Evolution in Electrical and Electronic Engineering Vol. 2 No. 2 (2021) 642-648

EEEE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/eeee
e-ISSN : 2756-8458

Soft Robot Fingers using 3D Printing

Anis Syazani Nazir[1], Mohamed Najib Ribuan[1]*

[1]Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/eeee.2021.02.02.077
Received 04 July 2021; Accepted 03 August 2021; Available online 30 October 2021

Abstract: Soft robot fingers are a new and undiscovered technology and the main objective is to design soft robot fingers using elastic and flexible material at the joint and tendon part. It also develops soft robot fingers that can have the same function as human fingers using the actual size and are designed using SolidWorks. The construction and coding of soft robot fingers will be the focus on the bending behaviour of various flexure hinges. This product will fabricate using 3D printing using material such as Thermoplastic Polyurethane (TPU) for its joint and Polylactic Acid (PLA) for the stiff part. These soft robot fingers will be tested with bending testing and grasping testing. These soft robot fingers can produce good bending and similar to human fingers.

Keywords: Soft Robot Fingers, 3D Printer, Bending Testing

1. Introduction

Soft is a texture that is not hard or firm to touch. A robot is a machine resembling a human being and able to replicate a few human movements automatically. A finger is a part of human hands and each of the four slender jointed parts attached to hands. The meaning of 3D printing is the process of producing a physical object from three-dimensional digital modelling. Human hands are a complex structure and it needs to be strong to carry out daily activities. The loss of hands affects the human ability to carry out daily activities and have limited their movement. The soft robot is a system capable of performing autonomous behaviour and consisting of soft materials [1].

Nowadays, there is a lot of research about a soft robot with help of current technology in this country. There are a lot of differences between the hard robot and the soft robot. The most obvious difference is the weight. A hard robot is heavier than a soft robot because a hard robot is designed and made from heavy metal. The heaviness of the hard robot also comes from the complexity of the robot. This is due to the hard robot used too many gears, motor and spring at each finger. Therefore, a soft robot is made from plastics, rubber and silicone so it will lighter than a hard robot. The soft robot is very flexible and made from stretchable material so it can reduce too many motors and gears at the same time can reduce the weight. However, there is improvement needed to produce the best soft robot since

**Corresponding author: mnajib@uthm.edu.my*

the previous soft robot still has complexity. Thus, it hopes the combination of hardware and software of soft robot finger can be archived successfully [2].

The man-made soft robot hands are composed of heavy metal, making it difficult for the user to use for an extended period. The intricacy in the fingers section is since each finger has three motors at each tendon and spring at each joint. By putting many motors in one finger, the soft robot hands become heavy and have restricted mobility. As a result, the material utilised to link the joints must be elastic and flexible. It is possible to minimise the power consumption of robot hands by employing elastic and flexible materials. Because of this material, the robot hands may revert to their previous shape without the need for excessive force.

2. Materials and Methods

The project is to design the flexible soft robot fingers using 3D printing. The soft robot fingers are designed using engineering software and simulate to obtain the flexibility of the joint.

2.1 Materials

To produce a flexible soft robot finger the material very important.

- Polylactic Acid (PLA) is used to fabricate the stiff segment of the fingers. This is because PLA one of the most common 3D printing materials, particularly for FDM. PLA filaments are an excellent starting point for 3D printing due to their ease of use and lack of warping. PLA is also one of the most ecologically friendly 3D printing materials, as opposed to ABS, and is biodegradable
- Thermoplastic polyurethane (TPU) is used to fabricate the finger’s joint. TPU can generate elastic, very durable pieces that can be readily bent or squeezed by combining the qualities of both plastic and rubber. This is will make the soft robot fingers more rigid.

2.2 Methods

The fabrication 3D printing process was utilised to create these squishy robot fingers. The design will be created in SolidWorks to be used in the fabrication of the soft robot fingers. After the fabrication is finished, all of the finger segments will be assembled for testing. To move the soft robot fingers, a programmed Arduino UNO is utilised to drive a servo motor that is linked to the fingers. An overview schematic diagram of the fabrication 3D printing process is shown in Figure 1.

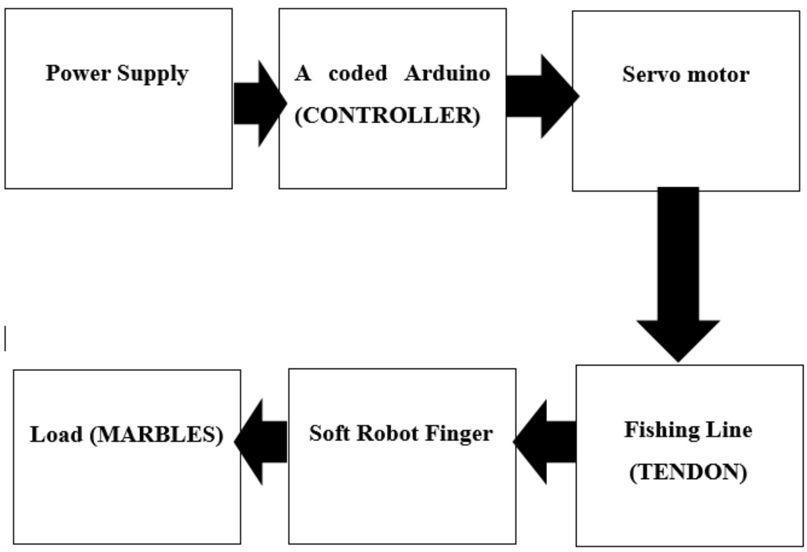

Figure 1: Overview schematic diagram

3. Results and Discussion

The hardware and software can communicate with each other to perform the best soft robot fingers. Soft robot fingers can archive the target in the workability testing such as grasping and bending test.

3.1 Results

The fabrication of this soft robot finger using 3D printing Creality CR-6 SE. This printer uses a single extruder with a 1.75mm filament device and has a minimum layer size of 0.1mm. It has a hot end maximum temperature of 260C and the heated print surface is up to 110C. The printing speed 80-100mm/s and 350W power supply needed. Fabrication of Soft Robot Fingers is shown in Figure 2.

Figure 2: Fabrication of soft robot fingers

Bending testing is utilised in the project to test the fingers, and it is done using a basic circuit that consists of a servo motor coupled to an Arduino UNO as shown in Figure 3. The MG996R servo motor is utilised to move the fingers, and the fishing rod is used as a tendon to bend the fingers. The usage of a servo motor in this project is since a servo motor is a type of motor that has a high degree of accuracy in its rotation. This sort of motor is generally made up of a control circuit that gives feedback on the present location of the motor shaft; this feedback allows servo motors to rotate with amazing accuracy. To move it, an Arduino Uno is used to operate the servo motor using simple code.

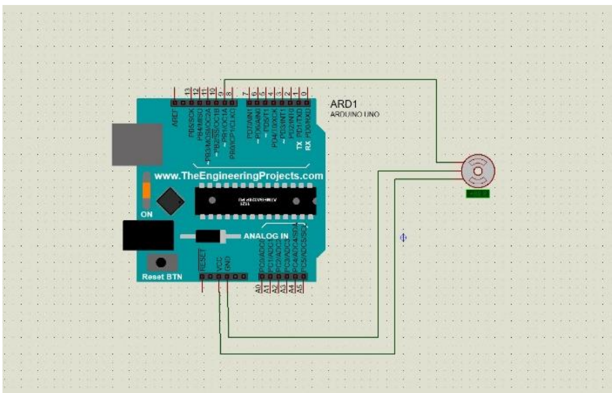

Figure 3: Circuit of the soft robot fingers

The wire jumper of the servo motor directly connected to an Arduino UNO which is the ground servo motor to ground Arduino UNO and the power supply of the servo motor connected to 5v Arduino UNO. The digital port connected to Arduino port 9. A power bank is used as a power supply.

3.2 Bending Testing

A simple test is made to measure the bending of the soft robot finger. In this soft robot finger using 3D printing, marbles are used as the load to measure the degree of bending. The reason marbles are used as load because the weight of marbles is fixed. So it is easy to testing with an appropriate weight for each test. The servo motor can lift the load to 11kg per centimetre with an operating voltage of 5V[3]. For this testing, the weight of 50g until 350g of marble are used. The result of testing of soft robot fingers is shown in Table 1.

Table 1: Bending testing of soft robot fingers

Load(g)	Degree Of Bending (˚)
0g	130.91˚
50g	136.79˚
100g	146.63˚
150g	158.36˚
200g	164.77˚
250g	169.17˚
300g	171.95˚
350g	178.95˚

Figure 4 shows the graph of bending testing. The graph demonstrates that it is a linear graph with a constant gradient. The greater the weight of the load, the more the finger bends. This experiment and project testing demonstrate that the finger can withstand a weight of up to 350g. When the finger is released at this moment, it will bend rearward. Because the finger is not very robust, it cannot withstand a significant load. There is a little space between the finger segments and no stopper, the finger cannot withstand a large weight. This is because the value of the degree of bending is determined by the thickness of the joints. The greater the thickness, the more elastic the joints. This is demonstrated by using Image J, a software that can compute bending by utilising an image.

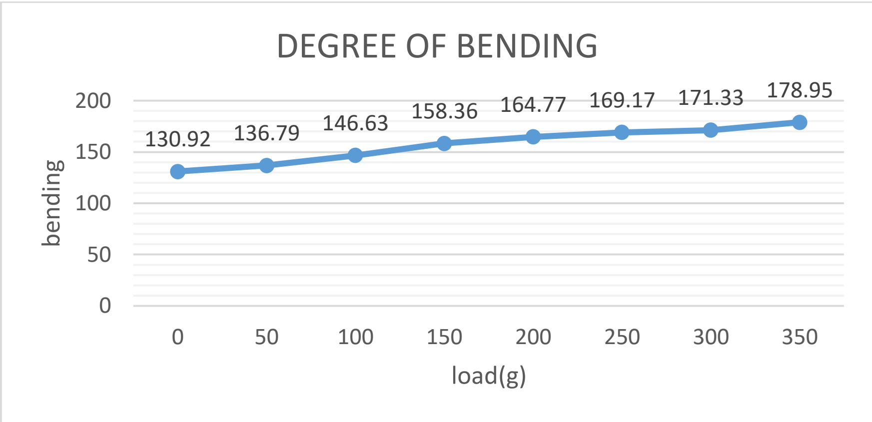

Figure 4: Graph of bending testing

3.3 Grip Strength Test

Grip strength is a measure of muscular strength or the greatest force or tension produced by the forearm muscles. It may be used as a screening tool to assess the upper body and total strength. It is particularly effective for tracking performance when several measurements are performed over time. To measure the grip strength a tool name dynamometer is used. This test cannot be run because of a lack of tools such as a dynamometer and due to pandemic covid-19. In the previous research by Archives of Plastic Surgery on 14th January 2013. In this grip strength test, 336 testimonies with 137 males and 199 females are used. The number of testimony by age from 10 years old until 79 years old were recorded in the Figure 5 [4].

Age (yr)	Male			Female		
	No. of subjects	Right (kg)	Left (kg)	No. of subjects	Right (kg)	Left (kg)
10-19	14	36.2 ± 5.5	34.9 ± 5.4	24	25.3 ± 4.6	23.6 ± 5.0
20-29	33	46.9 ± 6.4	44.9 ± 6.0	36	27.5 ± 4.2	26.4 ± 4.3
30-39	14	46.3 ± 6.5	43.8 ± 6.5	32	26.9 ± 3.7	25.4 ± 3.9
40-49	28	44.0 ± 5.9	42.4 ± 6.5	55	27.3 ± 4.4	25.3 ± 4.4
50-59	27	40.6 ± 7.2	39.1 ± 7.8	40	25.7 ± 5.0	24.0 ± 5.3
60-69	13	37.1 ± 6.9	36.2 ± 6.5	7	23.3 ± 3.9	22.2 ± 5.4
70-79	8	35.7 ± 7.7	34.8 ± 7.1	5	23.1 ± 5.5	21.3 ± 2.9

Figure 5: The benchmark of grip strength test by archives of plastic surgery [4]

The study will continue to compare grip strength in males and females, as well as by age. The graph comparison grip strength test in Figure 6 indicates that both genders have the strongest hand at the right. Males aged 10 to 19 have an average grip strength of 36.2kg in the right hand and 34.9kg in the left hand. The same is true for males aged 20 to 29 years old, who have a good grip strength in their right hand of 46.9kg and 44.9kg in their left hand. The graph indicates a 44kg drop to 40.6kg for males aged 30 to 49 and a 43.8kg decrease to 42.4kg for males aged 30 to 49. Male right and left-hand strength continue to decline from 50 to 59 years old, with 40.6kg and 39.1kg respectively. 13 testimonials range from 60 to 69 years old, with the grip strength of 37.1kg for the right hand and 36.2kg for the left hand, and 8 testimonies range from 70 to 79 years old, with the grip strength of 35.7kg for the right hand and 34.8kg for the left hand. This graph shows the grip strength of male right hand and left-hand increase at age 10 years old until 29 years old but it slowly decreases starting 30 years old until 79 years old.

Next, for the female right hand from age 10 years old until 29 years old, the graph shows increasing from 25.3kg to 27.5kg and for the left hand is from 23.6 increase to 26.4kg. But after age 30 years old it slowly decreases for both hands. From 30 years old until 39 years old the is 26.9kg for the right hand and 25.3kg for the left hand. 55 testimonies from age 40 until 49 years old have grip strength at 27.3 kg for the right hand and 25.3kg for the left hand. The grip strength decreases at age 50 to 79 years old from 25.7kg to 23.1kg for the right hand while female left hand from 24kg decrease to 21.3kg. based on the female grip strength test graph, it shows females started strong at 10 years old until 29 years old but decrease at 30 years old.

This previous research can be the benchmark for grip strength testing for the soft robot finger. The grip strength testing can be used on the soft robot finger by using all five fingers. Unfortunately, this testing cannot proceed due to some difficulties happen but it shows this soft robot finger can achieve this project testing

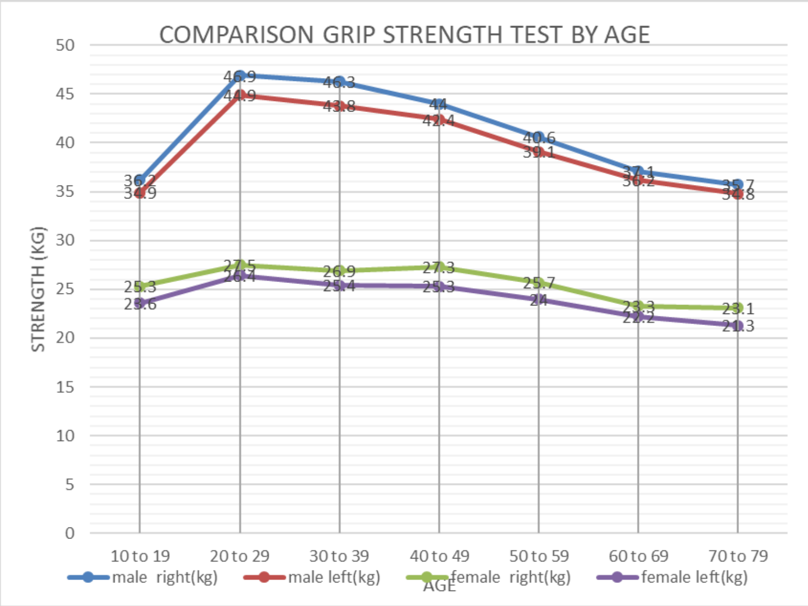

Figure 6: Graph comparison grip strength test by age

4. Conclusion

In conclusion, the design was created in SolidWorks by referring to the prior design and altering a few features to achieve the goal. The design of soft robot fingers was simulated using Abaqus CAE to determine the efficacy of the material and design. The elastic and flexible material was incorporated in the set programme to demonstrate the bending of the design. Sunlu PLA is responsible for the difficult portion. The material's profile is designed to give the fingers a hard body despite their flexibility. Due to several issues, the bending test of the soft robot finger is only performed on the index finger. However, because the index finger has a comparable dimension, the results of bending tests for it can be used as a standard for other fingers.

The bending testing for the thumb, middle finger, ring finger and little finger can be tested using the same medium so the experimental maximum load can be achieving as the theoretical. On the other side, a dynamometer can be used to measure the grip strength of this soft robot finger. This test can define the quality and strength of the finger and the suitability of the finger to a person according to gender and age. The finger differences in the right hand or left hand also play a role in the production of these soft fingers. This test cannot be done due to Pendamic Covid-19 and does not have insufficient equipment such as a dynamometer. This dynamometer price range is between RM50.00 until RM150.00 per unit.

Acknowledgement

The authors would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for its support.

Appendix A

```
include <Servo.h>

Servo myservo;
int pos = 0;
void setup() {
  myservo.attach(9);
}
```

```
void loop() {
  for (pos = 0; pos <= 180; pos += 1)
 {
   myservo.write(pos);
   delay(15);
  }
  for (pos = 180; pos >= 0; pos -= 1)
 {
   myservo.write(pos);
   delay(15);
  }
}
```

References

[1] S. B. Godfrey *et al.*, "The Softhand Pro: Functional evaluation of a novel, flexible, and robust myoelectric prosthesis," *PLoS One*, vol. 13, no. 10, pp. 1–20, 2018, doi: 10.1371/journal.pone.0205653

[2] C. Tawk, G. M. Spinks, M. In Het Panhuis, and G. Alici, "3D Printable Linear Soft Vacuum Actuators: Their Modeling, Performance Quantification and Application in Soft Robotic Systems," *IEEE/ASME Trans. Mechatronics*, vol. 24, no. 5, pp. 2118–2129, 2019, doi: 10.1109/TMECH.2019.2933027

[3] Automatic Addison, "How to Determine What Torque YouNeed for Your Servo Motors," *Build The Future*, 2020. https://automaticaddison.com/how-to-determine-what-torque-you-need-for-your-servo-motors/

[4] J. H. Shim *et al.*, "Normative measurements of grip and pinch strengths of 21st century Korean population," *Arch. Plast. Surg.*, vol. 40, no. 1, pp. 52–56, 2013, doi: 10.5999/aps.2013.40.1.52