DESIGNING ERGONOMIC TOOTHBRUSH, TOOTHBRUSH REFILL, AND TOOTHBRUSH CAP

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ABSTRACT

Used toothbrush is one type of waste that is difficult to unravel. Therefore, it is necessary to design a toothbrush refill that can be reused so that the amount of waste generated fewer.

The data collection was done by distributing questionnaires (preliminary, importance, open, QFD) and measured the molars. Furthermore, the next step was designing some alternative designs of toothbrush, toothbrush refill and toothbrush cap. The refill toothbrush design alternatives, were selected using the method of concept scoring which were based on the criteria of customer needs.

The selected alternative was alternative 1 (the method of screwing the neck of the toothbrush).

Keywords: toothbrush, design, ergonomic

1. INTRODUCTION

Currently, rapid industrial development is characterized by the establishment of a wide variety of plants. These plants produce a wide range of products to be consumed by the segment of consumers. Many consumers consume the product, the more the consumers produce waste from consumption of these products. Waste gives negative impact to humans. The negative impact, making people try to reduce industrial waste or waste generated by performing a variety of prevention and control. In the prevention of waste generated by consumers, then we can apply the principles of reduce (reduction), reuse (reuse), whereas in overcoming waste, recycling principle can be used (turnover reused or recycled). One of the waste that is unraveled, is made of plastic. One of the products that are made of plastic material is stalk toothbrush. Based on the above conditions, it is necessary to design a toothbrush that can be reused so that the number of the waste can be reduced. Factors that must be considered in designing of the toothbrush that can be reused is convenience for consumers who use them. Therefore, an ergonomic toothbrush was designed.

This paper was written based on the thesis titled “Designing Toothbrush, Toothbrush Refill, Shut Toothbrush, Toothpaste Place, Place Toothpaste Refill, and Box Place Toothpaste with Ergonomics Approach” by Andriyani, Novi, and Christina.

In making this report, limitations and assumptions used were as follows:
1. Toothbrush that would be designed was a toothbrush for adult users.
2. The design did not calculate the cost to produce the toothbrush, toothbrush refill and toothbrush cap.
3. The design and dimensions of the model only included toothbrush, toothbrush refill, toothbrush cap.
4. The level of accuracy that was used was 10% and the 95% confidence level.
5. It was assumed that anthropometric data obtained from the book "Konsep Dasar Ergonomi dan Aplikasinya" by Eko Nurmianto according to anthropometric data users toothbrush and toothpaste.
6. Sample data was assumed equal to the population data.

The formulation of the problem in this study were:
1. What were the customer needs of toothbrush from the point of view of ergonomics?
2. How to design an ergonomic toothbrush, toothbrush refill, and toothbrush cap?
2. STUDY LITERATURE

2.1 Quality Function Deployment

According to Cohen, Quality Function Deployment is a method for designing and developing of a structured product, which allows a team of developers to clearly specify all the wants and needs of customers, and then systematically evaluate each product or service’s ability to meet the wants and needs.

2.1.1 Parts of the House of Quality

2.1.2 The four-phase QFD model

According Day:

Phase 1: Product Planning

Phase 2 is where the Technical Design Requirements Planning (Technical Requirements) converted into Part Characteristic (Characteristics Section).

Phase 3: Process Planning

Phase 3 is where the Planning Process Part Characteristic (Characteristics Section) is converted into a Process Characteristic (Process Characteristics).

Phase 4: Production Planning

Stage 4 is where the Production Planning Process Characteristic (Process Characteristics) is converted to Production Requirements (Requirements Production).

2.2 Ergonomics

The term “ergonomics”, according Nurmianto, is derived from the Latin, which Ergon (work) and nomos (natural laws) and can be defined as the study of human aspects in the work environment are reviewed in anatomy, physiology, engineering, management, and design or design. Essentially, ergonomics is a branch of science that systematically utilize information about the properties, capabilities, and limitations of humans to design a working system so that people can live and work on the system properly, ie achieve a chill through the job effectively, safe, and comfortable.
2.3 The purpose of Ergonomics
The goal of ergonomics is no 2, ie:
1. To improve the effectiveness and efficiency of the work and activities undertaken, including the improvement of the usability, reduce errors, and increase productivity.
2. To enhance the number and value of the human element, including improving safety, reducing fatigue and tension, improve comfort, increase job satisfaction, and improve quality of life.

2.4 Anthropometry
According to the method of measurement, anthropometry is divided into two parts, namely:
1. Static anthropometry, where the measurements are performed on the human body are in a stationary position.
2. Dynamic anthropometry, which the body dimensions measured in various body positions that are moving, making it more complex and more difficult to measure.

It can be concluded that anthropometric data will determine the shape, size and exact dimensions associated with a product designed and man who will operate or use the product. The results of the design must be able to accommodate the dimensions of the body of the largest populations that use the products designed by them. In general, 90% to 95% of the target population in a group of users of a product must be able to use it properly.

2.5 Concept Scoring
Ulrich said that concept scoring is conducted to determine which is the best product concept among some concept products compared, based on certain selection criteria. Below is a table for purposes of valuation analysis concept.

Table 1. Analysis of Concept Scoring

<table>
<thead>
<tr>
<th>Compared Product Concept</th>
<th>A</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>weight (w)</td>
<td>Rating (r)</td>
<td>Value (r x w)</td>
</tr>
<tr>
<td>selectio n criteria analysis</td>
<td>1</td>
<td>..</td>
</tr>
</tbody>
</table>

Source: Ulrich & Eppinger (1)

3. RESEARCH METHODOLOGY
Research steps were as follows:

START

Preliminary Study
Understand the problem

Identifying Problems
Currently, there are no product manual toothbrush and toothpaste refilled.

Restrictions Problems and Assumptions
Limitation Problem:
1. Toothbrush that will be designed is a toothbrush for adult users.
2. The design does not take into account the costs incurred.
3. Measure used in designing toothbrush is a measure anthropometric data obtained from the book "Ergonomics Basic Concept and Its Application" by Eko Nurmianto.
4. The level of accuracy that is used is 10%.
5. The confidence level used is 95%.

Assumptions:
1. Anthropometric data were obtained from the book "Ergonomics Basic Concept and Its Application" by Eko Nurmianto according to anthropometric data toothbrush users.
2. Sample data same with population data.

Problem Formulation
1. What is the customer need of toothbrush from the point of view of ergonomics?
2. How to design a toothbrush, toothbrush refill, ergonomic toothbrush cap?

Research Objectives
1. Understanding customer need of the toothbrush from the point of view of ergonomics.
2. Designing toothbrush, toothbrush refill, lid ergonomic toothbrush.

Review of Literature
Literature study relating to the design of a toothbrush.

Data Collection and Processing
Data Collection:
1. Preliminary Questionnaire
2. Importance Questionnaire
3. Open Questionnaire
4. QFD Questionnaire
5. Measuring the size of the current brush.

Data Processing:
1. Percentage calculations for the preliminary questionnaire, Importance questionnaire, open questionnaire
2. Testing validity and reliability of the questionnaire CFD
3. Calculating normality, uniformity and adequacy of the data and the calculation of the molar percentile for men and women.
4. ANALYSIS AND DESIGN

After having validity and reliability tests, QFD questionnaire made design planning and product planning.
In designing toothbrush, it was required anthropometric data as follows:
- Toothbrush Alternatives 1, 2 and 3

### Table 2. Toothbrush Size Alternatives 1, 2 and 3

<table>
<thead>
<tr>
<th>Product dimension</th>
<th>Anthropometric Data</th>
<th>Allowance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
<td>Percentile</td>
</tr>
<tr>
<td>The length of toothbrush stalk</td>
<td>LFT+PFI</td>
<td>95%</td>
</tr>
<tr>
<td>The width of toothbrush stalk</td>
<td>Koll DG</td>
<td>9%</td>
</tr>
<tr>
<td>The thickness of toothbrush stalk</td>
<td>Koll DG</td>
<td>9%</td>
</tr>
<tr>
<td>The length of the gap</td>
<td>(survey of existing products)</td>
<td>-</td>
</tr>
<tr>
<td>The length of toothbrush neck</td>
<td>(survey of existing products)</td>
<td>-</td>
</tr>
<tr>
<td>The width of toothbrush neck</td>
<td>(survey of existing products)</td>
<td>-</td>
</tr>
<tr>
<td>The slope of the neck-head toothbrush</td>
<td>(survey of existing products)</td>
<td>-</td>
</tr>
<tr>
<td>The thickness of toothbrush neck</td>
<td>(survey of existing products)</td>
<td>-</td>
</tr>
<tr>
<td>The length of toothbrush head</td>
<td>(survey of existing products)</td>
<td>-</td>
</tr>
<tr>
<td>The thickness of toothbrush head</td>
<td>(survey of existing products)</td>
<td>-</td>
</tr>
<tr>
<td>The length of toothbrush handle</td>
<td>(survey of existing products)</td>
<td>-</td>
</tr>
<tr>
<td>The width of the tip toothbrush head</td>
<td>(survey of existing products)</td>
<td>-</td>
</tr>
<tr>
<td>The width of the central part toothbrush head (all 1.3 &amp; 3)</td>
<td>dental widest</td>
<td>5%</td>
</tr>
<tr>
<td>Elbow length (all 3)</td>
<td>2* Width Elbow</td>
<td>-</td>
</tr>
<tr>
<td>Elbow width (all 3)</td>
<td>Thick Materials (survey existing products)</td>
<td>-</td>
</tr>
</tbody>
</table>

Note:
- Circumference DG=3.14*DG
- LFT: Handwidths (Metacarpal)
- PFI: Long thumb
- DG: Diameter handheld
In designing toothbrush refill, required anthropometric data as follows:

Table 3. Refill Toothbrush Size Alternative 1,2,3

<table>
<thead>
<tr>
<th>Product dimension</th>
<th>Anthropometric Data</th>
<th>Allowance</th>
<th>Ergonomic size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
<td>Percentile (mm)</td>
<td>Size (mm)</td>
</tr>
<tr>
<td>The length of toothbrush bristles</td>
<td>(survey of existing products)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The length of Toothbrush Head (alt 1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The length of Toothbrush Head (alt 2 &amp; 3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The width of the tip of the toothbrush head</td>
<td>Tooth tip width</td>
<td>5%</td>
<td>Women</td>
</tr>
<tr>
<td>The width of the central part of the toothbrush head</td>
<td>Dental widest</td>
<td>5%</td>
<td>Men</td>
</tr>
<tr>
<td>The thickness of Toothbrush Head (alt 1)</td>
<td>(survey of existing products)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The thickness of Toothbrush Head (alt 2 &amp; 3)</td>
<td>(survey of existing products)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The length of toothbrush neck (survey of existing products)</td>
<td>-</td>
<td>-</td>
<td>1/2*45</td>
</tr>
<tr>
<td>The width of the toothbrush neck (survey of existing products)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The slope of the toothbrush neck head (survey of existing products)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The thickness of toothbrush neck (survey of existing products)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Elbow length (alt 3)</td>
<td>Thick material (surveys of existing products)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Elbow width (alt 3)</td>
<td>Elbow width (alt 3)</td>
<td>2 * width elbow</td>
<td>-</td>
</tr>
</tbody>
</table>

In designing a toothbrush cap, it was required anthropometric data as follows:

Table 4. Cap Toothbrush Size Alternatives 1, 2 and 3

<table>
<thead>
<tr>
<th>Product dimension</th>
<th>Anthropometric Data</th>
<th>Allowance</th>
<th>Ergonomic size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
<td>Percentile (mm)</td>
<td>Size (mm)</td>
</tr>
<tr>
<td>The length of toothbrush cap</td>
<td>The length of Toothbrush Head</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The thickness of toothbrush cap</td>
<td>The thickness toothbrush head + the length toothbrush bristles (survey existing products)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The length of toothbrush cap opener</td>
<td>1/2 IPJ</td>
<td>95%</td>
<td>Men</td>
</tr>
<tr>
<td>The width of toothbrush cap opener</td>
<td>1/8 PU</td>
<td>95%</td>
<td>Men</td>
</tr>
<tr>
<td>The length of toothbrush stalk’s hole</td>
<td>The thickness of toothbrush neck (survey existing products)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The width of toothbrush stalk’s hole</td>
<td>The width of Toothbrush neck (survey existing products)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The width of toothbrush cap (alt 1 &amp; 3)</td>
<td>The width of toothbrush head</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>The width of toothbrush cap (alt 2)</td>
<td>The width of toothbrush head</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note : IPJ: Thumb width
Refill toothbrush was made of nylon material, the attachment of the filaments using brass, head toothbrush alternatives 1 and 3 were made of plastic, while the second alternative was made of rubber. Is a rubber grip material, the neck and the stalk of a plastic toothbrush.

The difference of the three design alternatives was on the method of the installation of the toothbrush. The first alternative had the method of screwing the neck of the toothbrush. The second alternative was the toothbrush with the rails located at the head of the toothbrush. The third alternative had the method of pressing the base of the bristles to the toothbrush head.

Toothbrush cap was made of plastic material, and opened by the flick of a finger.

The best alternative was chosen based on the assessment concept (concept scoring) with a toothbrush concept evaluation criteria derived from the questionnaire revelation QFD and weights obtained from the sorting value ITC (Important to Customer). Here is a concept scoring of toothbrush:

<table>
<thead>
<tr>
<th>Table 5. Toothbrush Concept Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
</tr>
<tr>
<td>-------------------------------------</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

Alternative 1 was the most well compared with other alternative products.
Value analysis of this toothbrush refill product was based on 4 categories. Based on use value, this product had more than one purpose, that was in addition to cleaning teeth, could also be used to clean the tongue. Product design that was chosen was also easy to use, had ergonomic design, and also had simple replacement mechanism. Based on esteem value, the product design had a pretty good aesthetic value due to the exclusive look with bright colors. Based on the criteria of exchange value, product design had a high exchange rate, because we could refill the toothbrush bristles. However, there were currently no similar products circulated in the market, so there is no standard size. In this paper, it is not considered about the cost value.

5. CONCLUSION AND SUGGESTION

5.1 Conclusion
1. The customer needs for toothbrush-related aspects of ergonomics are the variables in the QFD.
2. The design of the toothbrush, toothbrush refill, toothbrush cap that was chosen was alternative 1. The mechanism of toothbrush alternative 1 was by screwing the neck of the toothbrush.

5.2 Suggestion
- In a subsequent study, it is suggested to measure anthropometric data for the dimension of the toothbrush which are the length of the toothbrush neck, width of the toothbrush neck, thickness of the toothbrush neck, length of the toothbrush head, slope of the toothbrush neck-head, thickness of the toothbrush head, length of the toothbrush bristles and thickness of material.

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