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# Reducing NG Wavy Defects in Slit Coil Processing Using the DMAIC Approach: A Case Study in Steel Manufacturing

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***Abstract.*** *NG wavy defects in slit coil products represent a recurring quality problem that disrupts downstream manufacturing processes and generates customer complaints. This study aims to identify the root causes of NG wavy defects and formulate corrective actions to improve process reliability in slit coil production. A descriptive qualitative approach was employed using field observations, document analysis, semi-structured interviews, and data triangulation involving customer representatives and personnel from the purchasing, production, and quality control functions. The analysis was conducted using the Plan, Do, Check, Act (PDCA) framework, supported by Fishbone Diagram and 5W+1H analysis. The findings revealed that NG wavy defects were repeatedly identified at the seventh slit coil position (B7). Triangulation of customer complaints, purchasing records, production history, and quality control inspections confirmed that the defect originated during the slitting process. Further investigation identified a non-standard part finger setup on the mini slitter machine as the primary root cause, resulting in surface waviness. Based on these findings, corrective actions were proposed, including machine setup standardization, operator training, and strengthened inspection procedures. The study highlights the importance of systematic process control in preventing defects and improving slit coil production quality*

***Keywords:*** *NG Wavy Defect; Slit Coil Processing; PDCA; Root Cause Analysis; Mini Slitter Machine*

## I. INTRODUCTION

Product defects remain a critical challenge in steel processing industries because they can disrupt downstream manufacturing operations, increase production costs, and reduce customer confidence (Huang et al., 2023a; Phokane et al., 2022). One of the most critical quality issues encountered in slit coil production is the occurrence of NG wavy defects, characterized by surface waviness that affects material flatness and dimensional consistency. This defect is particularly critical for SPC-ST material with a thickness of 0.20 mm because thin-gauge steel is highly sensitive to deformation during the slitting process. Consequently, NG wavy defects must be addressed promptly to ensure product conformity and manufacturing reliability.

NG wavy defects create significant operational challenges for downstream manufacturers. During stamping operations, wavy material may cause feeding instability, interruptions in machine setup, and difficulties in maintaining production flow. In many cases, operators are required to manually remove the defective section before processing, resulting in material losses and additional setup time. These conditions increase production downtime, reduce operational efficiency, and negatively affect the overall productivity of the manufacturing process. (Nguyen et al., 2023a; Phokane et al., 2022)

Beyond operational losses, recurring NG wavy defects may also create quality and business risks. Repeated defect occurrences can undermine customer trust, increase complaint frequency, and potentially lead customers to seek alternative suppliers. For steel processing companies operating in highly competitive markets, the inability to consistently deliver defect free products may result in both financial losses and reputational damage (Arifin et al., 2021; Wonglimpiyarat, 2023). Therefore, identifying and eliminating the root causes of NG wavy defects is

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essential to sustaining long-term customer relationships and ensuring continuous business performance.

The importance of defect prevention has increased alongside the growth of the steel industry. According to data from the Indonesian Ministry of Industry, national steel production reached 16.85 million tons in 2023, representing an increase of approximately 87% compared with 2019. As production volumes continue to expand, maintaining consistent product quality becomes increasingly important to ensure operational efficiency, supply chain reliability, and customer satisfaction.

In complex manufacturing systems, product defects and material inconsistencies represent critical operational risks that can severely disrupt the entire supply chain flow, from raw material procurement to downstream client order fulfillment(Shoffiyati et al., 2025). Therefore, integrating systematic risk identification and mitigation strategies within supply chain management is highly essential to minimize uncertainties, prevent operational bottlenecks, and sustain continuous productivity across the business network (Shoffiyati et al., 2025).

The prevention of product defects in the steel manufacturing industry heavily relies on the implementation of robust quality management practices, systematic root cause identification, and continuous process improvement. Adopting Total Quality Management (TQM) principles provides a comprehensive corporate strategy oriented toward overall management to consistently deliver high-quality products to customers. Furthermore, effective TQM execution involves critical operational activities such as thorough information analysis, precise process management, and continuous improvement, which are essential for identifying the underlying origins of defects and enhancing overall organizational performance at an efficient cost.(Prasetya, Kristianto, et al., 2025)

Despite improvements in production capacity, quality-related problems continue to be reported in slit coil manufacturing operations. The company examined in this study produces SPC-ST slit coil products for downstream manufacturing applications and has experienced recurring customer complaints related to NG wavy defects. These complaints became the starting point for a comprehensive investigation aimed at identifying the source of the problem and preventing future recurrence.

To address manufacturing quality problems, many organizations adopt continuous improvement methodologies. Among these approaches, the Plan–Do–Check-Act (PDCA) cycle is widely recognized as an effective framework for identifying quality issues, implementing corrective actions, evaluating outcomes, and standardizing improvements (Martins et al., 2024; Nguyen et al., 2023a). Previous studies have demonstrated the effectiveness of PDCA in reducing defect rates and improving process performance across various manufacturing sectors (Arredondo-Soto et al., 2021; Huang et al., 2023a).

In a broader organizational context, Standardization serves as the foundation for continuous operational improvement, as strict adherence to standardized procedures can eliminate systematic equipment setup anomalies in steel production while simultaneously streamlining the logistical compliance required in Bonded Zones.(Prasetya, Herdinata, et al., 2025)

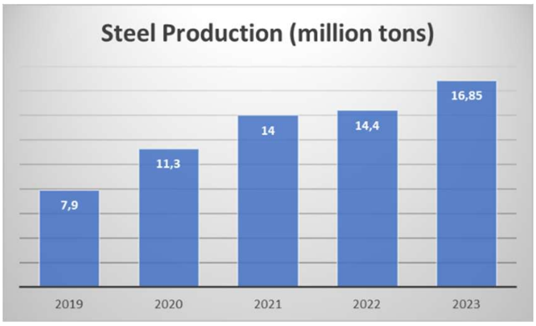


**Figure 1.** Indonesia Steel Production 2019 – 2023 (Source: kemenperin.go.id)

**Figure 2.** NG Wavy on slit coil products

However, although numerous studies have examined defect reduction using PDCA, most have focused on general manufacturing processes, automotive production, assembly operations, and packaging industries (Huang et al., 2023a; Sumasto et al., 2023). Limited attention has been given to NG wavy defects in thin-gauge SPC-ST slit coil processing, particularly regarding defect formation mechanisms associated with slitting operations. Consequently, the root causes of recurring NG wavy defects in slit coil manufacturing remain insufficiently explored in the existing literature.

This study contributes to the literature by investigating NG wavy defect formation in SPC-ST slit coil production through field observations, customer complaint analysis, and data triangulation involving purchasing, production, and quality control functions. The study further identifies a recurring defect pattern at the seventh slit coil position (B7) and reveals that a non-standard part finger setup on the mini slitter machine constitutes the primary source of the defect. Using the PDCA framework, this research aims to identify the root causes of NG wavy defects and formulate corrective actions to improve process reliability and product quality in slit coil manufacturing

# II. RESEARCH METHOD

### Research Design

This study employed a descriptive qualitative case study approach to investigate the root causes of NG wavy defects in SPC-ST slit coil production. A qualitative design was selected because the study aimed to explore defect formation mechanisms, operational conditions, and process-related factors within an actual manufacturing environment (Moeller et al., 2016). The research focused on understanding how NG wavy defects emerged during slit coil production and identifying corrective actions using the Plan–Do–Check–Act (PDCA) continuous improvement framework(Nguyen et al., 2023a; Sumasto et al., 2023). The case study approach was considered appropriate because the investigation involved an in-depth examination of a specific defect phenomenon occurring within a single manufacturing setting

In addition to qualitative inquiry, limited quantitative information was incorporated to support the investigation process, including defect occurrence patterns, customer complaint records, production history, and defect locations observed during the study period. The integration of qualitative and quantitative evidence enabled a more comprehensive understanding of the problem and strengthened the root-cause analysis process

### Data Collection Procedure

Data collection was conducted over a three-month observation period during regular production operations. The study utilized multiple sources of evidence, including direct observations, semi-structured interviews, document reviews, and customer complaint investigations. This multi-source approach was intended to capture operational conditions comprehensively and reduce the risk of single-source bias.

Purposive sampling was employed to select individuals directly involved in the NG wavy defect investigation process. Informants consisted of representatives from the Purchasing, Production, Quality Control (QC), and Production Planning and Inventory Control (PPIC) functions, as well as customer representatives who initially reported the defect. These participants were selected because they possessed direct knowledge regarding material inspection, production processes, machine setup activities, quality verification procedures, and complaint handling practices.

Semi-structured interviews were conducted using interview guides developed according to the research objectives. Interview discussions focused on defect occurrence history, material handling practices, machine operating conditions, production procedures, and corrective actions previously implemented. Information obtained during interviews was recorded through field notes and subsequently categorized according to emerging themes relevant to defect formation and process improvement.

The document review included customer complaint records, production history reports, slit coil traceability data, machine setup records, quality inspection reports, delivery documentation, and internal quality investigation reports. These documents provided supporting evidence for validating information collected through observations and interviews.

To complement interview and document data, direct observations were conducted throughout the slit coil production process, including material preparation, slitting, packing, loading, and shipment activities. Particular attention was given to machine operating conditions and production activities potentially associated with defect occurrence.

**Data Validation and Analytical Techniques**

To ensure the credibility and validity of the findings, this study applied source triangulation by comparing information obtained from customer representatives, purchasing personnel, production operators, and quality control inspectors. Interview findings were further cross-checked with production records, inspection reports, and customer complaint documentation. This verification process was used to confirm consistency across data sources and strengthen the reliability of the conclusions.

Data analysis was conducted using Fishbone Diagram and 5W+1H analytical techniques. The Fishbone Diagram was utilized to systematically categorize potential causes of NG wavy defects into six dimensions: man, machine, material, method, measurement, and environment. This approach facilitated the identification of potential relationships among operational factors contributing to defect formation(Kanti Bose, 2012).

**Table 1.** Research Variables, Indicators, and Data Sources

| No | Variable/ Indicator | Description | Data Source |
|---|---|---|---|
| 1 | Customer Complaints | Number and description of NG wavy complaints | Customer records |
| 2 | Defect Pattern | Location and frequency of defects | QC reports |
| 3 | Slit Coil Position | Identification of affected coil position (e.g., B7) | Production history |
| 4 | Machine Setup | Part finger configuration and setup condition | Machine inspection |

Source: Processed Data

Subsequently, the 5W+1H method was applied to investigate the defect phenomenon more comprehensively. This technique enabled the researchers to examine what occurred, why the defect emerged, where and when it occurred, who was involved in the process, and how corrective actions could be formulated. The combined use of Fishbone Diagram and 5W+1H analysis provided a structured mechanism for root-cause identification and improvement planning.

Several operational indicators were also reviewed to support the analysis process, including customer complaint frequency, defect occurrence patterns, slit coil position identification, production history records, machine setup conditions, and defect traceability information. These indicators assisted in validating recurring defect patterns and identifying potential sources of process variation.

**PDCA-Based Improvement Procedure**

The Plan–Do–Check–Act (PDCA) framework was adopted as the primary methodological approach for defect investigation and continuous improvement. PDCA has been widely applied in manufacturing environments to systematically identify quality problems, implement corrective actions, evaluate performance, and standardize improvements.

1. **Plan Phase**. The Plan phase focused on problem identification and preliminary investigation. Customer complaints related to NG wavy defects were collected and reviewed. Initial data were obtained from purchasing records, production reports, quality inspection documents, and direct field observations. Root-cause investigation was initiated using Fishbone Diagram analysis to classify potential causes into categories associated with manpower, machine, material, method,

measurement, and environment. The 5W+1H technique was subsequently utilized to define the nature and characteristics of the defect problem more systematically.

2. **Do Phase.** The Do phase involved collecting and validating operational data associated with the defect. Activities included customer communication, tracing slit coil identification labels, reviewing production histories, evaluating delivery records, and conducting Genba inspections at the customer site. Cross-functional collaboration involving Purchasing, Production, Quality Control, and customer representatives was established to obtain a comprehensive understanding of the defect occurrence process and identify potential contributing factors
3. **Check Phase.** The Check phase focused on validating and evaluating the findings obtained from previous stages. Information collected from observations, interviews, customer complaints, production records, and inspection reports was compared and verified through triangulation. The evaluation emphasized recurring defect patterns, machine setup conditions, slit coil positions, and procedural compliance to determine the most probable root cause of NG wavy defect occurrence
4. **Act Phase.** Based on the validated findings, corrective and preventive actions were formulated to eliminate the causes of NG wavy defects. The proposed improvement initiatives included standardization of machine setup procedures, revision of work instructions, strengthening of operator training programs, enhancement of inspection procedures, and development of monitoring mechanisms to prevent defect recurrence. These actions were intended to improve process reliability and support continuous quality improvement within slit coil production operations.

## III. RESULT AND DISCUSSION

### NG Wavy Defect Occurrence and Problem Identification

Customer complaints revealed recurring NG wavy defects in SPC-ST slit coil products delivered to downstream manufacturing operations. The defect became apparent during stamping machine setup, where the affected material exhibited surface waviness that interfered with feeding and processing activities. Consequently, customers were required to remove defective sections before production, resulting in material

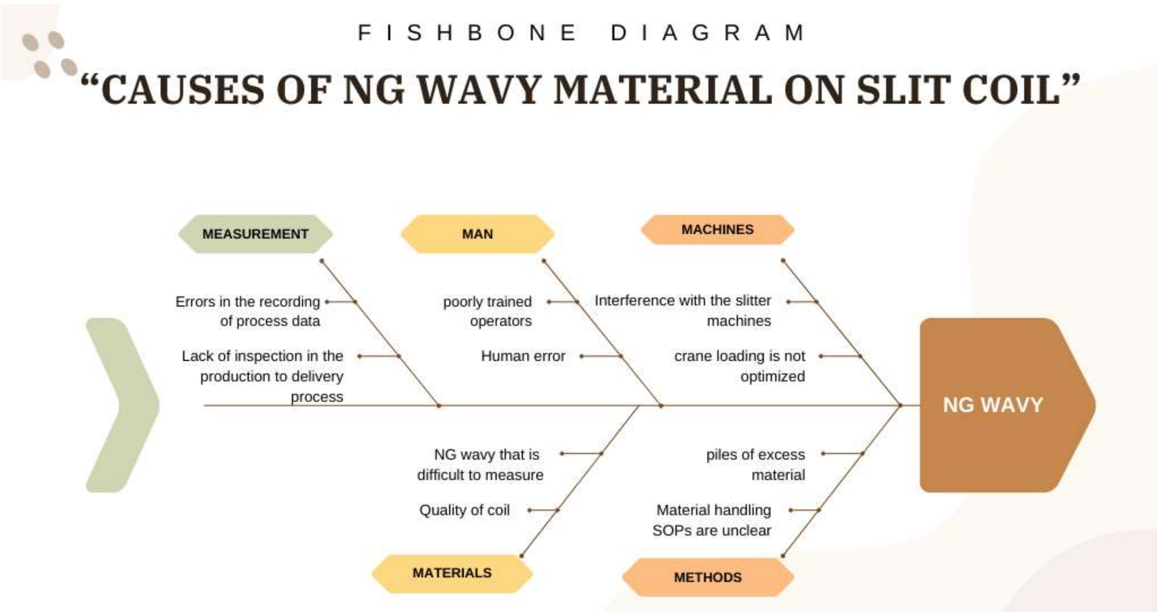


**Figure 3.** Fishbone Diagram Analysis: NG Wavy Material (Source: Data Processing)

losses, additional setup activities, and production downtime. These observations indicate that NG wavy defects not only affect product quality but also create operational challenges for downstream manufacturers.

To investigate the source of the defect, a structured root-cause analysis was conducted using the PDCA framework. Data were collected through customer complaints, production records, field observations, interviews, and quality control documentation. The investigation focused on identifying the origin of the defect and determining appropriate corrective actions to prevent recurrence.

**Root Cause Identification Using Fishbone Diagram**

The Plan phase began with a Fishbone Diagram analysis to identify possible contributors to NG wavy defect formation. According to Figure 3. The analysis classified potential causes into six categories: manpower, machine, material, method, measurement, and environment. Several possible causes were identified, including operator errors, machine instability, inconsistent material quality, inadequate operating procedures, insufficient inspection activities, and unfavorable environmental conditions.

Among these factors, machine-related variables emerged as the most critical area requiring further investigation because recurring defect patterns suggested a systematic process issue rather than random variation. Consequently, Fishbone findings were further validated using 5W+1H analysis and cross-functional data triangulation.

**Root Cause Validation Through 5W+1H Analysis**

To refine the findings obtained from the Fishbone analysis, the 5W+1H approach was applied to examine defect occurrence from multiple perspectives, including what occurred, why it occurred, where and when it occurred, who was involved, and how corrective actions could be implemented.


**Figure 4.** Material Process History (Source: Data Processed)

The analysis showed that NG wavy defects repeatedly disrupted customer stamping operations and generated material losses due to the removal of defective sections. Investigation results suggested that defect occurrence was associated with slitting operations rather than customer handling activities. Potential causes initially included machine setup conditions, material handling activities, environmental influences, and procedural inconsistencies.

To verify these assumptions, the investigation moved into the Do phase through production history reviews, traceability analysis, delivery verification, and on-site inspections (Genba).

**PDCA Implementation**

**1. Do Phase: Production Traceability and Genba Investigation**

The Do phase focused on validating the potential causes identified during the planning stage. Production records, material traceability data, delivery records, and customer complaint information were examined to identify recurring defect patterns.

The traceability investigation revealed that two NG wavy slit coils originated from different mother coils and different production batches. However, both defects were produced using the same mini slitter machine. This finding suggested that the defect was unlikely to originate from raw material quality alone and instead pointed toward

Table 2. Summary of Production Process Results and NG Material Identification

| No. | Activities | Details | PIC (Division) |
|---|---|---|---|
| 1. | Search for information related to material labels | 1. Contact customers to obtain material label information.<br>2. Identify coil 1 and 2 slit labels, including coil number, NG material, and other details | Sales & Marketing |
| 2. | Checking the process history | 1.Check process data on the mini slitter machine (date, shift, production team).<br>2. Ensuring the connection between mother coil and slit coil | QC, Production |
| 3. | Checking the delivery date | 1. Checking delivery records (trucking supplier or customer pickup).<br>2. Identify wavy material problems found during delivery. | QC, Production |
| 4. | Visit to customer for direct inspection (Genba) | 1. Conduct site visits to check the condition of problematic materials.<br>2. Observation of the visual/technical cause of the problem (wavy material). | QC, Production, Sales |
| 5. | Supplier internal analysis | 1. Analyze the results of process checks, deliveries, and spot inspections of problem materials.<br>2. Identify root causes related to process, packing, loading, and delivery. | QC, Production, PPIC |
| 6. | Improvement | 1. Develop an improvement plan based on the results of the analysis.<br>2. Implementation of temporary fixes and/or proposal of similar preventive measures in the future. | QC, Production, Management |
| 7. | Report preparation | Document analysis results, corrective actions, and recommendations for customers and internal company. | QC, Sales & Marketing |

factors associated with the slitting process.

The results presented in Table 2 revealed an important pattern. Despite originating from different mother coils, the NG wavy defect repeatedly appeared at the seventh slit position (B7). This recurring occurrence indicates that defect formation was systematic rather than random. The consistency of the B7 location suggested the existence of a machine-related condition affecting material quality at a specific slit position.

To validate this pattern further, an on-site inspection (Genba) was conducted at the customer facility. Visual observations confirmed the presence of deformation patterns corresponding to NG wavy characteristics. In addition, customer feedback indicated that the affected material caused difficulties during stamping machine setup, reinforcing the operational significance of the defect.

**2. Check Phase: Verification of Root Causes**

The Check phase aimed to verify the actual source of NG wavy defect occurrence using cross-functional analysis involving Production, Quality Control, and PPIC personnel. Production records, inspection reports, Genba findings, and traceability data were evaluated to eliminate non-contributing factors and identify the primary root cause.

The results showed that incoming material quality, storage conditions, loading activities, transportation processes, and customer material handling were operating under acceptable conditions. Therefore, these factors were excluded as primary causes of defect formation.

In contrast, abnormalities were identified during the slitting process, particularly in the configuration of part fingers on the mini slitter machine. The investigation found that the part finger setup did not conform to established specifications and was consistently associated with defects occurring at the B7 slit position.

Technically, part fingers function as guiding and stabilizing components during the slitting process. Improper setup can generate uneven guidance forces and localized stresses on thin-gauge SPC-ST material. Because SPC-ST 0.20 mm material is highly susceptible to deformation, instability during slitting can result in permanent surface waviness. The repeated occurrence of defects at the B7 position therefore provides strong evidence supporting the causal relationship between non-standard part finger configuration and NG wavy defect formation.

**3. Act Phase: Corrective and Preventive Actions**

Based on the validated findings, corrective actions were developed to eliminate the identified root cause and prevent defect recurrence. The primary focus of improvement was the standardization of part finger installation and machine setup procedures. Additional measures included operator retraining, revision of work instructions, enhanced inspection checkpoints, and strengthened supervision during machine preparation activities

The proposed countermeasures establish a standardized workflow for machine setup and

**Table 3.** Internal Check Results

| No. | Activities | Check Result | Note |
|---|---|---|---|
| 1. | Condition of mother coil when incoming and before processing | Normal | No problems found |
| 2. | Cutting process of mother coil into slit coil in Mini Slitter Machine | Abnormal | Found a problem in the process of setting part fingers |
| 3. | When storage is completed at the supplier's warehouse | Normal | No problems found |
| 4. | When loading and delivering materials | Normal | No problems found |
| 5. | When unloading and storing materials at the customer | Normal | No problems found |

**Table 4.** Flow Process and Countermeasures of NG Process

| NO. | DISPLAY | CONTROL POINT |
| --- | --- | --- |
| 1. |  | Setting up the machine - preparation before the process by paying attention to the following points:<br>After installing the mother coil on the machine, install a board in front of the slitter stand covered with felt and add spacers. Make sure the space presses into the entire surface of the coil to avoid the product shifting and warping during the process.<br>Install part fingers on the machine according to the number of product slits.<br>Setting the height of the knife with the finger according to the thickness using the thickness gauge.<br>Check the initial cutting area (top of coil product) of the process results after exiting the machine blade with a length of 2 meters or conditioned according to the condition of the top of the mother coil. Check whether there are NG areas such as: burry, wavy, cutter mark, chamber over size, dent, rust, scratch, backring, and other NG. |
| 2. |  | Periodically check the results of the process on the side of the loop to find out if there are waves / waves in the product. |
| 3. |  | Periodically check the condition of the product at the position of the separator and katenari, to ensure that the product flow does not come out of the separator. |

quality control activities. By reducing variability in part finger configuration and improving process discipline, these actions are expected to minimize defect occurrence and improve process consistency across production shifts.

Although quantitative post-implementation data were not yet available during the study period, the corrective actions directly address the verified source of the defect and provide a structured mechanism for preventing recurrence in future operations.

## Discussion

The findings demonstrate the effectiveness of combining Fishbone Diagram analysis, 5W+1H investigation, data triangulation, and PDCA methodology to identify manufacturing defects systematically. Similar to (Nguyen et al., 2023b) the PDCA framework enabled structured problem identification,verification, and corrective action implementation. Likewise, (Huang et al., 2023b)reported that PDCA facilitates defect reduction through systematic process evaluation and standardization.

Unlike previous studies that focused on automotive, assembly, or packaging industries, this study specifically examined NG wavy defect formation in thin-gauge SPC-ST slit coil production. The identification of recurring defects at the B7 slit position represents an important contribution because it provides direct operational evidence linking defect occurrence to specific machine setup conditions.

Furthermore, the integration of Fishbone Diagram, 5W+1H analysis, production traceability, Genba inspection, and internal verification successfully narrowed multiple potential causes into a single validated root cause: a non-standard part finger setup on the mini slitter machine. These findings highlight the importance of machine setup precision in maintaining product quality, particularly when processing thin-gauge materials that are highly sensitive to deformation during slitting operations.

To sustain the standardized machine setup procedures and minimize human errors in the long term, management should integrate these operational metrics into the employee performance appraisal system. As highlighted by (Nugraha et al., 2025) implementing structured and objective performance evaluation methods, such as Behaviorally Anchored Rating Scales (BARS), ensures that operational targets—including defect reduction and SOP compliance—are mutually understood and fairly assessed (Nugraha et al., 2025). Aligning operational continuous improvement with human resource performance evaluations will foster greater operator accountability and sustain quality consistency in slit coil production.

# IV. CONCLUSION

This study investigated the root causes of NG wavy defects in SPC-ST slit coil production using the Plan–Do–Check–Act (PDCA) framework. The findings revealed that NG wavy defects consistently occurred at the seventh slit position (B7), indicating a recurring and systematic process issue rather than random defect formation. Through field observations, production traceability analysis, customer complaint investigations, and cross-functional data triangulation, the study confirmed that the defect originated during the slitting process. The root cause was identified as a non-standard part finger setup on the mini slitter machine, which generated instability during material guidance and resulted in surface waviness on thin-gauge SPC-ST material.

The findings demonstrate the importance of machine setup accuracy and process standardization in preventing quality defects in slit coil manufacturing. Based on the identified root cause, corrective actions were proposed, including part finger setup standardization, revision of operating procedures, enhancement of operator training, and strengthening of inspection activities prior to production. These actions provide a systematic basis for reducing defect recurrence and improving process reliability in slit coil production operations.

**Managerial Implications**

The results of this study provide practical guidance for manufacturing organizations involved in slit coil processing. Management should prioritize the standardization of critical machine setup parameters, particularly those associated with part finger installation and alignment. In addition, regular operator competency development, preventive maintenance activities, and strengthened inspection procedures should be integrated into daily production operations to minimize process variation and improve product quality consistency. The findings also highlight the importance of cross-functional collaboration among production, quality control, purchasing, and customer-facing functions in identifying and resolving recurring manufacturing defects

**Research Limitations**

This study has several limitations. First, the investigation was conducted within a single manufacturing company and focused on one mini slitter production line. Second, the observation period was limited to three months and concentrated on SPC-ST material with a thickness of 0.20 mm. Third, quantitative post-implementation performance indicators, such as defect rate reduction, downtime reduction, and customer complaint reduction, were not available during the study period. Consequently, the effectiveness of the proposed corrective actions could not be evaluated using statistical performance measurements.

**Future Research**

Future studies are recommended to evaluate the effectiveness of the proposed corrective actions using measurable operational indicators, including defect rate, production downtime, customer complaint frequency, and production costs. Further research may also investigate NG wavy defect formation in different material thicknesses, production environments, and slitting machine configurations. Additionally, the integration of automated monitoring systems and real-time machine condition sensing technologies may provide opportunities for early defect detection and quality control improvement in slit coil manufacturing operation

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