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Passive Exoskeleton

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Abstract: *This project focuses on the design, development, and evaluation of a passive exoskeleton aimed at reducing musculoskeletal strain among industrial workers engaged in repetitive tasks. The exoskeleton provides mechanical support without active power sources, enhancing worker endurance and safety. Prototypes using aluminum alloys and carbon fiber composites were tested for load reduction, range of motion (ROM), and user comfort. Results indicated muscle activation reduction by up to 15%, highlighting its potential as a cost-effective occupational health solution.*

Keywords: Passive exoskeleton, musculoskeletal strain, industrial ergonomics, load reduction, occupational health

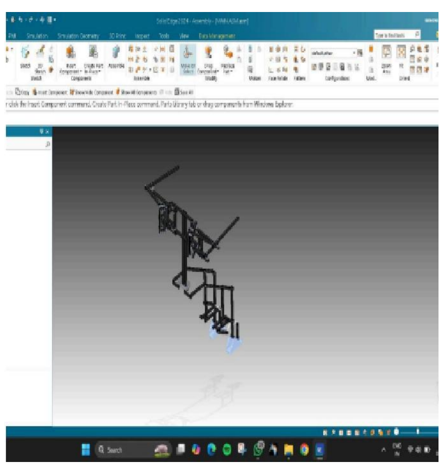
I. INTRODUCTION

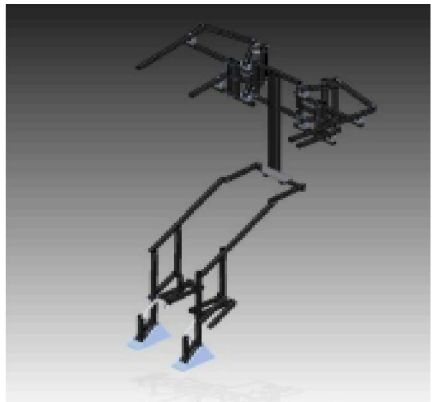
Industrial workers performing repetitive and strenuous tasks frequently suffer from work-related musculoskeletal disorders (WMSDs). Passive exoskeletons offer a viable solution by mechanically supporting the body without external power, thus reducing strain and enhancing productivity. This study designs and develops a passive exoskeleton suited for industrial environments, addressing safety and efficiency.

II. METHODOLOGY

The methodology for developing the **passive exoskeleton** follows a structured approach that ensures the design, development, and implementation process is **systematic, efficient, and practical**. The methodology is divided into **multiple phases**, each addressing different aspects of the project, from **conceptualization to testing and final implementation**.

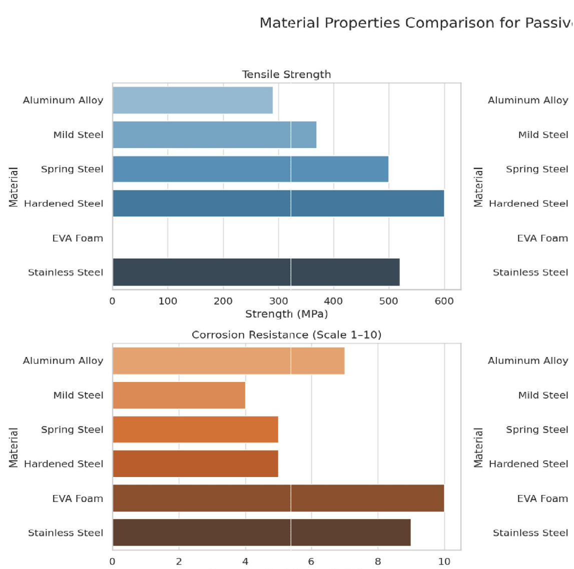
This section provides a **step-by-step breakdown** of the development process, including **design principles, material selection, prototyping, testing, and manufacturing considerations**.





III. MATERIAL SELECTION

Component	Material Selected	Properties	Application
Frame Structure	Aluminum Alloy (6061)	Lightweight, Corrosion-resistant, Strong	Main skeletal frame (arms, legs, back support)
Joints and Linkages	Laser-Cut Mild Steel	High tensile strength, Machinable, Cost-effective	Rotational joints, load-bearing plates
Energy Storage (Springs)	Spring Steel / Stainless Steel	High elasticity, Fatigue resistance, Durable	Assist lift motions, store and release mechanical energy
Structural Alignment (Spacers)	Hardened Steel / Mild Steel	Accurate tolerance, Load resistant	Ensure proper alignment of mechanical parts
Padding and Straps	EVA Foam and Nylon/Polyester	Soft, Sweat-resistant, Skin-friendly	Improve comfort and ergonomics for users
Fasteners and Hinges	Stainless Steel (Bolts, Rivets)	Corrosion-resistant, High integrity	Connect mechanical parts securely and enable motion



Model making

3.2 The development of the passive exoskeleton followed a structured process:

1. Concept Sketching: Initial hand-drawn designs were created to visualize structural layout and joint mechanisms.
2. 3D CAD Modelling: Detailed models were developed in CATIA V5 to simulate motion, load paths, and ensure ergonomic fit.
3. Material Procurement: Aluminum tubes, mild steel plates, springs, padding, and fasteners were sourced as per design requirements.
4. Component Fabrication: Laser cutting, drilling, and manual shaping were used to prepare frame and linkage components.
5. Assembly: The frame was assembled using bolts, hinges, and spacers. Springs were mounted for mechanical assistance.
6. Ergonomic Integration: Foam padding and adjustable nylon straps were added to enhance user comfort and fit.
7. Testing and Refinement: Initial trials were conducted for movement and load handling, followed by design adjustments based on user feedback.

IV. EVALUATION CRITERIA

The evaluation of the passive exoskeleton was conducted using key performance criteria to ensure functionality, comfort, and usability. Ergonomic comfort was assessed based on user feedback regarding pressure distribution, padding effectiveness, and the overall ease of prolonged wear. Mobility and flexibility were evaluated by observing the user's range of motion during essential movements such as walking, bending, and lifting. The system's load support efficiency was measured by the perceived reduction in physical effort during repetitive lifting tasks, enabled by the spring-assisted mechanism. Additionally, the overall weight and wearability of the exoskeleton were analyzed to confirm that the device did not contribute to user fatigue. Adjustability and fit were tested by fitting the exoskeleton to individuals of varying body sizes, ensuring that the frame and straps allowed proper customization. Finally, the structural integrity of the prototype was verified through load testing to confirm durability and resistance to mechanical failure during extended use.

V. CONCLUSION

The development of a passive exoskeleton presents a practical, low-cost solution for reducing physical strain in labor-intensive tasks. By utilizing mechanical components like springs and lightweight structural materials, the design offers improved ergonomics, mobility, and support without the need for external power. Through systematic design, prototyping, and testing, the exoskeleton demonstrates its potential to enhance worker safety, comfort, and efficiency in industrial environments. This research lays the groundwork for further refinement and real-world deployment of passive assistive devices.

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