



## **A PDCA Eight-Step Approach to Misrun Defect Reduction in Hatchback Gasoline Car Piston Castings**

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**Article Info :**

**Article history:**

Received: October 10, 2025

Revised: November 3, 2025

Accepted: January 2, 2026

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**Keywords:**

misrun defect; metal casting;  
PDCA cycle; eight-step approach;  
quality improvement.

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**Abstract**

**Background:** Misrun defects represent a critical quality issue in metal casting processes, particularly in gasoline piston manufacturing, as they lead to material waste, reduced productivity, and increased production costs. At PT XYZ, misrun defects constituted the highest proportion of total defects in 2024, indicating the need for systematic quality improvement.

**Objective:** This study aims to analyze the root causes of misrun defects in hatchback gasoline car piston castings and evaluate the effectiveness of corrective actions using the PDCA Eight-Step strategy.

**Method:** A qualitative–quantitative approach was employed through the application of the PDCA (Plan–Do–Check–Action) cycle with an Eight-Step problem-solving framework. Root cause analysis was conducted using fishbone diagrams and the 5 Why method. Corrective actions focused on mold design, cooling inspection procedures, and gas flow optimization.

**Results:** The findings show that misrun defects accounted for 52.56% of total defects, with piston type X contributing 9.84% of the overall misrun rate. After implementing corrective measures—namely additional and repositioned gas vents, standardized cooling mold inspections, and modified argon gas spray direction—the misrun defect rate was reduced to 5.16%. This represents a 47.5% reduction, exceeding the company's quality improvement target of 40%.

**Conclusion:** The PDCA Eight-Step strategy proved effective in significantly reducing misrun defects and improving casting quality. This study provides a practical and replicable framework for defect reduction in precision casting industries while reinforcing the theoretical relevance of structured PDCA-based quality improvement in manufacturing systems.

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**To cite this article:** Silitonga, M. P. R., Syafira, C. M., Setiyadi, R., & Putera, H. R. (2026). A PDCA Eight-Step Approach to Misrun Defect Reduction in Hatchback Gasoline Car Piston Castings. *Equivalent: Jurnal Ilmiah Sosial Teknik*, 8 (1), 1-12. <https://doi.org/10.59261/jequi.v8i1.237>

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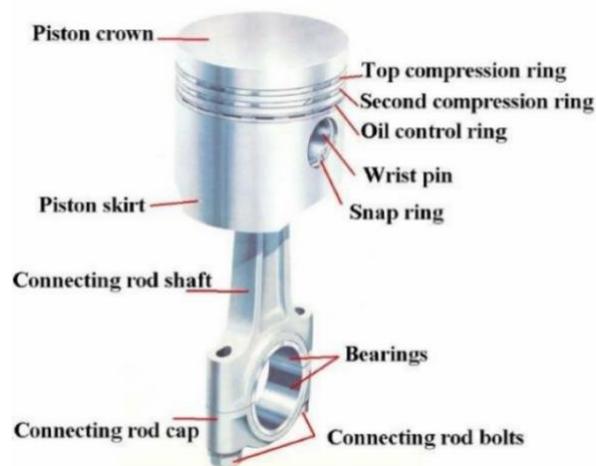
### **INTRODUCTION**

The growth of the automotive industry in Indonesia has driven an increase in demand for motor vehicles, particularly hatchback cars, which are popular due to their compact and efficient design (Silitonga & Khoirunnisa, 2024; Zakaria, 2014). One of the important components in a vehicle is the piston, which functions as a receiver of combustion pressure and plays a role in the

power transmission system from the combustion process to the motion mechanism (Kurniawan & Azwir, 2019). PT XYZ is one of the manufacturing companies in Indonesia engaged in the production of automotive components, including gasoline pistons for hatchback cars. The production process at PT XYZ applies metal casting technology using the gravity die casting method. However, during 2024, various types of production defects were found in the piston components produced, with misrun defects accounting for the largest proportion, namely 52.56% of the total defects. Specifically, the Gasoline X type piston product recorded the highest misrun defect rate of 9.84%, making it the main focus of quality improvement efforts.

Defect misrun occurs when molten metal solidifies before the mold cavity is completely filled, causing certain parts of the product to not form properly (Fauzy et al., 2021; Haq et al., 2024). This problem not only affects product quality but also increases production costs due to repair and recasting processes. Therefore, systematic and continuous improvement measures are needed. PT XYZ reported that in 2024 there were 37,315 misrun defects with an average defect percentage of 9.84% over 1 year. This study uses the PDCA (Plan-Do-Check-Action) method with an Eight Steps Problem Solving approach to analyze the root causes and implement solutions to misrun defects (Lestyánszka Škúrková et al., 2023). The identification process was carried out through observation, interviews, fishbone diagram analysis, and 5 why analysis. The solutions designed include the creation of additional gas holes, adjustment of the gas hole position on the flip core, addition of a cooling mold checking SOP, and modification of the argon gas jet direction (Faidin et al., 2024; Isniah et al., 2020; Made Suartika et al., 2024).

Pistons are important components in internal combustion engines, functioning to receive combustion pressure and transmit it to the crankshaft via the connecting rod (Chatterjee & Chakraborty, 2022; Teoh et al., 2023; Weber et al., 2023). Piston materials generally use aluminum-silicon alloys due to their heat resistance and good casting properties (Hermawati et al., 2020; Lohakare et al., 2022). In their manufacture, a casting manufacturing technique is used to mold molten metal into a mold according to the desired shape. One commonly used method is gravity die casting, which is the casting of metal using gravity to flow molten metal into a mold.



**Figure 1.** Piston

Source: Sucahyono, 2021

One of the main problems in the casting process is the appearance of defects, namely flaws in the cast product. Misrun is a type of defect that occurs when molten metal does not completely fill the mold due to premature solidification or poor metal flow (Cao et al., 2018; Rizkia et al., 2023). Misrun can cause structural damage such as holes, cracks, or low material strength. Factors that cause misrun generally include the design of the metal inlet (gating system), unstable mold temperature, poor ventilation, and metal oxidation due to exposure to air. The PDCA (Plan-Do-Check-Action) method is a continuous improvement cycle used in quality management to solve problems systematically (Fatah & Al-Faritsy, 2021). In the context of manufacturing, the PDCA approach is often combined with Eight Steps Problem Solving to increase effectiveness (Amin & Nawawi, 2018; Jonny, 2025). The eight steps consist of determining the theme, setting targets,

analyzing conditions, analyzing causes and effects, planning improvements, implementing improvements, evaluating results, and standardizing solutions.

Several previous studies have shown the effectiveness of the PDCA and eight steps methods in reducing defect rates. Fatah & Al-Faritsy (2021) noted a 22.95% reduction in production defects in refrigerators. Wahyudi & Ferdiansyah (2024) also showed that improvements in gate design and coating thickness settings were able to reduce misrun defects by 35% in cylinder head production. Based on the existing literature, it can be stated that the combination of the PDCA method and the eight steps approach can provide systematic and measurable improvement solutions in overcoming quality problems in the manufacturing industry. This study reinforces this approach by focusing on reducing misrun defects in X gasoline piston products, thereby contributing to quality control and production efficiency.

These studies indicate a gap in empirical research that combines PDCA with a systematic Eight Steps framework and validates its effectiveness through measurable defect reduction in a real industrial setting, particularly for misrun defects in gravity die casting. This study addresses that gap by integrating PDCA with the Eight Steps Problem Solving approach and implementing targeted technical interventions such as mold ventilation optimization, cooling inspection standardization, and gas flow modification specifically tailored to gasoline piston production at PT XYZ. The objective of this research is to identify the dominant causes of misrun defects, implement effective corrective actions, and quantitatively evaluate their impact on defect reduction. The findings provide both practical benefits, including reduced material waste, improved production efficiency, and enhanced product quality, and academic contributions by strengthening empirical evidence on the application of PDCA Eight Steps in precision casting processes within the automotive manufacturing sector.

## METHOD

### Research Method

This study uses a mixed method approach combining quantitative and qualitative methods. Quantitative methods are used to measure the level of misrun defects before and after repairs using simple statistical analysis, while qualitative methods are used to understand the root causes of defects through observation and in-depth interviews. The research was conducted at PT XYZ, a piston manufacturing company located in Cileungsi, Bogor Regency. The object of the research was the gravity die casting process for type X gasoline piston products, which had the highest misrun defect rate during 2024.

### Research Location and Object

The research was conducted at PT XYZ, a piston manufacturing company located in Cileungsi, Bogor Regency. The object of the research was the gravity die casting process for type X gasoline piston products, which had the highest misrun defect rate during 2024.

### Population and Sample

The study population comprised all type X gasoline pistons produced during the evaluation period from January to December 2024. The sample included defect data from three months with the highest misrun rates (identified through Pareto analysis) for pre-improvement analysis, and three months following intervention implementation for post-improvement evaluation. Census sampling was used for defect data collection, where all misrun defects occurring during the selected periods were recorded and analyzed.

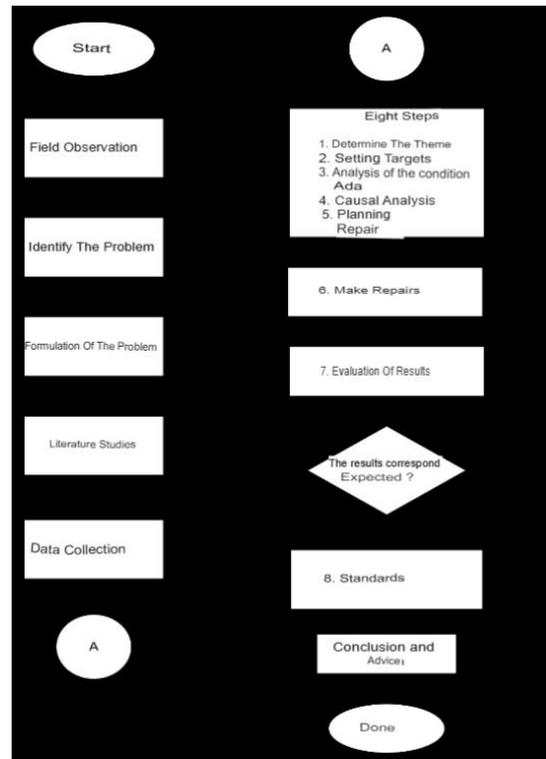
### Types and Collection of Data

This study utilized two data types: primary data acquired through direct production process observation and structured interviews with machine operators, casting supervisors, and relevant division heads; and secondary data derived from internal company reports encompassing production and defect data for 2024.

The research methodology comprised field observation for identifying actual production conditions and detecting potential defect causes, structured interviews with relevant stakeholders to explore in-depth causal factors of misrun occurrences, and documentation review for collecting historical data and production process records.

### Research Analysis

This study aims to reduce misrun defects in X gasoline pistons. Data obtained from field data collection was then processed in several stages, as shown in Figure 2



**Figure 2.** Research Flow Diagram  
source: author

Field observations were conducted in this study to identify problems occurring in the field, followed by problem identification within the company where defects were found in piston products, particularly misrun defects which had the highest defect rate compared to other types of defects. Problem formulation was then carried out in the study to collect existing problems, while the author conducted a literature study from books and journals as references to strengthen supporting theories and discuss ways to overcome misrun defects. Data collection was performed by the author to support the research, where the data was used as the basis for analysis.

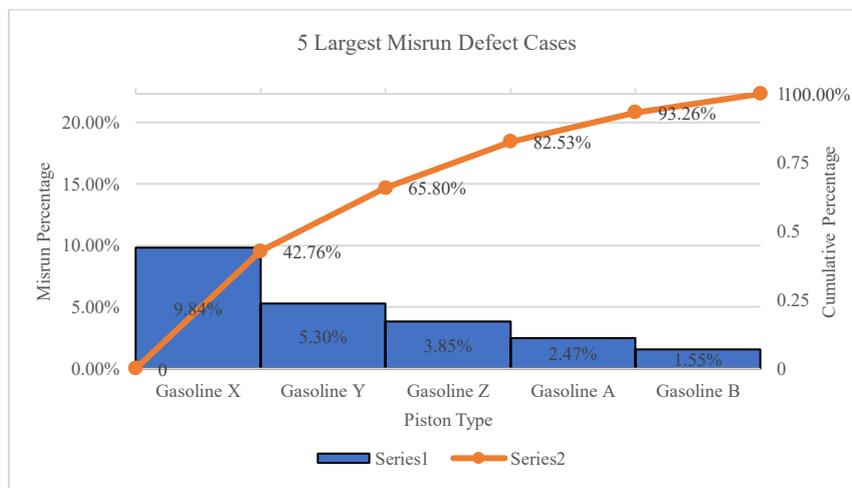
Theme determination in the eight-step method in this study was conducted to determine the time period and type of piston with the highest misrun defect rate, with the misrun defect reduction target established based on the company's standard target calculations. Analysis was then conducted in the field to identify factors that may cause misrun defects using the 4M + 1E method (man, machine, material, method, and environment), by examining aspects that did not comply with the applicable SOPs. Cause and effect analysis was carried out with the assistance of fishbone diagrams and why-why analysis tables to find the root causes of identified problems.

In the subsequent stage, an improvement plan was formulated to address existing problems using the 5W + 1H method to develop solutions based on the root causes of the problems, which were then implemented according to the established solutions. The improvement results were evaluated to determine whether there were changes, whether targets had been achieved, and whether the work met standards or still had shortcomings. The final stage was standardization, where standards were established as a reference for work procedures to ensure that the same problems would not recur in the future.

## RESULTS AND DISCUSSION

### Result

The analysis was conducted using the PDCA (Plan-Do-Check-Action) approach as a systematic framework for continuous improvement. In the Plan phase, the research theme was determined, defect reduction targets were established, and root causes were identified through fishbone diagrams and 5 Why analysis to ensure comprehensive understanding of the problems (Detera & Hanbal, 2024; Rahmana et al., 2021). The Do phase involved implementing solutions based on the formulated improvement plan, including mold modifications and work procedure adjustments to address the identified root causes. Subsequently, in the Check phase, the effectiveness of improvements was evaluated by comparing defect levels before and after corrective actions, providing quantitative evidence of the intervention's impact. Finally, the Action phase ensured improvement sustainability through standardization of successful solutions by developing additional SOPs and disseminating them to operators to prevent defect recurrence in subsequent production cycles.



**Figure 3.** Pareto Diagram of Data for the 5 Largest Misrun Defect Cases in 2024 source: processed data

The Pareto chart is used to determine problem priorities, while the effectiveness of improvements is calculated based on the percentage decrease in misrun defects using the company's internal formula. Based on an analysis of PT XYZ's production data for 2024 as shown in Figure 3, it was found that the most dominant type of defect in the hatchback gasoline piston casting process was misruns, accounting for 52.56% of total casting defects. Of the five gasoline piston variants, the Gasoline X type recorded the highest misrun rate of 9.84% of its total production, making it the main focus for quality improvement.

### Material Composition

The main material used to produce gasoline pistons X is A351. This material specification is a standard requirement from the customer. The material composition data shows that the total aluminum content for A351 material is 80.6%, which is an aluminum-silicon alloy. This alloy has good casting properties and is resistant to heat and corrosion. Table 1 shows the material composition.

**Table 1.** Composition of A351 Material

| Symbol                | Si    | Fe    | Cu   | Mn     | Mg    | Cr     | Zn     | Ti    | Na     | Ca     | Ni    | Pb     | P      | Al   |
|-----------------------|-------|-------|------|--------|-------|--------|--------|-------|--------|--------|-------|--------|--------|------|
| A351                  | %     | %     | %    | %      | %     | %      | %      | %     | %      | %      | %     | %      | %      | %    |
| <b>Min (Standard)</b> | 12,00 | -     | 4,50 | -      | 0,800 | -      | -      | 0,100 | -      | -      | 0,700 | 0      | 0,003  | -    |
| <b>Max (Standard)</b> | 13,50 | 0,300 | 5,50 | 0,100  | 1,20  | 0,050  | 0,100  | 0,200 | 0,003  | 0,0050 | 1,30  | 0,05   | 0,010  | -    |
| <b>Testing result</b> | 12,21 | 0,159 | 4,79 | 0,0085 | 1,09  | 0,0026 | 0,0089 | 0,128 | 0,0006 | 0,0013 | 0,974 | 0,0015 | 0,0036 | 80,6 |

source: processed data

Table 1 delineates the chemical composition specifications and actual testing results for A351 aluminum alloy material, presenting a comprehensive elemental analysis across fourteen constituent elements with their respective minimum and maximum standard threshold values expressed in percentage by weight. The compositional requirements establish silicon (Si) as the primary alloying element at 12.00-13.50%, copper (Cu) as the secondary constituent at 4.50-5.50%, and magnesium (Mg) at 0.800-1.20%, with trace additions of nickel (Ni), titanium (Ti), and controlled impurity limits for iron (Fe), manganese (Mn), chromium (Cr), zinc (Zn), sodium (Na), calcium (Ca), lead (Pb), and phosphorus (P), while aluminum (Al) constitutes the matrix balance.

**Analysis of Existing Conditions**

This analysis of existing conditions was conducted directly in the field to analyze several actual conditions that occurred, whether they were in accordance with standards or not, using several factors identified using the 4M + 1E method. Table 2 is the 4M+1E table.

**Table 2.** Root Cause Analysis Using 4M+1E Method

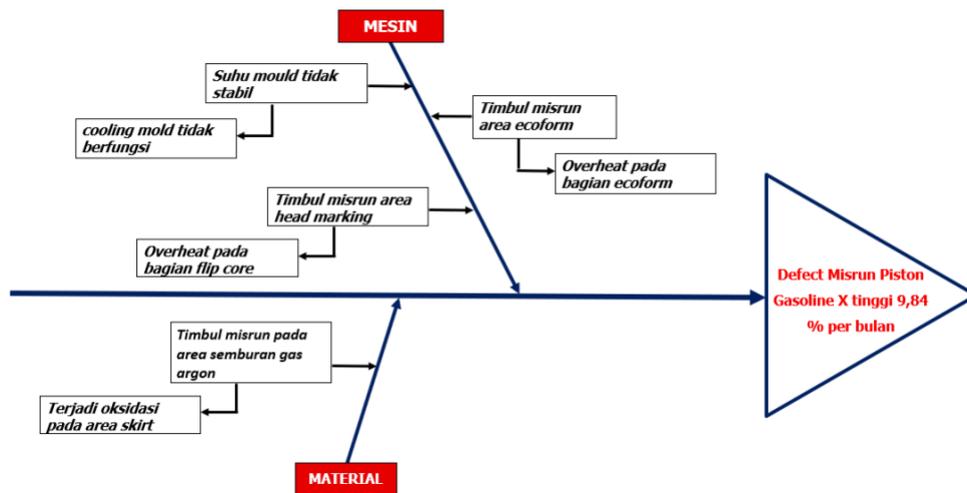
| Factor             | Item Cek                             | Ideal Condition  | Findings   | Judge          |
|--------------------|--------------------------------------|--|--|----------------|
| <b>Machine</b>     | Mold condition                       | The mold does not cause misruns.                             | Misrun occurs in the head area.  | Influential    |
|                    |                                      | The mold does not cause misruns.                             | Misrun occurs in the ecoform area.   | Influential    |
|                    |                                      | The mold temperature is stable.                              | Mold temperature is unstable.  | Influential    |
| <b>Material</b>    | Material composition                 | The material composition complies with standards.            | Material composition is in accordance with standards.                                    | No Influential |
| <b>Material</b>    | Argon gas installation               | The argon gas functions properly and does not cause misruns. | Argon gas installation is not functioning optimally and causes misrun in the skirt area. | Influential    |
| <b>Human</b>       | Operator skills                      | Operator skills comply with standards                        | Operator skills are in accordance with standards.  | No Influential |
| <b>Method</b>      | Pouring material into the mold       | The pouring method complies with standards.                  | Pouring method is correct and in accordance with standards.                              | No Influential |
| <b>Environment</b> | Lighting of the product viewing area | Lighting complies with standards.                            | Visual area lighting is in accordance with standards.                                    | No Influential |

source: processed data

Table 2 presents a root cause analysis of casting misrun defects using the 4M+1E methodology (Machine, Material, Man, Method, Environment), systematically comparing actual conditions against ideal operational standards. The analysis identifies three influential factors contributing to defect occurrence: mold-induced misruns in head and ecoform regions, mold temperature instability, and suboptimal argon gas installation causing skirt area defects. Conversely, material composition, operator skills, pouring methodology, and environmental lighting were deemed non-influential, conforming to established standards.

**Cause and Effect Analysis**

The identification of cause-and-effect relationships was carried out using a fishbone diagram and a 5 Whys analysis in table form to trace the root cause of the problem based on actual conditions in the field.



**Figure 4.** Pareto Diagram of Data for the 5 Largest Misrun Defect Cases in 2024 source: processed data

Figure 4 presents a visualization of the fishbone diagram that illustrates the misrun defect problem in the X-type gasoline piston. Table 3 is a 5 Whys analysis table used to find the root cause of the problem. From the results of this analysis, four root causes were obtained, consisting of three causes originating from the engine aspect and one from the material aspect.

**Table 3.** Why Analysis

| Factor  | Problem                      | Why 1   | Why 2  | Why 3   | Why 4   | Why 5 |
|---------|------------------------------|---|--|---|---|-------|
| Machine | Overheat area ecoform        | Hot air is trapped inside the ecoform area.   | There is no outlet or flow for hot air.                          | There are no gas holes in the ecoform section.              | The gas holes in the ecoform area have not been made.                               | -     |
|         | Overheat area flip core      | Hot air is trapped inside the flip core area. | The release of hot air from the flip core does not run smoothly. | The gas holes in the flip core are not working effectively. | The position of the gas holes on the flip core is not aligned with the misrun area. | -     |
|         | Cooling mold tidak berfungsi | Damage has occurred to the cooling mold.      | The damage was not detected from the start.                      | The cooling mold function is not checked regularly.         | No schedule has been set for checking the cooling mold.                             | -     |

| Factor          | Problem                          | Why 1                                       | Why 2  | Why 3   | Why 4  | Why 5 |
|-----------------|----------------------------------|---|--|---|--|-------|
| <b>Material</b> | Terjadi oksidasi pada area skirt | The skirt area is not exposed to argon gas. | The argon gas does not protect the entire side surface of the mold evenly. | The argon gas flow distribution does not reach the entire skirt area. | The argon gas is only installed on the upper side of the mold. | -     |

source: processed data

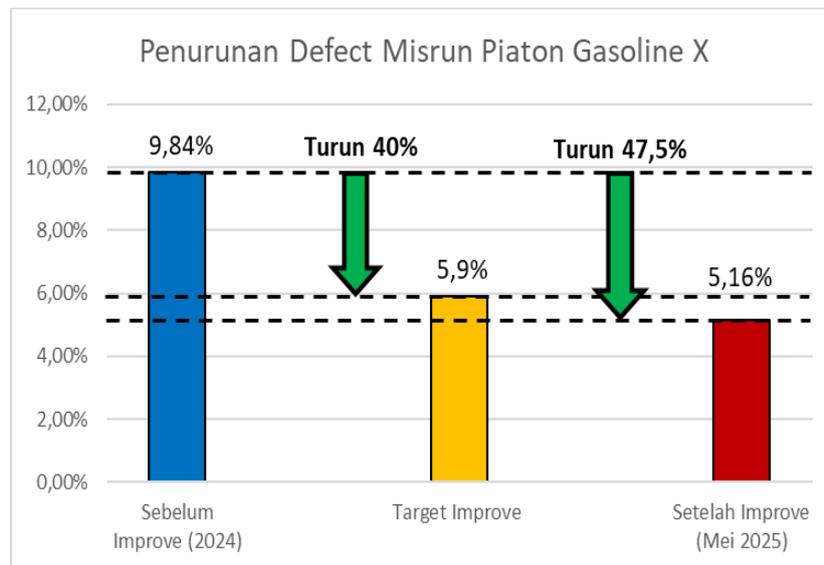
Table 3 shows why analysis, four primary root causes of misrun were identified, namely the absence of gas holes in the ecoform mold area, misaligned gas hole positions on the flip core with areas frequently experiencing misruns, lack of routine cooling mold inspection schedule, and insufficient argon gas flow coverage across the entire mold area due to suboptimal installation positioning.

### Improvement Implementation

Based on the identification results, improvements were implemented in accordance with the PDCA-Eight Steps method, including the creation of two new gas holes in the ecoform area with a diameter of 1 mm to reduce overheating and improve metal flow, repositioning of gas holes on the flip core to align with the misrun area, development and implementation of SOPs for routine cooling mold inspection at each shift change, and modification of argon gas jet direction to reach the skirt area more evenly.

### Result Evaluation

After the implementation stage, a re-measurement of the misrun defect rate was conducted during one month of production in May 2025. The results showed a decrease in the misrun percentage from 9.84% to 5.16%, or a decrease of 47.5%, exceeding the company's target of 40%, as shown in Figure 5.



**Figure 5.** Graph of Misrun Defect Reduction

source: processed data

Figure 5 illustrates the progressive reduction in defect rates for Misrun Piston Gasoline X across three temporal phases: pre-improvement baseline in 2024, target improvement threshold, and post-improvement achievement in 2024. The initial defect rate of 9.8% was strategically targeted for a 40% reduction to 5.9%, a goal that was successfully exceeded in the post-improvement phase, which achieved a defect rate of 5.16%—representing a 47.3% overall reduction from baseline.

**Table 4.** Comparison Before and After Repair

| No | Before Improve  | After Improve  |
|----|---|--|
| 1. |    |    |
| 2. |   |  |
| 3. |  |  |

source: processed data

Table 4 presents a comparative visual analysis of manufacturing defects in piston components, documenting three distinct specimens (numbered 1-3) in their pre-improvement and post-improvement states, with defect areas demarcated by red circular annotations for identification purposes. The before-improvement column reveals various casting defects including misrun formations, incomplete fill patterns, and surface irregularities—evidenced by visible voids, rough surface textures, and incomplete material deposition in the highlighted regions. Conversely, the after-improvement column demonstrates substantial quality enhancement across all specimens, characterized by complete metal fill, smooth surface finish, and elimination of the previously observed porosity and incomplete casting defects, with specimen 1 showing complete fill of the previously hollow cavity, specimen 2 exhibiting improved material consistency and density in the flagged region, and specimen 3 displaying enhanced surface integrity and reduced structural anomalies.

### **Standardization**

At this stage, standards are established as a reference for work procedures so that the same problems do not recur in the future. The standardization carried out is the creation of additional SOPs regarding the checking of cooling molds.

### **Discussion**

The findings demonstrate that the application of the PDCA cycle combined with the Eight Steps problem-solving approach is highly effective in reducing misrun defects in gravity die casting piston production. The Pareto analysis revealed that misrun defects accounted for 52.56% of total defects in 2024, with the Gasoline X piston contributing the highest proportion (9.84%). Root cause analysis using the 4M+1E framework, fishbone diagram, and 5 Whys method identified four critical factors: inadequate gas venting in the ecoform area, misaligned gas vent positioning on the flip core, lack of routine cooling mold inspection, and uneven argon gas distribution in the skirt area. These factors directly influenced molten metal flow behavior, premature solidification, and localized overheating, which are well-recognized causes of misrun defects in aluminum casting processes.

The corrective actions implemented during the Do phase—namely the addition and repositioning of gas vents, establishment of a cooling mold inspection SOP, and modification of argon gas spray direction—resulted in a significant reduction in misrun defects from 9.84% to 5.16%, achieving a 47.5% improvement and exceeding the company's target of 40%. This result aligns with previous studies that emphasize the effectiveness of PDCA-based continuous improvement in casting defect reduction. Systematic root cause identification combined with process standardization can substantially improve quality performance (Mahto & Kumar, 2008; Pietsch et al., 2024; Söylemez & Tarhan, 2018). Similarly, research found that improving mold ventilation and thermal management significantly reduced misrun occurrences in aluminum die casting, supporting the empirical results observed in this study (Cowell et al., 2022; Dybowski et al., 2023).

This research reinforces continuous improvement theory, which posits that defect reduction is most effective when technical interventions are integrated with procedural standardization and operator discipline. Practically, the study provides a replicable quality improvement framework for precision casting industries, particularly automotive component manufacturers facing similar misrun issues. The standardization of successful improvements through SOP development ensures sustainability and prevents defect recurrence, consistent with Total Quality Management (TQM) principles. Overall, the findings demonstrate that PDCA with an Eight Steps approach not only improves product quality but also enhances production efficiency, reduces material waste, and supports long-term operational excellence in manufacturing environments.

### **CONCLUSION**

The systematic PDCA-Eight Steps approach successfully reduced misrun defects in gasoline pistons X from 9.84% to 5.16% surpassing the 5.9% target with a 47.5% reduction rate by addressing four critical root causes: ecoform gas hole absence, misaligned flip core positioning, irregular cooling mold inspection, and suboptimal argon gas flow. This demonstrates that structured problem-solving methodologies yield measurable quality improvements in Indonesian metal casting operations when rigorously applied. However, the one-month evaluation period and single-product focus limit generalizability. Future research should extend validation periods to 6-12 months, employ DOE or CFD simulations for broader product line applications, and quantify economic impacts to strengthen implementation justification. Establishing continuous monitoring systems and cross-product SOP standardization will ensure sustained improvements and scalability across similar manufacturing contexts.

### ACKNOWLEDGEMENT

The authors would like to express their sincere appreciation to PT XYZ for granting permission to conduct this research and for providing access to production data, facilities, and technical information required for the study. Special thanks are extended to the production engineers, quality control staff, and operators who contributed valuable insights during field observations and interviews. The authors also acknowledge the support of colleagues and reviewers whose constructive comments helped improve the clarity and quality of this manuscript. Any remaining errors or interpretations presented in this article remain the sole responsibility of the authors.

### AUTHOR CONTRIBUTION STATEMENT

MPRS contributed to the conceptualization of the study, research design, data collection, root cause analysis, and drafting of the original manuscript. CMS was responsible for literature review, methodological development, data analysis, and interpretation of results. RS contributed to field observation, implementation of corrective actions, and evaluation of improvement effectiveness. HR Putera provided critical review, methodological refinement, data validation, and editorial revisions to enhance the academic rigor of the manuscript. All authors reviewed, revised, and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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