DESIGN AND FABRICATION OF A MYOELECTRIC CONTROLLED PROSTHETIC HAND

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ABSTRACT

The main goal of the project is to design and fabricate a Prosthetic Hand- A hand that can perform basic human activities using two degrees of freedom viz. gripping and releasing like holding an object, opening and closing doors ,etc. with load on the hand assumed to be 1 kg. The hand size is assumed to be made of standard human size. The beneficiary of this project is assumed to be Indian society and developing the project at an affordable cost is an important consideration. The major aspects of this prototype are design of the geometry of the hand, string pulley mechanism, selection of motor providing sufficient torque, programming of myoelectric sensors. The novel design incorporates four centrally actuated fingers powered to provide gripping and retraction motion. Provision is made in the palm design for mounting a D.C motor. Transmission of motion is achieved through a string pulley mechanism. The hand has been electronically programmed using myoelectric sensors to actuate the D.C motor at the will of the amputee. The myoelectric sensor picks up the signals from the target muscle in the forearm. The signals are of two types corresponding to the two motions of gripping and releasing. Accordingly, the D.C motor actuates in either direction and transmits the motion to the digits through the strings. Stainless Steel has been used as the material of the prototype, which has been manufactured using Laser cutting technique. The prototype has been successfully tested on people of different ages and sex. A prototype thus developed will serve as a platform for future modifications.

Keyword: - *Prosthetics, myoelectric sensors, string pulley mechanism, threshold, degrees of freedom*

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1. INTRODUCTION

In medicine, a prosthesis is an artificial device that replaces a missing body part, which may be lost through trauma, disease, or congenital conditions. Functional arm prosthetics can be broadly categorized into two camps: body-powered and externally-powered prosthetics. Body-powered prosthetics use cables and harnesses strapped to the individual to mechanically maneuver the artificial limb through muscle, shoulder, and arm movement. Externally-powered artificial limbs are an attempt to solve this physical exertion through using a battery and an electronic system to control movement. At the forefront of this technology is the myoelectric prosthetic.

1.1 PRESENT MARKET SOLUTIONS

Prosthesis has been used throughout history right from the Vedic times and the Egyptians being pioneers of this art. The modern prosthesis are closing the gap between biological human hand and prosthetic arm with modern technology providing better mechanical and electronic options, better materials and manufacturing techniques. Following are the few prosthetic hands available in the market.

- Be bionic Hand - et al [5]There are individual motors in each finger that allow the hand to be moved and gripped in the natural and coordinated way, further, the motors are positioned to optimize weight distribution making the hand feel lighter and more comfortable.
- Otto bock (Michelangelo's Hand) – In this hand, there is a provision for positioning the thumb separately. It provides a flexible wrist joint with seven different hand positions.
- DEKA Arm- et al [6]Also dubbed as DARPA'S Luka Arm after Skywalker's arm from Star Wars is the most advanced prosthetic arm which gives near natural control and enables the user to lift objects as delicate as a grape to big machine tools.

1.2 HUMAN HAND ANATOMY

There are over 30 muscles acting on the forearm and hand et al [1]. The human hand has 27 major bones and atleast 18 joint articulations with 27 or more degrees of freedom. The primary role of the hand is to enable a person to interact with the environment. The normal hand function is the result not only of a highly complex and versatile structural arrangement but also of an equally elaborate and fully automatic system of controls. In general, increasing the degrees of freedom of the hand results in a wider range of motions but at the cost of increasing complexities due to more number of actuators required for the additional degrees of freedom et al [4]

2. PROBLEM STATEMENT

The objective is to design and fabricate a Prosthetic Hand- A hand that can perform basic human activities using two degrees of freedom viz. gripping and releasing like holding an object, opening and closing doors ,etc. with load on the hand assumed to be 1 kg.

The design of the hand would require an in depth study to identify the mechanisms that could be used, and which would be the most suitable. Further, an actuator must be selected that can satisfy the torque requirements of the hand Once the design is finalized, the manufacturing processes could be initiated, and the appropriate components could be made according to the given specifications and calculations. Required changes could be made according to the dynamic issues faced in the design and manufacture. Once the hand is completed, the testing and analysis of the functionality of the hand would be needed to be carried out extensively.

3. MECHANISM

We have selected Wire Rope (Cable) mechanism for the application. The main advantage of the mechanism is that the size of the drive system is compact. Further, the drive link is long and flexible, its operation being smooth and silent. The working principle of the string pulley mechanism is as follows:

- The strings are passed from the fingers to the motor through the pulleys.
- As the motor rotates in say clockwise direction, the strings transfer the torque to the fingers through the pulleys.
- The length of the string being constant, the string starts wrapping around the motor thus pulling the fingers inwards (Gripping motion).
- When the motor is rotated in counter clockwise direction, the strings start unwrapping and the fingers move outward (Releasing motion).
- The controlled retraction is obtained using springs fitted on the fingers.

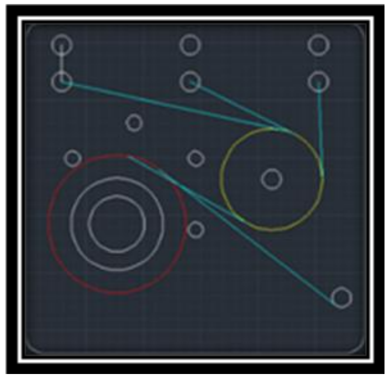

Figure 1: Mechanism

4. DESIGN OF COMPONENTS

4.1 Selection of Actuator

Actuation	Power (Torque)	Weight	Torque to weight ratio	Control	Cost	Size	Accessories
D.C Motor	Medium	Medium	Lowest	Better	Medium	Medium	Encoder, Feedback for controlled motion
Servomotor	Low	Low	High	Best	Medium	Small	Nil
Hydraulics	High	Medium	Medium	Good	Highest	Large	Pump, Reservoir, Solenoid Valve ,Motor ,FRL Unit
Pneumatics	High	Medium	Medium	Bad	Highest	Large	Reservoir, Solenoid Valve, Compressor
Mechanical	Medium	Least		Manual	Least	Small	

Table 1: Comparison of actuators

Based on the comparison, we selected D.C. Motor as an actuating mechanism.

4.2 Design of Essential Components

Spring:

Material: Stainless Steel.
Ultimate Tensile Strength:1700MPa
Spring index C:5
Coil diameter (D): 4mm
Wire diameter (d): 0.5 mm

Et al [3]

Wire Rope:

Diameter: 1mm
Strand: 7x7 Wire Rope
Material: 1770 Galvanized Steel

Et al [3]

5. DEVELOPMENT OF PROTOTYPE

5.1 Assemblage of Fingers and Palm

Finger Design
The prosthetic hand consists of four fingers. These are two middle fingers, one index finger and one thumb. Each finger is made of two identical parts. Provision in the form of drilled holes is made to connect two identical parts to form an individual finger. Three nut bolt assemblies are required to form each finger.

Palm Design
A 3D model of the palm is shown in the assembly. A central hole is provided as a provision for mounting the D.C motor. Holes are drilled for mounting of U shaped links which are used to connect the fingers to the palm through a nut bolt assembly. Provision is also made for mounting a pulley to facilitate the centrally actuated string pulley mechanism.

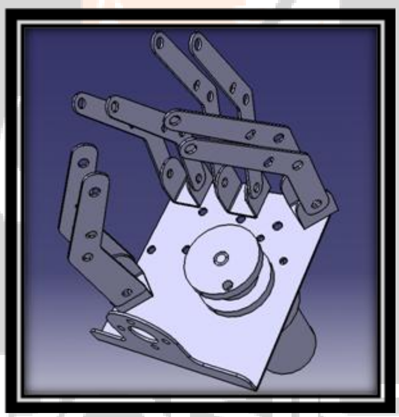

Figure 2: Hand Assembly

5.2 Manufacturing Technique

Laser Cutting Technology:
Laser cutting is a technology used to cut metals and is typically used for industrial applications. The laser optics and CNC (computer numerical control) are used to direct the material or the laser beam generated. A typical commercial laser for cutting materials would involve a motion control system to follow a CNC or G-code of the pattern to be cut onto the material. The focused laser beam directed at the material, which then either melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high-quality surface finish. The links used for forming fingers as well as the palm of the hand have been fabricated using laser cutting technique.

5.3 Prototype 1
Our main objective in this prototype was testing the string pulley mechanism which we had designed for the gripping and releasing motion of the fingers as well as testing the feasibility of the manufacturing method i.e. laser cutting technology.
Features of prototype 1:

- Provision was made for 5 fingers including thumb.
- Three pulleys were used over which the strings were passed which were further connected with the fingers.
- Once the gripping motion was done, no provision was made for retraction motion.

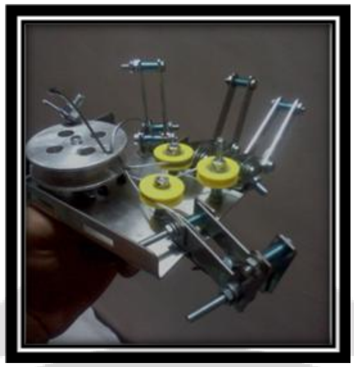

Figure 3: Prototye 1

Conclusions from prototype 1:

- The number of fingers used were 5, but we concluded that most of the gripping operations could be done with 4 fingers.
- There were 3 pulleys used in the prototype which could be reduced to just one pulley.
- No provision was provided for the retraction motion in this prototype due to which the hand wasn't smoothly functioning.
- The laser cutting method for manufacturing was found out to be feasible and was finalized for the manufacturing of other prototypes also.
- The overall weight as well as size of the hand could be reduced.

5.4 Prototype 2

With a rough idea of how the hand would look like which we got from the first prototype, we made the second prototype. The objectives in designing this prototype were mainly focused on making the model lighter, compact and smooth in working.

Features of prototype 2:

- The number of fingers was reduced from 5 to 4.
- The number of pulleys used in the string pulley mechanism was reduced from three to just one pulley.
- The overall palm size was reduced which made the hand much lighter and compact.
- Also, the joints in the individual fingers were reduced. The shape of the finger itself was made slightly slanted which helped in better gripping of objects.
- Springs were provided in each finger for controlling the retraction motion.
- Provision was made for motor mounting in this prototype.

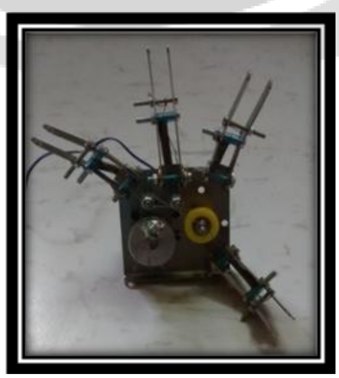

Figure 4: Prototype 2

Conclusions from prototype 2:

- We tested the electronic as well as mechanical aspects in this prototype.
- The motor was successfully running when the required signals were received by the myo sensors, thus the gripping and releasing motion could be successfully carried out.
- The weight was successfully reduced by reducing the number of fingers, pulleys as well as size of the palm.

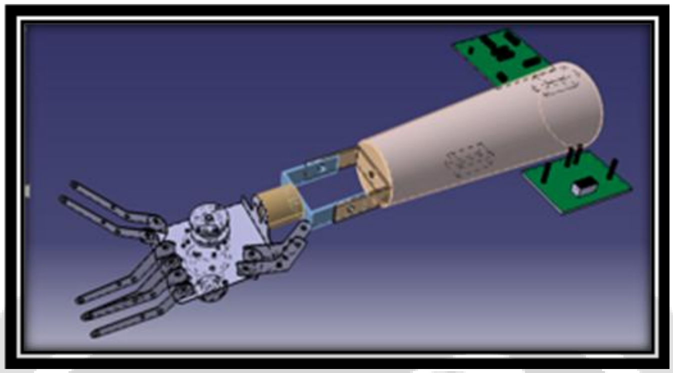

Figure 5: Prototype model

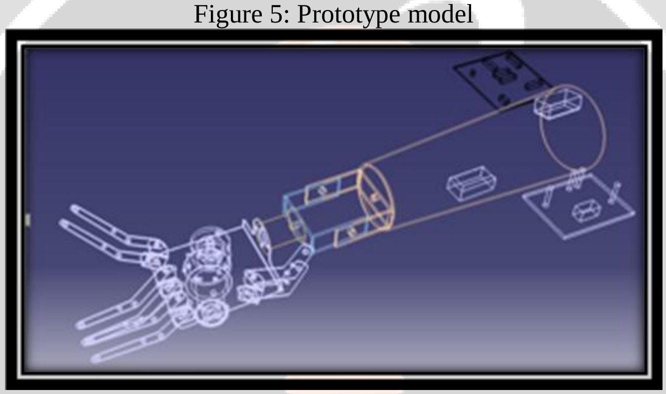

Figure 6: Prototype model

6. SENSOR AND TESTING

For the prosthetic hand to work, we require a signal from the human body. This is in the form of micro voltages from the muscles. We have identified the target muscle in the forearm for this purpose. The signals are picked up by the myoelectric sensor. When the target muscle is relaxed, low readings are recorded, and when the muscle is contracted, higher values of readings are obtained. We take the averages of the lower set of values and the higher set of values. This is now the absolute higher and lower value. Depending on these recorded values, a threshold value is set and stored in memory. This threshold is set in such a way so as to prevent getting false positives. Instead of just taking the average value from the lower and higher reading, we have set the threshold close to the higher value. The actuator is given the signal based on the threshold value. Every time the sensor obtains a value higher than the threshold value, it sends a signal to the actuator, which in turn causes the gripping movement. Thus, every time an amputee contracts the muscles in his forearm as he/she would ordinarily have done, if he/she had his hand, it results in the closing of the fingers of the prosthetic hand. Similarly, we have also identified target muscles on the back arm which are used for the opening of the hand.
We have tested the sensor on people having different ages and sex. Some of the sensor readings (when the target muscle is relaxed and contracted) are shown in the table. We have tested the sensor for age group from 13 years to 54 years. Based on the observations, we noted the following points:

- The lower and the upper readings (i.e. when the muscle is relaxed and clenched) vary from person to person. Hence it is not possible to set a common threshold for everyone.
- The threshold for a person usually doesn't vary much once set the range of reading, the upper and lower limit as well as the threshold remain same for a particular person.

- It was also observed that for some people as the muscle action changed from clenched to relaxed, the values dropped down very quickly whereas as for some they took a significant dropdown time.
- One thing common for all the people was that there was always a significant change in values which could be used to differentiate between the two muscle actions.
- Sensor positioning was a critical task, choosing the right muscle gave the perfect reading with a very large difference as well as fast dropdown when muscle position was changed from clenched to relax.

Sr No.	**Name**	**Age**	**Sex**	**Value (Muscle Relaxed)**	**Value (Muscle Contracted)**	**Threshold Value**
1	Tester 1	21	M	76	372	224
2	Tester 2	21	F	125	192	158
3	Tester 3	22	M	150	550	350
4	Tester 4	49	F	127	416	343
5	Tester 5	53	M	107	156	143

Table 2: Sensor Readings

7. CONCLUSION

India's escalating population coupled with the environmental accidents, lack of basic health safety, vascular diseases, diabetes, gangrene, birth defects, cancer, trauma and infections are increasing the number of amputees in India at an alarming rate. At present, in India, the research and development effort about prosthetics is inchoate and marginal. There is a huge void in the availability of prosthesis and the number of amputees. Unless we develop our institutions and use technology which is accessible to the blue collar section of society, there will be an accruement of thousands of amputees every year and these people 'may not succeed or might not be accepted by the society'.
Hence, we have made an effort to fulfill this void by developing a myoelectric prosthetic hand and have achieved success in the following aspects:

- The hand has been made at an affordable price.
- Weight of the hand has been optimized to be around 1 kg.
- The myoelectric sensor was tested successfully in integration with the string pulley mechanism on a number of amputees.

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REFERENCES

[1]. The Anatomy and Mechanics of Human Hand by Craig L Taylor, Ph.D. and Robert J Schwarz, M.D.
[2]. National Sample Survey Organisation Ministry of Statistics and Programme Implementation, Government of India.
[3]. Design of Machine Elements by V.B.Bhandari
[4].Gray's Anatomy by Henry Gray
[5] www.bebionic.com
[6] www.dekaresearch.com