Design, Fabrication & Analysis of Exoskeleton On Aluminium Alloy 6082(T6)

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Abstract - *In today's challenging world, man and machine share an equitable space at work, some working environments involve efforts of standing hours throughout the day, for such activities the fatigue increases subsequently decreasing the productivity. Machines can work at their best without rest, they don't get tired and boredom, but for humans, the needs & comforts plays a vital role, it is now time to adopt optimized & designed machines, mechanisms & principles which gives ease of access to our living standards, In order to subtle the requirement of worker, to provide instantaneous seating facility, chairs are not supplied in floor space or workshop, then it's time to think different and use a chair less chair which occupies less space, size and light in weight. 'Exoskeleton' is one of a kind, comes in compact, comfortable & wearable simple mechanical device which gives human prosthetic lower limb support. Exoskeleton is well Designed, Fabricated & Analyzed using Modern Manufacturing Techniques such as Solid-Works, DELCAM, CNC-VMC, Analysis Simulation.., In order to meet the requirement of the user, Also to reduce the weight, it is fabricated using high strength and low density materials Aluminum Alloy 6082(T6).*

Key Words: Exoskeleton, Prosthetic support, Solid-works, DELCAM-POWERMILL, CNC-VMC(Computer Numerical Control - Vertical Machining Centre), Analysis Workbench Simulation, Aluminium Alloy 6082(T6).

1. INTRODUCTION

Starting from the Evolution of human species, change is Inevitable in nature. Almost every requirement is the birth of Need, The world is moving into a better place day to day, From the invention of primary tools to modern advanced tools, From the discovery of wheel to industrial revolution, The world is ready to give results those who are adaptable to change, as we can't imagine an office, station or household without a seating chair, there is need to take rest for a worker, an employee or an elderly aged person after continuous working hours, but at work - a chair is a constraint, due to some unknown reasons such as not compact, not mobile and it occupies more space.

At this point of time some alternative seating system is supposed to be achieved, without any heavier mechanisms or bigger machine elements, a simple chair less chair is designed & optimized so that it can be compact, reliable, comfortable, light in weight, In order to meet the requirement.

1.1 Statement of the Problem

Some working environments involve efforts of standing hours throughout the day, for such activities the fatigue increases subsequently decreasing the productivity. It is very difficult to stand and work for overall shift in the company by a worker. This will reduce the efficiency of the worker. The solution to this problem is to have a portable device which has an ergonomic design, low cost Chair less Chair.

1.2 Scope of the Project

In this work a mechanical ergonomic device that is designed around the shape and function of the human body, with segments and joints corresponding to those of the person it is externally coupled with. It functions as a chair whenever it is needed; this machine element is coined as 'Exoskeleton'.

1.3 Importance/Significance of the Project

Having an attendant or using an assistive device is not safe always, it may cause some accidents as well, In these adverse conditions- using exoskeletons for walking, climbing, seating and doing work is safe and you're confident that you won't fall. While taking a walk at short distances carrying weight and size matters, exoskeletons are going to bring more flexibility, mobility, compatibility, reliability and most importantly the confidence. Apart from in medical therapy and military sector, exoskeletons offer other applications, for example as a power booster during assembly work in production. They act here as a strength support device to prevent signs of fatigue that occur especially when performing repetitive actions. It also aids as an elderly aged supporting mechanical wearable device for sitting assistance.

1.4 Aim/Objective of the Project

The objective of this project is to enable the user to have the ability to move around with absolute ease, comfort & flexible, with the use of a chair less chair, this exoskeleton based support would be useful to people whose current job requires them to stand for long hours. This modern chair will ease the aches in the thighs and back. It is especially of great use to the elderly, workers in assembly line, trekkers and military who don't always have the option of pulling a chair to rest them on the go!!

1.5 Need/Solution of the Project

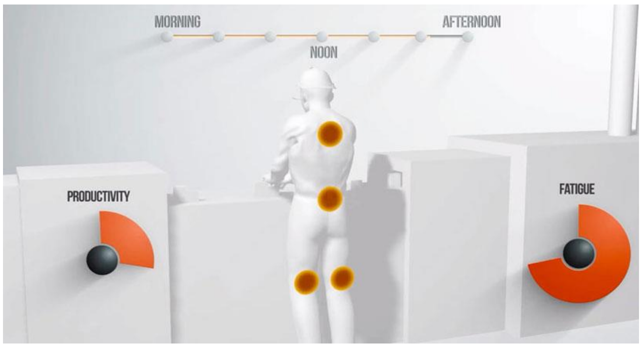
1. Cylinder with Damper Mechanism is used for smooth suspension.

2. Made out of Aluminium Alloy 6082 which is light in weight, High Strength & Lower Density.

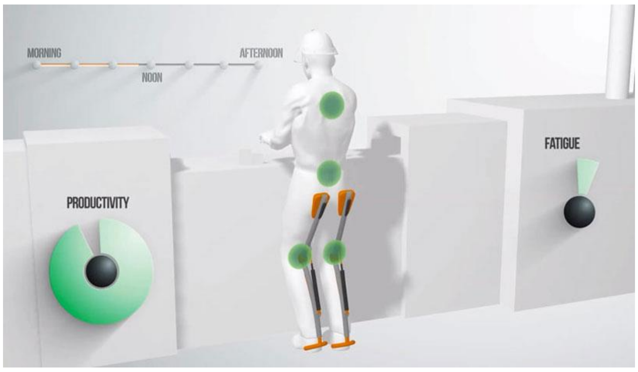
3. Modular & Compact Design.

4. Aesthetic & Low cost.

Productivity vs Fatigue of worker without Support



Productivity vs Fatigue of worker with Exoskeleton

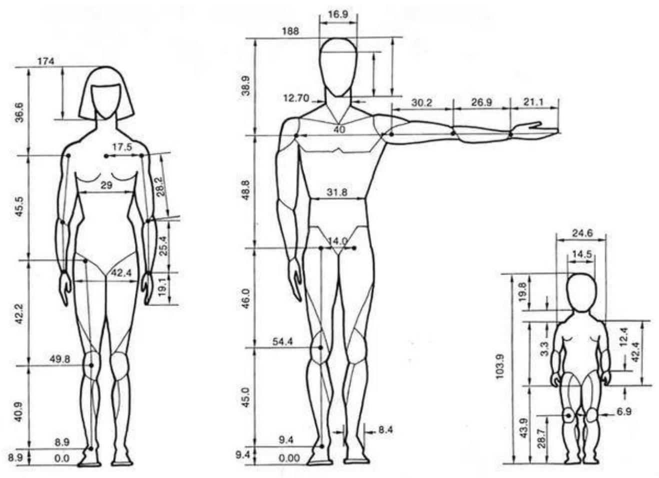


2. LITERATURE REVIEW

Swiss start-up noonee has created the chair less chair which is worn as an exoskeleton using hydraulic mechanism & electric motor assistance on the back of the legs. By using this device you can walk or even run as needed, but can be locked into a supporting structure when you go into a sitting position. The aim of this project is to give support to the worker who works for a long time in industry. So chair less chair helps users to rest their leg muscles by directing their body weight towards a variable. Our device is inspired from the works of Noonee.

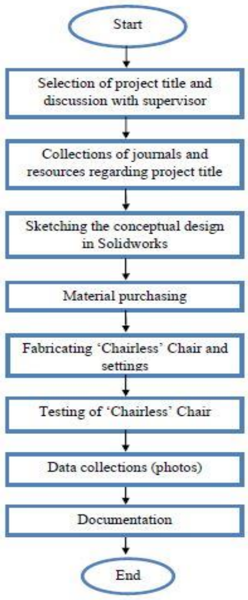
3. DESIGN CONSIDERATIONS

3.1 Anthropomorphic Charts (cm's)



The dimensional measurements of exoskeleton links length is taken from an average human body.

3.2 Flowchart – Step by Step Procedure



3.3 Classification of Exoskeletons

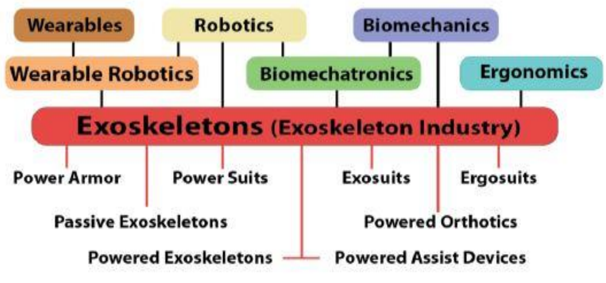


Figure 1: Classification of Exoskeletons

1) Active Exoskeletons

They are powered by external sources like a motor, battery powered. They work along with the passive exoskeletons to help in its functioning. Sometimes they are well equipped with sensors, electronic & electric control units.

2) Passive Exoskeletons

These are not powered by external power sources but work on the basis of mechanical linkages, pneumatic and hydraulic mechanisms, spring controlled devices etc. Since active exoskeletons pose a restriction to the amount of external energy that can be supplied in terms of quantity, quality and time we have focused purely on passive type of exoskeletons. Passive elements are implemented in the exoskeleton to either store or dissipate energy with the objective of reducing the residual energy that the human would have to expend for locomotion.

3.4 Factors to be considered in this Project

1) Statement of Problem & Definition of Solution.

2) Scope, Objective & Significance of Need, Material and Skill for Research & Design.

3) Design Considerations, Development & Modifications.

4) Estimation of costs in Design, Implementation, Material Selection, Manufacturing, Production and Marketing.

5) Cost and Availability of Capital required for Investment & Inventory.

6) Project Promotion & Public Satisfaction, Customer Feedback Criteria.

7) Growth Prospects for the Futuristic Scope.

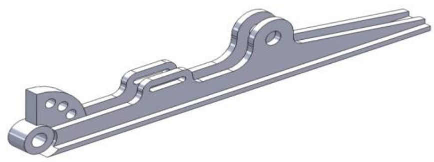
3.5 Bill of Material's Tabular Column

Sl/No	Component List	Material	Quantity
1	High Compressed Gas Actuated Damper	Stainless Steel	2
2	Exoskeleton Frame	Aluminium Alloy 6082	2
3	Adjustable Heel & Locking Mechanism	Aluminium Alloy 6082	2
4	Belt & Buckle	Fabric & Plastic	6
5	Hexagonal Nuts & Bolts	ISO M12x1.5 Steel	6

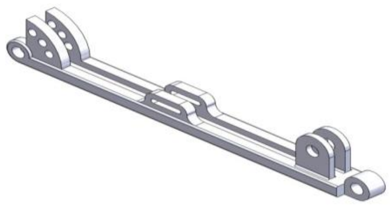
4. DESIGN METHODOLOGY

Exoskeletons are defined as Simple Mechanical Standalone Anthropomorphic Active Devices that are "wearable" machine elements with simple mechanism in it. Based on the Anthropomorphic study of human skeleton and as per dimensions of Indian wearers; the link lengths of the lower limb are derived. Using these standard design procedures the link dimensions are derived. It is Designed & Modeled in the SOLIDWORKS Modeling Software. All the parts are Sketched, Modeled, and Assembled along with Motion Study & Mechanism; also Analysis is performed to check the Factor of Safety and Load Bearing Capability.

1) Top Link



2) Bottom Link

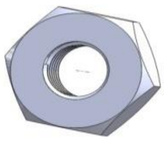


3) Damper Top

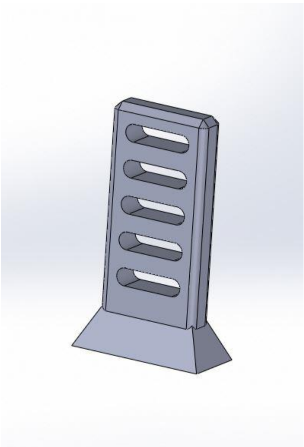
4) Damper Bottom

5) Hexagonal Bolt

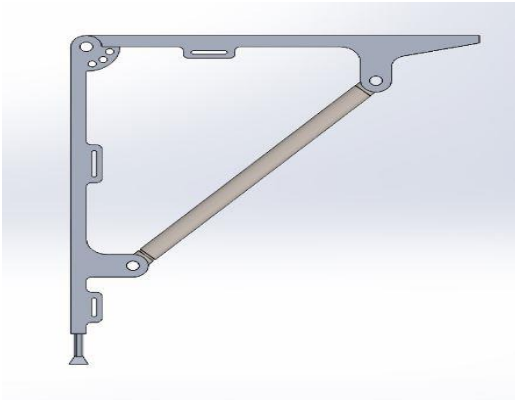
6) Hexagonal Nut



7) Adjustable Heel

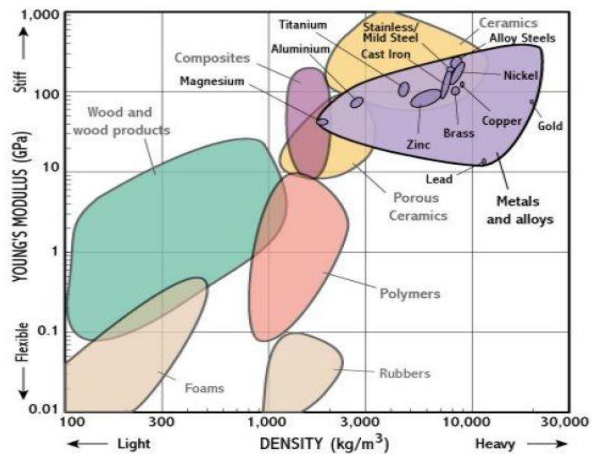


8) Assembly OF Exoskeleton



5. MATERIAL SELECTION

Let's say we're trying to decide how to make a rucksack & robust frame. We need to choose a material that is flexible, light, strong and cheap – we will therefore need to find data about the Young's modulus, density, strength and cost for lots of different materials.



Above chart shows that Aluminum alloys might be a good choice: although they are a bit less hard & tough than steel, they are a lot lighter. Of course there is need to check that the strength and cost of aluminum alloys were reasonable, we could keep zooming-in in order to determine which particular Aluminium alloy 6082 to use.

A quick look around aerospace, aircraft, automobile & structural parts & products shows that most rucksack & robust frames are indeed made from aluminum alloys. The charts above show why this might be alloys can be lighter, stiffer and stronger than metals – but you will have to pay more!!

5.2 Some important Mechanical properties of Aluminum Alloy 6082

Proof Stress 310 MPa

Tensile Strength 340 MPa

Shear Strength 210 MPa

Density 2.70 Kg/m3

Melting Point 555 °C

Thermal Expansion 24 x 10-6 /K

Modulus of Elasticity 70 GPa

Thermal Conductivity 180 W/m.K

Electrical Resistivity 0.038 x 10-6 Ω .m

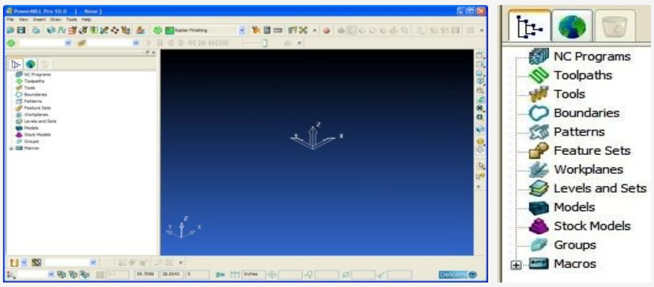
6. FABRICATION USING CNC-VMC & DELCAM

Autodesk Powered Power MILL Manufacturing Software helps us to machine, to operate, to inspect, and to fabricate - good quality & quantity of parts faster. Advanced CAD/CAM resolves multi-axis machining to shorten delivery times, boost productivity and increase profitability without compromising surface quality which increases overall Productivity Factors

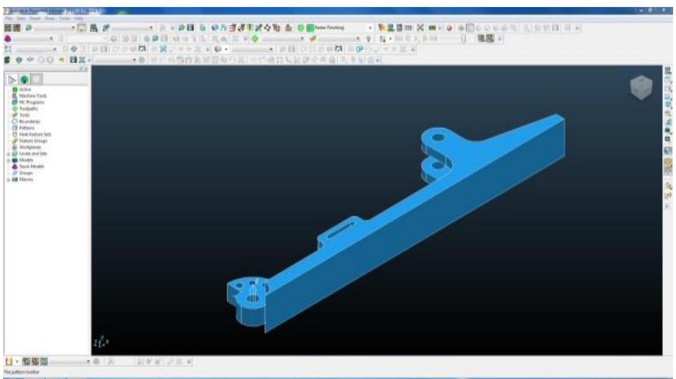
Power MILL offers a wide range of strategies to make efficient 5-axis programming in a real time work. The combination of power, flexibility and ease of access has enabled Power MILL to be used successfully in a wide range of applications.

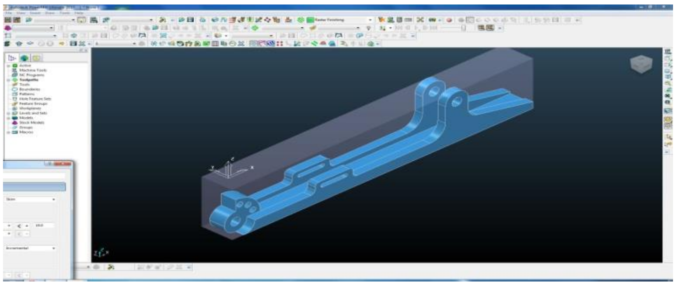
6.1 Working Procedure of PowerMILL (DelCAM)

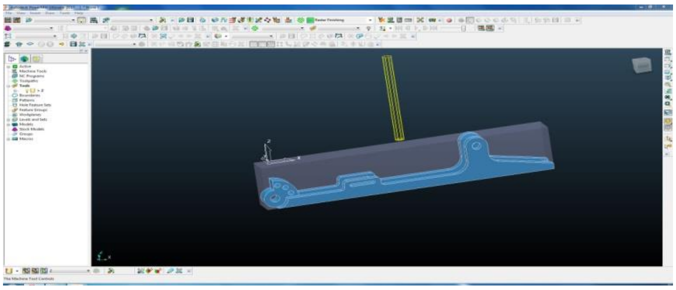
1) Introduction & Understanding DelCAM GUI

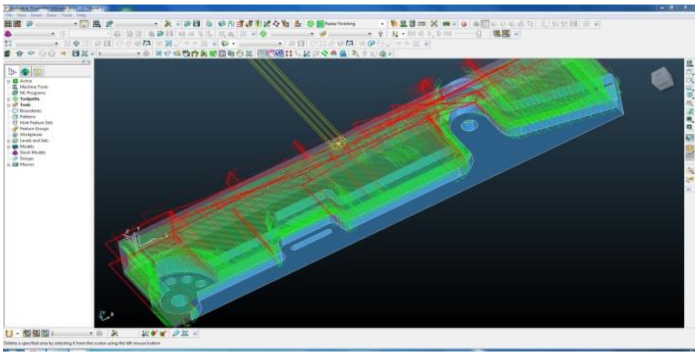


2) Work plane set up, wireframe modeler, data exchange, set block for machining

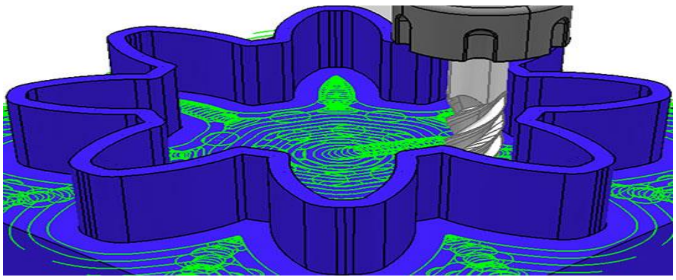


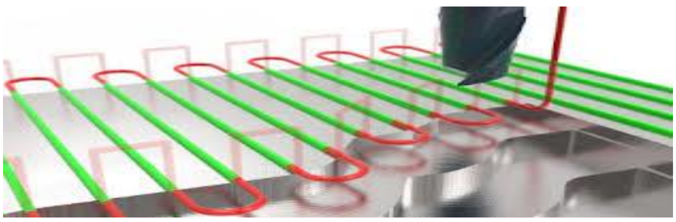






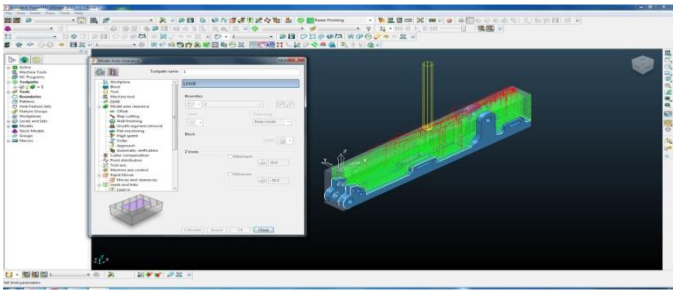
3) Machine TOOLPATH





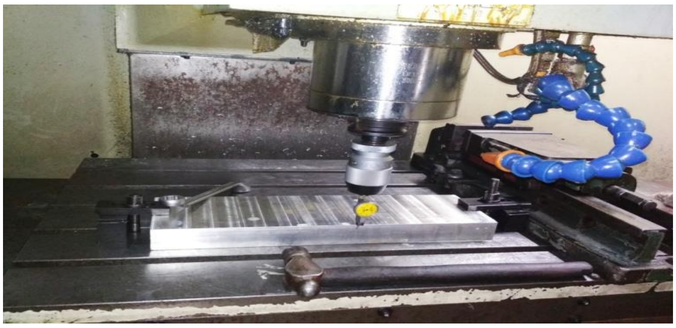
- Data exchange & Wireframe modeler
- Customizing Power MILL Stock Models, Define Working planes & Machining simulation
- Create process sheet Setup for machining
- Predefined boundaries for machining
- Defined block – measurement
- Face milling & Drilling

4) 3D Area Clearance Strategies



PowerMILL is a (Computer-aided manufacturing) software that runs on Microsoft Windows for the programming of 2D/3D Vertical Machining Centre machine tool paths for 2 to 5 axis CNC (Computer Numerical Control) Milling machines developed by Autodesk Inc. Earlier It was organized by DelCAM Pvt Ltd. The software is used in a huge range of enormous engineering fields to determine optimal tool paths and to reduce time and manufacturing costs as well as reduce delay time, Tool Loading and produce smooth surface finishes.

5) 2D-area clearance machining and post processor selection for G&M codes Generation



6.2 Impact of PowerMILL (DelCAM)

- Automatic Collision Avoidance
- Strengthen your Manufacturing Smarter
- CAM software for Superior CNC Machining
- Accelerates & Boosts Design & Manufacturing
- Resolves Complicated Models for Manufacturing
- Inspection for Every Working Environment
- Optimizes Complexity in Manufacturing
- Performs Fabrication Precisely.
- Total Control with Tool Axis Editing.
- Improves Machine efficiency & Cycle Time
- Effective in Smooth Surface finish.
- Reduces Delay Time in Tool Loading & Idling.

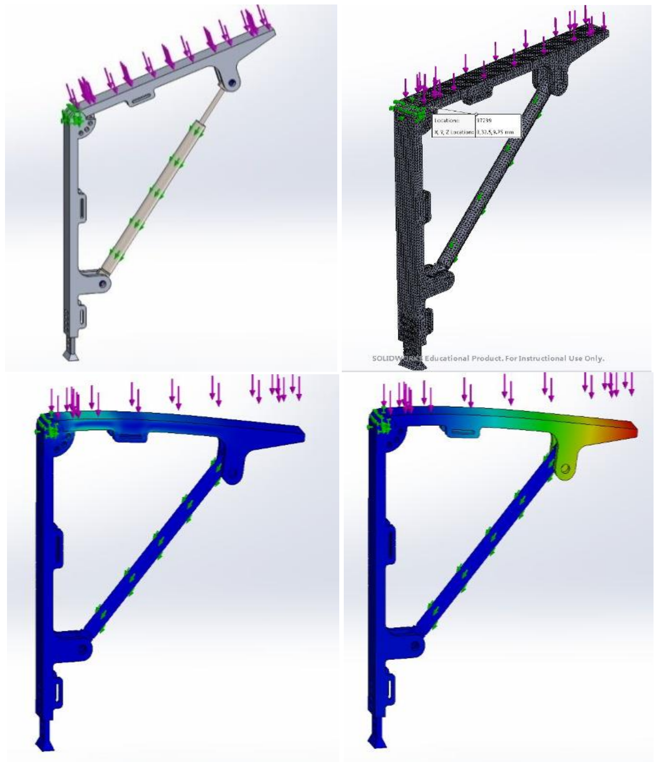
6.3 CNC VMC Fanuc G&M Codes Sample Data

***Post processor selection to convert DelCAM file into G&M codes Generation:**

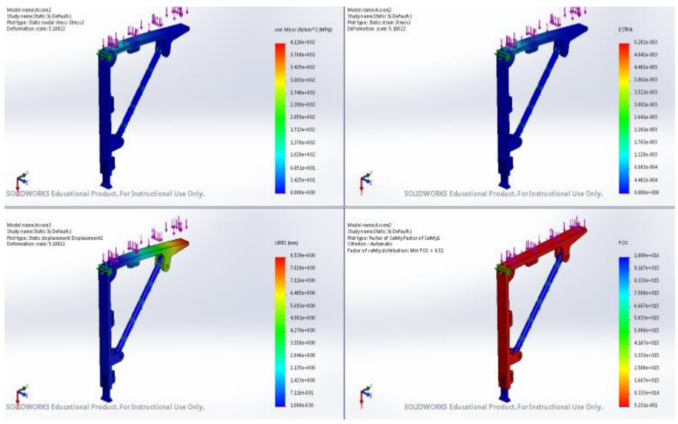
```
%
:0001
N10G91G28X0Y0Z0
N20G40G17G80G49
N30G0G90Z20M03 (SPINDLE START)
N40T1M6 (Tool Change: XX)
N50G54G90
N60 (Tool path Name:   1-5END)
N70 (Output:)
N80 (Units: MM)
N90 (Tool Coordinates: Tip)
N100 (Tool Number: 1)
N110 (Tool Id: 1-5END)
N120 (Coolant: Standard)
N130 (Gauge Length: 25)
N140 (Block:)
N150 (MIN X: -75)
N160 (MIN Y: -20)
N170 (MIN Z: -50)
N180 (MAX X: 2.77556e-015)
N190 (MAX Y: 20)
N200 (MAX Z: 8.34055e-015)
N210 (COORDINATE SYSTEM: WORKPLANE)
N220 (Datum - Tool Tip:)
N230 (X: -37.500)
N240 (Y: 0.000)
N250 (Z: 20.000)
N260 (Number of Flutes: 4)
```

```
N270 (Tool:   ENDMILL)
N280 (DIAMETER: 5)
N290 (Safety Factor:)
N300 (Tool Cutting Moves: Safe No Gouges)
N310 (Tool Leads: Safe No Gouges)
N320 (Tool Links: Safe No Gouges)
N330 (Cutting Moves: Collisions Checked)
N340 (Holder Leads: Collisions Checked)
N350 (Holder Links: Collisions Checked)
N360 (Tool path:   Constant Z Finishing)
N370 (TOLERANCE: 0.02)
N380 (THICKNESS: 0)
N390 (Tool path Stats:)
N400 (LENGTH: 19548.9)
N410 (TIME: 0/13/2)
N420 (LIFTS: 1)
N430G81Z0
N440P0.1,Q0.1(Repeat Canned Cycle Recall)
N450M07 (COOLANT OFF:)
N460G91G28Z0
N470M05 (SPINDLE STOP)
N480G49H0
N490G28X0Y0 (HOME POSITION RETURN)
N500M30(END OF PROGRAM :)
%
```

7. ANALYSIS & SIMULATION WITH MECHANISM



7.1 Analysis Representing Factor of Safety



7.2 Pictorial representation of Exoskeleton

a) Dissembled Components

b) Assembled Components

c) Fabrication & Partition of Al Alloy 6082 frame

8. APPLICATIONS

1) Medical field
a) Rehabilitation
b) Prosthetic support
c) Elder care Wearable
2) Industrial Field
a) Workshops
b) Job floors
c) Tool rooms
d) Production lines
3) Commercial purposes
a) Office & Business
b) Seminars & Function halls
c) Stadiums & Grounds
d) Travelling & Tours
e) Chairing & Seating
4) Home needs & Daily Activities
5) Army, Defense & Military
6) Trekking, Camps, Outdoor & other Activities..,

9. ADVANTAGES

1. It is a Simple Wearable Mechanical Device.

2. Eco-friendly, doesn't consumes any power.

3. Aesthetic & Modular Aluminum Alloy Design.

4. Light in Weight, Easy to Carry.

5. Compatible, Portable, Mobile & Reliable.

6. Maximum Comfort & Highly Flexible.

7. Instant Seating - Adaptable to Most Working Conditions.

10. DISADVANTAGES

- It drastically doesn't suit for all people due to different traditional clothes and shoes.
- Isn't adoptable for all heights.
- Adds an extra amount of weight while wearing.
- Startup project, So Initial costs may be high.

11. CONCLUSIONS

1) The Lower body Exoskeleton is successfully designed. The aim of this project is to develop a Lower body Exoskeleton to support human walking, sitting, and standing motions.

2) Future work will focus on improving mechanism and selection of material i.e.., light weight material like Aluminum, Chromium, Titanium etc.., for high strength, lighter in weight and comfortable angles.

3) In this project, a lower extremity exoskeleton mechanism is designed to support human walking, sitting, and standing motions synchronously with human and also it is developed to take significant portion of external load carrying by the user.

4) Once this is achieved, exoskeletons could become practically useful and start to appear in everyday life after make some improvement.

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