Low Cost Mechanical Prosthetic Hand (Metic Hand) Design for Under Elbow Hand Amputation Patients

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Abstract

Hands are one part of the human body that has an important role in human daily activities. A lot of people have experienced hand disabilities in Indonesia, which is 158,000 per year. This can reduce an individual's quality due to limitations in carrying out activities. So as to help bring prosperity to the people of Indonesia by giving them tools that can support their lives. The purpose of this design task is to make a mechanical hand-made product that is affordable to all Indonesians by providing a low price product. The step of making this product is doing a product selection from mechanical prosthetic hands based on the design method that is identifying customer needs, technical specifications, concept alternatives, concept selection, selected concepts, selected concept analysis, prototyping, product printing, product testing, and product evaluation. Based on the results of the process, a mechanical prosthetic hand is obtained on the alternative concept 2, which will then be tested with consumers. That mechanical prosthetic hand was tested at Mas Muhammad Andika with the result of the movement of taking a tissue, taking food, lifting a bottle, moving a bucket, and lifting a bag. From the results of the tests carried out that there is an evaluation that can be developed on the product that the width of the grip is too narrow, which is 4 cm, so that it is only limited in the size of the grip, it is necessary to develop the second alternative hand model.

Keywords: disability, hands, mechanical prosthetic hands, product design

Abstrak

Tangan merupakan salah satu bagian tubuh manusia yang memiliki peran penting dalam aktivitas manusia sehari-hari. Banyak orang yang mengalami disabilitas tangan di Indonesia, yaitu 158.000 per tahun. Hal ini dapat menurunkan kualitas individu karena keterbatasan dalam melakukan aktivitas. Sehingga dapat membantu membawa kemakmuran bagi masyarakat Indonesia dengan memberikan mereka alat-alat yang dapat menunjang kehidupan mereka. Tujuan dari tugas perancangan ini adalah membuat suatu produk mekanikal hand-made yang terjangkau oleh seluruh masyarakat Indonesia dengan harga yang terjangkau. Tahapan pembuatan produk ini adalah melakukan pemilihan produk dari tangan palsu mekanik berdasarkan metode perancangan yaitu mengidentifikasi kebutuhan pelanggan, spesifikasi teknis, alternatif konsep, pemilihan konsep, konsep terpilih, analisis konsep terpilih, prototyping, pencetakan produk, pengujian produk, dan evaluasi produk. Berdasarkan hasil proses tersebut didapatkan sebuah tangan palsu mekanik pada alternatif konsep 2 yang selanjutnya akan diujicobakan kepada konsumen. Tangan palsu mekanik tersebut diujicobakan di Mas Muhammad Andika dengan hasil gerakan mengambil tisu, mengambil makanan, mengangkat botol, memindahkan ember, dan mengangkat tas. Dari hasil pengujian yang dilakukan terdapat evaluasi yang dapat dikembangkan pada produk bahwa lebar grip terlalu sempit yaitu 4 cm sehingga hanya dibatasi pada ukuran grip saja. diperlukan untuk mengembangkan model tangan alternatif kedua.

Kata kunci: disabilitas, tangan, tangan buatan mekanik, desain produk

1. Introduction

Hands are one part of the human body that has an important role in human daily activities. Hands are one of the body movements in humans consisting of 19 bones, 24 muscle tissue, blood vessel tissue, and sensory and motor nervous systems (Taylor, 1955). Human hands are one mechanism with high complexity. But there are some people who cannot use their hands properly due to several things such as amniotic band syndrome, and amputations so that the person experiences a lifetime of disability.

According to the 2012 Sosial Ekonomi Nasional (SUSENAS) survey data, namely the population of persons with disabilities by 2.45% (6,515,500 people) of the total estimated population of 244,919,000 Indonesia in 2012. Meanwhile, according to the Program Perlindungan dan Layanan Sosial (PPLS) in 2012 the number of persons with disabilities nationwide is as much as 3,838,985 inhabitants. This difference in number is caused by the operational definition or instrument used in the different surveys (Kementerian Kesehatan RI, 2014).

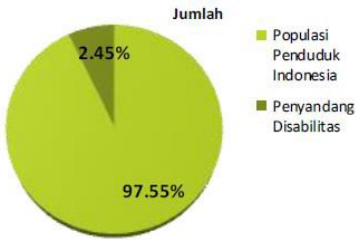

Figure 1. Population of persons with disabilities based on 2012 SUSENAS data [1]

Examples of persons with disabilities are based on data from a community concerned with persons with disabilities (P3D), namely Mr. Suroso who resides in Pekalongan, with the age of 52 years, he experienced hand disability under the elbow due to an accident. Then there was Muhammad Andika who came from Semarang, with the age of 14 years, he experienced electrocution until his hands needed to be amputated both. And the last one is Mbak Alfi who lives in Semarang, he has a hand disability under his elbow from birth.

Now there are many types of prosthetic hands that have been developed in the world and even in Indonesia. Like prosthetic cosmetic hands, bionic prosthetic hands, mechanical prosthetic hand funds. Of the three types of hands that have different functions and forms, therefore in developing this prosthetic hand it is necessary to survey the demand and conditions of the Indonesian people so that the types of hands made can be used by all Indonesian citizens who have disabilities. Based on the nature of Indonesians, the average of them is like goods that have almost the same function and are affordable. Also based on data from the Indonesian economy that there are still 25.9 million people who have a low economy.

Therefore it is necessary to develop prosthetic hands according to the needs of the Indonesian people, and the hands that have these criteria are prosthetic mechanical hands. In developing a mechanical prosthetic, the design process was obtained by getting the design chosen so that it could adjust the needs of the Indonesian people in detail regarding mechanical prosthetic hands.

2. Method of Design and Making of a Tool

2.1. Product Design Process

In the process of designing a product in order to get the maximum product when it is printed and after printing, the right product design process is needed. According to Ulrich and Eppinger [2] The process sequence of designing products that identifying customer needs, technical specifications, concept alternatives, concept selection, selected concepts, selected concept analysis, prototyping, product printing, product testing, and product evaluation.

From the sequence of product design above must be done sequentially and sequentially in order to get the maximum product when it will be marketed. So that the process carried out is not recommended randomly.

2.2. Identification of Customer Needs

Identification needs consumer function for knowing the right product - right desired by consumers. Identifying customer needs itself is a process, in the process of identifying customers there are interview methods, focus group discussions and observations . After the method is carried out then then do five steps [2]. The five steps are:

1. Collect raw data from customers.
2. Interpreting raw data in terms of customer needs.
3. Regulate needs into a hierarchy of primary, secondary and (if necessary) tertiary needs.
4. Set relative importance of needs.
5. Reflect on the results and the process.

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2.3. Technical specifications

In general, technical specifications are job descriptions in meeting predetermined needs (performance) or detailed descriptions of the quality of materials, methods and standards of quality of goods, services or jobs that must be provided by the provider. Technical specifications are obtained from the customer identification process.

Effective and efficient achievement refers to the characteristics of achieving value for money, namely the technical specifications of goods / services arranged have five characteristics, namely [3]:

1. Exact quality, quality as needed
2. Place number, quantity according to what is needed
3. Place of time, goods / services are held when needed
4. Right location / source, goods / services come from appropriate sources and sent / received at the destination
5. Pricing is at the end of the list by calculating efficient costs.

2.4. Alternative Concepts

Alternative concepts are made based on the technical specifications that have been made. Ideas from alternative concepts are developed based on problems and then solved by means of [4]:

1. Decomposition of complex problems is simple
2. Focus on critical subproblems

To get basic images in making alternative concepts can be done in 2 ways, namely [4]:

1. Search externally, searches are carried out based on ideas from outside themselves or groups.
   a. Primary user interview.
   b. Expert consultation.
   c. Looking for a patent.
   d. Search for published literature.
   e. Comparison with related products.
2. Search internally, searches are carried out based on ideas from yourself and the group.
   a. Discussion of individuals or groups
   b. Determine the concept of a solution by determining the analogy, desires and expectations, using related stimuli, using non-related stimuli, setting goals, and gallery methods.

After obtaining some information received to determine the concept to be made, namely by making a morphological matrix table.

2.5. Concept Selection

Concept selection is the process of evaluating a concept by paying attention to customer needs, comparing the advantages / disadvantages of each concept and then choosing one or more concepts to be developed further.

Based on the method developed by Stuart Pugh (1980) so that this method is often called the concept of Pugh selection, the following is the step of making it [5]:

1. Step 1: Prepare the selection matrix
2. Step 2: Assess concepts (rate the concepts)
3. Step 3: Determine ranking (rank the concepts)
4. Step 4: Combine and improve concepts
5. Step 5: Choose one or more concepts

2.6. Selected Concept

The selected concept is a concept that has been selected based on the selection process of the concepts that have been presented. This selected concept is a concept that will be developed, printed, tested, and evaluated. This selected concept will explain the general specifications of the reason this concept can be chosen and a general explanation of the parts of the concept that suit the needs of the customer..

2.7. Selected Concept Analysis

The selected concept analysis is a detailed explanation of the object to be made and the delivery of parts of the object in detail so that the reader knows the description of the shape of the item to be made in the form of a concept. Analysis of selected concepts in more detail is carried out at the design embodiment stage. The issues analyzed include form design, manufacturing and assembly design, material selection and industrial design [6].

2.8. Prototyping

The process of developing a prototype system is often used approach (prototyping). This method is very well used to solve the problem of misunderstanding between the user and the analyst arising from the user being unable to clearly define his needs [7] . Prototyping is the rapid development and testing of work models (prototypes) of new applications through an interaction and repetitive process commonly used by information systems experts and business experts. Prototyping is also called rapid application design (RAD) because it simplifies and speeds up system design [8].

2.9. Product Printing

Product printing is a rposes wherein a concept design is printed in a real form so that it can be used by customers. In the process of printing this product, it can be done in several ways, that is, through the workshop process, using a 3D printer, and so on. In the printing process must be adjusted the size of customer needs. At the time of printing there is a need for attention to the items being printed, because the presence of defects in the product causes customer disappointment.

2.10. Product Testing

Product testing is a process where to find out the weaknesses and strengths of concepts that are made in real terms. In the testing process there are several types of testing that can be applied depending on the needs of the tool. It needs to

be tested on how the examples of testing are product hardness testing, product strength testing, tensile testing on the product, and others.

2.11. Product Evaluation

Product evaluation is a process by which a product evaluates by a customer who feels directly about the product that has been made. Possible when in operation experience difficulties, sudden damage, etc. The function with this evaluation is used to determine the weakness of the product so that it can be developed in the future.

3. Results and Analysis of Discussion

3.1 Design Flow Chart

In a design, flow chart is needed to describe the course of the design process from the beginning to the end that has been done. The method used in this design is based on the product design process, namely identification of customer needs, technical specifications, alternative concepts, selection of concepts, selected concepts, and analysis of selected concepts.

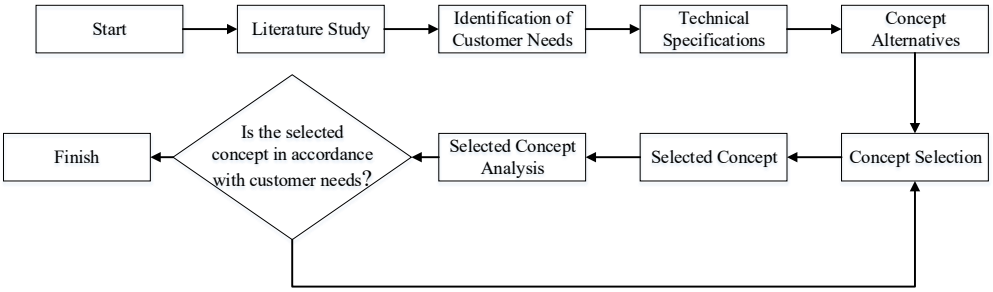


Figure 1. *Flow chart* design

3.2 Quality Function Deployment (QFD)

The first step in determining the design is conducting interviews and observations of the participant study. After conducting interviews and observations with respondents, the supporting data were obtained using the method of quality function deployment (QFD) which became a reference in the design stages of the mechanical prosthetic hand METIC HAND. Figure 2. is the house quality of the QFD method.

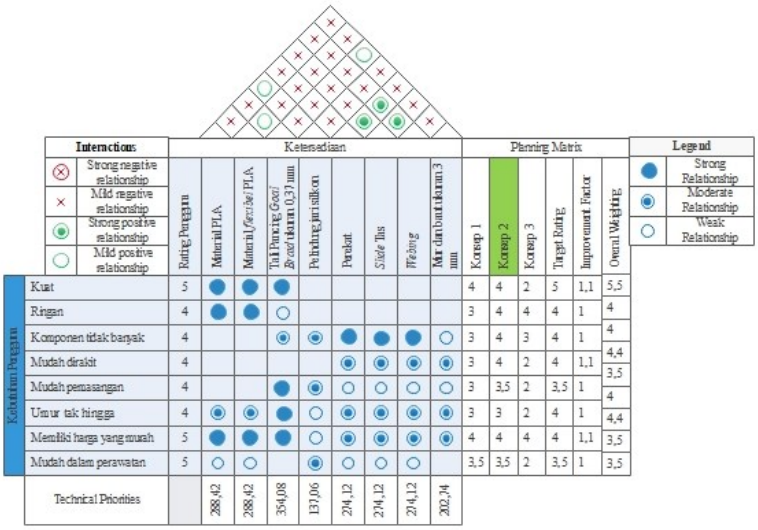


Figure 2. METIC HAND quality fuction deployment

Based on the quality function deployment (QFD), obtained some values that indicate customer needs for the type of mechanical prosthetic that will be made later. That the value of the product is more needed by the community, namely METIC HAND products with a second alternative design.

3.3 Selection of Product Concepts

Matrix morphology is the development of the function block into several sub-functions, sub-functions are developed into several sub-sub-fung si. Here in Table 1. will be displayed in the product matrix morphology HAND METIC which will be drawn up several alternative concepts of product that may be made

Table 1. matrix morphology for mechanical prosthetic hand

No	Sub function	Sub-functions	Sub sub-functions
1.	Material Selection	Polimer	A1 PLA
2.	Finger	Material	B1 PLA B2 Flexibel PLA B3 PLA dan Flexibel PLA
3.	*Linkage*	Material	C1 Rubber C2 Flexible PLA
4.	*Pins*	Material	D1 PLA D2 Flexibel PLA
5.	Rope	Material	E1 Fishing Line

After making a morphological matrix, the next step is to make alternative concepts by arranging these concepts then compared one by one. Making alternative concept product could arranged based on Tabel 1., so produce some concept / variant as the following:

Concept 1 : A1+B1+C1+D1+E1
Concept 2 : A1+B3+C2+D2+E1
Concept 3 : A1+B2+C3+D2+E1

Then compared the matrix into the decisions made based on criteria such as Table 1.

Table 2. Election concept based on matrix decision

No.	Kriteria Penilaian	Wt	Konsep		
			K- 1	K- 2	K-3
1.	Cheap	10	7	8	8
2.	Light	9	8	9	9
3.	Ability to Grip	9	8	9	5
4.	Ease of Manufacture	8	5	8	4
5.	Ease of Assembly	8	5	7	4
5.	Flexibility	7	5	7	4
6.	Ergonomics	8	6	8	5
7.	Ease of Maintain	7	6	7	5
	Jumlah		50	63	44

From the decision making matrix, the concept with the highest value is obtained as the chosen concept, namely the concept 2 with a value of 63 from the total value of 66. With the mixed finger material that is PLA and PLA flexibles, the linkage and pins use PLA flexible material the arm will then hold the finger, and the rope used is a fishing line that has a lift strength of up to 36 kg.

3.4 METIC HAND Design *Flowchart*

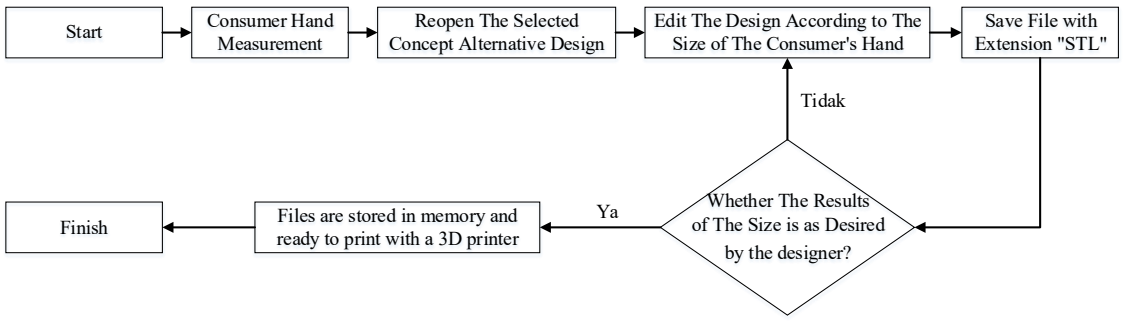


Figure 3.3 *Flow chart* design of mechanical prosthetic hands

In this design *process,* the first thing to do is do hand measurements on patients and then the consumer hand size data will be used as a reference in hand design . First open the chosen alternative design first. Then edit the design size according to the size of the consumer's hand. After editing for all parts, then the next process is to check the design that has been made whether all parts have been edited and adjusted to the size of the hand of the consumer. If it is appropriate,

each file is stored in the form of an extension, namely. STL, then the files are inserted into memory and ready to be printed into prototypes using 3D *Printing* .

3.5 Mechanical Prosthetic Hand Test Results

In this test a mechanical prosthetic hand was carried out directly by a patient named 14-year-old Muhammad Andika who lived in Terboyo, Semarang..

Tabel 3.3 The results of the use of mechanical mock hand users

Picture	Movement
	Take food
	Lift the bottle
	Take a tissue
	Lift the bucket
	Move the bag

3.6 Consumer opinion

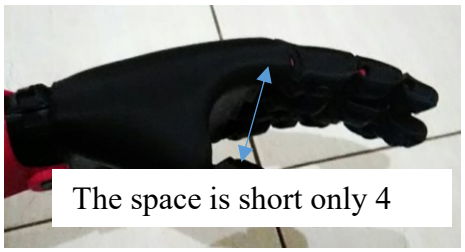
Based on the trial of mechanical imitation hands to the user, as for the opinion of the user, namely mas Muhammad Andika as a mechanical imitation hand evaluation, namely:

1. Mechanical prosthetic hands that are used there are several parts that are easily separated, especially the finger.
2. The width of the grip of the mechanical prosthetic hand is limited, because the location of the thumb is too close.
3. For printing results to be repaired again, because there are some prints that are still damaged.
4. The color of the hand is as much as possible adjusted to the color of the human hand, so as not to be too flashy when used.

4. Conclusions

The following are the results of conclusions obtained based on the discussion that has been done, namely:

1. That the mechanical copy hand chosen is version 2. Because it has the advantage that it is more than a type of mechanical prosthetic hand of another version. Many factors that support the prosthetic hand mechanical version 2 are lighter, easier to use, less material use, easier to assemble, and so on. But in terms of grip still not wide due to the location of the thumb that is too close.



Gambar 5.1 Ukuran lebar genggaman tangan

2. For this reason, it is necessary to develop this prosthetic hand mechanically by changing the width of the mechanical prosthetic hand to a wider extent so that large objects can be gripped.

5. Reference

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