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Bionic Arm Using Muscle Sensor

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Abstract*: In this paper, we have presented design and implementation of a 3D printed electromyography based bionic arm, having potential to be used by an upper limb amputee. The user flexes his or her muscles to electronically activate and control the arm. Our main goal was to obtain the fundamental control of the hand at a cost which makes bionic arm accessible to amputees with economic constraints. Although this technology is employed in a number of commercially available prosthetic arms in the global market, but they are not budget-friendly. We have analysed and investigated the several actuation techniques and design parameters used in the commercially available prosthetic hands. Electromyography (EMG) controlled Pulse Width Modulated (PWM) technique has been used for the actuation of servomotors using the microcontroller. The finished 3D model was created using PLA (polylactic acid), and the findings about the mechanical parameters have been briefly mentioned in the paper. This work includes elements from various engineering fields, including Biomechatronics, sensors, transducers, feedback, and control system. A creative mechanical design for a 3D printed prosthetic arm is the system's basis. Modern electronic actuators and microelectronic circuitry is responsible for desired motion and enables complex control architectures. It is intended that a broad readership would find value in this work.
Keywords: Bionic Arm, Electromyography (EMG), Mesh, Stress, Deformation, Polylactide (PLA), Arduino

I. INTRODUCTION

For a human, their body is valuable asset, and among all the organs, the upper limb, which includes the upper arm, forearm, and hand, and stretches from the shoulder joint to the fingers, is the most valuable one. Amputation of a human hand has a significant negative impact on a person's professionalism and renders them unfit for a variety of occupations and sports. Anatomy of human hand reveals that it is very complex organ containing 27 bones and a multitude of muscles and tendons to provide large number of degrees of freedom in movement and also each hand has an array of over 17000 tactile sensors [1].Due to the limited function of current commercially available upper-limb prosthetics and the increased incidence of amputation injuries being seen in wars [2].Existing technology has not been able to replicate mechanically similar object, however, using smaller and lighter motors has improved the functionality of prosthetic hand by achieving the increase in degrees of freedom available by compromising the maximum grasp force. The creation of unique prosthetic hands and terminal devices that utilise the most recent technical advancements has made considerable achievements over the past 20 years, leading to the development of more dexterous hand devices [3]. Recent prosthetic devices focus on increasing degree of freedom. This paper describes the designing and functioning of prosthetic hand focused mainly on replicating the few very basic movements of the human hand such as opening and closing of fingers and rotation of wrist.

II. PROPOSED SYSTEM

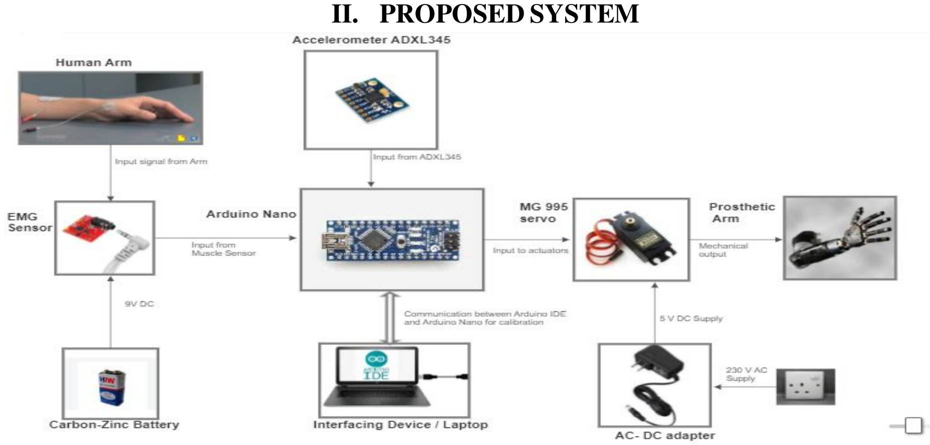

Fig. 1: Block diagram of the proposed system

Prosthetic devices are responsible for returning the functionalities to the amputees. This paper proposes the development of a Muscle sensor based prosthetic arm which provides the basic control of hand such as opening and closing of fingers as well as rotation of wrist via flexing of muscles.

III. ELECTRICAL CIRCUIT AND COMPONENTS

The main highlights of the process were planning and laying the pipeline for the major circuitry and picking components for the final assembly. A lot of time was dedicated in the planning process where the research about the sensors and other key components were done. Components like servos were chosen on the basis of their torque output and our requirements. Also, since the aim of this project was to make the prosthesis affordable, overall pricing was also brought down by proper planning. The micro-controller used is the Arduino-Nano, as it is compact and provides all the required functionality needed for this project.

A. *Circuit Operations*

The EMG sensor board has two sets of pins, first set has 3-pins which is used to provide power-supply to on-board amplifier circuit i.e., AD8226. Other set has 2-pins which is used to interface the board with microcontroller. The pins in the first set are +Vs, GND, -Vs. We are using 2 units of 9V batteries to power this sensor, 3-lead cable is used which has 3.5mm jack to connect the cables to the sensor board, then EMG electrodes are attached to the cable. There are 3 different coloured cables having red, yellow and green colour. RED is connected to middle of the muscle group into consideration. GREEN is connected to the end of the muscle group. And YELLOW, which is connected to the bony part of the body, near to the same muscle group.

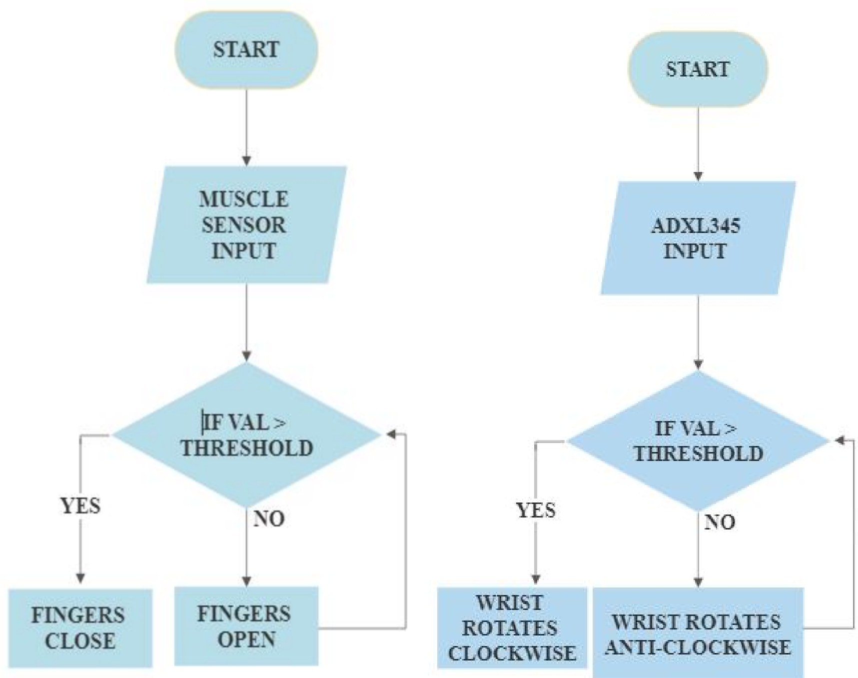

Fig. 2: Flow chart of the program

The EMG signals can range from 50µV to 30 mV. Contraction and relaxation of the target muscle group produces EMG potentials which is then picked-up by electrodes placed on the muscle group. The AD8266 sensor in the EMG sensor is the key component which offers gain up to 1000, and is used to amplify the EMG potentials to the mV level. The AD8226 instrumentation amplifier takes RAW EMG signals and amplifies, rectifies, and smoothens it. As the output signal from the sensor board is rectified (in mV range), so Arduino can easily read it, as it is programmed to read the analog input at its A1 pin and print the readings to the serial port. The received value is compared with the predefined threshold value and checks for the condition specified in the algorithm in order to send pulse signal to the actuators for the finger movements. These EMG readings can be monitored as numbers, ranging from 0 to 1023, on Arduino IDE's serial monitor or as a graph on its serial plotter. Similarly, the output from the Accelerometer ADXL345 is given to the Arduino Nano and the axis data is compared to the predefined condition present in the program if set truly it makes the wrist servo rotate by 90º.

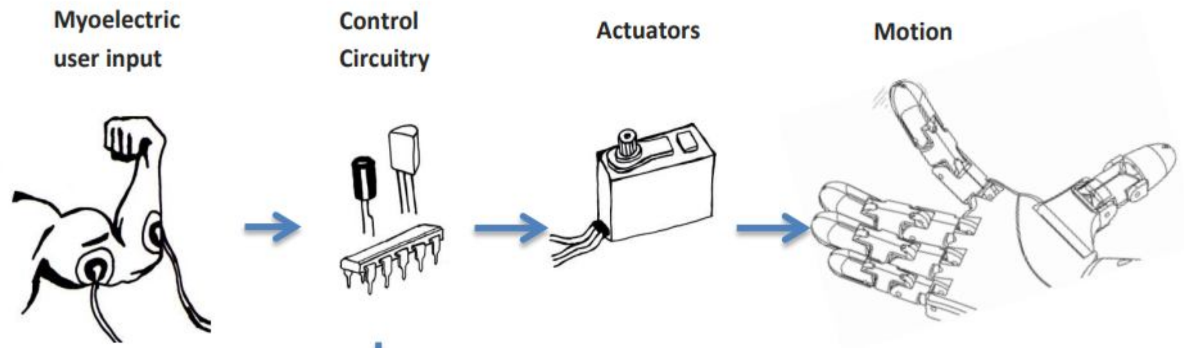

Fig. 3: Signal flow overview

B. Components Description:

The actuators used are standard servo motors i.e., MG995 as shown in fig.4. These servos provide a rotating torque of about 10kg-cm, and are light weight (around 55gms). These servos can be controlled to rotate about ±90 degrees from rest. Since the artificial tendons move fairly little for a finger to open or close, the angular precision of each servo affects how accurately the fingers can be controlled. Inexpensive servos are used in this project to reduce the overall cost. Use of better quality of servos will improve the control but the cost will increase accordingly.

Fig. 4: MG995 Servomotor

Arduino-NANO is the micro-controller board used in this project as shown in figure 5. The board is equipped with required analog and digital input/output pins which can be paired with various shields or breadboards for prototyping. The board includes serial communication interfaces and USB Port which are used to upload program in the main microchip i.e., ATMEGA328P. Arduino can be programmed using C and C++ language.

Fig. 5: Arduino Nano Board

The EMG device as shown in fig. 6, is a 3-lead Electromyography sensor, which comes with an on-board 3.5mm cable that attaches to the sensor board with one end and electrodes (sticky patches) on another end. Although, it is the commercially available sensor, it is effective for measuring muscle activities. This sensor has various other uses in the fields of robotics, prosthesis, bio-medical application and a variety of control applications. As it gives processed EMG signals rather than raw signals it is perfect to use with standard micro-controllers available in the market. Also, the sensor requires a DC source for power supply i.e., +/-3.5 to +/-18V.

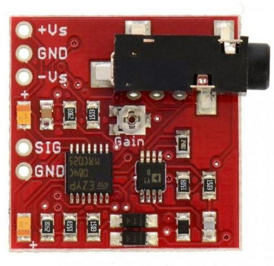

Fig. 6: Muscle sensor

Accelerometers, ADXL345 as shown in fig. 7 are the devices made to measure acceleration, which is the rate at which an object's velocity changes. They are measured in G-forces or metres per second squared (m/s^2) (g). For us, one G is equal to 9.8 m/s^2, though this varies somewhat with height. Accelerometers are helpful for detecting orientation or for detecting vibrations in system. Accelerometers can measure acceleration on one, two, or three axes.

Fig. 7: Accelerometer ADXL345

Power Supply, 9V Carbon Zinc Battery, as shown in fig. 8, is crucial that the prostheses should be transportable and run entirely on internal resources. For testing and debugging purposes, wall power supply is used, but a prosthetic arm needs to be powered by a device that an amputee can conveniently carry. When in use, servo motors draw a large quantity of current, because of which servos use power too quickly and require regular replacement, disposable batteries would not be a good alternative. Rechargeable lithium polymer (LiPo) batteries have a higher energy density. The batteries ought to be able to function for hours without any need to be recharged. To accomplish this, though, the battery's size can grow to an unmanageable extent.

Fig. 8: 9V Carbon Zinc Battery

IV. MECHANICAL ANALYSIS

Ansys is the popular software which allows the integration of data across engineering simulations to design the models and test it for the practical situations. We have used Ansys Workbench R15.0 for mechanical analysis. Ansys software is used to simulate our model of structures for analysing total deformation and equivalent stress.

A. Material

The material used for 3D printing of the model is PLA or polylactic acid. It is a plant based thermoplastic aliphatic polyester commonly used for filament fabrication. PLA is one of the most preferred materials for 3D printing because of its handy implementation, biodegradable properties and interesting mechanical properties. Other properties like low melting point, high strength, low thermal expansion, good layer adhesion and high heat resistance in annealed condition made this material ideal for our model.

Table 1: General Properties of PLA

Property	Value
Tensile Strength	50 MPa
Density	1.24 g / cm^3
Flexural Strength	80 MPa
Impact Strength (Unnotched) IZOD	96.1 J / m
Heat Deflection Temperature (HDT)	126ºF (52ºC)
Shrink Rate	0.37 - 0.41% (0.0037 – 0.0041 in / in)
Melting temperature	304ºF (151ºC)

Table 2: 3D Printing Processing Parameters

Nozzle Temperature	410- 446 ºF (210- 230 ºC)
Bed Temperature	122- 158 ºF (50- 70 ºC)
Bed material	Glass
Nozzle diameter	>= 0.4 mm
Print speed	40- 80 mm/s

B. Meshing

In Ansys software, we first uploaded a geometry or CAD model for meshing. Meshing is the process of obtaining irregular shapes into more visible volumes which are called Elements. It is used for obtaining precise results.

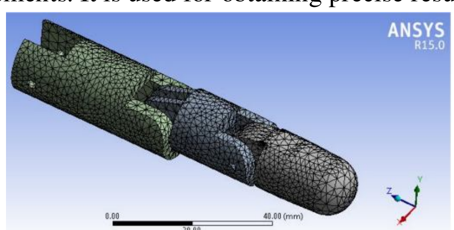

Fig. 9: Meshing (Nodes = 33828, Elements = 19040)

C. Boundary Condition

In boundary condition, we have applied revolute joints at joints A, B and C. Angles of rotation used are joint A = 60º, joint B= 64.5º and joint C = 81º. Boundary conditions are applied to restrict the rotation at joints.

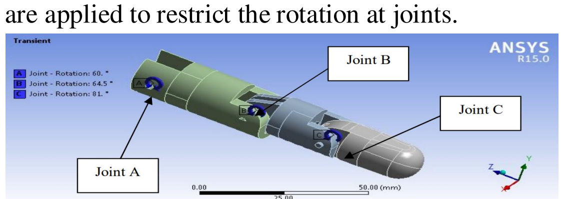

Fig. 10: Boundary Conditions

D. Total Deformation

Fingers will be directly engaged in order to hold an object. So, we have analysed the deformation of the finger at different points. After analysis we can conclude that the maximum deformation of 47.39 mm is obtained at tip of the finger and minimum deformation of 1.249 mm is obtained around joint A.

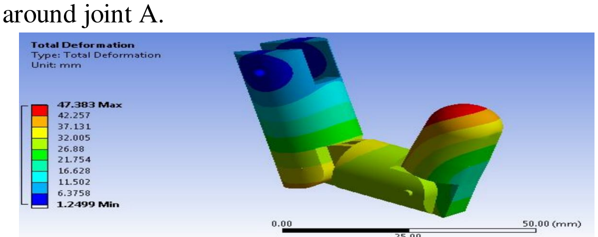

Fig. 11: Total Deformation

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E. Equivalent Stress

Von-Mises stress method is used to obtain equivalent stress. Similarly, from the stress analysis we can conclude that the maximum stress of 0.00269 MPa is obtained around joint A and minimum stress of 1.1393 e^{-8} MPa is uniformly obtained in all other regions.

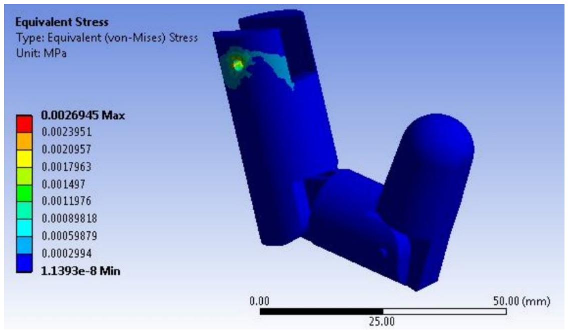

Fig. 12: Equivalent Stress

V. 3D PRINTING

Creality 10-S – a fused deposition modelling 3D printer was used for the production of all the mechanical components required for the model assembly. Assembly of the model turned out to be a quite tedious and challenging task requiring a lot of tools. Threading of the tendon line through the guide hole and ensuring right tensioning of the tendons for the accurate servo movement demanded a lot of precision and patience. The specifications for the 3D printing are given in the table 3.

Table 3: specifications for 3D printing

Printer	CREALITY CR – 10S
Software	Ultimaker Cura
Total Time for Printing	2 days 3 hrs 34 mins
Material Used	PLA (Generic, 104.71 m)
Infill %	15
Infill Pattern	Hexagon
Profile	0.2
Printing Temperature	210 ℃
Build Plate Temperature	60 ℃
Printing Speed	60 mm/s
Weight	312 g

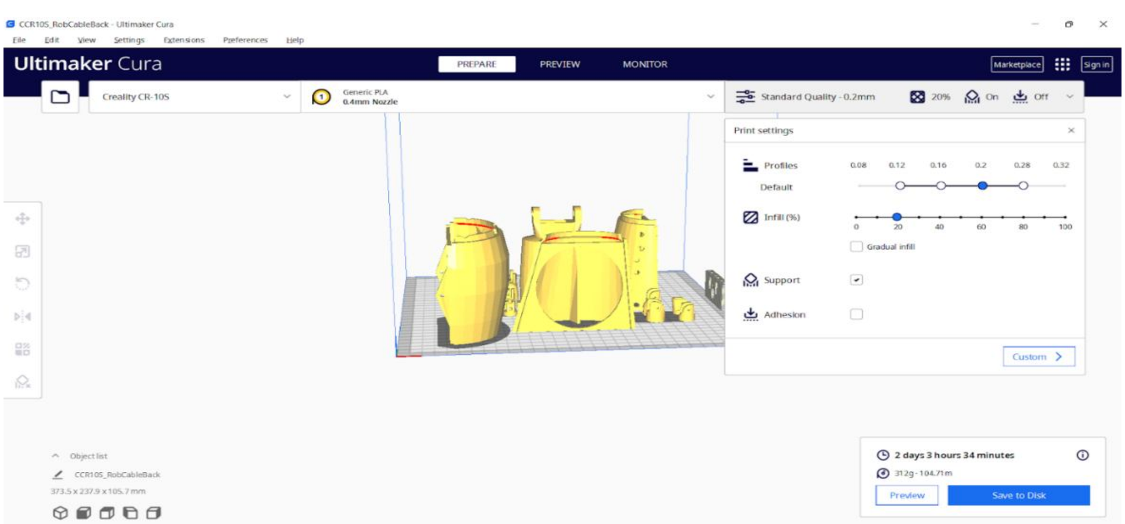

Fig. 13: Final preview of .STL file of the model displayed in the printing environment CURA

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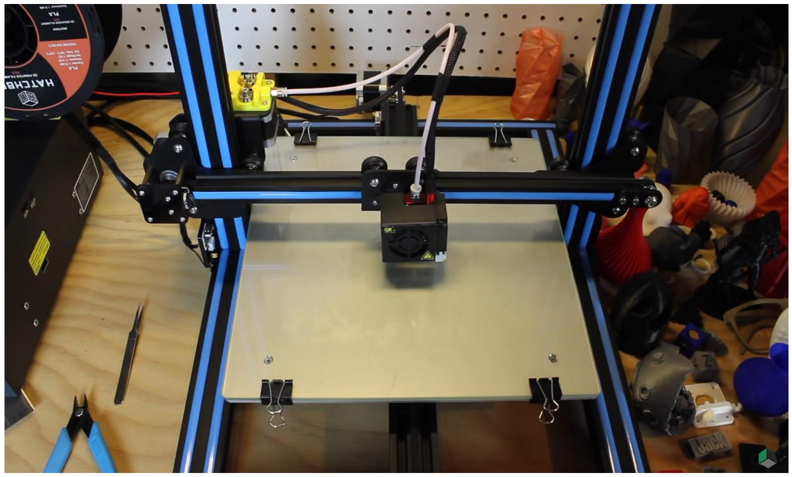

Fig. 14: 3D Printing under process

VI. RESULTS

The serial monitor gives the accurate EMG and accelerometer data which is further used for the calibration of the model through program. Serial plotter shows the graphical representation of the difference in flexion values received from the user's hand in the real time. These values are given to the micro-controller which generates the PWM signals for the activation of actuators resulting in opening & closing of fingers as shown in fig.15 as well as rotation of wrist as shown in fig. 16.

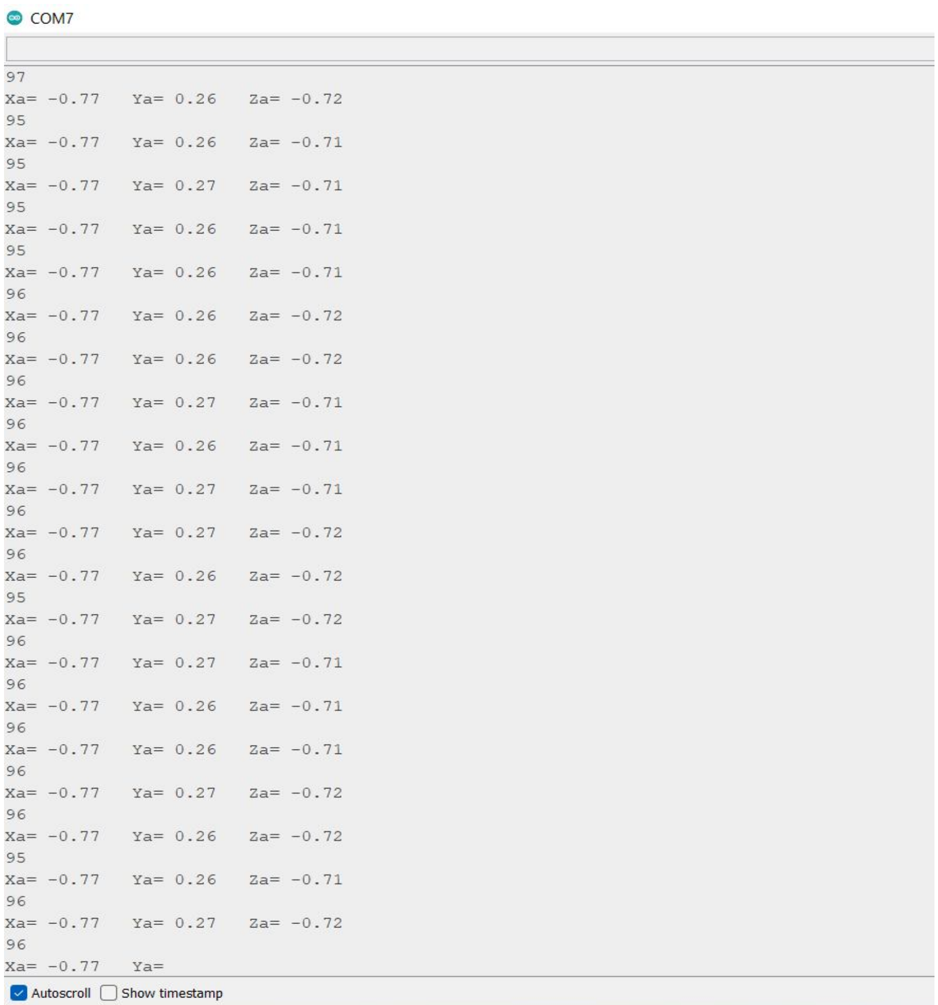

Fig. 14: Serial Monitor

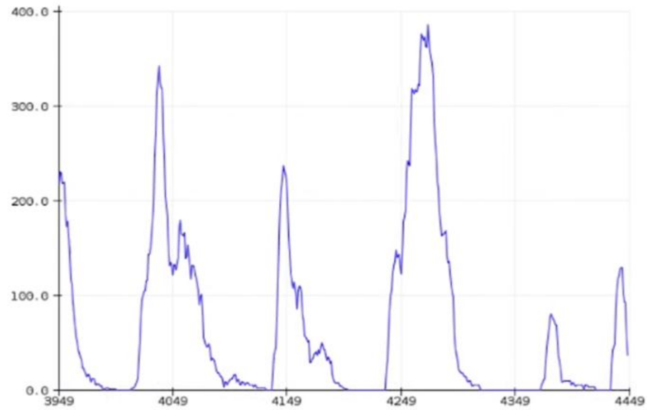

Fig. 15: Serial Plotter

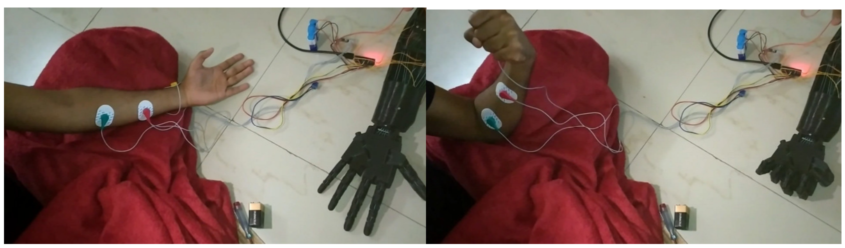

Fig. 15: opening and closing of fingers in the final prototype

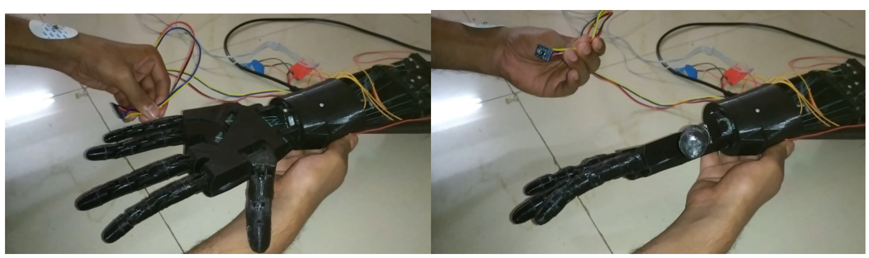

Fig. 16: Rotation of wrist

VII. CONCLUSION

The primary goal was to create a myoelectric prosthetic arm that could be 3D printed at a minimal cost. The objectives and expectations for this project have been met, and it is believed that the body of work now available will make it possible to do future research on a number of new thesis themes. The mechanical design of the model is similar to the human hand and was found stable in terms of stress analysis and deformation analysis done on the Ansys software. For a prototype 3D printed model, the finished system offers quite decent performance and attributes. Although it has limited strength, the device is quick and sensitive to electro-myography user input. The system has shown to be dependable during testing and has only needed minor maintenance since being put together.

REFERENCES

[1] D. P. J. Cotton, A. Cranny, P. M. Chappell, N. M. White, and S. P. Beeby, “Control strategies for a multiple degree of freedom prosthetic hand,” Meas. Control, vol. 40, no. 1, pp. 24–27, 2007, doi: 10.1177/002029400704000108.

[2] R. F. ff. Weir et al., “The intrinsic hand – a 22 degree-of-freedom artificial hand-wrist replacement,” MEC ’08 Meas. Success Up. Limb Prosthetics, no. January 2008, pp. 13–17, 2008.

[3] J. T. Belter, J. L. Segil, A. M. Dollar, and R. F. Weir, “Mechanical design and performance specifications of anthropomorphic prosthetic hands: A review,” J. Rehabil. Res. Dev., vol. 50, no. 5, pp. 599–618, 2013, doi: 10.1682/JRRD.2011.10.0188.

[4] Lillian Y. Chang and Yoky Matsuoka. A Kinematic Thumb Model for the ACT Hand. The Robotics Institute, Carnegie Mellon University. Proceedings of the 2006 IEEE International Conference on Robotics and Automation.

[5] Christian Pylatiuk, Stefan Schulz and Leonhard Döderlein. Results of an Internet survey of myoelectric prosthetic hand users. Prosthetics and Orthotics International, Sage Publications Dec1, 2007

[6] Samara Munaem Naeem*, Majid Habeeb, Stress and Strain Analysis for the Prosthetic Hand Design Actuated, Journal of Mechanical Engineering Research and Developments ISSN: 1024-1752 CODEN: JERDFO Vol. 44, No. 9, pp. 426-435 Published Year 2021

[7] Dunai L, Novak M, García Espert C. Human Hand Anatomy-Based Prosthetic Hand. Sensors (Basel). 2020 Dec 28;21(1):137. doi: 10.3390/s21010137. PMID: 33379252; PMCID: PMC7795667

[8] Introduction to Upper Limb Prosthetics, D. Farina, W. Jensen, M. Akay, Published 12 July 2013, Biology, DOI:10.1002/9781118628522.CH14, Corpus ID: 114227195