Deadlift Exoskeleton

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Table of Contents

1. Background/Motivation

Project Topic Need:

Heavy lifting plays a crucial role in both physical fitness and industrial operations, where strength and endurance are essential for success.Among these workouts, deadlifting is especially taxing and is frequently regarded as one of the riskiest and most difficult. When not done properly, this sport puts a great deal of strain on the knees, lower back, and supporting muscles, making it a major contributor to workout-related ailments. Deadlifting frequently causes problems such as increased joint tension, quick muscular exhaustion, and a high chance of acute injuries from improper form or trying to lift weights that are too heavy for a person. Despite modern safety measures like instructional training, appropriate warm-ups, and the use of supportive equipment like weightlifting belts, these dangers are nevertheless common. Deadlifting puts recurrent strain on important joints and muscles; creative ways to lessen strain and enhance safety results are required.

By creating a customized exoskeleton to meet these needs, the project's main goal is to increase deadlifting's efficiency and safety. The passive knee support that this exoskeleton attempts to offer not only lessens joint stress but also promotes healthy posture and movement mechanics. The gadget helps users lift higher weights with more confidence and less weariness by encouraging biomechanical alignment, which reduces the chance of injury. The dearth of flexible solutions that can accommodate a range of user needs is what inspired this effort. Users have few options for individualized support because existing aids frequently overlook differences in body types, lifting intensities, and specific biomechanical patterns.

Our exoskeleton bridges this gap by combining user-specific personalization with cutting-edge mechanical support. It ensures comfort and adaptability for a variety of lifting situations by combining lightweight, ergonomic materials with adjustable tension mechanisms. The exoskeleton is made to be a flexible and easily accessible tool, whether it is being used by professional athletes looking to maximize their performance or by industrial workers hoping to lessen physical strain. Through putting user safety and efficiency first, this project aims to change how people think about heavy lifting and make it safer and more sustainable for a wider range of people. This creative method emphasizes how crucial it is to blend engineering accuracy with user-centered design in order to produce a system that is both useful and practical.

Literature Review:

The research by Rouse, E. J., Mooney, L. M., & Herr, H. M. (2021) offered a comprehensive biomechanical model for examining lower-limb exoskeletons with an emphasis on increasing mechanical efficiency, decreasing joint strain, and boosting user adaptability. Weight distribution, joint alignment and force adaptability were highlighted by the researchers as three essential elements for exoskeleton design. The device's lightweight design guarantees that it won't add to user fatigue, and good joint alignment reduces the chance of injury and enhances biomechanical performance in general. The device can assist users with repeated motion or high-strain work because of the use of flexible force mechanisms, which facilitate more natural movement. The study demonstrated the important role of customizable support systems by using sophisticated computer modeling to simulate exoskeleton function. Because of their ability to adapt dynamically to user action, these systems guarantee less joint loading and increased muscle efficiency. The study came to the conclusion that flexible exoskeletons increase user comfort and pleasure while also improving safety during physically taxing exercises like deadlifts. Applications where perfect biomechanical alignment and dynamic flexibility are essential will find this study especially pertinent. [1]

This article analyzes how adaptive mechanisms have evolved in knee exoskeletons, highlighting how they enhance mobility and lessen joint misalignment-related pain. These adaptive mechanisms ensure natural alignment during flexion and extension by dynamically adjusting to the user's knee movements, in contrast to classic static designs. Users engaged in demanding exercises like deadlift, when joint strain is a major issue, would particularly benefit from this capacity. The essay emphasizes how low-profile designs, flexible parts, and lightweight materials may improve user comfort. Because of these materials, the exoskeleton weighs less overall, allowing for prolonged wear without experiencing discomfort or weariness. Tests showed that the adaptable designs greatly increase range of motion, lessen strain on the muscles, and improve user pleasure. Mechanisms that replicate normal knee motions give these exoskeletons their versatility, enabling the devices to enhance rather than impair biomechanical processes. These discoveries render exoskeletons appropriate for industrial and sporting uses in addition to rehabilitation. [2]

The article emphasizes the significance of optimizing muscle efficiency and reducing metabolic expenditure to enhance user comfort during motions. It explores strategies for enhancing energy efficiency by reducing engagement—a particularly advantageous approach—in cutting-edge exoskeletons designed to adjust based on user input captured by sensors to improve energy utilization and stave off muscular fatigue. The versatility of exoskeletons has the potential to significantly elevate the well-being of individuals facing obstacles. By taking into account feedback from users and enabling adjustments to be made in time for movement purposes, these advancements could revolutionize interactions by providing crucial assistance to muscles and enhancing practical mobility.[5]

Patent Review

The patent by Walsh, C. J., Asbeck, A. T., & Cochran, J. C. (2020) presents an advanced orthopedic device that uses motorized actuators, protruding parts, and Bowden cables to help in joint mobility. In order to give dynamic support, the system adjusts to the user's level of activity and delivers real-time, regulated resistance or help. Because of their strength and flexibility, bowden cables are used to efficiently transfer forces between motorized actuators and stiff structural elements. These wires reduce pressure on vital places like the knees and lower back by interacting with the user's joints to give focused support. The novelty is in the way it combines mechanical support and flexibility, allowing for more joint motion without compromising stability. One important aspect of the design is its capacity to adapt dynamically to human actions, guaranteeing peak performance during strenuous tasks like walking or lifting. With its focus on preserving range of motion and flexibility while applying force precisely, the invention represents a ground-breaking addition to the assistive device industry. Since repeated motion and joint loading are frequent problems in both industrial and rehabilitation settings, this strategy has important ramifications for lowering joint stress. [3]

The design of a passive knee exoskeleton that combines coil springs, hinges, and actuators to increase knee extension while reducing muscular activation is the main subject of this invention. Because the exoskeleton is passive, it doesn't require additional power sources, which makes it portable, affordable, and simple to use in a variety of situations. Exercises like squats, where joint stability and load reduction are crucial, benefit greatly from the design. By dispersing forces, the spring-assisted system lessens the pressure on the knee joint, reducing muscular fatigue and increasing efficiency. This makes the gadget appropriate for both industrial workers who do repetitive lifting duties and those undergoing rehabilitation who need joint assistance.

The design's capacity to support the knee joint while preserving natural mobility is a crucial component that guarantees users may carry out practical tasks without sacrificing biomechanical alignment. By offering dependable joint support and lowering the chance of damage, the patent illustrates how spring-assisted systems may improve performance during heavy lifting exercises like deadlift. [4]

The soft exosuit patent by the Harvard Biodesign Lab provides benefits for wearers and creators alike while representing progress in the wearable robotics technology market. Its adaptable and lightweight construction allows for motion without the heaviness and stiffness found in conventional bulky exoskeletons. This leads to decreased tiredness and energy usage. A feature very helpful for our target audience of athletes recovering from injuries and people with mobility issues seeking improved efficiency in performing actions. Manufacturers find that using fabrics and materials simplifies production processes by lowering costs and complexity in comparison to exoskeletons with intricate mechanical components needed for assembly and maintenance tasks to scale up for mass production easily. The exo suits design facilitates assembly and maintenance. Enables scalability for mass production purposes while providing engineers with the advantage of a modular architecture and mechanical freedom that allows customized adjustments for specific joints, like the hip, ankle, or knee. [6]

Improvements Over Previous Devices:

Exoskeletons designed for lifting heavy loads have improved over time, but most of the current models are still not without problems that make their practicality and appeal curtailed. They include inadequate ergonomic features, the designing and construction of furniture that is too heavy for the user, furniture that lacks flexibility of movement, and furniture that does not have adequate provision for adjustment. Current systems may handle mechanical stability or biomechanical incorporation predominantly and predominantly do not strike the optimal equilibrium of both configurations. It is evident that performing arts require more enhanced support than any current designs afford, and likewise, the users have more ways in which they can contribute than as designed here.

Unfortunately, many exoskeletons that are currently available have no adjustment capability. Fixed support systems do not receive the level of customization that is needed in terms of body size shapes, force being applied, or the strength of the user. Let's, for example, have a device designed for moderate loads. It cannot handle strong loads anymore, and it cannot supply the necessary amount of resistance for light loads either, which makes the product less valuable in terms of the broad market demand. To address this, our design includes the use of the spring-loaded piston mechanism using stainless steel with tension adjustment. It enables the users to decide on how much support they require depending on whether they are performing a one-rep max or the many rep sets. Another advantage of using the stainless steel is that it guarantees that the pittance is sturdy enough to be used with high stress over and over without fading.

Many devices being produced today remain heavy in nature, thus adding to the fatigue of the users rather than relieving it since so many of those used in the making are big and hefty. Despite these designs' goals of stability, they are very heavy, so they limit movement and are unsuitable for extended use. The issue is solved in our exoskeleton by using ABS plastic for the custom parts and spring steel for the spring ruler, backed up by stainless steel in the load-bearing parts. This combination significantly minimizes the total weight of the device to about 3 kg while retaining sufficient rigidity for the device itself, as well as for the operator's comfort and ease of handling the device. The lightweight structure of the exoskeleton reduces discomfort for the wearer, particularly during longer lifting periods.

Flexibility is another key area where present-day equipment is deficient. Most exoskeletons limit bio-motion, especially in the knee region, which essentially makes them inconvenient for dynamic activities like deadlifting. This limitation can actually affect the user's lifting style, and rather than reducing the risk of an injury, it enhances it. Whereas our design consists of a spring-loaded piston mechanism coupled with a spring steel spring ruler to facilitate this kind of flexing and extending of the knee from ninety degrees to one-eightieth degree. This will allow the exoskeleton to move in line with its user to provide the correct biomechanical posture and reduce stress on joints.

Issues of ergonomics are not taken into consideration in the current designs, hence creating devices that are uncomfortable or hard to fix. Harsh or unbendable straps, inadequate cushioning, and badly shaped parts press against the skin and generate discomfort for the end-user. Implementing these considerations into our design allows us to address these complications, as our exoskeleton utilizes appropriately placed Velcro straps for easy donning and doffing as well as padding braces for reducing pressure points. Also, by following parametric curves on the exterior design of the device, it wraps around the user's body for better comfort and stability. Using Velcro and ergonomic shaping of the exoskeleton allows the use of the device for different body constitutions and all kinds of lifting.

Combining the new materials, as well as more compact and efficient design elements, our exoskeleton is superior to previous models. Incorporating Autodesk®, ABS, and stainless steel with refreshing and gripping spring steel allows the creation of an ergonomic and resilient tool. The easily set-up tension and the nonlinear movement pattern of the exoskeleton allow for the exoskeleton to accommodate various user requirements. These improvements allow the device to maintain user posture and biomechanical positioning, effectively decreasing joint stress and muscle exhaustion, along with making lifting large objects safer and less strenuous for a wider population.

Design Specifications:

Feature	Specifications	Target	Improvements Over Target
Device Weight	The exoskeleton, which weighs around 3 kg, is made of spring steel for the spring ruler, stainless steel for the piston and connection, and ABS for the bespoke pieces.	Compared to existing devices that weigh between 5 and 10 kg, a lightweight design of 3 kg will greatly reduce user fatigue.	Achieved the goal with a robust yet lightweight design that permits prolonged usage without sacrificing comfort.
Support Mechanism	Features a Pneumatic piston with adjustable tension, allowing users to vary resistance.	Support users with varying lifting intensities and strength levels in a customisable manner.	With a wider range of tension adjustment than anticipated, the gadget may be used for a variety of exercises, including lunges, squats, and mild industrial applications.
Material Choice	Velcro provides adjustable and secure strapping; stainless steel allows the piston and connector to withstand heavy weights; spring steel gives the spring ruler exceptional	Use materials that are comfortable, strong, and long-lasting for heavy-duty applications.	ABS is used to minimize weight and improve customizing ease. While spring steel provides reliable support with superior fatigue resistance, stainless steel adds

	flexibility; and ABS ensures durability and moldability for unique parts.		strength and resistance to corrosion. Velcro increases use and adaptability.
Range of Motion	Supports the 90°–180° range of natural knee motion with seamless flexion and extension.	Give yourself complete freedom of movement so that you may do complex exercises like deadlifting with good lifting biomechanics.	The exoskeleton exceeded expectations by imitating human biomechanics with fluid, unrestricted articulation, which made it seem smooth and natural when moving.
User Comfort	Includes adjustable Velcro straps for a tight and secure fit, ergonomic bracing, and high-density foam cushioning.	While maintaining stability and usefulness for a variety of body shapes, it helps ease pressure spots and pain during extended usage.	Velcro straps and thoughtfully positioned cushioning are added to improve comfort for prolonged use and remove hot areas. For a range of user sizes, parametric curves guarantee an adaptable fit.
Biomechanical Alignment	Designed to match the user's natural joint axis with parametric curves and bracing that may be adjusted.	Achieve exact alignment to minimize joint strain while lifting and transmit force efficiently.	Improved over and beyond typical devices by dynamically adjusting to the posture and movements of the user, guaranteeing constant alignment and minimizing knee and lower back strain.
Structural Robustness	Designed to withstand weights of up to 150 kg while maintaining durability under pressure thanks to a safety factor of 3.	Assure user safety when performing heavy lifting operations by offering dependable performance under big weights.	Exceeded expectations by showing constant performance under numerous stress tests, proving long-term dependability and durability for usage in

			sports or industry.

2. Design

Thigh and Calf Casing:

Figure 1. Thigh Casing Part

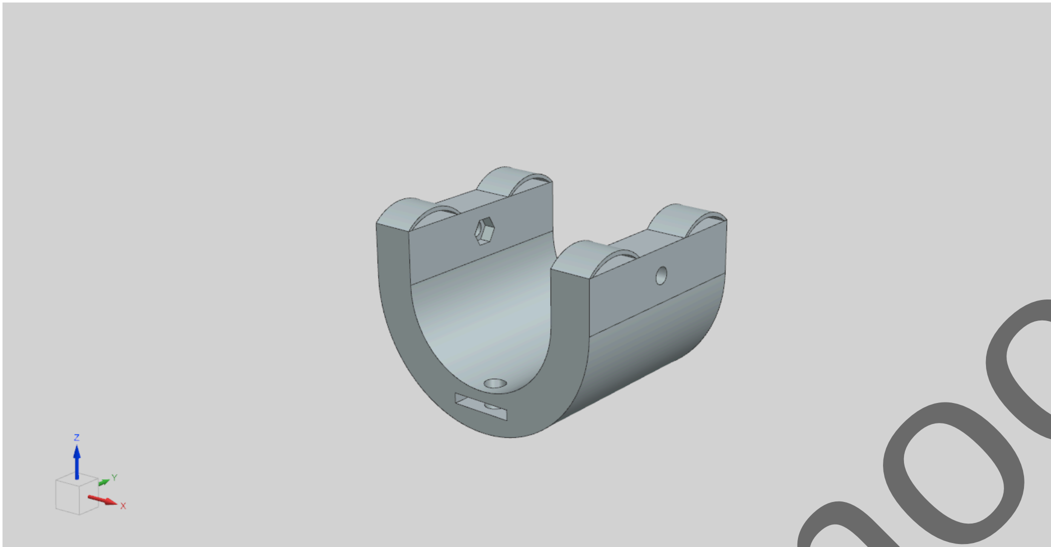


Figure 2. Calf Casing

The thigh and calf casing are the fundamental structural components of the exoskeleton designed to ensure both stability and user comfort. These casing attach to the piston using a piston connector and spring steel plate and envelops the upper and lower legs in an ergonomically crafted fit, which guarantees optimal alignment during movement. Constructed from durable yet lightweight materials—such as ABS plastic—these covers strike a balance between structural rigidity and user comfort, maintaining the device's stability without introducing excessive weight. The adjustable velcro straps and integrated cushioning within these covers offer a customized fit, accommodating a diverse range of body types and sizes, while evenly distributing pressure along the limb. This thoughtfully designed configuration uses localized strain, thus enhancing the exoskeleton’s functionality and comfort for high-intensity use by end users. However, achieving this balance can be challenging for the user to adjust to because it requires careful consideration of various factors. Although these covers are effective, there are instances where users may still experience discomfort.

Piston:

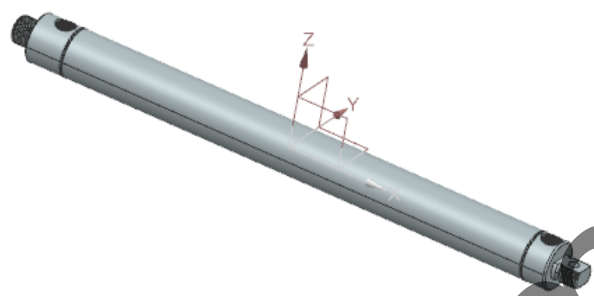


Figure 3. Piston Mechanism

The design is based on a piston system; the piston is sourced from Mcmaster Carr Part no. 6498K661, which represents our approach to dynamically assist the end users when lifting heavy objects. This mechanism is specifically made to aid in knee extension with effective forces. It manages biomechanical stress on the knee joint, enhances the fluidity of movement, and reduces strain on lower body joints. Piston tension is adjustable, allowing users to obtain the right amount of assistive torque for their unique lifting conditions. The exoskeleton can be tuned to work well for high intensity tasks, and across a range of body types and abnormal biomechanical conditions like old joint injuries in the bottom half of the body.

Spring Steel Plate:

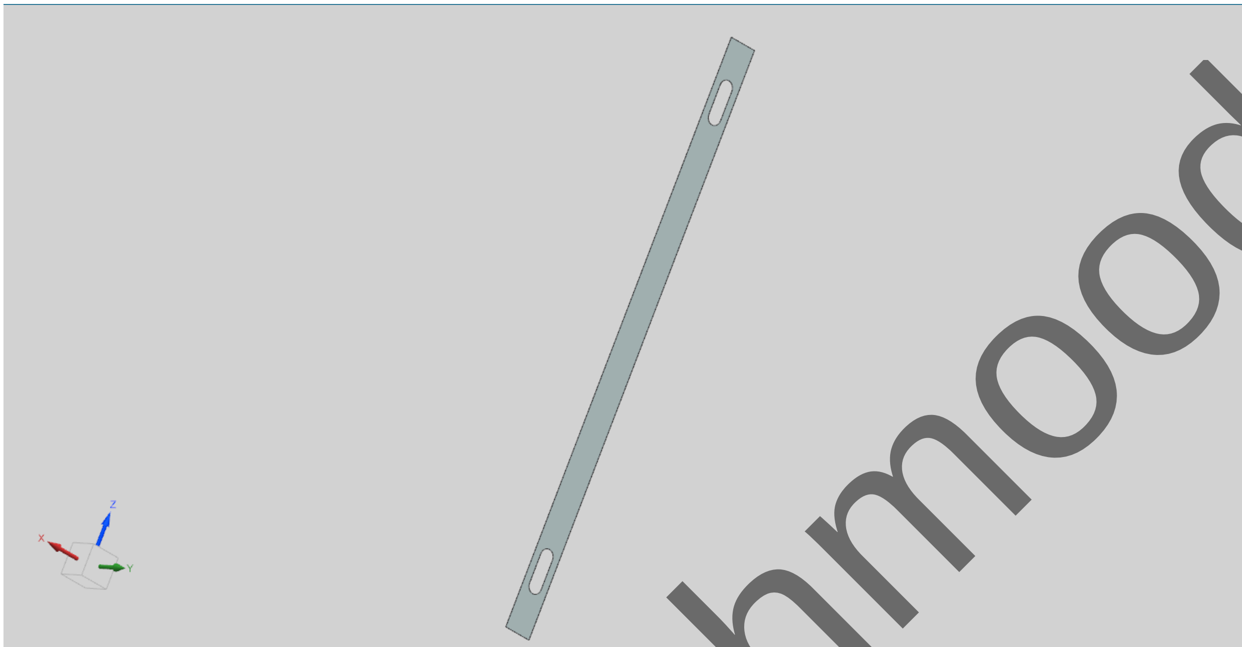


Figure 4. Spring Steel Plate

A flexible spring mechanism made from 1095 Spring steel, significantly boosts the exoskeleton's performance beyond that of a conventional machine. You could say it adds an element of not just mechanically supported performance, but also offers functionality which is desirable in a human-centered device. The system is designed in a way that ensures the springs will not break, under conditions that similarly prevent the human knee from breaking.This system works really well for the exoskeleton.When the user is performing in the exoskeleton, they should feel as though they're performing normally. The exoskeleton should not be something that the user has to work around or do something differently to achieve the motions they normally achieve.

Piston Connector:

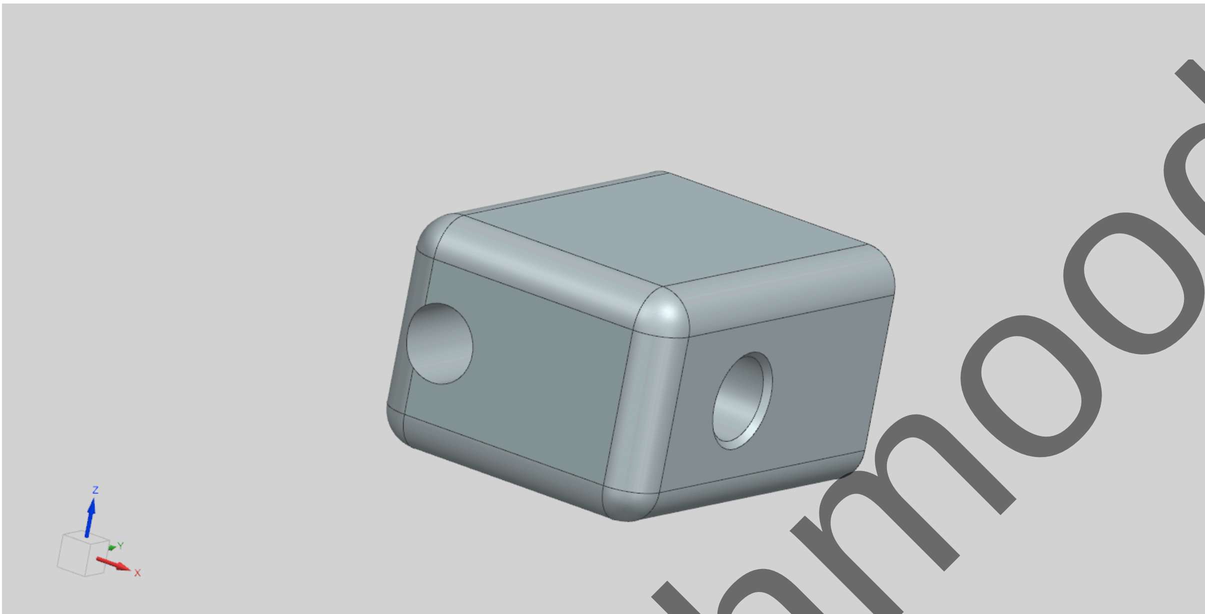


Figure 5. Piston Connector

The piston connector plays a crucial role in the assembly of the exoskeleton, linking the piston to the thigh casing securely using bolts. Made from robust stainless steel, it ensures a strong and durable connection that transfers the force from the piston directly to the casing, maintaining the structural integrity of the exoskeleton during movement. The piston connector features precision threads that interlock with the corresponding threads on the piston, providing a stable, fixed attachment that supports the efficiency of the device's operation. This component not only ensures the reliable transmission of force but also contributes to the overall strength and stability of the exoskeleton. Its stainless steel construction offers resistance to wear and corrosion, ensuring longevity under strenuous use. While the connector performs effectively, careful attention is needed during assembly and adjustment to maintain optimal performance and minimize wear on the threads, which could impact the stability of the exoskeleton over time.

Piston Sub Assembly:

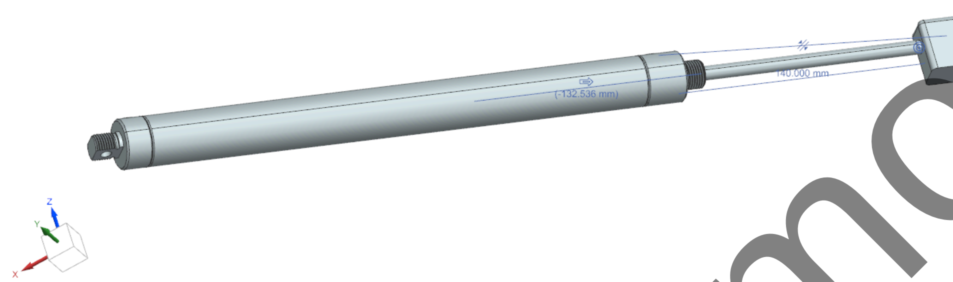


Figure 6. Piston Sub Assembly

This Sub assembly create the piston and attaches the piston connector on the piston using the thread on the piston and connector respectively

Final Assembly:

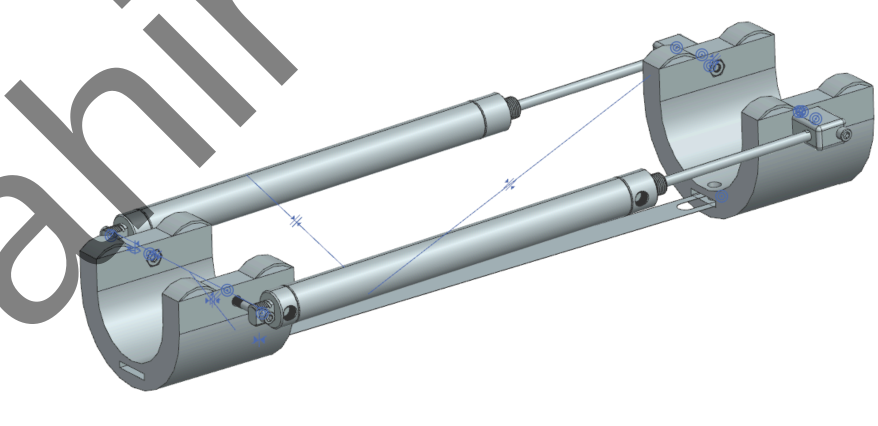


Figure 7. Final Assembly

Figure 7 Illustrates the full assembly of the mechanism using the parts mentioned above, the connectors being constrained concentrically to the thigh casing and the other ends of the piston being concentrically constrained to the bolts to the calf casing. Allowing rotational movement with respect to the casing that is fixed.

Design Decisions:

The exoskeleton's conceptual design is centered on developing a passive system that facilitates knee mobility during deadlifting. The spring-loaded piston knee joint is a crucial component that provides regulated resistance during flexion and mechanical help during knee extension. This dual purpose lessens knee strain while ensuring easier movement transitions. Users may alter the amount of support according to their lifting preferences and the weight being supported thanks to the pistons' psi adjustability. The exoskeleton may be used by a variety of people, including industrial workers and casual lifters, thanks to its versatility. The structural and functional elements of the knee exoskeleton are depicted in the supplied drawings. The general design idea is depicted in Figure 6, with special attention to the upper and lower halves of the exoskeleton and their function in supplying stability.

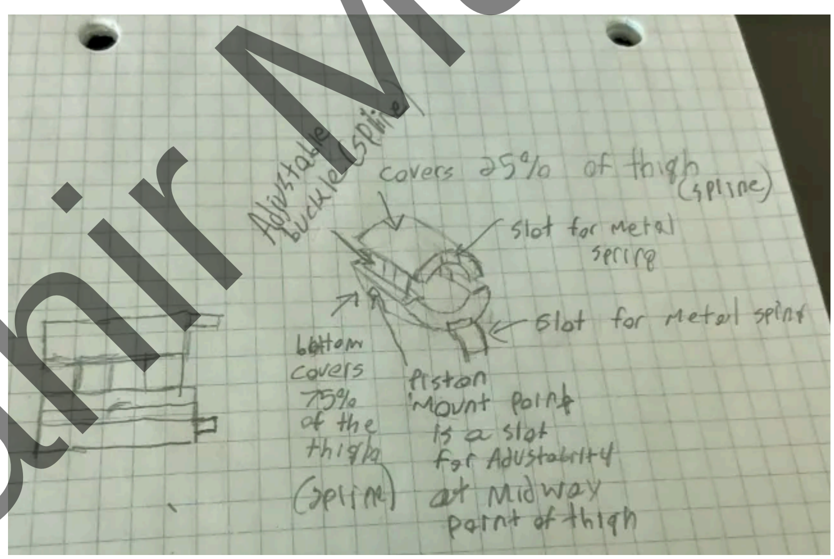


Figure 8: Sketch of support structure with adjustable straps and buckles.

A side view of the exoskeleton is shown in Figure 2, with particular attention to the integration of the spring-loaded piston mechanism. The piston, which is positioned diagonally across the knee joint, supports the user during flexion and extension by distributing force optimally. Velcro straps provide a tight and customizable fit for users of all sizes, and the spring mechanism replicates the knee's natural biomechanics by providing constant resistance and support. When taken as a whole, these drawings show the exoskeleton's ergonomic and functional features and show how well it supports the knees during demanding exercises like deadlift.

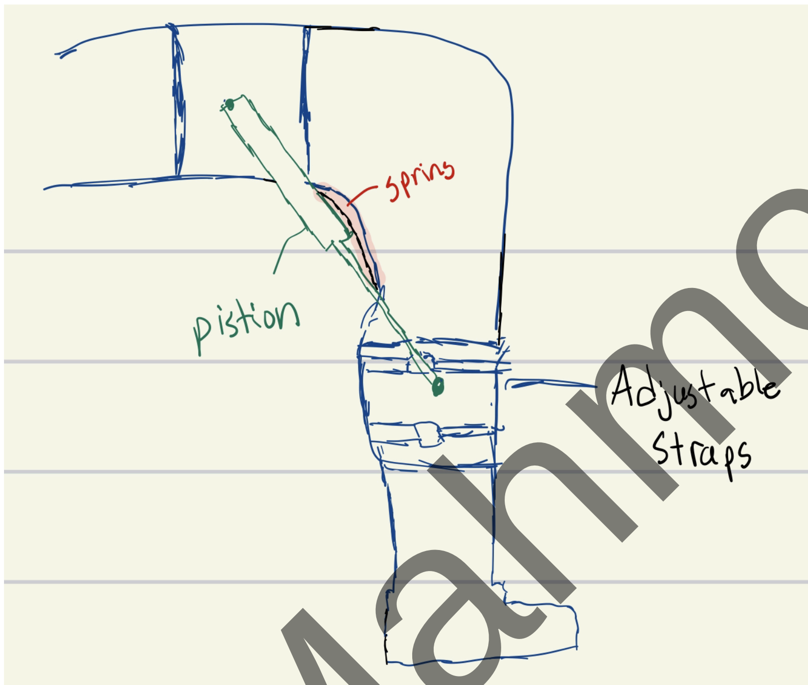


Figure 9: Knee brace sketch with a spring and piston mechanism.

The design places emphasis on the importance of the balance between mechanical support, ergonomics, and flexibility. In order to minimize fatigue during usage while preserving durability, lightweight materials were used, such as spring steel for the spring mechanism and ABS for bespoke components. The exoskeleton is adaptable for a range of users because of its adjustable piston mount and Velcro straps, which suit a range of body shapes and lifting capacities. By avoiding excessive knee movement and guaranteeing correct alignment during heavy lifting, the expanded lower section improves stability.

3. Design Analysis Documentation

Motion Simulation Analysis:

A Motion Simulation Analysis is a simulation conducted for the CAD Parts designed for the mechanism that is being implemented. It is a critical step in the mechanism development to understand the motion of the mechanism that will occur based on set inputs and outputs. In order to conduct the motion simulations the joints were created in which the mechanism interacts with different links. Then it was determined which joints will act like drivers to control the mechanism. In our mechanism for simplicity we have 3 Joints, 2 of which are Revolute joints to have the pistons be able rotate with respect to each respective casing which is attached to the thigh and calf respectively. Then a slider joint for the piston itself as it slides in and out of the bore. A spring connector was also added in between the two casing to simulate the Spring steel sheet that is being added to add extra support.

A linear driver is added to the slider joint of the piston and the bore this is in order to simulate that as the piston pressure is increased, a force is applied causing the piston to have translational motion which expands the piston supporting the motion of user trying to lift an item using their legs, reducing the force needed from the user. On the revolute joints, rotational drivers are added to represent the rotation of the thigh and calf with respect to each other. As the user raises their legs a moment is applied at the knee, the rotation simulates this moment. A spring connector was added to simulate the spring steel plate added for stability.

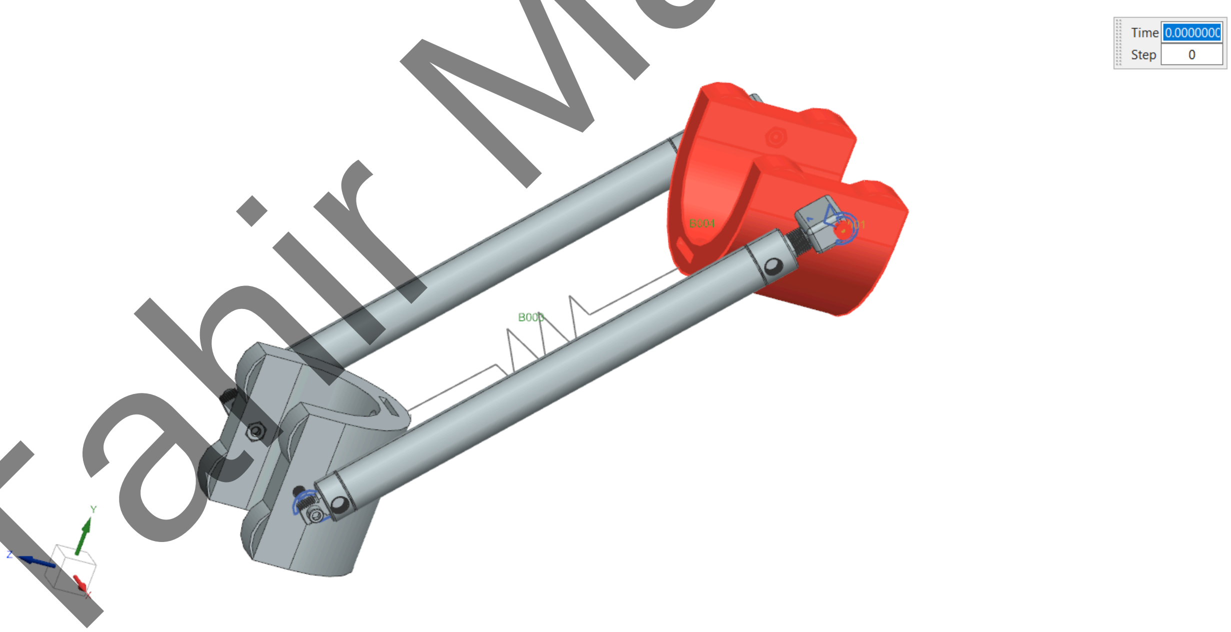


Figure 10. Motion Simulation at Unextended Position

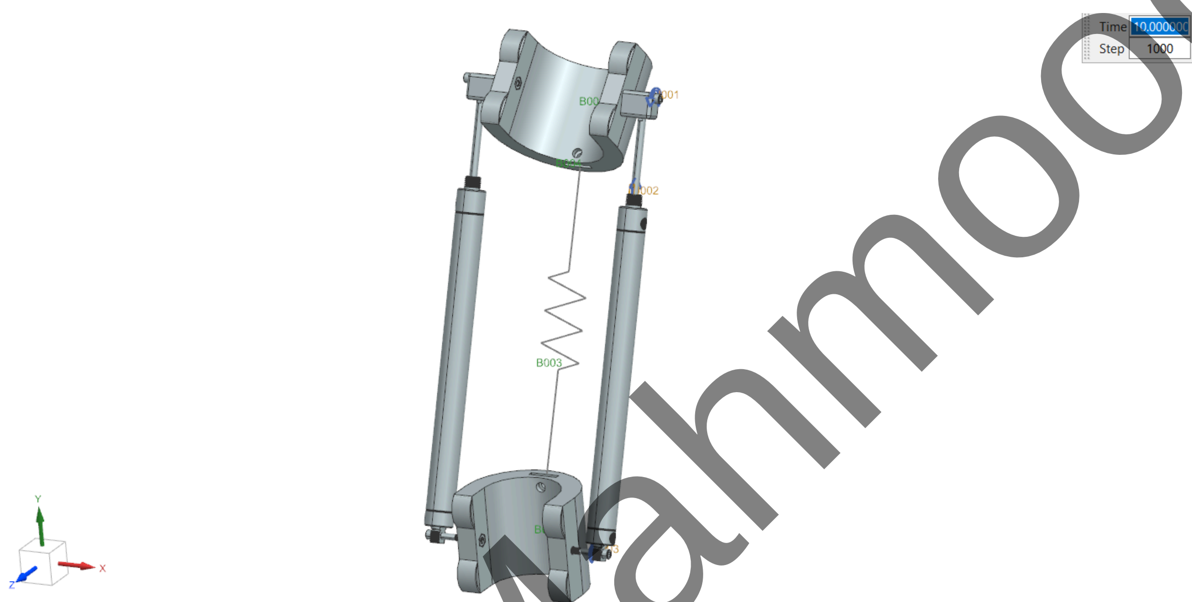


Figure 11. Motion Simulation at halfway point

Figure 12. Motion Simulation Fully Extended

Finite Element Analysis (FEA)

A Finite Element Analysis was conducted on the parts created for this mechanism. The FEA is a crucial step in the product development process, in order to ensure safety, functionality and efficiency of the mechanism. The Finite Element Analysis defines the boundary conditions around the mechanism and simulates how the mechanism will respond to various forces, loads, and boundary conditions. The FEA was simulated in order to approximate the loads the casing will experience when attached to the user.

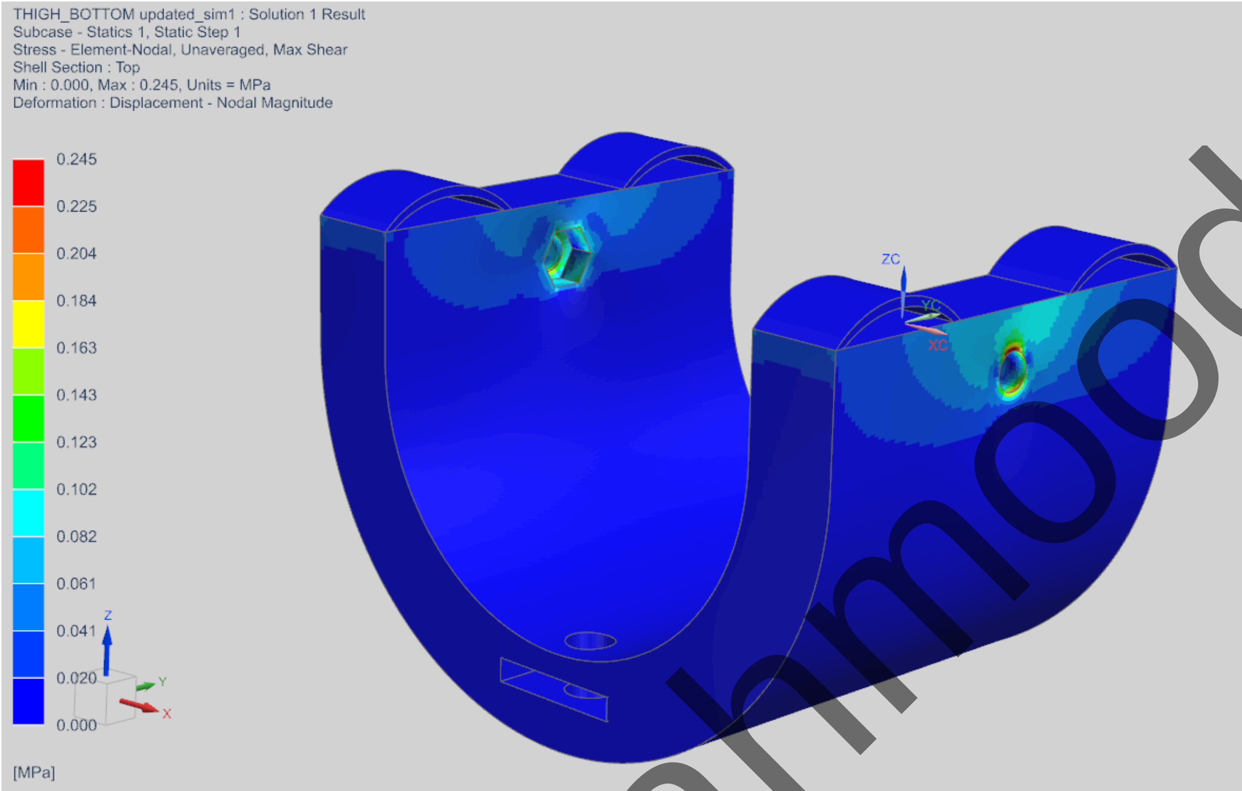


Figure 13. Thigh Case Stress FEA

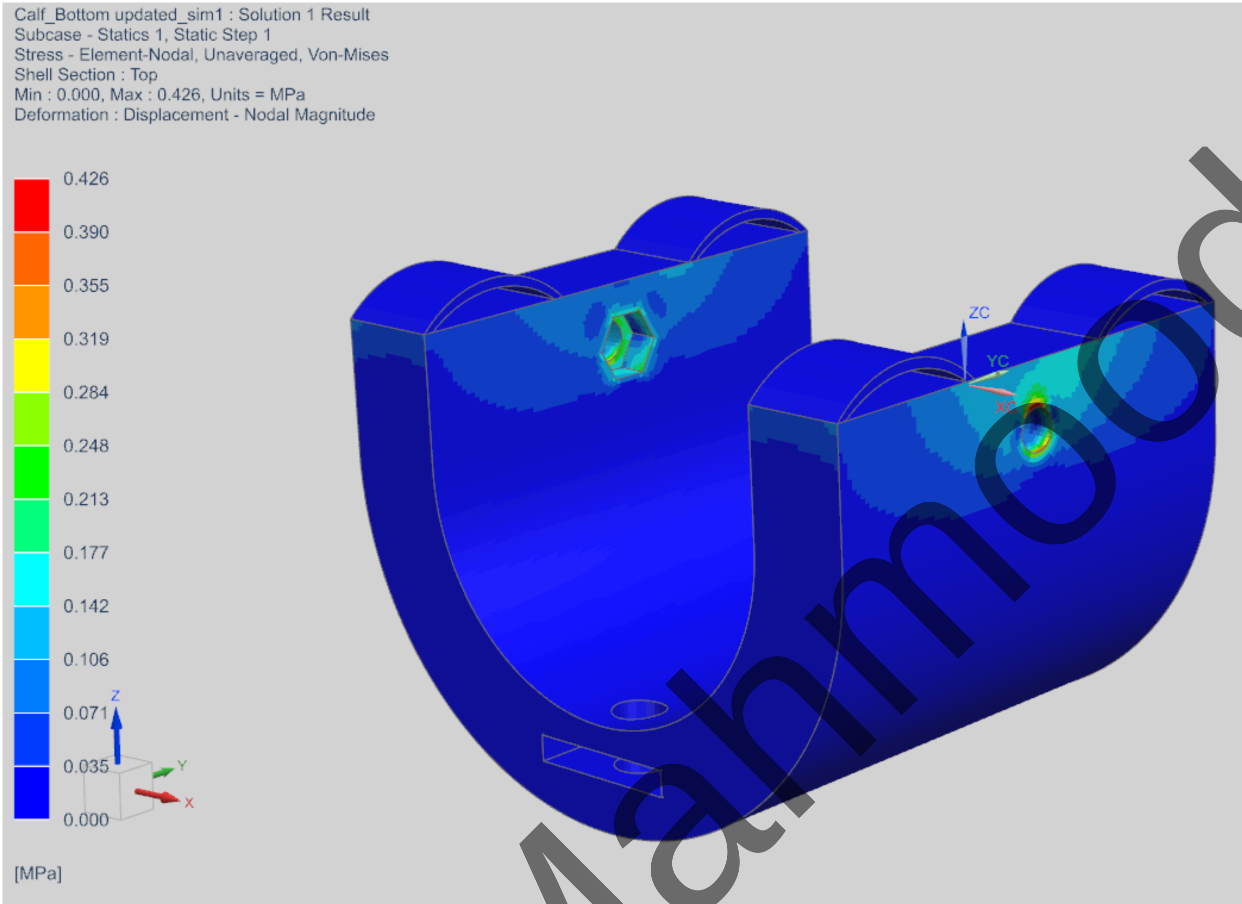


Figure 14. Calf Case Stress FEA

The Thigh Case and Calf case are the parts which attach to the user thigh and calf respectively , these are the main components of the mechanism in which the support of the piston, and the spring steel plate, are transferred to the user. The max load of the piston on the parts is applied, which at 50 PSI is a 45 lbf load, at the attaching point on both sides, with the direction of force being parallel with the piston. A load at the mounting point for the Spring steel plate is also simulated, the stress however is very little, the load by the spring steel is equal to the displacement of the plate multiplied by the K factor of 1095 spring steel. A fixed constraint is applied to the loops as that is where the Velcro binds the user thigh to the part. It can be seen that the calf stress is greater than the thigh stress due to the fact that the part is scaled down to fit the calf.

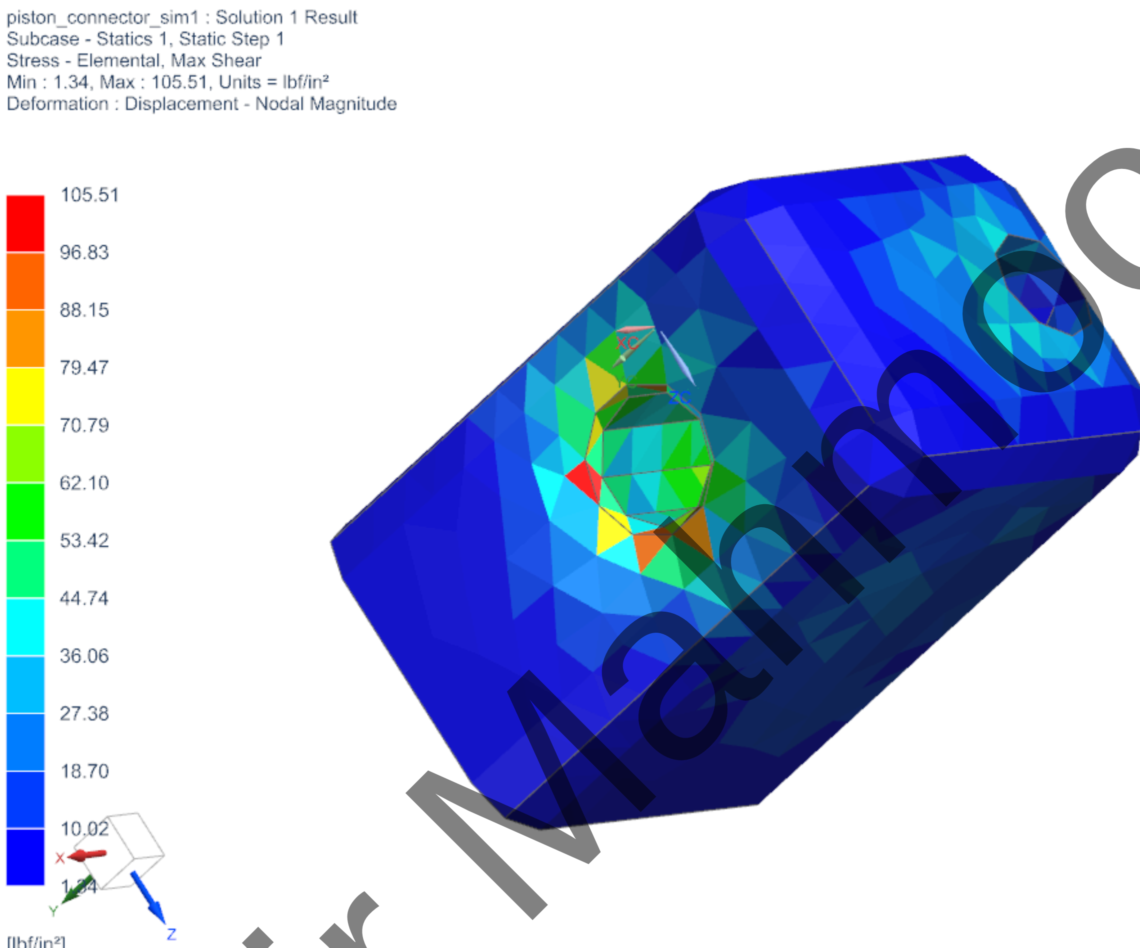


Figure 15. Piston Connector FEA

The Piston Connector, is a crucial component in this mechanism, this component takes the force from the piston and transfers it to the thigh casing. An FEA is crucial for this component to determine its structural rigidity and confirm it does not fail at the max psi of the piston. The Piston Connector was constrained using a fixed constraint around the pin hole where it attaches to the thigh casing,a force was applied through the threaded hole for the piston where it attaches, the force was equal to the max force the piston produces at 50 psi, which is 45 lbf. This part must be ensured it does not fail as this part directly affects the performance of the mechanism.

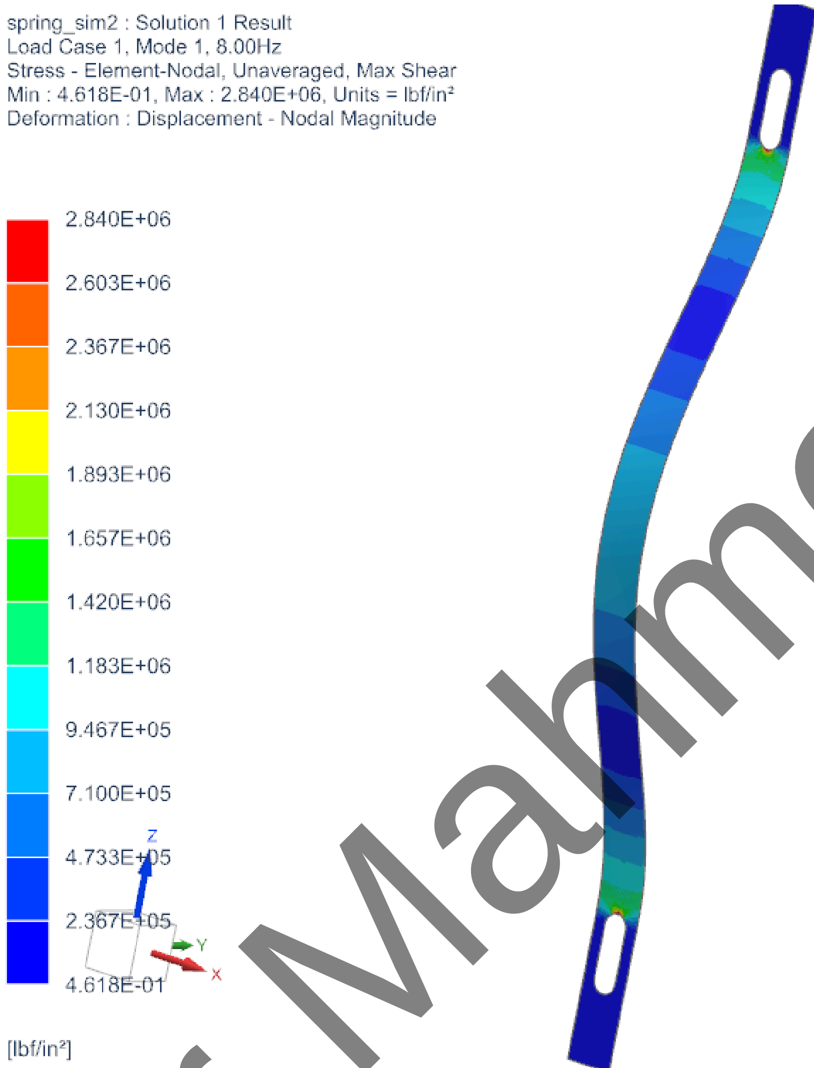


Figure 16. Spring Steel Plate FEA

The Spring Steel Plate made out of 1095 Spring steel, acts like a spring to support the knee joint, it adds more rigidity to the mechanism. The FEA for this part was conducted treating it as a flexible body element. As this is a flexible body element the stress on this part does not affect the performance of the mechanism.

4. Economic Analysis

The proposed knee exoskeleton is designed to enhance physical mobility by leveraging an innovative combination of materials and components for functionality and durability. An economic analysis of manufacturing and assembly processes for producing 10,000 units reveals a viable path to profitability through scaling and cost optimization.

Materials and Components:

The design utilizes key materials such as ABS plastic for the thigh and calf casings, ensuring a balance of durability, lightweight construction, and cost-effectiveness. The pistons, sourced from McMaster-Carr at $75 each, constitute the most significant material cost. The spring steel plate (1095 spring steel) enhances rigidity and provides natural spring-back during movement, further improving performance. Stainless steel connectors secure the pistons, ensuring long-term reliability. Velcro straps, chosen for their adjustability and user comfort, attach the device to the user's body.

Manufacturing Cost:

Mass production reduces unit costs significantly due to economies of scale. Injection molding for ABS components is highly efficient, with tooling costs amortized over a large production run. Stainless steel parts and spring plates require CNC machining, necessitating precision but benefiting from batch processing efficiencies. Labor costs, while non-negligible for assembly and quality assurance, are minimized through assembly-line workflows.

Cost Breakdown:

Component	Material Cost per unit	Machining/Processing Cost	Total Per Unit
ABS Casing	$5	$1.5	$6.5
Pistons (x2)	$75	N/A	$150

Stainless Steel Connector	$2.5	$5	$7.5
Spring Steel Plate	$3	$2	$5
Velcro Straps	$1.5	N/A	$1.5
Assembly Labour			$10
Total Cost			$180

Shipping and Distribution:

Logistics costs are factored based on weight and volume. Compact, modular packaging will lower transportation expenses. An estimated per-unit shipping cost of $5 reflects negotiated rates with freight providers.

Conclusion:

Optimizing manufacturing techniques, such as using lower-cost materials without compromising performance and adopting high-throughput processes like injection molding, will make the knee exoskeleton economically feasible for both prototyping and large-scale production. The total cost including shipping would be $185, with the cost for 10,000 Units being $1,850,000.

Manufacturing Process Planning (10,000 Units)

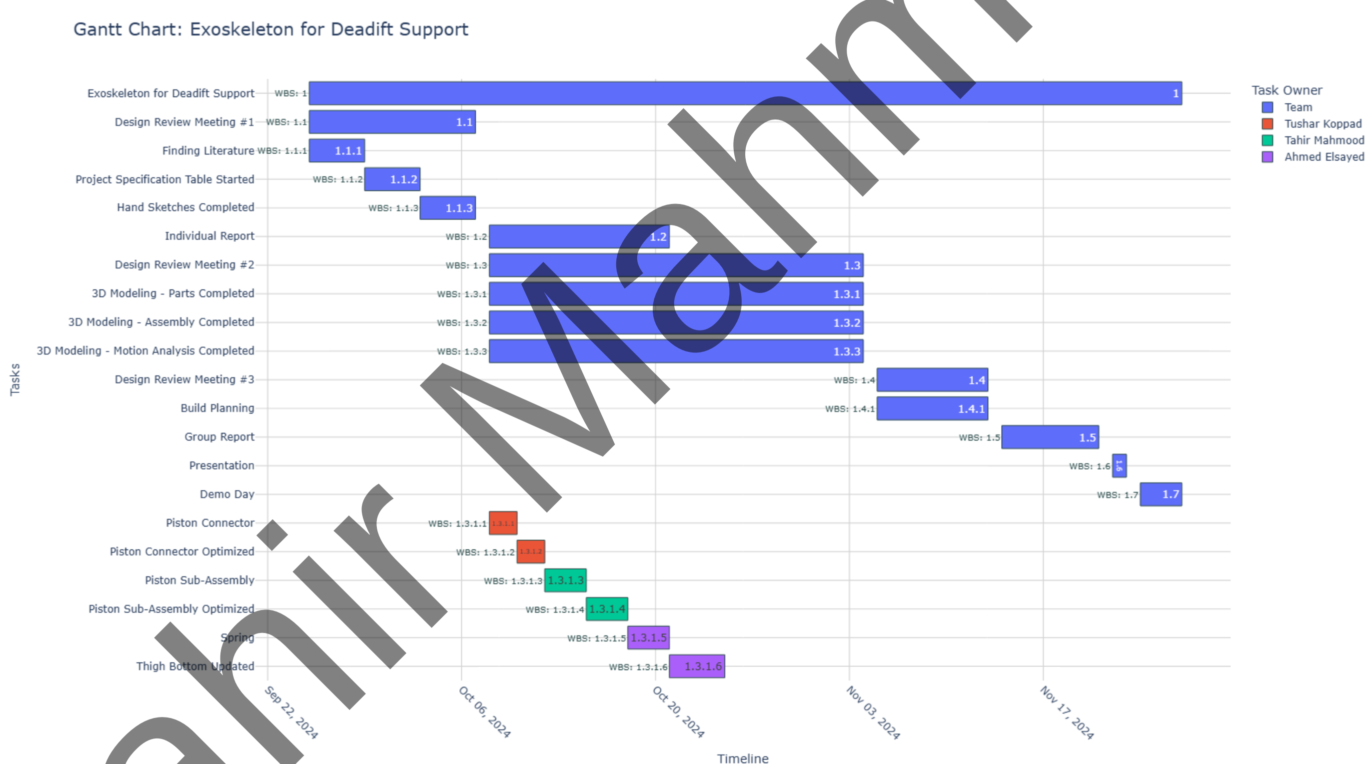
1. Material Procurement
    a. ABS sheets for casings
    b. Stainless steel rods for connectors
    c. 1095 spring steel plates (precut or custom dimensions)
    d. Velcro straps
    e. Pistons (purchased)
2. Manufacturing Workflow
    a. Injection Molding for ABS casings:
        i. Tooling setup ($20,000 initial cost for molds, amortized).
        ii. Output rate: 5 minutes per part.
    b. CNC Machining for stainless steel connectors:
        i. Precision milling with a batch size of 500.

c. Stamping/Cutting for spring steel plates:
   i. Progressive die stamping process for consistency.
d. Assembly:
   i. Semi-automated assembly line for piston mounting and Velcro attachment.
   ii. Final inspection for quality control.

3. Timeline
   a. Estimated total production time for 10,000 units: 4-6 months.

5. Design Project Management

Gantt Chart



In the image above depicted is the Gantt chart, which besides illustrating the tasks and responsibilities of the Exoskeleton for Deadlift Support project also depicts the assignments associated with the tasks. Most activities demanded the input of all members, for instance design review meetings as well as submission of individual reports. However, there were predetermined jobs in a day for each member, such as NX modeling and creation of parts, FEA and motion analysis. Both concepting and researching were performed as group projects, so as to get the input of the whole team, and so that one could combine ideas of several team members into one design. Some members were assigned with specific prototyping and building tasks because they are more likely to have easier access to both materials and equipment. However, tasks like report writing and preparing the presentation to be orally delivered were shared out with other members of the team so that it would be easy to achieve the goal of considering all the modules and avoid unequal distribution of work.

6.0 Conclusion:

The design and development of the knee exoskeleton demonstrate a careful balance between structural integrity, user comfort, and functionality. The integration of key components such as the thigh and calf casings, spring steel plate, and adjustable piston system enables the exoskeleton to provide effective support during high-intensity activities like deadlifting. Each part—designed with precision and subjected to rigorous Finite Element Analysis—ensures that the exoskeleton meets the demands of durability, flexibility, and user-specific adaptability.

Motion simulation and FEA analysis confirm the mechanism's ability to withstand operational loads while mimicking the natural biomechanics of the knee joint. The use of lightweight yet robust materials, such as ABS plastic and stainless steel, contributes to both user comfort and the device's longevity. Moreover, the economic analysis highlights the feasibility of scaling production through efficient manufacturing processes like injection molding and CNC machining, achieving a competitive unit cost for mass production.

By combining ergonomic considerations with cost-effective manufacturing, this design achieves a practical and versatile solution for reducing strain on the knees during heavy lifting. Future improvements may include refining the adjustment mechanisms and exploring alternative materials to enhance user comfort further while maintaining affordability. This innovative approach positions the knee exoskeleton as a viable tool for industrial workers, rehabilitation patients, and recreational lifters, promoting mobility and safety in demanding applications

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