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DESIGN AND CONSTRUCTION OF RH2000 CYBERNATICS HAND

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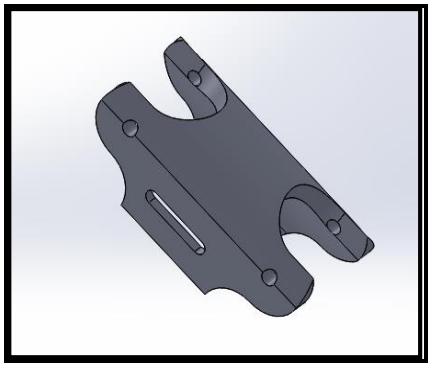
Graphical abstract



Abstract

Recently, the number of patients with wrist and forearm amputations increased tremendously due to trauma, prolonged constriction, or surgery. The amputees experienced lots of problems, especially in dealings with their daily life activities. Thus, as a solution, a prototype called as RH2000 Cybernetics Hand is designed. Early design of bionic hand comprises of 14 motors with 14 degree of freedom which caused the bionic hand to be costly and complex to control. In this research, design of a bionic hand that has 10 degrees of freedom with 5 motors attached to mechanical linkages is proposed. The bionic hand designs in SolidWorks that resembled the function and size of an actual human hand. It is fabricated using aluminum 6061 as it is light in weight and durable. As for the sensor, V3 muscle sensor is utilized to identify a signal generated from the human muscle and amplified it as the primary control signal to control the movement of the bionic hand. The performance of bionic hand is tested in terms of repeatability and accuracy. Repeatability accuracy test is divided into two phases, the first test is constructed to analyze the repeatability of angular movement for each finger while the second test is constructed to analyze the repeatability of wrist movement. Similarly, the accuracy test is also divided into two phases where the first test is conducted to analyze the accuracy of finger press while the second test is to analyze the accuracy of hand grasp. The results are compared with the natural human force and yielded acceptable results. Finally, the hand is tested in term of canonical hand posture and manage to emulate actual human hand.

Keywords: Cybernetics hand, bionic, human muscle

1.0 INTRODUCTION

Many researchers developed cybernetics hand to help the disability people. According to Buletin Perangkaan 2012, 359 203 the total of the numbers disabled people registered under the Social Welfare Department and the total amount of 123 346 that which were registered under the handicapped people with physical disabilities categories [1]. This included the record like, paralyzed, maimed limbs. Therefore, RH2000 Cybernetics Hand is invented.

In this section, the research about cybernetics hand is conducted. The research focuses more on the mechanism, degree of freedom (DOF) and actuator. There is some concept that must be considered before constructed the bionic hand, the first concept that must be considered is the type of mechanism that used to actuate each Degree of Freedom (DOF) for each finger. There are several mechanisms which are applied in the previous experiment to actuate the movement of the Proximal Phalanx (PP), Middle Phalanx (MP) and Distal Phalanx (DP). The second aspect that is considered from the previous research is the number of Degree OF Freedom (DOF). Degree of Freedom (DOF) is the number of movements that can be made by robots. A lot of Degree of Freedom (DOF) will help the robot to do the task better and easier, so if the robot has a lot of number Degree of

Freedom (DOF) more work can be done by robots. Bionic hand also needs to be constructed with Degree of Freedom (DOF) where each of finger must have at least two or three Degree of Freedom (DOF) to actuate the Metacapophalangeal joint (MCP), Proxima Interphalangeal joint (PIP) and Distal Interphalangeal joint (DIP). The third aspect is selection of motor to generate the good movement and in accordance with the requirement. A Fourth aspect that is considered in this research is the selection of material. A Material that used must be durable, light, easy to find and also low cost.

Ahmed Jaafar *et al.* (2011) introduce the multifingered anthropomorphic robotic hands that have fourteen degree of freedom (DOF) [2]. The objective of this journal is to mimic the functionality of the biological hand, especially in handling complex object [2]. The bionic hand consists of five fingers where each finger has three different phalanxes it is proximal, middle and distal phalanxes. These three phalanxes were separated by two joints that called the Interphalangeal joint. The design of this bionic hand is done by using CATIA and the fabricated of this prototype is done by using InVision XT-3D Modeler. In this paper the material that is choosed to fabricate this is Acrylic Plastic with the tensile modulus and tensile strength are 1772MPa and 34MPa.

Whereas in M.C Carrozza *et al.* (2001) the design consists of the 2 degrees of freedom (DOF) for each of the fingers where these bionic hand equipped with three fingers. These papers represent the design and fabrication of novel prosthetic hand base on a "biomechatronics" and cybernetic approach. The objective of this journal is to develop an upper limp prosthesis that can be fielded as a part of the body by the amputee. The prototype fabricated by using Fused Deposition Modeling (FDM) process while acrylonitrile/butadiene/styrene (ABS) plastic is used to construct the body structure for this prototype.

According to the Loredano Zallow *et al.* (2007), the biomechatronic approach is used for the design of an anthropomorphic artificial hand. The objective of this journal is to mimic the motion of the human finger [4]. The design of bionic hand consists of (thumb, index and middle) with 3 of freedom (DOF) for each finger and 1 degree of freedom (DOF) for ubanation. ProEngineer is used to design and modeling the prototype, where the prototype is constructed by using aluminum alloy while each of the fingers is a shell by carbon fiber. Totally this prototype has ten degrees of freedom (DOF) and 4 degrees of movement.

In paper done by W. Widhiada *et al.* (2011) presents how a three fingered gripper can be designed and simulate to provide both gross motion and fine motion of the finger [5]. The objective of this journal is to copy the human hand in term of dexterity and adaptive capabilities to function as either a manipulator or as a prosthetic device [5]. This bionic hand develops with three finger (thumb, middle, and index) and seven degrees of freedom (DOF) where all the part is assembling by using SolidWorks program.

The design in paper Skyler A. Dalley *et al.* (2010) done by using SolidWorks application to get the true dimensions of design. In this paper, to purpose high strength material, nickel coated thermoplastic are using to create the structure of the bionic hand. In this paper the author represents the design of multi-degree-of-freedom, anthormarphic hand for transradial amputees [6]. The objective of this paper is to provide eight canonical grasp postures [6].

Preliminary assessment of the ability to perform the activities of daily life living while using the MMC to control a multigrasp prosthesis is proposed by Skyler A. Delly *et al.* (2012) [7]. The objective of this paper is to present a preliminary characterization of the efficiency of the prosthesis during manipulation, capture in the characterization, physical interaction with the environment and demonstrate interdependence between the hand and affected limb [7]. In this paper construction of bionic hand consists of using nine degrees of freedom (DOF) where each of the fingers consists of tree phalange.

Whereas Praveen Lakkar Srinivasa *et al*. (2013) represent the development of a bionic hand, which perform hand opposition and reposition action (clasp and release) base of the real EMG signal from a below elbow amputee [8]. The objective of this paper is to develop human hand like prosthetic which can provide natural haptic functionality [8]. In this paper the bionic hand is developed by having two degrees of freedom (DOF) below elbow amputee.

Based on consideration of previous research projects, RH2000 Cybernetics Hand is developed. In Section 2, details of the design is shown. Furthermore, its fabrication process will be explained in section 3. Performance analysis will be shown in Section 4 and finally conclusion is written in Section 5.

2.0 DESIGN OF CYBERNETICS HAND

The mechanical design for this bionic hand is done by using the SolidWorks 2014 software. By Using this software, the bionic hand has been designed by following the dimension on an average adult Asian man (173cm, 75kg). This bionics hand is separated into 11 parts to design without including the actuator and mechanical linkages. The designs start with designing the Proximal Phalanx (PP) each of the fingers. Each of Proximal Phalanx (PP) has a different of dimension except the index finger and ring finger that have the same dimension of the Proximal Phalanx (PP). The Proximal Phalanx for thumb is shown in Figure 1. Figure 2 shows the dimension of the Proximal Phalanx (PP) for the thumb. All the dimension is shown in three views which is a top view, front view and side view.

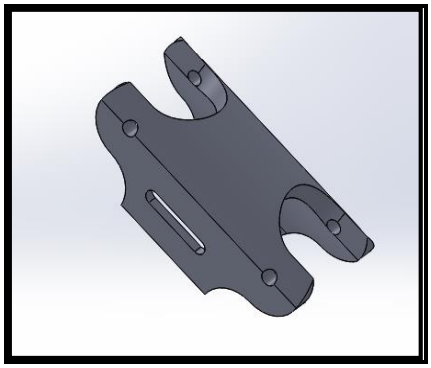


Figure 1 The Proximal Phalanx (PP) for Thumb

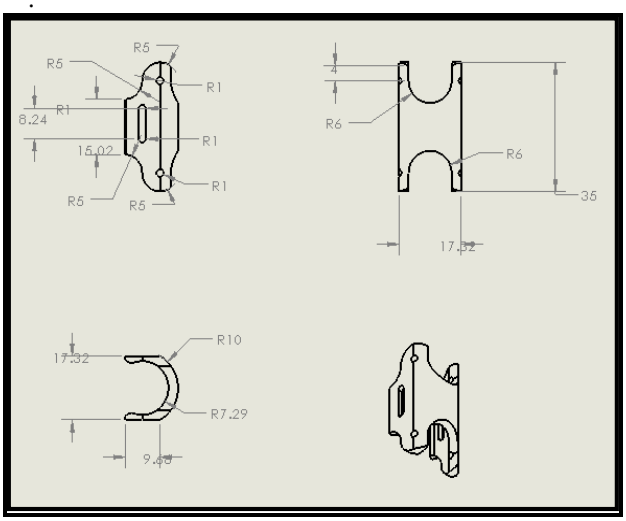


Figure 2 The Dimension of Proximal Phalanx (PP) for Thumb

The second step of mechanical design is to draw the part of Middle Phalanx (MP) and Distal Phalanx (DP) where the Middle Phalanx (MP) and Distal Phalanx (DP) is combining during the sketching to reduce the degree of freedom of bionic hand. All the Middle Phalanx (MP) and Distal Phalanx (DP) have a different dimension, except for the index and ring finger that have assumed to have the same dimension. The combination of Middle Phalanx (MP) and Distal Phalanx (DP) for middle finger is shown in Figure 3.

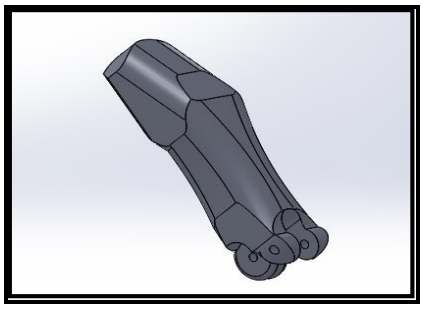


Figure 3 The Combination of MP and DP for Middle Finger

Figure 4 shows the structure of mechanical linkages that is placed in the Proximal Phalanx (PP). The function of this mechanical linkage is used to pull and push the Middle Phalanx (MP) and Distal Phalanx (DP). By applying this method, the bionic hand can produce the movement to grip the same object.

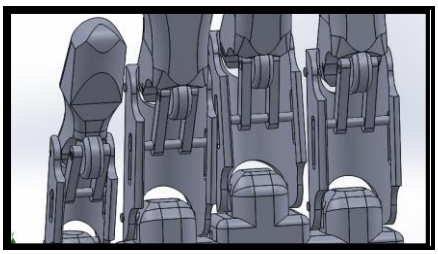


Figure 4 Mechanical Linkage Structure

The last part that's difficult to draw is palm part of cybernetics hand as shown in Figure 5. That is because in this part all the components like actuator and mechanical linkages need to assemble together in this part. During sketching this part, the problem that needs to consider is, how to assembly all the part of the finger, linear DC motor and mechanical linkages.

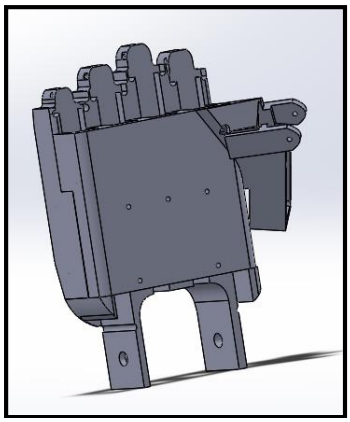


Figure 5 Mechanical Linkage Structure

3.0 FABRICATION

The other objective of this research is to construct the bionic or cybernetics hand, emulate the human hand shape. This project is consisted into three phases, the first phase is about the integration of mechanical part, the second phase is about the electrical integration and the third phase is about the software design. The bionic hand is constructed by using CNC and Milling Machine while the structure of bionic hand is built with Aluminum Alloy 6061. After the structure is finished, constructed, the prototype will install together with linear DC motor and controller. The electrode is used to capture the signal of muscle activities and the signal will amplify by using V3 Muscle Sensor. After that the signal is used to control the linear DC motor of the bionic hand using Arduino microcontroller Uno R3.

3.1 Mechanical Integration

Aluminum Alloy 6061 has been used as a material to fabricate this design. The advantage of using this type of aluminum, it's had a high quality material and it offers light weight and the strength is stronger compared to the other type of aluminum. The mechanical linkages have been used to transfer the motion from linear DC motor to the finger. Each of the fingers is designed to emulate the human hand shape and 5 linear DC motors is attached inside the palm. Figure 6 shows the assembly part of the base for bionic hand. Servo motor is used to actuate the wrist most part follow the desired degree where it is attached between the palm and forearm of bionic hand.

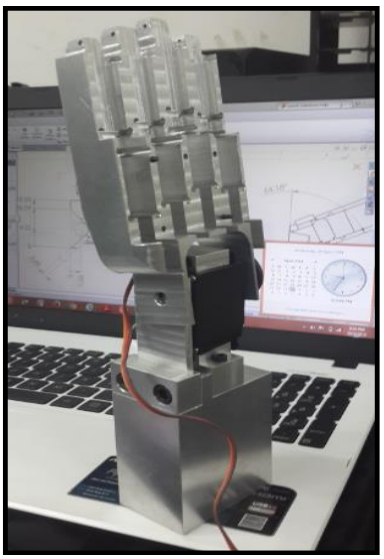


Figure 6 The Combination of Palm and Forearm

Figure 7 shows the linear DC motor position. There are four linear motors is placed inside the base of the palm. Combination of linear movement of the linear motor and the mechanical linkages in Figure 7 is used during the fabrication to actuate every joint for each finger. Mechanical linkages are used as a mechanism to transfer the power that will generate from the linear DC motor for each of the Proximal Phalanx (PP), Middle Phalanx (MP) and Distal Phalanx (DP) finger. The mechanical linkages are connected to the palm, Proximal Phalanx (PP), Middle Phalanx (MP) and Distal Phalanx (DP) part and linear DC motor will generate the movement to retract or extend the entire phalanx.

Figure 7 The Linear Motor for Actuation

3.2 Electrical Integration

The electrical design is the wiring between Arduino Uno R3, DC servomotor, electrode, V3 muscle sensor and other component. Figure 8 shows the integration of electrical component that used for the exoskeleton bionic hand. The function of electrode in the design is to capture the signal from muscle sensor. Servo motor And V3 muscle sensor is attached with external power supply.

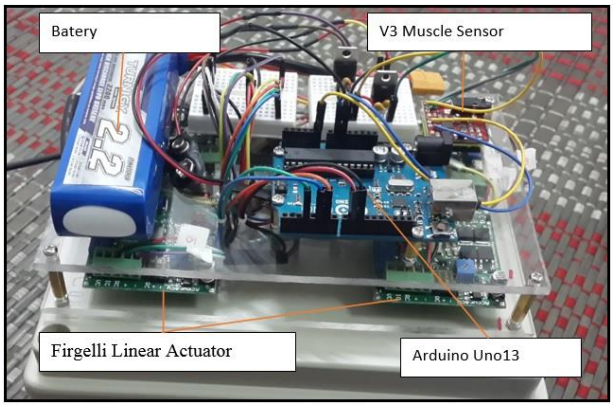


Figure 8 The Final Electrical Integration

Figure 9 shows the integration of hardware and software design for the exoskeleton bionic hand. The second objective to fabricate the bionic hand is successfully achieved and to make sure the bionic hand can emulate the natural human hand, this bionic hand need to be analysed.

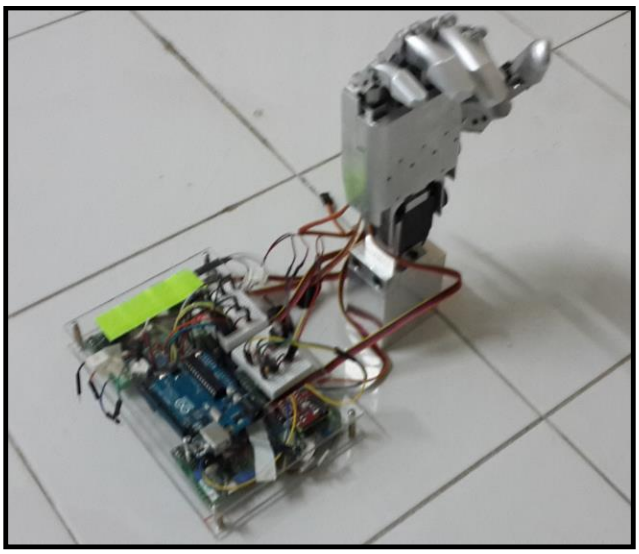


Figure 9 The Final Overall Integration

4.0 PERFORMANCE ANALYSIS

The performance of the cybernetics hand can be done by using repeatability for each finger. While the

other analysis can be done is accuracy tests in finger press and hand grasp strength.

The results for repeatability test of extension and flexion of the fingers of bionic hand based on the natural human hand are done for every fingers.

The result of the repeatability test for index finger movement is shown in Figure 10. In this experiment, three tests yielded same value which is test number 5, 9 and 10. From this the three numbers of tests, the data are recorded for extension is 66 degrees while the result in flexion is 77 degrees. Meanwhile, another 2 number of tests gave the same reading for extension and flexion in this experiment. The first test and test number 6 gave the results 65 degrees for extension and 75 degrees of flexion joint angle.

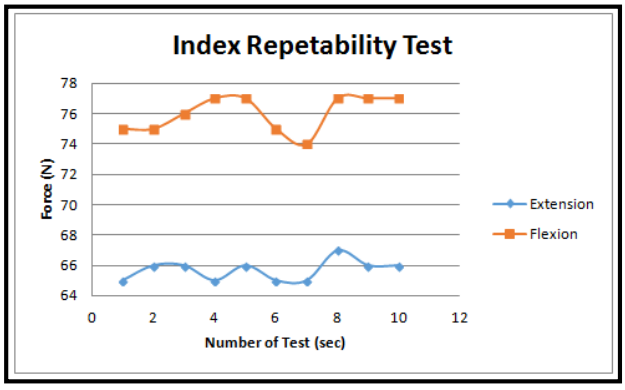


Figure 10 The Repeatability Test for Index Finger Movement

5.0 CONCLUSION

This paper has presented the design of RH2000 Cybernetics Hand that resembles the real human hand. The mechanical and electrical designs have been discussed in this paper. In this paper, the material selection and electrical component that used is also explained. Aluminum 6061 series is selected to construct this bionic hand while electrode is used to capture the signal of muscle activities and the signal is amplified by using V3 muscle sensor. After that the signal will use to control the motor of the bionic hand using Arduino microcontroller Uno R3. The last objective need to achieve in this project is to verify the performance of the exoskeleton bionic hand model in term of repeatability and accuracy. The repeatability tests have been done. In the future, performance in term of accuracy will be done.

Acknowledgement

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