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FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Industrial

Tesis

Design of a prototype of a hand bionic prosthesis with independent mobility and three-dimensional wrist rotation controlled by sEMG sensors

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Para optar el Título Profesional de
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Design of a Prototype of a Hand Bionic Prosthesis with Independent Mobility and Three-Dimensional Rotation of the Wrist Controlled by sEMG Sensors

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***Abstract*— The present research consists of the mechanical and electronic design of a hand prosthesis that is composed of a parallel robot platform to perform the movement of the wrist, on this platform 3 universal joints will be mounted that will be connected to the base of 3 linear actuators that represent a prismatic joint for the extension and flexion movement of which will be controlled by an Arduino Mega type board. The design of the prosthesis consists of a base that represents the palm of the hand joined to the proximal phalanx, which will be attached to the medial phalanx and finally attached to the distal phalanx assembled by means of mechanical couplings that will represent the fingers of a human hand, the mechanism for its movement will be through the medial internal link and proximal internal link to the interior of each finger interconnecting each phalanx and finally connected to the terminal link that is attached to the axis of the MG90S servo motor, that will allow the mobility of the links and in turn of the phalanges. Likewise, for the individual mobility of the thumb, a proximal internal link is used inside, 2 servomotors for the lateral and contralateral opposition of the thumb. These actuators will be controlled by the same microcontroller mentioned above. For the drive of the motors, EMG sensors are used to capture the user's intention of movement through muscle pulses of the residual limb, the methodology applied for this design is based on three stages (mechanical stage, electronic stage and the integrative stage). As a result, it is obtained that the design of the prosthesis achieves the independent movements of each finger and wrist, also the good communication of the sensors and actuators.**

Keywords*— *Servo motors, phalanges, parallel robot, muscle pulses.

I. INTRODUCTION

The activities carried out by human beings involve the exposure of hands and feet, the loss of the upper limbs generates a lifetime disability affecting psychologically and physically the people who are victims of these amputations.

The first prosthesis in the history of mankind was created in 2000 BC that consisted of a prototype of upper limb that was found in Egypt, in 1696 Pieter Verduyn developed a prototype of a lower limb prosthesis that marked a precedent in history to develop articulated prostheses [1]. Over the years, technology evolved and electronics was an important pillar for machine control, and prostheses evolved from being mechanical with certain joints to becoming intelligent systems that integrate sensors so that the user has better control of these devices [2].

Despite the evolution of prostheses there are details that the creators did not consider such as wrist movements, independent movements of each finger, high costs, etc. For this reason, it is important to design prototype prostheses that integrate these deficiencies [3].

The objective of this article is the mechanical design of a prototype of a prosthesis that contemplates the independent movements of each finger and a parallel robot design will be applied for the movements of the wrist. For the control of the drive of the hand motors, sensors are used to detect the patient's intention of movement, a triaxial accelerometer is also used for the movement of the actuators of the parallel robot. For signal processing an Arduino Mega controller is used, this device will allow the communication of sensors and motors.

II. METHODOLOGYA

For the design of the prototype of the upper limb prosthesis for transradial amputation will be made up of 3 important stages, stage 1 is the mechanical design where the prototype of the hand and wrist is developed. Stage 2 is the electronic design where the interaction of the sensors with the actuators is considered and stage 3 will contemplate the integration of mechanical design and electronic design.

A. Mechanical desing

To develop the mechanical design, standardized measurements are considered according to height as shown in Fig.1, the prototype design is focused for a height of 168 cm.

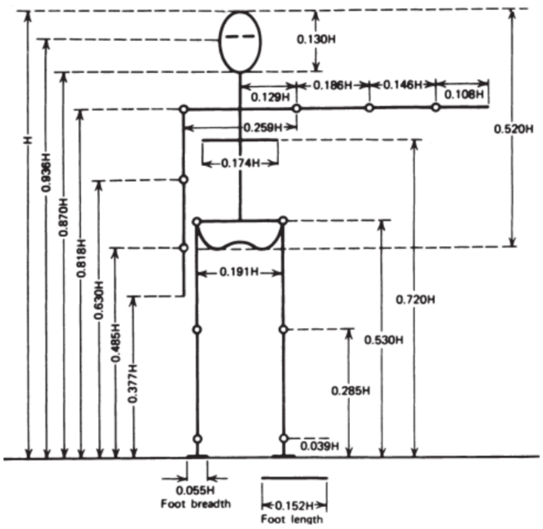

Fig. 1. Standardized measurements of the parameters of the human body as a function of height [4]

To make the design of the hand we must consider the bone structure that is divided into phalanges, metacarpal and carpus that make up 27 bones as can be seen in Fig.2, it should also be considered that the hand has 21 degrees of freedom. [5]

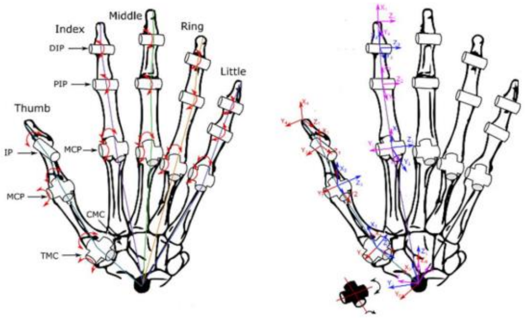

Fig. 2. Conformation of the bone structure of the hand and degrees of freedom. [5]

The design of the proposed prosthesis aims to achieve the greatest number of movements performed by a human hand, in Fig.3. Hand movements are observed.

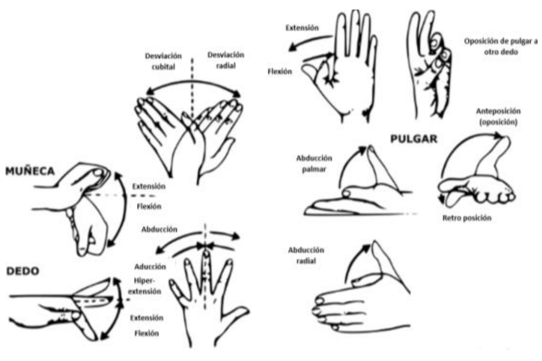

Fig. 3. Wrist and finger movements. [6]

In Fig.3 the movement of the wrist that makes up the extension and flexion is also observed, for the design of the prototype a parallel robot structure will be used or also known as the Stewart platform that will be composed of three linear actuators achieving the movements of the wrist. Fig.4 shows the original design of Stewart's mechanism.

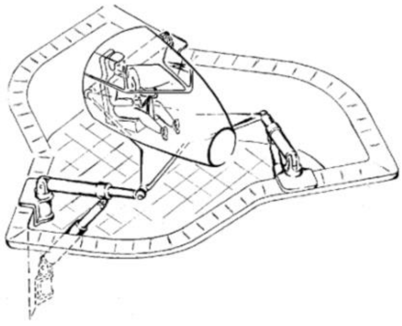

Fig. 4. Stewart Platform Mechanism. [7]

The Stewart Platform provides the design with six degrees of freedom thanks to the independence of movements of the linear actuators that at their ends have spherical movements type ball joint achieving movement at their point of contact. Fig. 5 shows the design of the movement.

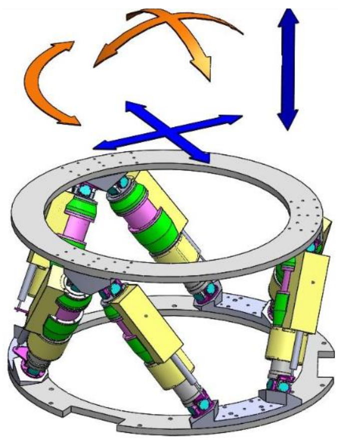

Fig. 5. Parallel robot model [8].

Fig.6 shows the isometric and frontal view of the design of the proposed prosthesis where each component that makes it up is described.

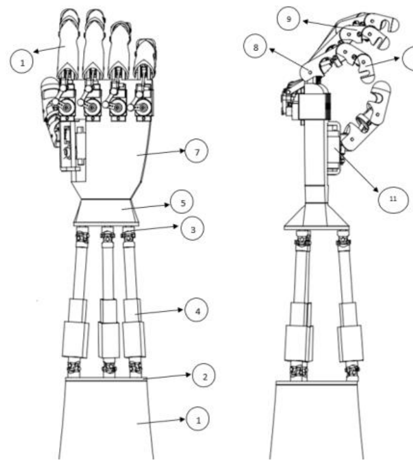

Fig. 6. Isometric and frontal view of the proposed prosthesis.

In the views shown the following elements can be observed:

Socket (1), fixed platform (2), universal articulation (3) linear actuator (4), mobile upper platform (5), palmar base (7), proximal phalanx (8), medial phalanx (9), distal phalanx (10) and servomotor (11).

For the design of the fingers of the prosthesis, a drive system was made through links this allows better support and precision. In general, most prosthesis designs are based on rope drive, in Fig. 7 the design of finger links that is driven by an MG90S servomotor is observed, in the globe 11,15 and 16 the proximal internal links are observed.

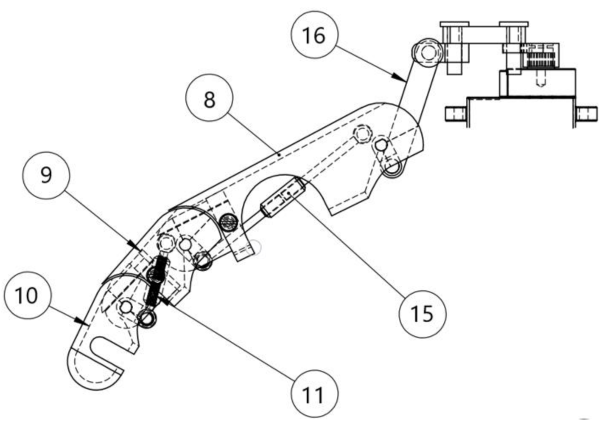

Fig. 7. Mechanical design of the finger drive system of the prosthesis.

B. Electronic design

For the actuation of the actuators EMGs sensors will be used, these devices have the ability to capture muscle pulses. It is important to consider that this prototype is designed for patients who suffered transradial amputation, that is, the residual limb still shows intention of movement in Fig.8 shows the sequence of signal detection and processing of the controller for the drive of the motors.

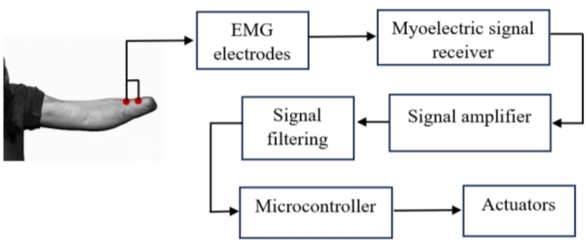

Fig. 8. Block diagram of EMG signal processing and control.

For the movement of the fingers of the prototype of the prosthesis the EMG sensor is used, but to control the movements of the parallel robot (wrist movements) a triaxial accelerometer of type MPU-6050 is used that will be located in the residual limb, this device will generate a three-dimensional reading (x, y, z axis) that will serve to activate the linear actuators in Fig. 9 the location of the three-dimensional sensor and the control is observed of each linear actuator.

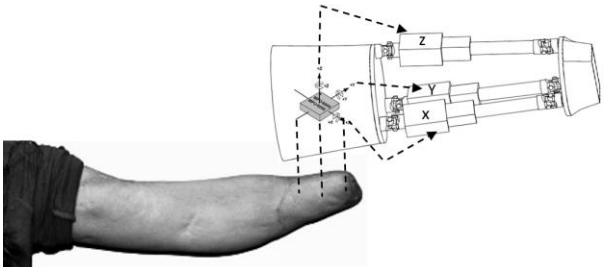

Fig. 9. Location of the three-dimensional sensor.

With Proteus software, the electronic circuit that will control the servo motors is designed. Taking into account the number of sensors and motors that will be used in the design of the prototype, the Arduino Mega board is used because it has 54 input and output pins of which 15 are PWM type and has 16 analog input pins, this controller will allow the processing of signals captured by the sensors to drive the appropriate actuators in Fig. 10. The electronic circuit that will control the prototype is observed.

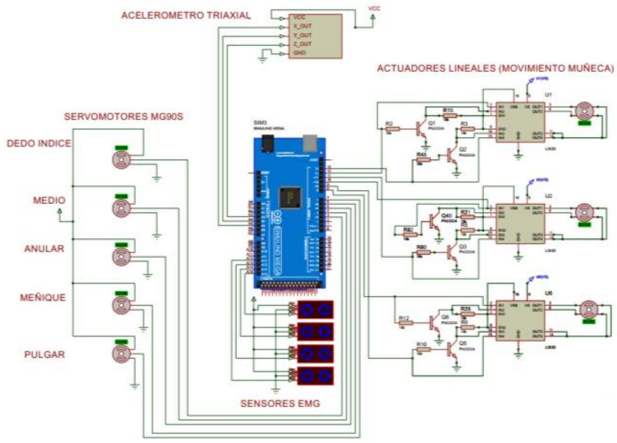

Fig. 10. Electronic circuit of the prototype of the prosthesis.

In Fig 10. The interaction of the sensors with the controller is observed, it is also observed that the linear actuators have an H bridge type driver to control the extension and compression of the opposite situation of the servo motors that have a microcircuit inside for the rotation control of each servomotor. EMG sensors use analog input pins A12, A13, A14 and A15 for control of the servo motors occupying the digital outputs, for the index finger digital output 3, for the middle finger digital output 4, for the ring finger digital output 5, for the little finger digital output 6 and for thumb digital output 7 as shown in Fig. 9. The triaxial accelerometer uses 3 analog pins for X pin A3, Y pin A4 and Z pin A5 respectively for the control of linear actuators that use two digital pins to open and close the rods of each motor, for the actuator controlled by the X signal it uses pins 8 and 9, for the actuator controlled by the Y signal use pins 10 and 11 and for the actuator controlled by the Z signal use pins 12 and 13.

C. Interaction of mechanical and electronic design

Fig.11 shows the interaction of electronic and mechanical part, where the location of each component that makes up the prototype of the prosthesis is represented.

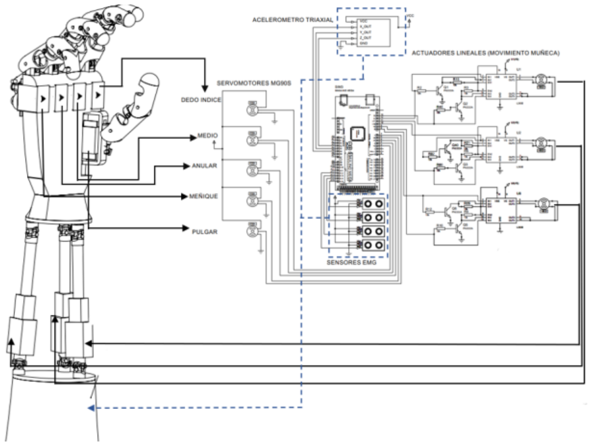

Fig. 11. Interaction of mechanical and electronic design.

Table I shows the electronic components and their characteristics that were used for the simulation of the circuit.

TABLE I. ELECTRONIC COMPONENT

Components	Description	Amount
Arduino MEGA	Motor control card	1
Sensor EMG	Detects the intention of movement of the arm and forearm	4
Driver L293	It allows the hourly and counterclockwise rotation of the actuators.	3
Triaxial accelerometer	located in the shoulder because it has two degrees of freedom	1

III. RESULTS

By performing the motion control in SolidWorks software, it is possible to perform the extension and bending movement through the parallel robot (Stewart Platform) as shown in Fig. 12.

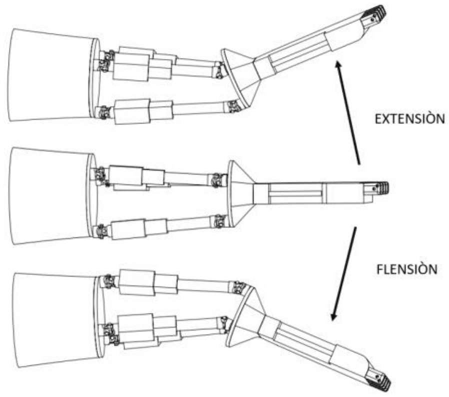

Fig. 12. Prototype wrist movement analysis (Flexion and Extension)

It was also possible to perform the clamp movement between the index finger and the thumb, this movement action is very important to hold small objects, the design raised with internal mechanical links helped to have a better control of these movements in Fig.13 it is possible to observe clamp type movement.

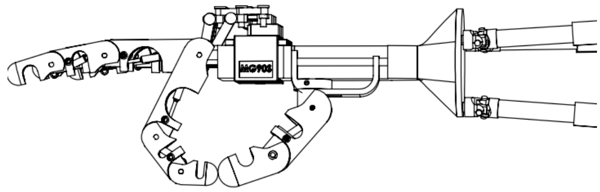

Fig. 13. Clamp-like movement between thumb and forefinger.

The synchronization of all the actuators was also achieved by performing the grasping movements, in Fig.14 the grip and opening of the prototype design is shown.

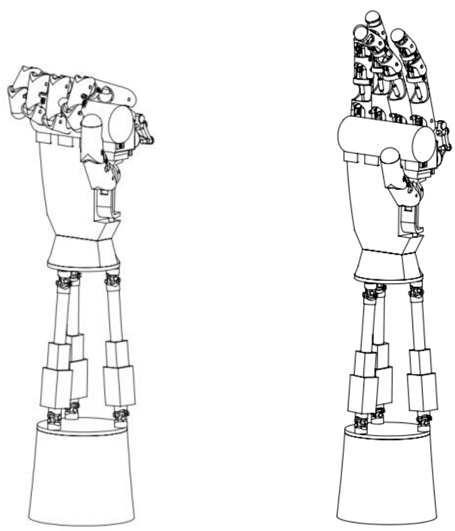

Fig. 14. Grip and opening of the prototype design

IV. CONCLUSIONS

With the design of the prototype, it was possible to perform the main movements of hand and wrist, the incorporation of a parallel robot controlled by triaxial accelerometer gives the design better control depending on the user's intention of movement.

With this design proposal through internal and external links, precision is achieved in the operation of the fingers, it also provides strength when holding objects because a servo motor was implemented for each finger.

The intention of this design is to have a good filtering of muscle signals so that the controller can process it and activate the actuator of the appropriate fingers, it is important to detail that this design is aimed at patients with transradial amputation and have some muscle movement in the residual limb because the EMG sensors can capture the patient's intention of movement.

In the electronic simulation, a correct interaction of the sensors with the Arduino Mega controller was achieved, achieving the appropriate actuator drive. This research is a first stage of design is expected an improved version having more focus on aesthetics and ergonomics.

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