Robotic Ankle Exoskeleton

Diego Avila, Emma De Korte, Tre Green

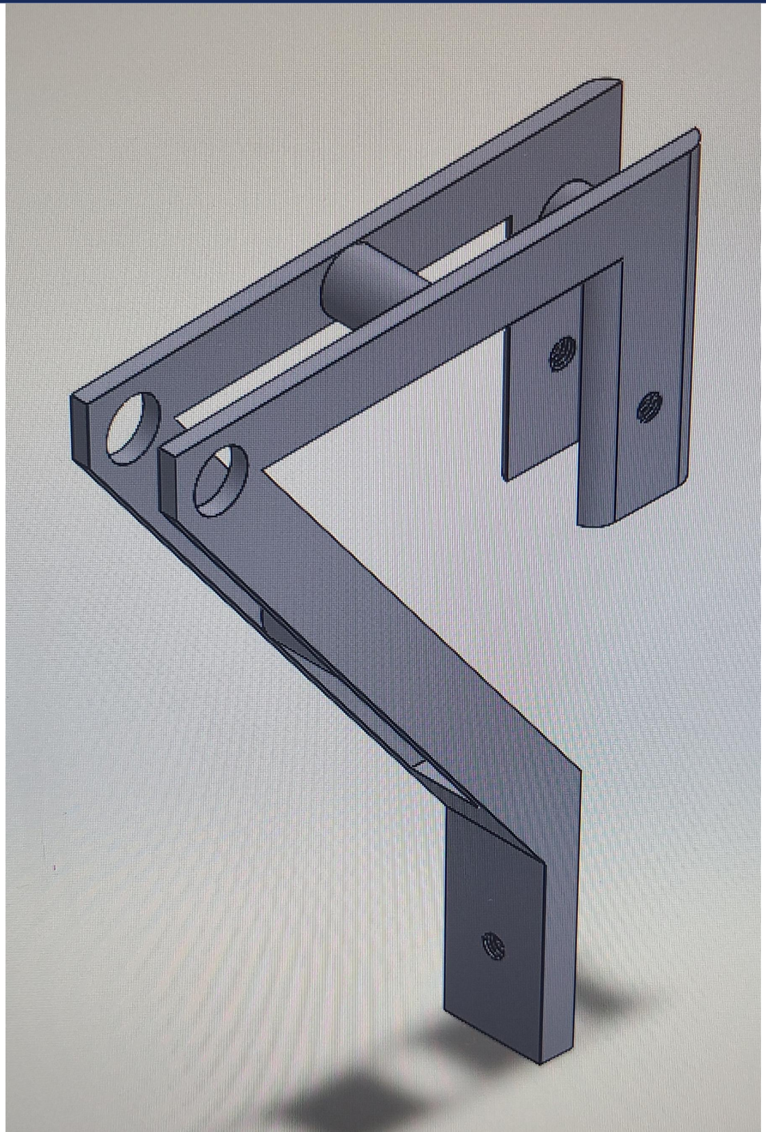
NAU NORTHERN ARIZONA UNIVERSITY

Project Description

- Partnered with Dr. Lerner to design an ankle exoskeleton that aids the motion of walking.
- previous trial “did not observe a significant group-level benefit relative to walking without the device. However, [they] did observe a marked benefit for [their] more impaired participants”[1]
- We have reiterated parts of their design (footplate, calf cuff, rod)
- Some differences (bracket, chain to cable, pulley)
- Requested permission to 3D print 2 brackets & rod (we don’t need to take apart the previous model)

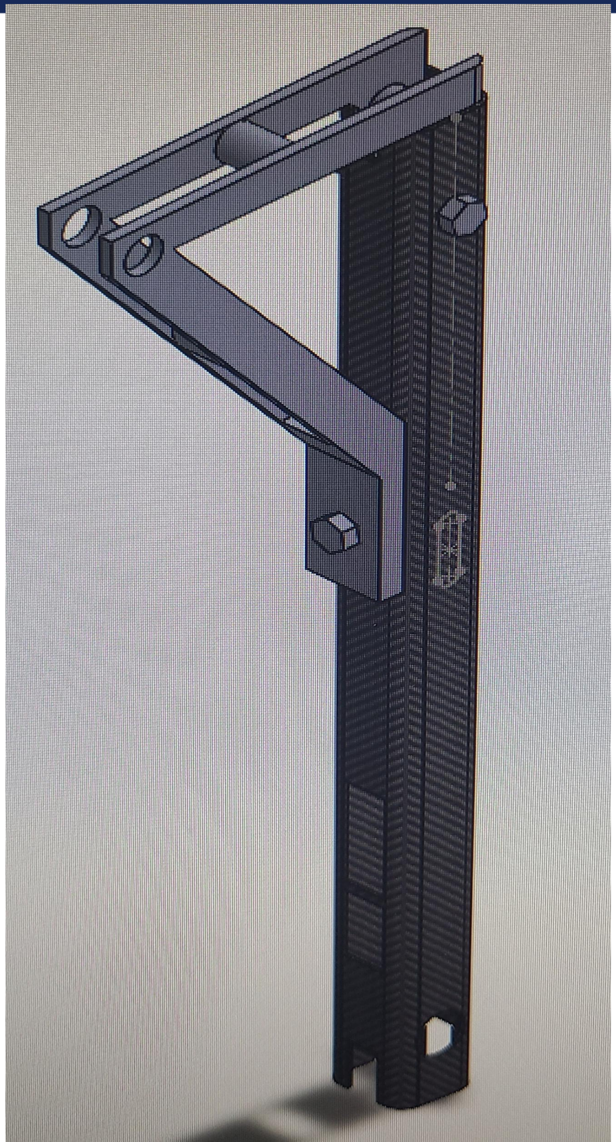
Design Description

- Bracket 3
- Internally mounted at the top, and externally midway down the rod
- Most force will be in Y direction
- Uses geometry of bolt and top ‘hook’ to prevent shear in Y direction
- ‘Hook’ braces against shear in X direction
- Bottom support braces against X & Y forces



Design Description

- Bracket 3 Assembly
- M4x0.7 bolts
- Flush fit at the top

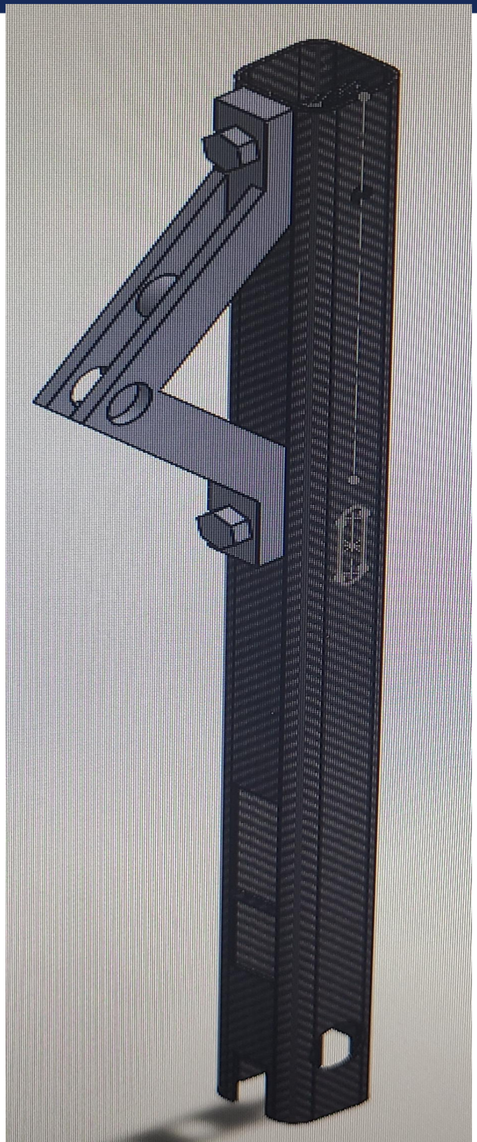


Design Description

- Bracket 4
- Exterior mounted
- Pulled down and to the right
- Motor position is lower
- Triangle shape braces in all directions
- Force is distributed as tension in the top beam & compression in the bottom beam

Design Description

- Bracket 4 Assembly
- M4x0.7 bolts



Design Requirements

Customer Requirements

- Lightweight
- Easy to put on and take off
- Durable
- Economical
- Low Profile

Engineering Requirements

- Each leg weighs <1kg
- Takes <1 minute to remove or put on
- Can withstand 100,000 steps
- Each leg cost <$2,000
- Nothing extending more than 10 cm from the leg

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Design Requirements

System QFD

Project:	Lerner Exoskeleton
Date:	9/18/2023

Legend	
A	Technaid Eobotic Ankle H3
B	Rewalk Restore Soft robotic Exosuit
C	Untelthered Robotic Ankle Exoskeleton

1	Decrease Weight				
2	Increase Durability	-			
3	Decrease Timing	0	-		
4	Decrease Cost of Each Leg	+	-	+	
5	Decrease Protrusion From Body	++	0	0	0

			Technical Requirements						Customer Opinion Survey				
	Customer Needs	Customer Weights	Decrease Weight	Increase Durability	Descrease Timing	Decrease Cost of Each Leg	Decrease Protrusion from Body		1 Poor	2	3 Acceptable	4	5 Excellent
1	Lightweight	3	5	3	3	3	3		A				BC
2	Easy to take on and off	4	3	1	5	3	3			BC		A	
3	Durable	4	2	5	1	2	1				ABC		
4	Cost Effective	5	4	4	1	5	1						
5	Small in size, close to body	3	5	2	3	2	5		A	B		C	
	Technical Requirement Units		kg	steps	min	dollars	cm						
	Technical Requirement Targets		<1	100,000	<1	<2000	<10						
	Absolute Technical Importance		19	15	13	15	13						
	Relative Technical Importance		1	2	3	2	3						

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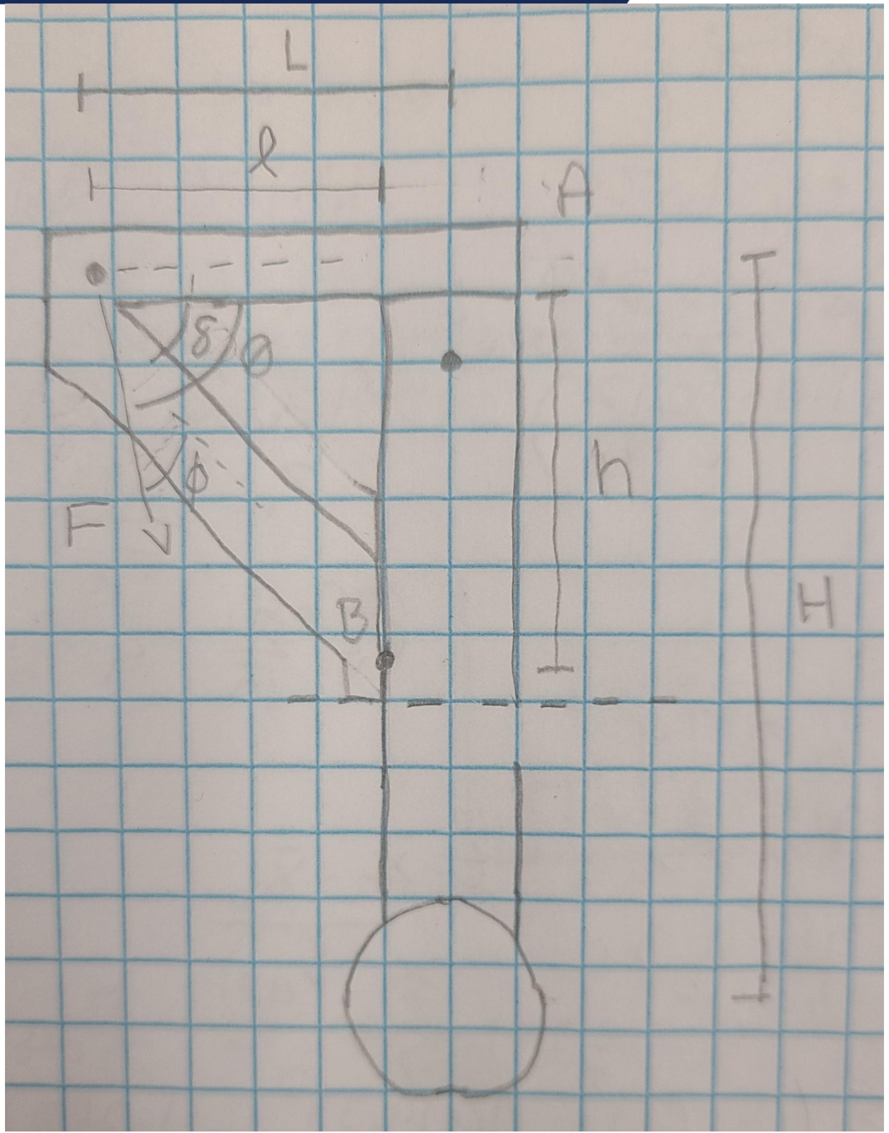
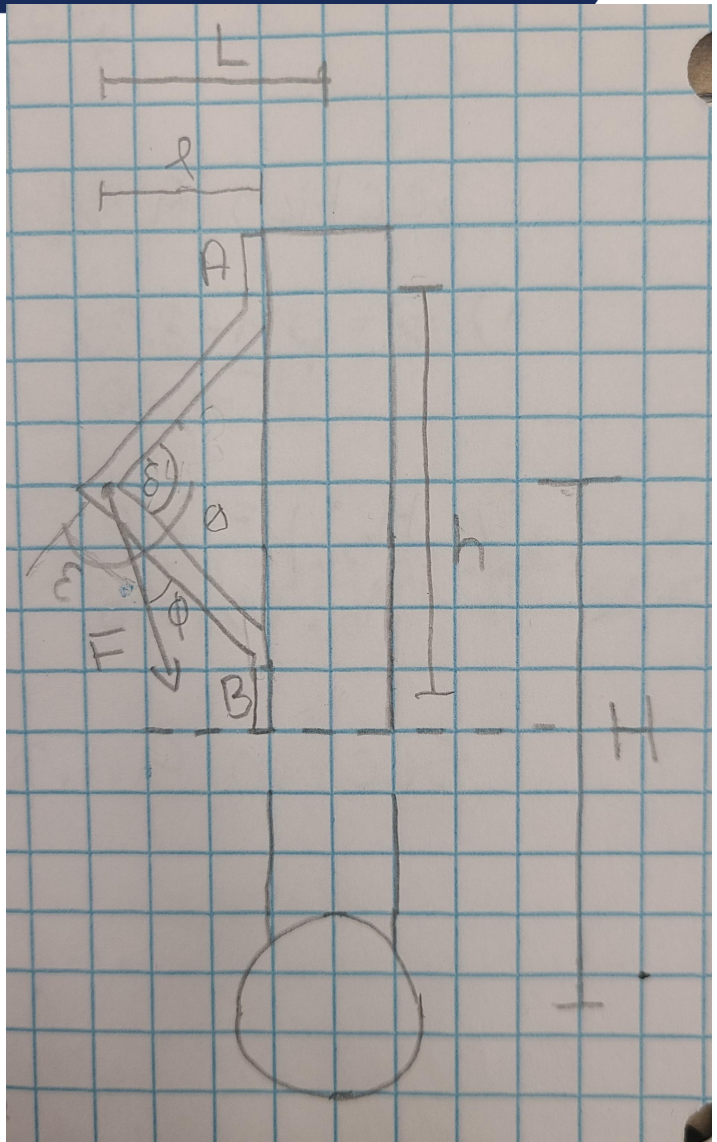
Engineering Calculations

- Predicted reactions to forces
- H = 262.25 mm
- L=78.5 mm
- h = 110 mm
- l = 68.5 mm
- Ø = tan(H/L)=
- δ = tan(h/l)=
- Φ = Ø - δ =
- Ax=Fcos(Ø) Ay=Fsin(Ø)
- Bx=Fcos(Φ) By=Fsin(Φ)
- Reaction found by Pythagorean's theorem.



Engineering Calculations

- L=42 mm
- H=200 mm
- l = 31.5 mm
- h= 100mm
- $\delta = 90$
- $\varnothing = \tan(H/L)$
- $\Phi = \varnothing - 0.5*\delta$
- $\varepsilon = 180 - \Phi - \delta$
- $Ax=F\cos(\varepsilon)$ $Ay=F\sin(\varepsilon)$
- $Bx=F\cos(\Phi)$ $By=F\sin(\Phi)$
- Reactions found by Pythagorean's theorem



Sprocket Material Selection

- Gear teeth bending stress (Lewis Equation)

$$\sigma_t = \frac{W_t P_d}{FY}$$

- Diametral Pitch

$$Dp = \frac{Teeth}{Pitch}$$

- Tangential Load

$$W_t = \frac{2T}{Dp}$$

- Variables

- Pd=Diametral Pitch= 3.75mm
- T=Torque= 3.5 NM
- Teeth= 30
- F=Face Width= 11mm from chain Width
- Y=Lewis Factor

Gear Material Selection

- Using the Lewis equation we found the tooth bending stress = 2031 pa
- the allowable stress for various materials
- Steel=840 MPA
- PLA= 37 MPA
- Aluminum= 290 MPA

- We can select any of these options for our gear

Cost Analysis for Bracket

- Average cost of CNC Machining is $80 to an hour
  - Higher quality, 5-axis CNC Machining may be $200

- Machining time = length of cut (mm)/feed (mm per revolution) * revolutions per minute

- Feed rate = speed * # of flutes * chip load
  - Speed is 12000 to 24000, there for average is 18000
  - 2 flutes for Aluminum or 4 for Steel, bracket will be Aluminum
  - 18000 * 2 * 0.4 = 14,400 mm per min

- Length of bracket 3: 135 mm
- Length of bracket 4: 100 mm

- Cost for Bracket 3: $73.92-$185.15
- Cost for Bracket 4: $24.00-$60.00

[8]-[11]

Design Validation FMEA

Product Name: Robotic Ankle Exoskeleton		Development Team: Joscelyn Green, Diego Avila, Emma K De Korte					Page No of			
System Name: Ankle Exoskeleton							FMEA Number 1			
Subsystem Name: Bracket Assembly							Date			
Component Name	Bracket									
Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of Failure	Occurance (O)	Current Design Controls Test	Detection (D)	RPN	Recommended Action	
1 Bracket to hold Motor	Stress Rupture & low Cyle Fatigue	Total lose of functionability	9	Incorrect bolt tolerances, incorect design, and material selection	4	Applying various forces to the bracket and seeing if the brackect moves	5	180	Make sure Bracket design can withstand the forces applied	
2 Bolt to attach bracket to the Rod	Impact Fatigue	Damage to the Rod and total lose of functionability	7	Loose tolerances and wrong size selection	4	Applying various forces to the bracket and seeing if the tolerances are correct	5	140	Design Bracket and rod for tight tolerances	
3 Rod	Surface Fatigue & Stress Rupture	Shearing of the rod and deformation of the Rod	8	Have a sustained load at 1 point of the bracket and bracket not being fully tighted to the rod	6	Applying various forces to the bracket and seeing if the tolerances are correct	6	288	Do FEA Analysis to make sure it can withstand the forces	
4 Sprocket	Cycle Fatigue	Deformation or shearing of Sprocket teeth	7	Stress on sprocket may cause deformation overtime	3	Have a durability test to see how many cycles the sprocket can handle	4	84	Make sure sprocket material Selection is correct	
5 Chain	Impact Deformation	chain having deformation in the links or pins causing it to break	7	The tension force acting on the the chain	3	Durability test to see if the chain deforms over a certain amount of cycles	4	84	Make sure the currect chain material is selected	
6 Pulley	Surface Fatigue Wear	Surface damage of pulley and a decrease of effectiveness	2	Friction of the wire rubbing on the pulley	2	Cycle test to see if there is any material errosion occuring on the pulley	8	32	Make sure that the material selected wont erode	
7 Pulley Wire	Deformation Wear	Wire deforming over time	4	Tension Stress on wire causing the wire to deform overtime	2	Durability test to see if the wire deforms overtime	2	16	Make sure the material selected can with stand the force	
8 Foot Plate	Impact Fracture	Fracturing of footplate at attachment point to the pully	8	Force acting on footplate are greater than what it can handle	2	Durability test to see if the footplate will break will in use	5	80	Do force analysis on footplate	
9 Bearing	Cycle Fatigue	Increase in friction in the bearings and a loss of power	3	Deteriation of bearings and lubrication in the bearing getting dirty	6	Cycle Test to see how the model will work overtime	3	54	Make sure to keep the bearing as clean as possible	
10 Motor	Cycle Fatigue	Loss of torque or the motor becoming nonfunctional	7	Deteriation of motor part over multiple cycles	2	Cycle test to see if there is a loss of power overtime	3	42	Make sure the motor selected can handle the amount of cycles required	
11 Calf Cuff	Impact Fracture	Calf cuff breaking	2	Impact force of the user breaking the calf cuff	1	Durabilty Tests to see if the calf cuff can withstand the forces	4	8	Make sure the calf cuff is accessible for all users	

Future Testing Procedure

- Testing
  - Weight Test
  - FEA Testing
  - Timed test of putting on and Taking off Device
  - Durability Test (Testing the amount of cycle the device can withstand >100,000 steps)
  - Cost Evaluation
  - Device Protrusion Test

- Equipment/ Space
  - Scale
  - Timer
  - Various user to wear device
  - Measuring Device
  - Using The Biomechatronics Lab for durability testing

Schedule

- Current Schedule
  - Prototype 1, Report 2, Final CAD and BOM, and Prototype 2
  - Complete those by the due dates
  - Focusing on completing items ahead of due dates
- Plan for next semester
  - Begin looking at ordering parts after Prototype 2, before the end of the semester
  - Have a complete built model by mid-March
  - Begin testing afterward complete model is finished
  - Have complete functional model by mid-April

Budget

- Current Budget is 4000 dollars
  - $2000 per leg
- Our Current Expense are= TBD (Receipt for Prototype)
- Anticipated Expenses
  - Based on previous projects final design is 1,646 dollars
  - Our largest expense will be our motor ≈ $773 and Gearbox ≈ $300+
  - We can expect our final design to be around that value, while the rest of the money will go toward prototyping.

Fundraising Plan is to try and receive part donations or create a crowdfunding website

Any Questions?

Thank you

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