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Exoskeleton for Enhancement for disabled person (EXED)

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Abstract: *Over the years, exoskeletons have evolved into smaller lighter, and more specialized devices. With the use of exoskeletons in the field of medicine, the military has been through a tremendous boost in the past few years. The human body becomes weak at a certain age, and it cannot move heavy loads or walk, even people suffering from the locomotive disorder cannot withstand stress at their joints.*

Our project provides a solution to this problem in a form of an exoskeleton suit for the lower limb which can facilitate movements of joints and limbs to promote walking, elevating, sitting operations with the help of an actuation mechanism. The suit will provide support to the lower portion as well as the back of the user without much effort and energy consumption. The disabled person can also use our product without much hindrance and with ease of operation. The lower bodysuit will have a controller which controls the mechanism to the intent of the users. The following section of the paper focuses on the importance of the proposed solution and its feasibility in today's medical field.

Keywords:*Exoskeleton, disability,Enhancement for disabled, gait control, locomotive disorder, EXED.*

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I. INTRODUCTION

There is an expanding acknowledgment and accentuation on the necessities and privileges of individuals with inabilities which has brought about a developing interest for data by the organizers and arrangement producers engaged with this field.

The project 'Lower Body Exoskeleton' focuses on helping people with disabilities to relieve pain/ to support locomotormovements/ to make movements easier.

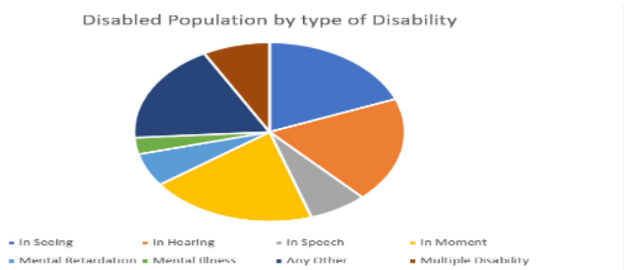


Figure: -Disabled population by type of disability

There has been a lot of cases in which the motion of the lower limb loses its ability to move when suffered from injury or in case of recovery from stroke. This paves a path towards the advancement in wearable robotics applications for such problems as upper or lower body exoskeleton.

Lower body /limb exoskeleton can be active or passive type depending upon the power source used. In our design of a lower-body exoskeleton, we are using a power source like a battery, four degrees of freedom (DOF) are provided at three locations viz. two at the hip which is controlled by a high torque car wiper motor. The DOF at the knee is arrested by a circular casing. The detailed architecture of the model is discussed in the proceeding sections.

1.1.1 Background

The 950-710 B.C. were Known as the earliest period where prosthetic toes were first made from wood and leather which was discovered in the 1800s attached to an Egyptian mummy (Figure: -B) [1]. The Greville Chester toe of the 600 B.C, create by the Egyptians and discovered in 2000 near present-day Luxor which was made of a cartonnage mixture of linen, glue, and plaster. 2000-2014 observed the year where prosthetic design has advanced to highly specialized prosthetics, including high performance, lightweight running blades, and responsive legs for navigating varying terrain, and motorized leg and hand prosthetics controlled by sensors and microprocessors.

Figure: -B Prosthetic toes

<u>Knee/calf supports: -</u>
The conventional supports include the walking stick or the calf/knee support which do not provide comfort while wearing due to misalignment, shortage of space, or in simple terms not adaptive as per the consumer requirements. The long terms of wearing such products can cause the person to feel uncomfortable, tidiness or in worst cases the person refuse to wear such supports which can cause the pain to increase in time.
<u>Rehabilitation support systems: -</u>
This includes the prosthetics, lumber belt support system used by the consumer if they are missing a body part due to a disorder or the due to some accidents, these systems also include the stroke recovery system which helps the user to walk again after suffering from stroke, hemiplegia a disorder that causes one half of the Human body to fail to perform its functions. This order is mainly because of the stroke or in many cases, it is due to its hereditary. The process of recovery from stroke is difficult and the treatment is prolonged.

1.1.2 Objectives
The team has laid forth the following objectives which it aims to accomplish through our project: -

i. To Build an exoskeleton suit to support the human body parts over which no control can be re-established (Disability).
ii. To provide motorized control over the suit for ease of operation.
iii. To make the project model smart, compact, and easy to use even for an untrained human the lower-body exoskeleton will provide better stability assisted by a simple mechanism that can be worn easily by the user.
iv. It will provide aid in the movement of lower limbs and ultimately the human body.
v. Exoskeleton utilizes external power i.e. Mechanical or electro-mechanical to give movement to the lower body. The lower body exoskeleton can be used in medical, industrial, and military sectors effectively.
vi. The lower body exoskeleton enhances the workability of workers in the workshop thus increasing productivity in the industry.

1.1.3Features

The following features of the project are mentioned below: -

<u>Lumber belt:</u> - serves as support to the lower back and thus spine for the stability of the body.

<u>Thigh covering:</u>- links including cushioning in inner side and mechanism outside cushion padding.

<u>Calf covering:</u> - includes cushion padding and means of connecting thigh covering to the footrest.

<u>Footrest</u>: - serves as the shoe to cover the foot and to move the ankle while walking.

<u>Servomotor/high torque wiper motor</u>: - provides movement to the whole assembly at their respective joints.

<u>Control system</u>:- to control the actions such as walking, seating, elevating, etc.

1.2LITERATURE REVIEW

Lower body exoskeleton (LBE) which is often called above-knee exoskeleton designed to assist in the rehabilitation of individuals suffering from lower limb paralysis due to spinal cord injury, stroke, multiple sclerosis, or other debilitating condition. [2]. LegX, ESKO, and BLEEX are fully autonomous, bionic exoskeleton robots that help people with physical disabilities walk again. Each system is unique in function, but all strive to create a new lifestyle for their users and increase the enjoyment of daily life. Using patented robotics technology, HAL provides high-quality bionic feet and legs that enable individuals with lower-limb amputations to walk more energetically, for longer durations, and with greater independence. [3]. BLEEX is the first human exoskeleton that was shown to walk energetically autonomous. It is a platform for the development of different wearable robotic technologies for assistive use, as well as for fundamental research on human biomechanics in various areas: rehabilitation, elderly care, mental disorders, and others. [4]. HAL is an advanced robotic wearable device enabling the wearer to do his daily task without any strength or muscle coordination. The core technology of HAL, All Sensors Fusion Technology, allows all the wearable sensors to seamlessly communicate and cooperate through wireless communication. This enables the user to control his limbs freely without and pain or injury after wearing the device. [5]. These exoskeletons are essentially developed to assist the ailing adults, physically weak incapably. However, the LBE can also be used to assist a normal person to support their routine work or reduce the stress on their bodies during strenuous jobs.

The U.S. military and Lockheed Martin have announced that Lockheed Martin's greatest accomplishment is to develop the world's first powered Exoskeleton suit the XOS 1 and XOS 2 Incorporated with DARPA (Defense Advanced Research Projects Agency). The prime objective of this development program is to provide an exoskeleton that will enhance the performance of operators who are responsible for heavy gear, such as combat troops, law enforcement, and emergency responders. [6].

There are limitations to most actuated exoskeletons while in a practical scenario. The power needed to operate the device, along with its mobility and user suitability place a considerable burden on the concept as well as other designs. A solution may be to design a Lower-body quasi-passive or passive exoskeleton that varies from the traditional model in that it does not rely much on only being powered by built-in motors and instead relies more on passive structures to manipulate the lower limb portion.

1.2.2 Problem definition

In today’s world, some people are suffering from various diseases like diabetes or due to old age and stressed life. People are not subjected to physical activities due to desk jobs and unbalanced diet all this results in the weakening of the bones and limbs due to less activity and can cause locomotive disorder. The limbs are not able to carry loads as soon as the age of one person increases. In our country, it is estimated around 16 million people are inflicted with locomotor disabilities.

There is no such product available in the country for disabled persons suffering from the locomotive disorder which can aid the person in walking and climbing the staircase. Due to lack of such services the people are not able to perform well in day-to-day activity. We have provided a solution to this problem by building an exoskeleton for the lower limb which helps assist in walking without any hindrance. Our Project will be used to reduce this figure and help patients with disabilities this is our small step in providing service to disable and making a better place for them to live in.

1.2.3 Methodology

<u>Material selection</u>: - The material selection is one of the most important phases in any project. In our project we have selected the materials as follows:

- Calf/Thigh assembly –AISI 4130 tubes.
- Knee and motor casing -Stainless steel 304.
- Lumber belt –reinforced plastic/polymer.

<u>Design of the calf/thigh assembly: -</u>

The design of the calf/thigh part is very well explained in Figure: -C below. The calf assembly has a stainless steel 304 casing which is circular for arresting DOF having relative motion with the thigh assembly. The AISI 4130 Tubes are bend in the shape of the calf to support the ergonomics structure and facilitate free movement without much hindrance to the user.

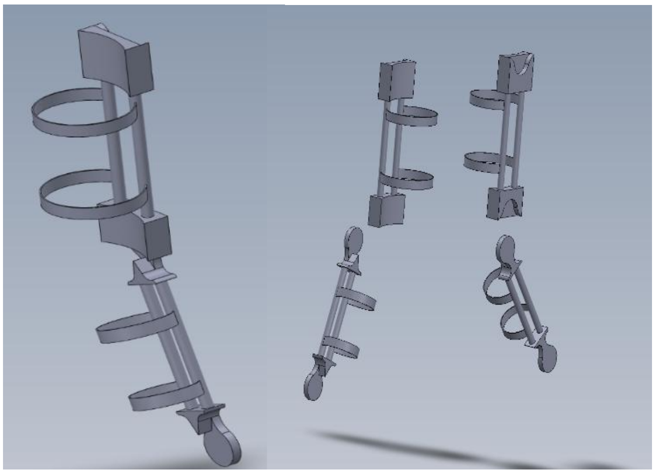


FIGURE: -C Calf/thigh assembly

Design of lumber belt: -
The lumber belt will support the thigh assembly and the battery mounting it has adjustable straps for universal fitting of the system. The mounts will also comprise the controlling system.

Control system: -
The control system has all the functions which will facilitate the movement of the limb motion relative to the motion of the high torque car wiper motor. Thecontroller will command the wiper motor to move at a certain degree of angle of the hip and the knee so that the system can assist the user to walk and sit and even climb stairs.

1.2.4 Market Survey

We carried out a market survey using google forms where we asked different users about the functions of LBE and the conventional knee support devices. We got feedback from our friend's grandparents, health care workers, Orthopedic doctors.During our research, we found out that in India, 75% Population of age 65 and above have some sort of knee problems, most commonly Knee Osteoarthritis. The common solution for the said problem is usually surgery along with 6 months of bed rest. To minimize pain and to help support the knee joint, the 'Lower body exoskeleton' is a viable solution. So, the project provides a more beneficial demonstration rather than going for a conventional system for walking and carrying out strenuous jobs.

2.1Stages of development:-
Stage 1. To prepare the model for the thigh system we have prepared a basic frame structure for checking the ergonomics FIGURE:-D

FIGURE:-D Ergonomic test using Aluminum frame

<u>Stage 2</u>. The motor selection was done by conducting experimentation gravity balance method by using a car wiper motor. The gravity balance method utilizes the movement of a constant mass (m), over a variable distance. Alternatively, the magnitude of the mass may be varied, keeping the radius (r) constant. This method is illustrated in (FIGURE: -E 1&2).


FIGURE: -E1 horizontal positionFIGURE: -E2 Elevated position

Let a mass ‘m’ be moved along an arm until the value of the torque exerted by the mass balancesthe unknown torque.Unknown torque, T= F x r   where F=mg (force exerted by the mass)
In both above cases, the arm must be kept horizontal so that arm distance is perpendicular to the line of action of the force. Since the shaft is supported at the bearing, there may be a friction torque leading to an error in the measurement of torque. This error may be eliminated by arranging to apply equal and opposite forces. The experiment consists of the motor, steel arm, L293D motor driver,12V DC power supply, material cup, metal weights of different sizes,Bevel Protractor. The result of the experiment is as follows:

- The weight & size of the sample: - 500gms 30*10*10cm.
- The length of arm: -MS plate 23*3 cm.
- Material cup: -10*7.5cm

TABLE -1 Experiment result

SR.NO	WEIGHT(GMS)	ANGLE (DEGREE)	DISTANCE FROM PIVOT(CM)
1	500	30	9
2	500	45	16
3	500	60	24
4	500	75	31

The torque for 0˚ =0.5*9.81*0.3 (for horizontal condition)
=<u>1.4715 N-m</u>
The torque for 30˚=0.5*cos (30) *0.3
=<u>0.1299 N-m</u>
The torque for 45˚=0.5*cos (45) *0.3
=<u>0.1060 N-m</u>
The torque for 60˚=0.5*cos (60) *0.3
=<u>0.075 N-m</u>
The torque for 75˚=0.5*cos (75) *0.3
=<u>0.0388 N-m</u>

<u>Stage 3</u>.
The torque obtained at the various angles gave a brief idea about the motor torque required. Thus, we decided to mount four wiper motors for hip and knee movement.

2.2TOOLS: -

<u>Hardware Requirement</u>

- ✓ 12V 30Ah Lithium phosphate Battery
- ✓ Arduino UNO
- ✓ PC/ laptop
- ✓ L293D motor driver- 4 no.
- ✓ Stainless Steel 304 blocks (30 X 120 X 60mm) -8no.
- ✓ AISI 4130 TUBES (0.75’’ OD X 2.5mm W/T)-12m
- ✓ 12V 5A Wiper Motor (Actuator)-4 no.
- ✓ 16 Gauge Wires
- ✓ HC-SR04 Ultrasonic sensors
- ✓ Wireless Remote control

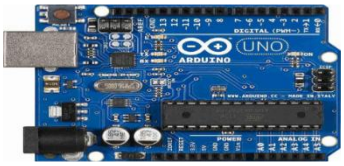
<u>Software Requirement</u>

- ✓ ARDUINO IDE
- ✓ Solid works
- ✓ Ansys R15
- ✓ Programmer V-5

2.3DESIGN, COMPONENTS & ANSYS

<u>Arduino UNO</u>

The motor base casing structure of our project consists of stainless steel 304 blocks because of their strength & toughness. For the processing and control of all components, we are using the Arduino Uno platform. There may be better solutions for our application but considering the budget constraints and ease of operation, we concluded that the Arduino Uno platform would be best suited to our needs. To operate the Arduino Uno, we installed the operating system ARDUINO IDE on it which can run programming languages for free and has the added functionality of the control.



This popular board — based on the ATmega328 MCU — features 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, USB connection, power jack, an ICSP header, and a reset button The Uno does not use the FTDI USB- to serial driver chip. Instead, it features the ATmega16U2 (ATmega8U2 up to version R2) programmed as a USB-to-serial converter.

In addition, Revision 3 of the Uno offers the following new features:

- ✓ Pinout added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board.
- ✓ Stronger RESET circuit.

<u>High Torque Car Wiper motor</u>

For moving the limb, we would be using four high torque wiper Motors (operating on slow motion with 10 RPM). We have chosen a lower RPM configuration for the motor as we would require more torque for the motion required for limb movement and considering the weight of the project upon completion.

There are three operating modes to a wiper motor:

a) Normal operation:

b) High-speed operation

c) Wipers off blade not in the park position

Since we require high torque and slow speed, we will be using the normal operation mode as shown in the FIGURE: F1

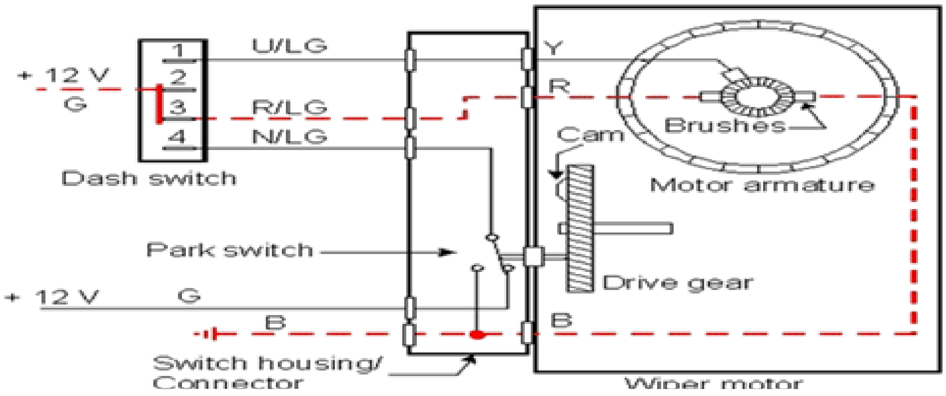


FIGURE: F1 Wiper motor operation mode

In this mode of operation, the dash switch is in the normal or low speed, position, and internally, terminal 2 of the switch is connected to terminal 3 as shown in the above figure. Current flows through the motor as shown by the dotted red line. The operation of the parking switch has no effect in this mode, as terminal 4 of the dash switch is not connected to any other terminal.

Stainless steel 304 Calf and Thigh casing

The design of the calf/thigh part is very well explained in FIGURE: - F2 Below. The calf assembly has a stainless steel 304 casing which is circular for arresting DOF having relative motion with the thigh assembly. A vertical CNC milling machine is used for carving the part from stainless steel 304 blocks using Programmer V-5.

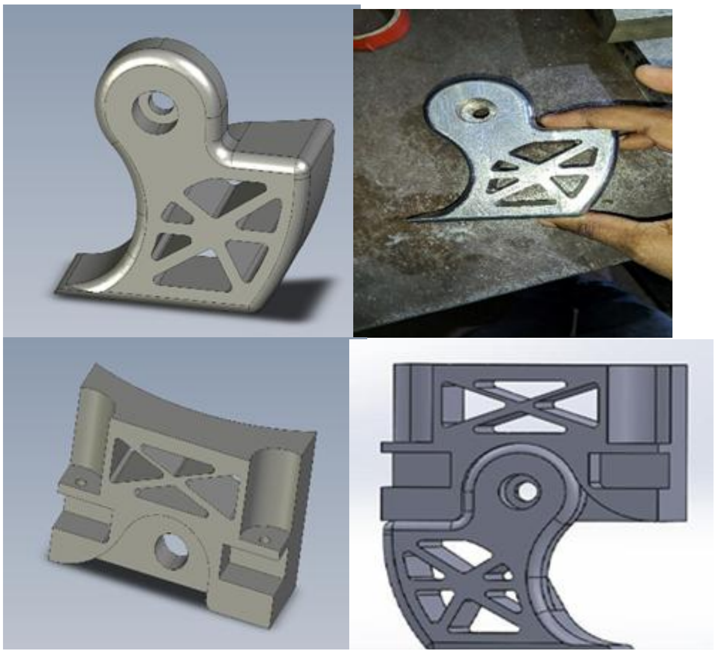


FIGURE:- F2 Calf and Thigh casing

For structural analysis of the calf, we used Ansys R15 for carrying out the stress analysis process we have used theoretical data for the force required to move a limb by a normal person i.e., 5000N torque as input value in the stress as well as bending analysis FIGURE: -F3. The stainless-steel casing of the calf and thigh assembly was modeled simplistically initially to find out the key design parameters. Based upon the outcomes, the structural design and optimization were done thereafter.

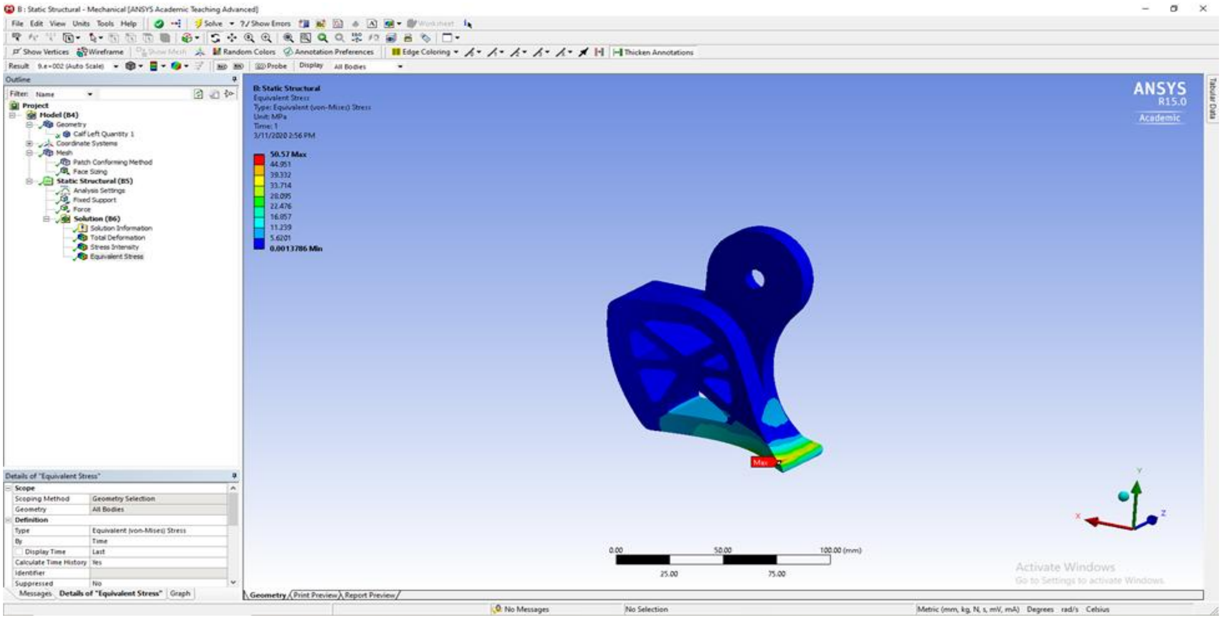


FIGURE: -F3.1Equivalent stress contour in calf casing surface

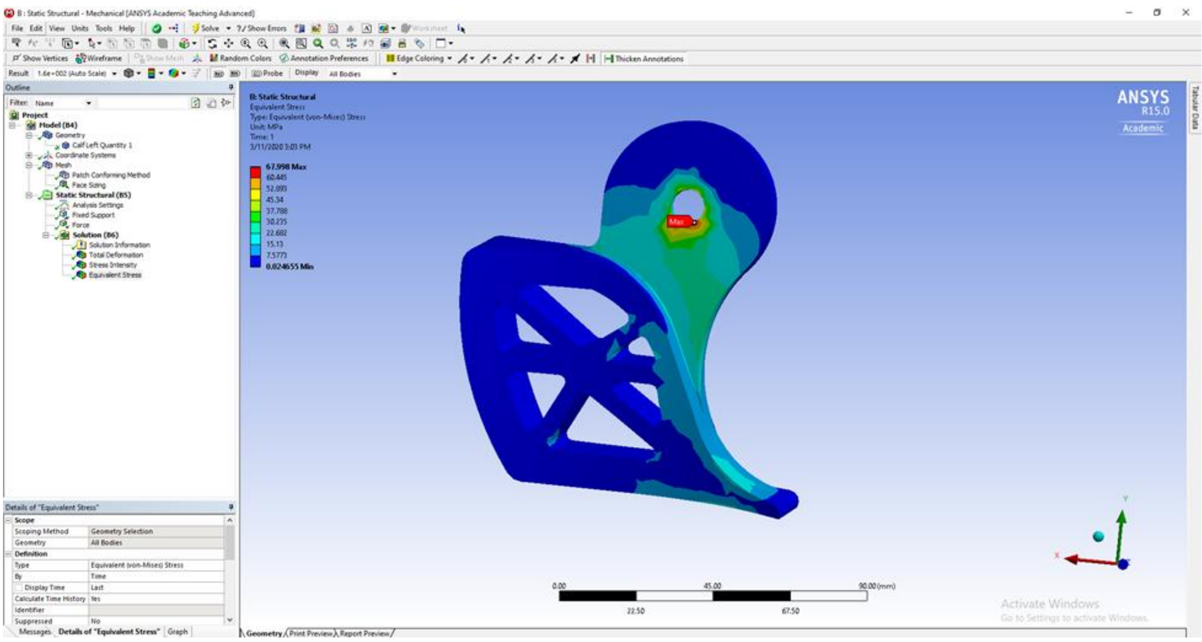


FIGURE: -F3.2Equivalent stress contour in calf casing joint

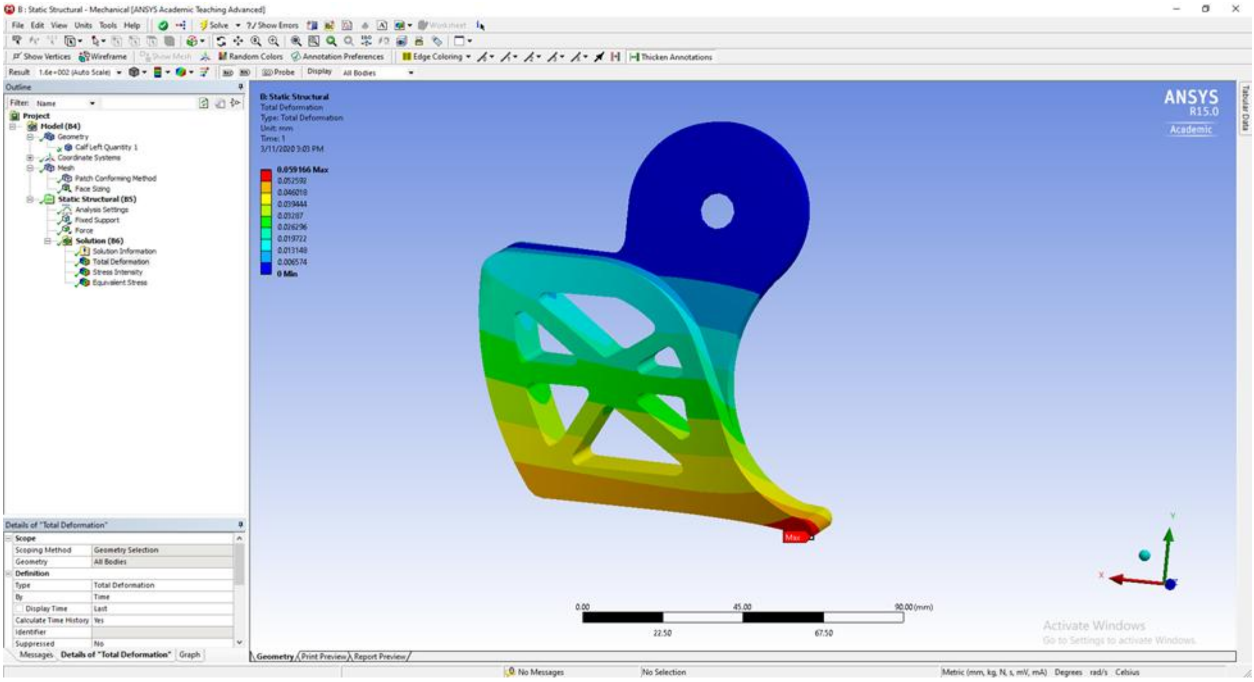
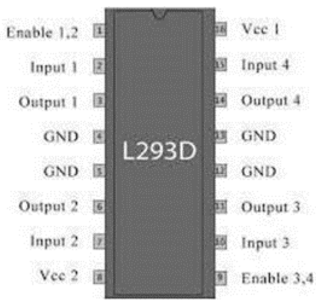


FIGURE: -F3.3Total Deformation contour in the calf.

The Maximum deformation wasfound out to be 0.059166 mm which is within the acceptable limits. The Maximum Equivalent Von-Mises stress was found out tobe 67.998 MPa. The yield strength of stainless steel 304 is 215MPa.Thus, we get a high Factor of Safety of about 85.

<u>L293D Motor Driver</u>

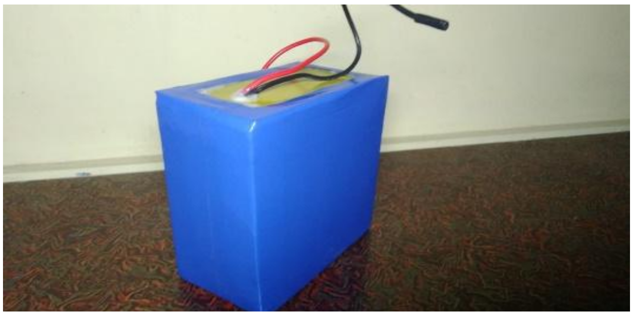
Motor Drivers L293D are generally used to increase the amount of current as the current from the pins of Arduino is insufficient to run the motors. 12V & 5A wiper motor for rotating motion and providing enough torque to lift the limbs supported on tube stands connected to the SS casing.



Motor Drivers are generally used to increase the amount of current as the current from the pins of Arduino is insufficient to run the motors. The motor drivers receive the current which accepts the small amount and amplifies it to a larger amount which is sufficient to run a motor. The L293D motor driver used by us consists of 4 terminals in pairs of 2 each, which receives the positive and negative terminals of the motor. The other 3 terminals received are GND, 12V which is the stepped-up voltage, and 5V, which is the input voltage. The L293D can drive both small, as well as large-sizedmotors. All the motors in the project would be controlled with the help of L293 Motor Drivers which can control up to two motors per unit. This would help reduce weight and space usage and ensure the Stainless-steel casing on each side move in synchronous with each other for all four motors.

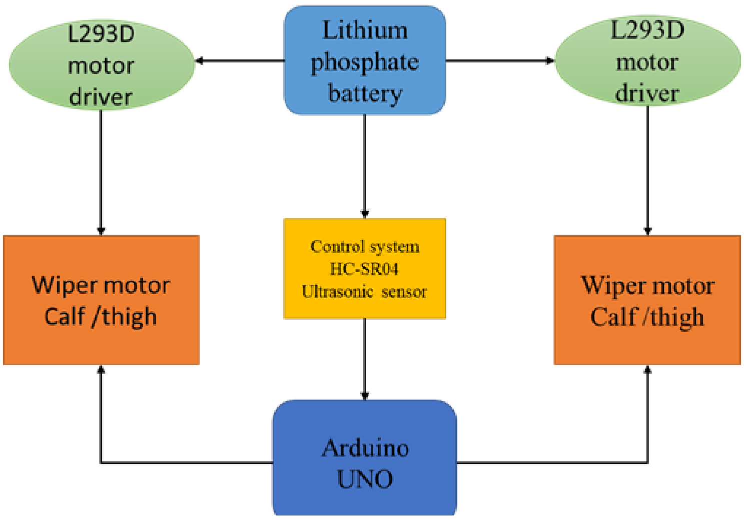
Lithium phosphate Battery

The system is backed by a 12V 30ah lithium phosphate battery to give a battery backup up to 90 minutes on a single charge.

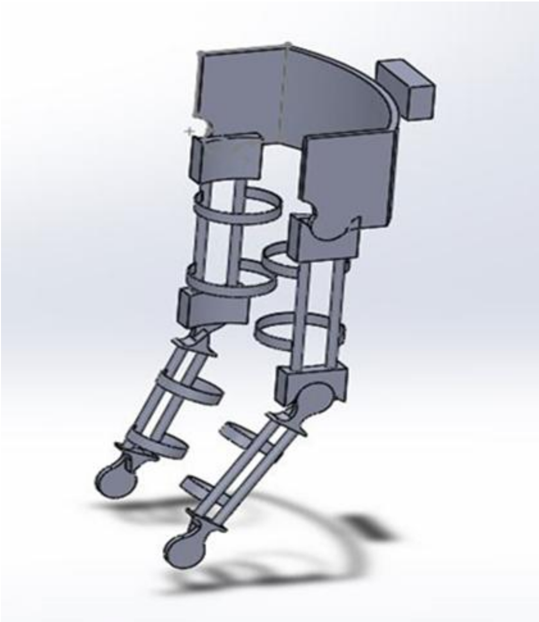


Control System

The system comprises a control system that helps in a linear walking pattern it has a 2-mode remote controller which can operate the system in two different modes according to user intent. The system also comprises ultrasonic sensors at the casing to move the limbs to their original position during voltage drop-down without causing harm to the system. The HC-SR04 Ultrasonic (US) sensor used is a 4-pin module, whose pin names are Vcc, Trigger, Echo, and Ground respectively. This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required. The module has two eyes like projects in the front which forms the Ultrasonic transmitter and Receiver. The sensor works with the simple high school formula that *Distance = Speed × Time.*



II. EXPECTED OUTCOME



- A selected number of motors to be used i.e., one motor on each Hip and one motor on knee side assembly.
- Providing 4 DOF for the assembly and formation of the circular casing for relative motion of the thigh and knee assembly.
- Selection of 12V DC 30 AH lithium phosphate battery up to 90 minutes battery backup.

III. FUTURE SCOPE

- Weight reduction is a key factor in the future versions comprising of lightweight & composite materials like carbon fibre.
- Reduction in motor weight by using a mechatronic drive system rather than wiper motors.
- Increasing the battery capacity, compactness, and battery cooling for an increase in operating time.
- Reductions of motor fluctuation during voltage drop-down by enhancing the synchronization of the motor
- Adjustable parts for universal acceptance.
- Water and dust protection of the system in a severe environment.
- Providing different modes of operation like running, climbing a staircase.
- Reduction in wear at the joints and contact surface

IV. CONCLUSION

In Lower Body Exoskeleton (LBE), we have purposed is an electro-mechanical structure that supports the lower limbs of the disabled person to enhance its moving ability. The Lower Body Exoskeleton consists of a Lumber belt to give support to the spine of the user. Sensors are attached to the inside of hip joints and side of knee joints which will ultimately move the Exoskeleton and thus the disabled person. As per commands received from the remote, sensors move the joints and make the lower structure move accordingly.

The lower body Exoskeleton finds its application mostly in medical sectors for people with mobility issues. Apart from that this Exoskeleton can also be used in industrial applications to reduce human efforts in strenuous jobs. Also, it can be used in the military sector for less energy consumption and the betterment of militants.

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