Increasing Efficiency in Pineapple Peeling Knife Sharpening through ECRS Principles

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Received: March 1, 2026 / Revised: June 17, 2026 / Accepted: June 17, 2026

***Abstract*—This study aims to improve the grinding process of pineapple peeling knives by addressing repetitive and time-consuming procedures, particularly non-value-added activities. These include bottleneck delays, equipment setup inefficiencies, and the ineffective use of grinding wheels. To address these issues, the researcher applied the ECRS principle through two main approaches: (1) designing and constructing a work-holding device (JIG) to enable faster and more precise knife assembly and (2) improving the grinding process by reducing the number of grinding wheels from two to one and increasing the hardness specification of the grinding wheel, thereby enhancing grinding efficiency.**

As a result of improving the grinding process for pineapple peeling knives using the ECRS principle, processing time decreased from 151 minutes per unit to 86 minutes per unit, while the number of operational steps decreased from 17 to 9. Production capacity increased from 70 units per month to 123 units per month, grinding wheel consumption decreased from 140 units per month to 45 units per month, and grinding costs decreased from 22,400 THB per month to 7,200 THB per month.

***Index Terms*—Pineapple Peeling Knives, Grinding Process, Grinding Wheels, Sharpening, ECRS Principle, Work-holding Device (JIG)**

I. Introduction

The fruit processing industry is a key sector contributing to Thailand's economic growth, particularly the canned pineapple industry, where Thailand is highly competitive in the global market. According to data from the Office of Agricultural Economics, in 2023, Thailand ranked first in the global canned pineapple export market, accounting for 45% of total export value [1]. Maintaining this competitive advantage requires continuous development and improvement of production efficiency.

The pineapple processing industry is one of the key sectors contributing to Thailand's economy, particularly the canned pineapple industry, which demonstrates strong competitiveness in the global market. However, many manufacturing plants continue to face challenges related to production inefficiencies, operational delays, and high processing costs. These issues reduce productivity and limit long-term competitiveness.

The production process of canned pineapple generally consists of several sequential stages, including raw material procurement, washing and sorting, peeling and cutting, blanching and pretreatment, filling and syruping, sealing and sterilization, labeling and packaging, and storage and distribution. Each stage uses labour, machinery, and resources. Inadequate process management at any stage may cause excessive waste, longer production times, and higher operating costs.

From a lean manufacturing perspective, these inefficiencies are often linked to non-value-added activities and waste, including waiting time, unnecessary transportation, redundant processing, excess inventory, unnecessary motion, overproduction, and product defects. In canned pineapple production, significant waste often occurs in peeling operations, knife grinding and maintenance, machine setup, material handling, and filling processes. These inefficiencies extend lead times and reduce product quality.

To systematically address these issues, the application of the ECRS principle, consisting of Eliminate, Combine, Rearrange, and Simplify, provides a practical framework for process improvement. Unnecessary activities can be eliminated, related operations can be combined, process sequences can be rearranged to enhance workflow continuity, and complex procedures can be simplified through equipment modification and automation. Implementing ECRS reduces cycle time,

improves labor utilization, and enhances operational consistency.

Therefore, this study applies the ECRS principle to improve the production process of canned pineapple, with particular emphasis on grinding and maintenance operations for pineapple peeling knives. The objectives are to enhance operational efficiency, reduce processing time and costs, and increase overall productivity. The findings of this study are expected to provide practical guidelines for process improvement in fruit processing and related food industries facing similar operational constraints.

A. Objectives of Research

- To analyze the existing grinding process of pineapple peeling knives and identify repetitive, time-consuming, and non-value-added activities.
- To apply the ECRS principle in redesigning the grinding process through the development of a work-holding device (JIG) and the optimization of grinding wheel configuration and specifications.
- To reduce processing time and the number of operational steps in the knife grinding process.
- To evaluate the impact of ECRS-based process improvements on grinding efficiency and operational costs.

B. Research Hypothesis

- The application of the ECRS principle significantly reduces processing time in the grinding process of pineapple peeling knives.
- The implementation of a work-holding device (JIG) improves the accuracy and efficiency of knife assembly and grinding operations.
- The redesigned grinding process based on the ECRS principle reduces non-value-added activities and enhances overall process performance.

C. Scope of Research

- The scope of this research is focused on improving the grinding process of pineapple peeling knives in a selected canned pineapple processing factory for three months.
- The study is limited to the analysis and improvement of activities related to knife grinding.
- This research covers the evaluation of existing grinding procedures, identification of non-value-added activities, and application of the ECRS principle to redesign the process.
- The study evaluates process performance in terms of processing time, number of operational steps, production capacity, grinding wheel consumption, and grinding costs. Data are collected before and after the implementation of improvements for comparative analysis.

D. Benefits

- This study provides several practical and academic benefits to the pineapple processing industry and related manufacturing sectors
- The research contributes to improving operational efficiency by reducing processing time, minimizing non-value-added activities, and simplifying grinding procedures through the application of the ECRS principle**.**
- The development and implementation of a work-holding device (JIG) improves the accuracy and consistency of knife grinding operations.
- The proposed methodology serves as a practical guideline for continuous improvement initiatives.

E. Definition

- ECRS Principle means a systematic process improvement method consisting of Eliminate, Combine, Rearrange, and Simplify, used to reduce non-value-added activities and enhance operational efficiency.
- Work-holding device (JIG) means a specially designed fixture used to securely position and align pineapple peeling knives during grinding operations to improve accuracy and reduce setup time.
- Processing time means the total time required to complete one grinding cycle for a pineapple peeling knife, measured from the beginning of setup to the completion of grinding.
- Non-value-added activities mean operations that consume time and resources without directly contributing to product quality or customer value, for example, waiting, unnecessary movement, and repeated adjustments.
- Production capacity means the maximum number of pineapple peeling knives that can be processed within a specified period, measured in units per month.

II. Literature Review

In pineapple processing, peeling is a critical step that directly affects product quality and the level of raw material loss [2]. Therefore, sharp and standardized peeling knives are essential for enhancing production efficiency. A study by Ibiyeye et al. [3] reported that the quality of peeling knives influences pineapple flesh loss by approximately 15-20 % and has a direct impact on worker performance.

An investigation of the grinding process for pineapple peeling knives in the selected case-study factory identified three major issues affecting production efficiency. First, excessive time was lost in unnecessary grinding operations, which is

consistent with the findings of Kumar [4], who reported that waste reduction in manufacturing processes can improve efficiency by 20-30%. Second, inappropriate grinding wheel speed settings were observed; Kannan [5] indicated that optimal grinding parameters can extend grinding wheel service life by up to threefold. Third, significant time was consumed in workpiece alignment, a common problem in grinding operations [6].

A review of the literature indicates that the application of the ECRS principle (Eliminate, Combine, Rearrange, and Simplify) can effectively improve production efficiency. Suhardi et al. [7] reported that implementing ECRS in manufacturing industries can reduce production time by 30-40%. Furthermore, its integration with other quality improvement tools, for example, Overall Equipment Effectiveness (OEE) [8] and Six Big Losses analysis [9], contributes to systematic enhancements in operational performance.

This study focuses on the application of the ECRS principle to improve the grinding process of pineapple peeling knives, with the objectives of enhancing efficiency, reducing processing time, lowering costs, and increasing process productivity. The findings not only address existing issues in the current production process but also demonstrate potential applicability to other manufacturing operations in the fruit processing and broader food industries that face similar constraints and challenges. This contribution supports the need to respond effectively to rapid growth and evolving demands in the global food industry.

III. Methodology

A. *Pineapple Peeler Knife*

In the grinding process of pineapple peeling knives, the knife frame components are manufactured from SUS304 stainless steel and brass, as shown in Fig. 1 (a) and (b), respectively.

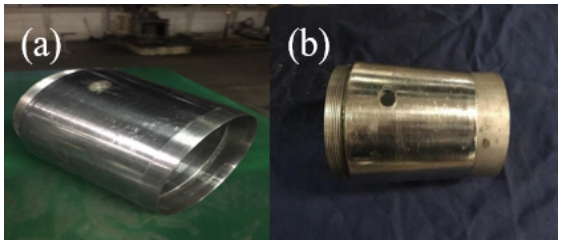

Fig. 1. Pineapple peeler knife, (a) SUS304 stainless steel and (b) brass

The blade components are made of S50C steel that has undergone a hardening process, resulting in a hardness value of 60 HRC. The hardened blades are subsequently assembled with the knife frames and then subjected to the grinding process to adjust their dimensions and geometry in accordance with the company's specified standards, as illustrated in Fig. 2.

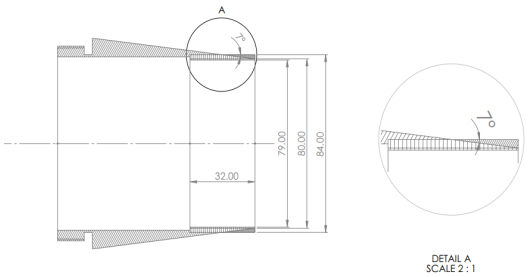

Fig. 2. Grinding specifications for pineapple peeling knives

B. *Grinding Machine*

The pineapple peeling knife grinding machine, as shown in Fig. 3, is designed to adjust the dimensions, geometry, and sharpness of the blades in accordance with specified production standards. Its operation is based on the coordinated function of seven main components, including the workpiece chuck, workpiece, rotational speed control system, grinding wheel, motor, grinding wheel turret, and belt–pulley system.

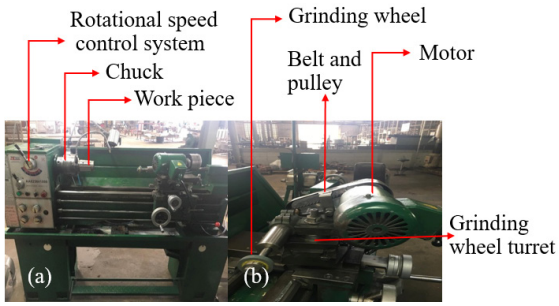

Fig. 3. Grinding machine, (a) Front view and (b) Side view

During operation, the assembled pineapple peeling knife is first secured on the workpiece chuck to ensure proper alignment and stability. This secure positioning minimizes vibration and prevents unwanted movement during the grinding process, thereby improving dimensional accuracy and surface quality. The workpiece, which consists of a hardened steel blade attached to its supporting frame, is positioned to allow both internal and external surfaces to be processed effectively.

The rotational speed control system regulates the rotational speed of the grinding wheel according to the specific grinding requirements, such as rough grinding and fine finishing. Appropriate speed adjustment is essential for maintaining consistent material removal rates, reducing thermal damage, and extending grinding wheel service life. The motor serves as the primary power source of the machine, converting electrical energy into mechanical energy

and transmitting it to the grinding wheel through the belt–pulley system. This transmission mechanism allows for flexible speed adjustment and stable torque delivery.

The grinding wheel functions as the primary cutting and finishing tool, removing excess material and refining the surface of the workpiece. Both coarse and fine grinding wheels are employed at different stages of the process to achieve the required surface roughness and dimensional accuracy. The grinding wheel turret supports and positions the grinding wheels and enables precise adjustment of their orientation and angle. This feature is particularly important for setting the cutting angle of the blade and ensuring uniform sharpening.

Throughout the grinding process, the operator adjusts the turret position and grinding parameters in accordance with process specifications. The interaction between the rotating grinding wheel and the stationary workpiece enables controlled material removal, resulting in the desired geometry and edge sharpness. After completing the rough and fine grinding stages, the workpiece is inspected to verify dimensional accuracy and surface smoothness. Once the required standards are met, the finished knife is removed from the machine and prepared for subsequent production stages.

C. Operation Process

The procedure consists of 17 main steps. The process begins with mounting the workpiece on the grinding machine chuck and performing workpiece centring, which requires approximately 20 minutes. Subsequently, the grinding wheel is assembled, followed by rough grinding of the inner surface.

After rough grinding, dimensional inspection is conducted, and the grinding wheel is replaced with a fine wheel for precision grinding. Measurements and surface smoothness inspections are then performed to ensure compliance with quality standards. The grinding wheel is later changed back to a coarse wheel for external edge grinding, and the tool post is adjusted to a 4-degree angle.

Rough grinding of the cutting edge is carried out, followed by dimensional and angular inspection. The grinding wheel is then replaced with a fine wheel for finishing operations. Final grinding, measurement, and inspection are conducted before the completed workpiece is removed and stored.

The total processing time for the entire grinding procedure is approximately 151 minutes per unit. Several stages involve repeated wheel changes and frequent inspections, which contribute to extended processing time and indicate the presence of non-value-added activities. These inefficiencies highlight the need for systematic process improvement through the application of the ECRS principle.

Table I presents an operation process chart illustrating each step of the pineapple peeling knife grinding process. The symbols represent different types of activities, including operation (Circle symbol), transportation (Arrow symbol), delay (D-shape symbol), inspection (Square symbol), and storage (Triangle symbol), which are used to analyze workflow efficiency and identify non-value-added activities.

According to Table I, the total processing time for the entire grinding procedure is approximately 151 minutes per unit. All processes can be classified into four subprocesses, namely the setup process, grinding process, inspection process, and other supporting processes. The grinding process accounts for the largest proportion of the total processing time, requiring 95 minutes. This is followed by other supporting processes, which require 26 minutes, while the setup and inspection processes require 20 and 10 minutes, respectively.

TABLE I
OPERATION PROCESS CHART FOR THE GRINDING PROCESS OF PINEAPPLE PEELING KNIVES

Order	Process	Symbols					Times (min)
		○	⇨	D	▽	□	
1	Setting on the chuck	●					1
2	Secure positioning	●					20
3	Assemble the grinding wheel	●					5
4	Rough grinding	●					45
5	Measure dimension					●	2
6	Change to fine grinding	●					5
7	Fine grinding	●					10
8	Measure dimension					●	2
9	Check surface smoothness					●	2
10	Change to rough grinding	●					5
11	Adjusted to a 4-degree	●					5
12	Rough grinding	●					30
13	Angular inspection					●	2
14	Change to a fine wheel	●					5
15	Fine grinding	●					10
16	Angular inspection					●	2
17	Removed and stored				●		-
	SUM	**11**	**0**	**0**	**1**	**5**	**151**

The grinding process of pineapple peeling knives involves multiple operational steps, and inefficiencies arising from unsuitable machine conditions and inappropriate grinding wheel selection result in excessive production time. In particular, the grinding stage requires up to 95 minutes, representing a substantial proportion of the total processing time. In addition, data on the consumption of both coarse and fine grinding wheels used in the grinding process were collected over three months, as illustrated in Fig 4.

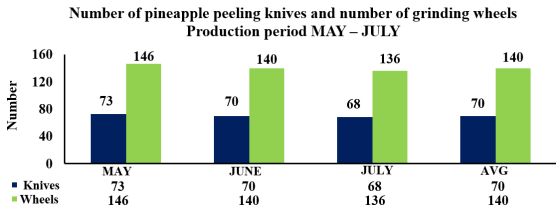

Fig. 4. Number of pineapple peeling knives and number of grinding wheels in the production period MAY-JULY.

Fig. 4 illustrates that the monthly consumption of grinding wheels exceeds the average number of workpieces produced. On average, approximately two grinding wheels are required to produce one pineapple peeling knife. Given that each grinding wheel costs 160 THB, this consumption rate results in substantial expenses associated with the pineapple peeling knife grinding process. Consequently, the total grinding wheel costs were 23,360 THB, 22,400 THB, and 21,760 THB for May, June, and July, respectively. The average grinding wheel cost over the three months was 22,506 THB.

Based on the analysis of the pineapple peeling knife grinding process, three major problems were identified. First, excessive time was consumed during the grinding operations. Second, inappropriate grinding wheel speed settings were observed, leading to inefficient material removal. Third, significant time was lost during workpiece centering and alignment. However, several studies emphasize that sustainable process improvement requires a thorough understanding of the underlying causes of problems, rather than addressing only their visible symptoms.

The **Why-Why analysis** is considered an appropriate tool for systematically identifying the root causes of operational problems, particularly those related to time losses and machine inefficiencies. In the grinding process of pineapple peeling knives, the major issues identified include excessive time consumption during grinding operations, inappropriate grinding wheel speed settings, and significant time loss during workpiece centering and alignment. These problems are complex in nature and are influenced by multiple factors, including operational methods, machine conditions, and operator skills. The insights obtained from this analysis provide a critical foundation for defining effective improvement strategies based on the ECRS principle. Such strategies aim to reduce processing time, optimize grinding wheel operating parameters, and simplify workpiece centering procedures in alignment with actual shop-floor conditions. The next section of this study presents the research methodology, detailing the procedures used to apply the **Why-Why** analysis and demonstrating how the identified root causes were translated into practical process improvement measures for the pineapple peeling knife grinding process.

While the application of ECRS principles is extensively documented across diverse manufacturing sectors, empirical research focusing on specialized supporting processes, specifically tool sharpening within the fruit processing industry, which operates under stringent hygiene and precision constraints remains markedly scarce. This study addresses this scholarly lacuna by integrating ECRS methodologies with engineering grinding techniques, thereby establishing a systematic and quantifiable framework to optimize the efficiency of the pineapple peeling knife sharpening process.

D. Why-Why Analysis

Based on the operational data collected from the production process, the researcher conducted a root cause analysis using the Why-Why analysis technique and formulated corrective measures in accordance with the ECRS principle [10]. Table II presents the analysis of the root causes associated with time losses in the grinding process.

The Why-Why analysis was conducted to identify the root causes of time losses in the grinding process of pineapple peeling knives. The analysis revealed that excessive processing time was primarily attributed to the complexity of the grinding procedure.

TABLE II
THE ROOT CAUSES ASSOCIATED WITH TIME LOSSES IN THE GRINDING PROCESS

Why I	Reson I→Why II	Reson II→Root cause
Time losses in the grinding process	The grinding process consists of multiple operational steps and requires the use of grinding wheels with various grades.	The grinding process is specified to include both rough grinding and fine grinding operations.
Solution	The improvement approach involved eliminating unnecessary operational steps by increasing the hardness of the grinding wheel to reduce redundant fine grinding operations and combining the rough and fine grinding stages into a single process.	

which consisted of multiple operational steps and required the use of grinding wheels with various grades. Further investigation indicated that the process specification mandated separate rough grinding and fine grinding operations, resulting in repeated machine setup, frequent grinding wheel changes, and extended processing time.

The analysis clearly demonstrated that the requirement for multiple grinding stages was not driven by essential quality needs but rather by traditional process design. This condition led to redundant operations and increased non-value-added time within the grinding process.

To optimize grinding wheel operating parameters, the root causes associated with machine conditions are presented in Table III.

TABLE III
THE ROOT CAUSES ASSOCIATED WITH GRINDING WHEEL OPERATING PARAMETERS

Why I	Reson I→Why II	Reson II→Root Cause
The operating parameters of the grinding wheel are not optimized	The standard operating procedure (work instruction) does not define the appropriate grinding wheel rotational speed.	No experiments have been conducted to determine the standard values for the appropriate grinding wheel rotational speed.
Solution	The improvement approach applied the principle of rearrangement by modifying the belt–pulley system to increase the rotational speed of the grinding wheel, followed by experimental testing to determine the optimal grinding wheel speed for the workpiece.	

The Why-Why analysis was conducted to investigate the root causes associated with non-optimized grinding wheel operating parameters. The analysis revealed that the primary issue was the absence of defined rotational speed values in the standard operating procedure (work instruction). Further examination indicated that this deficiency resulted from the lack of experimental studies conducted to determine appropriate grinding wheel rotational speed standards for the workpiece. Consequently, grinding wheel operating parameters were set based on operator experience rather than data-driven criteria, leading to inconsistent grinding performance and reduced process efficiency.

The third major problem relates to workpiece centering and alignment. Therefore, the root cause analysis of the centering and alignment problem during workpiece setup is presented in Table IV.

The Why-Why analysis was conducted to identify the root causes of time losses associated with workpiece centering and alignment during the setup stage. The analysis revealed that excessive setup time resulted from the need to repeatedly clamp the workpiece to the fixture. Further investigation indicated that insufficient clamping stability caused the workpiece to become dislodged during grinding operations, requiring frequent process interruptions for corrective action. These interruptions significantly increased setup time and reduced overall process efficiency.

TABLE IV
THE ROOT CAUSES ASSOCIATED WITH CENTERING AND ALIGNMENT PROBLEM DURING WORKPIECE SETUP

Why I	Reson I Why II	Reson II Root cause
Time losses associated with workpiece centering and alignment.	The workpiece must be repeatedly clamped to the fixture.	When the workpiece is not securely clamped in the fixture, it may become dislodged, requiring the grinding process to be halted for corrective action.
Solution	The improvement approach applied the simplification principle by designing a JIG to facilitate knife positioning, thereby reducing workpiece setup time and improving clamping stability.	

E. Problem – Solving Procedure

To address time losses in the grinding process, the researcher replaced the existing grinding wheels with a new specification featuring increased hardness in accordance with ISO 525:2020 [11]. Previously, a coarse grinding wheel with the specification GC 90 GV was used for rough grinding, while a fine grinding wheel with the specification GC 180 LV was applied for finishing operations. These were replaced with a newly specified grinding wheel that increased the bonding grade from G (very soft) to K (Soft) and adjusted the abrasive grain size from 90 to 100, as shown in Fig 5. Consequently, the rough and fine grinding stages were combined into a single grinding operation (Combine).



Fig. 5. Grinding wheels, (a) Grade G (very soft) and (b) Grade K (soft)

F. Experimental Investigation of Feed Rate and Rotational Speed

Following the replacement of the original grinding wheel with a new specification featuring increased hardness, grinding experiments were conducted on pineapple peeling knives to determine the grinding wheel wear rate using the minimum weight-loss method before practical application. The experiments were performed by varying the workpiece rotational speed at 70 and 115 RPM and the feed rate at 0.10, 0.15, and 0.20 mm/rev, while maintaining coolant application as a controlled variable. Each experimental condition was repeated three times, resulting in a total of 18 specimens. After each test, the grinding wheel was weighed as shown in Fig 6, and the weight loss was calculated in milligrams per hour for comparison. To minimize grinding wheel weight loss, a two-way ANOVA at a significance level of 0.05 was used to evaluate the effects of rotational speed and feed rate on grinding wheel weight loss. The grinding condition associated with the lowest weight loss was subsequently selected for implementation in actual grinding operations.



Fig. 6. The weight of the grinding wheel

G. Design and fabrication of a Work – Holding Device (JIG)

To reduce the time required for workpiece centering before grinding, which was excessively long due to direct clamping of the workpiece that could cause damage to the knife frame, a dedicated work-holding device was designed. This device was developed to prevent structural damage and to reduce workpiece setup time, as shown in Fig 7.

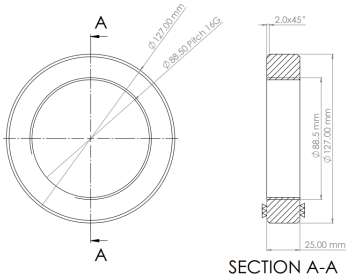

Fig. 7. The section view of the wok–holding device (JIG)

The work-holding device was fabricated from SUS304 stainless steel with an outer diameter of 127 mm and a thickness of 25 mm. It features an internal thread with a diameter of 88.5 mm and a pitch of 16G, configured as a left-hand thread to enable secure locking with the workpiece according to the design specification. The device was subsequently used to improve knife clamping stability and to function as a JIG, as illustrated in Fig 8.

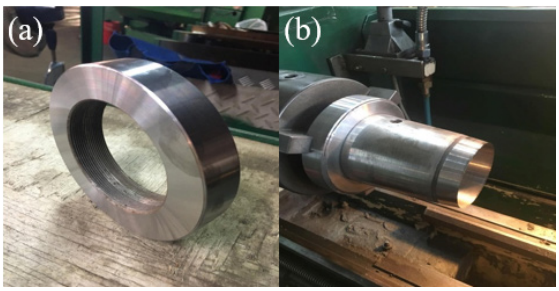

Fig. 8. A work–holding device (JIG), (a) uninstalled and (b) installed condition

IV. Research Results

The results of this study are presented in this section, highlighting the investigation of feed rate and rotational speed, their effects on grinding wheel weight loss, and the performance of the work - holding device (JIG) developed to improve workpiece centering and clamping stability in the grinding process.

A. Experimental results

For the experimental investigation of feed rate and rotational speed, Fig. 9 presents the average weight loss of grinding wheels at different rotational speeds and feed rates.

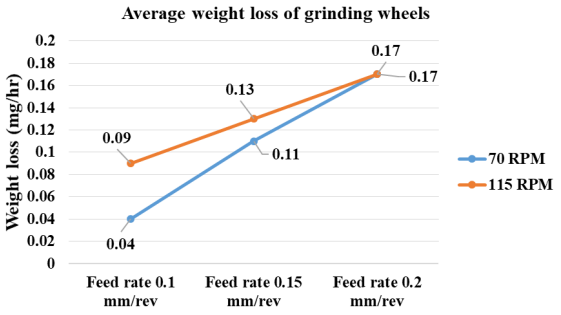

Fig. 9. Average weight loss of grinding wheels after use at different feed rate and RPM

The results show a consistent increase in grinding wheel weight loss as the feed rate increases from 0.10 to 0.20 mm/rev for both rotational speeds. This trend indicates that higher feed rates lead to greater material removal forces and increased abrasive wear. At all feed rates, grinding performed at **115 RPM** results in higher weight loss compared to **70 RPM**, demonstrating that rotational speed has a measurable influence on grinding wheel wear. The lowest weight

loss, approximately **0.04 mg/hr**, is observed at a feed rate of **0.10 mm/rev** and a rotational speed of **70 RPM**, indicating the most favorable condition for minimizing grinding wheel wear. In contrast, the highest weight loss, approximately **0.17 mg/hr**, occurs at a feed rate of **0.20 mm/rev** for both rotational speeds, suggesting that the effect of feed rate becomes dominant at higher levels.

Feed rate was identified as the most influential factor affecting grinding wheel wear. As the feed rate increased from 0.10 to 0.20 mm/rev, the average weight loss of the grinding wheel increased substantially. This trend can be attributed to the higher material removal rate and increased contact forces between the grinding wheel and the workpiece at higher feed rates, which accelerate abrasive grain fracture and bond wear. These findings are consistent with established grinding theory, which suggests that aggressive cutting conditions lead to increased tool wear.

Rotational speed also exhibited a significant effect on grinding wheel weight loss. Higher rotational speed (115 RPM) resulted in greater wheel wear compared to lower speed (70 RPM), particularly at lower feed rates. This behavior is associated with increased sliding velocity and frictional heat generation at the grinding interface, which promotes bond softening and abrasive degradation. However, the effect of rotational speed became less pronounced at higher feed rates, indicating the presence of an interaction effect between rotational speed and feed rate.

Table V presents the results of the grinding experiments, which were analyzed using a two-way analysis of variance (ANOVA) to evaluate the effects of rotational speed and feed rate on grinding wheel weight loss. The ANOVA results indicate that both main factors, namely rotational speed and feed rate, have statistically significant effects on grinding wheel wear, as well as their interaction ($p < 0.05$). This confirms that grinding wheel weight loss is influenced not only by individual process parameters but also by their combined effect.

The statistically significant interaction between rotational speed and feed rate demonstrates that the influence of rotational speed on grinding wheel wear depends on the selected feed rate. Specifically, at a feed rate of 0.10 mm/rev, increasing rotational speed led to a notable increase in weight loss, whereas at 0.20 mm/rev, the difference in wear between the two speeds was relatively small. This interaction highlights the importance of considering combined parameter settings rather than optimizing individual factors independently.

TABLE V
TWO-WAY ANOVA FOR GRINDING WHEEL WEIGHT LOSS

Source of Variation	Sum of Squares (SS)	DF	Mean Square (MS)	p-value
RPM	0.0027	1	0.0027	0.0007
Feed rate	0.0300	2	0.0150	<0.0001
Interaction	0.0012	2	0.0006	0.0317
Error	0.0016	12	0.0001	-
Total	0.0355	17	-	-

Based on the optimization objective of minimizing grinding wheel weight loss, the optimal operating condition was identified as a rotational speed of 70 RPM and a feed rate of 0.10 mm/rev. Under this condition, the grinding wheel showed the lowest average weight loss, indicating reduced abrasive wear and improved tool life. From an industrial perspective, adopting this parameter combination can lower tooling costs, improve process stability, and enhance the sustainability of the grinding operation.

B. The Performance of The Work–Holding Device (JIG)

Following implementation of the proposed corrective actions, a before–and–after comparison was conducted to evaluate process performance. As shown in Table VI, the post-improvement production process substantially reduced total processing time from 151 minutes to 86 minutes, and the number of operational steps decreased from 17 to 9, indicating a considerable simplification of the production process.

TABLE VI
OPERATION PROCESS CHART FOR THE GRINDING PROCESS OF PINEAPPLE PEELING KNIVES AFTER PROCESS IMPROVEMENTS

Order	Process	Symbols ○	⇨	D	▽	□	Times (min)
1	Setting on the Chuck	●					1
2	Secure Positioning	●					1
3	Assemble Grinding Wheel	●					5
4	Rough Grinding	●					40
5	Measure Dimension					●	2
6	Adjust to 7 Degrees	●					5
7	Fine Grinding	●					30
8	Measure Dimension					●	2
9	Removed and Stored				●		-
	SUM	**6**	**0**	**0**	**1**	**2**	**86**

After implementing process improvements, the workpiece setup stage required 20 minutes before the improvement, while no setup time was required after the improvement. In the grinding stage, processing time decreased from 95 minutes before improvement to 70 minutes after improvement. For the dimensional measurement and inspection stage, the time decreased from 10 minutes to 4 minutes. In addition, the time required for other supporting processes decreased from 26 minutes before improvement to 12 minutes after improvement, as shown in Table VII.

TABLE VII
COMPARISON OF OPERATIONAL TIME BEFORE AND AFTER PROCESS IMPROVEMENT BY WORK CATEGORY

Work Category	Times (Minute)	
	Before Improvement	After Improvement
Setting	20	0
Grinding	95	70
Measure dimension	10	4
Other	26	12
SUM	**151**	**86**

C. Production Capacity

An evaluation of production capacity in the grinding process indicates that, before process improvement, the grinding time was 151 minutes per unit with a total of 17 operational steps. After process improvement, grinding time fell to 86 minutes per unit, and the number of operational steps decreased to 9. Consequently, the reduced processing time significantly increased production capacity. Based on an average of 22 working days per month and an 8-hour working day, production output increased from 70 units per month before improvement to 123 units per month after improvement, representing an increase of approximately 75.7%, as shown in Fig 10.

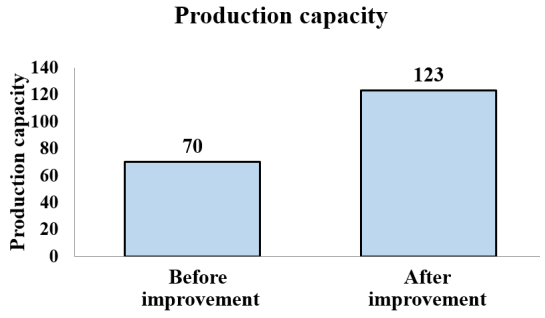

Fig. 10. Production capacity

Based on the collected data on grinding wheel consumption for pineapple peeling knife production, grinding wheel usage decreased. This reduction resulted from replacing the original grinding wheels with a new specification and decreasing processing time after process improvement. Consequently, production required fewer grinding wheels, as shown in Fig. 11.

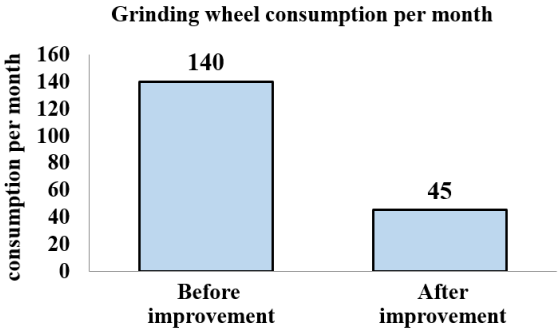

Fig. 11. Grinding wheel consumption per month

After the process improvement, grinding wheel consumption fell from 140 units to 45 units per month. Accordingly, the grinding wheel cost before improvement was 140 units at 160 THB per unit, for a total of 22,400 THB per month. After improvement, the consumption decreased to 45 units per month, corresponding to a total cost of 7,200 THB per month. This represents a cost reduction of approximately 68.01%, as illustrated in Fig. 12.

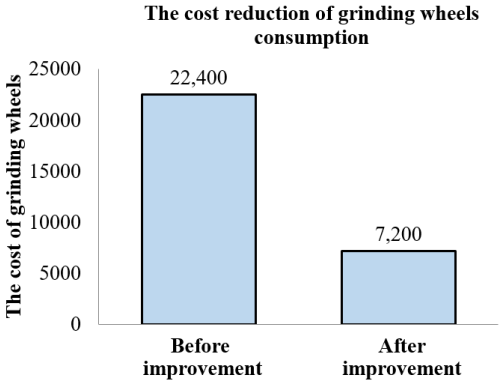

Fig. 12. The cost of grinding wheel consumption per month

V. DISCUSSION

The results show that systematic process improvement based on root cause analysis and ECRS principles can significantly improve the efficiency of the pineapple peeling knife grinding process. The initial analysis revealed that excessive processing time, high grinding wheel consumption, and unstable workpiece setup were the primary contributors to inefficiency. These issues aligned with non-value-added activities commonly reported in grinding and tool maintenance operations.

The Why-Why analysis effectively identified the fundamental causes of inefficiency rather than addressing only surface-level symptoms. In particular, the separation of rough and fine grinding operations, the lack of standardized grinding wheel rotational speed parameters, and unstable workpiece clamping

were identified as the dominant root causes of time losses and excessive tool wear. This finding highlights the importance of structured root cause analysis in guiding appropriate improvement strategies and avoiding ineffective or superficial solutions. Applying the ECRS principle provided a systematic framework for translating analytical findings into practical improvements.

Eliminating and combining grinding stages by using a single, harder grinding wheel directly reduced redundant operations and machine setup time. This modification significantly shortened the grinding cycle and simplified the overall process flow. Rearranging the belt–pulley system to increase grinding wheel rotational speed addressed machine-related inefficiencies and enabled operation under calculated optimal conditions. Experimental determination of feed rate and rotational speed further ensured that process parameters were optimized based on empirical evidence rather than operator experience. The design and implementation of a dedicated work-holding device (JIG) played a critical role in improving workpiece centering and clamping stability.

Before the improvement, workpiece setup depended heavily on operator skill and required repeated clamping, often leading to misalignment, workpiece damage, and process interruptions. The JIG effectively eliminated these issues by providing consistent positioning, reducing setup time to zero, and preventing damage to the knife frame. This result underscores the importance of fixture design in grinding operations, particularly when precision and repeatability are required. Statistical analysis using two-way ANOVA confirmed that feed rate and rotational speed significantly affected grinding wheel weight loss, with feed rate identified as the most influential factor. The statistically significant interaction between feed rate and rotational speed further indicated that optimization must consider combined parameter settings rather than individual factors in isolation.

The experimental results validated the selected optimal condition of 70 RPM and 0.10 mm/rev, which achieved the lowest grinding wheel wear and supported longer tool life. These findings are consistent with established grinding theory, where lower feed rates and controlled speeds reduce abrasive grain fracture and bond degradation. Operationally, the reduction in processing time from 151 minutes to 86 minutes per unit and the decrease in operational steps from 19 to 9 represent substantial improvements in process efficiency. These changes directly translated into increased production capacity, with monthly output rising by approximately 75.7%. In parallel, grinding wheel consumption fell by 68.01%, delivering significant cost savings. This dual improvement in productivity and cost efficiency highlights the effectiveness of the proposed approach and its practical value for industrial implementation.

Overall, the discussion confirms that integrating root cause analysis, ECRS principles, experimental optimization, and fixture design provides a robust methodology for improving grinding processes. The results not only validate the effectiveness of the proposed improvements for pineapple peeling knife manufacturing but also demonstrate their potential applicability to similar grinding and tool maintenance operations in food processing and other manufacturing industries.

VI. Conclusions

This study demonstrated that systematic process improvement based on Why-Why analysis and the ECRS principle can significantly enhance the efficiency of the pineapple peeling knife grinding process. By identifying and addressing the root causes of excessive processing time, inappropriate grinding parameters, and unstable workpiece clamping, the study successfully implemented effective improvement strategies. Integrating a redesigned work-holding device (JIG), optimizing grinding wheel rotational speed and feed rate, and consolidating grinding stages substantially reduced processing time and the number of operational steps.

Experimental optimization confirmed that a workpiece rotational speed of 70 RPM and a feed rate of 0.10 mm/rev minimized grinding wheel wear, while statistical analysis verified the significance of these parameters and their interaction. As a result of the proposed improvements, processing time was reduced from 151 minutes to 86 minutes per unit, production capacity increased by approximately 75.7%, and grinding wheel consumption decreased by 68.01%, leading to considerable cost savings.

Overall, the findings confirm that the proposed approach provides an effective and practical framework for improving grinding operations. The methodology and results offer valuable guidance for similar tool grinding and maintenance processes in food processing and related manufacturing industries.

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