



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJIRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 6, June 2022

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.118



9940 572 462



6381 907 438



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# An Exoskeleton Attached to the Lower Body to Minimize Fatigue Stress

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**ABSTRACT:** The abstract of this paper is to create an exoskeleton for long term standing workers. The purpose of the exoskeleton is to augment or reinforce the performance of a worker's existing body parts. Standing for long periods of time places stress on your lower back and actual pressure on lumbar vertebrae. This support helps users to rest their leg muscles by directing their body weight towards a variable damper attached to the frame and directs the weight to the ground. This exoskeleton system is designed to be an appropriate mechanism with the human lower extremity and it operates synchronously with the human.

**KEYWORDS:** Exoskeleton, Human lower body, Stress, Damper, Mechanism, Operates Synchronously.

## I. INTRODUCTION

Standing for a long time is not good for health. Meanwhile sitting for a long time is also not good for health as it affects the body's metabolic rate which causes various diseases. In workstation, mostly the productivity is considered as the main factor but the workers fatigue stress on their lower body is not considered as an important factor. Though the workplace is ergonomically constructed, they are not much effective in relieving worker fatigue stress. Mostly the workers have to work in a particular standing position for a long time even though there are many machines to support to do that work for them. Many workstations do not provide comfort to the workers.

Exoskeletons are designed to support human movement and supply medical rehabilitation. The exoskeleton should support the natural human movement while ensuring the protection and comfort of the workers, which should not affect their productivity rate. The engineering concept application on the human movement control provides computational and neuroscientific analysis.

A bilateral asymmetry in lower limb lengths is known as leg length discrepancy (LLD), or anisomelia. During movement of the lower extreme joints stresses are further increased by the activities of muscles needed to control the segments, by inertial forces created by the moving segments, and by the impulsive force transferred to the ground by foot.

This exoskeleton is a wearable chair. Workers can work when they are in a partial seating posture and they can also walk to a particular extent. The aim of this product is to develop an exoskeleton which seems to be like a wearable chair. This product will help to improve worker's seating posture and help them to sit anywhere without an actual chair and provides comfort for their legs. This helps them to increase the productivity of the workers and help them to relax their legs.



The main aim of this product is to make the design simple and strong and to reduce the cost as much as possible so that it can be affordable for all workers including leg injury patients also. The use of this exoskeleton will reduce the cases of MSD (Musculoskeletal Disorders) which developed in workers because of prolonged standing conditions.

Exoskeleton also creates the possibility to:

1. Support injured workers and help them to work again.
2. Reduce, otherwise minimize the need for small breaks, rotation of workers among tasks, and other inefficient practices.
3. Give a many range of employees (such as older or smaller workers) the ability to do tasks safely and quickly.

## **II. PROBLEM STATEMENT**

A huge mass of people in today's industry based work environment are facing long term standing hours due to the increasing work extraction methodologies used by various management companies. This leads to discomfort, medical ailments, reduction in the efficiency of work of the employees, induced stress, increased break hours etc.

## **III. OBJECTIVES**

Many industries involves in helping workers by doing many exercise to mitigate the effects of microgravity on bones and muscles. There are not much seats available for workers when they want to sit for some time due to stress or pain or other factors. It is also much difficult to provide them a seating equipment for all workers in cramped spaces such as warehouses, small workstation etc. and workers standing for long time are often detrimental to health. To overcome this situation a wearable Chair is constructed which acts like a mobile exoskeleton that helps people or workers to sit anywhere. This exoskeleton is created by using a dynamic model of the musculoskeletal system of the lower leg combined with the dynamics from a damper or a C member to provide resistive forces to the muscle forces. The main objective of this product is to design an exoskeleton assistive device which helps for normal motion of humans like walking and running while the workers or other people wear it.

## **IV. NEED ANALYSIS**

The ultimate need of this exoskeleton is to help workers who are standing for a long time. To reduce the fatigue stress induced in the lower part of the human body. To provide a more comfortable work environment. Assembly line workers, Store sales persons, End-line workers, Traffic police, Securities, Sculptors, Chef, Vendors, Beauticians will be the major users of our product. The human body will act as a medium on this exoskeleton. The purpose of this exoskeleton is to reduce the fatigue stress and pain induced in the lower back and legs due to excessive standing.

#### IV.1. BULL DIAGRAM

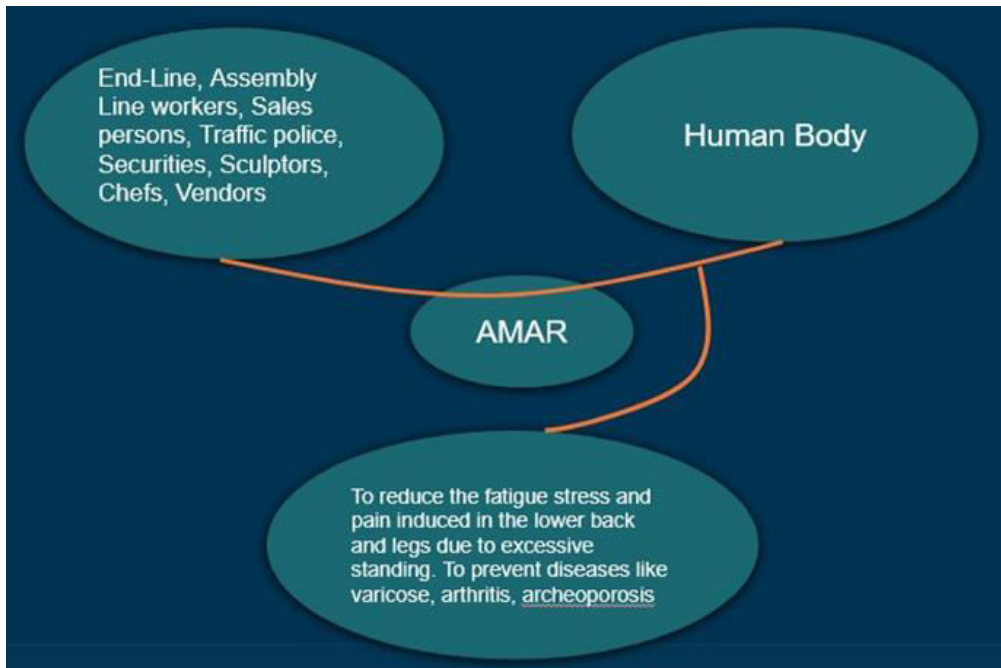


Fig.1 Bull Diagram

#### V. FUNCTIONAL ANALYSIS

The functional analysis helps us to get a clear idea about the available constraints which may affect our project. A tool that is used is the Octopus Diagram

#### V.1.OCTOPUS DIAGRAM

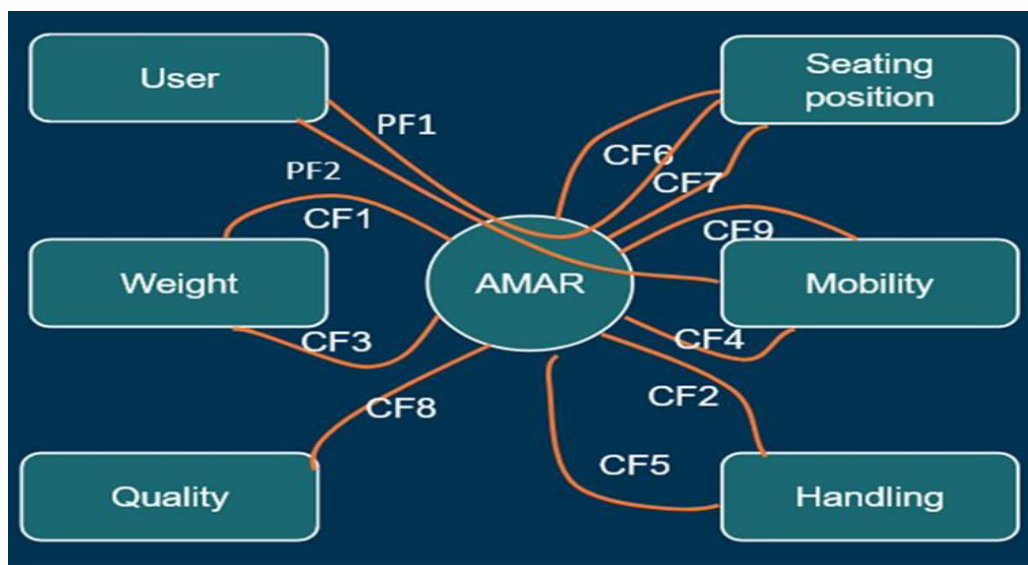


Fig.2 Octopus Diagram



Table.1 Principle Functions

	3.2 Principal Functions (The product links two external elements)
PF1	To support the lower body of the user
PF2	To allow movement to the lower body of the user

Table.2 Constraint Functions

	3.3 Constraint Functions( The product link links one external element)
CF1	Should be light in weight
CF2	Easy handling by the user
CF3	Should be able to withstand more weight
CF4	Manuarubility
CF5	Wearability
CF6	Adjustable to various heights and angles
CF7	Should provide comfortable seating
CF8	Durable for a long period
CF9	Easily portable

## VI.FAST DIAGRAM

In this fast diagram, we have researched various technical solutions for our product from which we can find how the component performs. We have selected the solution which is most adapted to the project according to our own criteria (Budget, Quality, etc)

### VI.1 MATERIAL SELECTION

#### 1.1 Stainless Steel

Table.3 Stainless Steel

Merits	Demerits
Corrosive resistance	Buckling
Aesthetic appeal	High cost
High and low temperature resistant	
Easy to manufacture	

#### 1.2 Chromoly

Table.4 Chromoly

Merits	Demerits
Lighter and stiffer than steel	Heavier than aluminum
Less chance of rust	Brittle

#### 1.3 Aluminium 6-Series

Table.5 Aluminium 6-Series

Merits	Demerits
Light-weight	Difficult to weld
Corrosive resistance	Expensive
Long lifetime	
Flexibility	

Since Aluminium 6-Series have more advantages. This material is chosen.

## VI.2 EXTRA SUPPORTIVE MEMBER

2.1 Secondary support member from tibia to

transfer the whole weight to the ground2.2 Cross member-support that connects femur and tibia part

Table.6 Secondary Support Member

Merits	Demerits
Can withstand high load	More material consumption
Easy handling by the user	Difficult to manufacture because it involves many inertial miscellaneous components and springs to push the member to its desirable position.
	More weight
	High cost

Table.7 Cross Member Support

Merits	Demerits
Easy handling by the user	More moving parts
Easy to manufacture	Lot of friction
Simple adjustment	
Less material consumption	
Price	

## 2.3 Adjustable C member (restricting the motion of the femur part)

Adjustable C member is chosen because it has more advantages.

Table.8 Adjustable C Member

Merits
Can withstand high load
Easy handling by the user
Simple adjustment

## VI.3 SEAT MATERIAL

### 3.1 Metal Resting

Table.9 Metal Resting

Merits	Demerits
Lasts for longer time	Heavy
Resistance to scratch	Less comfort
Tough and hard	Difficult to replace
Cannot be damaged easily	Price

### 3.2 Foam Resting

Table.10 Foam Resting

Merits	Demerits
Provides more comfort	Can be damaged easily
Less in weight	It is not resistance to scratch
Cost is less	
Easy to replace	

Foam resting is chosen because it has more advantages.

## VI.4 FEMUR & TIBIA MEMBER

### 4.1 Hollow Slightly Bent Pipe

Table.11 Hollow Slightly Bent Pipe

Merits	Demerits
Provides perfect balance	Manufacturing is difficult
Resist backward motion	Bending may occur

### 4.2 Hollow Straight Pipe

Table.12 Hollow Straight Pipe

Merits	Demerits
Easy manufacturing	Material consumption
Bending will not occur	

Hollow straight pipe is better than slightly bent pipe.

## VI. CALCULATIONS

**1 Calculation of force acting on different sitting posture and also calculating the stresses acting on it**  
Consider a person weighing 150 kg.

G Force to be considered for mechanical parts  $G = (0.5 - 1.5)$

Assume  $G = 1.5$  (Worst Case Scenario)

Total load acting on the body  $F_g = W \cdot g \cdot G$

$F_g = 2500 \text{ N (app)}$

Tensile strength = 290 MPa

Yield Strength = 241 MPa

Weight is divided equally as 75 kg per leg.

Area of pipe used =  $22 \times 1.25 = 27.5 \text{ square mm}$

Force applied on seating (Considering Single Leg) = 1250 N

$A = (\pi D^2)/4 = \pi (25)^2/4 = 490.87 \text{ mm}^2$

Assuming clockwise direction as positive.

$\sigma = F/A$

$\sigma$  = Stress acting on the street

F = Force applied on the seat

A = Area on which force is acting

6.1.1 For 135° sitting posture

$\theta = 45^\circ$ , OB = 15 cm.

Taking Moment about O,  $\Sigma M = 0$

$2500 \times \cos 45^\circ \times 15 + F \times \cos 45^\circ \times 20 = 0$

$F = 1875 \text{ N (Downwards)}$

$\sigma = 3.8197 \text{ N/mm}^2$

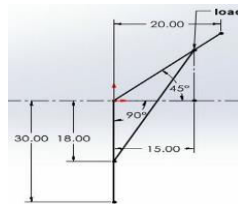


Fig.3 135° Sitting Posture

6.1.2 For 100° sitting posture

$\theta = 10^\circ$ , OB = 19 cm

Taking Moment about O,  $\Sigma M = 0$

$2500 \times \cos 10^\circ \times 19 + F \times \cos 10^\circ \times 20 = 0$

$F = 2375 \text{ N (Downwards)}$

$\sigma = 4.838 \text{ N/mm}^2$

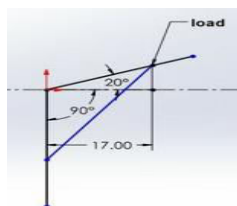


Fig.4 100° Sitting Posture

6.1.3 For 90° sitting posture

$\theta = 0^\circ$ , OB = 21 cm

Taking Moment about O,  $\Sigma M = 0$

$2500 \times \cos 0^\circ \times 20 + F \times \cos 0^\circ \times 20 = 0$

$F = 2500 \text{ N (Downwards)}$

$\sigma = 5.092 \text{ N/mm}^2$

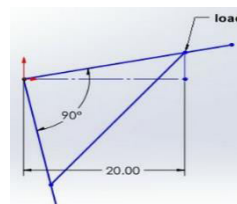


Fig.5 90° Sitting Posture

## 2 Forces and Stress on different seating posture

Table.13 Forces and Stress on different seating posture

Angle (Degree)	135	110	100	90
Force (N)	1875	2125	2375	2500
Stress (N/mm <sup>2</sup> )	3.8197	4.329	4.838	5.092

## VII.DESIGN

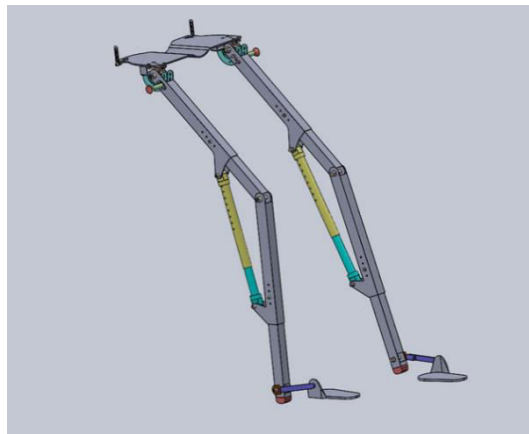


Fig.6 Design

## VIII.ADVANTAGES

- 1) Adjustable position as per desire.
- 2) Reduces human efforts and fatigue free work.
- 3) Easy to wear and operate.
- 4) No frequent maintenance and service.
- 5) High efficiency and increase in production rate and can be used for seating.

## IX.APPLICATIONS

- 1) This portable chair would be helpful to workers and anyone who needs to stand for long hours at stretch.
- 2) Once into mass production, a company can completely alternate the usage of portable chairs to Exoskeleton Chair and maximize the efficiency.
- 3) In food and manufacturing industries, for labourers who work standing for long time.
- 4) Can be used by the people standing in crowded trains to relax themselves without occupying much space.

## X.CONCLUSION

The Exoskeleton for long term standing workers system is successfully designed and analysed. The upcoming work will focus on making the design lighter and using high grade materials for greater strength at smaller dimensions and





weight .This is eco friendly and can be used multiple times. This product is reliable, easy to carry and requires less space. This product helps to reduce musculoskeletal disorder and since it is cost efficient , this product can be bought in many small scale industries.

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