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The Application of Quality Function Deployment and Ergonomics: A Case Study for A New Product Design of A Texon Cutting Tool

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Abstract: This paper presents a model of Quality Function Deployment (QFD) and Ergonomics combined to propose an innovative product design. At the first phase, QFD is employ, assess and collect the voice of customer (VoC) and technical responses without ignoring the principles of ergonomics. At the second phase, the identification and determination of the critical components are done to propose the new design. The ergonomic aspects is also consider in the development of product design by allowing the inclusion of anthropometic dimensions. The results showed that the new design reduces musculoskeletal complaints, especially in the neck, back and waist, increase the quality, and simplify the product utilization.
Keywords: QFD, Ergonomics, Product Design, Footwear Industry.

I. INTRODUCTION

Based on data from the Ministry of Micro, Small and Medium Enterprise in Indonesia, there were 57.9 million Small and Medium-Sized Enterprises in Indonesia. In the period 2013-2015 the progress growing rapidly. However, textile industry, leather goods and footwear, decrease - 0.81%. In addition, the Gross Domestic Product (GDP) contribution from large industry. Meanwhile, small and medium industries have not been able to contribute significantly to the GDP, which only amounted to 9.24% of total GDP in the manufacturing sector. Moreover, the textile industry, leather goods and footwear contribute only 1.48% [1]. The proportion of SMEs in the manufacturing exports and GDP is still relatively low compared to many companies due to the lack of application of innovative technologies, still rely on tools and traditional methods, the production process is inefficient, skilled workers are limited, not qualified and product standardization unclassified [2,3]. SMEs of XYZ is one of the footwear industry in Medan, Indonesia. The process of making shoes in this company was still using conventional technology and simple instruction that are categorized as manual traditional. The purpose of this equipment do not take into consideration the principles of ergonomics, and cause of musculoskeletal on the body of the operator. During the last 5 years, researchers [4,5] have conducted several activities related to the development of cutting tools through the footwear industry. Based on feedback obtained from these activities, required the development of a more in-depth, specific and structured the design of ergonomics products in accordance with anthropometric and user desire.

Based on the description above, through this paper, the researchers propose a product design of cutting tool of Texon pattern using a combination model of Quality Function Deployment (QFD) method with Ergonomics. QFD method is applied in this study is focused on the House of Quality (HOQ) matrix of Phase 1 and Phase 2. Meanwhile, the application of ergonomics to evaluates the product design in accordance with the principles of ergonomics. Evaluation in the design of the cutting tool is demonstrated through the anthropometric dimension.

Product design using QFD-Ergonomics combined as applied in this research has been widely implemented by some researchers to redesign products. For example, [6], was used QFD to design school furniture by defining the most important variables and characteristics of the final product based on the customers' voice. Meanwhile, ergonomics was used to identify and evaluated the mismatches between anthropometrics of the customer and the dimensions of the tables and chairs. As a result, based on QFD and Ergonomics, the new design are low maintenance, low cost, ergonomicsally correct, strong and durable. [7] Successfully implemented the QFD by identified and prioritized user and technical requirement to develop a modified workstation of school workshop based on ergonomics approach. [8] was used the integrated of QFD, Kano and Ergonomics to design classroom furniture from the customer`s viewpoint. As the result, these techniques reducing all risk of getting an ergonomics-related problems and enhances customer-oriented design without ignoring ergonomics principles. [9] Designed a truck cabin for improved ergonomics and comfort for the driver in Indian. [10] Designed and development of Compound Lever Handle for Hand Pump. This article designed and developed a compound lever handle for a hand pump. He observed the reduction in the force required to operate the pump and change in posture of the operator, resulting in less fatigue and stress. [11] implemented Ergonomics method to design public transport by assessing the level of ergonomics values of public utility vehicles from the side of anthropometry and the level of ergonomics public transport from the side of anthropometry. Meanwhile, QFD was used to improve the technical dimensions of utility and load-unloading facilities by categorizing into eleven priorities on the QFD matrix. As the result, this method showed that 95% of users satisfied, safe, and comfortable.

II. Literature review

2.1. Cutting Tool of Texon Pattern.

The process of shoe making in SMEs XYZ consists of two parts, namely the upper (top) and the layer (bottom). To make a layer, there is a process to cut a Texon pattern. It is a hard material which is used as a part of layer pattern. As seen in Figure 1, this work used a sharp knife and tend to ignore the principles of ergonomics. Moreover, this work carried out by the operator by sitting on the floor and body bent forward.This activity unconsciously paying less attention to the convenience factors, health or safety, ineffective and inefficient.

Fig 1. Cutting Texon Manually

2.2. Ergonomics

Quality, as well as ergonomics, aims at meeting the demands of the customer [6]. Ergonomics, can be considered as a fundamental tool of looking for quality of product design. Ergonomics has become a widely known and respected discipline. The use of ergonomics attributes (such as ease of use, ease of learning, high productivity, comfort, safety and adaptability) are largely used by the media as elements that will add quality to products and be perceived by users as necessary for the fulfillment of their needs [12].

Overall stages of product development are usually handled by engineering specialists. The absence of ergonomist, for example, may result in undesirable product design [13]. It is because of the ergonomics design of the workstation and furniture must be based on the anthropometry and biomechanics of a human body [14]. Several studies have implemented the ergonomics oriented-designs. For example [15] demonstrated a new design workstation chair to minimize physical discomfort and the risk of Cumulative Trauma Disorder (CTD). Reference [16] designed a helmet considering the anthropometry measurement as a reference. As the result, its design improved the helmet’s stability and reduces its weight.

2.3. Quality Function Deployment

Quality Function Deployment (QFD) was developed in 1966 by Yoji Akao in Japan. It is a structured methodology to translate the desires of the customer into product design or engineering characteristics, and subsequently into parts characteristics, process plans, and production requirements associated with its manufacture [17] QFD is used for three basic reasons: to save design and development time, focus on customer satisfaction, and to improve communication in all parts of the organization [18]. QFD has the advantage of being attentive to the customer need, so that the product will completely satisfy the consumer [19]. Basically, QFD is known by several names, the most common is the voice of the customer (VOC) and a matrix is the House of Quality (HoQ) [20]. HOQ is a tool used by engineers during the design and development of new products, and HOQ helps engineers identify the important features to be considered during the product design [21]. Each matrix represents every stage of the process and also represented QFD phases, as shown in Figure 2. [22]:

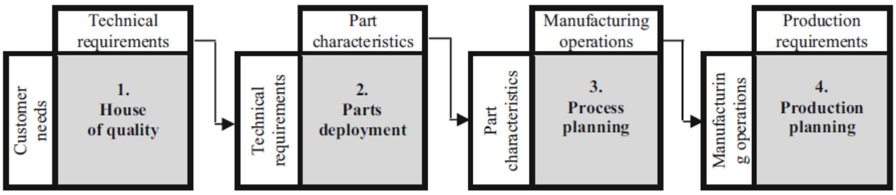

Fig 2. The Four Phase of QFD [Cohen, L, 1995]

A four-phase QFD plan, based on a series of matrices, was developed to create an innovative product that (1) satisfied customer needs, (2) fulfilled target specifications, (3) achieved target cost objectives, (4) was achievable within a set development timetable and (5) realized high production yields [23].

2.2.1. Phase 1 : Product Planning.

Phase 1 as the first matrix of QFD. Phase 1 document the customer requirements, warranty data, competitive opportunities, product measurement, competing product measurement, and the technical ability of the organization to meet each customer requirement. Getting good data from the customer in Phase 1 is critical to the success of the entire ofQFD process [24].

2.2.2. Phase 2 : Product Design.

Phase 2 translates the output of the product planning into critical part characteristics and explores the relationship between engineering characteristics and part characteristics [25].

III. Methodology.

This study uses a survey method, which aims to propose an improvement of product design based on customer need. This research was conducted in SMEs XYZ in Medan, Indonesia, with the object study is cutting tool of Texon pattern. Samples of this research are operators that use the cutting tool as 8 workers. Meanwhile, the total sampling technique is used in this research. The instrument was (1) Questionnaire to identify complaints, (2) Martins Human Body Measuring Instrument Model YM-1 to capture body dimensions of operators, (3) Digital camera, (4) Open and closed questionnaire to define the attributes of consumers need through a brainstorming activity, and (5) Software to design the product model.

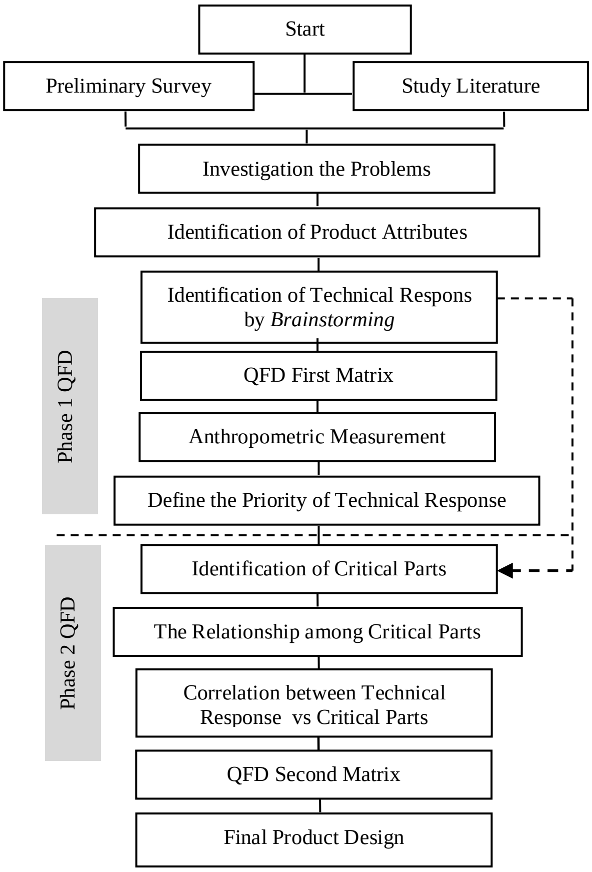

Fig 3. Applied Methodology

This study consists of several stages, as shown in Figure 3. In this study, researchers focused on Phase 1 and 2 of QFD. Phase 1 was used to identify: (1) the operator complaints, (2) operator needs, (3) important variables of technical characteristic, and (4) the correlation matrix (the impact of design requirements on operator need). Meanwhile, the second phase was used to identify the critical parts are the product and its relationship with technical response. This research was done in the XYZ Footwear Industry in Medan City. Type of this study is survey research. A questionnaire (open & closed) and interview method were used as a tool to acquire these data. Population and sample in this study were the operators of cutting of Texon pattern. The sampling was used non probability sampling with Judgment method.

IV. CASE STUDY.

The stages in the research methodology are represented to designing the cutting tool as follows:

Stage 1. Identification customer need.

At this stage, distributing an open questionnaire to eight workers. The questions attributes are: (1) material of handle upholstery, (2) material of blade, (3) material of rod suppressor (4) color, (5) foot buffer design, (6) thickness of session frame, (7) thickness of cutter anvil, (8) thickness of blade, (9) additional functions, and (10) durability. Summary of the open questionnaire can be seen in Table 1.

Table 1. The Summary of Open Questionare

No.	Questions	Answer	Total	Modus
1	Material of handle upholstery	Foam	6	Foam
		Rubber	2	
2	Material of blade	Cast iron	1	
		Waja iron	4	Waja iron
		Stainless	3	
3	Material of rod suppressor	Iron pipe	5	Iron pipe
		Solid round iron	3	
4	Color	Yellow	2	
		Blue	4	Blue
		Green	2	
5	Foot buffer design	Square	6	Square
		Round	2	
6	Thickness of session frame	8 mm	5	8 mm
		10 mm	3	
7	Thickness of cutter anvil	10 mm	2	
		15 mm	2	16 mm
		16 mm	4	
8	Thickness of blade	8 mm	2	10 mm
		10 mm	6	
9	Additional functions	Table of croton glueing	5	Table of croton glueing
		Cutting of upper pattern	3	
10	Durability	5 years	1	
		10 years	5	10 years
		20 years	2	

Stage 2. Define the customer importance.

Having recapitulated the open questionnaire, then drafted a closed questionnaire. Respondents gave an assessment of the attributes with Likert scale method. The closed questionnaire for the level of importance (the perception of respondents) and the level of satisfaction (expectations of respondents) was used to weight the importance of customer need .

Stage 3. Identification the technical response

Attributes of technical response collected through open and closed questionnaires which preceded by Brainstorming activity for determining the attributes on the questionnaire.

Stage 4. Define the relationship matrix

To determine the resistance matrix, then, attributes which had translated into the technical response is placed on the vertical edge the left side, while the technical characteristics laid out in the horizontal section at the top edge. Meanwhile, to identify the relationship between product attributes to the technical response is done using the highest scores to identify the technical characteristics that most affect customer satisfaction.

Stage 5. Define the correlation matrix

The next step is to identify the relevant interactions between each of the technical characteristics. In HoQ, quantity is placed on the roof. By using roof matrix, it will facilitate the examination of the interrelationship among the technical response.

In the next stage, determined targets to be achieved for the measurement of parameters of technical response, thus generates a product that satisfies the customer.

1) Determine the level of difficulty; determined from the relationship of technical response. The calculation is performed by translating all weight value of the relationship and dividing the weight of each technical response with total weight. Furthermore, the level of difficulty (by a scale of 1 to 9) is given based on the range of percentage.
   a) 0 – 5 % level of difficulty = 1
   b) 6 – 11 % level of difficulty = 3
   c) 12 – 17 % level of difficulty = 5
   d) 18 – 23 % level of difficulty= 7
   e) >24 % level of difficulty= 9
2) Determination the level of interest; value for the importance level can be known by calculating the total weight for each of relationship between product attributes and technical response.
3) Cost estimation; the estimated cost is a factor of difficulty level, the harder technical response is made, the more expensive cost allocation. The estimated cost is expressed in percent and is influenced by many considerations of the designer.

Stage 6. House of Quality (HoQ)of Phase 1

The last stage of phase 1 of QFD, is shown in Figure 4.

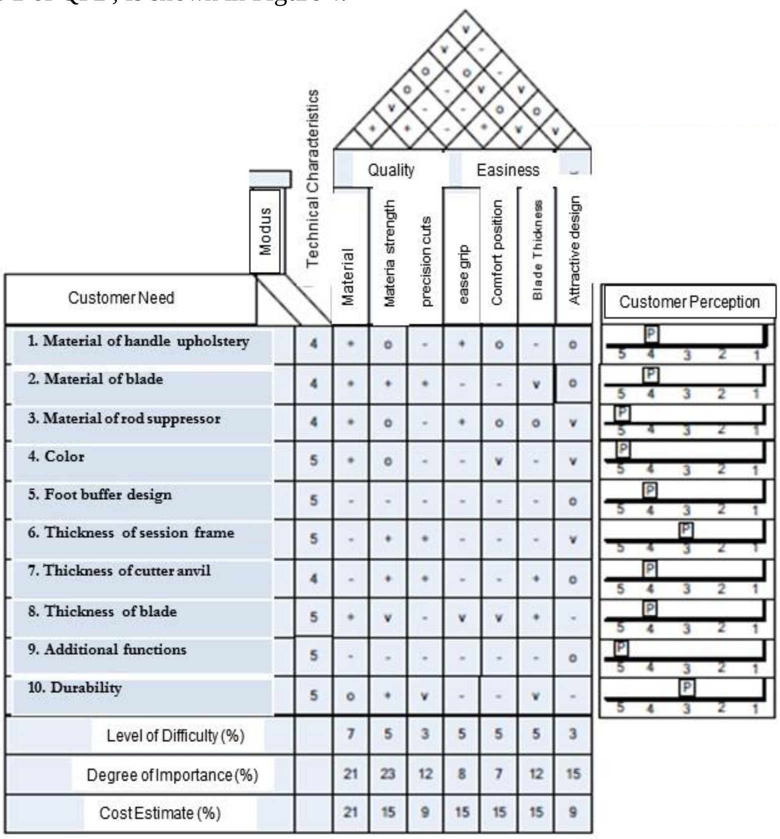

Fig 4. QFD of Phase 1 of Texon Cutting Tool

From the HoQ above, it can be analyzed several things, as follows:

a. The Level of difficulty: almost all the technical response is difficult, unless on the type of material, precision of cutting and attractive design.
b. The level of importance: very important criteria is indicated in technical response on the type of material and material strength. The Important criteria are indicated on the precision of cutting and attractive design. Meanwhile, the ease of grip and comfortable working position have the medium level.

c. Estimated cost: estimates of the product design cost are quite expensive.
d. Customer perception: for attribute 3, 4 and 9 are at a very good level. Attribute 1, 2, 5, 7 and 8 are at a good level. For the rest of the other attributes of 6 and 10 are at an adequate level

Stage 7. Determine the anthropometric measurement.

Having obtained the anthropometric data of all operators, further will be determined percentile value of 5, 50, and 95. The values of percentile 5.50, and 95 for all anthropometric dimensions can be seen in Table 2.

Table 2. Percentille value of 5, 50 and 95

No	Dimension	$\bar{X}$	σ	P5	P50	P95
1	High of shoulder with stand upright	131.93	1.43	129.57	131.93	134.28
2	High of elbow with stand upright	95.56	1.42	93.22	95.56	97.89
3	Width of palm	8.09	0.36	7.50	8.09	8.68
4	Diameter of hand grip	4.06	0.11	3.88	4.06	4.24
5	Hand lenght, measured from the elbow to the fingertips in a grasp position	36.06	0.17	35.78	36.06	36.34

Data processing to determine the dimensions of work facility design using the principle of extreme anthropometric data with the purpose of the design can be used comfortably with a normal size. The results of data processing to determine the dimensions of work facility design are as follows:

1. The design of the high on cutting table; is designed with anthropometric dimensions of the high elbow of stand upright with a percentile value 5%. The purpose is in order to the operator can reaches the table. Meanwhile, the operator that has higher dimensions can adjust. The calculation as follows:
   - Dimension of High of elbow with stand upright, the size is 93.22 cm
2. Hand widths; is designed for anthropometric dimensions of hand widths with a percentile value of 95%. The purpose is in order to operator who has a wide palm can use the cutting tool comfortably. The calculation as follows:
   - Dimension of hand widths, the size is 8.68 cm
3. The handle is designed with the anthropometric dimension of grip with a percentile value of 5%. The purpose is for operators that have a small hand grip can be grasped, while who have a big grip can adjust. The calculation as follows:
   - Dimension of Handle, the size is 3.88 cm + 0.3 cm (thickness of handle coating) = 4.18 cm
4. The designed of the thigh handle is adjusted to anthropometric dimensions of the shoulder, with a percentile of 5%. The purpose is for operators that have shorter dimension can be reached. The result, as follows:
   - Dimension of High of shoulder with stand upright + Hand length, the Size is 129.57cm+35.78 cm = 165.35 cm
5. The dimension of the blade, is designed using anthropometric data of feet, long leg, wide legs and wide stalk leg with a percentile value of 95%. The result as follows:
   - Dimension of length of palm, the size is: 24.93 cm
   - Dimension of length of sole, the size is 18.18 cm
   - Dimension of lenght of leg, the size is 21.16 cm
   - Dimension of wide of leg, the size is 9.66 cm
   - Dimension of wide of limb, the size is 5.98 cm

Stage 8. Determine the priority of the technical response

Technical characteristics from Phase 1, will be used as input for Phase 2.

Stage 9. Determine the critical parts

Critical Part, is a characteristic part or priority components of the product, that is obtained from the literature and interview with the expert. Critical parts can be seen in Table 3, as follows:

Table 3. Critical parts of cutting tool

No	Critical parts
1	Content of Steel
2	Thickness of plate
3	Temperature of welding

Stage 10. Determine the relationship among critical parts

Next compilation of design matrix deployment is to compare the relationship among critical parts by analyzing whether the critical part is a strong, moderate or weak.

Stage 11. Determine the relationship between the technical response with critical parts

This stage is done by comparing the relationship between the technical response with critical parts.

Stage 12. Determine the *technical matrix*

Determining technical matrix is based on performance measures of phase 2, which consists of three aspects, namely: the level of difficulty, the level of interest and cost estimates.

a. The level of difficulty.

   The level of difficulty is determined from the relationship of critical parts. The calculation is done by translating all weight value, then dividing the weight of each critical part. The level of difficulty is given by the percentage range. The value of the level of difficulty can be calculated by calculating the total weight of the relationship among critical parts.

b. The level of importance

   The value of importance degree can be obtained by calculating the total weight for each of the relationships between technical response and critical parts.

c. Cost estimates

   The level of difficulty factors is used as the basis of cost estimates, which is expressed in percent and influenced by many considerations of the designer.

Data on the previous steps is summarized using a matrix design deployment. A second phase of QFD can be seen in Figure 5, as follows:

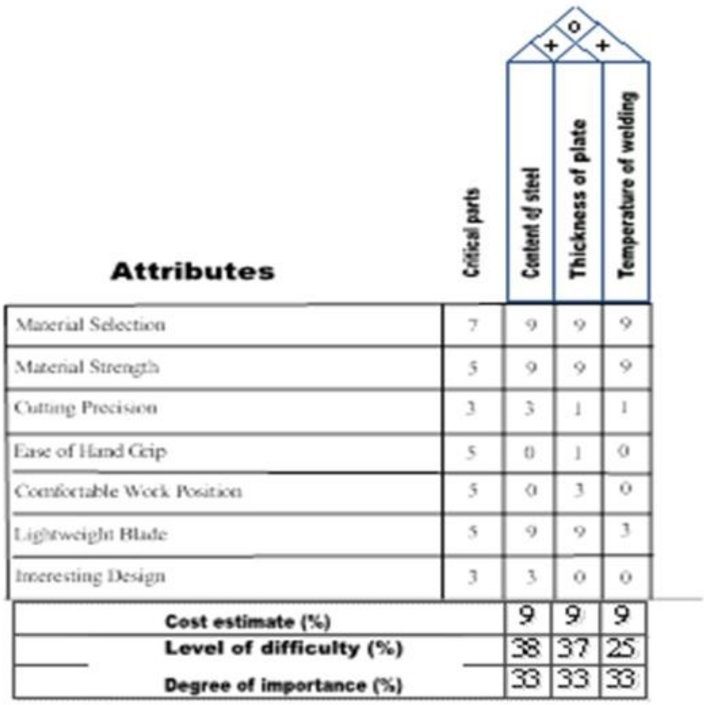

Fig 5. QFD of Phase 2 of Texon Cutting Tool

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V. Results

After the measurement of anthropometric dimension and design with QFD of Phase 1 and Phase 2, then the final design of cutting tool of texon pattern can be seen in Figure 6.

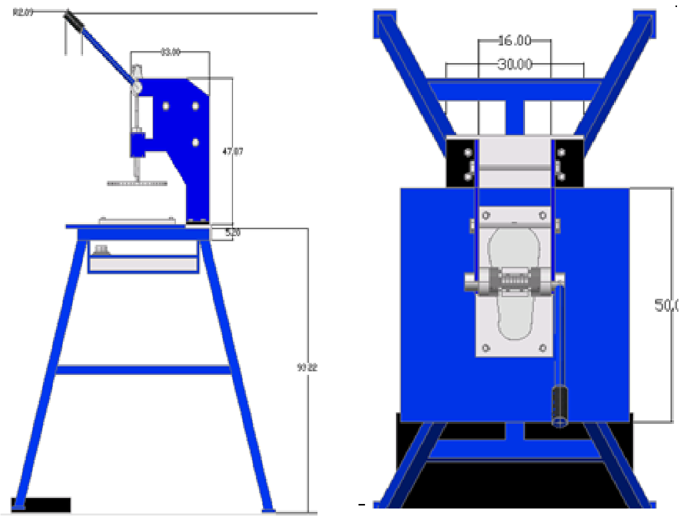

Fig. 6. New Design of Cutting Tool of Texon Pattern *(Side and Top view)*

VI. Discussion

The result of the study has obtained a decrease in actions from immediate corrections to possible and necessary. This shows a decrease in the level of work risk from high to small and medium work position with the design of a proposed work facility that has a small level of risk will reduce the musculoskeletal complaints that occur in the body of the operator. All of the levels of technical characteristic difficulty of the house of quality is in the category of *"difficult"* except for the type of material that is very difficult, and the characteristic of cutting precision and interesting design techniques are not difficult

The level of the technical characteristic importance of the quality house of *"very important"* is shown in the technical characteristics of the material type and the strength of the material. It is important to show the characteristics of cutting precision, light knives, and attractive designs. While the ease of grip and comfortable work position has *"moderate importance"*.

VII. Onclusion and Future Recommendation

This study was successfully designed a cutting tool of texon pattern by identifying the user need and priority technical response. The proposed facility design is adjusted to the anthropometric data of the operator in order to be comfortable when used, with dimension of high of cutting tables is 93.22 cm, width of the handle is 8.98 cm, diameter of the handle is 4,18 cm, height of the handle is 165, 35 cm. The attributes of cutting tool of texon pattern, are material of the handle coating from Foam, blade material from allusion steel, the material of suppressor trunk from iron pipe, color tool is blue, thickness of platform is16 mm, thickness of the blade is 10 mm, thickness of frame session is 8 mm, additional functions of table gluing and endurance of cutting tool is 10 years. Almost all of the difficulty level on the technical response is difficult, except on for the type of material, precision cutting and attractive design. The level of very important on the technical response is shown on the type of material and its strength. Important level, is shown on precision cutting, the blade is easy to carry and attractive design. Meanwhile, the moderate level is shown on ease of grip and comfortable working position.

For future recommendation, to fulfill customer satisfaction, therefore the implementation of improvement should be integrated into all aspects and application, not only in ergonomics, but also quantitative methods.

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