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Dissertation on

‘Transradial prosthesis - Development of a bionic arm using an EEG sensor’

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Aug – Dec 2023

under the guidance of

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DEPARTMENT OF MECHANICAL ENGINEERING
PROGRAM: B.TECH – MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the Report entitled

‘Transradial prosthesis - Development of a bionic arm using an EEG sensor’

is a bonafide work carried out by

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In partial fulfillment for the completion of 7th semester course work in the Program of Study **B.Tech in Mechanical Engineering** under rules and regulations of PES University, Bengaluru during the period **Aug – Dec 2023**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report. The report has been approved as it satisfies the 7th semester academic requirements in respect of project work.

Signature with date & Seal	*Signature with date & Seal*	*Signature with date & Seal*
Internal Guide	*Chairperson*	*Dean of Faculty*

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1.			
2.			
3.			

DECLARATION

We, **Rakshith V, Pranav Adiga, Sanketh Chebbi and Sai Preetham R V**, hereby declare that the Report entitled, '***Transradial prosthesis - Development of a bionic arm using an EEG sensor',*** is an original work done by us under the guidance of **Dr. D Sethuram**, Designation, Affiliation, and is being submitted in partial fulfillment of the requirements for completion of 7^{th} Semester course work in the Program of Study **B.Tech in Mechanical Engineering**.

Place : Bengaluru

Date **:** 15-11-2023

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ABSTRACT

This paper presents the design, implementation, and analysis of an innovative EEG-controlled robot gripper tailored for individuals with transradial prostheses. Leveraging advanced prosthetic technology, the gripper integrates EEG sensors to harness user attention as a means of actuation. The project prioritizes user experience, incorporating gecko skin for enhanced gripping functionality. Through a comprehensive ANSYS analysis, we validate the gripper's structural integrity under load conditions, ensuring safety and reliability. The gripper's versatility is tested through usability evaluations across diverse user groups, focusing on improving post-fitting quality of life. The use of 3D printing, specifically Fused Deposition Modeling (FDM), allows for customized and adaptable gripper fabrication. Our findings demonstrate the successful integration of EEG technology, biomechanics, and additive manufacturing in developing an intuitive and efficient prosthetic solution. This research contributes to the evolution of assistive technologies, emphasizing user-centric design, robustness, and practical functionality. The presented gripper showcases a promising advancement in the field, with implications for improving the daily lives of individuals with limb differences.

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CHAPTER 1
INTRODUCTION

Even the most routine everyday duties can become difficult when you lose the use of a limb. Technology-based tools can aid in regaining independence. Even the mind can be linked to an artificial limb thanks to new technologies. These prosthetic limbs are known as bionic prosthetics. The term ‘bionics’ was first used in the 1960s. It combines the prefix ‘bio’—meaning life—with the ‘nics’ of electronics. Bionics is the study of mechanical systems that function like living organisms or parts of living organisms. Since 600 BC, simple artificial limbs have been in use. While these archaic replacements restored some movement or function to the wearer, they were frequently uncomfortable, challenging to use, had subpar functionality, and were aesthetically unappealing.

Development of a bionic arm that benefits amputees whose hands are amputated just below their elbows, i.e; Transradial Prosthesis. This helps them perform basic daily tasks such as opening doors, grabbing a bottle of water etc.

Before, simple prosthetic arms have been just fixtures on the body that do not help in dynamic human movements that our bionic arm aims to achieve. With generic prosthetic arms, trivial tasks like opening a door or grabbing a bottle of water is difficult for amputees. With our bionic arm, we can help them perform these actions as humanely as possible.

Bionic arm is quite different from a prosthetic arm. A bionic arm is a type of prosthetic arm that incorporates electromechanical components.

A prosthetic arm, on the other hand, refers to an artificial limb designed to replace a missing or amputated arm.

A prosthetic arm can be powered in three different ways: myoelectric, motor, and by the body. Body-powered prosthetics use cables that are tied to the opposing shoulder and the prosthetic, such that when the shoulder moves, the prosthetic also moves. Similar mechanisms are used by motor-powered prosthetics, but the opposite shoulder controls buttons or switches to generate the desired activity in the prosthetic.

Myoelectric power, which is the electrical impulses produced by contracted muscles, is used by the most sophisticated prosthetic devices. On the residual limb, electrodes are positioned, which records the electrical signals generated when the muscle contracts and moves the prosthetic in accordance.

CHAPTER 2
LITERATURE REVIEW

Sahil Shaikh, et al [1], This project describes how the Brain waves can be used to control a prosthetic arm using Brain Computer Interface (BCI). The Brain signal acts as command signals and is transmitted to the microcontroller and this command signal is based on concentration level and eye blink strength of the subject. The microcontroller is coupled with servo motors to perform flexion and extension of fingers.

R. Swetha, S, et al[2], In this work, the design of a prosthetic arm is proposed by reconstructing the structure and proportions of an amputated arm using high-precision methods and dimensions. The exported file is entered into computer-aided design software, and the geometry of the socket was designed on the basis of an affected arm and the prosthetic arm was designed according to the mirrored geometry of the unaffected arm.

S. Sree Krishna, et al[3], In this study, a bionic arm made of poly lactic acid polymer, a basic material for 3D printing. The arm is mechanized using artificial tendons which are actuated by smart servo dynamixel AX-12A motors. The final assembled arm provides 7 DOF (5 for fingers, 1 each for wrist and elbow). Information is acquired with the help of Neurosky MindWave Mobile which is incorporated with an EEG sensor.

Dany Bright, et al[4], The BCI system consists of an EEG sensor to capture the brain signal, which will be processed using theThinkGear module in MATLAB. The extracted brain signals act as command signals that are transmitted to the Microcontroller via RF medium. The designed prosthetic arm module consists of an Arduino coupled with servo motors to execute the command. The flexion and extension of fingers can be successfully controlled with an accuracy of 80 percent.

Taha Beyrouthy, et al[5], The prosthesis is 3D printed and controlled via brain commands, obtained from an electroencephalography (EEG) headset, and is equipped with a network of smart sensors and actuators that provide the patient with intelligent feedback about the environment and the object to be touched. This network gives the arm normal hand functionality, intelligent reflexes and smooth movements.

Dildar Ahmed Saqib, et al[6], The research work presents the design of prosthetic arm and hand. It’s a bioengineering approach in order to develop a robotic arm and hand for the disabled persons, resembling the human upper limb. EMG sensor is interfaced with the upper limb of the human body to receive signals from human muscle and motion of each joint is actuated by its respective motor accordingly.

O A Ruşanu [7], The paper describes the development of an Arduino-based mobile robot controlled by voluntary eye-blinks using a LabVIEW graphical user interface (GUI) and a NeuroSky Mindwave Mobile headset. The system allows users to control the robot's movement through different environments using their eye blinks, as detected by the headset. The authors evaluated the system's performance and found that it was able to achieve a high level of accuracy in controlling the robot's movement.

Sarayu Pai.[8], The research resulted in the development of a controllable dry adhesive tape that mimics the gecko's grip using van der Waals forces. The triangular structures in the tape enable variable contact surface area, increasing grippiness when needed and only the tip area for release. The adhesive has better functionality on smooth surfaces and is being improved for non-smooth materials.

2.1 Literature gap

- Prosthetic arms must be rigid and movements must be as humane as possible. Previous work on this topic hasn't used effective design and operation.
- Limited research on sorting algorithms for the data. We intend to use data sets from the EEG sensor to detect signals more accurately.
- Current literature lacks a comprehensive evaluation of prosthetic arm usability tailored to different user demographics.
- There is a lack of evaluation of the impact of prosthetic arms on improving quality of life after being fitted with a prosthetic arm, which we aim to address.
- The fingertips on the prosthetic arm aren't equipped enough to grip objects except for flexion. We aim to use gecko skin for gripping for better functionality.
- Limited papers have explored the possibility of using blink strength as actuation.

CHAPTER 3
PROJECT WORK DETAILS

3.1 Problem statement

Development of a bionic arm that benefits amputees whose hands are amputated just below their elbows, i.e; Transradial Prosthesis. This helps them perform basic daily tasks such as opening doors, grabbing a bottle of water etc. Before, simple prosthetic arms have been just fixtures on the body that do not help in dynamic human movements that our bionic arm aims to achieve. With generic prosthetic arms, trivial tasks like opening a door or grabbing a bottle of water is difficult for amputees. With our bionic arm, we can help them perform these actions as humanely as possible.

3.1.1 Need for prosthetic care

Prosthetic care is essential for people who have lost a limb due to injury, illness, or congenital condition. Here are some reasons why prosthetic care is necessary worldwide:

Improved Quality of Life: Prosthetic devices can help people regain their independence and mobility, allowing them to perform daily activities and participate in social and recreational activities. This can greatly improve their quality of life.

Better Health Outcomes: Prosthetic devices can help prevent complications such as joint pain, pressure sores, and muscle atrophy, which can occur when an amputee does not have a proper prosthetic device.

Economic Empowerment: By restoring mobility and independence, prosthetic devices can enable individuals to return to work, school, and other activities that generate income, contributing to the economic growth of their communities.

Social Inclusion: Prosthetic care can help reduce the stigma associated with amputation, allowing individuals to participate more fully in their communities and reducing the risk of social isolation.

Humanitarian Aid: In areas affected by conflict or natural disasters, prosthetic care can be critical in restoring mobility and independence for those who have been injured or displaced.

Overall, prosthetic care is crucial for restoring function and improving the quality of life for amputees worldwide

3.1.2 Objectives

1) Development of a bionic arm that has movements as human as possible for natural hand actions.

2) Development of a proprietary sleeve for connection of the prosthetic arm to the amputated arm that aims to fit different user groups.

3) Development of a sophisticated control engineering system that helps in better transmission of data

4) To build a robot gripper capable of lifting a water bottle

3.1.3 Methodology

1. Development of a bionic arm for amputees whose hands are amputated below the elbow, i.e. transradial prosthesis using solidworks and analyze the design using Ansys Workbench to effectively find load ratings of the arm.
2. Analyze the electrical activity of the brain using an EEG sensor via electrodes affixed to the forehead.
3. Sorting the brain waves according to the frequencies like Alpha, Delta etc. and exploring them under various conditions.

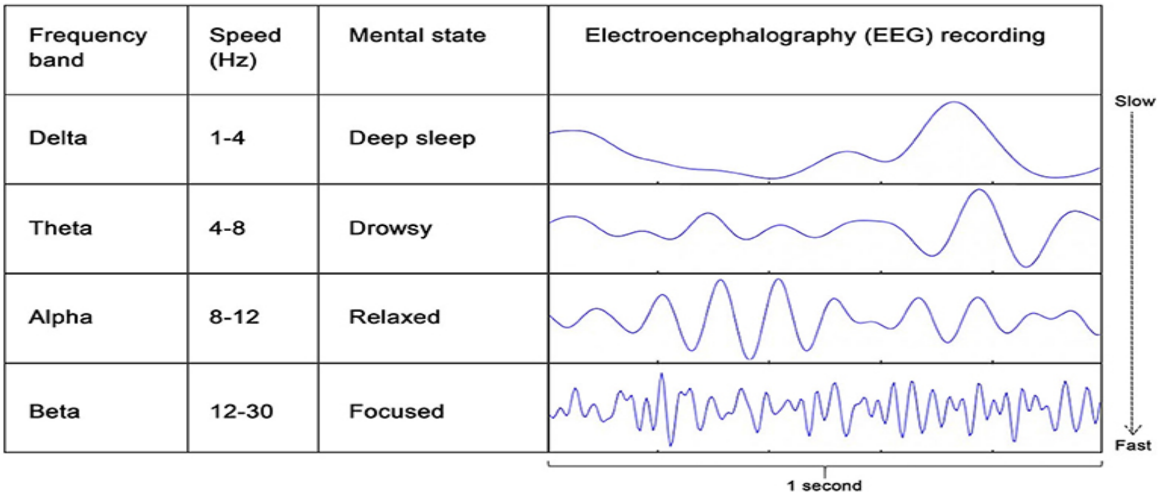

Figure 3.1 Brain wave frequency chart

4. Make use of a microcontroller such as Arduino and Bluetooth module HC-05 Bluetooth Transceiver to receive and process the data from the EEG sensor.
5. Using a bluetooth module to interpret the data received and display it on the serial monitor in terms of attention values.

6. When attention level reaches a certain threshold, the servo motor is programmed to move by a certain degree in order to perform a function for a suitable application.
7. With slicing software, we can convert 3D digital models into printing instructions for a specific 3D printer to create an object. In 3D printing technology, 3D objects are created by adding material layer by layer. Slicing software virtually "slices" 3D models into many horizontal 2D layers that are later printed one after another.
8. With the instructions from the slicing software, we can 3D print the prosthetic arm and test it physically.
9. After 3D printing, we assemble the entire arm with fasteners to actuate the end-effectors. Run a final test to make sure all the components work together.

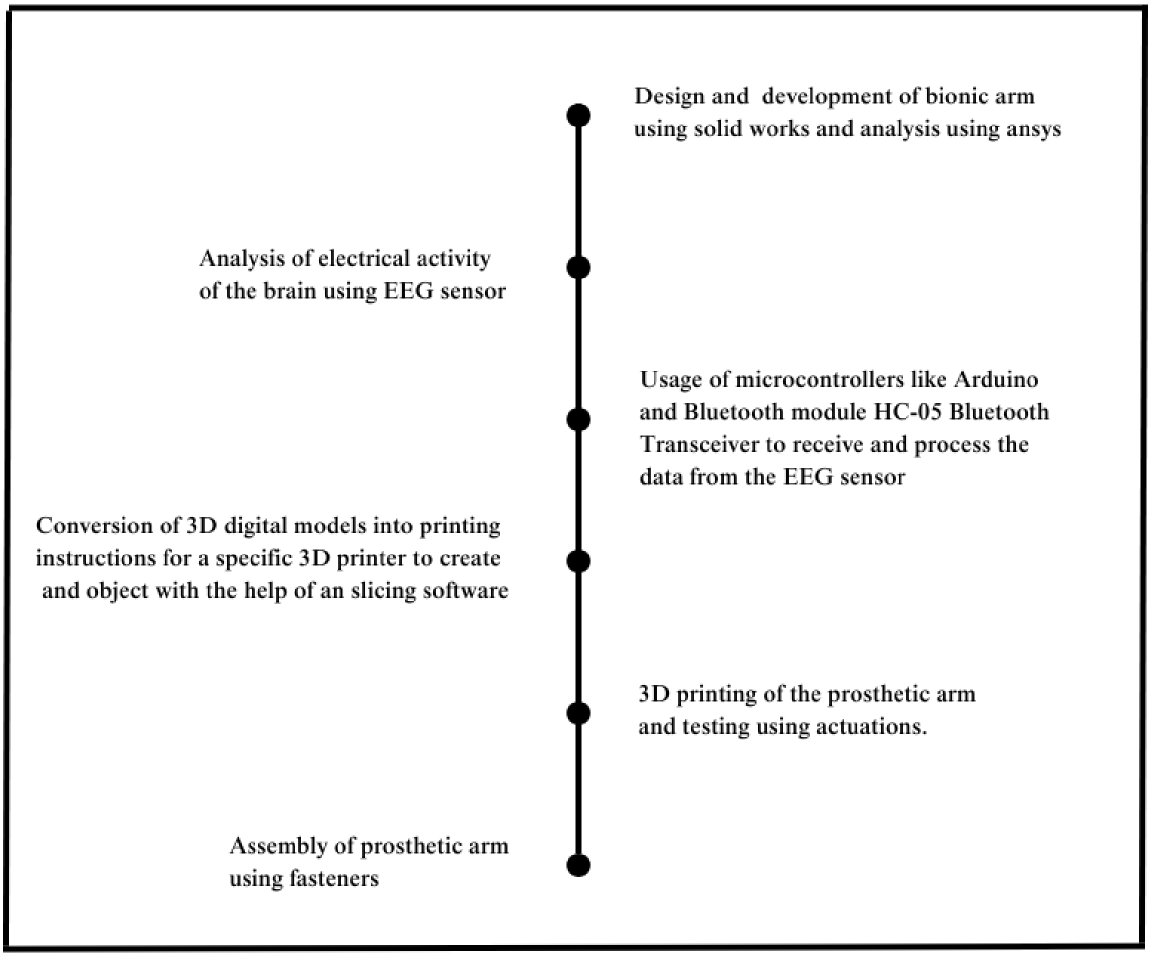

Figure 3.2 Methodology chart

3.2 Design Development

The maximum load that the robotic arm in the image can lift depends on a number of factors, including:

- The weight of the arm itself.
- The weight of the gripper.
- The strength of the servo motor.
- The gear ratio of the arm.
- The distance from the center of mass of the load to the joint where the load is attached.

Sl no	Parameter	Value
1	Module	1.125
2	No of teeth	24
3	Face width	3mm
4	Normal shaft diameter	3mm
5	Pressure angle	20 degrees

Table 3.1 Gear Parameters

A spur gear is a type of cylindrical gear with straight teeth that are cut parallel to the axis of rotation. They are the simplest and most common type of element in mechanical drive systems.[9]
In our project, we employed spur gears as essential components in the transmission mechanism. Spur gears, characterized by their straight teeth positioned parallel to the gear axis, facilitated precise and efficient power transfer within the gripper assembly. By carefully selecting gear ratios, we optimized the system for torque and speed requirements, enabling controlled and reliable movements. The simplicity and effectiveness of spur gears contributed to the overall robustness of our gripper design, ensuring smooth operation and enhancing the gripping capabilities crucial for our project's success.

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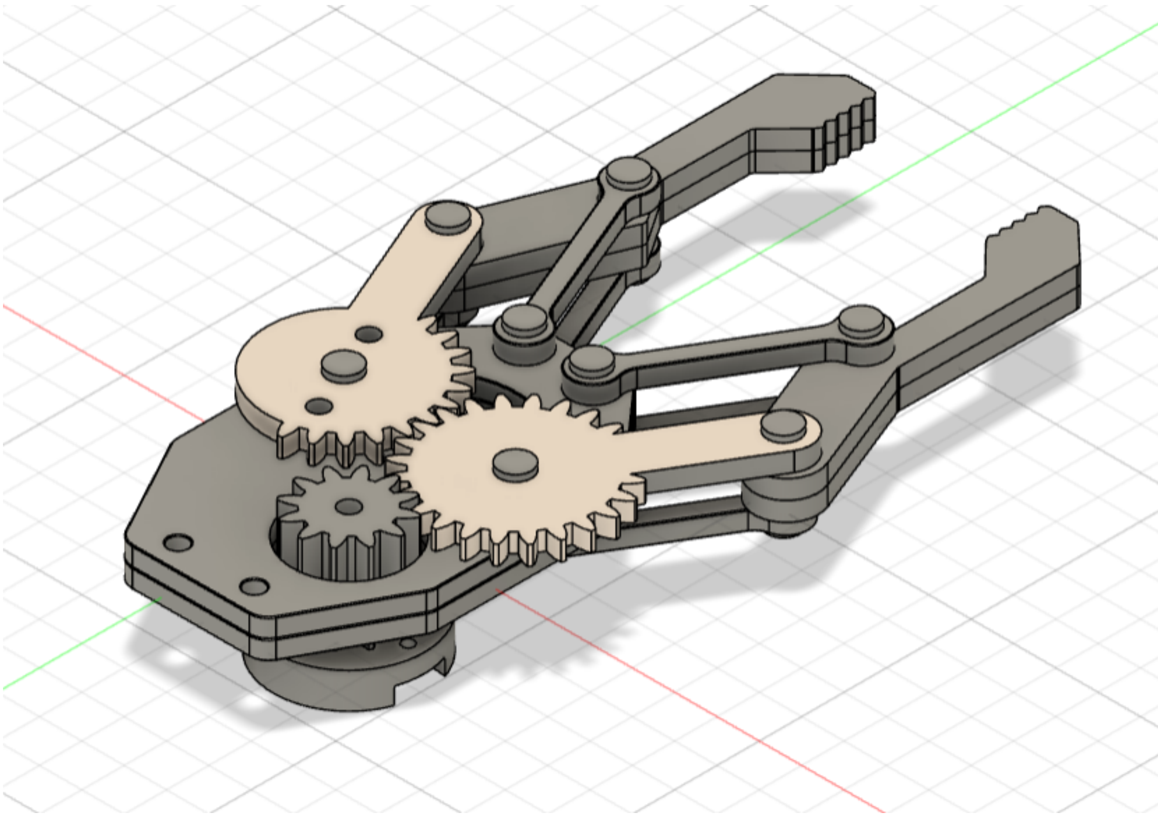


Fig 3.3 Orthogonal view of the gripper

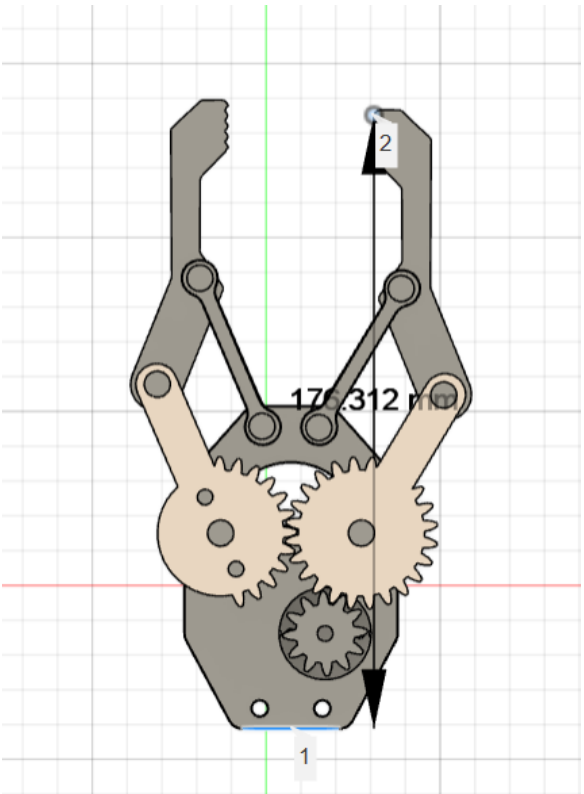


Fig 3.4 Top view of the gripper

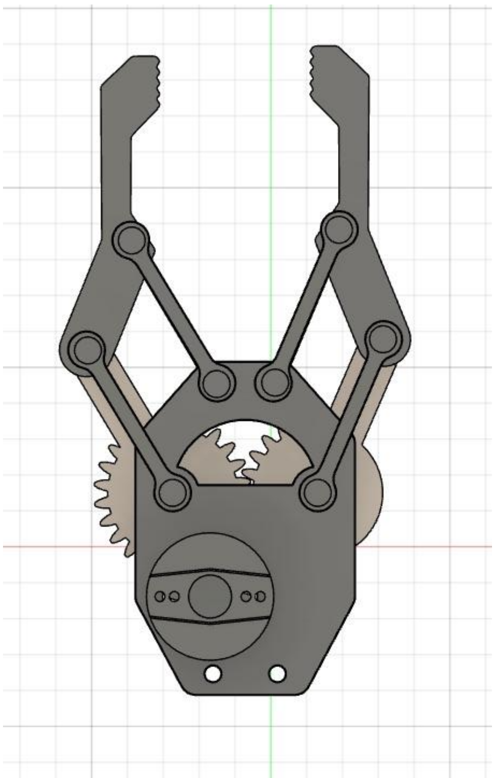


Fig 3.5 Bottom view of the gripper

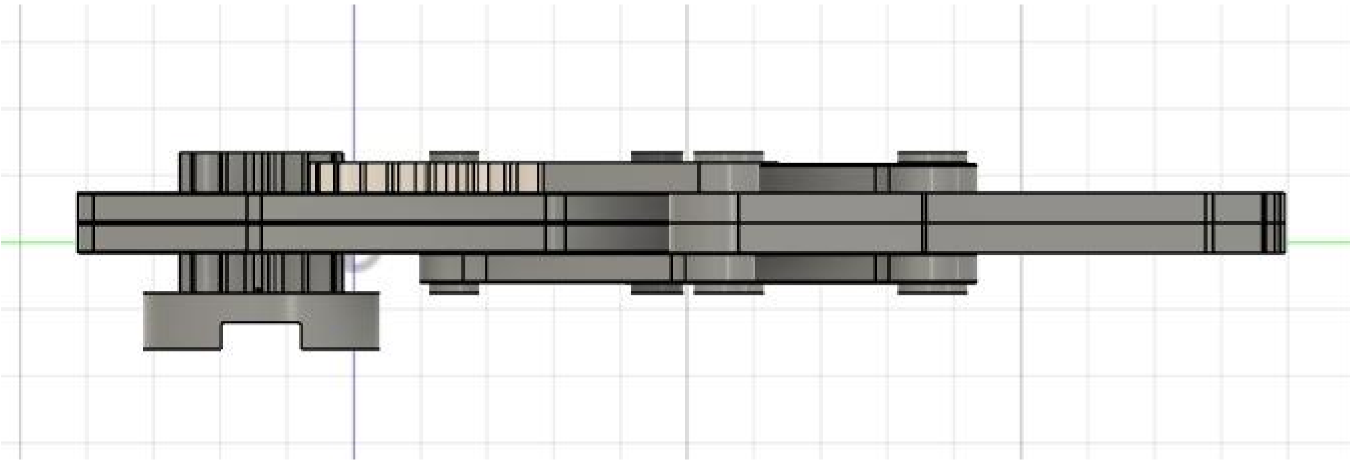


Fig 3.6 Side view of the gripper

3.2.1 Calculations

Calculation of Safe Load Capacity for Robotic Arm:

<u>Given:</u>

Number of teeth of driver gear (pinion): 12
Number of teeth of driven gear: 24
The gear ratio is calculated using the formula:

Gear ratio = Number of teeth in driven gear / Number of teeth in driver gear
Gear ratio = 24 / 12 = 2

To find the maximum weight that the robotic arm can lift, the following equation is used:

Maximum weight = Stall torque / Gear ratio × Lever length

Given:
Stall torque: 36 kg cm
Lever length: 15.05 cm

Maximum weight = 36 kg cm / 2 × 15.05 cm
Maximum weight ≈ 1.20 kg

However, accounting for factors such as friction and Rated torque, a safety factor (FOS) of 2 is applied:

Safe Load = Maximum weight / FOS

Safe Load = 1.2 kg / FOS

Safe Load = 610 grams

Therefore, considering a safety factor of 2, the safe load capacity for the robotic arm is approximately ***610 g.***

3.3 Experimental Setup and Calibration

3.3.1 FT&S MINDLINK EEG HEADBAND

Fig 3.7: FT&S Mindlink EEG Sensor

Electroencephalography (EEG) sensors are used to measure the electrical activity in the brain. EEG sensors are often used in research, medicine, and other fields to help understand how the brain works and to diagnose conditions such as epilepsy.

There are several different types of EEG sensors available, including wet and dry electrodes, caps, and headbands. Wet electrodes use conductive gel to improve the electrical conductivity between the electrode and the scalp, while dry electrodes use no gel and instead rely on a strong connection between the electrode and the scalp. Caps cover the entire head and typically use several electrodes to capture data from different regions of the brain. Headbands are similar to caps, but are smaller and typically use fewer electrodes.

The FT&S MindLink EEG headband is a particularly popular EEG sensor due to its ease of use and affordability. It uses dry electrodes, making it less messy and more convenient than wet electrode systems. The headband is also lightweight and comfortable, making it easy to wear for extended periods of time. Additionally, it can be used with a variety of different software applications, making it a versatile option for research and other applications.

While there are certainly more advanced EEG sensors available, the FT&S MindLink EEG headband is a great choice for many applications due to its ease of use, affordability, and versatility. Its dry electrode system and comfortable design make it a particularly appealing option for researchers and other professionals who need to gather EEG data without causing discomfort to their subjects.

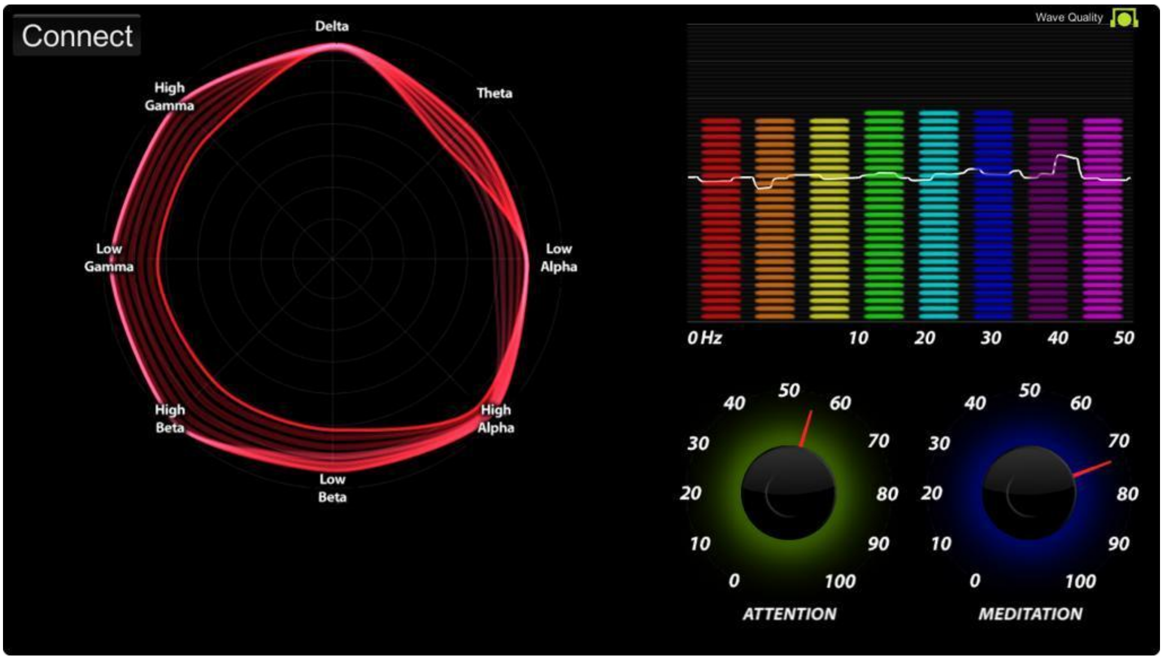


Fig 3.8 Brainwave visualiser

3.3.2 Cys-S8218 SERVO MOTOR DATA SHEET

A servo motor is a crucial component in robotics and automation systems, designed to provide precise control over angular position, velocity, and acceleration. Typically, servos operate based on feedback control systems, using a control signal to command the motor to move to a specific position. The servo motor's core design includes a motor, control circuitry, and a feedback system, often utilizing a potentiometer to continuously monitor the motor's actual position.

Item No. CYS-S8218 is a digital servo motor weighing 164g, measuring 59.529.255.2mm, and designed for various applications. With an operating voltage range of 6.0 to 7.4 Volts, it exhibits an operating speed of 0.20sec/60° at 6.0V and 0.18sec/60° at 7.4V with a no-load condition. The servo offers a stall torque of 38kg.cm at 6.0V, making it suitable for tasks requiring substantial force. Its control system utilizes Pulse Width Control, with a neutral point at 1500µsec. With its specific electrical characteristics and robust design, the CYS-S8218 servo motor is an integral component for applications demanding precise and powerful motion control.

Fig 3.9: S8218 Servo Motor

Specification Sheet	
Item No.	CYS-S8218
Type	Digital
Weight	164g ± 1 g
Size	59.5*29.2*55.2mm
Control System	(+)Pulse Width Control 1500usec Neutral
Operating Voltage	6.0~7.4Volts
Operating Temperature Range	(-)10 to +50 degree C
Operating Speed (6.0V)	0.20sec/60° at no load
Operating Speed (7.4V)	0.18sec/60° at no load
Stall Torque (6.0V)	38kg.cm
Operating Angle	45deg. one side pulse traveling 500 usec
360 Modifiable	No
Direction	Anticlockwise/Pulse Traveling 1000~2000usec
Current Drain (6.0V)	20mA/idle and 180mA no load operating
Current Drain (7.4V)	20mA/idle and 200mA no load operating
Stall Current	7.5A/8.6A
Dead Band Width	4usec
Motor Type	NdFeB motor
Bearing Type	Dual Ball Bearing
Horn gear spline	17T
Gear Type	Metal
Connector Wire Length	300mm
Wire info	Brown/Black = Negative
	Red = Positive
	Orange/White = Signal

Table 3.2 Servo Motor Datasheet

3.3.3 Arduino UNO

The Arduino Uno is a versatile microcontroller board widely used in electronics projects and prototyping, features digital and analog input/output pins, making it suitable for various applications.

The Arduino Uno operates on a 5V supply voltage and is programmed using the Arduino IDE, a user-friendly development environment. With 14 digital pins, 6 analog inputs, and a variety of communication interfaces, the Uno provides a platform for interfacing with sensors, actuators, and other hardware components.

In our project, we plan to integrate the Arduino Uno to control the CYS-S8218 servo motor. Using the digital output pins, we'll send pulse-width modulation (PWM) signals to the servo, specifying the desired position. The servo's control wire will be connected to one of the digital pins, allowing the Arduino to precisely manipulate the motor's angular position.

Through Arduino programming, we can create sequences of instructions to automate movements, control angles, and respond to external inputs. The Uno's flexibility, coupled with its ease of use, makes it an ideal choice for managing and coordinating hardware components, enabling us to implement sophisticated control strategies for our servo motor within the project

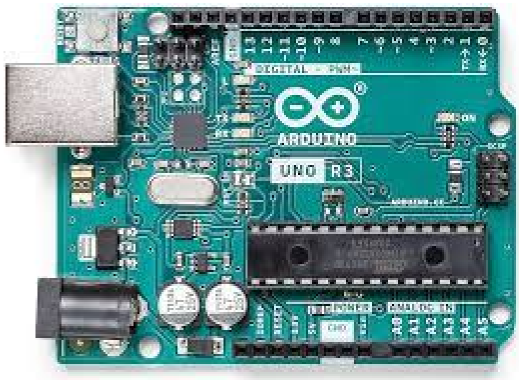


Fig 3.10 Arduino UNO

3.3.4 HC-05 Bluetooth Module

The HC-05 is a Bluetooth module widely employed for wireless communication in electronic projects. With its serial communication capabilities, the HC-05 facilitates the establishment of Bluetooth connections between devices. In our project, we aim to integrate the HC-05 module to establish a wireless link between an EEG (electroencephalogram) sensor and our central processing unit, likely an Arduino or another microcontroller.

The HC-05 module operates on a 3.3V supply voltage, ensuring compatibility with various microcontrollers. Using its serial interface, we'll configure the HC-05 to operate in the slave mode, allowing it to receive data from the EEG sensor. The module will be connected to the microcontroller via its serial pins, enabling seamless communication.

To gather attention values from the EEG sensor wirelessly, we'll leverage the HC-05's Bluetooth capability. The EEG sensor will transmit attention-related data to the HC-05 module, which will then relay this information to the microcontroller. Our programming logic on the microcontroller will interpret the received data and potentially trigger actions or display information based on the user's attention levels.

This wireless connection enhances the flexibility and mobility of our EEG-based project, allowing users to interact with the system without being tethered to physical connections. It provides a streamlined approach for collecting and processing attention data, offering a more user-friendly and adaptable solution for our project.

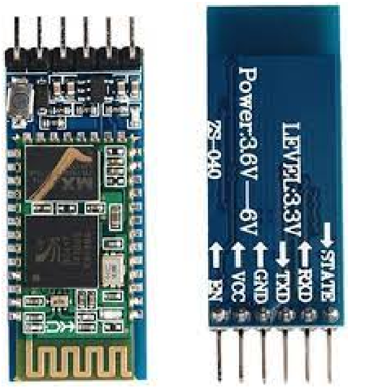


Fig 3.11 HC-05 Bluetooth Module

3.3.5 Circuit Diagram

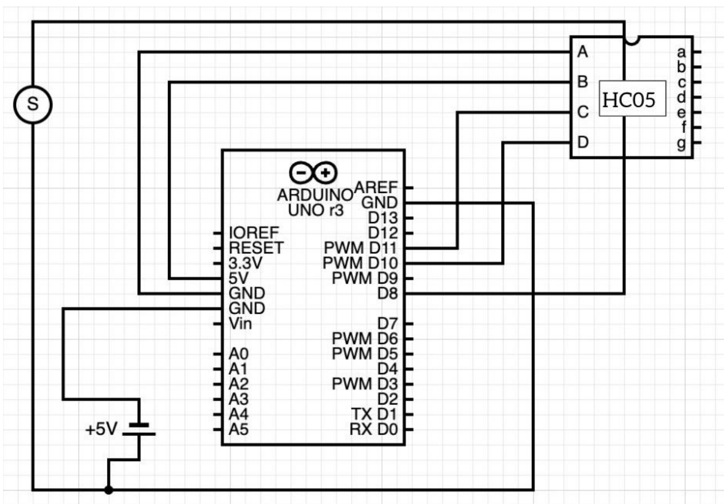


Fig 3.12 Circuit diagram

3.4 Arduino Programming

```
void loop() {
  if (ReadOneByte() == 170) {
    if (ReadOneByte() == 170) {
      payloadLength = ReadOneByte();
      if (payloadLength > 169)
        return;

      generatedChecksum = 0;
      for (int i = 0; i < payloadLength; i++) {
        payloadData[i] = ReadOneByte();
        generatedChecksum += payloadData[i];
      }

      checksum = ReadOneByte();
      generatedChecksum = 255 -
generatedChecksum;
      if (checksum == generatedChecksum) {
        poorQuality = 200;
        attention = 0;
        for (int i = 0; i < payloadLength; i++) {
          switch (payloadData[i]) {
            case 2:
              i++;
              poorQuality = payloadData[i];
              bigPacket = true;
              break;
            case 0x04:
              i++;
              attention = payloadData[i];
              break;
            case 5:
              i++;
              break;
            case 0x16:
              i++;
              break;
            case 0x80:
              i = i + 3;
              break;
            case 0x83:
              i = i + 25;
              break;
            default:
              break;
          }
        }
```

Fig 3.13 Arduino Code Block-1

This code is an Arduino sketch that reads data from a MindWave Mobile EEG headset via Bluetooth and controls a servo motor based on the level of attention detected.

First, the required libraries, SoftwareSerial and Servo, are imported. The SoftwareSerial library allows the Arduino to communicate via Bluetooth, while the Servo library allows the Arduino to control a servo motor.

The code defines various constants and variables used throughout the program. These include the LED pin, the baud rate used for communication, and several variables to store the received data from the MindWave Mobile headset.
In the setup() function, the LED pin is set to output mode, the Bluetooth communication is initiated, and the Servo library is initialized.

In the loop() function, the code checks for incoming data from the MindWave Mobile headset via Bluetooth. When two consecutive bytes with a value of 170 are detected, this indicates the start of a packet of data from the headset.
The code then reads the length of the packet, checks if the length is valid, and calculates a checksum for the packet to ensure that the received data is valid.

```
#if !DEBUGOUTPUT
        if (bigPacket) {
          if (poorQuality == 0)
            digitalWrite(LED, HIGH);
          else
            digitalWrite(LED, LOW);
          Serial.print("Attention: ");
          Serial.print(attention);
          if (attention > 60 && !servoActivated) {
            myservo.attach(8);
            servoActivated = true;
            Serial.println("\nActivating servo motor!");
            myservo.write(45);
            delay(5000);
            myservo.write(120);
          } else {
            if (servoActivated) {
              myservo.detach();
            }
          }
```

Fig 3.14 Arduino Code Block-2

This Arduino program integrates an EEG sensor, LED, and servo motor to create an interactive system. Initially excluding debugging output, the program processes a substantial data packet ('bigPacket') and evaluates the EEG signal quality. If the signal quality is deemed satisfactory, an LED is illuminated, serving as a visual indicator.

The program then prints the 'attention' value to the serial monitor, providing insights into the user's cognitive state. Notably, the servo motor is activated only when the attention value exceeds 60 for the first time, as indicated by the conditional check. This activation involves attaching the servo to pin 8, moving it to 45 degrees to simulate a gripping motion, waiting for 5 seconds, and then moving it to 120 degrees. This specific sequence is designed to enable amputees to grip objects, such as a water bottle, offering a tangible and functional outcome triggered by the user's attention level.

This innovative integration of EEG signals and servo motor control holds promise for creating responsive and user-centric prosthetic systems, enhancing the daily lives of individuals with limb differences

3.5 Material Selection and 3D printing

3.5.1 PolyLactic Acid

Poly(lactic acid) or PLA is a biodegradable and biocompatible polyester that is derived from renewable resources such as corn starch, sugarcane, and other starch-rich plants. It is a polymer made up of repeating units of lactic acid, which is a naturally occurring organic acid.

PLA is widely used in the manufacturing of a variety of products, including packaging materials, disposable tableware, 3D printing filaments, medical implants, and drug delivery systems. It has gained significant attention in recent years as a sustainable alternative to traditional petroleum-based plastics.

Here are some key characteristics and properties of PLA:

Biodegradability: PLA is biodegradable, which means that it can be broken down by microorganisms in the environment into simpler, natural compounds such as carbon dioxide and water. This property makes it an eco-friendly material that can help reduce pollution and waste.

Biocompatibility: PLA is also biocompatible, meaning that it does not elicit an adverse reaction from living tissue. This makes it an ideal material for use in medical implants and drug delivery systems.

Mechanical properties: PLA has moderate mechanical strength and stiffness, and can be processed using a variety of techniques such as injection molding, extrusion, and 3D printing. Its properties can be tailored by adjusting the degree of polymerization, molecular weight, and stereochemistry.

Thermal properties: PLA has a low glass transition temperature (Tg) of around 60-65°C, which means that it becomes soft and pliable at relatively low temperatures. This property makes it easy to process, but also limits its use in high-temperature applications.

Optical properties: PLA is transparent and has good light transmission properties, which makes it suitable for use in clear packaging materials.

While PLA has many advantages as a sustainable and biodegradable material, there are also some challenges associated with its use. For example, it can be brittle and may degrade over time when exposed to moisture and high temperatures. However, ongoing research and development are focused on addressing these issues and improving the performance and versatility of PLA as a material.

Property	Value
Heat Deflection Temperature (HDT)	126 °F (52 °C)
Density	1.24 g/cm³
Tensile Strength	50 MPa
Flexural Strength	80 MPa
Impact Strength (Unnotched) IZOD (J/m)	96.1
Shrink Rate	0.37-0.41% (0.0037-0.0041 in/in)

Table 3.3 PLA Properties [11]

3.5.2 3D Printing

Three-dimensional (3D) printing, also known as additive manufacturing, is a revolutionary technology that has transformed the landscape of design, prototyping, and production. Unlike traditional subtractive manufacturing methods, 3D printing constructs objects layer by layer from digital models. This process allows for unparalleled design flexibility, enabling the creation of intricate and customized structures with greater efficiency. One of the key advantages of 3D printing is its ability to democratize manufacturing, empowering individuals and small businesses to fabricate prototypes and end-use products without the need for extensive resources or complex tooling. This democratization has led to breakthroughs in various industries, from healthcare to aerospace, fostering innovation and accelerating the product development cycle.

Fused Deposition Modeling (FDM) in 3D Printing:

Fused Deposition Modeling (FDM) is a popular and widely-used 3D printing method, particularly valued for its simplicity and versatility. In FDM, a thermoplastic filament is fed through a heated nozzle, which extrudes the material layer by layer to create the desired object. The layering process is repeated until the entire three-dimensional structure is formed. FDM excels in producing durable and functional prototypes, making it a preferred choice for various applications. Its affordability and accessibility further contribute to its widespread adoption, making FDM a go-to method for rapid prototyping and low-volume production.

Incorporating 3D Printing in Gripper Fabrication:

In our project, we harness the power of 3D printing, specifically FDM, to fabricate a versatile and adaptive robotic gripper. The intricate design of the gripper components is made possible through the layer-by-layer deposition of thermoplastic material. This methodology not only allows for the precise construction of complex geometries but also ensures the gripper's durability and lightweight characteristics. The use of 3D printing in gripper fabrication facilitates rapid prototyping, enabling iterative design improvements based on testing and user feedback.

Furthermore, 3D printing offers the flexibility to tailor the gripper to the specific needs of amputees who have undergone transradial prosthesis. By incorporating this technology, we can produce customized grippers that accommodate individual preferences and functional requirements. The adaptability and cost-effectiveness of 3D printing make it an invaluable tool in the creation of prosthetic components, opening new possibilities for enhancing the quality of life for prosthesis users. In conclusion, the integration of 3D printing, particularly FDM, in our gripper fabrication process exemplifies the transformative potential of this technology in advancing the field of assistive devices, offering solutions that are not only functional but also tailored to the unique needs of the end-users.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Data Evaluation

A	B	C
No. of trials	Attention Values(avg.)	Time spanned(in min.)
1	32	2.5
2	29	3.8
3	58	1.7
4	86	2.2
5	76	3.4
6	33	1.5
7	67	3.9
8	80	2.8
9	29	3.1
10	28	2.3
11	31	1.9
12	45	3.6
13	49	2
14	88	1.4
15	48	3.5
16	89	2.1
17	29	3.2
18	45	1.6
19	67	3.7
20	78	2.9
21	78	1.8
22	29	3.3
23	77	2.4
24	28	3
25	79	1.3
26	29	3.6
27	45	2.2
28	28	3.8
29	83	2.7
30	64	3.4

Avg attention value after 30 trials	**54**

Table 4.1 Data Evaluation

In conclusion, our rationale behind setting the attention threshold for **actuation at 60** in our prosthetic system stems from an empirical examination of 30 carefully conducted trials. Through these trials, we endeavored to replicate real-world conditions, aiming for an average attention value of 54 over a specific timeframe. The choice of 60 as the actuation threshold represents a deliberate calibration to strike a balance between functionality and user accessibility. By selecting this threshold, we aim to ensure that the prosthetic actuation aligns with heightened user attention, a crucial aspect for intentional control. Simultaneously, the chosen value is practical and achievable for a diverse user demographic, reflecting our commitment to designing a system that is both precise and user-friendly. This strategic calibration is pivotal in optimizing the prosthetic control mechanism, fostering a seamless integration of technology into the daily lives of individuals undergoing transradial prosthesis, and enhancing their overall experience and independence.

4.2 Ansys Analysis

We are employing static analysis as our gripper consistently handles a 500ml water bottle during its operation. Static analysis enables us to assess stress distribution, deformation, and safety factors under steady-state loading, providing valuable insights into the gripper's capacity to withstand the anticipated forces. By utilizing ANSYS, we gain a deeper understanding of the gripper's mechanical response, aiding in the identification of potential failure points and guiding iterative design improvements. This approach not only streamlines the development process but also enhances the reliability and efficiency of the robotic gripper, contributing to the overall success of our project and its potential impact on assistive technologies for individuals with limb differences. The gripper's operation involves grasping and holding a standard-sized water bottle without rapid or dynamic movements; a static analysis has been chosen to provide accurate results. It allows us to assess the structural integrity of the gripper under the anticipated steady-state loading conditions, such as the weight of the water bottle.

<u>Total Deformation:</u>
In our ANSYS analysis of the robot gripper, the total deformation results reveal the extent of structural displacement under applied loads. This crucial output aids in assessing the overall flexibility and resilience of the gripper, guiding design improvements for optimal performance and longevity.

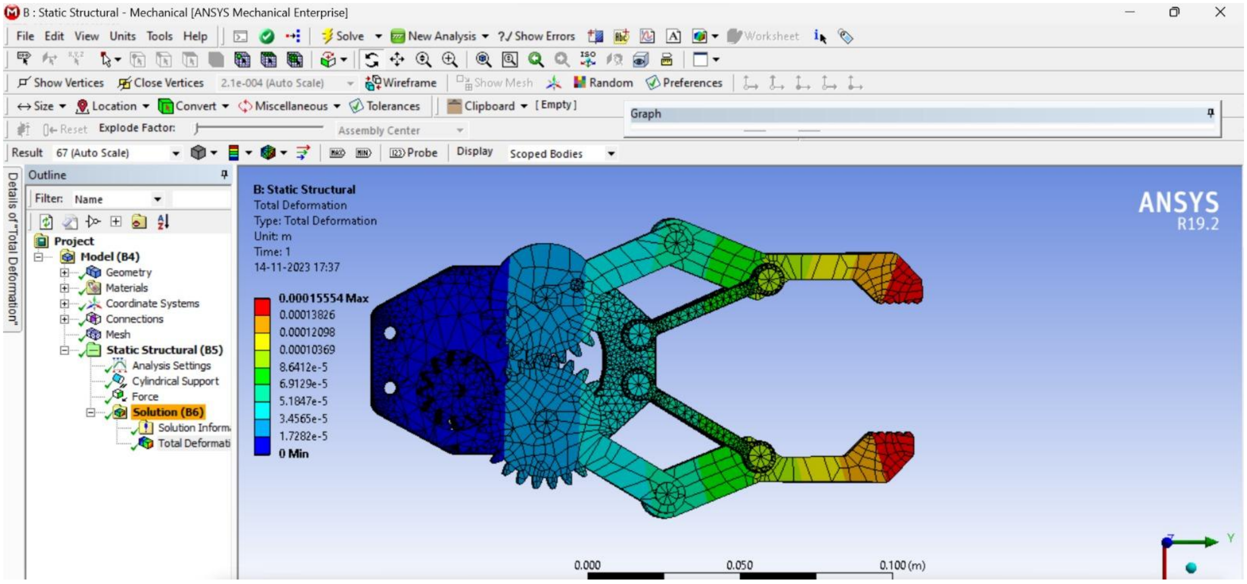


Fig 4.1 Total Deformation

<u>Max Principal Stress:</u>

The ANSYS analysis on our robot gripper includes the evaluation of maximum principal stress, a pivotal indicator of potential material failure. By identifying stress concentrations and critical areas, we ensure the gripper's structural integrity and guide design enhancements for enhanced reliability and safety in real-world applications.

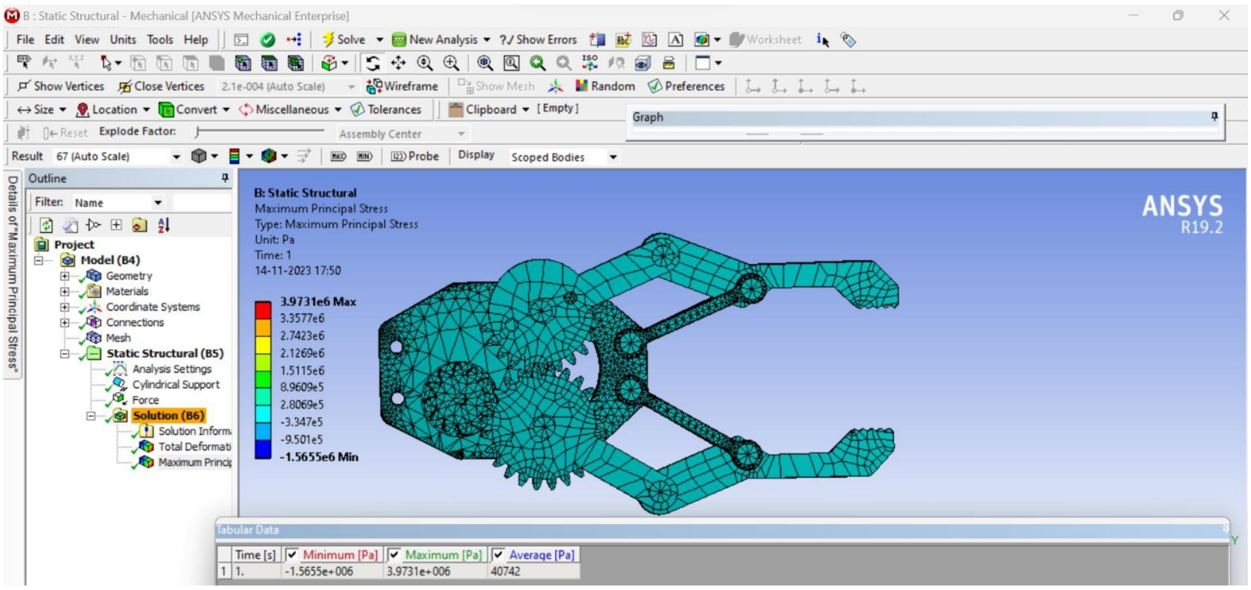


Fig 4.2 Maximum Principal Stress

CHAPTER 5
CONCLUSIONS AND SCOPE FOR FUTURE WORK

5.1 Conclusion

In conclusion, our research successfully addresses critical gaps in the existing literature on prosthetic arms. By implementing advanced design principles and leveraging EEG sensor data, our prosthetic arm demonstrates enhanced rigidity and movement precision, marking a significant advancement in the field.
Moreover, our usability evaluation across diverse user groups provides a nuanced understanding of the prosthetic arm's adaptability. The forthcoming comprehensive assessment of post-fitting impact on individuals' quality of life is anticipated to contribute valuable insights into the broader implications of prosthetic arm integration. The innovative use of gecko skin for gripping is poised to surpass the limitations of traditional designs, enabling the prosthetic arm to perform everyday tasks with remarkable functionality in future developments. Notably, our prosthetic arm successfully lifts a water bottle, demonstrating practical applicability and user-centric design.

This research contributes not only to the technical aspects of prosthetics but also addresses the holistic user experience, promising a positive impact on the lives of amputees. Our findings pave the way for future advancements in prosthetic technology, with the potential to redefine the standards of usability, adaptability, and overall quality of life for prosthetic arm users.

5.1.1 Bill of Materials

Sl no	Material	Cost
1	Arduino UNO	₹300
2	FT&S Mindlink EEG sensor	₹8000
3	Cys- S8218 Servo Motor	₹3000
4	HC-05 Bluetooth Module	₹200
5	Jumper Wires	₹40
6	3D printing	₹4000
7	4 Cell battery	₹80

Table 5.1 Bill of Materials

5.2 Future Scope

Enhanced Sensory Feedback: Integrate advanced sensory feedback mechanisms to provide users with a more natural sense of touch and grasp. This could involve incorporating pressure sensors in the gripper to detect the force exerted during grasping.

Machine Learning and Adaptability: Implement machine learning algorithms to enhance the adaptability of the robotic gripper. This would involve the gripper learning and adapting its movements based on individual user preferences and habits over time.

Improved EEG Signal Processing: Invest in research to improve the signal processing algorithms for EEG sensors. Enhancing the accuracy and speed of interpreting neural signals will lead to more precise and responsive control of the robotic gripper.

Gesture Recognition and Customization: Explore the integration of gesture recognition technologies to allow users to control the gripper through predefined or customizable gestures. This could be especially beneficial for performing specific tasks with varying levels of complexity.

User-Centric Design and Ergonomics: Conduct extensive user studies to understand the ergonomic requirements and preferences of amputees. Use this information to refine the design of the robotic gripper, ensuring it is comfortable, intuitive, and meets the specific needs of individual users.

Energy Efficiency and Power Management: Focus on developing energy-efficient systems and explore advanced power management solutions. This would aim to extend the battery life of the robotic gripper, making it more practical and user-friendly for everyday activities.

Collaboration with Healthcare Professionals: Foster collaboration with healthcare professionals, including prosthetists and rehabilitation specialists, to ensure that the technology aligns with the medical and rehabilitation requirements of amputees. This collaboration can lead to more personalized and effective solutions.

By focusing on these areas, future research can contribute to the ongoing development and improvement of robotic grippers for transradial prosthesis users, ultimately enhancing their quality of life and level of independence.

5.2.1 Gecko Skin

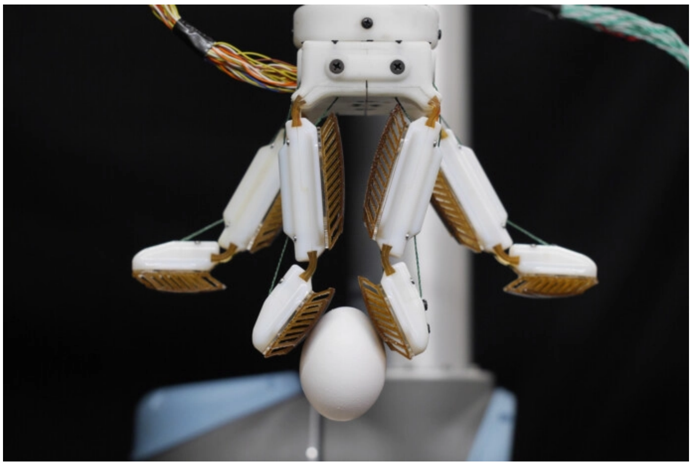


Fig 5.1: Gecko skin on a bionic arm

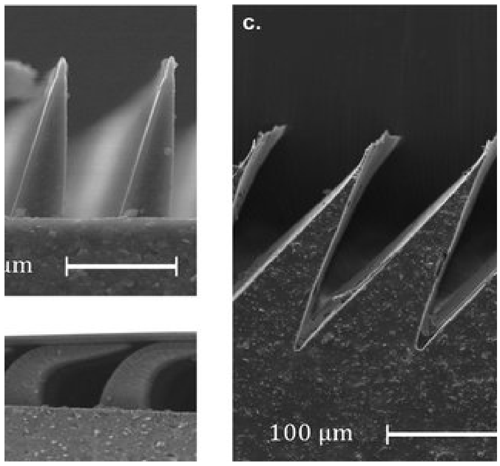


Fig 5.2: Microscopic view of a gecko skin

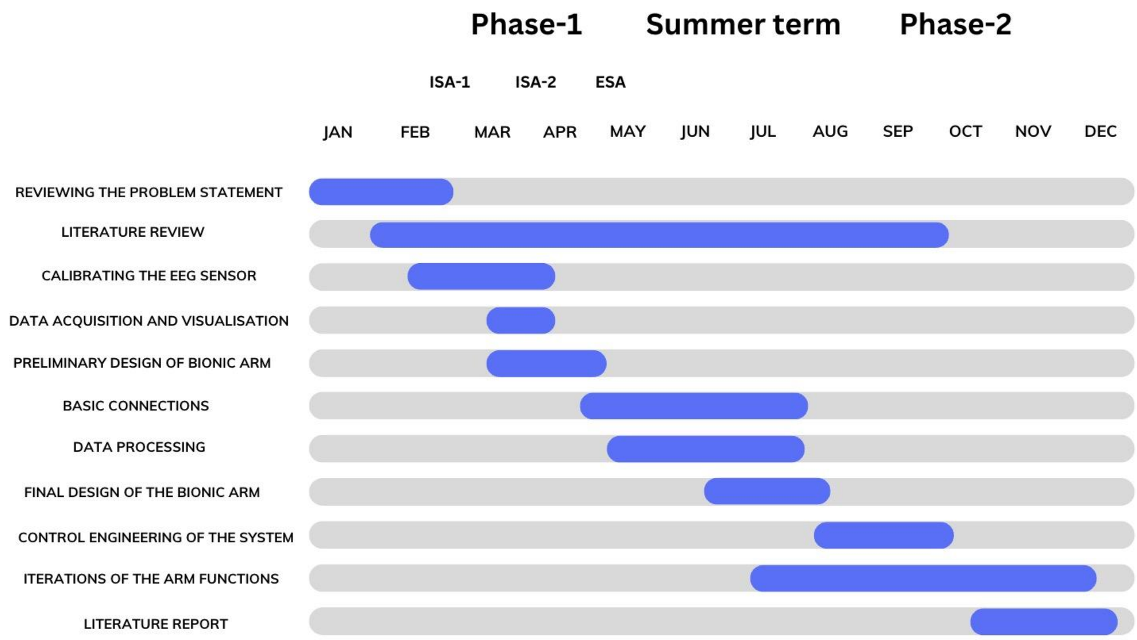
Gecko skin is a remarkable material that has inspired scientists to develop new technologies for a wide range of applications. One of the latest breakthroughs in this area involves the use of gecko-inspired adhesives in prosthetic arms that are controlled by an EEG sensor.

Researchers at Stanford University have developed a new type of prosthetic arm that uses gecko-inspired adhesives to provide a better grip and greater dexterity. The arm is controlled by an EEG sensor that detects electrical signals from the wearer's brain and translates them into movements of the prosthetic hand. The key to the success of this technology is the use of a new type of adhesive that mimics the properties of gecko skin. This adhesive is able to provide a strong grip on a variety of surfaces without leaving any residue, making it ideal for use in prosthetic arms.

Implementing this technology in a project requires a solid understanding of both the mechanics of the prosthetic arm and the EEG sensor that controls it. Researchers must also be able to develop and test new types of gecko-inspired adhesives that are compatible with the prosthetic arm and can provide the necessary level of grip.

Overall, the use of gecko skin in prosthetic arms controlled by an EEG sensor has the potential to revolutionize the field of prosthetics, providing greater dexterity and functionality to amputees and individuals with disabilities.

TIMELINE


Phase-1
Summer term
Phase-2
ISA-1
ISA-2
ESA
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
REVIEWING THE PROBLEM STATEMENT
LITERATURE REVIEW
CALIBRATING THE EEG SENSOR
DATA ACQUISITION AND VISUALISATION
PRELIMINARY DESIGN OF BIONIC ARM
BASIC CONNECTIONS
DATA PROCESSING
FINAL DESIGN OF THE BIONIC ARM
CONTROL ENGINEERING OF THE SYSTEM
ITERATIONS OF THE ARM FUNCTIONS
LITERATURE REPORT

REFERENCES

[1]Sahil Shaikh, Vaibhavi Jadhav, Jagrutee Dhanawade, Prof. Vishwajit Gaikwad.2020. EEG Controlled Prosthetic *ARM.International Research Journal of Engineering and Technology (IRJET) - 2020*

[2] R. Swetha, S. Nirmala Devi.2021. Design of Prosthetic Arm.*Open Access by IOS Press - 2021*

[3]S. Sree Krishna, V. Ramnath, Dr. Anjan Kumar Dash. 2019. EEG Controlled Bionic Arm. *International Conference on Computing, Power and Communication Technologies (GUCON) 2019*

[4]Taha Beyrouthy, Samer K Al Kork, Joe Akl Korbane, Alhamza Abdulmonem . 2016. EEG Mind Controlled Smart Prosthetic Arm. *IEEE - Institute of Electrical and Electronics Engineers 2016*

[5]Dany Bright, Amrita Nair, Devashish Salvekar, Prof.Swati Bhisikar. 2016. EEG-Based Brain Controlled Prosthetic Arm. *2016 Conference on Advances in Signal Processing (CASP) Cummins College of Engineering for Women, Pune. Jun 9-11, 2016*

[6]Dildar Ahmed Saqib, Urwah Arif, Jahan Zaib Islam, and Muhammad Qasim . 2018. Prosthetic Arm and Hand Design. *International Journal of Materials, Mechanics and Manufacturing,2018.*

[7]O A Ruşanu.2020. Arduino based mobile robot controlled by voluntary eye-blinks using LabVIEW GUI & NeuroSky Mindwave Mobile Headset. *IOP Conference Series: Materials Science Engg. 997 012059- 2020*

[8]Sarayu Pai. 2023. Gripping like geckos: Stanford lab develops the world's "stickiest non-sticky" material. *The Stanford Daily - Stanford Engineering - February 2023.*

[9] Gear solutions

https://gearsolutions.com/departments/tooth-tips/what-is-a-spur-gear/

[10] CYS MODEL
https://www.cysmodel.com/wp-content/uploads/2019/08/CYS-S8218-Specification.pdf

[11] TWI-GLOBAL
https://www.twi-global.com/technical-knowledge/faqs/what-is-pla