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Research Article

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Exoskeleton For Specially Abled

Abstract

This is a paper about a wearable exoskeleton that addresses the lack of assistive devices for people with walking difficulties. The research revolves around the major problem in which the inpatient suffer for their dependency on a caretaker for basic tasks such as toiletries and fetching water or food or even for basic cores for themselves. People with disabilities suffer from many social and mental pressures due to exclusion from society just for being different from normal human beings. Hence, the usage and purpose of robotic technology trims down this segregation and promote vocational incorporation.

Keywords: wearable exoskeleton, disabilities

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Introduction

Since 1960, robotic exoskeletons have been developed primarily for military applications. As a rehabilitative tool for people with physical limitations, biomedical engineers are increasingly using technology to promote mobility. Exoskeletons are designed primarily to support the limbs of people who are unable to walk on their own. Designed to improve the lower limbs and offer support torque to increase the torque at the knee and hip when walking. An exoskeleton is a user-oriented robotic technology that is worn to support or replace limb function.

With the support of this exoskeleton, users will be able to carry out basic daily tasks independently of caregivers while also resolving several related issues brought on by wheelchair use. The results of the literature survey reveal that wearable exoskeletons have a potential for several applications including early rehabilitation, promoting physical exercise, and carrying out daily living activities both at home and the community.[1] Likewise, wearable exoskeletons may improve mobility and independence in non-ambulatory people, and may reduce secondary health conditions related to sedentariness, with all the advantages that this entails.[1]

About those who have lower limb disabilities, this project tackles the absence of assistive and rehabilitative equipment. Patients' reliance on a caregiver for fundamental duties is a serious issue that causes them harm. These everyday challenges in the workplace or at home will be addressed by this effort. Following are the proposed outcomes of this project: Eliminating the pain statement – The device would assist in gaining independence from caregivers in doing simple daily chores, while various secondary issues resulting from wheelchair use might be resolved. Decrease in the price of medical care Robotic exoskeletons for over-the-ground training reduced hospital expenses related to spinal cord injury and other lower limb problems, as well as the need for physiotherapy assistants (Figure 1).

Present theory and practices

Human gait analysis: Because wearability is one of the most important characteristics of a lower limb exoskeleton for rehabilitation, lower limb anatomy andhuman gait analysis can serve as the foundation for the design and operation of such systems. The complex functions of a person's visual, sensory, and vestibular systems combine to form their gait. Postural and gait irregularities can be caused by issues with these systems as well as issues with the associated joints.

D-H model: Robotics frequently uses Denavit-Hartenberg (DH) parameters to define robot characteristicslike axis orientations and arm lengths.

Figure 1 Various mechanism of lower limbs.[7]

Actuation design: Lower limb rehabilitation exoskeletons are driven by rigid transmission without compliance in their actuation design. This has a significant vibration impact, makes it challenging to directly manage the force, and results in a complex robot system. To provide force management and improve drive flexibility in the exoskeleton, a series elastic drive must be designed. By varying the stiffness of the elastic parts driven by series elastic, an elastic actuator with variable stiffness may also be designed for lower limb exoskeletons. Kinematics describes the connection between the robot's end effector and the articular space. This method is helpful for creating trajectories and setting control points for joint actuators.

Direct kinematics: Using the values of the articular coordinates, the direct kinematics analysis seeks to determine the position and orientation of the robot's link. Structure often seen as a kinematic chain of rigid bodies interconnected by joints (Table 1).

Table 1 The DOF of a lower limb exoskeleton[5]

Joints	DOF	Range of freedom	Driving force needed
Hip	Flexion / extension	$-120° \leq \theta \leq 65°$	80-100 N/m
Hip	Adduction / Abduction	$-30° \leq \theta \leq 40°$	Spring
	Rotation	$-30° \leq \theta \leq 30°$	Spring
Knee	Flexion / extension	$-120° \leq \theta \leq 0°$	45-70 N/m
Ankle	Pronation / Rotation	$-15° \leq \theta \leq 30°$	Spring

Need

The main worry for government authorities, human resources departments, and labor unions is injuries related to lifting and transporting large loads. Since worker injury still happens, efforts to reduce workload, enhance ergonomics, and shorten the time spent carrying heavy objects have only been seen as temporary fixes. Exoskeletons, however, may provide the disabled a revolutionary new way of life. Assisting those in need of independent movement and removing the primary function of caregivers - Patients with lower extremity mobility loss can use upper-extremity exoskeletons to help their damaged shoulder and arm during rehabilitation. This allows for larger dosages of medication, more rigorous therapy, and a wider active range of motion during rehabilitation sessions.

Problem statement

There were 496,000 paralyzed youngsters in India, and the incidence of stroke and paralysis is rising considerably by over 50% year.[2–4] Exoskeleton technology will provide far greater mobility than traditional leg orthotic technology for people who have had partial limb paralysis because of neurological disease.

Another problem is that post-stroke patients and other SCI patients often receive inadequate care and therapy, which leads in them having to pay exorbitant medical costs that most people discontinue after receiving treatment for their problems. This causes people to need more traditional means of support, including a walker and a stick, which raises the difficulty of maintaining adequate balance.

Conventional equipment like Walker and Stick has trouble in keeping balance and require learning and depend on external assistance. The drawbacks of walkers include stigma, musculoskeletal diseases, slower reaction times, fall danger, and technical or practical elements criticized by users.

Methodology

The purpose of this research is to assist the disabled and address their needs for standing, walking, and enhancing the person to reduce their idleness. To execute this project, following tasks are identified: Completed literature review and determined the possible ways of proceeding with the design procedure.

1. Determine the suitable dimensions for the design available related to it.
2. Designing and modelling of exoskeleton structure on software initiated.
3. Analysis, determine its stresses, and point of deformation on its components.

Design approach

Finding DOF

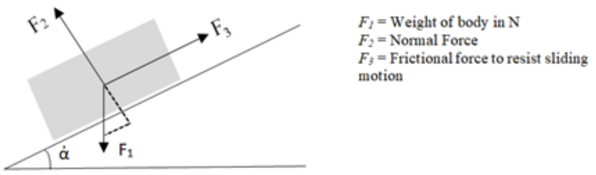
The exoskeleton axis and its pertinent parameters are tried to create in the work using the Denavit-Hartenberg (D-H) technique. The D-H approach is a disciplined way to create complex robotic modelling, even though its mathematical solution is lengthy and complicated.

Study on links

Forces in the links equal and opposite to tension in the shaft resulting in zero net force on the exoskeleton. The three unknowns—heel rope tension, ground response force, and ground reaction force direction—can then be determined using this joint force. To find the answers to our three unknowns, we can use three static balance equations (the sum of the forces acting in the x and y directions plus a moment balance).

Study on forces

Simply said, a force diagram is a diagram that shows all the forces that are acting on an item, together with their direction and magnitude. It is a streamlined representation of the scene that only depicts the forces. Given is the typical diagram of active three-dimensional forces.



If r is the displacement vector, F is the force vector is the torque, and can get from the definition of torque.

$$\tau = r \times F \text{ ------------------------------- } (4.1)$$

The unbalanced torque on a body along axis of rotation determines the rate of change of the body's angular momentum,

$$\tau = \frac{dl}{dt} \text{ ------------------------- } (4.2)$$

Equating equations (1) and (2),

$$X_2 + Y_2 = l_1^2 + 2l_1l_2\cos\theta_2 + l_2^2 \text{ -------------------- } (4.6)$$

Where,

Θ = Angle subtended by link from vertical reference axis

Parts Calculations:-

Leg Segments

Specifications and Calculations of Segments:

Thickness = 6mm

Length = 655mm

Width = 60mm

Hole Diameter = 6.35mm

Now,

Y_C = 30mm -- (By Symmetry)

$$X_C = \frac{655 \times 60 \times \frac{655}{2} - \left[x\left(6.35^2\right)(6.35) - x\left(6.35^2\right)(650)\right]}{(650)(50) - \left[(3x)\left(6.35^2\right)\right]}$$

X_C = 336.86mm

Now,

Centroid (336.86mm, 30mm)

Moment of Inertia,

$$I_x = \frac{bh^3}{12} - \left[\frac{x}{64} \cdot \left(d^4\right)\right] \text{ -------------------- } (4.7)$$

Citation: Wani VA, Shaikh MS, Shewale YS, et al. Exoskeleton For Specially Abled. *MOJ App Bio Biomech.* 2023;7(1):72–76. DOI: 10.15406/mojabb.2023.07.00177

$$I_x = \frac{(60)(655)^3}{12} - \left[\frac{x}{64}\cdot\left(12.7^4\right)\right]$$

$$I_x = 1405053046\text{mm}^4$$

Load Acting on link,

Assuming weight of rod 1.5kg = 15N on the basis of overall weight of exoskeleton

Load due to human body = UDL

Weight of human on an average = 50kg (Figure 1.1)

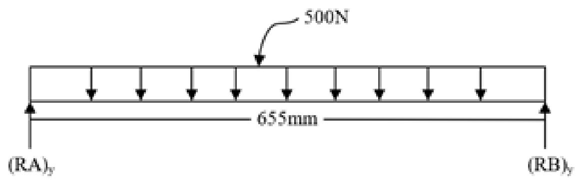


Figure 1.1 FBD of leg segment.

$$\Sigma\frac{MA}{600x}=0$$

$$(RA)y + (RB)y = 500\times655 + 15 \qquad (1)$$

$$\sum MA = 500\times\frac{655}{2} + \left(15\times\frac{655}{2}\right) = RA_y\times655$$

(RB) y = 163757.5N
(RA) y = 163757.5N

$$\sigma = \frac{M}{I}$$

$$\sigma = \frac{26814.06\times336.86\times1000}{1405053046}$$

= 6.42 N/mm^2
Motor
Name – Wiper MotorN = 30rpm
Torque = 1000N-cm

$$P = \frac{2\pi NC}{60}$$

$$P = \frac{2NC}{60\times1000}$$

$$P = \frac{2\times\pi\times30\times1000\times10^2}{60\times100}$$

$$P = 104\cdot66\text{kW}$$

Connecting Rod

r = 1000 $N - mm$

Force acting on y axis.

$$r = f\times d$$

$$1000\text{ N-mm} = f\times(298.34 + 187.63)$$

F = 2.05N (Figure 1.2)

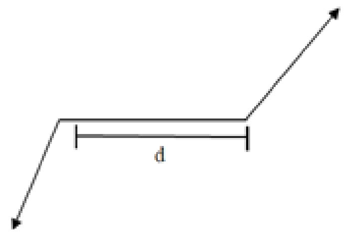


Figure 1.2 Schematic diagram of Connecting Rod.

Using $\sum fx = 0$

As the unit are placed approx. same angle initially,

$$2.65\ (Cos\theta) = f(x)\times Cos\theta$$

$$F_X = 2.65\text{N}$$

Now, Same applicable to lower segments by the equilibrium

Hence, Moment at joint is

$$M = F\times d$$

$$M = 2.65 \times 531.42$$

$$M = 1408.20\text{N-mm}$$

Foot base

Neglecting small parts, neglecting dimension is negligible.

Total weight of skeleton = 8~9 kg approx.

= 85N (Figure 1.3)

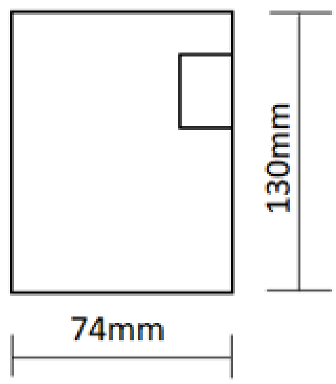


Figure 1.3 Schematic diagram of foot rest.

Weight of human = 600N

Total load acting on footrace= 685N

A = two footrace hence load will be halved = $\frac{685}{2} = 342\cdot5$N

Design

As the model is created in SolidWorks, the assembly is shown in the above Figures 2–5. The final assembly that is depicted in SolidWorks refers to the complete exoskeleton that has been put together from all of its individual parts. This includes any frame, joints, motors, sensors, and other components that make up the exoskeleton. Creating a digital model in any designing and modelling workspace can be a crucial step in the development process of an exoskeleton for the specially-abled. The device would assist in gaining independence from caregivers in doing simple daily chores, while various secondary issues resulting from wheelchair use might be resolved.[6–10]

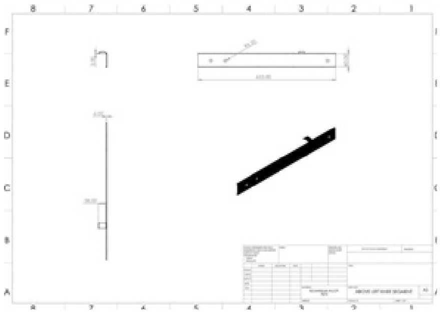


Figure 2 Above left knee segment.

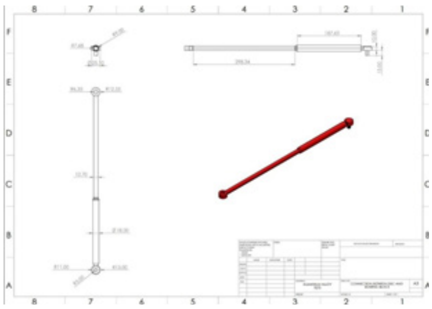


Figure 3 Connection element block.

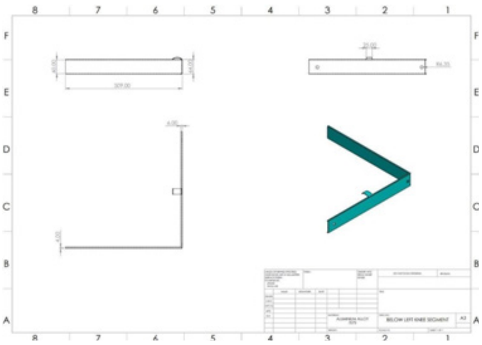


Figure 4 Below left knee segment.

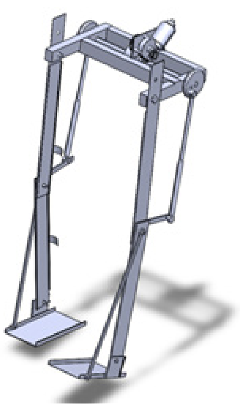


Figure 5 Assembly of Exoskeleton.

Analysis

(Figure 6–9).

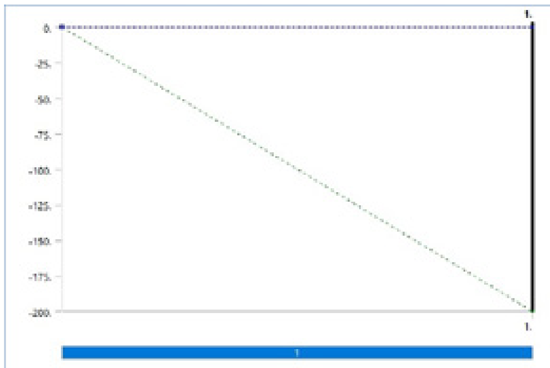


Figure 6 Force applied on Motor Casing

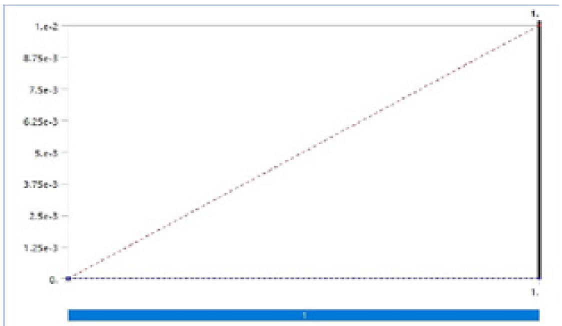


Figure 7 Moment of Motor Casing

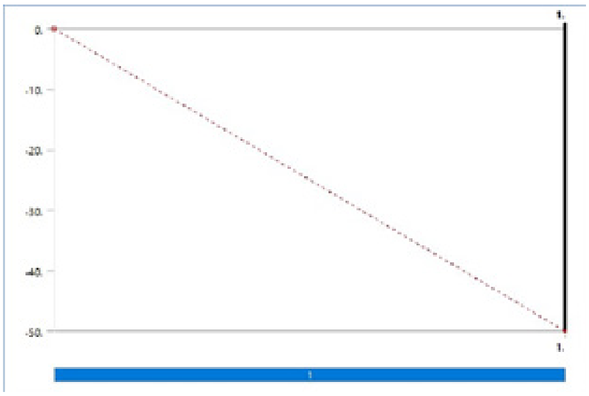


Figure 8 Force applied on Foot Rest.

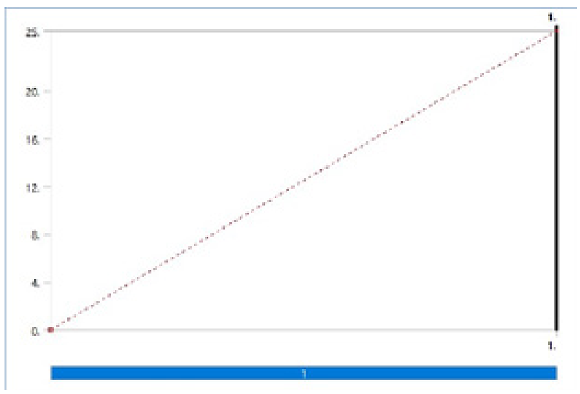


Figure 9 Force analyses on Linkages.

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Conclusion

The development of an exoskeleton with reduced weight and cost has the potential to make this technology more accessible to individuals with disabilities, who may currently be priced out of the market for existing devices.

By using lightweight materials and cost-effective manufacturing processes, your team is working to create an exoskeleton that can provide similar levels of support and assistance to users as existing products, but at a lower cost.

The success of our project will be determined not only by the effectiveness of the exoskeleton itself, but also by its affordability and accessibility to a wider range of individuals with disabilities.

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Author statement

Vaibhav Anil Wani: Data curation, Reviewing, Original draft preparation

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Yash S Shewale: Methodology, Design calculations and Analysis

Sreelakshmi M Nair: Design calculations, Software

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None

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

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