ACTIVE ANKLE PROSTHESIS

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Abstract*– *According to a large number of people with diabetes, peripheral vascular disease, neuropathy and trauma, we find a large number of amputees. These people lose their jobs, their routines, their lives. All this is supposed to have a negative effect on amputees and push them into depression. Therefore, we need to help them to go on with their lives normally and not be dependent on society. Where prosthetics were in the 20th century, their main drawback was that they were not part of the human body, and therefore amputees could not feel them, so they must always monitor and focus on the position of the leg; So that they do not fall to the ground as they walk.* Active Ankle Prosthesis is the important field in now days it helps amputee to return our partial of their life's. Prosthesis now days doesn't use for cosmetic purpose, but it must do their duty in best ways. In our report, we will talk about gait cycle of ankle (below knee), mechanism of prosthesis & how we implement it in real. Then, we will talk about graphs and equation followed to achieve the gait cycle in right way with respecting the torque and speed of ankle. All that *must follow with allowable load of prosthesis corresponding of weight of the man. Then we will talk about control strategy of prosthesis & control circuit & application to detect the patient wants the ankle to be on it.

Keywords— Gait Cycle— speed of ankle— weight of human— torque and position of ankle— weight of prosthesis_ control strategy_ components selected _ control circuit _ application.

I. Introduction

There are many patients who lost their leg or part of their leg in accidents. Below the knee amputations is an alarming health problem, causing high rates of physical, mental and considerable social impact on the amputee. The need for mechatronic prosthesis is booming to aid the patients to continue their life efficiently. The goal of the active ankle is to mimic the function of areal ankle to make the amputee able to participate in day to day. From different types of active ankles, we mentioned the choice of mechanical design due to low cost, easy maintenance & easy manufacturing. We used ball screw, high torque motor, timing pulley & other parts in this mechanism to perform & fit movement, torque and speed of the ankle foot. Ball screw used to reduce torque of ankle to torque equal motor after timing pulley. Then, we selected aluminum material to have ability to carry the weight of the human without failure in system. To mimic the ankle joint, there needs to be a smart system and this smart mechatronic system starts with detecting the phase in which the ankle joint is in the gait cycle and this is achieved by certain sensors electronic component to monitor the gait cycle and return feedback of system. Also, we apply application on mobile to select type of movement (walk or run).

II. Working Principle

A. Mechanical Studies

1) Gait cycle

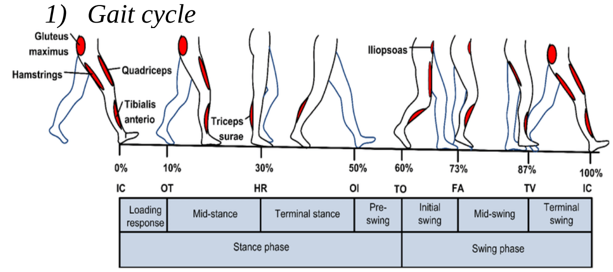


Fig. 1 Gait Cycle

2) Speed

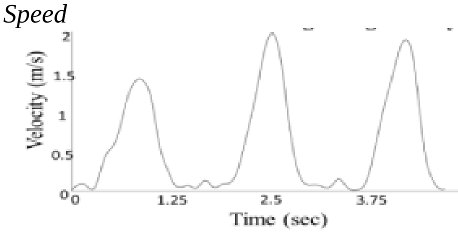


Fig. 2 speed of ankle

3) Torque

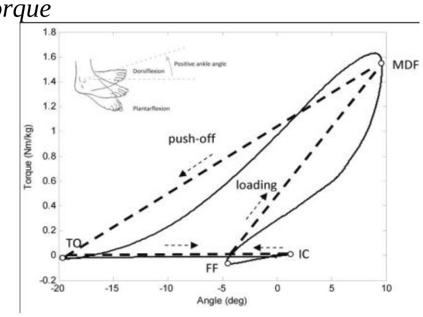


Fig. 3 Torque of ankle

4) Angle

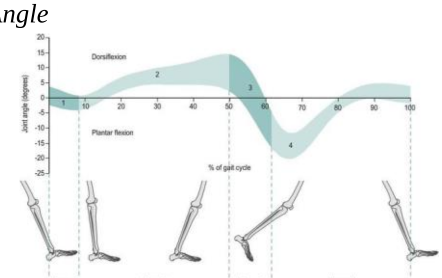


Fig. 4 angle of foot

B. Control

1. CONTROL STRATEGY

2. COMPONENTS SELLECTED

3. COMPONENTS CIRCUIT

4. APPLICATION

III. Methodology

A. Forces on Ankle

1) Heel-Strike

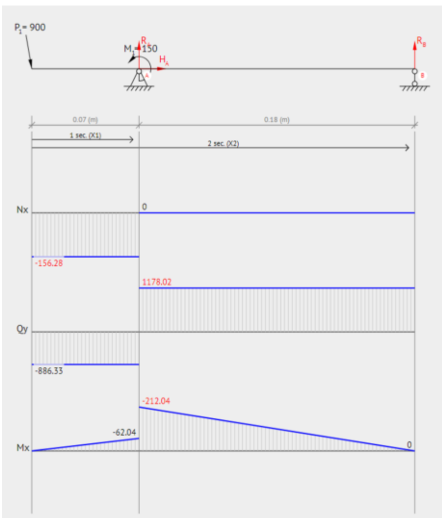


Fig. 5 forces in heel strike phase

2) Stand phase

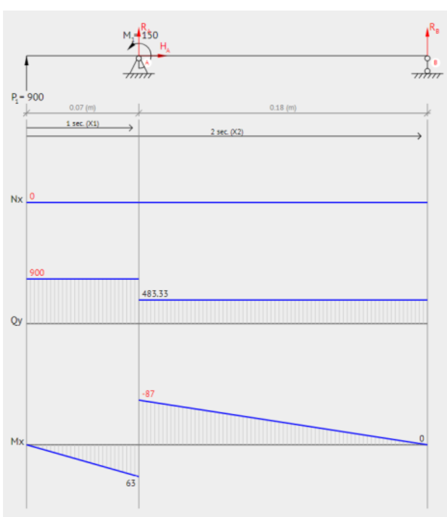


Fig. 6 forces in stand phase

2) Toe Off

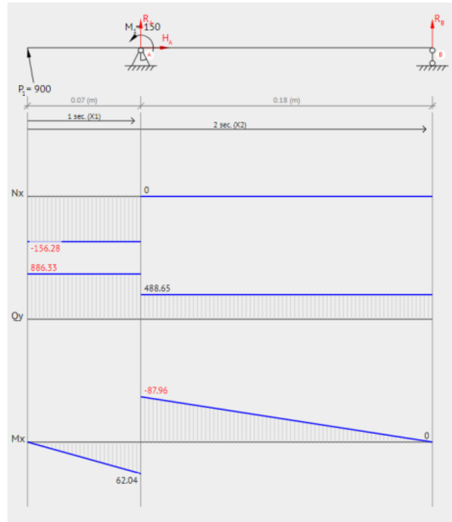


Fig. 7 forces in toe off phase

B. Mechanical Design

1) Material: we used aluminum due to high strength and light in weight of it. We now had ability to carry heavy weight with light body

2) Design:

2-1) Timing pulley: used to reduce speed and increase torque of motor

Fig. 8 Timing pulley

2-2) Ball screw: used to increase torque to ankle to had ability to move

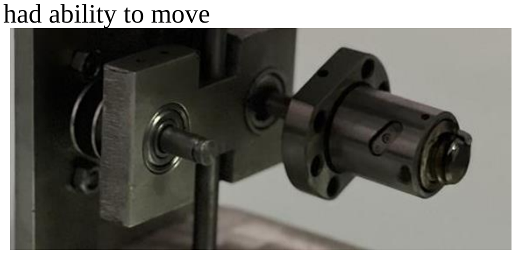


Fig. 9 ball screw

2-3) foot: used layers of natural leather and it has ability to carry up to 135 Kg

Fig.10 Foot

2-4) pyramidic connector: used to connect prosthesis to leg

Fig.11 pyramidic connector

3) Stresses on body:

3-1) Foot:

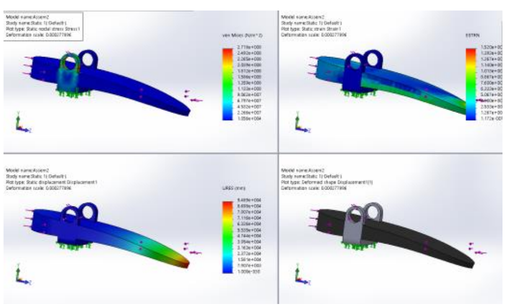


Fig.12 stresses on foot

3-3) Ankle:

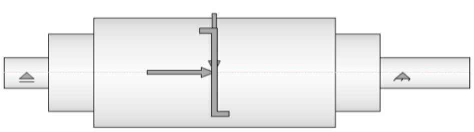


Fig.13 stresses on ankle

Length	L	104.000 mm
Mass	Mass	0.323 kg
Maximal Bending Stress	σ_B	275.465 MPa
Maximal Shear Stress	τ_S	55.105 MPa
Maximal Torsional Stress	τ	0.000 MPa
Maximal Tension Stress	σ_T	3.979 MPa
Maximal Reduced Stress	σ_{red}	291.531 MPa
Maximal Deflection	f_{max}	10.487 microm
Angle of Twist	φ	0.00 deg

Fig.14 stresses on ankle

3-3) Body:

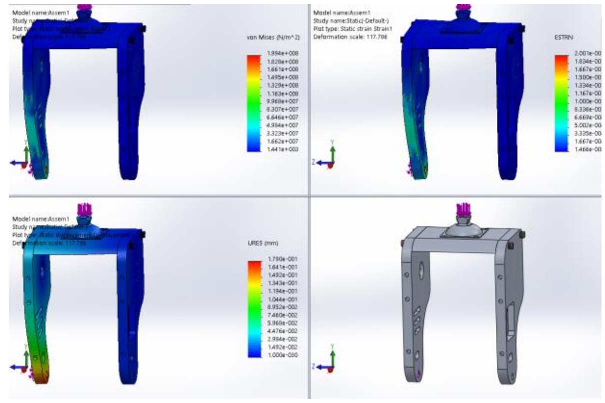


Fig.15 stresses on body

3-4) Ball Screw:

We will calculate at high force F = 900 N

$$T = \frac{F_a L}{2\pi * \mu} = \frac{900*5*10^{-3}}{2\pi*.9} = 0.8\ N.m$$

Determine the diameter of the ball screw

$$\tau = \frac{16T}{\pi {d_r}^3} = \frac{16*.8}{\pi*(13*10^{-3})^3} = 1.9\text{Mpa}$$

$$\sigma_{axial} = \frac{F_a}{\pi * {r_r}^2} = \frac{900}{\pi(6.5*10^{-3})^2} = 6.8\text{Mpa}$$

$$\sigma_{max} = \sqrt{{\sigma_{axial}}^2 + 3\tau^2} = 6.8\text{Mpa}$$

$$\text{Safety factor} = \frac{\sigma_{strength}}{\sigma_{eq}} = \frac{620.4}{6.8} = 92\ (\text{safe})$$

Buckling load of ball screw

$$P = \frac{\gamma \pi^2 EI}{L_b^2} = \frac{2 \times \pi^2 \times 200 \times 10^9 \times 1.4 \times 10^{-9}}{(2 \times 8 \times 10^{-2})^2}$$

$$= 216\ \text{KN} > F_a (\text{safe})$$

$$I = \frac{\pi\, d_r^4}{64} = \frac{\pi(13 \times 10^{-3})^4}{64} = 1.4 \times 10^{-9}\ m^4$$

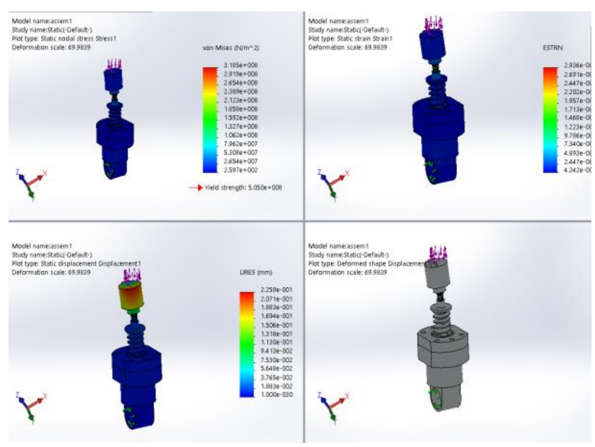


Fig.16 stresses on ball screw

3-5) Ball Screw:

We choose belt 3:1

$$Z_{driver} = Z_2 = 60$$

$$Z_{drives} = Z_1 = 20$$

$$n = \frac{d_2}{d_1} = \frac{47}{33} = 1.4$$

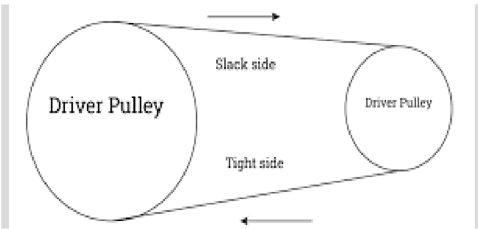


Fig.17 Timing pulley

B. CONTROL

1. CONTROL STRATEGY

In our strategy we used two load cells in the front of the foot each one with acceptable maximum load up to 50kg and at the heel we used two strains gauge each one with acceptable maximum load up to 50kg.The normal man walk at speed 1m/s each meter takes in walking average 3 steps by the two limbs. So, he takes 10% in loading response, 20% in mid stance, 20% in terminal stance, 10% in pre swing, 13% initial swing ,14% in mid swing and 13% in terminal swing. In running the normal man runs at speed 3.6m/s and it happen when the double touch of the stance phase decreases. So, it happens when the heel strike and the toe off happen in a short time. But in our mechanism minimum time to make a planter flexion and dorsiflexion is 0.3s, so we make in our project two modes: running mode and walking mode. So, in our project we make the walking mode and the running mode three times the normal human average to be capable with our mechanism.

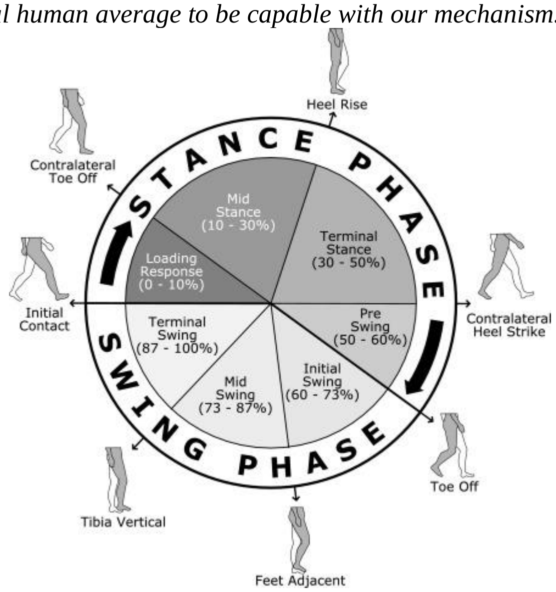
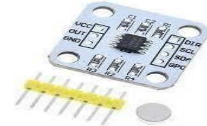
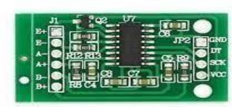
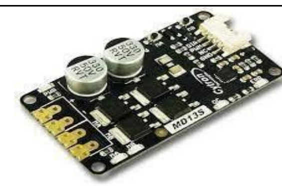


Fig.18 Strategy of walking

2. COMPONENT SELECTED

Table1

COMPONENTS

Components	Description	Image
Esp32	Microcontroller	
Load cell	Strain gauge sensor full bridge	
AS5600	Magnetic encoder	
HX711	Amplifier (analog to digital converter)	
MD13S	H-bridge motor driver	
converter (Buck converter)	Decrease volt	
RS-550S	DC-Motor	

3. COMPONENTS CIRCUIT

the full circuitry of the electronics used in our project, the controller (ESP32), signal conditioning circuit (HX711) and magnetic encoder (AS5600) needing to supply voltage of 3.3V by using a buck converter to step down the battery from 24v to 3.3V with important notes that the supply for the electronics even the microcontroller (ESP32) is drawn from the main li-ion battery (24V) which supplying our whole system. All logic level power is divided as following: AS5600 draws 100mA maximum, HX711 amplifier draws 1.6mA each and we are using four of them, microcontroller (ESP32) draws 80mA. This in total does not exceed 500 mA.

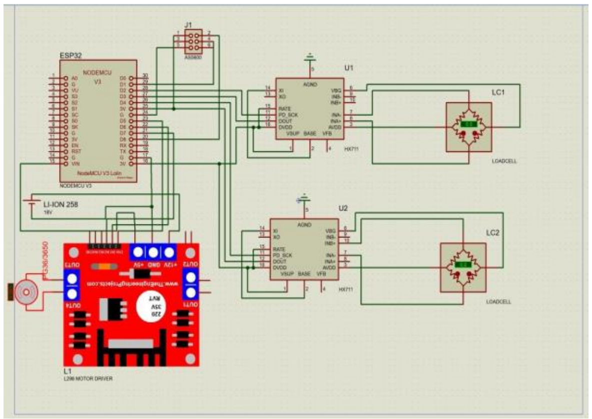


Fig.19 Control circuit

4. APPLICATION

Each ankle prosthesis has its own application to detect the patient wants the ankle to be on it. There is some application make a lot of modes available for the patient such as walking, running, wearing heels. We make application for our project by using MIT app inventor and connect it with the esp32 Bluetooth we made on the application two modes one for running and the other for walking. We take feedback from the battery to make the user know when the battery is fully charged or if he should charge the battery.

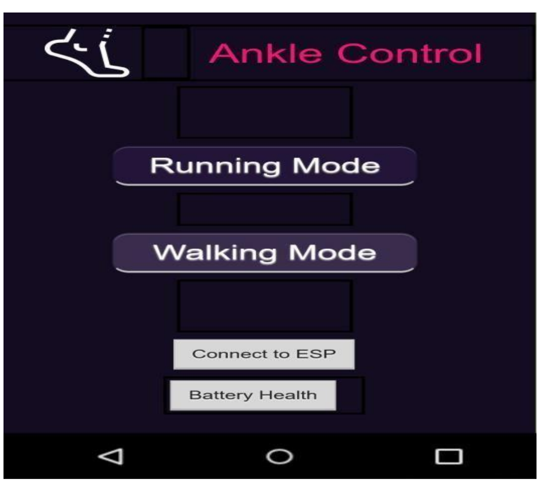


Fig.20 mobile application

IV. ACKNOWLEDGMENT

In fact, there are many people to whom I must express my gratitude for their contributions to the successful completion of this dissertation. I would like to express my sincere appreciation and thanks to my supervisors, Dr. Ahmed El Sawaf and Dr. Moustafa A. Fouz as they supported me in completing my work and I am so grateful for their assistance and guidance forever. I appreciate their comments and encouragement throughout this project. Thanks to all my friends and colleagues who have provided invaluable help and exchanged fructiferous views from time to time that has been vital to my progress. My heartiest thanks are due to my highly respected family, without their constant support and encouragement through this year.

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