Type of Contribution:
Editorial
Research Paper
Review Paper
Case Study

ENERGY: JURNAL ILMIAH ILMU-ILMU TEKNIK
Vol. 16, No. 2 (2026) pp 288-304
DOI: 10.51747/energy.v16i2.p288-304
E-ISSN: 2962-2565

This article contributes to:
SUSTAINABLE DEVELOPMENT GOALS
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Quality Improvement Analysis of Timing Chain Cover Components Using Six Sigma DMAIC in an Automotive Component Assembly Line

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Abstract

Product quality is a critical factor in maintaining process stability and competitiveness in the automotive component manufacturing industry. An automotive component manufacturing company in Karawang, Indonesia, experienced quality problems in the Timing Chain Cover assembly process, particularly porosity and dantsuki defects. This study aims to analyze the defect rate, identify dominant critical-to-quality (CTQ) defects, evaluate process capability, determine potential defect causes, and propose improvement and control actions using the Six Sigma DMAIC approach. The research used production and quality inspection data from January to June 2025. The analysis was conducted through the Define, Measure, Analyze, Improve, and Control stages using defect rate, Defect Per Unit, Defects Per Million Opportunities, sigma level, p-chart, Pareto analysis, fishbone diagram, and 5W+1H improvement planning. The results showed that 1,142 CTQ defects were found from 64,130 units produced, consisting of 611 porosity defects and 531 dantsuki defects. The average defect rate was 1.78%, exceeding the company's internal target of less than 1.5%. The average DPMO value was 8,899, with a process capability level of 3.87 sigma. The p-chart result indicated that the process was statistically stable, but stable at a defect level that remained above the company target. The potential causes of defects were related to machine parameter stability, mould condition, SOP compliance, inspection discipline, material handling, measurement control, and workplace conditions. This study proposes prioritized improvement actions and a measurable control plan as recommendations for future implementation. The findings provide a practical DMAIC-based framework for identifying dominant defects, evaluating process capability, and

Article Info
Submitted: 2026-06-02
Revised: 2026-07-09
Accepted: 2026-07-10
Published: 2026-07-14

Publisher
Universitas Panca Marga

developing structured quality improvement strategies in automotive component assembly processes.

Keywords: Timing Chain Cover, Six Sigma, DMAIC, CTQ defects, DPMO, quality control.

1. Introduction

Product quality is a critical factor in maintaining competitiveness, process efficiency, and customer satisfaction in the automotive component manufacturing industry. Automotive components must meet strict dimensional, functional, and visual requirements because minor defects can affect reliability, assembly performance, and customer acceptance. Product defects may also lead to rework, scrap, additional inspection, production delays, and higher quality costs. Therefore, a systematic and data-driven quality control approach is required to identify dominant defects, reduce process variation, and maintain stable production performance [1].

Six Sigma has been widely applied as a data-driven quality improvement method to reduce defects and improve process capability. The Define, Measure, Analyze, Improve, and Control (DMAIC) approach provides a structured framework for defining quality problems, measuring process performance, analyzing root causes, proposing improvement actions, and maintaining process control [2]. Previous studies have shown that DMAIC can reduce defect levels, improve sigma performance, and support continuous quality improvement through tools such as DPMO measurement, Pareto analysis, and root cause analysis [3]. Other studies also reported that DMAIC is effective in improving process consistency and supporting corrective actions in automotive component manufacturing [4]. Recent research further confirms that DMAIC remains relevant for manufacturing defect reduction because it supports measurable improvement through rejection rate reduction, process efficiency improvement, and structured corrective actions [5].

Timing Chain Cover is an important automotive component because it protects the engine timing chain system and supports sealing performance. Defects in this component may affect surface quality, assembly compatibility, sealing function, and product reliability. In the automotive supply chain, defective components can also increase inspection workload, rework activities, delivery risk, and customer complaints. Therefore, defect prevention in Timing Chain Cover production is important to maintain product conformity and production stability.

An automotive component manufacturing company in Karawang, Indonesia, experienced quality problems in the assembly line of Timing Chain Cover components. Final inspection data from January to June 2025 showed 1,142 critical-to-quality (CTQ) defects from 64,130 units produced, consisting of 611 porosity defects and 531 dantsuki defects. The average defect rate reached 1.78%, exceeding the company's internal target of less than 1.5%. Porosity was selected as a CTQ defect because holes or cavities on the component surface may affect sealing performance and reliability. Dantsuki was selected because uneven step or height difference may affect assembly compatibility and dimensional conformity. These conditions indicate that the assembly process requires systematic analysis to identify dominant defects, measure process capability, and determine potential defect causes.

Previous studies on Six Sigma implementation have mainly focused on reducing defect rates and improving process performance in manufacturing sectors. However, several studies still provide limited discussion on the Control stage to maintain long-term process stability [6]. In addition, studies on automotive component defects often focus on general defect reduction, while specific analysis of porosity and dantsuki defects in Timing Chain Cover assembly processes remains limited. Recent studies also emphasize that future quality control should move toward preventive monitoring and zero-defect manufacturing through digital and Industry 4.0-based quality systems [7]. Therefore, this study extends previous Six Sigma applications by integrating defect characterization, process capability measurement, potential root cause analysis, improvement planning, and control strategy development within a specific automotive component assembly process.

This study aims to analyze the defect rate of Timing Chain Cover components, identify the dominant CTQ defects, evaluate process capability using DPU, DPMO, and sigma level, and determine the root causes of porosity and dantsuki defects using Pareto analysis and fishbone diagram. Furthermore, this study proposes improvement actions and a control plan to support continuous quality improvement in the automotive component assembly line.

2. Methods

This study used a descriptive quantitative approach with a case study method. The quantitative approach was applied because the analysis was based on numerical production and quality inspection data, including production volume, defect quantity, defect rate, Defect Per Unit (DPU), Defects Per Million Opportunities (DPMO), sigma level, and p-chart. The case study method was used because this research examined one specific production process, namely the Timing Chain Cover assembly line at an automotive component manufacturing company in Karawang, Indonesia. The Six Sigma DMAIC approach was selected as the main framework because it provides systematic stages for defining quality problems, measuring process performance, analyzing potential causes, proposing improvement actions, and preparing a control plan [8].

2.1 Research Object and Data Source

The object of this study was the Timing Chain Cover component produced in the assembly line of an automotive component manufacturing company in Karawang, Indonesia. Timing Chain Cover was selected because this component has an important function in protecting the engine timing chain system and supporting sealing performance. Defects in this component may affect surface quality, assembly accuracy, sealing function, and product reliability.

This study used production and quality inspection data from January to June 2025. The data consisted of monthly production volume, number of defective products, defect types, critical-to-quality (CTQ) defects, and internal quality targets. Primary data were obtained through direct observation of the assembly line and interviews with Quality Control personnel, Quality Assurance personnel, supervisors, and production operators. Secondary data were obtained from the company's internal Quality Control report. The data were used with company permission, and the company identity was anonymized to maintain confidentiality.

The production and CTQ defect data used as the basis of analysis are presented in **Table 1** This table describes the monthly production volume, porosity defects, dantsuki defects, total CTQ defects, and defect rate during the observation period.

Table 1. Production and CTQ defect data from January to June 2025

Month	Total Production	Porosity	Dantsuki	Total CTQ Defects	Defect Rate (%)
January	10,350	95	82	177	1.71
February	10,620	102	88	190	1.79
March	10,480	98	85	183	1.75
April	10,870	105	91	196	1.80
May	11,020	110	96	206	1.87
June	10,790	101	89	190	1.76
Total / Average	**64,130**	**611**	**531**	**1,142**	**1.78**

Source: Company internal data, processed by the author, 2025.

Table 1 shows that the total production of Timing Chain Cover components during the observation period was 64,130 units. The total CTQ defects consisted of 611 porosity defects and 531 dantsuki defects, resulting in 1,142 CTQ defects. The average defect rate was 1.78%, which exceeded the company's internal target of less than 1.5%. Therefore, further analysis was required to identify the dominant defects, measure process capability, and determine the root causes of defects.

2.2 Research Procedure

The research procedure was arranged based on the Six Sigma DMAIC framework. The stages consisted of problem identification, data collection, data processing, DMAIC analysis, improvement proposal, control plan formulation, and conclusion. The DMAIC framework was selected because it is suitable for analyzing production defects through measurable and systematic quality improvement stages [9].

The research procedure used in this study is presented in **Figure 1**. The figure shows the logical flow of the research from the initial problem identification to the formulation of improvement and control recommendations.

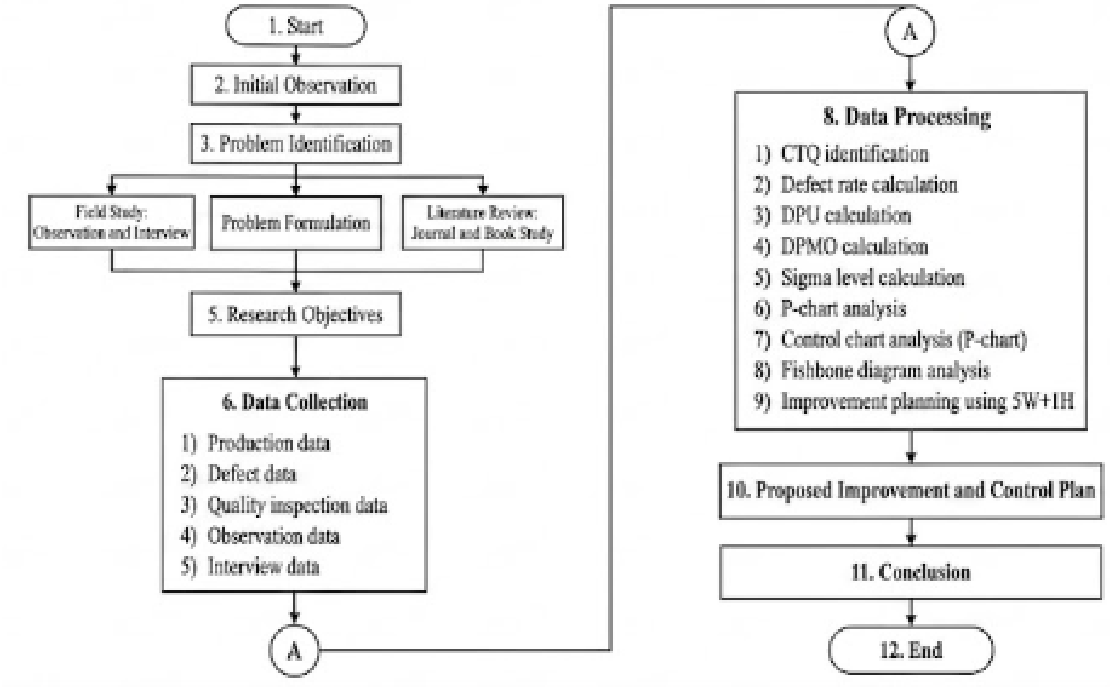

Figure 1. Research procedure based on Six Sigma DMAIC

Figure 1 shows that the research was conducted systematically. The process started with identifying quality problems in the Timing Chain Cover assembly line. After that, field observation and literature review were conducted to understand the process condition and theoretical basis. The collected data were then processed and analyzed using the DMAIC stages to determine CTQ defects, calculate quality performance indicators, identify root causes, propose improvement actions, and prepare a control plan.

2.3 Data Processing and Analysis

The collected data were processed using descriptive statistical analysis and the Six Sigma DMAIC framework. Microsoft Excel was used to tabulate production and defect data, calculate quality performance indicators, and prepare supporting tables and charts. The analysis focused on two critical-to-quality (CTQ) defects, namely porosity and dantsuki. Porosity refers to small holes or cavities on the component surface, while dantsuki refers to an uneven step or height difference on the component surface. These defects were selected because they had the highest contribution to total defects and directly affected product conformity.

The DMAIC framework was used as a structured analysis sequence. The Define stage was used to identify the quality problem and determine CTQ defects.

The Measure stage was used to calculate defect rate, DPU, DPMO, sigma level, and p-chart. The Analyze stage was used to identify dominant defects and potential root causes using Pareto analysis and fishbone diagram [10]. The Improve stage was used to formulate improvement recommendations using the 5W+1H approach, while the Control stage was used to prepare a control plan for process monitoring. Detailed interpretation of each DMAIC stage is presented in the Result and Discussion section.

2.4 Measurement Formulas

The performance of the Timing Chain Cover assembly process was measured using defect rate, DPU, DPMO, and sigma level. The defect rate was used to determine the percentage of defective products compared with total production [11]. The formula is shown in Equation (1).

$$\text{Defect Rate (\%)} = \left(\frac{\text{Total CTQ Defects}}{\text{Total Production}}\right) \times \mathbf{100\%} \tag{1}$$

DPU was used to calculate the average number of defects per unit produced. The formula is shown in Equation (2).

$$\text{DPU} = \frac{\text{Total CTQ Defects}}{\text{Total Production}} \tag{2}$$

DPMO was used to estimate the number of defects per one million opportunities. Since this study focused on two CTQ defects, namely porosity and dantsuki, the CTQ opportunity value was set at 2. The formula is shown in Equation (3).

$$\text{DPMO} = \left(\frac{\text{Total CTQ Defects}}{\text{Total Production} \times \text{CTQ Opportunity}}\right) \times 1{,}000{,}000 \tag{3}$$

The sigma level was obtained by converting the DPMO value using the standard Six Sigma conversion table with a 1.5 sigma shift assumption. A lower DPMO value indicates better process performance, while a higher sigma level indicates a more capable process [11].

3.Results and Discussion

3.1 Define Stage

The Define stage was conducted to identify the main quality problem, determine the critical-to-quality (CTQ) defects, and clarify the scope of improvement in the Timing Chain Cover assembly line. Based on company quality inspection data from January to June 2025, the average CTQ defect rate reached 1.78%, which exceeded the company's internal target of less than 1.5%. Therefore, the quality problem in this study was defined as the occurrence of dominant CTQ defects that affected product conformity and assembly process performance.

The CTQ defects were determined based on defect contribution and their impact on product conformity. The CTQ classification used in this study is presented in Table 2.

Table 2. Critical-to-quality defects of Timing Chain Cover components

No	CTQ Defect	Defect Characteristics	Impact on Product
1	Porosity	Small holes or cavities appear on the component surface	Reduces material strength and affects surface quality
2	Dantsuki	Uneven step or height difference appears on the component surface	Causes non-flat surface conditions and does not meet quality standards

Source: Company internal data, processed by the author, 2025.

Table 2 shows that porosity and dantsuki were selected as the main CTQ defects in this study. Porosity was prioritized because holes or cavities on the component surface may reduce sealing performance and product reliability. Meanwhile, dantsuki was prioritized because uneven step or height difference may affect dimensional conformity and assembly compatibility. These two defects became the focus of further analysis because they had the largest contribution to total defects and directly affected the quality requirements of Timing Chain Cover components.

The project scope was limited to the Timing Chain Cover assembly line at an automotive component manufacturing company in Karawang, Indonesia. The improvement focus was directed toward porosity and dantsuki defects, with the objective of evaluating process capability, identifying potential defect causes, and proposing improvement and control actions. The improvement target was to support the company's internal quality target of reducing the defect rate to less than 1.5%. This Define stage became the basis for the Measure stage, where defect rate, DPU, DPMO, sigma level, and process stability were evaluated.

3.2 Measure Stage

The Measure stage was conducted to evaluate the actual quality performance of the Timing Chain Cover assembly process based on production and CTQ defect data from January to June 2025. The measurement focused on defect rate, Defect Per Unit (DPU), Defects Per Million Opportunities (DPMO), sigma level, and p-chart analysis. These indicators were used to determine the process capability, evaluate the achievement of the company's internal defect target, and provide a quantitative basis for the Analyze stage.

To improve calculation transparency, January data were used as an example of process performance measurement. In January, the total production was 10,350 units and the total CTQ defects were 177 defects. Since this study focused on two CTQ opportunities, namely porosity and dantsuki, the DPMO calculation used two opportunities per unit [12].

$$\text{Defect Rate (\%)} = \left(\frac{177}{10{,}350}\right) \times 100\% = 1.71\%$$

$$DPU = \frac{177}{10{,}350} = 0.0171$$

$$\text{DPMO} = \left(\frac{177}{10{,}350 \times 2}\right) \times 1{,}000{,}000 = 8{,}551$$

Based on the Six Sigma conversion table, the DPMO value of 8,551 was equivalent to a sigma level of approximately 3.89. The same calculation procedure was applied to the production and CTQ defect data from February to June 2025.

The monthly calculation results of defect rate, DPU, DPMO, and sigma level are presented in **Table 3**.

Table 3. Quality performance of Timing Chain Cover assembly process

Month	Total Production	Total CTQ Defects	Defect Rate (%)	DPU	DPMO	Sigma Level
January	10,350	177	1.71	0.0171	8,551	3.89
February	10,620	190	1.79	0.0179	8,945	3.87
March	10,480	183	1.75	0.0175	8,731	3.88
April	10,870	196	1.80	0.0180	9,015	3.86
May	11,020	206	1.87	0.0187	9,347	3.84
June	10,790	190	1.76	0.0176	8,804	3.88
Total / Average	**64,130**	**1,142**	**1.78**	**0.0178**	**8,899**	**3.87**

Source: Company internal data, processed by the author, 2025.

Table 3 shows that the average defect rate of the Timing Chain Cover assembly process was 1.78%. This value exceeded the company's internal quality target of less than 1.5%, indicating that the process still required quality improvement. The highest defect rate occurred in May at 1.87%, while the lowest defect rate occurred in January at 1.71%. The average DPMO value was 8,899, with an average sigma level of 3.87. This result indicates that the process had not yet reached a high Six Sigma capability level and still had opportunities for defect reduction.

In addition to DPMO and sigma level calculation, p-chart analysis was used to evaluate the stability of the defect proportion during the observation period. The p-chart is appropriate for monitoring the proportion of defective units in a production process, especially when the sample size varies across periods [13]. The p-chart calculation results are presented in **Table 4**.

Table 4. P-chart calculation of CTQ defect proportion

Month	Total Production	Total CTQ Defects	Proportion (p)	CL	UCL	LCL
January	10,350	177	0.0171	0.0178	0.0217	0.0139
February	10,620	190	0.0179	0.0178	0.0217	0.0140
March	10,480	183	0.0175	0.0178	0.0217	0.0139
April	10,870	196	0.0180	0.0178	0.0216	0.0140
May	11,020	206	0.0187	0.0178	0.0216	0.0140
June	10,790	190	0.0176	0.0178	0.0216	0.0140

Source: Company internal data, processed by the author, 2025.

Table 4 shows that all monthly defect proportions were within the upper control limit and lower control limit. This indicates that the Timing Chain Cover assembly process was statistically under control during the observation period. However, the process average remained above the company's internal target of less than 1.5%. This condition means that the process was stable, but stable at an unacceptable defect level. Therefore, the quality problem was not caused by extreme monthly variation, but by recurring process conditions that consistently generated porosity and dantsuki defects.

The Measure stage confirms that the assembly process had an average defect rate of 1.78%, an average DPMO of 8,899, and an average sigma level of 3.87. These findings show that the process still had improvement opportunities, especially because CTQ defects occurred consistently every month. Therefore, the next stage focused on identifying the dominant defect contribution and determining the potential root causes of porosity and dantsuki defects.

3.3 Analyze Stage

The Analyze stage was conducted to identify the dominant defect types and determine the potential root causes affecting the quality of Timing Chain Cover components. In this stage, Pareto analysis was used to identify the defect types with the highest contribution, while fishbone diagram analysis was used to classify the potential causes based on man, machine, material, method, measurement, and environment factors. The results from this stage became the basis for formulating improvement actions in the Improve stage [14].

Although the Measure stage focused on 1,142 CTQ defects consisting of porosity and dantsuki, the Pareto analysis used the complete defect distribution to confirm the dominance of these two CTQ defects compared with other defect types. The overall defect distribution from January to June 2025 is presented in **Table 5**.

Table 5 shows that porosity was the most dominant defect, with 611 defects or 39.39% of total defects. Dantsuki was the second most dominant defect, with 531 defects or 34.24% of total defects. Together, porosity and dantsuki contributed

73.63% of the total defects. This result confirms that both defects were the main priority for root cause analysis and improvement planning. Although other defects such as dent, scratch, crack, step, peeling, kiriko, and kurokawa were still present, their contribution was lower than the two dominant CTQ defects.

Table 5. Pareto analysis of Timing Chain Cover defects

No	Defect Type	Number of Defects	Percentage (%)	Cumulative Percentage (%)
1	Porosity	611	39.39	39.39
2	Dantsuki	531	34.24	73.63
3	Dent	123	7.93	81.56
4	Scratch	90	5.80	87.36
5	Crack	48	3.09	90.45
6	Step	47	3.03	93.48
7	Peeling	39	2.51	96.00
8	Kiriko	35	2.26	98.26
9	Kurokawa	27	1.74	100.00
Total		**1,551**	**100.00**	

Source: Company internal data, processed by the author, 2025.

To visualize the dominance of each defect type and support improvement prioritization, the Pareto diagram was prepared based on the defect distribution in **Table 5**. The Pareto diagram is shown in **Figure 2**.

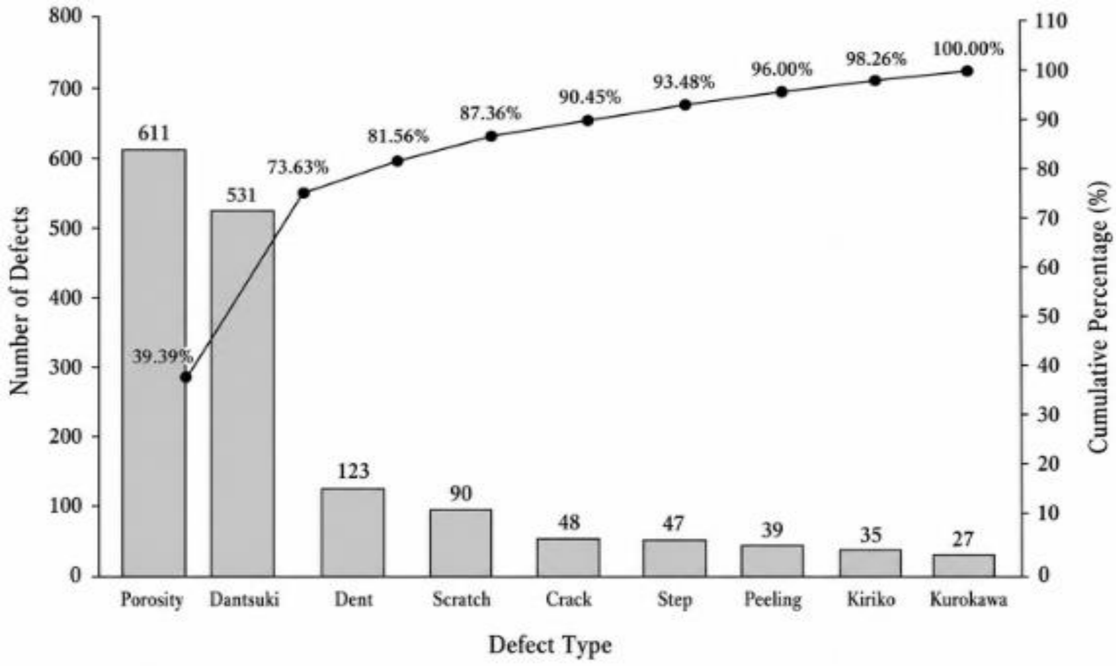

Figure 2. Pareto diagram of coating machine downtime components

Figure 3 shows that porosity and dantsuki were the two largest contributors to total defects. The cumulative percentage of both defects reached 73.63%, indicating that improvement actions should be prioritized on these two defect types. This finding supports the CTQ selection in the Define stage and confirms that the next analysis should focus on identifying the potential causes of porosity and dantsuki defects [15].

After identifying the dominant defect types, fishbone diagram analysis was used to classify the potential causes of porosity and dantsuki defects. The potential causes were grouped into six categories: man, machine, material, method, measurement, and environment. The fishbone diagram is shown in **Figure 3**.

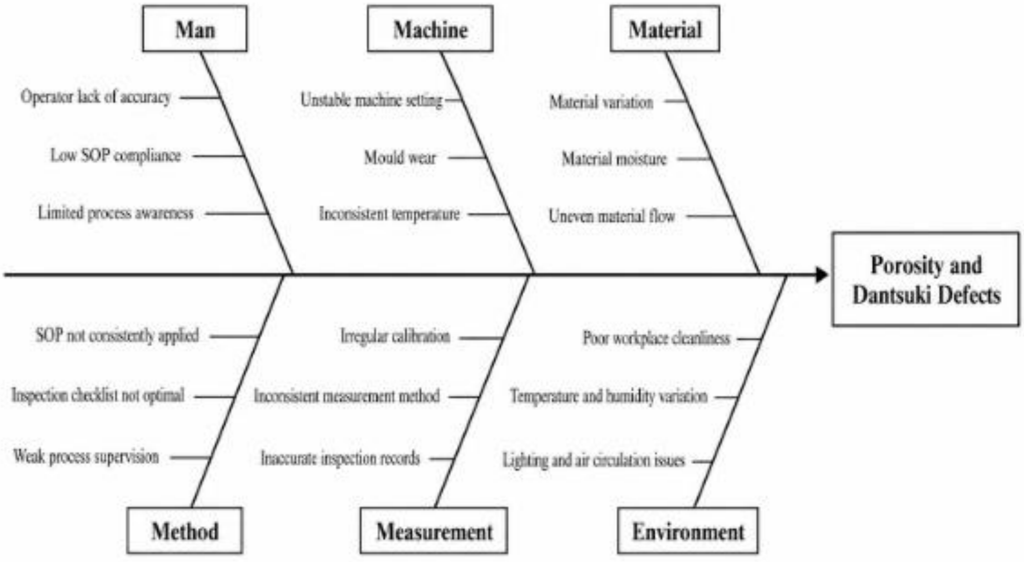

Figure 3. Fishbone diagram of porosity and dantsuki defects

Figure 3 shows that porosity and dantsuki defects were not caused by a single factor, but by a combination of several process-related factors. From the man factor, operator accuracy and SOP compliance were identified as potential causes. From the machine factor, unstable machine settings, mould wear, and inconsistent temperature could increase process variation. From the material factor, material variation, moisture, and uneven material flow could affect product surface quality. From the method factor, inconsistent SOP implementation and weak inspection control could increase the possibility of defects passing through the process. From the measurement factor, irregular calibration and inconsistent measurement procedures could reduce inspection accuracy. From the environment factor, workplace cleanliness, temperature, humidity, lighting, and air circulation could influence both production stability and inspection effectiveness.

To clarify the relationship between each defect type and its potential root causes, the root cause classification is summarized in **Table 6**.

Table 6 shows that the root causes of porosity and dantsuki were closely related to process variation and control weaknesses. Porosity was mainly associated with material moisture, unstable machine temperature, inconsistent SOP implementation, and weak measurement control. Meanwhile, dantsuki was mainly associated with mould setting error, mould wear, uneven material flow, and inconsistent dimensional inspection. These findings indicate that improvement actions should not only focus on operators, but also on machine parameters, material handling, measurement reliability, and workplace conditions.

Table 6. Root cause classification of porosity and dantsuki defects

Factor	Potential Causes of Porosity	Potential Causes of Dantsuki
Man	Operator lack of accuracy, low SOP compliance	Error in mould setting, low operator accuracy
Machine	Unstable machine temperature, poor machine monitoring	Mould wear, mould condition not properly controlled
Material	High material moisture, poor material storage	Uneven material flow, variation in material quality
Method	SOP not consistently applied, weak process supervision	Inspection process not optimal, weak quality supervision
Measurement	Irregular measuring instrument calibration, inconsistent parameter recording	Inconsistent dimensional measurement, irregular calibration
Environment	Poor workplace cleanliness, uncontrolled temperature and humidity	Poor workplace cleanliness, inspection environment not fully supportive

Source: Processed by the author, 2025.

Based on the Analyze stage, porosity and dantsuki were confirmed as the dominant CTQ defects in the Timing Chain Cover assembly process. The root cause analysis showed that both defects were influenced by man, machine, material, method, measurement, and environment factors. Therefore, the next stage focused on developing improvement actions using the 5W+1H approach to reduce the possibility of recurring defects and support process quality improvement.

3.4 Improve Stage

The Improve stage was conducted to develop improvement recommendations based on the root causes identified in the Analyze stage. The improvement actions focused on reducing the possibility of recurring porosity and dantsuki defects by controlling the main process factors, including man, machine, material, method, measurement, and environment. In the DMAIC framework, the Improve stage is used to formulate corrective actions based on verified root causes so that process performance can be improved in a systematic and measurable way [16].

The proposed improvement actions were arranged using the 5W+1H approach to clarify what action should be taken, why the action is needed, where it should be implemented, when it should be conducted, who is responsible, and how the action should be carried out. The proposed improvement plan is presented in **Table 7**.

Table 7 shows that the 5W+1H improvement plan was maintained but presented in a more concise format. The proposed actions address the main root cause factors affecting porosity and dantsuki defects, including man, machine, material, method, measurement, and environment. These actions are expected to support the company target of reducing the defect rate to less than 1.5%, although the actual impact still needs to be evaluated after implementation.

Table 7. Proposed improvement actions using 5W+1H approach

What	Why	Where	When	Who	How
Improve operator accuracy and SOP compliance	To reduce human error in the assembly process	Production area	Before and during production	Production supervisor and production leader	Conduct operator training, daily briefing, and SOP reinforcement
Standardize machine and mould control	To reduce process instability and surface defects	Production machine and mould area	Before production and periodically	Production operator and maintenance team	Standardize machine parameters, check mould condition, and apply preventive maintenance
Strengthen material inspection and storage	To reduce material variation and moisture-related defects	Material warehouse and production area	Before material is used	QC material staff and warehouse staff	Inspect incoming materials and improve material storage conditions
Standardize work method and inspection procedure	To minimize process variation between operators and shifts	Production and inspection area	During production	Production supervisor and QC staff	Update work instructions and use standardized inspection checklists
Improve measurement reliability	To increase inspection accuracy and reduce false judgment	QC area	Periodically and during inspection	QC staff	Calibrate measuring tools and standardize measurement recording
Control workplace conditions	To support stable production and effective inspection	Production area	Routinely	Production supervisor, QC staff, and all employees	Implement 5S and monitor cleanliness, temperature, humidity, lighting, and air circulation

Source: Processed by the author, 2025.

3.5 Control Stage

The Control stage was prepared to ensure that the proposed improvement actions can be monitored consistently if implemented by the company. This stage focuses on maintaining process stability, preventing recurring porosity and dantsuki defects, and supporting continuous quality improvement. In the DMAIC framework, the Control stage is important to sustain improvement results through monitoring, standardization, documentation, and corrective action when deviations occur [16]. The proposed control plan is summarized in **Table 8**. The table presents the main control aspects, monitoring activities, frequency, responsible parties, and reaction plans.

Table 8. Proposed control plan for Timing Chain Cover assembly process

Control Aspect	Monitoring Activity	Frequency	Responsible Party	Reaction Plan
Machine parameter	Check temperature, pressure, and process setting	Every shift	Production operator	Adjust parameter based on standard setting
Mould condition	Inspect mould wear, surface condition, and alignment	Periodically	Maintenance and QC	Repair or replace mould if abnormal condition is found
Material quality	Check material condition and storage suitability	Before production	QC material and warehouse staff	Hold material and report to supplier or related department
Operator compliance	Monitor SOP implementation and inspection discipline	Daily	Production leader	Conduct briefing and corrective instruction
Measurement accuracy	Check calibration status and inspection method	Periodically	QC staff	Recalibrate tool and repeat inspection if needed
Defect rate	Review daily or monthly defect trend	Daily and monthly	QC and supervisor	Conduct root cause review if defect rate exceeds target

Source: Processed by the author, 2025.

Table 8 shows that the control plan focuses on the main factors affecting porosity and dantsuki defects, including machine condition, mould condition, material quality, operator compliance, measurement accuracy, and defect rate monitoring. If the defect rate exceeds the company target of less than 1.5%, corrective action should be taken through parameter checking, mould inspection, material review, operator briefing, and repeated quality inspection. This control plan is expected to help the company maintain process stability and support continuous improvement in the Timing Chain Cover assembly line.

4. Conclusion

his study evaluated the quality performance of Timing Chain Cover components using the Six Sigma DMAIC approach. The results showed an average CTQ defect rate of 1.78%, exceeding the company's target of 1.5%. A total of 1,142 defects were identified from 64,130 units, with porosity and dantsuki accounting for 73.63% of all defects. The average process performance reached 8,899 DPMO and a sigma level of 3.87, indicating a capable but improvable process. Although the p-chart confirmed that the process was statistically stable, the defect level remained above the acceptable quality target, suggesting that quality issues were driven by recurring process conditions rather than abnormal variation.

Root cause analysis identified machine parameter stability, mould condition, SOP compliance, inspection discipline, material handling, measurement control, and workplace conditions as the primary contributors to defects. Accordingly, this study proposed practical improvement actions, including machine parameter standardization, routine mould inspection, SOP reinforcement, improved inspection discipline, material handling control, measurement calibration, workplace condition improvement, and continuous quality monitoring.

This study demonstrates that the DMAIC framework provides a systematic approach for identifying critical quality problems, prioritizing improvement actions, and establishing measurable control plans for automotive component manufacturing. However, the study was limited to a six-month dataset, and the proposed improvements were not implemented during the research period. Future studies should validate the effectiveness of the proposed actions through post-implementation evaluation using quality performance indicators such as defect rate, DPMO, sigma level, and statistical process control.

Acknowledgement

The authors would like to thank the automotive component manufacturing company in Karawang, Indonesia, for providing permission and access to production and quality inspection data used in this study. The authors also express their appreciation to the Quality Control, Quality Assurance, production, and maintenance personnel for their support during observation, interview, and data collection activities.

Authors' Declaration

Authors' contributions and responsibilities - The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation, and discussion of results. The authors read and approved the final manuscript.

Funding - No funding information from the authors.

Availability of data and materials - All data is available from the authors.

Competing interests - The authors declare no competing interest.

Additional information - No additional information from the authors.

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