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Enhancing Insert Lifetime in Side Cutting of Special Nut Products Using The QCC Method to Reduce Cost Per Piece

Henri Ponda[1]*, Suyanto[2]
[1,2,3] Universitas Muhammadiyah Tangerang

***Corresponding Author**: henri.ponda@gmail.com

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ABSTRACT
This study aims to increase the life time insert SNGX12003-ME used in the side cutting process of special nut products D.8 x 21.5 mm at PT. GM. The main problem identified is the high value of Cost Per Piece (CPP) due to the waste of cutting tools and the lack of classification of insert usage based on material differences, namely K-40 and K-25. To overcome these problems, the Quality Control Circle (QCC) method is used with the PDCA (Plan, Do, Check, Action) cycle approach and the help of the Seven Tools analysis tool. This study uses primary data through observation and interviews, as well as secondary data in the form of insert usage history during January-December 2024. The results showed that the application of additional treatment coating to the insert can significantly increase the life time, which has a direct impact on reducing CPP by up to ±50%. In addition, the classification of insert usage based on material also results in efficiency in stock control and decision-making. These findings prove that the QCC method is effective as a continuous improvement strategy in the manufacturing industry, particularly to lower costs without sacrificing product quality.

INTRODUCTION

PT GM is a manufacturing company producing nuts and bolts since 1982. Increasing production costs have reduced profitability, creating the need to reduce the Cost Per Piece (CPP). Previous studies have demonstrated the effectiveness of QCC in minimizing defects and improving process efficiency (Nashida & Syahrullah, 2021; Kusuma & Azizah, 2024). However, research rarely focuses on insert lifetime optimization in machining operations. This study fills this gap by applying QCC to improve insert lifetime through coating treatment and usage classification.

However, prior studies rarely address insert lifetime improvement as a main variable, despite its strong influence on machining cost structure. This study fills that gap by applying the QCC method not merely to reduce defects but to extend insert lifetime through recoating and proper classification. This aligns with Industry 4.0 efficiency demands and sustainable (green manufacturing) principles through reduced solid waste and optimized tool utilization.

The scientific contribution of this research includes: (1) introducing QCC-based insert lifetime optimization, which is underrepresented in literature; (2) demonstrating cost-efficiency improvements through mechanical and procedural interventions; (3) presenting quantitative evidence that tool-life doubling leads to a proportional CPP reduction, strengthening the economic justification for QCC implementation.

MATERIAL AND METHOD

Material

The Quality Control Circle (QCC) method is a structured quality management approach designed to improve processes, identify problems, and implement effective solutions within the workplace. QCC involves small groups of employees—typically 5 to 10 members from various functions—who voluntarily meet to analyze problems, identify root causes, and propose improvement plans that can be implemented sustainably [1],[2].

The QCC concept is closely related to Total Quality Management (TQM), where continuous improvement (*Kaizen*) and employee participation are key components of success [3],[4]. The method applies the PDCA (Plan–Do–Check–Action) cycle, enabling organizations to make iterative and measurable improvements over time [5],[6].

In this study, QCC is applied to reduce production costs and increase the insert life time in the side cutting process of D.8 x 21.5 mm special nut products at PT GM. The problem identified was the high Cost Per Piece (CPP) due to excessive insert consumption and lack of classification based on material type (K40 and K25).

The improvement efforts were supported by the Seven Quality Control Tools (Seven Tools) as statistical aids [7], which include:

1. Pareto Diagram – identifying the main problems based on frequency or cost impact.
2. Cause and Effect Diagram (Fishbone) – analyzing potential root causes.
3. Check Sheet – collecting data systematically.
4. Histogram – visualizing data distribution and variation.
5. Scatter Diagram – determining the relationship between two variables.
6. Control Chart – monitoring stability and process capability.
7. Flow Chart – visualizing process flow and improvement points.

The QCC framework also refers to studies [8]-[10] which demonstrate that the combination of QCC and PDCA successfully improves product quality and reduces defects in manufacturing systems. Similarly [11],[12] highlight the QCC method’s effectiveness in minimizing waste and enhancing process efficiency.

In addition, the concept of green manufacturing is integrated into this study, where reducing tool scrap and improving reusability through recoating directly contribute to sustainability and environmental performance [13].

Method

The research methodology was designed to systematically address the high CPP issue through the implementation of the QCC method**,** structured according to the PDCA cycle.

1. Data and Information

Two main sources of data were used:

- Primary Data: obtained through field observation, interviews with production and engineering personnel, and direct monitoring of side cutting processes.
- Secondary Data: sourced from PT GM production records, including tooling usage history, CPP calculations, and company documentation from January to December 2024.

2. Data Collection Techniques

The data collection was conducted through several complementary methods:

- Literature Review: A comprehensive review of QCC theory, PDCA methodology, and previous research on process improvement and cost reduction [14]-[16].
- Field Observation: Conducted to identify actual problems related to insert wear, machine conditions, and operational parameters.

- Interviews: In-depth interviews with technicians and supervisors to identify behavioral and procedural factors affecting insert life time.
- Documentation: Collection of historical records including production logs, insert usage data, and maintenance reports.

3. Data Analysis Techniques

The analysis process followed the QCC stages supported by the PDCA framework and Seven Tools, consisting of:

1. Problem Identification**:** Analyzing tooling usage data for 12 months to identify the main sources of cost inefficiency.
2. Target Setting**:** Establishing realistic improvement goals using the SMART principle (Specific, Measurable, Achievable, Reasonable, Time-based).
3. Current Condition Analysis: Applying the 4M+1E framework (Man, Method, Material, Machine, Environment) to determine influencing factors (Nashida & Syahrullah, 2021).
4. Cause and Effect Analysis: Utilizing a fishbone diagram to identify root causes of high CPP (Kusuma & Azizah, 2024).
5. Countermeasure Planning: Designing solutions using the 5W+2H approach to ensure clarity in what actions, who is responsible, and when they should be implemented (Prihandoko et al., 2020).
6. Implementation: Conducting process improvement by applying coating treatment, refining handling procedures, and optimizing cutting parameters.
7. Evaluation: Comparing pre- and post-QCC results to assess the effectiveness of improvements based on insert lifetime and CPP values.
8. Standardization and Follow-up: Developing operational standards and determining future improvement themes [17],[1]**.**

4. Research Framework

The entire research process was carried out in the following stages:

1. Identification and formulation of the problem.
2. Determination of research objectives.
3. Implementation of QCC activities using the PDCA cycle.
4. Evaluation of improvement results and validation of effectiveness.
5. Documentation and standardization of new work procedures.

This structured approach ensures that the QCC project aligns with continuous improvement principles (Kaizen) and supports PT GM goals for cost efficiency, productivity, and environmental sustainability**.**

RESUT AND DISCUSSION

QCC activities were carried out over four months, starting from November 2024 to February 2025. The QCC (Quality Control Circle) activity timeline plays a crucial role as a reference for time management and setting the completion boundaries (deadlines) for each improvement activity.

Determining the QCC theme is a very crucial first step, as it becomes the main focus of the improvement to be undertaken by the team. The theme is chosen based on real problems in the work area that impact quality, efficiency, safety, or productivity.

In this QCC activity, waste was found in the side cutting process, with the resulting problem identification as follows:

1. Establish the QCC theme

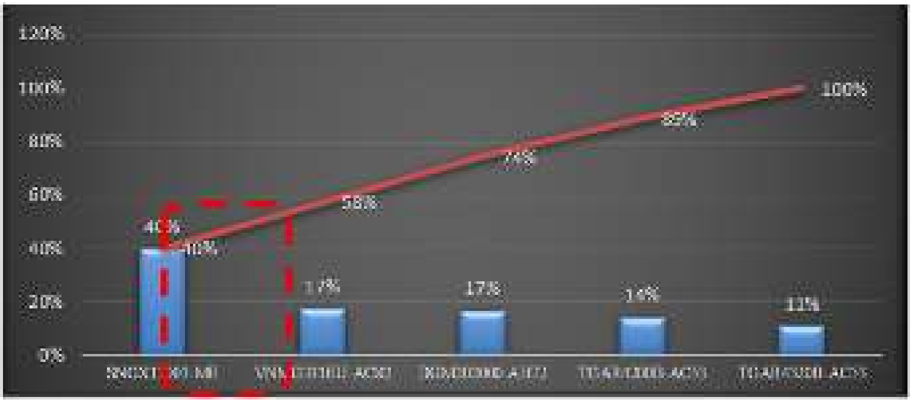


Figure 1. Insert Tooling Usage for the year 2024

After identifying the tooling usage data for 2024, five types of tooling with the highest usage rates were obtained, with the insert category recorded as the most frequently used. Next, the insert usage data was broken down to determine the objective for improvement and simultaneously identify the root cause leading to high production costs.

The analysis results show that the SNGX1203-ME insert type had the highest usage rate, with a total of 2,240 pieces used throughout 2024, resulting in a Cost Per Piece (CPP) value of Rp,133. Based on these findings, the theme for the QCC activity was set as:

"Enhancing Insert Lifetime In Side Cutting Of Special Nut Products Using The QCC Method To Reduce Cost Per Piece."

2. Establishing the Target

Based on the data above, the target is to provide added value to the insert by increasing its service life or output per piece from 1,500 pieces (30,000/set) to 3,000 pieces (60,000/set), where 1 set = 20 pcs. The expected life time target is a 100% increase after the QCC activity is implemented, in order to achieve a target CPP reduction of 50%.

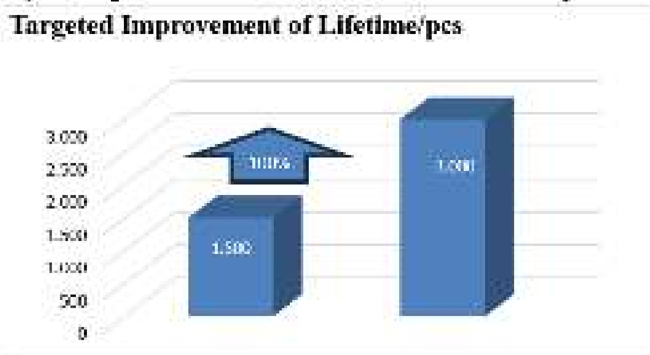


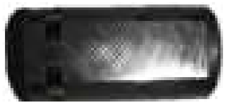
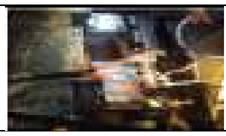
Figure 2. Life Time Target

3. Analysis of Current Conditions

The 4M+1E analysis yielded five influential factors that will form the basis for the cause-and-effect analysis using the fishbone diagram.

Table 1. 4M+1E Factor Analysis

4M+1E Factor	Standard	Finding (Genba)	Impact on Problem	Photo	PIC & Genba Date	Status (X /√)
Man	Equal operator skill	Operator skill varies among individuals	Variation in machine setting results		Bobby, 25–26 Nov 2024	✕

Material	One product, one material type	Product materials vary	Affects insert life (tool wears quickly)		Yanto, 27–28 Nov 2024	✕
Method	Black alkrona coating, dense and uniform	Coating is unclear and not dense	Tool wears and chips easily		Ardilah, 27–28 Nov 2024	✕
Machine	Lubrication applied during process	No lubrication in the process	Defective products (*burrs*)		Ardilah, 25–26 Nov 2024	✕
Environment	Machine 5R maintained	Machines dusty and dirty	Machine performance and cutting quality decrease		Bobby, 25–26 Nov 2024	✕

4. Cause and Effect Analysis

Following the current condition analysis, the next step involves using a fishbone diagram (cause-and-effect diagram) to pinpoint the factors contributing to the high Cost Per Piece (CPP) of the SNGX1203-ME insert.

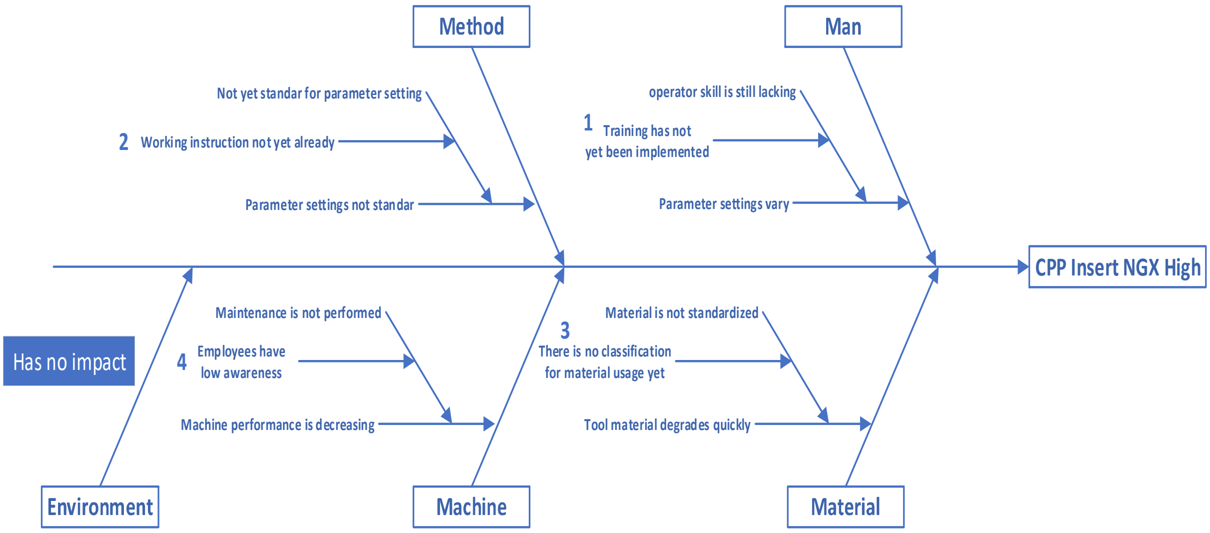


Figure 3. Fishbone Diagram

5. Planning Countermeasures

After identifying the main causes of the problem, the next stage is to plan corrective actions by implementing the **5W+2H method**. This method is a systematic analytical tool used to comprehensively understand a problem or design improvement activities.

The **5W+2H method** consists of seven fundamental questions — What, Why, Where, When, Who, How, and How Much — which help in gathering essential information and formulating appropriate and measurable steps for improvement.

Presented below are the influential factors based on the results of the cause-and-effect (fishbone) analysis, along with the corresponding planned corrective actions:

Table 2. Corrective Action Plan (5W+2H Method)

No	Factor	What Problem	What Improvement Plan	Why Reason	How Improvement Activity	Who, Where, When PIC, Location, Time	How Much Cost	Target
1	**Man**	No training conducted for operators	Schedule **training sessions**	To equalize operator skill levels	Register and coordinate training program with HRD	Ina, Training Room, Feb 2025	–	Equal skill level
2	**Method**	Working instruction not yet already	Create a working instruction	Ensuring consistency, safety, efficiency, and compliance with applicable standards in every activity or work process within an organization or company	Conduct a discussion with the related team	Yanto, Inventory Area, Feb 2025	-	Working instruction already
3	**Material**	No classification for insert usage	Develop **One Point Lesson (OPL)**	To prevent improper use of inserts for different materials	Prepare OPL document and conduct field socialization	Dilah, Machining Area, Feb 2025	–	Clear standard and increased lifetime
4	**Machine**	Employees have low awareness	Increase employee awareness	To ensure machine maintenance is carried out consistently	Develop a training and socialization program	Boby, Machining Area, Feb 2025	–	Machine performance improves

6. Implementing of Countermeasure

Based on the table above, it can be seen that there are five main influential factors that require corrective action. After the implementation of improvements was carried out in accordance with the 5W+2H analysis results, the outcomes of these improvements can be explained as follows:

Table 3. Implementing of Countermeasure

No	Problem	Improvement	Improvement Activity	Systematic Improvement	Result (Target)	Cost	PIC, Place, Time
1	No operator training yet	Conduct **training program**	Register and schedule **training** with HRD	Prepare training registration and request training program approval from HRD.	Equal skill level achieved	–	Ina, Machining, March 2025
2	**Method**	Working instruction not yet already	Create a working instruction	Conduct a discussion with the related team	Machine settings are standardized	–	Dilah, Machining, March 2025
3	**Material**	No classification	Develop **One Point Lesson (OPL)**	Prepare OPL document and	Clear standard and	–	Boby, Machining,

		for insert usage		conduct field socialization	increased lifetime		March 2025
4	**Machine**	Employees have low awareness	Increase employee awareness	Develop a training and socialization program	Machine performance improves	–	Ina, Machining, March 2025

The comparison of results before and after the Conducting Recoating is presented below:

a) Before Improvement
In the condition before improvements were made, the insert was used only once, with an average life time of 1,500 pcs/insert, or 30,000 pieces per set.
Furthermore, the waste or tool scrap returned from production experienced significant accumulation (piling up) in the work area. This condition caused the Cost Per Piece (CPP) value to increase to Rp.133, thus directly impacting the rise in production costs.
From a green manufacturing perspective, the accumulation of these used inserts has a serious impact—on the environment, due to the increase in solid metal waste; on cost, due to the high frequency of cutting tool replacement; and on operational efficiency, due to the increased activity required for handling and managing production waste.

b) After Improvement
- Initial Condition: The insert was scrapped after going through two stages of use.
- First Usage Life Time:
  - Reached 1,200 pcs/insert, which is a 20% decrease from the previous standard life time of 1,500 pcs/insert.
  - In this condition, the insert was still considered usable, having not yet experienced wear or damage (chipping).
- Second Usage Life Time (After the Recoating Process):
  - Increased to 2,000 pcs/insert, which is a 33% increase compared to the initial life time (1,500 pcs/insert).
  - This result exceeded the targeted increase of 20%, which was 1,800 pcs/insert.
- Total Average Usage Life Time (Stage 1 and 2):
  - Reached 3,200 pcs/insert, or equivalent to 64,000 pcs per set.

7. Checking The Result

After all improvement steps were carried out, the next stage is checking the results to assess the effectiveness of implementing the QCC method in increasing the insert's life time. This evaluation is performed by comparing the conditions before and after QCC implementation, both in terms of the life time achieved per insert and the efficiency of production costs (CPP).

The measurement results indicate a significant increase in the insert life time after corrective actions were taken. The details of this achievement are presented in the following section.

a) Achievement Life Time After QCC

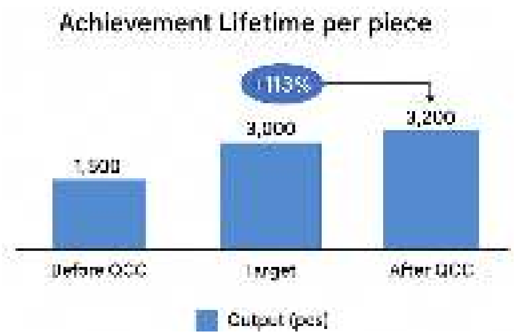


Figure 4. Achievement Life Time Per Piece

b) Cost Calculation

The cost calculation obtained in this research is as follows:

1. *Saving cost*	= Rp.95.760.000/Year
2. *Total Cost Project*	= Rp.17.315.446/ Year
3. *Net Quality Income*	= Rp.95.760.000 – Rp.17.315.445 = Rp.78.444.554/ Year
4. *Return of Invesment*	= 0.18 Year = 66 Day
5. *CPP* after QCC	= (Rp.199.500+Rp.23.529)/3.200 = Rp.70/pcs
6. *CPP* Decrease	= Rp.133 – Rp.70 = Rp.63/pcs

After the entire research series and the application of the Quality Control Circle (QCC) method were carried out, the results showed that the insert life time achievement increased significantly, from an initial 1,500 pcs to 3,200 pcs per insert. This increase in life time directly impacted the reduction of the Cost Per Piece (CPP) value by 48%, specifically from Rp.133 to Rp.70 per piece.

These results demonstrate that the application of the QCC method is proven effective in increasing the efficiency of insert usage and reducing production costs without compromising the quality of the cutting results.

8. Standardization and Future Plans

a) Standardization

Standardization is carried out with the aim that the implemented improvement proposals from the research process can be executed sustainably. Through the application of this new work standard, it is expected that the Cost Per Piece (CPP) value can continue to decrease, and product quality can consistently improve, in line with the application of measurable and continuous improvement practices.

b) Future Plans

Based on the results of the research that has been conducted, it is known that the life time of the SNGX insert for the K25 model is still relatively low, reaching only 1,500 pcs per insert and cannot be reused. This condition indicates the need for further efforts to improve the performance of this insert.

Therefore, the theme for the next research plan is focused on: "Upgrading the SNGX Model K25 Insert to Increase Life Time."

Comparative analysis with related research shows consistency with QCC outcomes found in Tantri et al. (2023) and Kencana et al. (2024), which reported improvements of 30–40% in process performance. However, this study surpasses those outcomes in economic impact by directly affecting CPP through tool-life optimization rather than defect reduction alone.

The CPP decreased from Rp.133 to Rp.70, resulting in 48% cost savings. The annual financial impact includes a net quality income of Rp.78,444,554 and a return on investment (ROI) of 66 days. These outcomes confirm that the QCC method is not only technically effective but also financially advantageous.

CONCLUSION

This research demonstrates that the QCC method effectively increases insert lifetime and reduces CPP in the side cutting process for D.8 × 21.5 mm nut products at PT GM. The recoating treatment and insert classification significantly increased lifetime from 1,500 pcs to 3,200 pcs per insert, reducing CPP by 48%. The scientific contribution includes demonstrating QCC's effectiveness in tool-life optimization, cost reduction, and sustainable manufacturing practices through reduced tooling waste

The lifetime of the SNGX1203-ME insert increased from 1,500 pcs to 3,200 pcs, accompanied by a 48% reduction in CPP (from Rp.133 to Rp.70). This demonstrates that recoating treatment and improved insert classification were effective in lowering production costs and strengthening operational sustainability.

Moreover, the QCC approach fosters a culture of continuous improvement (*kaizen*) within the production team, ensuring that quality enhancement and cost reduction can be sustained through proper standardization and follow-up activities.

Future research is recommended to focus on upgrading the SNGX insert model K25 to further enhance its lifetime and overall cutting efficiency.

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