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Fabrication and Analysis of Chairless Chair

Suhail.P.S.¹, Akhil.R¹, Muhammed Aashiq. A¹, Mohammed Afsal M. A¹, Premkrishnan P²

B. Tech Student, Dept. of ME, KMEA Engineering College, Edathala, Kerala, India¹

Asst. Professor, Dept. of ME, KMEA Engineering College, Edathala, Kerala, India²

ABSTRACT: Chairless chair is a portable contraption that looks nothing like a chair and allows you to sit on it whenever you want and wherever you want. This flexible, ergonomic device looks more like an exoskeleton and extends from the hip to the backs of the feet and adapts to different body sizes and safety shoes.

Its intended use is for employees at manufacturing firms who have to stand for long periods of time at work and sometimes bend into unnatural positions to assemble a product. For the user's quality of work life is improved while for the factory, there will be reduction of the work-related pain of the workers. With the chairless Chair the users walk together with the sitting support while wearing it, without obstructing the workspace, at the same time avoiding strenuous postures such as bending, squatting or crouching. It is meant to reduce worker fatigue and work-related accidents while improving productivity. It can be customized to fit all sizes and outfits.

For an Industry, space management is an important factor. Unnecessary chairs and resting places can be avoided by maximizing the use of chairless chair. Such spaces can be utilized for several other purposes.

KEYWORDS: Ergonomics, Chairless Chair, Exoskeleton, Productivity, Flexible

I. INTRODUCTION

Ergonomics is a branch of science that aims to learn about human abilities and limitations, and then apply this learning to improve people's interaction with products, systems and environments. Ergonomics aims to improve workspaces and environments to minimize risk of injury or harm. So as technologies change, so too does the need to ensure that the tools we access for work, rest and play are designed for our body's requirements.

Exoskeletons have been constructed to assist human locomotion and provide medical rehabilitation. In particular, the field of medical rehabilitation has utilized exoskeletons in an increasingly effective manner, and several relatively compact powered exoskeletons for mobile applications have recently been demonstrated, but the duration of usage is often limited due to power constraints. A leg exoskeleton could benefit people who engage in load carrying by increasing load capacity, lessening the likelihood of leg or back injury, improving metabolic locomotory economy, or reducing the perceived level of difficulty.

Exoskeletons are of two types:

- a) Active Exoskeletons
- b) Passive Exoskeletons

Active Exoskeletons: They are powered by external sources like a motor, battery powered etc. They work along with the passive exoskeletons to help in its functioning.

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.

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This device, we call as chairless chair possess minimum weight as compared to a normal chair and is mobile and portable. A virtual chair, which can be imagined as an exoskeleton can be worn on a person's lower body part. With the help of this he/she can move anywhere and sit anywhere and anytime he/she wishes to.

The use of chairless Chair is likely to bring down the cases of MSD (Musculoskeletal Disorders) which develops in workers indulged in prolonged standing conditions.

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 at different angles.

II. RELATED WORK

Workers in workshops and industries need to undergo several sitting and standing postures for long hours depending on their work load. We came across a worker in a local manufacturing industry. He mentioned that he suffers from severe muscle pain every day after his work. So, as a remedy to reduce muscle stress and to work freely, providing a support below the hip was a solution. Finally, we heard about an exoskeleton support that can be provided to the body as a support while doing work.

Several Journals were published related to this topic earlier. Noonee, a swiss start-up introduced the chairless chair for BMW and Audi in the year 2015. It's working was controlled by mechatronics system. H. Zurina and A. Fatinhas worked on the Design and Development of Lower Body Exoskeleton. Aditya Bhalerao and Sandesh Kamble have worked on the Pneu portable chair for employees to seat while working.

Apart from that our chairless chair is based on simple link mechanism and does not require any battery or power for successful working and is manually controlled. So this make it acceptable and affordable for every common people.

III. WHY PRODUCTIVITY IS IMPORTANT

Productivity is the measure of efficiency of a person or a machine or a factory in converting inputs into useful outputs. It is the ratio of the actual output produced to the actual input. Worker's efficiency is an important aspect in productivity. So, increasing the efficiency of worker is a way to increase the productivity in an industry.

A worker's efficiency can be increased by providing him with a better working condition, providing him incentives and extra pay for extra works. For doing the extra work the productivity of the individual was unmatched in the department so we decided to keep him during lay-offs. If there is any device which help him to reduce the workload or working condition in any way, his efficiency can be increased, hence, productivity also increases.

IV. LINK SUPPORTED CHAIRLESS CHAIR

Chairless chair consists of following parts;

- 1) Calf support
- 2) Thigh support
- 3) Connecting Link
- 4) Height adjuster

The design of all the above parts have been modelled in SOLIDWORKS.

1. Calf Support

The material proposed for calf support is a square pipe of 1 inch and span of 40.5 cm. 2 metal pieces were welded at the one end of the support with holes drilled using 6 mm drill bit.

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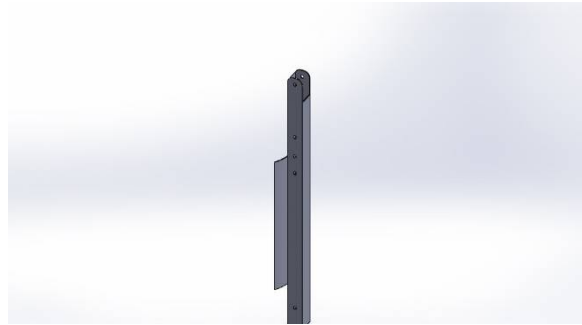


Fig. 1. Calf support

2. Thigh support

Calf support is of MILD Steel and is 40.5 cm in length. This provides support for thigh portion.

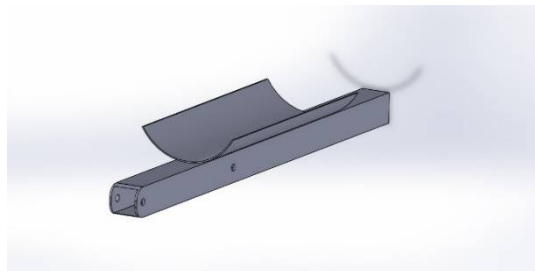


Fig. 2. Thigh Support

3. Connecting Link

Connecting link is of 30 cm in length. This is the portion that connects the calf and thigh supports and hence provide a better seating position. This link can be detached easily and users can change their sitting angle without much problem.

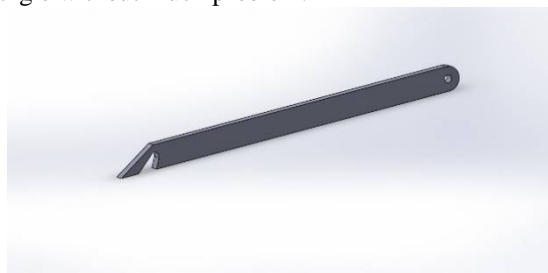


Fig. 3. Connecting Link

4. Height adjuster

It is the base structure which is attached to the end of the thigh support in order to adjust the chairless chair to make it suitable for person with different heights. A ground touching part is attached to this rod in order to ensure stability whenever the chair activates

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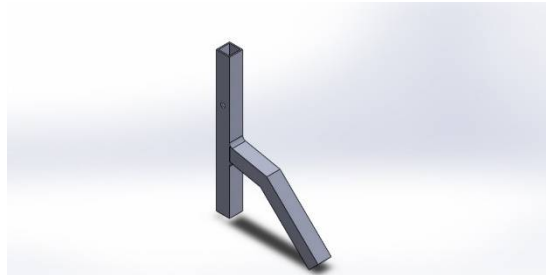


Fig. 4. Height Adjuster

V. CALCULATION

Consider a person weighing 100 kg. His weight is divided equally as 50kg per leg.

Area of the pipe used = $2.5 \times 2.5 = 6.25 \text{ cm}^2$

Force applied on seating = $50 \times 9.81 = 490.5 \text{ N}$

1) For 135° sitting posture

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

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

$$490.5 \cos 45^\circ \times 15 + F \cos 45^\circ \times 20.25 = 0$$

$$F = 363.18 \text{ N} \downarrow$$

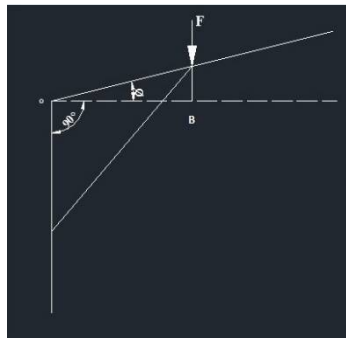


Fig. 9. Force diagram

2) For 110° sitting posture

$\theta = 20^\circ$, $OB = 17 \text{ cm}$

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

$$490.5 \cos 20^\circ \times 17 + F \cos 20^\circ \times 20.25 = 0$$

$$F = 411.35 \text{ N} \downarrow$$

3) For 100° sitting posture

$\theta = 10^\circ$, $OB = 19 \text{ cm}$

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

$$490.5 \cos 10^\circ \times 19 + F \cos 10^\circ \times 20.25 = 0$$

$$F = 459.75 \text{ N} \downarrow$$

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VI. FABRICATION OF CHAIRLESS CHAIR

Mild Steel and Galvanised iron was chosen as the primary materials. The structure to support thighs and calf was made of Mild Steel square pipe of 1 inch and the connecting link is made of Galvanised Iron. The manufacturing of each part is discussed below:

a. Calf support

Pipe of 40.5 cm was cut and 3 holes were drilled in order to attach the link in order to attain sitting postures in 100°, 110°, 135°. A hole is drilled at one end to connect it towards thigh support.



Fig. 5. Fabricated Calf support

b. Thigh support

Pipe of 40 cm was cut and a hole was provided at the centre of the pipe so as to attach the link. Two metal pieces were welded to the 2 sides of one end with holes in it, so as to connect it with calf support for attaining a hinge.



Fig. 6. Fabricated Thigh support

c. Connecting Link

30 cm length was cut from Galvanised Iron sheet. One hole was drilled at one end in order to attach it to thigh support and another hole was drilled at other end for attaching it to calf support.



Fig. 7. Fabricated Connecting Link

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Vol. 7, Issue 4, April 2018

d. Height adjuster

A pipe of 12 cm span was cut. And a bended piece was welded to towards the end so as to provide base support and to increase stability when the user activates the chair.



Fig. 8. Fabricated height adjuster

e. Assembly

The calf support and thigh support are joined together using M6 bolts and tightened. So that it can be rotated up to 180°. Then the height adjuster is bolted towards the calf support and is tightened according to required height. The connecting link is bolted to the thigh support into the provided hole. The link is then hooked up into the bolts provided at required angle when seating posture has to be achieved. The device is attached to the human body using straps.



Fig. 9. Assembled Chairless chair

VII. ANALYSIS

Finite Element Analysis is carried out on the chairless chair in order to find the maximum weight that the product can accommodate. Based on the finite element test, the maximum load that can be applied on this chairless chair is 120 kilograms. If the load is slightly greater than this value, the damper at the chairless will start to bend thus failure will occur. In order to prevent this from happening in the future, we can replace the damper with high quality material so that it can support more load.

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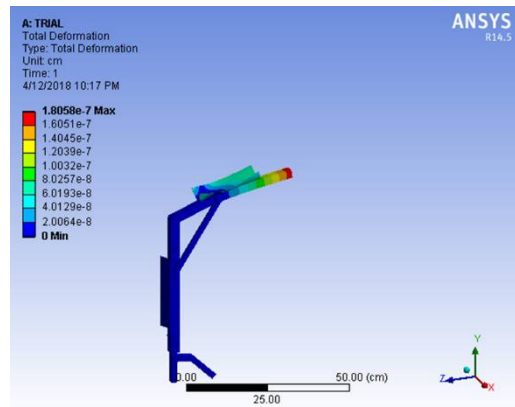


Fig 10. Total Deformation

The 3 component deformation X, Y, Z and the deformed shape are available as individual result. Scoping is also possible to both geometry entities and underlying meshing entities. Numerical data is for deformation in the X, Y, Z direction. This result can be viewed with the model under wireframe display facilitating their visibility at interior nodes.

The deformation result can exhibit a node-based display limitation. A node represents a remote point, the application does not produce result data for it and as a result, mechanical does not display result data.

Figure 10 shows a fixed calf support, fixed link support and a load of 490.5N is applied on the thigh portion. We can see that the deformation value varies from 0 - 10858x 10⁻⁷. So, this shows that it is safe.

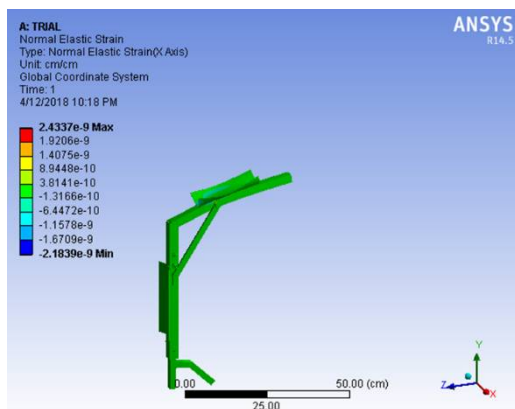


Fig. 11. Normal Elastic Strain

Normal strain is given by equation $\epsilon = \delta/L$, where δ is the total elongation of the bar within the length L. Hookes law for tensile specimen is given by $\sigma = E \epsilon$. Where constant E is called young's modulus of elasticity.

When a Material is placed in tension, there exists an axial strain as well as a negative strain perpendicular to axial strain. Assume a linear, homogeneous, isotropic material, this lateral strain is proportional to axial strain. If the axial direction is X, then the lateral strains are $\epsilon_y = \epsilon_z = -\nu \epsilon_x$ where ν is called poisons ratio which is about 0.3 for most structural metals.

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From the figure 11, it can be seen that the minimum value obtained is -2.1839×10^{-9} and maximum value is 2.4337×10^{-9} . Here also the calf support is kept fixed and also the link support and a load of 490.5 N is applied. So the design is safe.

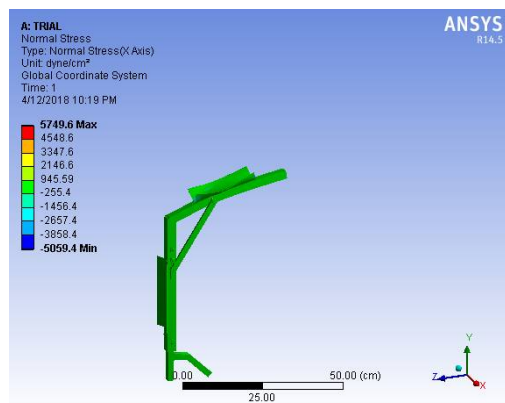


Fig. 12. Normal Stress

Normal stress occurs when a member is placed in tension or compression. Here a force of 490.5N is applied and the normal stress deformation can be seen in the figure 12. Minimum value obtained is -5059.4 N and maximum is 5749.6 N. Hence the design is safe.

VIII. ADVANTAGES

The main advantage of this chairless is that it is portable. It can be carried anywhere easily by keeping in a bag. The user can even walk some distance chairless chair attached to their legs. So that the user doesn't need to detach the exoskeleton every time he moves from one place to another. Next, it is proven to be suitable with a range of height up to 183cm.

In addition, our prototype offers user to comfort themselves with three levels of degree depending on their comfort level. This can help user to do their work with high serenity compared to chair with constant degree because some work not require the user to be seated but if its longing for a long time, it might be a problem to their muscle or having leg cramp, therefore, this is where chairless chair play an important role.

IX. CONCLUSION

The chairless chair is successfully fabricated, assembled and analysed. The aim of this project was to develop an exoskeleton with simple link mechanism to support human walking, sitting and standing motions synchronously with human. It also helps to take significant portion of external load carrying by the user. Once this is achieved, exoskeletons can be made as a part of everyday life to reduce down the cases of MSD (Musculoskeletal Disorders). Since the cost of fabrication is comparably less, so this can be made affordable to the workers in small scale industries also.

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