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Controlling Material Mismatch in Stamping through Total Quality Management and the PDCA Approach

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Abstract. *Material mismatch in stamping can trigger defects, rework, scrap, and productivity loss because incorrect material directly affects forming quality and downstream stability. This study evaluates Total Quality Management implemented through the Plan-Do-Check-Act cycle to control material-usage errors on machine S1 in a stamping company. A case-study design was used by combining January 2025 baseline records, March 2025 post-improvement records, direct observation, Pareto analysis, root-cause analysis, and 5W1H action planning. Before improvement, production reached 500,560 pcs with 8,490 reject pieces and a 1.6961% reject rate. After corrective actions and standardization, production reached 418,886 pcs with 2,235 reject pieces and a 0.5336% reject rate. Total reject declined by 73.67%, while the material-mismatch category decreased from 5,360 pcs to zero. The findings confirm that clear material identification, verification checkpoints, operator discipline, and standard work effectively prevent dominant stamping defects.*

Keywords: *material mismatch; PDCA; quality control; stamping; total quality management*

I. INTRODUCTION

In manufacturing systems, quality performance is inseparable from operational efficiency, cost control, delivery reliability, and customer satisfaction. Defects generated on the shop floor reduce not only good output but also create hidden costs through rework, additional inspection, excess handling, delayed shipment, and the consumption of scarce machine capacity. This prevention-oriented view is consistent with foundational quality thinking, which states that quality should be built into the process rather than inspected only at the final stage (Crosby, 1979; Deming, 1986; Juran & Godfrey, 1999).

The stamping process is especially sensitive to material conformity because differences in grade, hardness, temper, thickness, and surface condition can alter bending response, burr formation, dimensional stability, and downstream assembly performance. Recent studies on stamping and metal-forming defects confirm that defect behavior is strongly influenced by material properties, process parameters, and control quality, making early verification and material traceability critical on the production floor (Huang et al., 2023; Zhang et al., 2025). Machine-vision and surface-inspection studies likewise show that defect prevention in stamping is moving toward tighter integration between process control and quality assurance rather than reliance on end-of-line inspection alone (Ma et al., 2025; Xia et al., 2025).

In the observed company, several materials used in the stamping area have a similar physical appearance when viewed quickly by operators during changeover. Materials with different grades and temper conditions may have similar width, thickness, and coil appearance, particularly when the remaining material from previous orders is returned to temporary storage. Under these circumstances, the risk of selecting the wrong material becomes high, especially when the labeling system is weak, operator briefing is brief, and verification before machine start-up depends too heavily on individual experience. Internal records indicated that material mismatch dominated reject in January 2025 and therefore

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represented a substantial operational and financial loss.

The problem is not merely technical, but socio-technical. The defect emerges at the intersection of people, methods, materials, storage practices, and setup routines. A solution focused only on inspection would therefore be insufficient. A more suitable approach is one that treats quality as a system property and improves the process at the source. Total Quality Management (TQM) offers such a framework because it integrates customer focus, process orientation, standardization, employee involvement, and long-term continuous improvement. Recent reviews and empirical studies consistently report positive links between TQM practices, quality performance, organizational outcomes, and sustainability in industrial contexts (Permana et al., 2021; Wassan et al., 2022; Alateyyat et al., 2024; Sagher et al., 2025; Xu et al., 2026).

In practical terms, TQM is not merely a philosophy. It requires operating mechanisms that align people, materials, methods, measurement, and control points so that defects are prevented at the source instead of corrected after they occur. One of the most widely used mechanisms for TQM implementation is the Plan-Do-Check-Act (PDCA) cycle. PDCA provides a disciplined logic for identifying the dominant problem, testing corrective action, checking results, and standardizing successful practices. Recent manufacturing case studies still confirm the relevance of PDCA for reducing reject, sustaining improvement, and strengthening problem-solving discipline in production systems (Singh & Gandhi, 2024; Naughton et al., 2024).

Previous studies published in Jurnal Ilmiah Teknik Industri show that defect reduction in manufacturing commonly relies on data-driven approaches such as Six Sigma, Statistical Process Control (SPC), FMEA, barcode-based control, and continuous-improvement logic. JITI articles documented successful applications of Six Sigma for product-defect reduction, quality control planning, and process improvement in yarn, bread, and steel-plate manufacturing settings (Putri & Primananda, 2021; Djunaidi et al., 2024; Djunaidi et al., 2025). Other JITI studies also reported that real-time tracking and traceability systems can strengthen defect prevention and process monitoring in manufacturing environments (Rusman et al., 2024), while lean-service and SOP-development studies reinforce the importance of standardized procedures and visible controls as a basis for improvement discipline (Pujiyanto et al., 2021; Asih & Fitriani, 2018).

Although the literature on quality management is extensive, practical studies that explicitly position material mismatch as the dominant reject source in stamping and evaluate the result of a TQM-PDCA intervention at the operational level are still limited. Much of the available stamping literature emphasizes forming simulation, surface-defect detection, and parameter optimization (Huang et al., 2023; Papavasileiou et al., 2024; Sánchez-Rodríguez et al., 2025), while broader quality-management studies often discuss general organizational outcomes rather than a specific shop-floor failure mode. This gap matters because material mismatch is not a trivial administrative error; in stamping, an incorrect material can immediately produce out-of-specification parts, generate burr or bending abnormalities, trigger setup rework, and consume significant labor hours and machine time.

Based on the company estimate, the January material-mismatch incident generated 5,360 rejected pieces and required rework attention involving four workers across two shifts, equivalent to approximately 16 labor hours. The direct operational loss linked to this problem was estimated at IDR 757,706. Although this amount does not fully capture hidden quality cost, it reinforces the urgency of a preventive intervention focused on material control. Therefore, this study aims to describe the baseline reject condition, identify the dominant reject categories and their root causes, formulate and implement corrective actions based on PDCA, and evaluate the improvement result using before-after production data.

Table 1 shows that the novelty of the present study lies in connecting a dominant stamping

Table 1. Positioning of the present study against related quality-improvement studies

Study	Context / method	Main finding	Gap addressed by this study
Putri & Primananda (2021)	Yarn defects; quality control	Data-based quality control reduced product defects	Did not address material mismatch in stamping
Asih & Fitriani (2018)	SOP development	Standard work stabilized process consistency	No before-after reject evaluation
Pujiyanto et al. (2021)	Lean service	Process redesign reduced service waste	Service context, not manufacturing material control
Djunaidi et al. (2024)	SQC and FMEA for bread	Defect priorities can be reduced through analytical control	No PDCA intervention on stamping operations
Rusman et al. (2024)	Barcode-based traceability	Real-time tracking improves process control	Traceability emphasized, but not material mismatch in stamping
This study	Stamping; TQM-PDCA	Dominant material mismatch was eliminated and total reject fell 73.67%	Provides shop-floor evidence for material-control improvement

reject problem with a practical TQM-PDCA intervention and evaluating the outcome using before-after production evidence. In other words, the contribution is not only methodological but also operational, because the study demonstrates how low-cost quality controls can be translated into measurable reject reduction on the shop floor. To clarify the observed production object, the flow of material usage in the stamping process is presented in Figure 1.

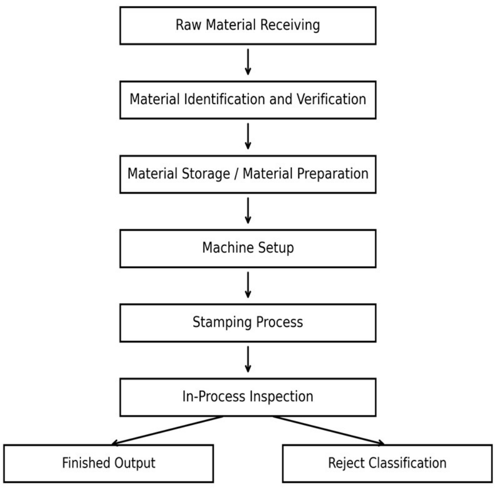

Figure 1. Flow of material usage in the stamping process

II. RESEARCH METHOD

This research employed a case-study approach in a stamping manufacturing environment. The unit of analysis was the production process at machine S1, with special emphasis on material use, reject generation, and work-standard compliance. The method was selected because the objective was not only to measure reject levels but also to understand the dominant failure source and evaluate the effect of corrective actions implemented on the shop floor.

The study used both quantitative and qualitative evidence. Quantitative data consisted of monthly production quantity, reject quantity, reject categories, and detailed January 2025 production records by material weight and output lot. Qualitative evidence was obtained from direct observation, discussion with operators and leaders, and examination of routine work practices related to material retrieval, material labeling, setup verification, and temporary storage handling.

The research design consisted of five steps. First, the baseline condition was documented using production and reject data. Second, Pareto analysis was used to identify the dominant reject category. Third, root causes were analyzed using the 5M logic consisting of man, method, material, machine, and environment. Fourth, a corrective action plan was formulated through PDCA and translated into practical measures using 5W1H.

Table 2. Operational indicators and data sources

Indicator	Definition	Data source	Purpose
Production output (pcs)	Total units produced per month	Production record	Measure process volume
Total reject (pcs)	Total rejected units per month	Quality record	Measure defect burden
Reject rate (%)	Reject quantity / production quantity x 100%	Calculated from records	Compare before and after
Material mismatch (pcs)	Reject caused by wrong material use	Reject classification	Identify dominant preventable defect
High burr, bending, missing hole, others	Other defect categories	Reject classification	Assess spillover effects after improvement
Direct operational loss	Estimated direct labor-related loss from mismatch event	Internal estimate	Strengthen preventive justification

Table 3. Baseline production profile of machine S1 in January 2025

Material weight (kg)	Production output (pcs)	Weight/pcs	Reject (pcs)
20.3	7,000	0.0029	115
155.6	55,571.43	0.0028	910
20.3	7,250	0.0028	120
108.4	57,052.63	0.0019	930
259.5	129,750	0.0020	2,250
13.5	13,500	0.0010	225
96.4	50,736.84	0.0019	830
359.4	179,700	0.0020	3,110
1,033.4	500,560	-	8,490

Fifth, improvement effectiveness was evaluated by comparing January 2025 and March 2025 performance.

The main performance indicator was reject rate, calculated as the ratio between reject quantity and production quantity. Improvement effectiveness was evaluated by comparing January 2025 (before improvement) and March 2025 (after improvement) data. The analysis also examined the change in each reject category to determine whether the intervention solved only the dominant problem or also created spillover effects on other defect categories.

In the Plan stage, the team identified the dominant reject source, reviewed work records, and mapped possible causes. In the Do stage, corrective actions included clearer material identity, segregation of similar materials, operator briefing, verification checkpoints before stamping, and revision of work instructions. In the Check stage, before-after reject data were compared. In the Act stage, effective actions were converted into standardized work practices, while unresolved defects were assigned as the focus of the next improvement cycle.

$$Reject\ rate = \frac{Reject\ quantity}{Production\ quantity} \times 100\%$$

III. RESULT AND DISCUSSION

Baseline production profile

The results are presented in a sequence that follows the logic of the intervention: baseline production profile, dominant reject pattern, root-cause analysis, corrective action design, and improvement evaluation. This structure keeps the analysis close to the operational problem while grounding the discussion in the TQM-PDCA framework.

Table 3 shows that the January baseline involved 1,033.4 kg of material and generated 500,560 pieces with 8,490 reject pieces. The lot using 359.4 kg material generated the highest reject count (3,110 pcs), followed by the 259.5 kg lot (2,250 pcs).

Together these two lots accounted for 63.13% of total January reject, indicating that

Table 4. Reject composition before improvement (January 2025)

Reject type	Reject (pcs)	Share (%)	Cumulative (%)
Material mismatch	5,360	63.13	63.13
High burr	1,740	20.49	83.63
Bending	1,155	13.60	97.23
Missing hole	200	2.36	99.59
Others	35	0.41	100.00
Total	8,490	100.00	100.00

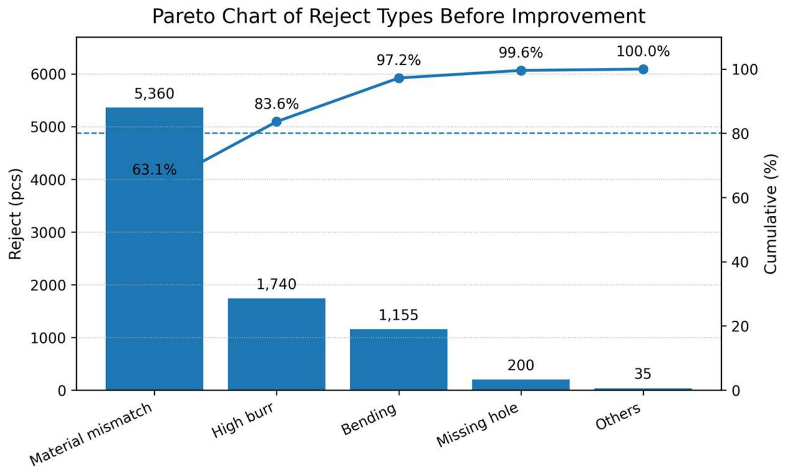

Figure 2. Pareto chart of reject types before improvement

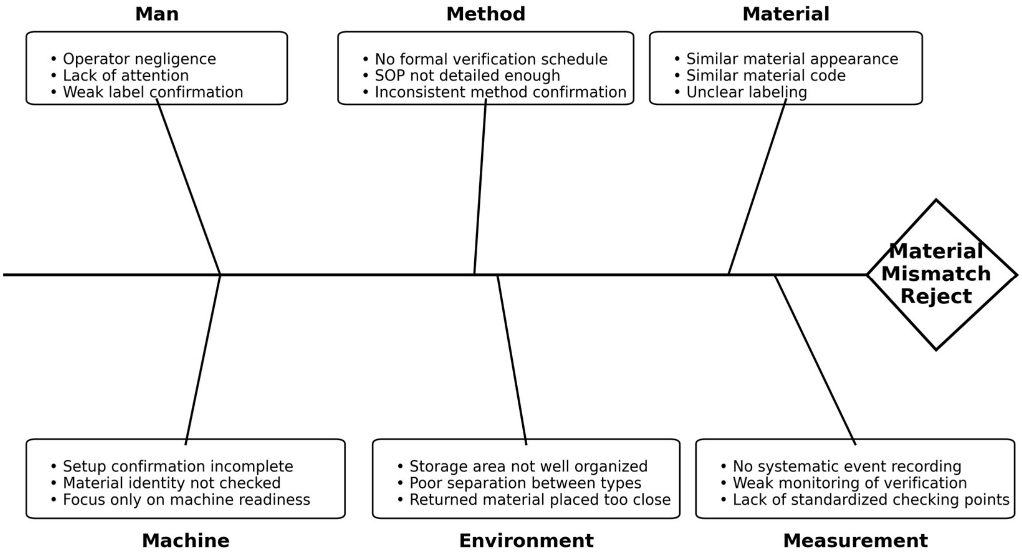

Figure 3. Fishbone diagram of material mismatch causes

improvement efforts should focus on dominant process conditions rather than treating all lots as equally problematic.

The Pareto pattern confirms that material mismatch was the critical defect and should become the main focus of the Plan stage. In quality-improvement logic, prioritizing the dominant source is essential because a relatively small number of causes often explains most of the loss, making corrective action more efficient and easier to standardize (Ishikawa, 1985; Pande et al., 2000). Similar prioritization logic is widely used in JITI studies that combine Pareto, root-cause analysis, and structured improvement proposals (Putri & Primananda, 2021; Untoro & Iftadi, 2020).

Based on the Pareto analysis, material mismatch was identified as the most dominant reject category. Therefore, a root-cause analysis was conducted using a fishbone diagram, as shown in Figure 3.

Figure 3 shows that material mismatch was caused by multiple interrelated factors, including operator negligence, unclear material labeling, weak verification procedures, insufficient work standardization, and inadequate workplace organization. These findings indicate that the material mismatch problem should be addressed through a systematic improvement approach rather than isolated corrective action.

Table 5. Estimated operational loss caused by material mismatch before improvement

Item	Value
Material mismatch reject	5,360 pcs
Workers involved	4 persons
Shifts affected	2 shifts
Rework attention time	16 hours
Estimated direct loss	IDR 757,706

The operational-loss estimate in Table 5 strengthens the case for preventive action. Even when the direct loss is calculated conservatively, the company still bears avoidable quality cost, labor consumption, schedule disturbance, and the risk of shipping incorrect parts. The quality literature emphasizes that such losses are often only the visible portion of a much broader cost-of-poor-quality problem (Crosby, 1979; Juran & Godfrey, 1999).

Root-cause analysis and corrective action design

The root-cause analysis shows that the dominant problem did not originate from a single technical parameter. Instead, it emerged from the interaction between human discipline, method clarity, material similarity, setup practice, and storage arrangement. This finding fits the TQM view that most quality problems are systemic and therefore require process-based correction rather than individual blame (Deming, 1986; Evans & Lindsay, 2014).

Table 6. Summary of root causes of material mismatch

Cause category	Observed root cause
Man	Operators had difficulty distinguishing similar material grades and were not always disciplined in confirming labels before setup.
Method	Replacement procedure and verification sequence were not standardized clearly on the machine.
Material	Several materials looked visually similar in width, thickness, and coil appearance, increasing the risk of mix-up.
Machine	Setup confirmation was focused on machine readiness, not on material identity verification.
Environment	Temporary storage and returned-material handling allowed similar coils to be placed too closely, reducing traceability.

The Do stage emphasized low-cost but high-discipline interventions. This choice is consistent with continuous-improvement studies showing that substantial defect reduction can be achieved through better visual control, standardization, and frontline engagement before moving to expensive automation (Singh & Gandhi, 2024; Naughton et al., 2024; Fitriana et al., 2024). In the present case, the actions were deliberately designed to make material identity visible and verification unavoidable during changeover.

Improvement evaluation

Table 10 shows that the intervention reduced total reject from 8,490 pcs to 2,235 pcs, equivalent to a 73.67% decline. More importantly, the material-mismatch category fell from 5,360 pcs to zero. This result strongly suggests that the selected corrective actions addressed the true dominant cause and that the company succeeded in converting the most critical latent risk into an explicit and controllable standard. In TQM terms, the intervention improved conformance through

Table 7. PDCA-based corrective action plan (5W1H summary)

What	Why	Who	When	Where	How
Material identity labels	Prevent wrong pickup	Leader and operator	Before setup	Storage and machine area	Apply larger labels and code signs on coils and remnants
Verification checkpoint	Ensure correct material before run	Operator and leader	Every changeover	Machine S1	Use pre-run checklist and dual confirmation
Operator briefing	Increase awareness and discipline	Supervisor	Start of shift	Production floor	Brief on material code, job order, and mix-up risks
Storage segregation	Reduce similarity confusion	Warehouse and production	Daily	Temporary storage	Separate returned materials by type and marked location
SOP revision	Standardize improvement	Engineering/ production	After trial	Machine S1 process	Add material check step into standard work instruction

Table 8. Standardized control points after implementation

Control point	Standardized practice	Expected effect
Returned material	Re-label every remnant before storage	Prevent unidentified coil reuse
Temporary storage	Separate similar material families and marked zones	Reduce mix-up during retrieval
Machine setup	Dual verification by operator and leader	Prevent wrong material loading
Shift handover	Brief incoming shift on active material and order	Maintain continuity of information
Work instruction	Add mandatory material check item	Embed improvement in routine work

Table 9. Reject composition after improvement (March 2025)

Reject type	Reject (pcs)	Share (%)	Remarks
High burr	925	41.39	Still dominant after improvement
Bending	680	30.43	Reduced but not eliminated
Missing hole	600	26.85	Increased and requires next cycle
Others	30	1.34	Minor category
Material mismatch	0	0.00	Eliminated
Total	2,235	100.00	-

better prevention and process discipline, not through more end-of-line sorting (Crosby, 1979; Deming, 1986; Evans & Lindsay, 2014).

The result also confirms the practical relevance of PDCA. In the Plan stage, reject data were translated into a clear improvement target. In the Do stage, the company implemented specific changes in labeling, verification, storage segregation, and work instruction. In the Check stage, the comparison between January and March data revealed that the target problem had been removed. In the Act stage, the improvement was institutionalized as part of routine standard work. Similar PDCA-based learning cycles have been reported as effective in manufacturing improvement projects and continuous-improvement deployment (Singh & Gandhi, 2024; Naughton et al., 2024).

At the same time, the post-improvement profile shows that quality improvement is dynamic. Once material mismatch was eliminated, High burr and missing-hole defects became more visible. The rise of missing-hole reject from 200 pcs to 600 pcs indicates that defect migration can occur when the dominant source is solved and attention shifts to other process weaknesses. This pattern is important because it demonstrates that the first PDCA cycle should not be interpreted as the end of improvement, but as a successful phase in a broader continuous-improvement program (Ishikawa, 1985; Fitriana et al., 2024).

From a manufacturing engineering perspective, the persistence of High burr, bending, and missing-hole defects indicates that the next improvement cycle should focus on tooling condition, die alignment, punch wear, setup parameters, and inspection discipline.

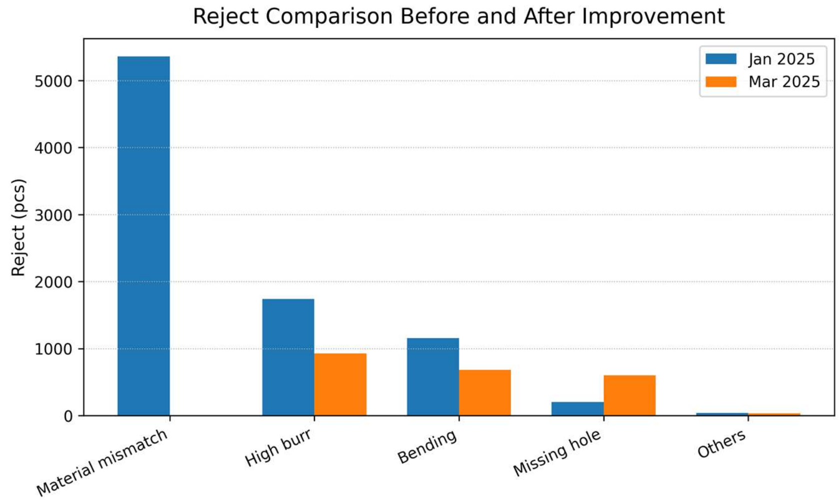

Figure 4. Reject comparison before and after improvement

Table 10. Before-after evaluation of reject reduction

Indicator	Jan 2025	Mar 2025	Change	Improvement (%)
Production output (pcs)	500,560	418,886	-81,674	-
Total reject (pcs)	8,490	2,235	-6,255	73.67
Reject rate (%)	1.6961	0.5336	-1.1625 pts	68.54
Material mismatch (pcs)	5,360	0	-5,360	100.00
High burr (pcs)	1,740	925	-815	46.84
Bending (pcs)	1,155	680	-475	41.13
Missing hole (pcs)	200	600	+400	-200.00
Others (pcs)	35	30	-5	14.29

Contemporary stamping studies similarly emphasize that defect prevention requires the simultaneous control of material characteristics and process parameters, and that defect detection technologies should be combined with robust process standards (Huang et al., 2023; Sánchez-Rodríguez et al., 2025; Papavasileiou et al., 2024).

The study also contributes to the quality-control literature by showing that a focused, low-cost intervention can generate major impact when the loss concentration is high. This complements previous JITI studies that used SPC, Six Sigma, barcode systems, and FMEA to reduce defects and improve traceability (Putri & Primananda, 2021; Rusman et al., 2024; Djunaidi et al., 2025). Rather than introducing a complex statistical model, the present study demonstrates that TQM-PDCA can still produce strong practical results when supported by disciplined data use, clear prioritization, and standardization.

Managerially, the implication is straightforward: reject information must be treated as a strategic process signal rather than only as a routine reporting metric. When reject is decomposed by type and linked to specific operating conditions, improvement resources can be directed to the highest-loss source first. This is especially important in environments where different materials have similar visual appearance and where returned material can re-enter production without adequate re-identification. A company that strengthens material traceability at the point of use will not only reduce reject but also reduce hidden downtime, confusion during changeover, and dependence on individual memory.

The present study has several limitations. First, the analysis used a before-after comparison on one machine and one dominant defect problem; therefore, the findings should be generalized carefully. Second, the study emphasized practical operational evidence rather than advanced statistical modeling. Third, post-improvement evaluation covered one month, so longer-term sustainment still needs to be confirmed. Even so, the evidence is sufficient to show a strong operational effect and to justify the continuation of the next PDCA cycle.

For future research, the improvement model can be extended by integrating SPC control charts, FMEA prioritization, or barcode-based traceability for returned materials. Such integration would align the practical simplicity of PDCA with deeper risk analysis and digital process control. It would also bring the study closer to recent JITI and manufacturing-quality work that combines structured defect analysis with stronger traceability and real-time monitoring (Rusman et al., 2024; Djunaidi et al., 2025; Papavasileiou et al., 2024).

IV. CONCLUSION

This study found that material mismatch was the dominant reject source in the observed stamping process. Before improvement, January 2025 production reached 500,560 pcs with 8,490 reject pieces and a reject rate of 1.6961%. Material mismatch alone contributed 5,360 pieces, or 63.13% of total reject, making it the main quality priority.

PDCA approach, March 2025 reject fell to 2,235 pieces with a reject rate of 0.5336%. The most significant result was the complete elimination of material-mismatch reject, while total reject decreased by 73.67%. These findings confirm that the intervention was effective because it addressed the dominant source through clearer material identification, better verification, operator briefing, storage segregation, and standardized work instruction.

However, the increase in missing-hole reject indicates that the improvement process should continue. The next PDCA cycle should focus on technical process variables such as tooling, die condition, alignment, and setup accuracy. Overall, the study demonstrates that TQM-PDCA is a practical and effective approach for controlling material-usage errors in stamping and for strengthening defect prevention in manufacturing operations.

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