Design of Wearable Robotic Exoskeleton for Over Ground Walking

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Abstract - *Humans are optimized to walk efficiently, however normal walking can be disrupted when carrying heavy load which can injure or fatigue the muscle and tendons at the same time for people with disability, they often have reduced their muscle functions, in this world there are nearly 1 out of 50 people living with paralysis, with 27.3% being caused by spinal cord injury leaving them unable to move. This paper is coved with the robotic exoskeleton to improve the walking ability of a disabled person and perform its daily basis task on its own with minimum support. This exoskeleton will support the legs muscle and tendons to perform the function. Human walking is so efficient in part because it's a passive dynamic process where body and leg have pendulum like motion, whereas the purpose is to inject power or bust of power to the exoskeleton so as to maintain the walking motion. These wearable exoskeletons provide means to transmit assistive torques to a wearer's joints without the use of rigid external structures. Exoskeleton is attached to the body securely and comfortably, and transmit forces over the body through beneficial paths such that biologically-appropriate moments are created at the joints. Apart from the demands in health care, the applications of robotic assistive devices for human strength augmentation are also in great need. Legs can adapt to a wide range of extreme terrains, and therefore legged locomotion is a desired method of transportation in these circumstances.*

Key Words: **Exoskeleton, Walking Disabilities, Wearable Mechanism, Medical Device, Human Walking Assistance, Lower Limb Exoskeleton, Rehabilitation Robot.**

1.INTRODUCTION

Throughout the most recent couple of years, there have been significant improvements in this field, offering desire to individuals with spinal rope wounds, neurological problems, and strokes. The utilization of this exoskeleton during recovery is developing and their advantages getting all the more broadly perceived. The exoskeleton is wearable for individuals to make up an insufficiency during achieving occupations, for example, remunerating development, enlarging strength, and convey load. Human strolling is a convoluted and cadenced kinematic development that includes the coordination of the mind, nerves, and muscles. An aggravation in their coordination may bring about a walking issue. Commonly, it is found among old patients who have removed appendages, musculoskeletal issues, spinal line injury, and so on These patients might be treated by physically helped step preparing or with the guide of assistive exoskeleton. The physically helped walk preparing has different disadvantages like the long preparing term and its recurrence of the preparation. It is additionally reliant upon the accessibility of the specialist. Also, it is backbreaking and actually requesting for the specialists, and needs repeatability.

A few exoskeletons have been created to decrease the impact of hefty payloads during strolling. The plan of these exoskeletons fluctuates from full leg exoskeletons to single-joint exoskeletons that help the client at the hip or at the lower leg. Note that the most ordinarily utilized measurement to assess this exoskeleton is the metabolic expense of strolling which is the energy devoured by the human body during strolling. Exoskeletons have shown extraordinary potential in decreasing the metabolic expense of strolling. The force produced on the lower leg joint during the push-off stage is the biggest contrasted with different joints of the leg. Consequently, adding positive force during this stage on the lower leg can beneficially affect the strolling energetics. Interestingly, robot-helped walk preparing (for example assistive devices) can be utilized to expand the term and number of meetings for preparing. What's more, it restricts the prerequisite of the number of advisors per patient. These assistive gadgets might be utilized to conquer the restrictions of physically helped step preparing. Nonetheless, these gadgets are intended for patients at clinics and restoration focuses as they give preparing in the restricted territories, and patients don't feel the sensible experience of strolling. On the other hand, convenient wearable robots are required, which can be utilized at home. An exoskeleton is a wearable bionic gadget that is outfitted with amazing actuators at human joints and incorporates human knowledge and robot power. With an underlying multisensory framework, an exoskeleton can get the wearer's movement intentions and as needs are help the wearer's movement. It can apply outside power/force to the wearer's appendages leveled out and consequently give user-initiated portability. The exoskeleton upgrades the strength of the wearer's joints. For instance, an exoskeleton permits individuals with versatility problems to recapture the capacity to stand and to stroll over the ground, higher up, and the first floor. Contrasted with conventional non-intrusive treatment, exoskeleton assistive restoration has the upsides of diminishing crafted by specialists, permitting concentrated and redundant preparing, and it is more advantageous to use for quantitatively evaluating the recuperation level by estimating power and development designs. In different applications, it can likewise help a physically fit individual convey weighty burdens. Subsequently, with the assistance of an exoskeleton, wearers can accomplish an undeniable degree of execution. In the previous quite a few years, the advancement in the improvement of exoskeletons has been momentous. A few exoskeleton frameworks have been created and tried. In view of the piece of the human body the exoskeleton upholds, exoskeletons can be delegated furthest point exoskeletons, lower limit exoskeletons, full-body exoskeletons, and explicit joint help exoskeletons.

The paper is organized as follow: Section 2 is about literature survey in which it is discussed why people are losing walking ability, Section 3 is methodology which covers points such as 3.1 Selection of material for exoskeleton, 3.2 Prototype of exoskeleton, 3.3 Design of exoskeleton parts, 3.4 Analysis of exoskeleton parts in ANSYS. Section 4 covers details of epoxy resin glass fiber, Section 5 Architecture of exoskeleton, Section 6 Motor & Worm and worm gear, Section 7 Selection of battery, Section 8 Electronics & Section 9 for Calculations.

2.LITERATURE SURVEY

Clinical exoskeletons for paraplegics are utilized to help patients enduring a sort of loss of motion. loss of motion is the failure in the tangible engine usefulness of the lower appendages to forestall ordinary movements like standing and strolling. A few customary techniques have been utilized including supports and braces, wheelchairs, and orthotic gadgets. Supports and bolsters neglect to give full-movement self-sufficiency to the individual and consequently have restricted use.

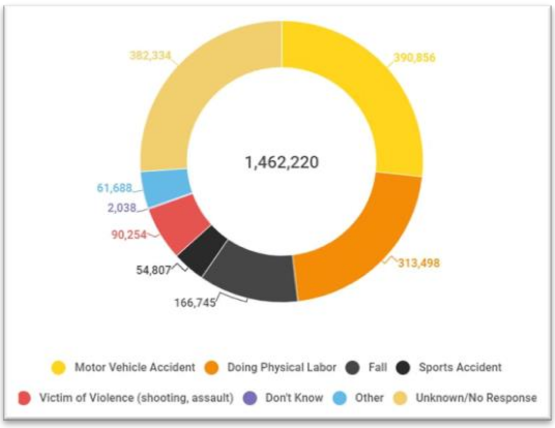

Figure -1: Reason for Loosing Waking Ability

In clinical exoskeletons, the movement directions for singular joints can't be given by the wearer as the patient can't make the necessary developments, while sound people can typically have adequate actual usefulness which should be 'beat up' as opposed to needing it 'completely made up for or supplanted by' as in clinical circumstances, for example, giving versatility arrangement to SCI people. This implies numerous specialized issues like UIs, control systems, mechanical interfaces, etc. should be planned explicitly to take into account the individualistic requirements of the patient/wearer.

As of late, because of maturing cultural concerns, new situations for giving help to old individuals to doing day by day living exercises have additionally begun to get consideration, and there is a developing direness for such assistive advances to assist older individuals with staying autonomous. As people age, we begin to have physical and intellectual issues and when these become serious, we are not, at this point ready to do essential living exercises and need care backing to help us. A significant issue in being free is close-to-home portability abilities. On the off chance that we can keep on moving around, we can remain dynamic and consequently keep on living in our own homes with great personal satisfaction. Actual assistive exoskeletons can help in such circumstances. Likewise, individuals are losing their strolling capacity because of numerous reasons like mishaps, loss of motion, sports mishaps, and so on.

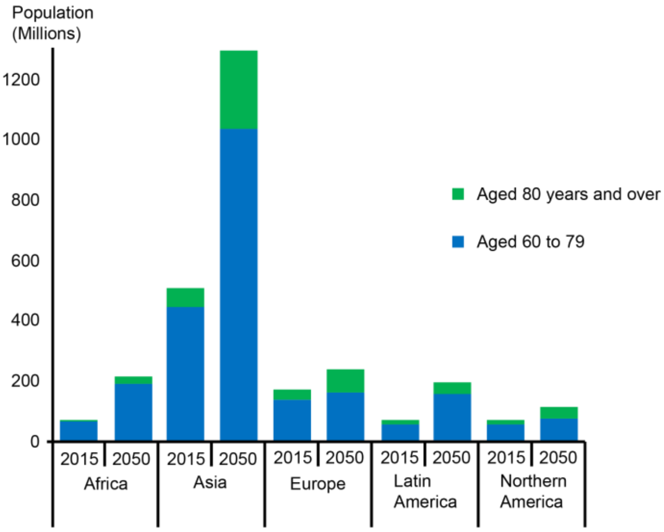

Figure -2: Aged Group For Loosing Walking Ability

3. METHODOLOGY

3.1SELECTION OF MATERIAL FOR EXOSKELETON

Material choice is a stage during the time spent planning any actual item. With regards to the item plan, the primary objective of material determination is to limit cost while meeting item execution objectives.

Table 1 shows the various parts and their sorts and position strategy continued in the plan of robotic exoskeleton.

Sr. No	Parameter	Description
1	Exoskeleton Body	Customized Built Mild Steel (M.S)
2	Motor	12 Volt DC Brushed / Brushless
3	Motor Assembly	Casing, Worm & Worm Gear, Motor
4	Motor Location	Knee Ankle
5	Switch	Push Button Switches
6	Battery Location	Near Waist
7	Foot Rest	Epoxy Resin Glass Fibre
8	Other Support	Hand Sticks

Table -1: Material Used For Exoskeleton

3.2PROTOTYPE OF EXOSKELETON

The proposed leg exoskeleton depends on a linkage instrument that has been planned to satisfy primary human headway errands with ease simple activity highlights. An appropriate 3D model has been created and the full leg exoskeleton has been demonstrated and re-enacted into ANSYS. Figure 3 shows the total plan of the model.

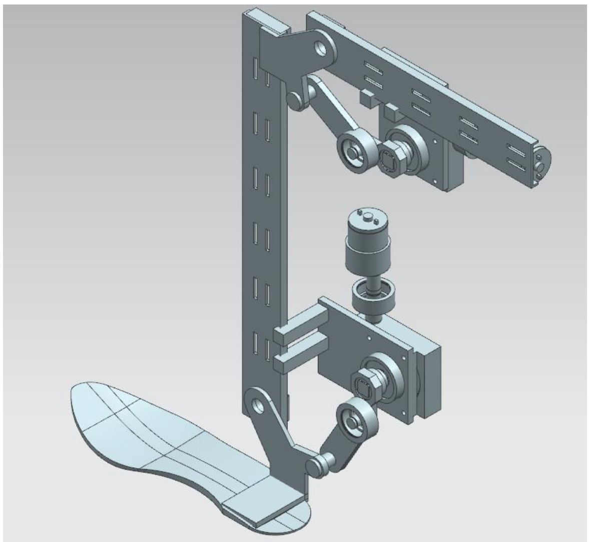

Figure -3: 3D Model of Exoskeleton

3.3DESIGN OF EXOSKELETON PARTS

Design consists of application of scientific principles, technical information and imagination for development of new or improvised machine or mechanism to perform a specific function with maximum economy & efficiency. Hence a careful design approach has to be adopted. The total design work, has been split up into two parts;

- System Design.
- Mechanical Design.

System design mainly concerns the various physical constraints and ergonomics, space requirements, arrangement of various components on main frame at system, man + machine interactions, No. of controls, position of controls, working environment of machine, chances of failure, safety measures to be provided, servicing aids, ease of maintenance, scope of improvement, weight of machine from ground level, total weight of machine and a lot more. In mechanical design the components are listed down and stored on the basis of their procurement, design in two categories namely,

- Designed Parts.
- Parts to be Purchased.

For designed parts detailed design is done & distinctions thus obtained are compared to next highest dimensions which is readily available in market. This amplifies the assembly as well as postproduction servicing work. The various tolerances on the works are specified.

The parts which are to be purchased directly are selected from various catalogues & specified so that anybody can purchase the same from the retail shop with given specifications.

Following are the parts designed in ANSYS

Worm Gear

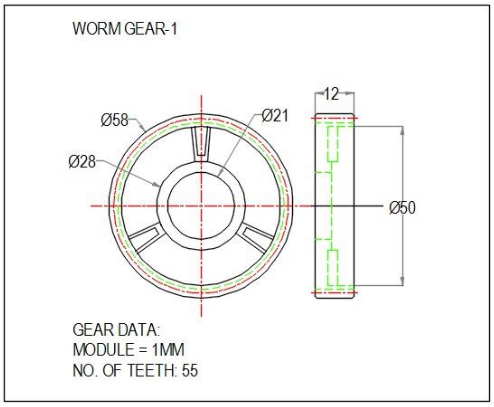

Figure -4: 2D Model of Worm Gear

Worm Gear

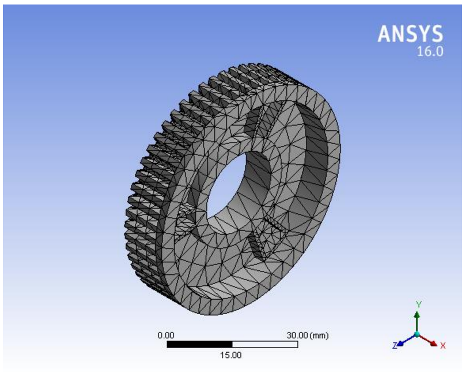

Figure -5: 3D Model Of Worm Gear

Foot Plate

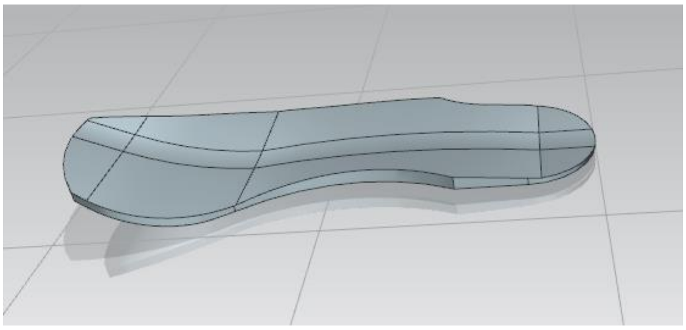

Figure -6: 3D Model of Foot Plate

3.4ANALYSIS OF EXOSKELETON PARTS IN ANSYS

3.4.1WORM GEAR

Structural Analysis or Finite Element Analysis (FEA) is used to affirm the strength of the planned model for various burden conditions. The FEA examination of the hip and lower leg association and knee joint rocker has been done for other lower appendage exoskeleton frameworks. The weighted impact of various strolling positions on the hip joint is talked about by FEA for a totally particular model of the lower appendage exoskeleton framework, this interaction is by and large totally completed in ANSYS.

Analysis of Worm Gear for force equivalent to 9-N-m stall torque.

Geometry

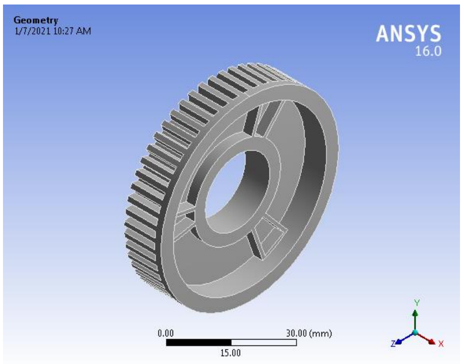

Figure -7: Geometry Of Gear In ANSYS

Geometry of gear was developed using Unigraphics Nx-8 and the step file was used as input to Ansys work bench.

Meshing

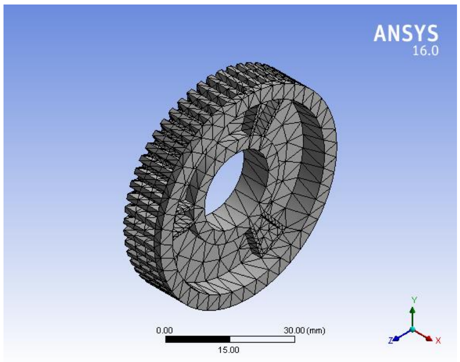

Figure -8: Geometry Of Gear In ANSYS

Meshing was done using Ansys free Mesher and mesh parameters are as follows:

Nodes	17142
Elements	9619
Mesh Elements	None

Boundary Conditions

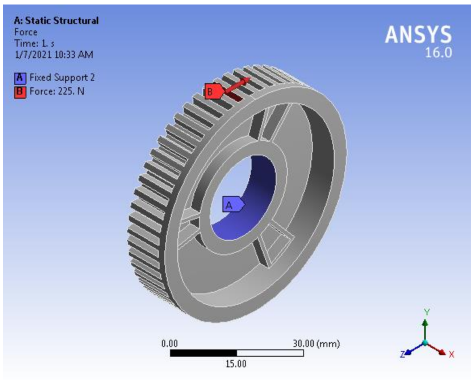

Figure -9: Boundary Conditions of Gear In ANSYS

The boundary conditions were defined as above, the central hub of gear is considered to be fixed and the tangential tooth load corresponding to 9-Nm stall torque i.e., Ft = 225N is applied.

Maximum Stress Induced

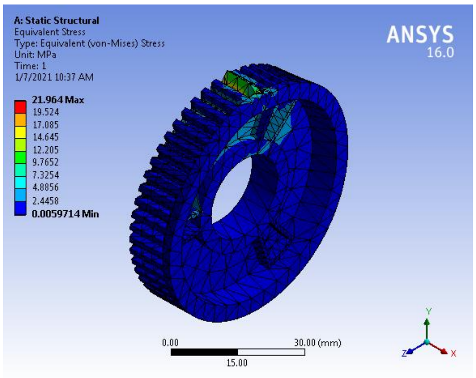

Figure -10: Maximum Stress Induced Of Gear In ANSYS

The maximum stress induced in the material = 21.96 Mpa which is below the allowable value of 33 Mpa hence the gear is safe.

Maximum Deformation

The maximum deformation induced is limited to 0.25164 mm which is considerably low hence the gear is safe.

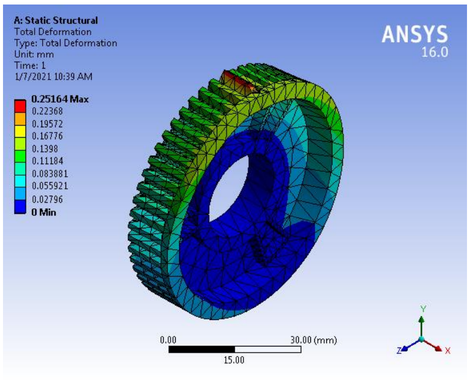

Figure -11: Maximum Deformation Of Gear In ANSYS

3.4.2FOOT PLATE

Geometry

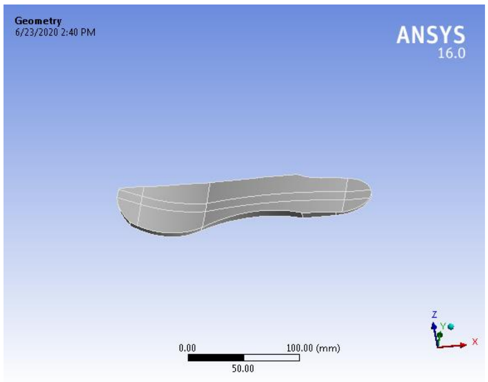

Figure -12: Geometry Of Foot Plate In ANSYS

Geometry was developed using Unigraphics Nx-8 software and the step file was used as input to Ansys.

Meshing

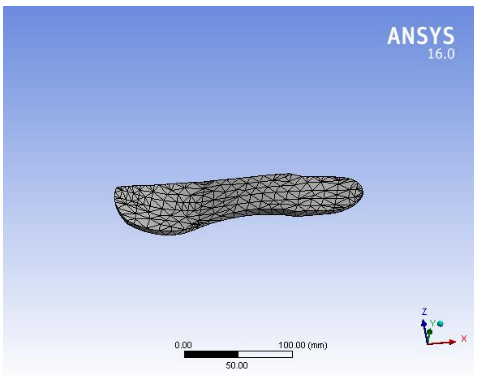

Figure -13: Meshing Of Foot Plate In ANSYS

Meshing was done using Ansys free Mesher and mesh details are as follows:

Nodes	2073
Elements	918
Mesh Elements	None

Boundary Conditions

The boundary conditions and loading conditions are defined as below in figure:

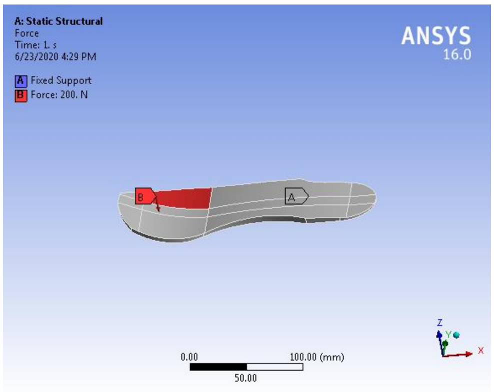

Figure -14: Boundary Condition of Foot Plate In ANSYS

Von-mises Stresses

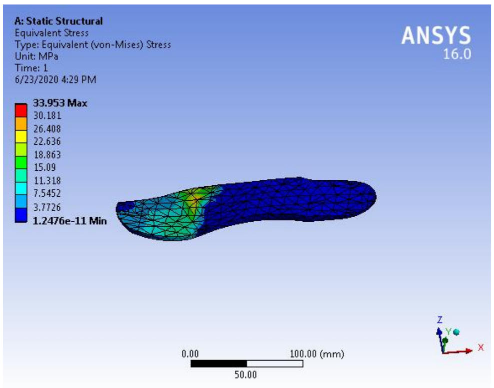

Figure -15: Von-Mises Of Foot Plate In ANYSIS

The maximum von mises stress developed is 33.953 Mpa which is well below the allowable stress hence the frame is safe underweight force load.

Maximum Deformation

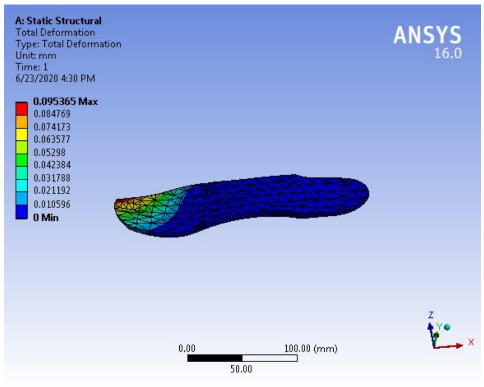

Figure -16: Maximum Deformation of Foot Plate In ANYSIS

The maximum deformation is 0.09536 mm which is very negligible hence the foot plate is safe.

4. DETAILS OF EPOXYRESIN GLASS FIBER

4.1GLASS FIBER DETAILS

Glass fiber properties, such as tensile strength, Young's modulus, and chemical durability, are measured on the fibers directly. Other properties, such as dielectric constant, dissipation factor, dielectric strength, volume/surface resistivities, and thermal expansion, are measured on glass that has been formed into a bulk sample and annealed (heat treated) to relieve forming stresses. Properties such as density and refractive index are measured on both fibers and bulk samples, in annealed or unannealed form.

Density of glass fibers is measured and reported either as formed or as bulk annealed samples. ASTM C 693 is one of the test methods used for density determinations. The fiber density (in Table 4) is less than the bulk annealed value by approximately 0.04 g/cc at room temperature. The glass fiber densities used in composites range from approximately 2.11 g/cc for D Glass to 2.72 g/cc for ECRGLAS reinforcements. Tensile strength of glass fibers is usually reported as the pristine single-filament or the multifilament strand measured in air at room temperatures. The respective strand strengths are normally 20 to 30% lower than the values reported in Table 3 due to surface defects introduced during the strand-forming process. Moisture has a detrimental effect on the pristine strength of glass. This is best illustrated by measuring the pristine single-filament strength at liquid nitrogen temperatures where the influence of moisture is minimized. The result is an increase of 50 to 100% in strength over a measurement at room temperature in 50% relative humidity air. The maximum measured strength of S-2 Glass fibers at liquid nitrogen temperatures is 11.6 GPa for a 12.7 mm gauge length, 10 µm diameter fiber. The loss in strength of glass exposed to moisture while under an external load is known as static fatigue. The pristine strength of glass fibers decreases as the fibers are exposed to increasing temperature. E Glass and S-2 Glass fibers have been found to retain approximately 50% of their pristine room-temperature strength at 538°C (1000°F) and are compared to organic reinforcement fibers. The Young's modulus of elasticity of unannealed silicate glass fibers ranges from about 52 GPa to 87 GPa. As the fiber is heated, the modulus gradually increases. E Glass fibers that have been annealed to compact their atomic structure will increase in Young's modulus from 72 GPa to 84.7 GPa. For most silicate glasses, Poisson's ratio falls between 0.15 and 0.26. The Poisson's ratio for E Glasses is 0.22 ± 0.02 and is reported not to change with temperature when measured up to 510°C. High strength S-2 Glass fibers' annealed properties measured at 20°C are as follows: Young's Modulus 93.8 GPa Shear Modulus 38.1 GPa Poisson's Ratio 0.23 Bulk Density 2.488 g/cc

	E Glass
Oxide	**%**
SiO_2	52 - 56 %
Al_2O_3	12 - 16 %
B_2O_3	5 - 10 %
CaO	16 - 25 %
MgO	0 - 5 %
ZnO	
BaO	
Li_2O	
$Na_2O + K_2O$	0 - 2 %
TiO_2	0 - 1.5 %
ZrO_2	
Fe_2O_3	0 - 0.8 %
F_2	0 - 1 %

Table -2: Composition Range of Glass Fiber

	E Glass
Density gm/cc	2.58
Refractive Index	1.558
Softening Point ^{0}C (^{0}F)	864 (1555)
Annealing Point ^{0}C (^{0}F)	657 (1215)
Strain Point ^{0}C (^{0}F)	615 (1140)
Tensile Strength Mpa	
-196 ^{0}C	5310
23 ^{0}C	3445
371 ^{0}C	2620
538 ^{0}C	1725
Young's Modulus Gpa	
23 ^{0}C	72.3
538 ^{0}C	81.3
Elongation %	4.8

Table -3: Properties of Glass Fiber

Physical Properties			
Property	**ASTM Standard**	**75 ^{0}F**	**22 ^{0}C**
Elastic Constants		**Msi**	**Gpa**
Longitudinal Modules	D3039	7.7 - 8.5	53 - 59
Transverse Modules	D3039	2.3 - 2.9	16 - 20
Axial Shear Modules	D3518	0.9 - 1.3	6 - 9
Poisson's Ratio	D3039	0.29 - 0.28	0.26 - 0.28
Strength Properties		**ksi**	**Mpa**
Longitudinal Tension	D3039	230 - 290	1590 - 2000
Longitudinal Compression	D3410	100 - 180	690 - 1240
Transverse Tension	D3039	6 - 12	41 - 82
Transverse Compression	D3410	16 - 29	110 - 200
In-Plane Shear	D3518	9 - 24	62 - 165
Interlaminar Shear	D2344	Aug-15	55 - 103
Longitudinal Flexural	D790	180 - 250	1240 - 1720
Longitudinal Bearing	D953	68 - 80	469 - 552
Ultimate Strains			
Longitudinal Tension	D3039	2.7 - 3.5 %	
Longitudinal Compression	D3410	1.1 - 1.8 %	
Transverse Tension	D3039	0.25 - 0.50 %	
Transverse Compression	D3410	1.1 - 2.0 %	
In-Plane Shear	D3518	1.6 – 2.5 %	
Physical Properties			
Fiber Volume (%)	D2734	57 - 63 %	57 - 63 %
Density	D792	lb/in^3 0.071 - 0.073	g/cm^3 1.96 - 2.02

Table -4: Glass Fiber Unidirectional Epoxy Composite Properties

4.2DETAILS OF EPOXY RESIN

4,4'-(2,2-Propanediyl) diphenol-2-(chloromethyl) oxirane (1:1)

- CAS: 25068-38-6
- EC Number: 500-033-5
- Molecular Formula: C18H21ClO3
- IUPAC Name: 4,4'-(2,2-Propanediyl) diphenol - 2-(chloromethyl) oxirane (1:1)
- Molar Weight [g/mol]: 320.810

Synonyms: 4,4'-Isopropylidenediphenol, Epoxy Type 7, oligomeric reaction products with 1-chloro-2,3-epoxypropane; PKHH; Paphen; Phenoxy; Epon; Araldilt; Aicarpox; Adeka; AER; reaction product: bisphenol-A-(epichlorhydrin); 4,4'-Isopropylidenediphenol, oligomeric reaction products with 1-chloro-2,3-epoxypropane.

5. ARCHITECTURE OF EXOSKELETON

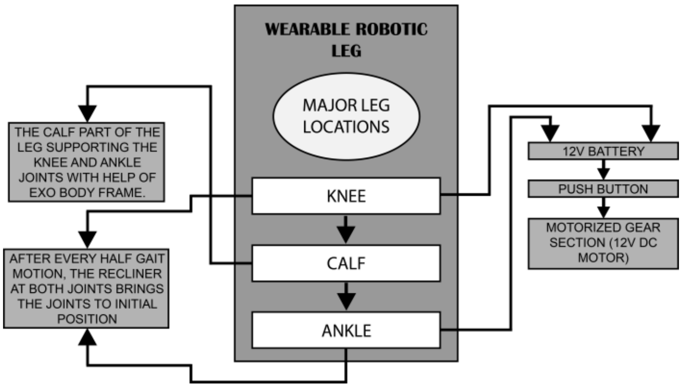

Figure -17: Architecture of Exoskeleton

6. MOTOR & WORM AND WORM GEAR

With power motor you push the button up or down, and the ankle joint and knee joint move. It all begins with the battery that sends the power to the power distribution box, from there the power is directed to the motor; so that when you turn on the witch the joints will be in operation.

The switch works by closing and opening two different sets of wire circuits, and then the wires are redirected to the power motor. When you push the switch one way, one set closes and another opens. If you push the switch the other way the opposite sets open and close. This is necessary in determining which way the motor should run. The majority of power motors work in the same way by having an automatic down feature on the joints; if you hold the switch down the joint will lower until you release the switch. The power motor is a small motor that has an attached worm gear. This worm gear is a length of metal with a spiral on one end, similar to that of a screw. The worm is attached to a gear; this circular gear has teeth around the outside. We can all picture this as a form of cog. As the worm turns it moves the gear by linking the teeth inside the spiral; the gear is then linked to several linkages. Linkages are used to create motion in exoskeleton with motors.

The worm is fixed at a specific angle to the gear, which allows the worm to turn the gear, but prevents the gear from turning the worm. The motion of the worm and gears create a gear reduction which gives enough force to turn or rotate things, this is called torque.

Power Motor:

Figure -18: Power Motor

Exoskeleton mechanism comprises of three main parts:

a) The drive motor, 12-volt DC
b) The gear box that provides the necessary amplification of motor torque and reduction in speed in order to operate the power window mechanism
c) The driver gear or the output gear from the power motor that drives the linkage mechanism

6.1POWER MOTOR CONSTRUCTION

Structure and Operation

• The power motor consists of a motor, connector and gear.

• Two Hall effect switches are set in the connector.

• The Hall effect switch utilizes magnets set on a rotating axis to sense the power window motor rotation, and outputs a synchronized pulse to the power window main switch.

• Hall effect switch No. 1 outputs one pulse cycle for each rotation of the power window motor axle. Accordingly, the power window main switch detects the rotational speed of the power window motor.

• The power window main switch detects the rotational direction of the power window motor by the difference between high and low pulse points from Hall effect switch No. 1 and 2.

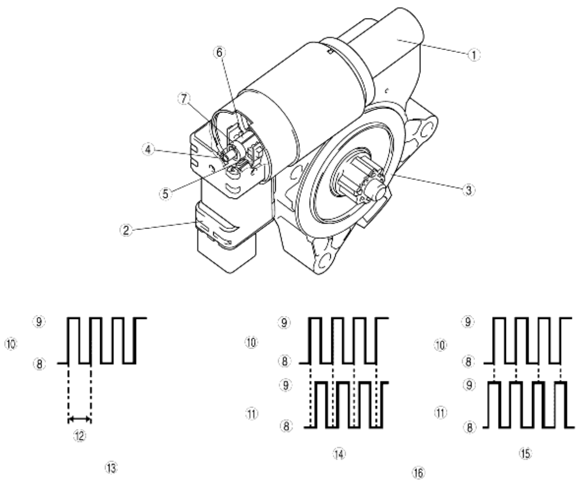

Figure -19: Power Motor Parts

1	Motor
2	Connector
3	Gear
4	Hall effect switch No.1
5	Hall effect switch No.2
6	Shaft
7	Magnet
8	Low
9	High
10	Pulse (Hall effect switch No.1)
11	Pulse (Hall effect switch No.2)
12	One revolution of power motor
13	Detection of linkage movement distance
14	Up
15	Down
16	Detection of linkage movement direction

Table -5: Description of Power Motor

6.2SPECIFICATION OF MOTOR SELECTED

12V DC Universal Automotive Power Window Lift Motor

1) Key Specifications/Special Features:

Sr. No.	Parameter	Value
1	Mounting Hole	6 Nos.
2	Voltage	12 VDC
3	No Load Speed	92 rpm
4	No Load Current	1.30 A
5	Stall Torque	9 N-m
6	Stall Current	24 A
7	Water Resistant	Yes

Table -6: Key Specifications Of Power Motor

Schematic of the gear box layout:

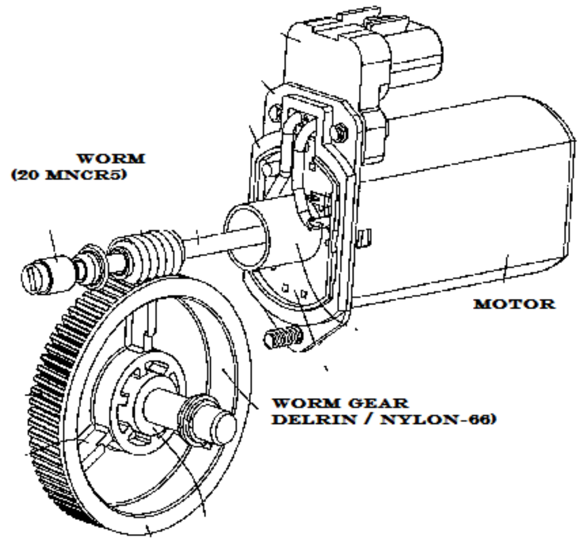

Figure -20: Gear Box Layout

Motor is 12 V Dc motor gear box ratio to be 1:55 reduction output of the gear box will be a direct shaft with dynamometer pulley arrangement to carry out the testing of the gear box under various load conditions.

7. SELECTION OF BATTERY

A large portion of the financially accessible exoskeletons utilize battery-powered Lead Acid particle batteries, which require successive charging. The battery charging turns into a major bottleneck, when the individual, wearing the exoskeleton, requirements to go for seven days stumble on journeying or mountaineering.

7.1 SPECIFICATION OF BATTERY

Specification of motor is provided in Table 5
Volt : 12 V
Power : 12 W

Required voltage of battery is 12 volts
Therefore,
12 W x 1 Hour = 12 Watt – Hour (Whr)

Battery efficiency of 90% ------- Assumption

12 Whr x 1.3 = 15.6 Whr
15.6 Whr / 12 Volt = 1.3 Ahr

So, the battery should be at least 1.3 Ah so that the 12 Volt motor can be run in ideal condition.

7.2BATTERY SELECTION

For the exoskeleton the battery is selection of Kweight 12 Volts & 1.3 Amps Lead Acid Battery.
The battery is completely rechargeable & weights around 500 grams to 750 grams. This battery will also last for 3 to 5 years if it is recharged & operated properly. The battery is consider to be efficient for normal working conditions weighing the human weight from 30 Kgs to 95 Kgs.

Figure -21: Lead Acid Battery

8. ELECTRONICS

There are several electronics components fitted in the exoskeleton so as the exoskeleton can perform its task, it includes various components like sensors, motors, motor drive(L293D), etc. To power up the exoskeleton a circuit is being design.

8.1MOTOR DRIVE (L293D)

The L293D is a popular 16-Pin Motor Driver IC. As the name suggests it is mainly used to drive motors. A single L293D IC is capable of running two DC motors at the same time; also the direction of these two motors can be controlled independently. So if you have motors which has operating voltage less than 36V and operating current less than 600mA, which are to be controlled by digital circuits like Op-Amp, 555 timers, digital gates or even Micron rollers like Arduino, PIC, ARM etc.. this IC will be the right choice for you.

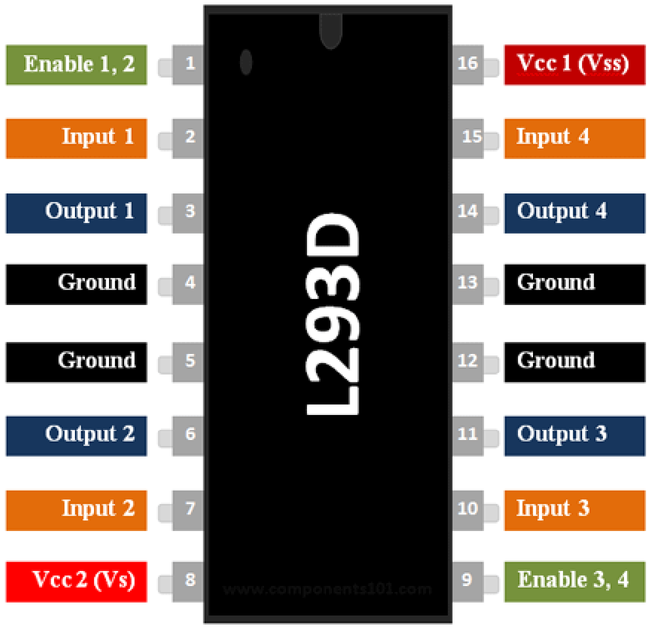

Figure -22: Pin Diagram of L293D

8.2PUSH BUTTON

Push-Buttons are normally-open tactile switches. Push buttons allow us to power the circuit or make any particular connection only when we press the button. Simply, it makes the circuit connected when pressed and breaks when released. A push button is also used for triggering of the SCR by gate terminal. These are the most common buttons which we see in our daily life electronic equipment's.

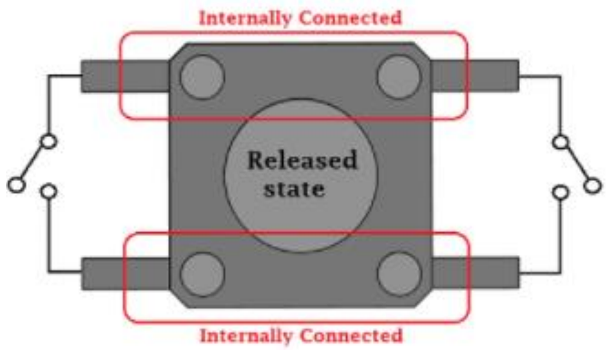

Figure -23: Push Button

9. CALCULATIONS

9.1DESIGN OF WORM GEAR

The pair of worm and worm wheel used in the machine is designated as 1/55/10/1

Z1 = 1

Z2 = 55

q = 10

M = 1

I = z2 / z1 =55

N = 5060 rpm

N2 = 5060 / 55 =92 rpm

D2 = m x z2 =1 x55 =55

tanU = z1 / q

u = 5.71 ^{0}

F = 2m sq.rt (q+ 1) = 6.63

Da1 = m(q+2) =12

C = 0.2mcosU = 0.3

Lr = {da1+2c} sin-1[F/(da1+2c)]

Lr =403.27

For case hardened steel Sb =2.82

For Nylon-66, Sb =0.62

Xb1 = 0.25

Xb2 =0.48

$Mt_1 = 17.65\ Xb_1\ Sb_1 m\ Lr\ d_2\ cosU$

= 2.749 x 10^5N-mm

$Mt_2 = 17.65\ Xb_2\ Sb_2 m\ Lr\ d_2\ cosU$

= 60.4x 10^3N-mm

Thus, theoretical torque transmitting capacity of Nylon -66 worm gear is close to 60.4N-m whereas the stall torque of the motor is 9 N-m Thus the worm gear of nylon-66 is theoretically safe to transmit the given power and torque for the power window application.

9.2DESIGN OF GEAR CONSIDERING BEAM STRENGTH OF TOOTH

Power = 15 watt

Speed = 92 rpm

b = 10 m

Reduction ratio (i) = 55

Gear speed = 92 rpm

Material of gear Nylon - 66

Tensile strength = 55 N/mm^2

Service factor (Cs) = 1.5

dg = 55

Now; T = Pt x (dg / 2)

We know that the stalling torque of the motor is 9N-m hence the failure load

Net load on gear tooth will be

Pt = 9000/ (55/2) + (14 x1.7 /2) = 225 N.

Peff = 225N --------(A)

Lewis Strength equation

WT = sbym

Where ;

sy= (0.484 – 2.86) / Z

sy = (0.484 - 2.86) / 55

sy = 0.0432

sy = 23.65

W_T = (Sy) x b x m

=23.65 x 10m x m

W_T= 236.5 m^2----------(B)

Equation (A) & (B)

236.5 m^2 = 225 N

m = 0.98

Selecting Standard Module = 1 mm

9.3GEAR DATA

Number Of Starts Of Worm = 1

Module = 1

Number Of Teeth On Gear = 55

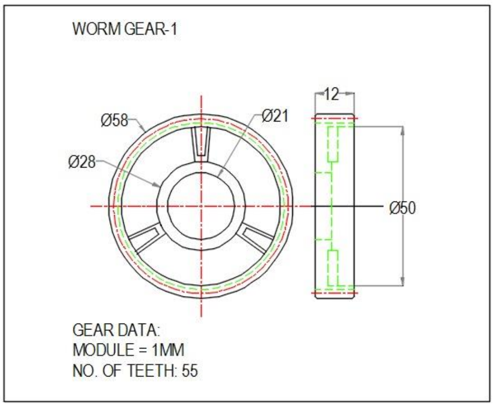

Figure -23: Worm Gear

9.4DESIGN OF WORM GEAR BLANK

Designation	Ultimate Tensile Strength	Yield Strength
Worm Gear (Mild Steel)	55 N/mm^2	40 N/mm^2

Table -7: Description Of Worm Gear

fs allowable = 55 / 2 = 27.5 N/mm^2

T design = 9 Nm

Check For Torsional Shear Failure Of Shaft.

$Td = \Pi / 16 \times fs_{act} \times (D^4 - d^4) / D$

$fs_{act} = (16 \times Td) / \{\Pi \times [(D^4 - d^4) / D]\}$

$fs_{act} = (16 \times 9 \times 10^3) / \{\Pi \times (55^4 - 21^4) / 55\}$

$fs_{act} = 13\ N/mm^2$

As $fs_{act} < fs_{all}$

Pinion shaft is safe under torsional load.

10. APPLICATION

The principal approach of this task depends on exoskeletons for the clinical field.

1. To help old, part of the way debilitated or incapacitated individual to stroll to change engine capacities.

2. As recovery hardware for people experiencing walk issue.

3. With the assistance of help handles, a person who can't keep up body direction because of spinal line injury, it offers help with the assistance of gyrator direction gadget on the back to keep up a negligible stance.

4. This exoskeleton will be the best option for people utilizing a wheelchair.

5. The uses of exoskeleton robots are differed, going from military applications to the clinical field.

Figure -24: Wearable Robotic Exoskeleton

11. CONCLUSIONS

The project is completely built and ready to test. This exoskeleton is built so that a paralyzed person can wear and have a support to walk on a ground.

In this project we have performed the designing of the Worm & Worm Gear along with Foot Plate in ANSYS Software. The required material is being selected according to various parameter.

The power motor is placed near knee & ankle which will provides enough torque to perform walking action. For now, this exoskeleton is built for only one leg which uphold both joints of the leg.

The complete model is built in ANSYS Software & completely build in hardware.

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[14] Figure -2: Aged Group For Loosing Walking Ability is taken from the website: https://www.google.com/imgres?imgurl=https://www.researchgate.net/profile/Baltej_Rupal/publication/320407167/figure/fig1/AS:568210925395968@1512483449339/Population-of-elderly-persons-estimated-for-2015-and-projected-for-2050-3_Q320.jpg&imgrefurl=https://www.researchgate.net/profile/Gurvinder-Virk-2&h=320&w=320&tbnid=tDcdWEJgL_DE_M&tbnh=225&tbnw=225&osm=1&hcb=1&source=lens-native&usg=AI4_-kSfc-xIxf8klL_Ox6yFtrkG75vPmA&ved=0ELLNBQgAKAAwAA&docid=XlDlM-lGXiEMBM

[15] Figure -21 Battery is being purchased from this website and image is being added from same website: https://m.alibaba.com/product/60250126831/12V-1-3AH-rechargeable-battery-smf.html

[16] Figure 22 pin diagram of L293D Motor Drive is taken from this website: https://components101.com/ics/l293d-pinout-features-datasheet

[17] Figure 23 push button is taken from this website: https://components101.com/switches/push-button