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1-DOF FINGER MECHANISM DESIGN FOR ANTHROPOMORPHIC PROSTHETIC HAND WITH SIMILARITY CRITERIA FOR HUMAN HAND FINGER MOVEMENT

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Abstract. Development of prosthetic hands continues to be made to get prosthetic which has special characteristics, namely anthropomorphism. The anthropomorphic prosthetic design refers to the improvement and development of the design to the stage of the similarity of the prosthetic movement to human hand movements. This study carries the design of the anthropomorphic 1-DOF prosthetic finger mechanism to get prosthetic at an affordable price. The optimization criteria for the similarity of movement with the human hand are formulated with two objective functions, namely the similarity of the range of motion and the total length of the finger that is completed simultaneously. The human hand movement that is a reference is the movement of conical object grasping on a standard size conical according to the maximum hand-held diameter anthropometry of an Indonesian people.

Keywords : Prosthetic Hand, Anthropomorphic, Range of Motion.

1. INTRODUCTION

Prosthetic hands that can replace the function of human hands are said to fulfill the anthropomorphic aspect. Until now several studies have been conducted to produce prosthetic anthropomorphic fingers. Banks [1]-[3], developed a design and control system on anthropomorphic finger equipped with touch sensors. Zollo et al. [4], describes research on anthropomorphic prosthetic design through a biomechatronic approach. Kurita et al. [5], developed an anthropomorphic hand with a driving mechanism on the arm and the force transmitted to the hand through the gear on the wrist. Jaffar et al. [6], designed anthropomorphic hands that can perform grasping movements for varying object sizes. Azlan and Yamaura [7], optimize parameters in the design of anthropomorphic fingers to perform movements in the form of grasping and pinching.

Most of these studies produce expensive designs because of the complex control mechanisms. The Laboratory of Robotics and Mechatronics (LARM), Italy, developed a system of low-cost easy operation in robotic hand designs, named LARM Hand [8] LARM Hand is an anthropomorphic finger design developed by the Robotics and Mechatronics Laboratory, Cassino, Italy. LARM Hand is designed from materials that are cheap and not too heavy, namely aluminum alloys with a 1-DOF movement [9]. Construction of LARM Hand 4 consists of three fingers with each finger having three phalanx and composed of 5 links. The motion mechanism used in the LARM Hand is a cross-four bar link with the press system or push on the link at the base of the finger. The design of the connecting link on the LARM Hand is inside the main link (phalanx) so that the design of the anthropomorphic hand in terms of its shape can be achieved.

The design form of LARM Hand gives hope for Indonesian to develop a functional prosthetic hand at a price that is affordable for the people of Indonesia. The design of the anthropomorphic fingers on the LARM Hand uses a driving mechanism in the form of a push or push system on the base link, which then moves the middle and end segments.

This study aims to create a finger mechanism with anthropomorphic aspects by considering the LARM Hand mechanism. The design of anthropomorphic fingers in this study uses a 1-DOF low-cost easy operation system and has a drive system at the base of the finger in the form of a pull to prevent buckling. In addition, there is no standard for the position of grasping objects in previous studies. This study proposes the standard size of objects that are in accordance with the maximum hand-held anthropometric data of the Indonesian people. This is closely related to the use of prosthetic anthropomorphic fingers for industrial work requirements and the user's daily activities.

2. METHODS

The method used is to build the linkage which support the prosthetic hand mechanism to move naturally like human fingers. The data collected are the anthropometric measurements of the human hands. The anthropometric measurements of human hands were carried out on 60 respondents with details of 30 men and 30 women in the productive age range of 20 to 60 years. Anthropometric data taken is represented by 25 dimensional classifications according to Purnomo [10],[11]. Data retrieval is done by direct observation using measuring instruments in the form of rulers, calipers, and 3D printed cones to measure the grip diameter shown in Figure 1.

(a) (b) (c)

Figure. 1. Hand Anthropometry Measuring Instrument, (a) Ruler, (b). 3D Printed Cones, (c). Caliper

The collected data is processed by the normality test to find out the data from the samples that belong to the population with normal distribution. All collected anthropometric size data are then validated using control charts to check and ensure the data obtained does not come out of the control limit value. Furthermore, the 50-th percentile data was taken for use in research after all the dimensions collected were mapped and processed. The 50-th percentile is chosen because the data accommodates the entire user's hand. When the data collecting is completed, range of motion of human hand is determined. Range of motion determining is done by imitating the natural position of the human finger during the process of grasping the object. The imitation process is carried out on the middle finger and thumb when holding the object in the form of a cone that is used in measuring the grip diameter. The process of imitating human finger grips is done to get a range of motion. The grasping process is carried out on the object with the maximum grip diameter according to the average data obtained.

All the collected data used to build the linkage. The design of the linkage system that is used on the finger is a double crossbar system that is driven by a pull system at the base of the finger. The design consists of several link constituent parameters which are adjusted to the size of the anthropometry that has been obtained.

3. RESULTS AND DISCUSSION

3.1 Anthropometric Measurement of Human Hand

All anthropometric measurement data include the average size, standard deviation, and percentile size shown in Table 1. The data is then processed to be used as a basis for measurement in this study.

Table 1. Average, Standard Deviation, and Percentile Dimensions of the Hand

Hand Dimension	$\bar{x}$	σ	Percentile (mm)		
			5th	50th	95th
Width of Thumb	16.41	2,15	13.98	16.41	18.83
Length of Thumb	57.86	6,06	47.96	57.86	67.76
Width of Index Finger	15.16	2,01	12.57	15.16	17.75
Length of Index Finger	82.94	10,17	67.22	82.94	98.66
Width of Middle Finger	15.36	2,35	12.43	15.36	18.28
Length of Middle Finger	90.96	11,99	73.73	90.96	108.19
Width of Ring Finger	14.48	1,86	12.27	14.48	16.68
Length of Ring Finger	83.01	12,24	65.81	83.01	100.21
Width of Little Finger	12.34	1,87	9.69	12.34	14.98
Length of Little Finger	66.14	9,33	52.46	66.14	79.81
Length of the Hand	172.76	14,00	151.86	172.76	193.66
Length of Hand Palm	99.55	10,39	75.59	99.55	123.51
Width of Metacarpal	72.5	7,77	62.03	72.50	82.96
Hand Width	87.89	9,60	74.36	87.89	101.42
Thick of the Hand	30.67	8,00	21.71	33.79	45.88
Thick of Metacarpal	25.27	6,28	15.15	24.25	33.35
Thick of Thumb	14.84	2,56	8.5	14.84	21.19
Thick of Finger	13.94	3,12	8.34	13.94	19.54
Hand Holding Width	83.97	12,71	63.82	83.97	104.12
Hand Holding Length	102.48	13,69	79.25	102.48	125.7
Width of Thumb to Little Finger	183.33	20,31	151.65	183.33	215.01
Maximal Hand Grip	47.85	6,64	37.75	47.85	57.95
Minimal Hand Grip	5.28	2,68	1.09	5.28	9.47
Length of Fist	58.78	6,05	47.91	58.78	69.66
Width of Fist	83.31	11,17	66.85	83.31	99.77

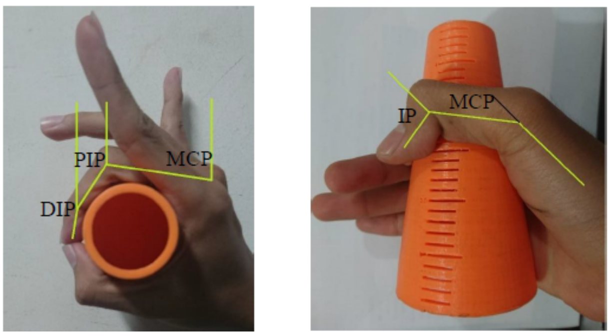
From the data above, finger length can be determined using ratio of 5: 4: 3 for the middle finger and 5: 4 for the thumb. The middle finger and thumb length shown in Table 2.

Table 2. Finger Length

Finger Segment	Length (mm)	
	Thumb	Middle Finger
Phalanx Proximal	32,14	37,90
Phalanx Media	-	30,32
Phalanx Distal	25,72	22,74

3.2 Determining Range of Motion

The grasping process is carried out on the object with the maximum grip diameter according to the average data obtained in Table 1 which is 48 millimeters. The process of mimicking the grip on the thumb and the middle finger is done as in and it is known that the range of motion is formed as shown Figure 2.



(a) (b)

Figure 2. Acquisition of ROM, (a) Middle Finger, (b). Thumb

From the picture above can be obtained ROM on each finger segment shown in Table 3.

Table 3. ROM Acquisition of Joints

Joints	Range of Motion
MCP *Joint*	34°
PIP *Joint*	87°
DIP *Joint*	142°
MCP *Joint* (Thumb)	38,50°
IP *Joint* (Thumb)	101,11°

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The range of motion and finger length that have been obtained are then used as the basis for designing the finger mechanism, so that the design of the finger to be created has the same ROM as the original human finger.

3.3 Design of the Finger Linkage System

In the design of linkage there are two designs of the designed finger mechanism, which includes the thumb and middle finger.

a. Thumb Linkage

The thumb mechanism is designed using a crossbar system. Design the prosthetic mechanism of the anthropomorphic fingers, as shown in Figure 3.

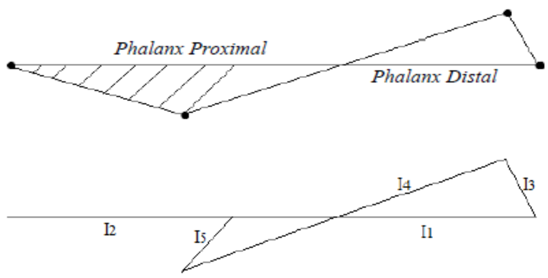

Figure 3. Thumb Linkage Mechanism

The length of each link in the image above is described in the data in Table 4. The lengths and angles that have been determined are used to illustrate the simulation of finger movements during the gripping process. The graph of the mechanism of finger movements looks like Figure 4.

Table 4. Link Length of the Design Parameters of the Thumb

Link	Length (mm)
I_1	32.14
I_2	25.72
I_3	5.00
I_4	31.21
I_5	2.10

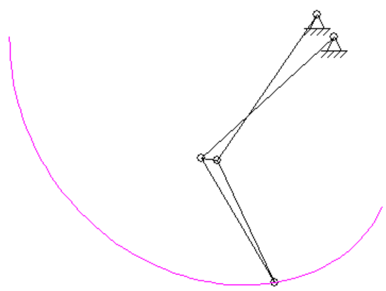

Figure 4. Thumb Mechanism Movement

b. Middle Finger Linkage

The middle finger mechanism is designed using double crossbar system. Design the prosthetic mechanism of the anthropomorphic fingers, as shown in Figure 5.

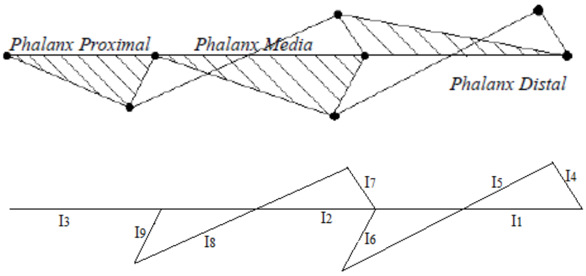

Figure 5. Middle Finger Linkage Mechanism

The length of each link in the image above is described in the data in Table 5. The lengths and angles that have been determined are used to illustrate the simulation of finger movements during the gripping process. The graph of the mechanism of finger movements looks like Figure 6.

Table 5. Link Length of the Design Parameters of the Middle Finger

Link	Length (mm)
I_1	38.26
I_2	29.88
I_3	22.82
I_4	8.50
I_5	37.57
I_6	3.40
I_7	3.50
I_8	29.87
I_9	2.10

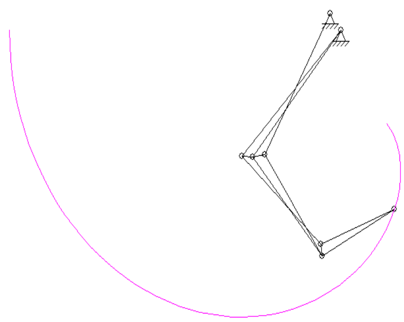

Figure 6. Middle Finger Mechanism Movement

4. CONCLUSION

In this study the prosthetic design of anthropomorphic 1-DOF fingers with a driving mechanism on the link at the base of the finger using a pull system to minimize the possibility of buckling is produced. The design of the anthropomorphic fingers is designed based on the similarity of the angle position and the total length of the finger when the fingers of the human hand hold maximum. To develop the prosthetic design of the anthropomorphic fingers, further research is needed on the application of the linkage system that has been made to the prototype so that the accuracy of the range of motion produced in the prototype is known.

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