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Designing Cutting Tools for The Eva Foam Cutting Process in The Production of Polynet Mesh Spare Parts in CV. ELM Using the QFD Method

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ABSTRACT

CV. Era Langgeng Mandiri is a company engaged in fabrication and mechanics that implements a make-to-order production strategy. In the production of sparepart mesh polynet, defective products exceed the specified tolerance limit of 5%. Based on the data, defective products often occur during eva foam cutting. We were finding the root cause of the eva foam cutting process using the Six Sigma method with the DMAI approach (Define, Measure, Analyze, Improve). The analysis using fishbone diagrams and 5 why's, found that the factor causing defect products is that the eva foam did not match the pattern. From the root of the problem, the improvement priority was selected using the FMEA, and the highest RPN was 327 in the machine factor. The design that can be done for the root of the problem on the machine factor is the design of the eva foam cutting tool. The design is carried out using the Quality Function Deployment method. The design of the proposed eva foam cutting tool is expected to minimize defect products in the eva foam cutting process as much as 80% of the number of previous defect products and increase process capability by measuring the current sigma level from 3,386 sigma to 3,593 sigma.

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1. INTRODUCTION

Organizations such as manufacturers, distributors, transportation companies, financial service organizations, health service providers, to government agencies carry out its business strategy by improving quality (Montgomery, 2013). According to Mitra (Mitra, 2021), the quality of the product/service is the suitability of a product/service that equals/exceeds its intended use as required by the customer. Companies generally carry out quality engineering or a series of operational, managerial and engineering activities to ensure that the quality characteristics of their products reach the minimum requirements of these products (Montgomery, 2013) as in the CV. Era Langgeng Mandiri (CV. ELM). CV. ELM is a company engaged in fabrication and mechanics. This company is a supplier of parts and equipment for manufacturing companies to support various production activities in related manufacturing companies. CV. ELM is a company that implements a make-to-order production strategy, where the company will produce products according to customer specifications. The main target of CV. ELM is a manufacturing industry such as the ceramics, textile, automotive, and others. One of the products produced by CV. ELM is a polynet mesh spare part. The polynet mesh spare part is one of the spare parts for smoothing ceramics. In the manufacture of polynet mesh spare parts, there are products that do not meet the specified product CTQ. Products that do not meet the CTQ products can be categorized as defective products.

Based on production data for 18 months (July 2020 - December 2021), there are 13 months of which the percentage value of defective products exceeds the tolerance limit of 5% (red mark). If this defective product is not handled, the quality of the product sold to the client will decrease and will not meet the client's request. Client dissatisfaction can reduce client confidence and company image. Therefore, the efforts that have been made by the company are to dispose of the defective product and then re-produce the defective product. These efforts are considered ineffective and inefficient from time to cost. This needs further evaluation to find the root cause of the high level of defects in the production of polynet mesh spare parts.

In the manufacture of polynet mesh spare parts, the company has a CTQ process which contains a detailed description of the quality characteristics that must be met in each polynet mesh spare part production process. CTQ Production Process is the main basis for operators in carrying out the production process of polynet mesh spare parts. If there is a CTQ process that is not fulfilled, then the process is problematic because it will produce defective products.

It is known that the production process that produces the most defective products is the eva foam cutting process. Furthermore, a root cause analysis was carried out to make improvements to the problems in the eva foam cutting process.

Based on the types of defective products, the problem that occurs in eva foam cutting is the incompatibility of the eva foam cutting results with the pattern, so there is a CTQ process that is not fulfilled, namely the eva foam cutting process, the third stage.

There were 5 root problems from cutting eva foam that did not match the pattern, namely the cutter did not match the pattern, the operator was not focused, the operator cut the eva foam did not match the pattern, the raw material easily fell out (powder), and the work environment was dim. Furthermore, an analysis using FMEA was carried out to select the root cause of the problem which was the priority of improvement to overcome the cutting of eva foam that did not match the pattern. Based on the FMEA analysis, the alternative solution that can be chosen is to design a proposed tool in the form of an eva foam cutting tool as a repair solution. The cutting tool will be designed following the dimensional specifications on the Product CTQ. As a result, the purpose of this study is to design cutting tools for the eva foam cutting process that will be used in the production of polynet mesh spare parts in CV. ELM utilizing the QFD method.

2. RESEARCH METHOD

A. Data Collection Mechanism

The solution to the problem in this research is to use the Quality Function Deployment (QFD) method to provide suggestions for improvements to the process of making Mesh Polynet spare parts. The flow chart of the design stage of this research can be seen in Figure 1.

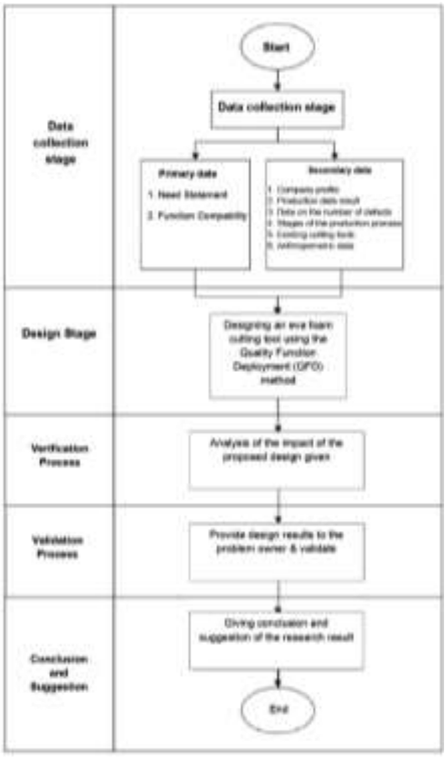

Figure 1. Systematics of Problem Solving

B. Design Stage

Meanwhile, the steps in designing using Quality Function Deployment are begin with identifying the needs attributes. Afterwards, technical requirements and specification targets with Grid and Planning Matrix. Hence, the stage followed by determining the relationship of attributes of needs and technical requirements as with analyzing the findings with House of Ergonomic and finally the concept selection stage.

3. RESULTS AND DISCUSSIONS

A. Integrated System Design

The design process contains the steps in designing proposed improvements to the polynet mesh spare parts production process. The improvement proposal is designed based on flowchart data of existing cutting tools, namely cutter, customer statement and anthropometric data.

1. Identification of Needs Attributes

At this stage, identification of the required attributes of the eva foam cutting tool is carried out based on the customer statement. Then the identification of this need attribute will be set as a need statement. The results of the identification of product needs attributes can be seen in Table 1.

Table 1. Product Attribute Identification

No	Customer Statement	Need Statement
1	The process is less concise, you have to make a pattern before you can cut it.	Products can streamline the production flow
2	The hope is that there is a tool that can immediately cut the eva foam according to the size needed, so that it is neater and according to size.	The product can cut eva foam according to the required dimension specifications
3	What is certain is that it can cut the eva foam easily, it's sharp, it can be cut directly into rounds according	The product can cut eva foam material

	to its size, easy to use, safe, durable and not easily damaged.	Easy to use product
		Durable product The cutting tool has a size that matches the anthropometric data

From the identification of product attributes, it is found that the recapitulation of the need statement for the eva foam cutting tool is as follows:

1) Products can streamline the production flow
2) The product can cut eva foam according to the required dimension specifications
3) The product can cut eva foam material
4) Easy to use product
5) Durable product
6) The cutting tool has a size that matches the anthropometric data

2. Technical Requirements and Target Specifications

At this stage, the technical requirements for each need statement are determined along with the target specifications. The target specification is then used as a reference for the design of the eva foam cutting tool for the eva foam cutting process in the production of polynet mesh spare parts. The technical requirements and target specifications can be seen in Table 2.

Table 2. Technical Requirements and Target Product Specifications

No	*Need statement*	Technical Requirements	Target Specification	Unit
1	Products can streamline the production flow	Blade shape	Tube	*Type*
2	The product can cut eva foam according to the required dimension specifications	Blade dimensions	Diameter: 4.5cm Thickness: 0.5 cm.	*Centimeter*
3	The product can cut eva foam material	Blade material type	Steel / Stainless steel	*Type*
4	Easy to use product	There is an anti-slip component	Yes	*Binary*
		There is a tool to remove the cut eva foam	Yes	*Binary*
6	Durable product	Cutting tool material type	*Handle*& Controller : ABS	*Type*
7	The cutting tool has a size that matches the anthropometric data	Dimensions of cutting tools according to anthropometric data	Diameter: 4.5cm Height: 6.5 cm	*Centimeter*

3. Klein Grid Matrix & Planning Matrix

Making the Klein Grid Matrix and Planning Matrix are used to determine the weight of each product need statement. The matrix is obtained from the results of the questionnaire on the level of satisfaction and the level of interest in production operators and production managers from the manufacture of polynet mesh spare parts. After creating the Klein Grid Matrix, a planning matrix is created. The output obtained from the Planning Matrix is in the form of weighting of each need statement. The Klein Grid matrix can be seen in Figure 2 and the Planning matrix can be seen in Table 3.

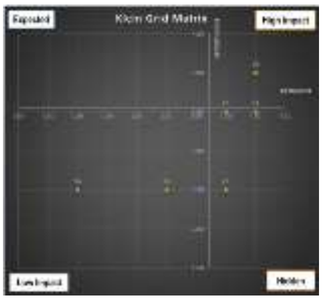

Figure 2. Klein Grid Matrix

Table 3. Planning Matrix

No	Needs Statement	Klein Grid Matrix	Customer Satisfaction Performance	Importance to Customer	Goal	Improvement ratio	Sales point	Raw weight	Normalized raw weight
1	Products can streamline the production flow	HID	4	3.50	3.50	3.50	1.5	18.38	0.43
2	The product can cut eva foam according to the required dimension specifications	HID	3.5	3.50	4.00	1.14	1.5	6.00	0.14
3	The product can cut eva foam material	HIM	4	4.00	4.00	1.00	1.5	6.00	0.14
4	Easy to use product	LIM	2.5	2.50	3.00	1.20	1	3.00	0.07
5	Durable product	HID	3.5	2.50	3.00	0.86	1	2.14	0.05
6	The cutting tool has a size that matches the anthropometric data	LIM	1	2.50	3.00	3.00	1	7.50	0.17
				TOTAL				43.02	1.00

4. Product Attribute Relationships and Technical Requirements

The next stage is to describe the relationship between the attributes of needs and technical requirements. The relationship between the attributes of needs and technical requirements can be seen in Table below where this relationship will then be used in making the HOQ.

Table 4. Relationship of Attribute Needs and Technical Requirements

Technical Characteristics / Product attribute	Blade shape	Blade dimensions	Blade material type	There is an anti-slip component	There is a tool to remove the cut eva foam	Cutting tool material type	The cutting tool has a size that matches the anthropometric data
Products can streamline the production flow	Strong	Strong	Moderate				
The product can cut eva foam according to the required dimension specifications	Strong	Strong	Moderate				
The product can cut eva foam material	Weak	Weak	Weak				
Easy to use product				Strong	Strong		Weak
Durable product			Moderate			Strong	
The cutting tool has a size that matches the anthropometric data							Moderate

5. Relationship Between Technical Requirements

The next step is to describe the relationship between the technical requirements. The depiction of the relationship by giving symbols. The provisions for giving symbols can be seen in Table 5.

Table 5. Symbol of Relationship Between Technical Requirements

Symbol	Connection	Information
√√	Strong Positive	Strong and directly proportional relationship
√	Moderate Positive	Medium and directly proportional relationship
(blank)	No Impact	No connection
X	Moderate Negative	Medium and inverse relationship
XX	Strong Negative	Strong and inverse relationship

The description of the relationship between technical requirements can be seen in Figure 3.

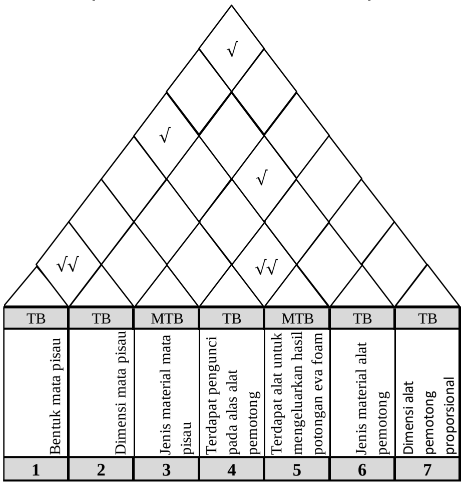

Figure 3. Relationship Between Technical Requirements

6. House of Quality

Next, a House of Quality is drawn up to determine the priority order of the need statements. The description of the House of Quality can be seen in Figure 4.

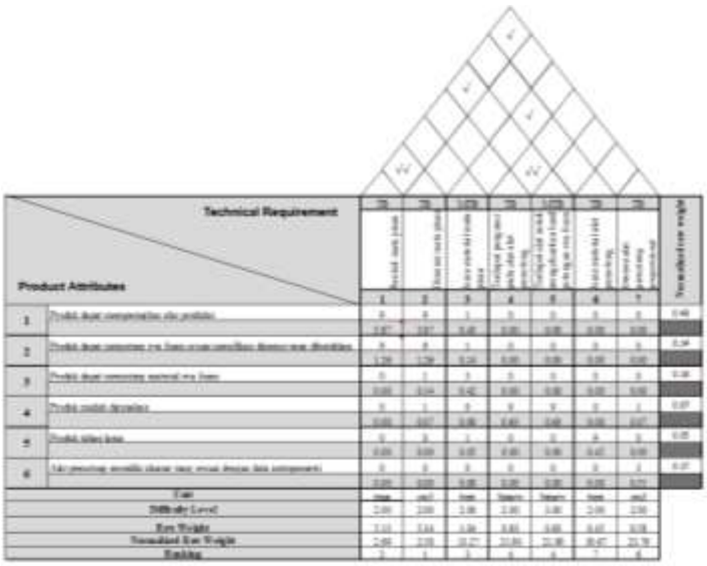

Figure 4. House of Quality

From the results based on the House of Quality obtained the order of priority technical requirements, namely:

1. Blade dimensions
2. Blade shape
3. Blade material type
4. There is an anti-slip component
5. There is a tool to remove the eva foam pieces
6. Cutting tool dimensions according to anthropometry
7. Cutting tool material type

7. Concept Selection

a) Morphological Map

The morphological map contains several alternatives for each required product function. The morphology map for the proposed eva foam cutting tool can be seen in Table below.

Table 6. Morphological Map

Technical Requirements	Alternative	
	Alternative 1	Alternative 2
Blade shape	Round	
Blade dimensions	D : 4.5 cm T : 0.5cm	
Blade material type	1 mm . steel sheet	*Stainless Steel*1 mm
There is an anti-slip component	*Rubber*	
There is a tool to remove the cut eva foam	*Swirl*	*Button*
Cutting tool material type	ABS Plastic	
Cutting tool dimensions according to anthropometry	D : 4.5 cm T : 6.5cm	

From the morphological map that has been determined, a combination of the available alternatives is obtained. The combinations formed are 1 x 2 x 1 x 1 x 2 x 1 x 1 = 4 combinations. The combinations formed can be seen in Table 7.

Table 7. Combination Concept

Technical Requirements	Combination			
	1	2	3	4
Blade shape	Round	Round	Round	Round
Blade dimensions	D : 4.5 cm T : 0.5cm	D : 4.5 cm T : 0.5cm	D : 4.5 cm T : 0.5cm	D : 4.5 cm T : 0.5cm
Blade material type	1 mm . steel sheet	*Stainless Steel*1 mm	1 mm . steel sheet	*Stainless Steel*1 mm
There is an anti-slip component	*Rubber*	*Rubber*	*Rubber*	*Rubber*
There is a tool to remove the cut eva foam	*Swirl*	*Swirl*	*Button*	*Button*
Cutting tool material type	ABS Plastic	ABS Plastic	ABS Plastic	ABS Plastic
Cutting tool dimensions according to anthropometry	D : 4.5 cm T : 6.5cm	D : 4.5 cm T : 6.5cm	D : 4.5 cm T : 6.5cm	D : 4.5 cm T : 6.5cm

b) Concept Screening

Concept screening is an attempt to filter the existing 6 alternative concepts. Filtering is done by giving signs (+), 0, and (-) for each alternative combination of product attributes. The (+) sign indicates the alternative is better than the reference, the 0 sign indicates the alternative has the same value as the reference, and the (-) sign indicates the alternative is worse than the reference (Ulrich, Eppinger, & Yang, 2020).

Table 8. Concept Screening

Product attribute	alternative combination			
	1	2	3	4
Products can streamline the production flow	+	+	+	+
The product can cut eva foam according to the required dimension specifications	+	+	+	+
The product can cut eva foam material	+	0	+	0
Easy to use product	+	+	0	0
Durable product	0	0	0	0
The cutting tool has a size that matches the anthropometric data	0	0	0	0
Sum(+)	4	3	3	3
Sum 0	2	3	3	4
Sum (-)	0	0	0	0
net score	4	3	4	3
Rank	1	2	3	4
Continue?	YES	YES	NO	NO

c) Concept Scoring

After screening, the next step is to calculate the weighting of the previously determined criteria. This calculation is done by multiplying the weight of each criterion by its rating. Provisions for rating each criterion can be seen in Table 9.

Table 9. Rating Concept Scoring

Relative Value	*Rating*
Much worse than a reference	1
Worse than a reference	2
Same with reference	3
Better than a reference	4
Much better than a reference	5

Next, assign a rating for each criterion with the provisions in Table 9. The predetermined rating is then multiplied by the weighting that has been obtained from the planning matrix calculation. Calculation of concept scoring can be seen in Table 10.

Table 10. Concept Scoring

Technical Requirements	Weight	Concept			
		1		2	
		Rating	Weight Score	Rating	Weight Score
Blade shape	0.40	4	1.6	4	1.6
Blade dimensions	0.13	4	0.52	4	0.52
Blade material type	0.13	4	0.52	3	0.39
There is an anti-slip component	0.07	4	0.28	4	0.28
There is a tool to remove the cut eva foam	0.06	3	0.18	3	0.18
Cutting tool material type	0.05	3	0.15	3	0.15
Cutting tool dimensions according to anthropometry	0.16	4	0.64	4	0.64
Total			3.89		3.76
Rank			1		2

Technical Requirements	Weight	Concept			
		1		2	
		Rating	Weight Score	Rating	Weight Score
Continue?			YES		NO

Based on the calculation of concept scoring in Table 10, it is known that the combination that has the highest value, namely combination 1 with the combination concept can be seen in Table 10. Therefore, the concept of combination 1 will be the specification of the reference for the design of eva foam cutting tools.

B. Design Results

From the results of the proposed eva foam cutting tool design, there are specifications for the proposed tool design. Specifications can be seen in Table 11.

Table 11. Final Specification of Eva Foam Cutting Tool Design

No	Technical requirements	Part
1	Blade dimensions	Diameter: 4.5cm Height: 0.5 cm
2	Blade material type	Steel
3	There is an anti-slip component	*Rubber*
4	Cutting tool material type	ABS Plastic
5	There is a tool to remove the cut eva foam	*Swirl*
6	Cutting tool dimensions according to anthropometry	Diameter: 4.5cm Height: 6.5 cm
7	Blade shape	Round

From the final specifications that have been determined, the final design of the 3-dimensional design is obtained for the eva foam cutting tool. The results of the design that will become the specifications of the reference for the design of the eva foam cutting tool, namely the combination concept number 1. The final design of the proposed eva foam cutting tool can be seen in Figure 5 and Figure 6.

Figure 5. Proposed Eva Foam Cutting Tool

Figure 6. Proposed Eva Foam Cutting Tool (Open Blade Position)

The proposed cutting tool is a tool that has 5 components, namely the blade, blade lock, anti-slip rubber, swirl controller and body. Figure 7 is the extent view of the proposed cutting tool.

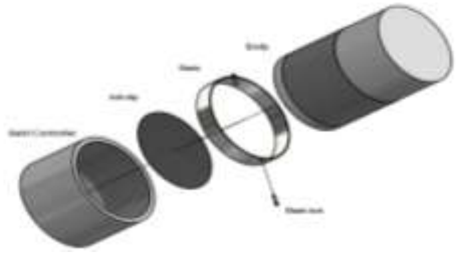

Figure 7. Expanded View Proposed Tool

This proposed eva foam cutting tool has a slightly different way of working from the existing tool. It is expected that 80% of the defective product rate in the eva foam cutting process can be lowered if the proposed eva foam cutting tool is put into use. The reduction of defective products in the eva foam cutting process is because the proposed tool is considered effective enough to reduce defective products. By using the proposed tool, the eva foam cutting process will be in accordance with the required specifications because the design is made based on specifications. From the reduction in the number of defects, the number of existing defective products in 18 months is 390 units, which will change to 287 after implementation. That way, the number of defective products in 18 months is reduced by about 26%. Furthermore, the simulation of the calculation of the new sigma value, obtained a sigma value of 3,593. This value is an increase of 0,208 from the existing sigma value. This figure equals to 18,160 potential defects in 1.000.000 units of productions.

C. Analysis

a) Cost Estimation Analysis

Cost estimation is needed to be considered by the company in implementing the proposed tool. The estimated cost of making the proposed eva foam cutting tool can be seen in Table below.

Table 12. Estimated costs

No.	Component	Unit (cm)	Price	Unit Required (cm)	Price per pcs
1	Steel Chip	30 x 40 x 0.8	Rp. 80.000, -	14.4 x 1 x 0.8	Rp. 1.000, -
2	3D Printing Cost				Rp. 200.000, -
		Total			Rp. 201.000, -

b) Analysis of the Advantages and Disadvantages of Tools

In this section there are advantages and disadvantages of the eva foam cutting tool design. The advantages and disadvantages of the design results can be seen in Table below.

The advantages of the proposed eva foam cutting tool have a tube blade shape, in accordance with the required eva foam shape specifications. That way, cutting can be done directly without having to make a pattern first before cutting. Besides, it has anti-slip on the surface of the tool. The use of this anti-slip so that when cutting eva foam, cutting tools and eva foam are not easy to shift.

On the other hand, the disadvantages of the proposed eva foam cutting tool are that the blade shape is not available in the market, so when the blade needs to be replaced due to use, it is necessary to re-create a special blade

4. CONCLUSION

Based on data processing using the DMAI approach, the root cause of the eva foam cutting did not match the pattern. The root of the problem obtained includes aspects of man, machine, material, and environment. From all the existing root causes, one root problem was chosen in the machine aspect, namely the cutter is inadequate. The selection of the root of the problem is done using FMEA tools. Therefore, the solution design that is carried out focuses on the equipment aspect (machine).

After designing using the Quality Function Deployment method, the results obtained in the form of an eva foam cutting tool design that has a tube blade. The shape of this blade will make it easier for the operator to cut the EVA foam and reduce the possibility of errors in the shape of the cutting process. In addition, by using this proposed eva foam cutting tool, there is a process that is omitted, namely making patterns before cutting the eva foam. This is because the proposed cutting tool has been integrated with the required shape based on existing specifications, so there is no need to make a pattern first. With the implementation of the proposed cutting tool, it is expected to reduce the number of defective products by 26% and increase process capability by increasing the sigma value of 0.208.

From the results of the design carried out, the proposed design of eva foam cutting tools is effective and efficient for the eva foam cutting process in order to reduce defective products in the production of polynet mesh spare parts at CV. Era Langgeng Mandiri.

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