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Redesign the Wood Wood-Cutting Saw to Be More Ergonomic Using The TRIZ Method

Rizky Ravsanjani[1]*, Fakhrur Raji[2], Manda Salahuddin[3]
[1,2,3] Universitas Muhammadiyah Kalimantan
Jl. Ir. H. Juanda No.15, Sidodadi, Kec. Samarinda Ulu, Kota Samarinda, Kalimantan Timur
E-mail: Ravsanjani.rizky16@gmail.com

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ABSTRACT

A cutting saw is one of the tools used to cut wood material. In this regard, the cutting saw still has shortcomings in its application. Several testing methods were conducted to analyze the failures of cutting saws circulating in the community, including the Nordic body map questionnaire. After checking directly, there are complaints of pain when using a cutting saw, especially on the right hand. For this reason, it is necessary to redesign it as a consideration later expected to improve the shortcomings in the current cutting saw. Several methods are used in this redesign, including TRIZ, OWAS, and anthropometry. TRIZ is a method used in the development of a design. This method's concept leads to solutions to the problem of contradictions that occur and leads to innovative solutions that have been tested with 100% success. After obtaining the function or attributes of the product, the next stage is to improve the user's posture so that the cutting saw tool can be used optimally and can initiate. The OWAS method corrects the postural position used in cutting saws. The specification of the handsaw product design based on the processing of the voice of the customer using a tree analysis diagram is that the features are reducing fatigue levels and being able to cut quickly, as well as for reliability, namely the handle with anti-slip qualities.

Keywords: TRIZ, Cutting Saw, Anthropometry

INTRODUCTION

The rapid development of the times forces every company to constantly innovate in developing its products. This is because when there is no innovation done on a product at the company, the product will die [1]. After all, it is inferior to competing companies that constantly innovate their products. In addition, most consumers also feel bored using products with no added value [2]. When there is a death in the product, the company will automatically experience a considerable loss,

including losses on the production machinery [3]. However, some products have not undergone development but are still often used by consumers. One of them is a manual handsaw [4].

A handsaw cuts materials such as wood, iron, and others. Handsaws are very much in demand by consumers because they are easy to use and designed to be simple and easy to store [5]. In addition, when used, handsaws do not need to use electrical energy because the use system is still manual [6][7]. However, handsaws have disadvantages in their use [6].

The weakness of using saws on hard materials is the potential to cause high work fatigue because it requires large cutting forces and repetitive movements. Based on the results of interviews with respondents, some limitations exist in hand saws, including when cutting the saw blade, which is often stuck, resulting in imperfect cuts. This is due to the unsturdy saw design. Most handsaw users argue that the factor causing the saw blade to get stuck is because the saw material is too soft or flexible so that during the cutting process, at a certain depth, the accuracy of the saw blade becomes improper and causes the saw blade to be pinched and stuck. When this happens, saw users usually give more power to the cutting process and adversely affect specific body parts.

When there is force, the force expended when the saw is stuck hurts the body. Some users argue that when the energy expended is more incredible, the level of fatigue is also greater. It also has adverse side effects such as hand cramps, numbness, and stiffness, causing difficulty for the hand to move. This is evidenced by the distribution of Nordic body map questionnaires to respondents. The results of the Nordic body map can be seen in Figure 1.

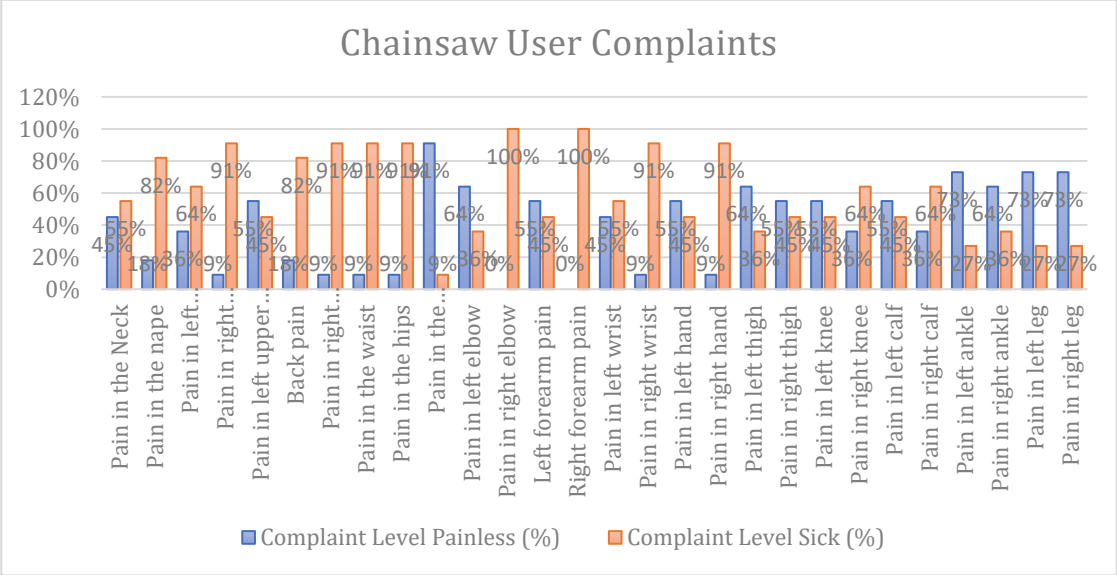

Figure 1. Nordic Body Map

Complaints experienced by saw users. Especially in the parts of the body that experience the most dominant pain. Complaints with the highest percentage were found in the right shoulder, right upper arm, waist, hip, right wrist, and right hand, which was 91%. On the body, forearm, and right elbow, it is worth 100%. This is because cutting is carried out repeatedly and requires extra energy when cutting on these body parts.

In addition, handsaws still have another weakness today, namely, too many variants of handsaws with different functions. Enget et al. describe the types of variations and their functions, such as rip saws, crosscut saws, panel saws, and other kinds of handsaws. This saw has different parts, such as a split saw, which precisely cuts large blocks of fibrous wood. Meanwhile, the cutting saw carved wooden blocks, longboards, and slats that cut processed timber. This is very inefficient when users who want to cut wood material must carry so many handsaws with different functions.

However, this problem has been corrected by manufacturers by changing the saw's work system by replacing it with a machine. Using devices is considered more effective and efficient than still manual saws. A practical cutting system and speed are added values of chainsaw products that use machines. Even so, it turns out that using devices on saws also has disadvantages.

The use of chainsaws tends to use ample engine power, so the electrical power needed for use is also significant. This also causes the use of safety on chainsaws to be further increased so that there are no accidents that cause fatal events experienced by users [7]. In addition, the price of chainsaws is also expensive, which is one of the weaknesses [5]. Ch chainsaws are considered effective and efficient only for large-scale production, such as making frames, doors, and so on [8]. But chainsaws are not effective for daily use because their heavy weight makes it difficult to carry everywhere. In addition, the need for electrical power causes this tool to only be used in areas with a wall outlet [9].

Based on the problems previously described, this research is about redesigning effective and efficient handsaw designs [10]. The focus on innovation is to improve less effective, efficient, and comfortable plans than previous designs [11]. The method to be used in this study is TRIZ (Teoriya Rezheniya Izobretateskikh Zadact) [12]. TRIZ is a problem-solving method based on logic and data, not intuition, accelerating the project team's ability to solve problems creatively [13]. In this method, an Innovative Situation Questionnaire (ISQ) is deployed to determine the product's current condition. An ISQ is an initial template for analyzing a problem and consists of questions that help one look at a problem situation from a different point of view [14]. This method is used for solving critical system problems. TRIZ has stages or identifies contradictions that occur. The resolved denial will be applied to a general solution to a specific solution [15]. In addition, researchers also use microergonomic methods, namely anthropometry [16]. Anthropometry is one of the branches of ergonomics. This method presents various parts of the human body in specific valid percentiles when making a product. This method will overcome the user's body complaints when using a handsaw [17].

METHOD

Data collection techniques

Data collection techniques are measuring tools needed in carrying out a study. In this study, the sampling technique used was purposive sampling, often called consideration sampling. This type of sampling occurs when sampling is done based on individual considerations or by establishing criteria that can represent the desired answer [18]–[21].

Determination of the number of samples

Determination of sample size must be done so that the sample taken can truly represent or represent an existing population. According to Griffin and Hauser, 90% of a customer's need for a product will be revealed after the distribution of questionnaires of 30 respondents.

Kuesioner ISQ (Innovation Situation Questionnaire)

In addition to collecting data on consumer needs attributes, another questionnaire that was disseminated was the ISQ Questionnaire. This questionnaire is conducted to get a view of the current product situation. Interview techniques are used to distribute this questionnaire to respondents who already understand or have experts in using or applying handsaws. Several indicators are compiled for creating the ISQ Questionnaire: Operating Environment, Resource Requirement, Primary Useful Function, Harmful Effects, and Ideal Final Result [22]–[25].

Data Processing

Data processing in the form of goal classification and identification of customer needs, making closed questionnaires, testing the data obtained such as validity and reliability using software to concept testing. Creating product attributes to be designed, this information is obtained from the data

that has been collected. Product attributes are an interpretation of consumer statements made by interviews. Then, innovations were made to some of the attributes of the initial product, which underlies the manufacture of handsaw products that will later be based on consumer wishes. The flow of data processing techniques is shown in Figure 2.

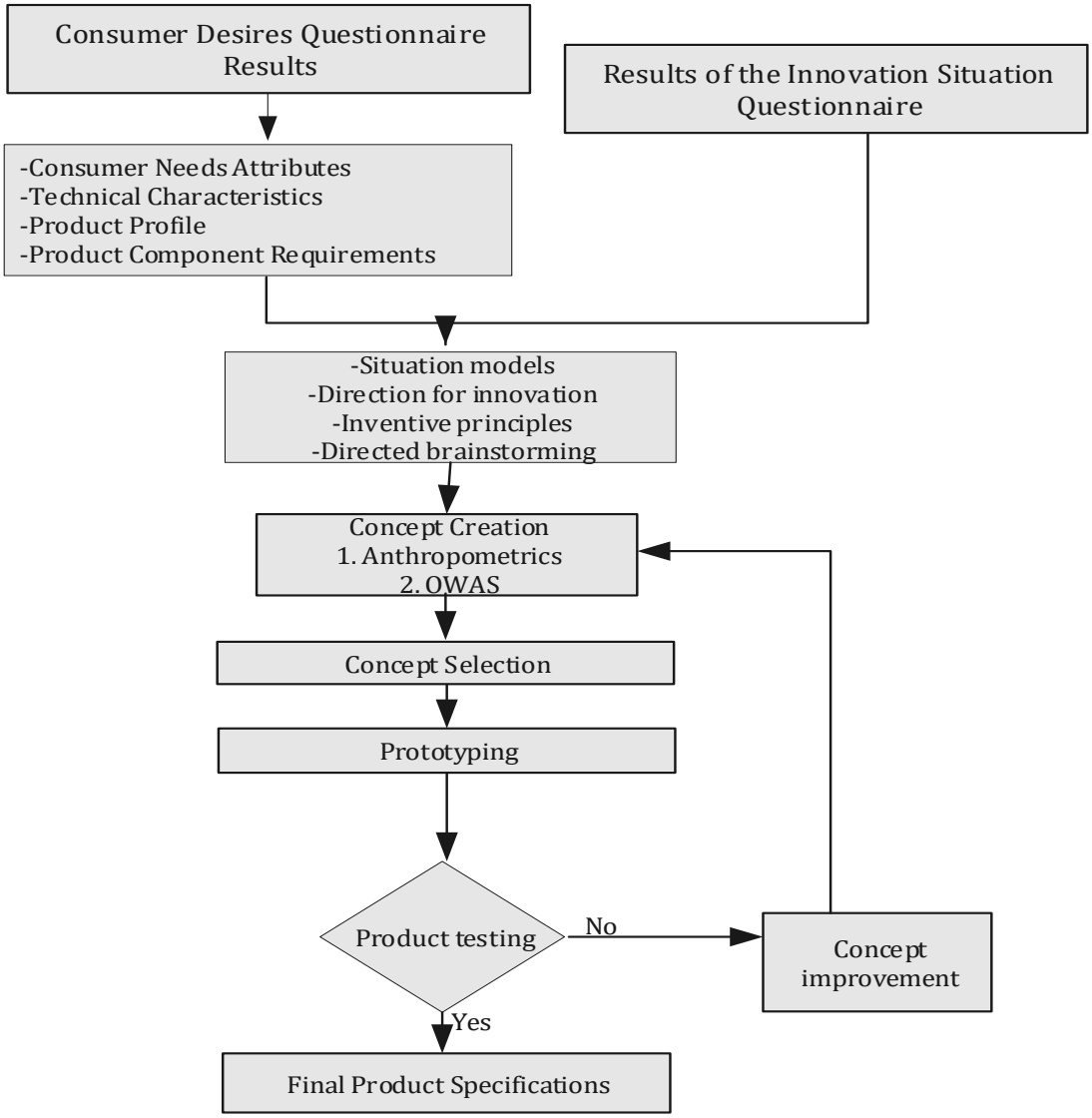

Figure 2. Data Processing Engineering Flow

RESULTS

Determining the Degree of Importance

The importance that respondents pay the most attention to this can be obtained by calculating the scale based on an assessment of each indicator that has been done before. The higher the value, the higher the level of importance.

$$IC = \frac{\sum(\text{Importance level scale})(\text{Number of respondents i})}{\text{Total Number of Respondents}}$$

The results of the calculation of the overall degree of importance (IC) of each item of the product attribute statement can be seen in Table 1.

Table 1. Degree of Importance (IC) Results

Number	Consumer Needs	IC Value
1	Handsaw with skillfulness reduces fatigue levels	4,100
2	Handsaw capable of cutting quickly	4,267
3	Handsaw designed with *handle* using anti-slip feature	4,600
4	Handsaws are designed to be customizable using the user's wishes	4,467
5	The handsaw is designed with sharp, strong, and sturdy saw blades	4,267
6	Ergonomically designed handsaw	4,567
7	The handsaw has an exciting design	4,500
8	Handsaws have an affordable price	4,633

Situation Model

The situation model is a combination of functional diagrams and fishbone diagrams. The situation model consists of two main elements: function and link. A role contains a box containing text describing a problem or system. A part is an event or condition in the form of actions, components, requirements, process steps, and others. The situation model provides four links: eliminates, causes, and hinders. The following is a table of saw model situations based on attributes/indicators that have been obtained previously.

Table 2. Handsaw Model Situation

Notation	Function	Notation	Function
A	Handle design with anti-slip/non-slip feature	A-1	Comfortable to hold
		A-2	Easy to carry
B	Ease of Use	B-1	Can cut different materials
		B-2	Users do not need to have multiple saws to perform different material cuts.
C	Product Aesthetics	C-2	Attractive Saw Display
D	Ergonomic Design	D-1	The size of the saw is based on the anthropometry of Indonesians
E	Fast cutting process	E-1	Sharp saw blade
F	Low Fatigue Level	F-1	The power required is not large
G	Solid and sturdy saw blade design		
H	Priced		

The conditions of the relationship between the existing functions are described to determine whether there is a contradiction between these functions.

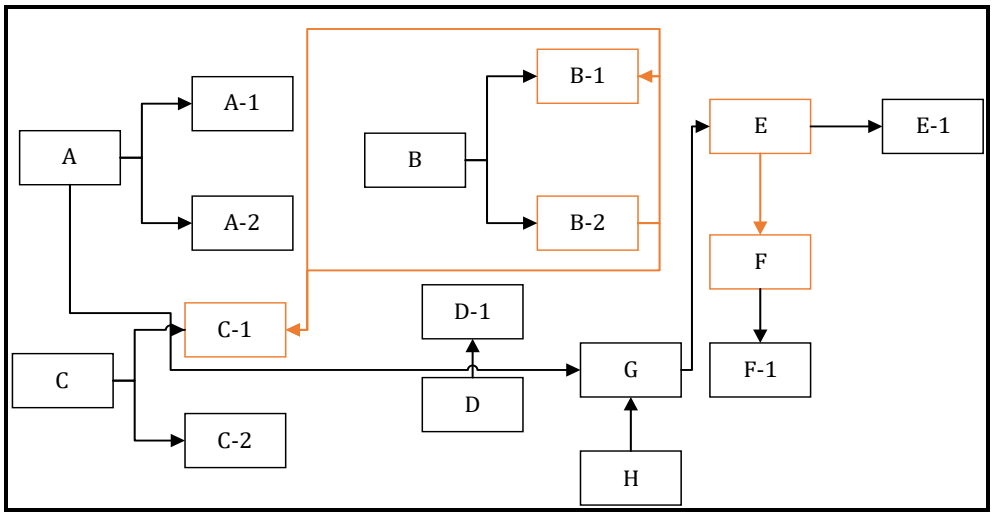

Figure 3. Model Situation

Figure 3 shows the contradiction in some functions, which give the opposite effect when the function is used as an indicator for the saw's design. Based on this, the contradictions can be used to determine the direction for innovation, as shown in Table 3.

Table 3 Direction for Innovation

Function	Direction for Innovation
B-1	Discover how handsaws can cut different materials
B-2	Find a way so users don't need multiple saws to perform different material cuts.
C-1	Discover how to make handsaws available in different variants.
E	Discover how handsaws can make cuts quickly.
F	Determine how a handsaw can reduce fatigue levels.

Product Concept Creation

1. Concept A

This concept of the material used is lightweight carbon steel, and the handle will be given a rubber band that is soft but strong and comfortable when held. But in this concept, the handle does not follow the curve of the fingers, whereas anthropometry is only the circumference of the hand.

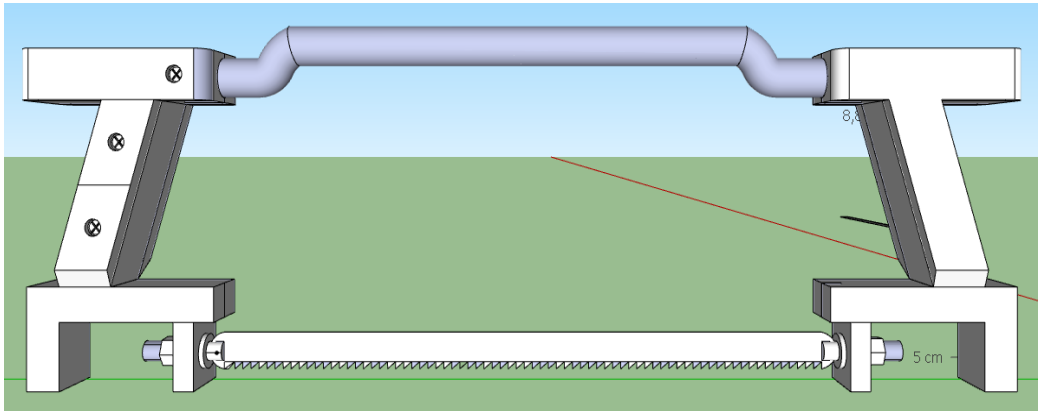

Figure 4. Concept A

2. Concept B

This concept of material used remains the same, namely carbon steel, where the design minimizes raw materials but still maintains the first concept, namely comfort when held. In this concept, the handle is designed to follow the groove of the finger where, when held, the finger will get its distance or space so that the grip becomes sturdier and reduces slip when used.

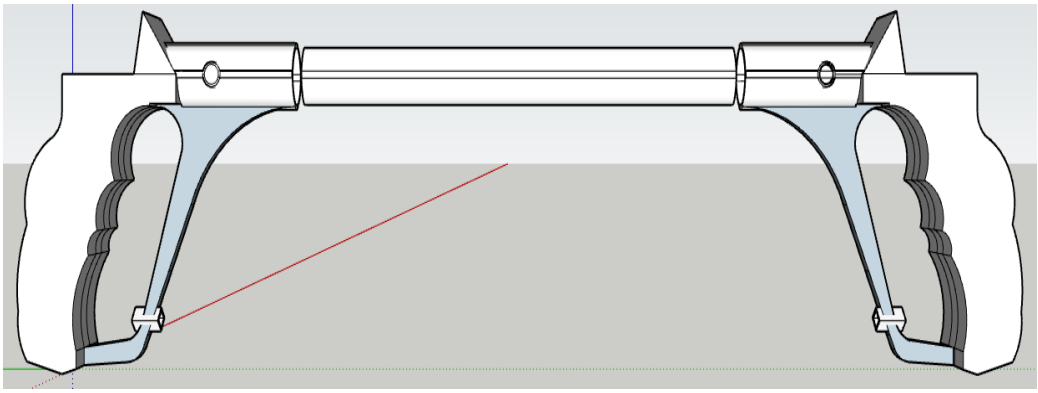

Figure 5. Concept B

Concept scoring

Concept scoring assessment uses weighting selection criteria and rating scales. Concept assessment based on concept scoring is carried out after obtaining the dominant concept from the concept screening assessment in Table 4.

Table 4. Concept Scoring Assessment

Number	Selection of Criteria	Weight (%)	Concept A		Concept Concept B		Reference	
			Rating	Score weighting	Rating	Score weighting	Rating	Score weighting
1.	Handle design with non-slip features	10	4	0.4	4	0.4	3	0.3
2	Comfortable to hold	5	4	0.2	4	0.2	3	0.15
3	Easy to carry	5	4	0.2	4	0.2	3	0.15
4	Ease of Use	5	2	0.1	4	0.2	3	0.15
5	Separated part of blade saw	17	4	0.68	4	0.68	2	0.34
6	The double handle of the saw	23	4	0.92	4	0.92	2	0.46
7	Saw view Interesting	5	2	0.1	4	0.2	3	0.15
8	Ergonomic Design	5	2	0.1	4	0.2	3	0.15
9	Solid and sturdy saw	10	4	0.4	4	0.4	2	0.2

10	blade design Priced	15	2	0.3	4	0.6	3	0.45
Score			**3,4**		**4**		**2,5**	
Rank			**2**		**1**		**3**	
Continue			**No**		**Yes**		**No**	

Concept Testing

Testing prototypes, workers or testers will cut material in broth wood or wood blocks with a thickness of 11.5cm x 5 cm. The wood will be cut using different saws, namely prototype saws and pre-existing handsaws. Energy Consumption Calculation is a method used to measure energy expenditure through energy intake during work.

Table 5. Concept Testing

Early model handsaws			
Worker Name	**Heartbeat**		**Cutting Duration**
	Before	**After**	
Sakirin	74 Bps	131 bps	00.05.04
Derry	69 Bps	124 bps	00.05.39
	Concept B Handsaw		
Sakirin	79 Bps	101 Bps	00.03.44
Derry	71 Bps	94 Bps	00.03.44

After getting the heart rate testing data, the next step is to convert the heart rate into energy consumption (calories) using the following equation:

$$Y = 1.80411 - 0.0229038X + 4.71733.10^{-4}X^2$$

$$Y = 1.80411 - 0.0229038(74) + 4.71733.10^{-4}(74)^2$$

$$Y = 0.11181201 \text{ Kcal/min}$$

Table 6. Energy Consumption (calories)

Worker Name	**Early model handsaws**		**Energy Consumption (Kcal/min)**
	Energy expenditure		
	Before	**After**	
Sakirin	2.692329	6.898779	4.20645
Derry	2.469573	6.217098	3.74753
	Concept B Handsaw		
Sakirin	2.938671	4.302771	1.3641
Derry	2.555845	3.819209	1.26336

DISCUSSION

From the results of the open questionnaire that has been distributed, criteria for consumer needs for handsaw products to be developed are obtained. Consumers want handsaws with designs to cut material quickly [26]. Due to user experience, the handsaw-cutting process tends to be slow and makes users uncomfortable [27]. When cutting materials, Handsaws can overcome high fatigue because consumers want handsaw products that overcome user fatigue when carrying out long shooting processes. This causes effect fatigue, which causes pain in muscles and joints, and the user feels discomfort and stops his work. Handsaw with a design with sturdy and robust material because when used, a sturdy saw will provide durability and long durability and extend the service life of the saw [28].

Handsaw with a design that can be adjusted to the user's wishes. Because the handsaw used by users tends only to have one function [29], namely to cut, this becomes a weakness when the material cut is different or with other work functions such as splitting, making elbows, degrees, etc. Some factors require users to have more saws with the necessary parts later [30]. This design will have an impact where users do not need to bother having many saws with different functions, but only with one saw can the user fulfill other jobs. Handsaws use sharp, anti-rust materials. Due to the use of saws to cut materials classified as complex, saws need to use more robust materials, making the process more accessible [31]. In addition, the use of hand saws tends not to look at the condition of the fabric, whether it contains water or not, so this impacts the saw blade, which easily rusts and causes the saw's age to be damaged faster. Handsaws are ergonomic in size so that consumers can easily use the saw without complaints of pain or discomfort, and the saw handle or handle is designed with anti-slip or non-slip features. Because the cutting process using a saw requires considerable power, this causes sweat to come out and wet the palm and cause the grip to begin to weaken [32].

CONCLUSION

The specification of the handsaw product design based on the processing of the voice of the customer using tree analysis diagrams is that the features (primary function) are reducing fatigue levels and being able to cut quickly, as well as for reliability, namely handles with anti-slip qualities. Next is durability: a saw blade with a sharp, sturdy, anti-rust design. Then, the aesthetic part of ergonomics, the attractive design, and the price section are affordable. The method of handsaw products based on consumer desires using the TRIZ, which has been processed using the inventive principle where there is a contradiction in the feature "cutting different materials and users do not need to have many handsaws for each material" and "handsaws are available in various variants." That is, by comparing the amount of substance with capacity parameters with the selected principles, namely local Quality, and disposal, namely "in the saw blade, design changes are made, and the saw blade with the saw itself is separate and can be replaced with the desired saw blade.

Furthermore, in contrast to the anti-fatigue feature and being able to cut quickly, the comparison of these parameters is speed and power. So, 2 principles were chosen: periodic action and transformation of properties with features in the saw design. Design changes were made to eliminate parts that were not needed and add details that were required, namely additional double handle power.

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