Prioritizing critical parts of crumb rubber product by using quality function deployment (QFD) phase II: Product design matrix

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Abstract. Product quality is the most important thing in product design. To produce a qualified product, the designer must adjust the technical characteristics to the customer’s needs, so that the critical part of the crumb rubber product can be determined. The critical part of crumb rubber product is carried out using the second phase of quality function deployment (QFD) method. Quality Function Deployment (QFD) is a method used to improve the quality of a product by considering consumer needs associated with technical characteristics, and to obtain critical part priority, the designer must develop QFD phase II, which is a continuation of QFD phase I. In QFD phase I, the result obtained is a priority of technical characteristics so the priority of technical characteristics becomes input for QFD phase II as attribute of consumer needs. The results obtained from QFD phase II method in this study is the critical part priority which is used as the corrected part of a crumb rubber product to improve the quality of the crumb rubber product type SIR 20. The critical part priority obtained is the resistance of the rubber product to the heat, the resistance of plasticity, and plastic resistance to heat.

Keywords: Quality Function Deployment, House of Quality, Critical parts

1. Introduction
PT XYZ located at North Sumatra as a company producing crumb rubber with standard SIR (Standard Indonesian Rubber). The company produces crumb rubber products with a make-to-order system, which means the company produces crumb rubber on demand from consumers. However, with the principle of make to order, the company has 10 permanent export oriented buyers, so the company operates because there are 10 regular buyers. In other words, the existence of the principle of make to order, the company keeps stock product in quantity in accordance with the historical data of crumb rubber product demand so that the company produces with the principle of make to stock in accordance with the order received. With 10 permanent buyers, the company must be able to maintain the quality of the crumb rubber products produced. Although the company has a regular buyer, it does not mean the quality of the product is not well maintained. One of the products of this company is rubber crumb type SIR 20 which will become the object of research. The crumb rubber product of SIR 20 type is rubber with the lowest quality type. The crumb rubber SIR 20 product is said to be the lowest because it is still found
PO levels that are less than standard. PO indicator is Zero Plasticity or initial plasticity which expressed plastic crab rubber value before heated.

P0 test results indicate that there are still produces crumb rubber products that do not meet SIR standards according to ISO 1903: 2011, this may lead to the shift of the company's consumers to other similar products providers. Besides not being able to meet the standard of ISO 1903: 2011, this company also has not been able to meet the standards of the consumer.

Based on the result of testing of P0 level and standard determined by ISO 1903: 2011 and standard set by buyer, it can be seen that there is a gap between consumer perception and consumer expectation. Gap indicates that the company has not been able to meet consumer demand due to the gap between the quality of crumb rubber products SIR 20 produced by PT XYZ in the hope of the desired quality by the company's customers. PT XYZ should pay attention to consumer desire by way of translating consumer desires with technical characteristics to improve the quality of crumb rubber products. However, to be able to improve the quality of the product of course the company must still be able to reduce production costs so that in addition to producing quality products, production costs can also be suppressed.

The technique that can be used to realize the condition is by implementing the method of Quality Function Deployment (QFD), especially by developing quality function deployment phase II to maintain the critical parts to be improved. So, the main goal of doing research are converting of customer requirements to characteristics requirements and prioritizing the critical parts of crumb rubber products. Based on the research of Rosnani, et.al. (2015), a quality function deployment (QFD) was developed using kano model to determine the need of customer and turn it to technical characteristics, so that each of functional areas and level of organization can be understood and do improvements to achieve the purpose. Beside that research, M.H. Karimi Gavareshki (2017) did the design of automotive product using quality function deployment (QFD) and value engineering methods. The using of QFD is to determine the priority of critical part that can be improved using value engineering method. The using of value engineering method is to modify the materials of product that can be used to reduce the production cost and to increase the quality of crumb rubber products.

2. Methods

This research was conducted by conducting a survey in rubber company crumbs to the respondents in the company. Respondents surveyed were employees of the production process and production department supervisors at the company. The sampling method used is purposive sampling with quota sampling type. The sample of research is 27 people who is the total employee of production. The first step in data processing is to determine the priority of the technical characteristics that have been obtained in QFD phase I. The second step is to determine the degree of importance of the technical characteristics.

The third step is the determination of kiris part which is done by survey with the supervisor of production department. The fourth step is to mapping the relationships among the critical part. The next step is to mapping the relationship between the critical part and the technical characteristics. The sixth step is to construct a subsystem deployment matrix. The last step is to perform performance measurement calculations.

3. Result and Discussion

3.1. Determining Priority Technical Characteristics In QFD Phase I

Results from QFD Phase I are used as inputs for processing on QFD Phase II. Priority technical characteristics are determined on the basis of the greatest weight of the degree of difficulty, degree of importance, and cost estimates. Priority technical characteristics in Phase I QFD can be seen in Table 1.
3.2. Determination of Degree of Importance
The determination of degree of importance is obtained based on the difficulty level of each characteristic priority in the Phase I QFD matrix. The degree of importance of each technical characteristic can be seen in the table as follows.

Table 2. Degree of Importance

| No | Priority Technical Characteristics | Degree of Importance |
|----|-----------------------------------|----------------------|
| 1  | Production speed                  | 4                    |
| 2  | Production cost                   | 3                    |
| 3  | Production time                   | 3                    |
| 4  | Milling speed                     | 3                    |
| 5  | Cooking temperatures              | 3                    |
| 6  | Chopping speed                    | 2                    |
| 7  | Drying                            | 2                    |
| 8  | Machine capacity                  | 2                    |

3.3. Formatting author affiliations
The next step after determining the priority of technical characteristics in building HoQ Phase II is to define the critical part in production process planning. The determination of critical parts is an analysis of the critical / critical parts of the product. Determination of critical product parts based on interviews and discussions with factory production supervisors. The critical part of the product is as follows.

- Dry Rubber Content (DRC)
  Dry Rubber Content (DRC) is a dry rubber content contained in a crumb rubber product SIR 20.
- Resistance to Cracking
  Resistance to Cracking is the level of rubber resistance to cracks if rubber is worn style.
- Plasticity Resistance
  Plasticity Resistance is the plastic level of crumb rubber product that does not become elastic (remain plastic) although it is dried at high temperatures.
- Resistance to Heat
Heat Resistance to Heat is the durability of crumb rubber products that are not crushed / melted when cooked at temperatures above 3000C.

- **Ability Not Stretch**
  Ability Not Stretch is the ability of the rubber to not expand / widen / change size when given tensile force on crumb rubber products.

- **Plastic Strength**
  Plastic strength is the ability of plastic to not tear when supporting / crumb rubber products.

- **Plastic Thickness**
  Plastic thickness is the ability of plastic to keep crumb rubber products so as not exposed to contaminants easily.

- **Plastic Resistance to Heat**
  Plastic Resistant to Heat is the ability of plastic to keep crumb rubber products remain in good condition when exposed to heat.

### 3.4. Establish Relationships Between Critical Part

At this stage determined the level of relationship between each critical part that exists to be analyzed whether between the critical part there is a strong relationship, weak or unrelated. Determining the level of relationship between each of the existing technical characteristics based on the following symbols:

- **V**: shows a strong positive relationship = 4
- **v**: shows a weak positive relationship = 3
- **x**: shows a weak negative relationship = 2
- **X**: shows a strong negative relationship = 1
- **O**: no relation = 0

Level of relationship between each critical parts can be seen in Figure 1.

![Figure 1. Relationship Between Each Critical Part](image)

### 3.5. Establish Level of Relationship Between Technical Characteristics of Products With Critical Part

The next step is to determine the level of relationship between the critical part and the technical characteristics of the product. The level of relationship in question starts from the scale of strong, medium, weak, and not related at all. Assessments will be based on rules:

- **Value 9**: shows a strong relationship
• Value 3: indicates a moderate relationship
• Value 1: shows a weak relationship
• Value 0: shows no connection at all

The correlation score between the critical part and the technical characteristics can be seen in Figure 2.

|                         | Dry Rubber Content (DRC) | Resistance to Cracking | Plasticity Resistance | Resistance to Hat | Ability Not Stretch | Plastic Strength | Plastic Thickness | Plastic Resistance to Heat |
|-------------------------|--------------------------|------------------------|-----------------------|-------------------|---------------------|-----------------|-----------------------|-----------------------------|
| Production Time         | 1                        | 3                      | 3                     | 9                 | 3                   | 3               | 3                     | 3                           |
| Chopping Speed          | 1                        | 3                      | 3                     | 9                 | 3                   | 3               | 3                     | 0                           |
| Production Cost         | 3                        | 3                      | 9                     | 9                 | 3                   | 3               | 3                     | 9                           |
| Drying Time             | 3                        | 9                      | 9                     | 9                 | 3                   | 0               | 0                     | 0                           |
| Production Speed        | 1                        | 3                      | 3                     | 3                 | 3                   | 3               | 3                     | 3                           |
| Cooking Temperatures    | 9                        | 9                      | 9                     | 9                 | 9                   | 9               | 9                     | 9                           |
| Milling Speed           | 3                        | 3                      | 3                     | 3                 | 0                   | 0               | 3                     | 3                           |
| Machine Capacity        | 1                        | 3                      | 3                     | 3                 | 1                   | 1               | 1                     | 3                           |

Figure 2. Relationship Between Critical Part and Technical Characteristic

3.6. Building a House of Quality Matrix (HOQ) Phase II Crumb Rubber Product Type SIR 20

Before building a house of quality (HOQ) Phase II, it is necessary to calculate the performance measures of the HoQ consisting of three aspects: difficulty level, importance level and cost estimation. The calculation of these three aspects can be shown in the following description:

3.6.1. Determination of difficulty level

The degree of difficulty is determined from the critical part relationships. The calculation is done by translating all the weight of the relationship value and then dividing the weight of each critical part with the amount of weight was. Furthermore, the difficulty level is given based on the percentage range obtained.

• 0 - 5% difficulty level = 1
• 6 - 11% difficulty level = 2
• 12 - 17% difficulty level = 3
• 18 - 23% difficulty level = 4
• >24% difficulty level = 5

The value of the difficulty level can be calculated by first calculating the total weights for each relationship between the critical parts.

\[
\text{Weight} = \sum B_i K_i
\]  

Weight of Dry Rubber Content (DRC) = 0 + 3 + 4 + 4 + 0 + 0 + 3 = 14

Total weight for all relationships between technical characteristics
Total Weight = $\sum Bi$ (2)

Total weight = $14 + 16 + 18 + 24 + 18 + 12 + 13 + 21 = 136$

To calculate the difficulty level for each critical part used the formula:

$$\text{Difficulty Level} = \frac{\text{Weight each critical parts}}{\text{Total weight of critical parts}} \times 100\%$$ (3)

Example of calculation:

Difficulty Level of Dry Rubber Content (DRC) = $\frac{14}{136} \times 100\% = 10\% = 2$

3.6.2. Determination of Degree of Interest

The value of the degree of importance can be calculated by calculating the total weight for each relationship between the attribute of technical characteristics with the critical part. Calculation of degree of importance to attribute technical characteristics with critical part using the formula:

$$\text{Weight} = \sum Bi$$ (4)

The weight of Dry Rubber Content (DRC) = $1 + 1 + 3 + 3 + 1 + 9 + 3 + 1 = 22$

The total weights for all relationships between the attributes of technical characteristics and the critical part are:

$$\text{Total Weight} = \sum Bi$$ (5)

= $2 + 30 + 42 + 54 + 30 + 22 + 22 + 30 = 252$

To calculate the degree of importance for critical part attributes with technical characteristics used the formula:

$$\text{Degree of Importance} = \frac{\text{Weight each critical parts with attribute}}{\text{Total weight of critical parts with attribute}} \times 100\%$$ (6)

Example of calculation:

The degree of importance of Dry Rubber Content (DRC) = $\frac{22}{252} \times 100\% = 9\%$

3.6.3. Cost estimation

The difficulty level factors serve as the basis for cost estimates because the more difficult a critical part is made, the more costly the allocation will be.

The total weight of the difficulty level of the critical part of the product is, as follows:

$$\text{Total Weight} = \sum BiP$$ (7)

= $2 + 3 + 3 + 4 + 3 + 2 + 2 + 3$

= 22

The following approximate cost formula:

$$\text{Estimated Cost} = \frac{\text{Weight of each difficulty level of critical parts}}{\text{Total weight each difficulty level of critical parts}} \times 100\%$$ (8)

Estimated cost of Dry Rubber Content (DRC) = $\frac{2}{22} \times 100\% = 9\%$
Determination of Difficulty, Degree of Interest and Cost Estimation can be seen in Table 3.

| Table 3. Difficulty Level, Degree of Importance, Cost Estimation |
|---------------------------------------------------------------|
| **Difficulty Level** | 2 | 3 | 3 | 4 | 2 | 2 | 3 |
| **Degree of Importance** | 9 | 12 | 17 | 21 | 12 | 9 | 12 |
| **Cost Estimation** | 9 | 14 | 14 | 18 | 14 | 9 | 14 |

The Phase II HoQ matrix is based on the data that has been obtained in the previous steps. QFD Phase II of SIR 20 type crumb rubber products can be seen in Figure 3.

![Quality Function Deployment (QFD) Phase II](image)

### 4. Conclusion

Conclusion that can be obtained from this research is QFD Phase II of crumb rubber products results show that the highest critical part priority is product resistance to heat, plasticity resistance, and plastic resistance to heat. These are the priority of critical part that can be improved to increase the quality product. By improving the product resistance to heat, it can increase the plasticity resistance as well. The company may looking forward for the substitution of the materials used by the materials which have
the resistance to the heat. LUMP material is used as well as raw material but it isn’t resistance to heat. So that, it could be replace by SLAB material which has the resistance to the heat. And polypropylene is the best plastic if the main criteria is resistance to the heat.

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