Design and Analysis of Lower Limb Exoskeleton

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Abstract

Lower Body Exoskeleton is nothing but chairless chair used in Industries. The people who are working in Industry can wear it on legs like Exoskeleton. It is a mechanical ergonomics device that is designed according to the shape and function of the human body. It is not a chair but it acts like a chair. The concept of this chairless chair is when it activatates you can walk. And then if it is inactive, it locks into place from an angle of 900, 1200 and 1500 and you can sit down on it. It is mainly used for industrial workers, standing for a long period of time leads to discomfort and reduce productivity. So Design and Analysis is an important parameter to know the forces induced in each element and actuators.

Keywords: Lower body Exoskeleton, Ergonomics, angle, actuator

I. INTRODUCTION

Now a days many industries across the globe are mainly concentrate on the improvement of their quality and increase their productivity to increase their profits. So companies understand the employees work stress and willing to provide stress and fatigue free working environment to maintain the standards and productivity of the company [1].

Thousands of workers standing for 10-12hrs a day , which may results physical problems like back pain, neck, head, shoulder and lower limb, upper back and lower back. In order to overcome this problem there is a simple chairless chair which is a wearable device. It is worn on the legs, which allows the user to walk or run and sit. It has a belt to avoid slip and it straps wrap around the thigh. So this device provides comfort to the operator who works continuously for a long time.

II. METHODOLOGY

Methodology of this work is concentrated on the development of chairless chair to support human body part which is a wearable device especially industrial workers need to stand for a long time around 10-12hrs per day[2]. The device consists a frame to hugs the back of the workers leg and it has a belt to avoid slip. Workers can stand and walk like normal, but when they want to sit pushing a button locks the frame into place at the desired angle. So the weight of the body is transferred through the frame to the floor or the heels.

III. LITERATURE REVIEW

Our aim is to give support to the worker who works for a long time in industry. So chairless 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. Swiss start-up noonee has created the chairless chair which is worn as an exoskeleton on the back of the legs[2]. 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.
IV. ANTHROPOMETRIC MEASUREMENTS OF HUMAN BODY

Where, A=H; B=0.9243H; C=0.870H;
D=0.818H; E=0.630H; F=0.468H; G=0.3676H;
H*=0.122H; I=0.5367H; J=0.7384H; K=0.5693H;
L=0.2252H; M=0.039H; N=0.1165H; O=0.1569H;
P=0.1581H; Q=0.1156H; R=0.2495H; S=0.04698H;
T=0.1479H.
The above data is as per non-Indian standards. So as per Indian standards,
L=Height from knee to foot is 0.2252H.
K=Height from hip to foot is 0.5693H.
M=Height of foot is 0.039H.

V. FORCE CALCULATION

Assume, the person height H= 180 , weight m= 70kg
Free Body Diagram Of Chairless Chair: (Angle=180°)
L = 0.2252H = 0.405m = 405mm (H=180cm)
K-L = 0.5693H - 0.2252H = 0.3441H = 0.619m = 619mm.
Body weight acting on lower exoskeleton,

\[ W = (70) \text{kg} \times 9.81 \]
\[ = 686.7 \text{N} \]

A. Mechanism for 90° angle:
A= Foot; B=Knee; C=Hip

B. Mechanism for 120° angle:
C. Mechanism for 150° angle:

D. Free body Diagram for 90°:

E. Force and moment calculations:

<table>
<thead>
<tr>
<th>LINKS</th>
<th>Angle=90°</th>
<th>Angle=120°</th>
<th>Angle=150°</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>M=27327.99 (N-mm)</td>
<td>M=95120.419 (N-mm)</td>
<td>M=48293.90 (N-mm)</td>
</tr>
<tr>
<td>BA</td>
<td>M=178767 (N-mm)</td>
<td>M=171675 (N-mm)</td>
<td>M=130473 (N-mm)</td>
</tr>
<tr>
<td>DC</td>
<td>M=44288.88 (N-mm)</td>
<td>M=88240 (N-mm)</td>
<td>M=44288.88 (N-mm)</td>
</tr>
</tbody>
</table>

VI. DIMENSIONS

A. For link BC & AB:

Material: Wood
Density of Wood is 650 kg/m³ [3]
Tensile Strength is 40 Mpa
Young’s Modulus is 12 Gpa
Factor of safety is 7.
1) Cross Section: I - Section
Take \( B = 6t, H = 5t, (b/2) = 2t, h = 2t. \)

\[
I = \frac{BH^3 - bh^3}{12}
\]

\[
I = \frac{6t \times (5t)^3 - 4t \times (2t)^3}{12}
\]

\[
I = 60t^4 \quad [4]
\]

Bending Equation:

\[
\frac{M}{I} = \frac{\sigma_b}{Y}
\]

\[
\frac{273.227 \times 10^3}{60t^4} = \frac{40}{2.5t}
\]

\( t = 7\,\text{mm} \)

For safe condition take \( t = 9\,\text{mm} \)

Therefore \( B = 54\,\text{mm}, H = 45\,\text{mm} \)

\( b/2 = 18\,\text{mm}, h = 18\,\text{mm}. \)

**B. For link DC:**

Material: Mild steel
Density of mild steel is 7800 kg/m\(^3\)
Yield Strength is 370 Mpa
Working Stress is 123.33 Mpa
Young's Modulus is 200 Gpa
Factor of safety is 3.

1) Cross Section: Circular Section

Link DC has circular cross section, so \( Y = D/2 \)

\( I = (\pi D^4/64) \)

Moment = 88240 N-mm

\[
\frac{M}{I} = \frac{\sigma_b}{Y}
\]

\[
\frac{88240}{\pi d^4/64} = \frac{123.33}{d/2}
\]

\( d = 20\,\text{mm} \)

**VII. Modeling**

Modeling the components by using SOLID EDGE
A. For 180°

B. For 90°

C. For 120°
VIII. Finite Element Analysis using ANSYS Workbench

A. For angle 120°

<table>
<thead>
<tr>
<th>Angle</th>
<th>Total Deformation (mm)</th>
<th>Maximum Shear Stress (Pa)</th>
<th>Equivalent Stress (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>180°</td>
<td>0.149</td>
<td>3.063*10^6</td>
<td>5.526*10^6</td>
</tr>
<tr>
<td>120°</td>
<td>3.55</td>
<td>7.150*10^7</td>
<td>1.315*10^8</td>
</tr>
<tr>
<td>90°</td>
<td>1.27</td>
<td>2.353*10^7</td>
<td>4.624*10^7</td>
</tr>
</tbody>
</table>

B. Stress table for different angles:

IX. Conclusion and Future Work

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. The finite element analysis is performed on chairless chair, using Ansys Workbench to find the total deformation, Maximum shear stress and Equivalent stress for three different positions i.e. 90°, 120°, and 180°. By observing the stress table, if the angle increases total deformations and Maximum Shear stress are increased gradually up to 120° after that gradually reduced. Future work will focus on improving mechanism and selection of material i.e. light weight material like Aluminum and for more comfortable angles.

REFERENCES

[3] Design data by PSG