing contaminant accumulation through automated cleaning based on production cycles. This approach is more applicable to continuous production conditions, as it does not require halting the machinery for cleaning.

Secondly, regarding the application of A3 Problem-Solving in the manufacturing industry, Krisna et al. [8] and Kurnia et al. [9] Documenting the effectiveness of the A3 method as a framework for communication and problem-solving in a lean manufacturing environment. Geraldo's research [12] It demonstrates that integrating A3 with fishbone-based root cause analysis can reduce problem-solving time by up to 40% compared to conventional approaches. This study aligns with those findings, as the use of A3 enabled the team to identify the magnetic shielding mechanism as the root cause an issue that had previously gone undetected by conventional schedule-based maintenance systems.

Third, regarding PLC-based preventive maintenance automation: Alif et al. [24] demonstrates that the implementation of a PLC-based condition monitoring system on injection moulding machines can reduce downtime. Basan et al. [25] The study found that integrating Supervisory Control and Data Acquisition (SCADA) and PLCs effectively balances a real-world assembly line, demonstrating that the proposed system

improves productivity, efficiency, throughput, workforce utilization, costs, and processing time. The results indicate a shorter payback period (0.4–1.5 months), attributable to the very high cost of component failures (IDR 47,000,000 per incident), thereby making the automation investment highly beneficial in relative terms.

Fourth, regarding the stability of injection moulding process parameters: research by Xue An et al. [26] Demonstrates that fluctuations in the cushion value exceeding 20% of the nominal value can lead to significant variations in product dimensions. The study found that an average cushion value of 4.2 representing a 47.5% deviation from the standard midpoint of 7 constitutes a highly critical condition. The increase to an average value of 8.4 following implementation indicates a dramatic stabilization of the process, consistent with the theory proposed by Silva et al. [27] That consistent cleaning of the filtration system is a key prerequisite for the stability of cushion values in injection moulding machines. Overall, this study provides empirical evidence that integrating a managerial approach (A3) with a technical solution (PLC automation) yields a more comprehensive impact than a purely technical approach, as it ensures the implemented solution truly addresses the root cause rather than merely treating visible symptoms.

3.7. Research Implications

The results of this study have significant implications at three levels: operational, managerial, and strategic. Regarding operational implications, the findings demonstrate that a PLC-based magnetic self-cleaning filter system can effectively eliminate the magnetic shielding phenomenon a critical source of process failure. This has direct implications for production and maintenance departments in the automotive plastics industry: first, the time-based preventive maintenance schedules currently in use have proven ineffective and need to be replaced by a condition-based maintenance approach; second, eliminating manual intervention in the filter cleaning process significantly reduces human-induced variability, thereby ensuring greater consistency in process quality; and third, investing in small-scale automation at critical points within the production system can yield a disproportionately large impact on product quality and component service life.

In terms of managerial implications, this study demonstrates the strategic value of the A3 Problem-Solving method as a diagnostic tool capable of uncovering root causes that remain invisible to conventional problem-solving approaches. These findings highlight the need for a data-driven problem-solving culture on the production floor, where every improvement initiative is preceded by an in-depth analysis of actual conditions and root causes, rather than relying merely on intuition or operator experience.

Regarding strategic implications, this study illustrates the relevance of smart manufacturing and Industry 4.0 concepts within the context of medium-scale manufacturing in Indonesia. The PLC-based automation implemented in this study represents an initial step that can be further developed through integration with Manufacturing Execution Systems (MES) or the Industrial Internet of Things (IIoT) to enable real-time and predictive machine condition monitoring. This aligns with the "Making Indonesia 4.0" policy initiative, which promotes the digital transformation of the national manufacturing industry.

4. Conclusion

The A3 Problem-Solving method successfully identified in a systematic manner that the primary root cause of quality issues and high costs associated with injection moulding machines at PT. XYZ was the phenomenon of "magnetic shielding." This phenomenon involves the accumulation of metal particles on the surface of passive magnets, forming a barrier layer that causes mechanical interference with the check ring. Conventional, schedule-based maintenance approaches previously employed had failed to identify this issue. This research has successfully developed a control panel equipped with a Mitsubishi PLC, input/output (I/O) modules, and other supporting components. The panel is designed to integrate signals from cylinder position sensors with ladder logic that governs the operating sequence of pneumatic actuators. The organized panel layout facilitates maintenance and accelerates troubleshooting in the event of system malfunctions. The Mitsubishi PLC-based automatic magnetic self-cleaning filter system designed and implemented in this study successfully eliminated the need for manual cleaning. Operating automatically during every material transfer cycle via a neodymium magnet-based pneumatic actuator, the system proactively prevents magnetic shielding without requiring operator intervention. Implementation of this automation system resulted in measurable performance improvements across all established indicators: (a) total elimination of 26 technician-hours per year previously wasted on manual cleaning; (b) stabilization of the cushion value from an average of 4.2 to 8.4, thereby meeting the company's operational standard (6–8); (c) consistent capture of 100 grams of metal contaminants per week;

and (d) savings of IDR 47,000,000 per check ring replacement incident, with a very short investment payback period of 0.4–1.5 months.

This research demonstrates that integrating Lean methodology (A3 Problem-Solving) with automation technology solutions (a PLC-based self-cleaning filter) constitutes an effective, efficient, and sustainable continuous improvement strategy for addressing material contamination issues in the automotive injection moulding industry. This approach not only provides a technical solution but also builds organizational capacity to manage complex problems systematically and based on data. Recommendations for future research include integrating digital Gaussmeter sensors with an IoT platform to monitor magnetic flux strength in real-time, allowing cleaning schedules to be determined based on the magnet's actual condition rather than solely on cycle timing. This would enable more adaptive optimization of cleaning frequency.

5. Acknowledgements

The authors extend their gratitude to PT XYZ for granting permission and providing research facilities, as well as to the entire team of technicians and operators in the production department who assisted with data collection and system implementation throughout the research.

References

[1] C. Jaqin, H. Kurnia, H. H. Purba, T. D. Molle, and S. Aisyah, "Lean Concept to Reduce Waste of Process Time in the Plastic Injection Industry in Indonesia," *Niger. J. Technol. Dev.*, vol. 20, no. 2, pp. 73–82, 2023, doi: 10.4314/njtd.v18i4.1396.

[2] R. Thorat and G. T. Mahesha, "Improvement in productivity through TPM Implementation," *Mater. Today Proc.*, vol. 24, pp. 1508–1517, 2020, doi: 10.1016/j.matpr.2020.04.470.

[3] F. Y. Agung and A. Siahaan, "Overall Equipment Effectiveness (OEE) Through Total Productive Maintenance (TPM) Practices: a Case Study in Chemical Industry," *Emerg. Mark. Bus. Manag. Stud. J.*, vol. 7, no. 1, pp. 23–36, 2020, doi: 10.33555/ijembm.v7i1.124.

[4] A. Zulaihan and N. Siswanto, "Modeling of Supplier Selection Strategy And Raw Material Order Allocation With Analytic Hierarchy Process Approach and Linear Programming at PT. IKSG," *Eduvest - J. Univers. Stud.*, vol. 5, no. 4, pp. 4079–4090, 2025, doi: 10.59188/eduvest.v5i4.17484.

[5] M. A. Yafi, S. Kustiwan, and T. N. Wiyatno, "Efisiensi Waktu Change Model Injection Molding Machine Menggunakan Metode Single Minute Exchange of Dies (SMED) di PT. XYZ," *G-Tech J. Teknol. Terap.*, vol. 8, no. 3, pp. 1859–1868, 2024, doi: 10.33379/gtech.v8i3.4610.

[6] P. Saothong, B. Ninchan, K. Sriroth, K. Rattanaporn, and W. Vanichsriratana, "Kinetics of saccharomyces cerevisiae fermentation under metal ions stress during ethanol production," *Walailak J. Sci. Technol.*, vol. 18, no. 6, pp. 1–10, 2021, doi: 10.48048/wjst.2021.9133.

[7] L. Setiawan and S. Hasibuan, "Improve Ramp-Up Performance on the Sewing Process in a Sports Shoe Factory Using 8-Disciplines and Lean Manufacturing," *Qual. Innov. Prosper.*, vol. 25, no. 2, pp. 19–36, 2021, doi: 10.12776/qip.v25i2.1516.

[8] K. B. Juliantoro, H. Kurnia, and S. R. Feriaty, "Reduction of changeover time and solvent cleaning cost in tank cleaning process in paint manufacturing industry in Indonesia," *TEKNOSAINS J. Sains, Teknol. dan Inform.*, vol. 12, no. 2, pp. 191–203, 2025, doi: 10.37373/tekno.v12i2.1520.

[9] H. Kurnia, K. Budi, and A. T. Zy, "Combination of Lean Thinking and A3 Problem-Solving Methods to Reduce the Cost of Purchasing Cleaning Agents in the Paint Industry in Indonesia," *Sinergi*, vol. 5, no. July, pp. 1–12, 2023, doi: 10.22441/sinergi.2024.1.011.

[10] M. Kumar, R. Vaishya, and Parag, "Real-Time Monitoring System to Lean Manufacturing," *Procedia Manuf.*, vol. 20, pp. 135–140, 2018, doi: 10.1016/j.promfg.2018.02.019.

[11] D. Sjarifudin and H. Kurnia, "The PDCA Approach with Seven Quality Tools for Quality Improvement Men's Formal Jackets in Indonesia Garment Industry," *J. Sist. Tek. Ind.*, vol. 24, no. 2, pp. 159–176, 2022, doi: 10.32734/jsti.v24i2.7711.

[12] G. M. Santos Filho and L. E. Simão, "A3 methodology: going beyond process improvement," *Rev. Gest.*, vol. 15, no. 4, pp. 1–15, 2022, doi: 10.1108/REGE-03-2021-0047.

[13] S. Perdana and D. Santoso, "Implementation of repairing production machine productivity of spare parts speaker based on OEE value achievement," *J. Appl. Res. Ind. Eng.*, vol. 6, no. 1, pp. 26–32, 2019, doi: 10.22105/JARIE.2019.169386.1075.

[14] S. Jaskó, A. Skrop, T. Holczinger, T. Chován, and J. Abonyi, "Development of manufacturing execution systems in accordance with Industry 4.0 requirements: A review of standard- and ontology-based methodologies and tools," *Comput. Ind.*, vol. 123, 2020, doi: 10.1016/j.compind.2020.103300.

[15] T. N. Wiyatno and H. Kurnia, "Increasing Overall Equipment Effectiveness in the Computer Numerical Control Lathe Machines Using the Total Productive Maintenance Approach," *J. Optimasi Sist. Ind.*, vol. 15, no. 2, pp. 284–292, 2022, doi: 10.31315/opsi.v15i1.7284.
[16] X. Li, Y. Wang, D. Lu, X. Zheng, and X. Gao, "Optimization of airflow field for pneumatic drum magnetic separator to improve the separation efficiency," *Minerals*, vol. 11, no. 11, pp. 1–9, 2021, doi: 10.3390/min11111228.
[17] R. Cheng, T. Zhu, and L. Mao, "Three-dimensional and analytical modeling of microfluidic particle transport in magnetic fluids," *Microfluid. Nanofluidics*, vol. 16, no. 6, pp. 1143–1154, 2014, doi: 10.1007/s10404-013-1280-z.
[18] M. Ghasemi, M. Govahi, and H. R. Litkohi, "Investigating the high gradient magnetic separator function for highly efficient adsorption of lead salt onto magnetic mesoporous silica microspheres and adsorbent recycling," *Int. J. Biol. Macromol.*, vol. 12, no. 4, pp. 1–23, 2024, doi: 10.1016/j.cep.2019.107770.
[19] L. Lin, W. Jiang, X. Xu, and P. Xu, "A critical review of the application of electromagnetic fields for scaling control in water systems: mechanisms, characterization, and operation," *npj Clean Water*, vol. 3, no. 1, pp. 1–19, 2020, doi: 10.1038/s41545-020-0071-9.
[20] D. Sjarifudin, H. Kurnia, A. Nuryono, and E. B. M. Tambunan, "Hazard Identification Risk Assesment and Determining Control (HIRADC) Method for Shoe Cutting Dies Production," *J. Sist. Tek. Ind.*, vol. 25, no. 09, pp. 322–333, 2023, doi: 10.32734/jsti.v25i2.12186.
[21] M. E. Beatrix and N. E. Triana, "Improvement Bonding Quality of Shoe Using Quality Control Circle," *Sinergi*, vol. 23, no. 2, p. 123, 2019, doi: 10.22441/sinergi.2019.2.005.
[22] A. I. Faria, J. C. Sá, M. T. Pereira, J. E. Sordan, and O. Mcdermott, "Assessing the Impact of Lean Tools on Sustainability — A Case Study," *J. Mech. Eng. Manuf.*, vol. 10, no. 4, pp. 1–25, 2026, doi: 10.53941/jmem.2026.100015.
[23] I. Zulkarnaen, A. Vendhy, A. Nuryono, and O. Widhi, "Benefits of implementing Industry 4 . 0 technology in health services," *J. Ind. Serv.*, vol. 10, no. 2, pp. 295–306, 2024, doi: 10.62870/jiss.v10i2.28364.
[24] S. A. Alif, A. I. Sakib, S. Shakur, S. Rafin, and B. Alam, "PLC Based Monitoring and Prediction : A Case Study of Injection Molding," *Proc. Int. Conf. Ind. Mech. Eng. Oper. Manag.*, vol. 26, no. 4, pp. 435–443, 2021.
[25] B. Tomar, N. Kumar, and M. Sreejeth, "A Smart PLC and SCADA based control framework for automated assembly line in process industry with effluent ratio control strategy," *Sadhana - Acad. Proc. Eng. Sci.*, vol. 50, no. 3, pp. 1–22, 2025, doi: 10.1007/s12046-025-02878-9.
[26] X. An, B. Huang, and D. Shi, "Cushioning properties and application of expanded polystyrene for a dynamic nonlinear system," *Eng. Reports*, vol. 5, no. 9, pp. 1–12, 2023, doi: 10.1002/eng2.12648.
[27] B. Silva *et al.*, "Enhance the Injection Molding Quality Prediction with Artificial Intelligence to Reach Zero-Defect Manufacturing," *Processes*, vol. 11, no. 1, pp. 1–24, 2023, doi: 10.3390/pr11010062.