American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-10, pp-110-117
www.ajer.org
Research Paper Open Access

Low Cost Design of 3D printed Wearable Prosthetic Hand

Abd al-sahib N. Kadhim , Muhammed Abdulsattar. ,and Ali Abdulghani ,
Department of mechanical engineering, Al NahrainUnivirsity ,Baghdad Iraq
Corresponding author: Abd al-sahib N. Kadhim

ABSTRACT:*One of the most common problems that disabled persons with amputation in upper limb they couldn't buy a commercial prosthetic hand because it very expansive and Up to thousands of dollars , Researchers and developers aspire to manufacture an prosthetic hand that performs the same functions and activities of natural hand , This paper includes the design and development of a low-cost prosthetic hand (less than a1000$) that capable of wearing from The persons who has amputation in the hands , This design represent a hand with five fingers capable of movement and gripping the object , rotatable wrist and socket connect with amputation body capable to up and down the forearm .the design of this prosthetic hand possess 18 degree of freedom (DOF) ,3DOF for each finger except the thumb has 4DOF , 2DOF for wrist and 2DOF for socket .the design prosthetic hand work by under actuated system 7 servo motors with tendon to move the fingers . the manufacture process done by put the design into 3d printer software and begin to print in by using plastic material (PLA). The design explement and test in solid work to avoid overlapping between fingers and then after manufacture the design try it in real life to movement and gripping the object .*
KEYWORDS: *prosthetic hand, degree of freedom, 3d printing, solid work*

Date of Submission:02-10-2018 Date of acceptance: 13-10-2018

I. INTRODUCTION

The human hand is an amazingly complex set of mechanisms. It can be said that the hand is the brain's ultimate tool, and loss of even one of these amazing tools has a profound impact on a person's life. The human hand has a full 22 degrees of freedom [1] which are created by 27 unique bones and 30 muscles [2].Studies indicate that than tens million people in the whole world They are suffer from amputated limbs or any parts from the body [3] . almost thirty five percent of amputated limbs are amputate of arm or part of arm. Until a few years ago, the evolution of prosthetic hand that bring back the functions and dependability For people who have amputation , The plan and development of any prosthesis depend both on the many-sided quality of the body part being supplanted and rehabilitative necessities of the prosthesis client. Upper limb prostheses are set for those individuals who have either part or whole upper limb absence, which may either be acquired (through amputation) or inborn The prosthetic hand is the only part that can mimic the movements and functions of the human hand in daily work.

In Riaan Fourie ,explain the design and evolution of a modular mechanical design for a prosthetic hand that can be upgraded from a pure mechanical system to a mechatronic system, depending on the amputee's needs. The tests that have been conducted with the functionality of the prosthetic hand is presented and discussed[4]

In GK Jones and R Stopforth, they steady on the mechanical design of the major hand components, and an overview of the programmed control system is described, with possible future additions of amputee feedback ,The Touch Hand II printed in 3D printed prosthetic hand that has been developed to improve on the first design iteration, in order to reach the goal of providing transradial amputees with a low-cost alternative prosthetic hand[5]

In Abd Al-Sahib N. Kadhim , Muhammed A.M.,this paper presents a methodology to design and manufacture an artificial hand for prosthetic application. The proposed design is a five finger hand with the forearm actuated by under-actuated system composed of tendons and servomotors. The manufacture strategy started by design the model using the solid works software and manufacture by 3d printing technique. it possess 15 DOF, 3dof for each finger..[6]

this paper study a kinematic motion and a method to design a low cost prosthetic with full function of movement and analysis each part of figure , manufacture of each part in prosthetic hand and assembly it and then test to handle the objects.

II. METHODOLOGY:

A-Geometry Design:

This part will Explains the geometry design procedure used to design a mechanical function for prosthetic hand , the design of prosthetic hand draw by using Solidwrok , Since solidworks is introduced, it has been a great tool to every engineer who is interested in designing. It is a complete Cad package that offers modeling of complicated structure as parts the first part to design was a finger, the finger consist of three part (distal phalange , intermediate phalange and the proximal phalange), the distal phalange exists a hitch in front who the tendon pull up the finger ,while the proximal and middle phalanges are rigidly connected, A link between the servo motor and phalanges(proximal, middle and distal) by tendon wire extend form forearm to phalanges ,when servo motor pull the tendon the distal move up and linked with middle phalange by screw and the middle phalange linked with proximal phalange., the thumb is designed to do different functions more from any other parts designed and its drive by servo motor pull the tendon to up the thumb finger and its capable for extension and flexion , the thumb design allows space in the hand palm for inserting the tendon and sensors wire,

the palm divided to three region one support little finger and another one to support ring finger and large one to support other fingers ,The bottom of the palm is designed to insert wires of sensors and tendon from holes in bottom then covered by covers to hidden them ,these divided part Work is similar to the human hand, The forearm is designed as a base to support the the palm and elbow of the socket.

On the top of the forearm hinge to support a socket (figure 3.9) .The bottom of the forearm is designed to handle the fifth servo motor and the wires from all the servo motors and sensors, in back of forearm is elbow to join the socket with forearm. , The wrist design to joint the forearm with palm and to rotate the palm to left and right , the wrist consist the servo motor and to gears to rotate palm and tow hinges to join palm, The socket design for prosthetic to give prosthetic hand a capable of wearing to help the Patient to control on prosthetic hand by different way ,the socket design consist of tow part the large part is the socket to join with ambition upper limb and the another part(structure) to handle a servo motor and join the forearm to the socket, All design parts was assembly together in solidworksto form the final shape of prosthetic hand .see the figures of design bellow

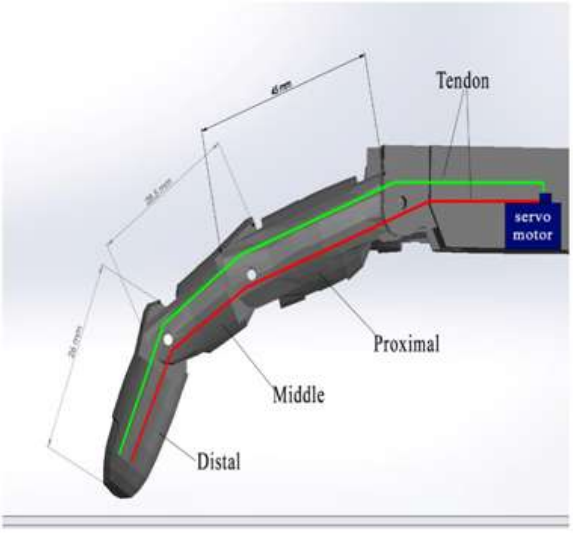

Figure 1: index finger design

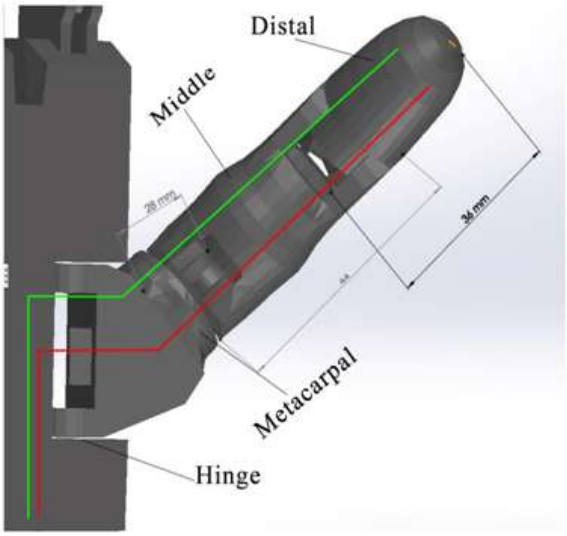

Figure 2:Thumb finger design

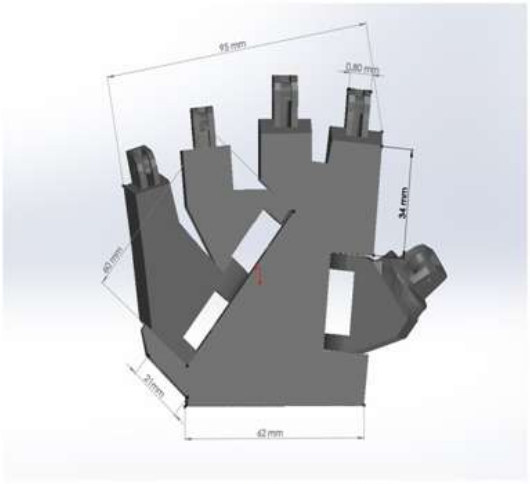

Figure 3: palm design

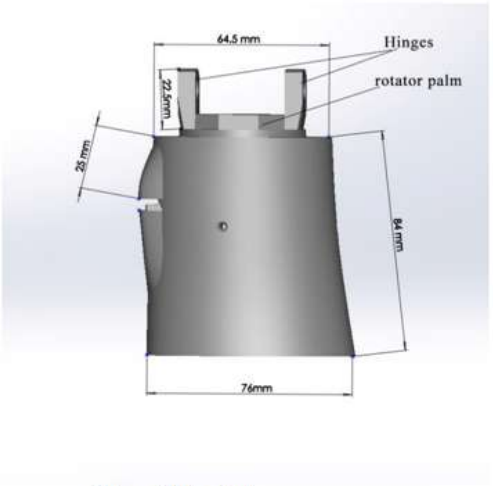

Figure 4:Wrist design

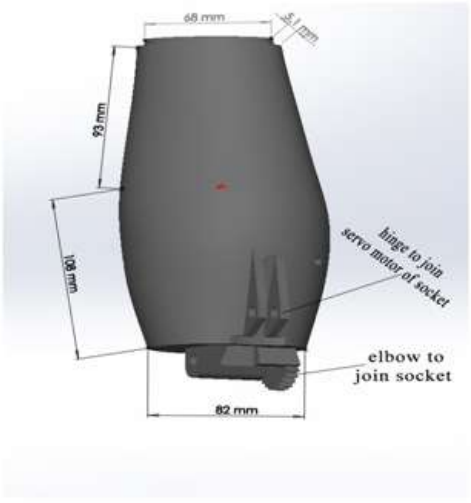

Figure 5: forearm design

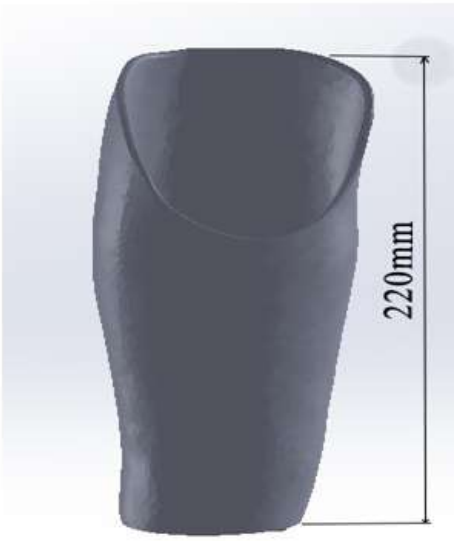

Figure 6: socket design

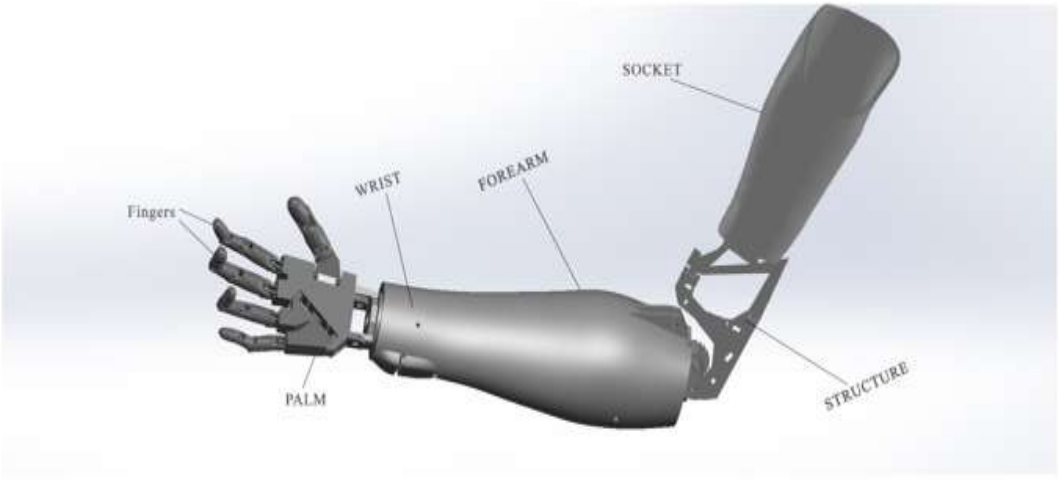

Figure7 : complete prosthetic hand design

B-Finger Kinematics

In our kinematics model, the prosthetic finger comprises of three connections relating to the three phalanges of the genuine finger. The finger is set with one active DOF and two passive. The active DOF is at the main joint and the two aloof are in the second and third joints combined with the first. Denavit-Hartenberg (D-H) is the generally utilized technique to take care of forward kinematics issue, where the change in arrangement are utilized to create an individual change demonstrating the heading and position of the fingertip as for palm. The finger kinematics can be considered in 2D kinematics lying in the X-Y plane [7].The D-H theorem contains four parameters which are: angle θ_i, the link/phalanx offset d_i, the link /phalanx length L_i, and the link/phalanx twist α_i. The past four factors are utilized to figure the position and orientation of the fingertip. It is worth mentioning that the four fingers have the same range of rotation of joints but they differ in the dimensions of the phalanges (only the max length L_i) .see the figures bellow of parameter in finger

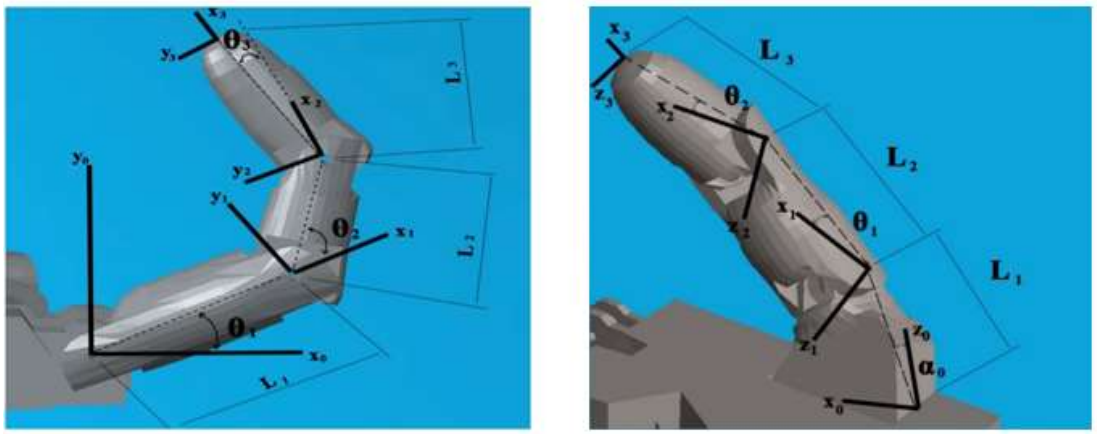

Figure 8: Left :Coordinate Frames of thumb , Right : Coordinate Frames of finger

Link No.	L_iLength	Twist α_i	Offset d_i	Angle θ_i
1	L1	0	0	θ_1
2	L2	0	0	θ_2
3	L3	0	0	θ_3

Table 3.3: DH parameters for Thumb

Link No.	L_iLength	Twist α_i	Offset d_i	Angle θ_i
1	L1	$\frac{\pi}{2}$	0	θ_1
2	L2	0	0	θ_2
3	L3	0	0	θ_3

Each finger is considered as three link manipulator, thus the homogenous transformation that represents the coordination of finger fingertip which is:

$$ {}^{0}T_{3} = \begin{bmatrix} c_{123} & -s_{123} & 0 & L_1c_1 + L_2c_{12} + L_3c_{123} \\ s_{123} & c_{123} & 0 & L_1s_1 + L_2s_{12} + L_3s_{123} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} $$

$$ {}^{0}T_{3} = \begin{bmatrix} x_i & y_i & z_i & p_i \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

The solution for the position of the fingertip is found as given as :

$$P_{x_{fingertip}} = L_1\cos\theta_1 + L_2\cos(\theta_1+\theta_2)+L_3\cos(\theta_1+\theta_2+\theta_3)$$

$$P_{Y_{Fingertip}} = L_1\sin\theta_1 + L_2\sin(\theta_1+\theta_2)+L_3\sin(\theta_1+\theta_2+\theta_3)$$

$$P_{Z_{fingertip}} = 0$$

$$\phi = \theta_1+\theta_2+\theta_3$$

C-Prosthetic Hand manufacture

The prosthetic hand was built by using the additive manufacturing .commonly referred to as 3D printing, which is a method to construct almost any computer aided design (CAD) model using thermoplastics such as the ABS, PLA, and PET. This method promises customization, simplicity with low cost. The application of this method to fabricating parts suited to address local needs in developing countries has become of interest in recent years. The application of 3D printing in low-income countries, especially using open source designs, holds much promise for delivering a whole range of desired equipment on demand. Actually, the technology has been used to deliver humanitarian aid to those in need [8]

Each finger of the prosthetic hand is actuated by a servo motor located at the forearm . and the socket prepared with a large servo motor .the servo motors used are (Tower Pro mg995)for figers actuation and (Rovan RS 2050) for socket servomotors ,

The proposed design of the hand was interred in the printer software and the parts were printed. The printing technique promises a very high accuracy when it comes to dimension; i.e, there was not much difference between the final shape dimensions and the cad design . As proposed, each finger is composed of three these parts where connected together and fastened by pins which were metal screws with the end removed . Figure (4-9) shows the finger in its final assembly. The palm on the other side was printed as tow part as designed. The fingers were connected to the palm in a very easy, simple way .and as seen; all parts are fitted together without noticeable clearance. Figure bellow shows the final shape of prosthetic hand parts .

Figure 9: assembly of finger

Figure 10: palm with Fingers

Figure 11: Socket

Figure 12: Hand with forearm

Figure 13: fully prosthetic hand

III. RESULT :

A-Kinematics motion

The kinematics motion of prosthetic hand means establishing the coordination of the fingertip with relation to the base frame and presenting the workspace and how the manipulator will move.To describe the trajectory fingers tip motion utilize statistical analysis for each point in finger (x,y and z) , in figure 13 show the 2D plot of fingers tip express in point it each part of finger and it represent the angle of joint of finger part to avoid overlapping

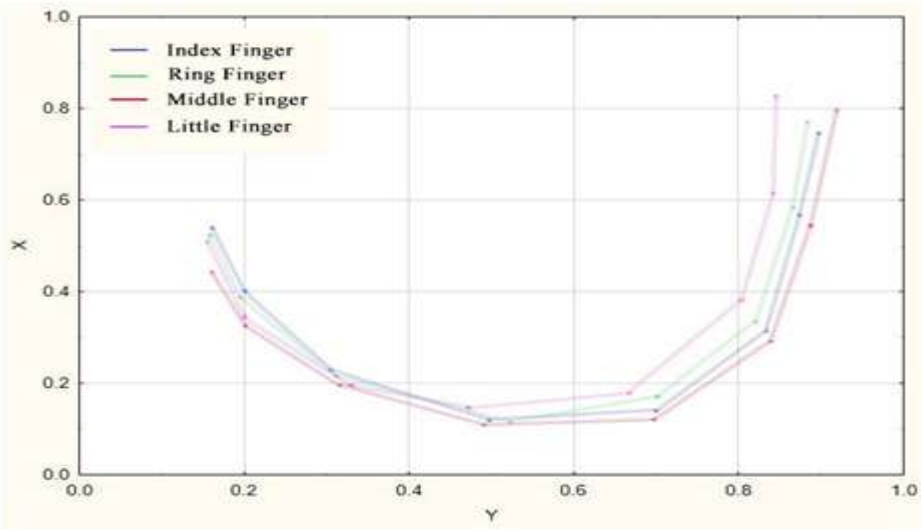

Figure 13: 2D Fingertip Kinematic Motion

The plot of Figure 14 gives a 3D perspective of the fingers kinematic motion with the same incremented first joint angle.

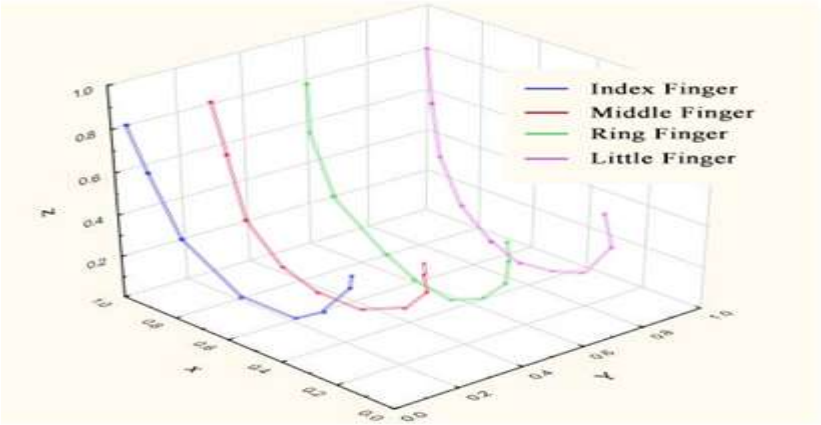

Figure 14: 3D Fingertip Kinematic Motion Profiles

In figure 15 the black line represent a thumb which it intersect with other line (fingers) ,This intersection represents the validity of the prosthetic hand to grasp the objects. From figure 5.3 you can see the thumb is not intersect with little figure while the human thumb can intersect with little figure. This intersection of finger and over lapping with thumb to anthropomorphism of human hand and express the hand design is capable of movement and gripping object

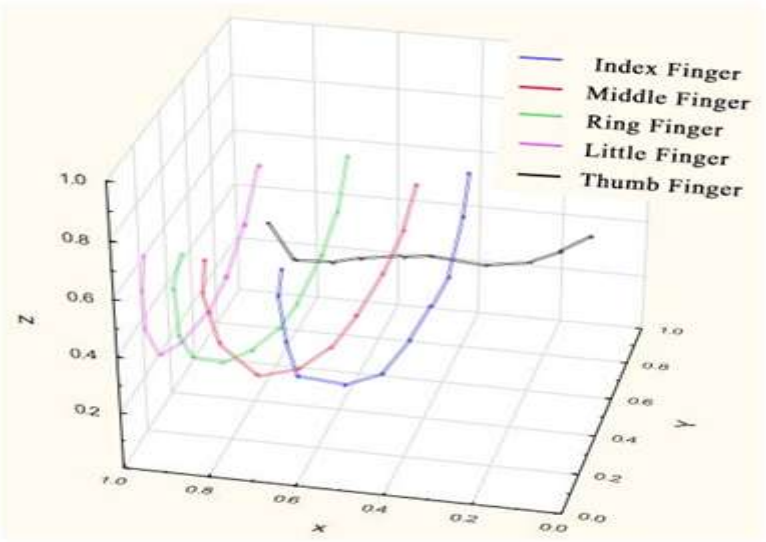

Figure 15: 3D plot showing the intersection between thumb and fingers

B-prosthetic hand Gripping object

The prosthetic design was testing to gripping different object ,key ,pen , ball and glass using EEG Mind wave sensor with arduino micro controller and the signal generate from activities of neurons ,see the figures bellow

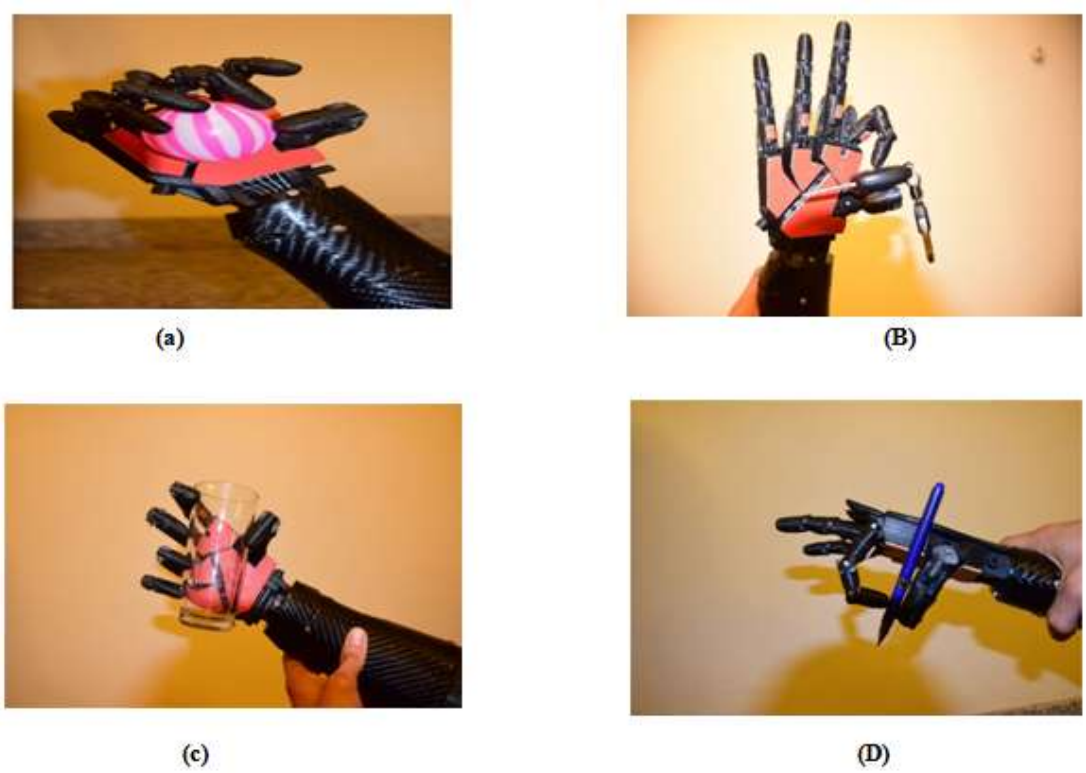

Figure 16: Prosthetic hand Gripping (a)ball ,(b) key ,(c) glass and (d) pen

IV. CONCLUSION

The prosthetic hand designed approximate the function abilities of human hand very well. A number of movements are produced and number of variety objects can be grasped in a natural way. The five fingers have 16 degrees of freedom driven by five actuators which enables the movements of each finger independently which offers more manipulation abilities. The kinematic motion analysis of the finger showed that: the fingers is not overlapping between them except the thumb In order to get the best gripping of object wit out slipping

BIBLIOGRAPHY

[1]. S.-y. Jung, S.-k. Kang and I. Moon, "Design of Biomimetic Hand Prosthesis with Tendon driven Five Fingers," in 2nd Biennial IEEE/RAS-EMBS International Conference Biomedical Robotics and Biomechatronics, Scottsdale Arizona USA, 2008.
[2]. H.-M. Schmidt and U. Lanz, SurgicanAnatomy of the Hand, Thieme, 2003.
[3]. LeBlanc, M. Give Hope - Give a Hand. 2011 [cited 2015 25/02]; Available from:http://web.stanford.edu/class/engr110/2011/LeBlanc-03a.pdf
[4]. Fourie R,"The Mechanical design of a biologically inspiredprosthetic hand",Stopforth Mechatronics, Robotics and Research Lab,University of KwaZulu –Natal,International Conference (PRASA-RobMech),South Africa,December 1 2017.
[5]. Jones G and StopforthR,"Mechanical Design and Development of the Touch Hand II Prosthetic Hand", Institution of Mechanical Engineering , R & D Journal of the South African ,13 June 2016, 32, 23-34
[6]. Abd Al-Sahib N. Kadhim,"Design and Manufacture A 3D Printed Artificial Hand", American Journal of Engineering Research (AJER) e-ISSN: 2320-0847 p-ISSN : 2320-0936 Volume-7, Issue-2, pp-156-164, 2018.
[7]. Beng G. Lau, "An Intelligent Prosthetic Hand Using Hybrid Actuation and Myoelectric Control ", Phd thesis submitted to University of Leeds, Leed, 2009
[8]. Micheal King, Brienna Phillips, Marc Shively, Venkatch Raman, Aaron Fleishman, Sarah Ritter and Khanjan Mehta, "Optimization of Prosthetic Hand Manufacturing", Proceeding in IEEE 2015 Global Humanitarian Technology Conference, USA, 2015.pp.59-61.

Abd al-sahib N. Kadhim "Low Cost Design of 3D printed Wearable Prosthetic Hand "American Journal of Engineering Research (AJER), vol. 7, no. 10, 2018, pp. 110-117