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Redesign of Pineapple Peeler Using The Integration of Ergonomic Function Deployment (EFD) and Theoriya Resheniya Izobreatatelskikh Zadatch (TRIZ) Method

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Abstract. *The main ergonomic problem in the UMKM Berkah Sekar Abadi Women Farmers Group lies in the effectiveness of the pineapple peeler used. Physical complaints are also experienced by workers due to tool dimensions that are not in accordance with the user's posture. There are two types of peeler tools, the first tool with a fixed dimension knife, and the second tool with a knife that can be adjusted in diameter but is less effective in removing pineapple eyes. This study aims to redesign the pineapple peeler to be more ergonomic, easy to use, and able to adjust the knife diameter to the size of the fruit. Data collection was conducted through the distribution of Ergonomic Function Deployment (EFD) stage 1 and 2 questionnaires accompanied by open discussions. Analysis was conducted using the EFD method to identify user needs, as well as the TRIZ method to resolve design contradictions. From the processing results using the EFD method, 15 customer needs were obtained with an importance level value of 5 for 11 attributes and 4.5 for 4 attributes. In addition, to answer 15 customer needs, 14 technical responses were designed that can answer all customer needs. In the house of ergonomic matrix there are 9 negative correlations that occur. Then the 9 negative correlations were identified and resolved with the TRIZ method into 5 contradictions. With the TRIZ method, a design proposal was obtained by using anodized aluminum alloy material for the frame and food grade stainless steel for the peeler knife and pineapple fruit clamp, adding a protective cover, and dividing the two functions between anti-slip on the support leg and the wheels used to move the pineapple peeler.*

Keywords: *ergonomics, pineapple peeler, tool redesign, Ergonomic Function Application, Theoriya Resheniya Izobreatatelskikh Zadatch*

I. INTRODUCTION

Ergonomics is the ability to apply information that is appropriate to human characteristics, capacities, and limitations to the design of work, machinery, and systems, as well as work spaces and environments, so that humans can live and perform their work in a healthy, safe, comfortable, and efficient manner (Tarwaka and Bakri, 2004). The purpose of ergonomics is to design objects, equipment, and machinery that can be used effectively by humans (Susanti, Zadry and Yuliandra, 2015).

The application of ergonomic principles is crucial for industries, including micro, small, and medium enterprise, as it plays a significant role in supporting productivity improvements.

Over the past five years, Indonesia has ranked third as the world's third-largest exporter of canned pineapples (Darmawan, 2023). One of the main pineapple production centers in Indonesia is Dusun III Siwarak, Karangreja Subdistrict, Purbalingga Regency, Central Java. One of the SMEs processing pineapples into various types of food and beverages is the UMKM Kelompok Wanita Tani Berkah Sekar Abadi. As a relatively new micro-enterprise entering the industrial sector, this SME still faces various operational challenges that could hinder its competitiveness.

The problem faced by UMKM KWT Berkah Sekar Abadi is an inefficient production process. The contributing factor is the lack of pineapple peeling tools suitable for the size of pineapples grown in the Siwarak plantation, resulting in the peeling process still being done manually with kitchen knives. This causes the production process to take longer and prevents the company

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from meeting market demand. The main ergonomic issue faced by the UMKM KWTBerkah Sekar Abadi is related to the effectiveness of the pineapple peeling tool. In addition, another issue is that workers in the peeling section experience discomfort in several parts of their bodies, such as the back, waist, and hands, due to the dimensions of the pineapple peeling tool not being suitable for the body size of the workers in the peeling section.

UMKM KWT Berkah Sekar Abadi already has two pineapple peelers, as shown in Figure 1 One of the pineapple peelers is a machine provided by the agricultural department, painted silver, while the other pineapple peeler was made by the UMKM KWT Berkah Sekar Abadi, painted blue. However, the pineapple peelers currently available are not being used to their full potential for production activities, as they face the same issue during application. The second tool, which was independently developed by the KWT Berkah Sekar Abadi, has advantages over the first pineapple peeler. The second pineapple peeler has blades of varying diameters so that it can be adjusted to the diameter of the pineapple, but it has a problem in that it leaves behind the pineapple eyes, which should be discarded.

Figure 1. Pineapple Peelers Existing

Figure 2. Siwarak pineapple

Based on Figure 1. the pineapple peeler, which was provided by the agricultural office, has a problem with its blade diameter, which is not adjustable to the diameter of the pineapple. The blade diameter is more suitable for pineapples with a diameter of 25–30 cm, while the diameter of Purbalingga honey pineapples is around 6 – 11 cm, as shown in Figure 2.

One way to solve the problems encountered in the pineapple peeling process is to redesign the pineapple peeler to be more effective and better suited to the needs of users, with an emphasis on ergonomics. One aspect of this is the distance between the peeler and the pineapple, which can be adjusted to suit the diameter of the pineapple. In the process of designing this pineapple peeler, an appropriate method is needed so that the new design can be implemented and have a positive impact on the KWT Berkah Sekar Abadi.

Based on research conducted by Ahmady, Martini and Kusnayat (2020) using the EFD method to redesign material handling equipment (MHE) by applying ergonomic aspects, it was possible to produce ergonomic design proposals. Additionally, a similar method was applied to the redesign process of an ergonomic dish trolley, which was proven to assist workers in the dish-lifting process, improve work efficiency, and reduce the risk of poor posture based on OWAS measurements from lev el 3 to level 1 (Siska and Syahbana, 2020). Research conducted by (Sarpong *et al.*, 2024) integrated several methods such as TRIZ, AHP, and QFD to redesign a cassava grater machine with a more modern design that meets the innovative and effective needs of customers, while also improving the efficiency and productivity of the cassava grater machine.

The process of redesigning a tool can be carried out using several methods to solve design problems, including QFD, DFMEA, KANO, and Kansei Engineering (Bakhtiar and Puspitasari, 2021). The methods used to generate solution ideas for a problem that occurs and is appropriate can utilize the trial-and-error method and TRIZ with the TRIZ contradiction matrix tool (Pratikno, 2020). Ergonomic Function Deployment (EFD) combined with the Theory of Inventive Problem Solving (TRIZ) is an effective approach for redesigning a pineapple peeler to meet user needs. Ergonomic Function Deployment (EFD) is an evolution of Quality Function Deployment (QFD), adding a new relationship between customer needs and the ergonomic aspects of the product. The House of Quality matrix has been developed into the House of Ergonomic Matrix to assess the suitability of the design from an ergonomic perspective (Siska and Syahbana, 2020). The advantage of the EFD method lies in its ability to assist the design and decision-making process through representation in the form of a matrix, enabling evaluation and modification of the design to ensure it meets ergonomic criteria (Anshori, 2020).

The TRIZ method is often used to solve technical problems, innovation, technology strategy (forecasting and planning), and business management. The advantage of this method lies in its ability to identify problems, generate more varied and innovative ideas, and accelerate the solution acquisition process (Ilevbare, Probert and Phaal, 2013). Both methods are widely used in the design or innovation process of a product to improve the effectiveness and efficiency of the design.

Based on the problems encountered by the Berkah Sekar Abadi Women Farmers Group MSME, this study will redesign the pineapple peeler by integrating the EFD and TRIZ methods with the aim of producing a pineapple peeler that meets user requirements.

II. Research Method

At this stage the researchers conducted direct observations and interviews at the research location, namely the KWT Berkah Sekar Abadi UMKM. The data collection process in this study was carried out by distributing stage 1 and stage 2 questionnaires. The distribution of open questionnaires (stage 1) was carried out by means of informal discussions and open interviews with 4 respondents to find out the needs and expectations of users. Then the stage 2 questionnaire. The stage 2 EFD questionnaire was used to identify the priority of customer needs based on the perceived importance of each product attribute Respondents gave an assessment of each question using a 5-point Likert scale. In addition to these two data, this study also collected data on respondent characteristics based on gender, age, height and weight, and hand dominance when working which will be used as a basis for determining anthropometry. The purpose of this research is to find out the voice of the customer, both the needs, constraints, and expectations of the pineapple peeler, which is then analyzed to provide solutions that are poured into the design of the 3D pineapple peeler design.

The method used to analyze user needs and expectations for the pineapple peeler in this study is Ergonomic Function Deployment (EFD). Through the EFD approach, the relationship between customer needs and technical responses was mapped, and the relationship between technical responses and user needs was identified. From this analysis, several design conflicts or technical contradictions emerged which were then resolved using the Theory of Inventive Problem Solving (TRIZ) approach. The TRIZ method was used to formulate innovative solutions to these contradictions by referring to relevant inventive principles. The resulting solution was then realized in the form of a three-dimensional design proposal (3D CAD model) as the final result of the ergonomics-based product redesign process.

The first stage of data collection is the distribution of preliminary questionnaires (stage 1). From the distribution of the stage 1 questionnaire, which was an open questionnaire, data was obtained in the form of Voice of Customer from workers at KWT Berkah Sekar Abadi. Identification of consumer needs is carried out by translating the results of Voice of Customer that have been obtained from the distribution of stage 1 questionnaires. The following are the results of the identification of consumer needs.

Then the customer needs are made into an importance rating questionnaire (stage 2). The importance rating was conducted to determine the workers' assessment of the design of the pineapple peeler. This value is obtained from the results of the assessment of pineapple peeling workers through filling out the importance level questionnaire (stage 2) regarding the assessment of their wishes from the design of the pineapple peeler.

III. Result and Discussion

Analysis of Ergonomic Function Deployment Method

The development of the House of Ergonomics (HOE) begins by filling in the left side of the matrix with customer needs obtained from the results of the preliminary questionnaire (stage 1). The next stage is to determine the technical response to meet each customer need. In this study, five dimensions of ergonomics were used, namely ENASE, which resulted in 15 customer needs for the design of a pineapple peeler. Of these 15 customer needs, 14 could be met with technical responses.

After all technical responses to all customer needs have been determined, the next step is to identify the relationship between the two, which is then entered into a relationship matrix indicated by symbols with different values. The values in this relationship matrix are 9 (strong), 3 (moderate), and 1 (weak). Next, the relationship values are multiplied by the weight values of each customer need, resulting in the weight values for each column of technical responses. The weight values are then sorted from highest to lowest, serving as the priority reference for the redesign process of the pineapple peeler. The technical response with the highest weight value is the sharp blade technical response with a column weight value of 195, and the technical response with the lowest column weight value is made of stainless steel (thick) material and an ergonomic sitting work position with a column weight value of 45.

The correlation in this matrix is not only between customer needs and technical responses, but there is also a correlation between technical responses, which is called technical correlation. This matrix is part of the HOE roof, and the identified relationship is the relationship between one technical response and another technical response. In addition to the correlation matrix between technical responses, there is also a matrix of relationships between customer needs.

Based on the HOE matrix in Figure 3., there are 6 strong positive relationships in technical correlation and 10 strong positive relationships in customer needs correlation, which are direct and have a strong impact, 4 positive relationships in technical correlation and 11 positive relationships in customer needs correlation, which are direct but have a weaker impact, 3 strong negative relationships in technical correlation and 4 strong negative relationships in customer needs correlation, which are inversely related (not in the same direction) but have a strong impact on each other, and 1 weak negative relationship in both technical correlation and customer needs correlation, which are inversely related with a weak impact.

Overall, the HOE matrix provides a comprehensive overview of technical priorities and potential contradictions when redesigning pineapple peeling machines. The negative correlation results on the HOE roof form the basis for the process of identifying contradictions and technical solutions using the TRIZ approach.

Analysis of Theory of Inventive Problem Solving

Based on the results of processing using the EFD method on the HOE matrix, several strong negative and negative relationships were found in the technical correlations between technical responses and between customer needs. To resolve these contradictions, the TRIZ method can be used as a systematic approach to generate innovative solutions. Out of the 9 negative correlations identified, both in the relationships between technical responses and customer needs, there are 5 negative relationships that require analysis to find solutions for each contradiction. Four of these are negative relationships between technical responses, and one is a negative relationship between customer needs. The remaining 4 negative correlations between customer needs were not resolved using the TRIZ

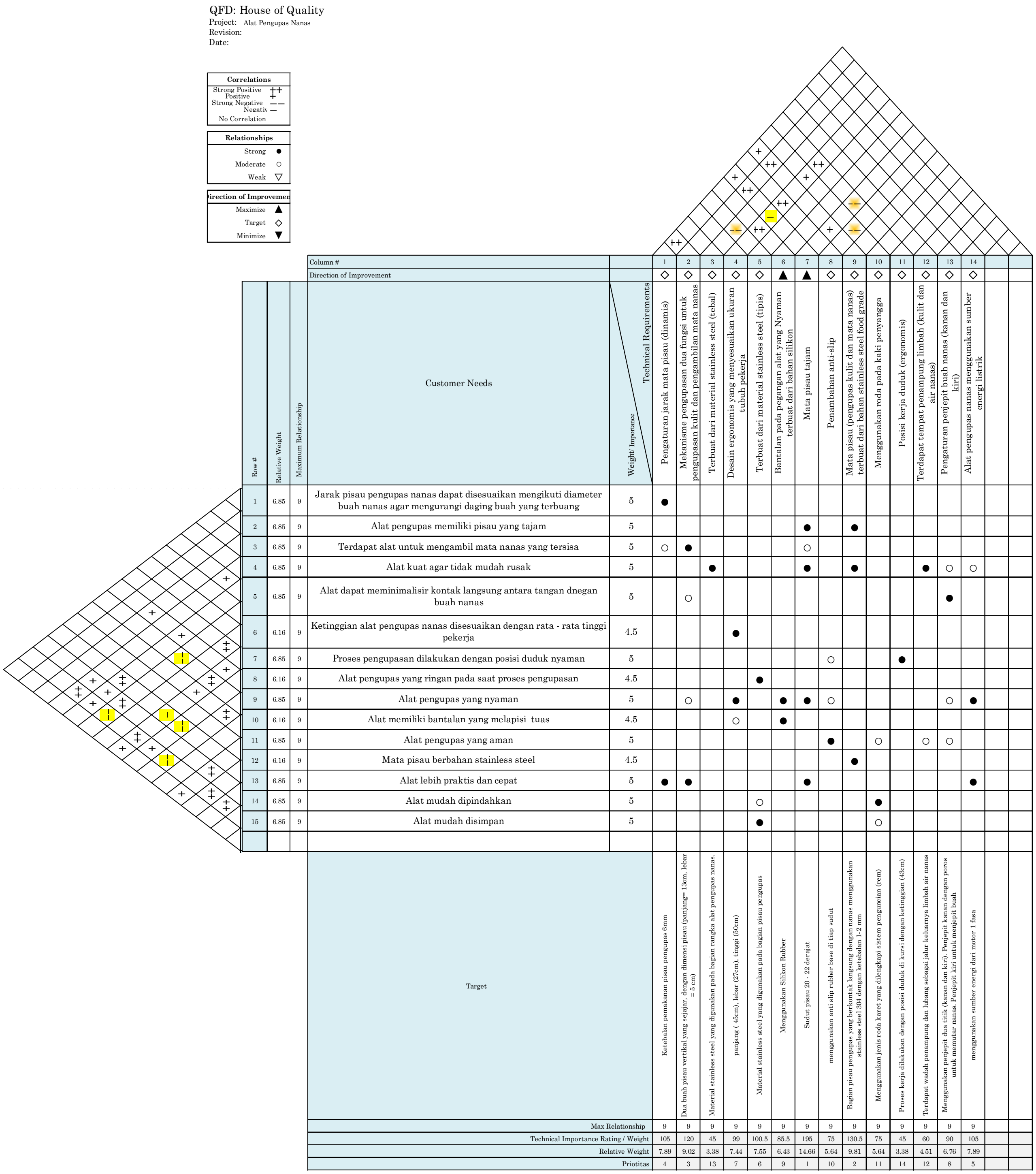

Figure 3. House of ergonomics

method, as they were already addressed in the 4 negative correlations between technical responses.

Based on Table 1., there are five contradictions that occur. The first contradiction arises between the use of thick and thin stainless steel materials. The use of thick material aims to increase the strength of the tool and prevent it from being easily damaged, while the use of thin material aims to make it lightweight when used. Based on the 39 TRIZ parameters, the parameter to be improved is strength, as it is expected that using thicker material will enhance the strength of the pineapple peeler. However, there is a negative impact: when using thicker material, the peeling process requires more energy to operate (power), resulting in the pineapple peeler becoming heavier when used. The first contradiction between parameter 14 (strength) and 2 (power) based on the matrix yields 4 inventive principles. The appropriate solution for the design of the pineapple peeler is #35 Transformation Properties.

The second contradiction that occurs is the ergonomic sitting position (TR13) with the use of sharp blades (TR6). The sharpness of the blade increases efficiency and reduces the force required, but it has the potential to endanger the safety of users when working in a sitting position. In this contradiction, the parameters to be improved are strength and force, but these two parameters have a negative impact on the object parameter – generating harmful factors. The use of sharp blades can enhance tool durability, making them less prone to damage, and reduce the force required for the pineapple peeling process. However, this poses risks to the user (object – generated harmful factors) due to the system's sharp blades and seated working position.

Table 1. Recommended Solution

No	Improving Parameter	Worsening Parameter	Inventive Solution			Design Implementation
			No Solution	Inventive principle	Inventive solution	
1	14 (strength)	21 (power)	10, 26, 35, 28	#10 Prior Action	#35 Transformation Properties	Anodized aluminum alloy material is used for the pineapple peeler frame so that it remains strong and durable yet lightweight. However, stainless steel 304 material is still used for the peeling blade.
				#26 Copying		
				#35 Transformation Properties		
				#28 Replacement of Mechanical System		
2	14 (strength)	31 (object - generated harmful factors)	15, 35, 22, 2	#15 Dynamicity	#15 Dynamicity	A change in work position where the work is no longer performed while sitting but while standing, thereby eliminating the potential danger during the pineapple peeling process.
				#35 Transformation Properties		
				#22 Convert Harm into Benefit	#35 Transformation Properties	Changing the height of the proposed pineapple peeler so that it is more comfortable to use in a standing position. The height of the pineapple peeler is 150 cm (table = 105 cm, upper frame = 45 cm)
				#2 Extraction		
	21 (power)	31 (object - generated harmful factors)	13, 3, 36, 24	#13 Do It in Reverse	#24 Mediator	Use of protective covers on all sides to increase the safety level of the peeling device.
				#3 Local Quality		
				#36 Phase Transition		
				#24 Mediator		
3	13 (Stability of the object's composition)	1 (weight of moving object)	21, 35, 2, 39	#21 Rushing Through	#2 Extaction	Use wheels that can be removed when not in use or when the pineapple peeler will be used for the pineapple peeling process.
				#35 Transformation Properties		
				#2 Extraction	#35 Transformation Properties	Dividing these two functions into two independent parts, where the support legs still use anti-slip rubber and there are separate square-shaped wheels with 4 wheels.
				#39 Inert Environment		
		10 (force)	10, 35, 21, 16	#10 Prior Action	#10 Prior Action	Place the pineapple peeler on a safe and suitable surface/area before using it.
				#35 Transformation Properties		
				#21 Rushing Through	#35 Transformation Properties	Dividing these two functions into two independent parts, where the support legs still use anti-slip rubber and there are separate square-shaped wheels with 4 wheels.
				#16 Partial or Excessive Action		

Table 1. Recommended Solution (contd.)

No	Improving Parameter	Worsening Parameter	Inventive Solution			Design Implementation
			No Solution	Inventive principle	Inventive solution	
4	39 (Productivity)	31 (object - generated harmful factors)	35, 22, 18, 39	#35 Transformation Properties #22 Convert Harm into Benefit #18 Mechanical Vibration #39 Inert Environment	#35 Transformation Properties	Changing the working position to standing and changing the height of the pineapple peeler to 150 cm (table = 105 cm, upper frame = 45 cm). However, a sharp peeling knife is still used so that peeling can be done easily.
5	14 (strength)	33 (Convenience of use)	32, 40, 28, 2	#32 Changing the Color #40 Composite Materials #28 Replacement of Mechanical System #2 Extraction #32 Changing the Color	#40 Composite Materials	Anodized aluminum alloy material is used for the pineapple peeler frame so that it remains strong and durable yet lightweight. However, stainless steel 304 material is still used for the peeling blade.

The third contradiction is related to the addition of anti-slip (TR9) using wheels on the support legs (TR11). The use of anti-slip improves the stability of the pineapple peeler when placed on a table, but the addition of wheels facilitates mobility while reducing the stability of the pineapple peeler. In this contradiction, the parameter that is improved is the stability of the object’s composition, but this has a negative impact on the weight of the moving object. By using anti-slip, the stability of the pineapple peeler is improved during operation (Stability of the object’s composition), but the addition of wheels on the support legs, which aims to facilitate the mobility of the machine, reduces the stability of the pineapple peeler (weight of the moving object). Additionally, the presence of wheels makes the tool easier to move when unwanted, requiring more force control.

The fourth contradiction relates to ergonomic design that adjusts to the size of the worker's body (TR4) with sharp blades (TR8). The use of sharp blades can increase the effectiveness and efficiency of the peeling process, but a design that adjusts to the size of the worker's body can pose a potential for workplace accidents. The parameter to be improved is productivity, but this has a negative impact on worker safety (object-generated harmful factors). The fourth contradiction between parameter 39 (productivity) and 31 (object-generated harmful factors) yields four inventive principles. The principle selected as the solution is #35 Transformation Properties.

The fifth contradiction is related to the need for a strong and durable tool (CN4) and a comfortable peeling tool (CN9). When creating a strong and durable tool, it is necessary to use strong and durable materials, but using these materials can cause discomfort when using the tool, such as heaviness when operating it and discomfort when holding it. The parameter improved in this contradiction is the strength of the peeling tool, but this results in a negative impact on comfort during use. The fifth contradiction between 14 (strength) and 33 (convenience of use) yields 4 inventive principles. The principle selected as the solution to this contradiction is #40 Composite Materials.

Through the application of the TRIZ method, the contradictions previously identified in the EFD method, both between technical responses and customer needs in the design of the pineapple peeler, can be resolved with a systematic approach. The designed solution not only resolves technical conflicts but also considers aspects of comfort and safety for users.

Analysis of the proposed design of a pineapple peeler

The dimensions of the pineapple peeler frame are adjusted to the anthropometric measurements of the pineapple peelers at KWT Berkah Sekar Abadi. The frame measures 120 cm in length, 40 cm in width, and 150 cm in height. The frame is made of anodized aluminum alloy, which is strong and durable yet lightweight.

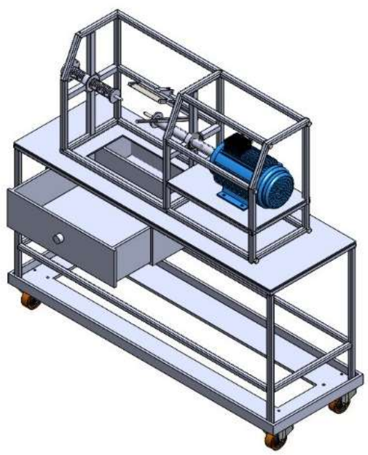

Figure 4. Proposed Design of a Pineapple peeler based on EFD

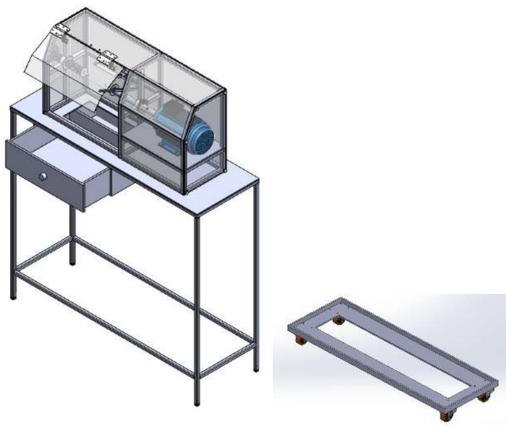

Figure 5. Optimized Proposed Design of a Pineapple Peeler based on TRIZ

The pineapple peeling knife, with dimensions of 13 cm in length and 2.5 cm in width, is designed to match the average height of Siwarak pineapples, which is approximately 9–13 cm. The material used for the peeling knife is food-grade stainless steel 304, selected for its strength, corrosion resistance, and food-grade standards.

The pineapple clamp in the proposed pineapple peeler design consists of two parts, namely the right and left clamps. The left clamp is used to clamp the left side of the pineapple. The distance between the pineapple clamps can be adjusted according to the size of the pineapple and is equipped with a lock so that once the distance is set, it will not change during the peeling process. The right clamp is the part that comes into direct contact with the right side of the pineapple and functions as a support for the fruit during the peeling process. The right clamp is directly connected to the machine's drive shaft. Therefore, during the peeling process, the right clamp will rotate 360º. The material used for the pineapple clamps is food-grade stainless steel 304, as these clamps come into direct contact with the pineapple.

Using the handle located on the right side of the pineapple peeler. The blade pressure lever handle is equipped with a silicone rubber pad, making it more comfortable to use and preventing water absorption and stickiness.

This anti-slip feature prevents the pineapple peeler from shifting or changing position during use, enhancing the stability of the pineapple peeler and thereby improving its safety. In the proposed design, anti-slip material made of rubber base is used on each support leg of the tool.

Based on data analysis using the EFD method, several customer needs were identified, particularly regarding the ease of moving the tool. Based on the results of processing using the TRIZ method, a design proposal was made that there should be separate square-shaped wheels with four wheels that can be used when the tool needs to be moved.

The function of these wheels is to facilitate tool mobility, where when the pineapple peeler needs to be moved from one place to another, these wheels can be used, but when it needs to be used, the wheels are not used.

This waste container is located at the bottom of the peeling blade, so that peeling waste, whether pineapple skin or pineapple juice, will directly enter this container and not accumulate on the peeling machine frame. When waste, especially pineapple juice, directly enters the container and does not pool on the pineapple peeling machine frame, it reduces the risk of corrosion on the pineapple peeling machine frame. Additionally, the presence of this waste collection container makes it easier to dispose of pineapple peeling waste.

The proposed design includes protective covers on the right, left, top, front, and rear sides. The addition of protective covers on all sides is intended to improve safety when using the pineapple peeler. Additionally, the benefit of having protective covers on all sides is that the pineapple peel waste generated during peeling does not fly out of the tool, ensuring that the waste remains contained within the pineapple peeler and is directed into the waste collection container. The protective covers are made from transparent, lightweight polycarbonate material.

IV. Conclusion

Based on a preliminary questionnaire with five ENASE dimensions (Effective, Comfortable, Safe, Healthy, Efficient), users want: reduction of fruit damage caused by dull/inappropriate-diameter knives, improvement of tool dimensions and ergonomic working position, minimal hand contact, lightweight design, waterproof and non-stick knife handle, hygienic and rust-resistant stainless steel material, as well as a tool that is fast, practical, easy to operate, move, and store.

Through the EFD method, these 15 needs were addressed with 14 technical responses: sharp and dynamic blades with dual functions (peeling the skin and removing the pineapple core), a frame and main components made of food-grade stainless steel 304, an electric motor, an ergonomic design tailored to body size, a waste container, a fruit clamp, wheels, and anti-slip feet.

Design optimization using the TRIZ method resulted in the following solutions: a frame made of anodized aluminum alloy, blades and clamps made of food-grade stainless steel 304, a standing work position, tool dimensions adjusted for standing comfort, a full protective cover, separation of wheel and anti-slip functions, and proper tool placement before use.

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