Dynamic Hand Brake for Manual Wheelchairs

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Mission: Provide a dynamic braking solution for manual wheelchairs

Introduction

Tetraplegia (or quadriplegia) is a collection of spinal cord injuries resulting in loss of voluntary limb function [1]. Many people with tetraplegia use manual wheelchairs as their primary daily transportation. Due to loss of hand/wrist function, slowing down their wheelchairs can be difficult. Most manual wheelchair users use their palms or wrists to create friction on the tire, but this leads to dirty, calloused, burned, or even severely injured hands. Wheelchair users desire a device they can attach to their chairs that allows them to dynamically slow themselves down without assistance from others. Currently, only one option exists on the market. It is heavy, expensive, and inaccessible. After interviews with industry experts and current wheelchair users, the team developed the metrics listed below.

Engineering Metrics from User Needs

#	Metric Description	Target Value	Achieved Value
1	Minimum brake distance from 4 mph on horizontal surface	< 20 ft	16 ft
2	Brake operating force per side	< 13.5 lbf	5 lbf
3	Device Failure force	> 200 lbf	75 lbf
4	Total device weight	< 1.5 lbf	1.5 lbf
5	Unit cost to customer	< $250	Est. $200

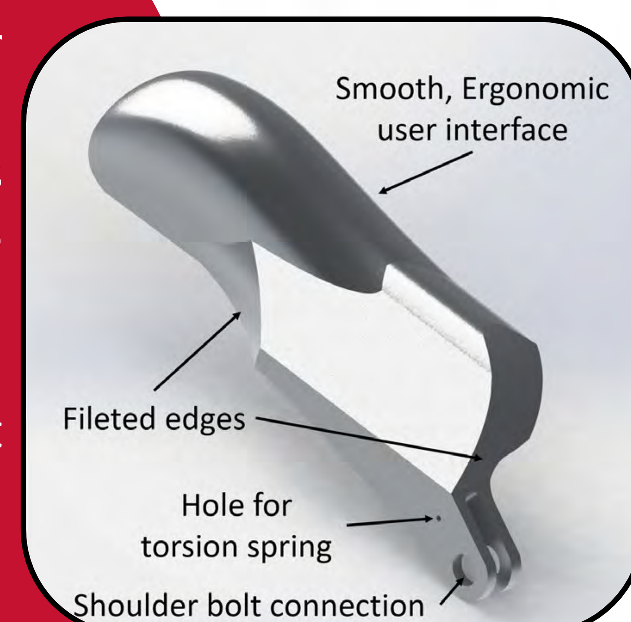
Design

The hand brake prototype fits a Quickie Q7 wheelchair. Active, independent wheelchair users commonly choose this or similar lightweight models as their primary day-to-day chair. Most lightweight wheelchairs have similar critical dimensions, such as the frame outer diameter and distance between the frame and wheels. Small adjustments to the prototype can be adapted to fit various other chairs. The final design consists of four primary components: fender, spring base, T-bracket, and collar.

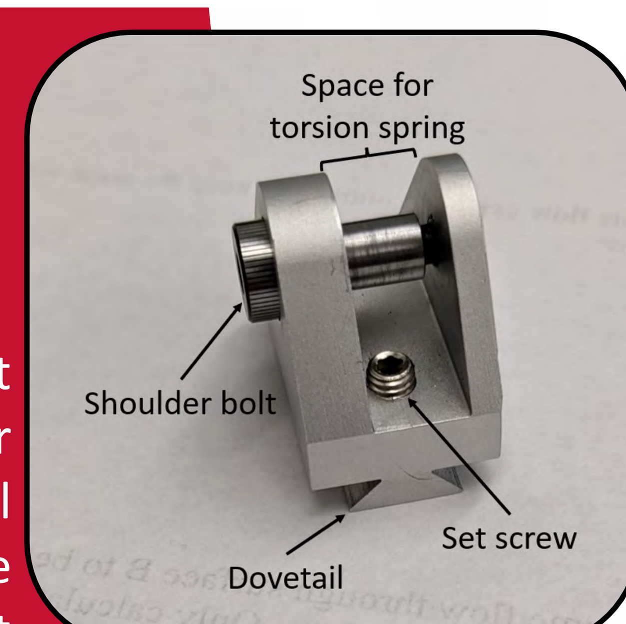
The fender creates a barrier between the user's hands and the wheelchair tires. Users push down on the fender to create friction on the tires that slows the wheelchair. The fender is ergonomically designed for people with or without grip abilities. Stress concentration points were thickened or given generous filets through multiple iterations. The final iteration is cast out of aluminum to give it a smooth surface finish.

The spring base, T-bracket, and collar attach the fender to the wheelchair frame. As a system, it has two degrees of adjustability so the device can accommodate multiple users. The system is secured to the wheelchair with two set screws and 4 bolts. This design fits securely to a wheelchair with a 1" frame and adjusts based on user needs.

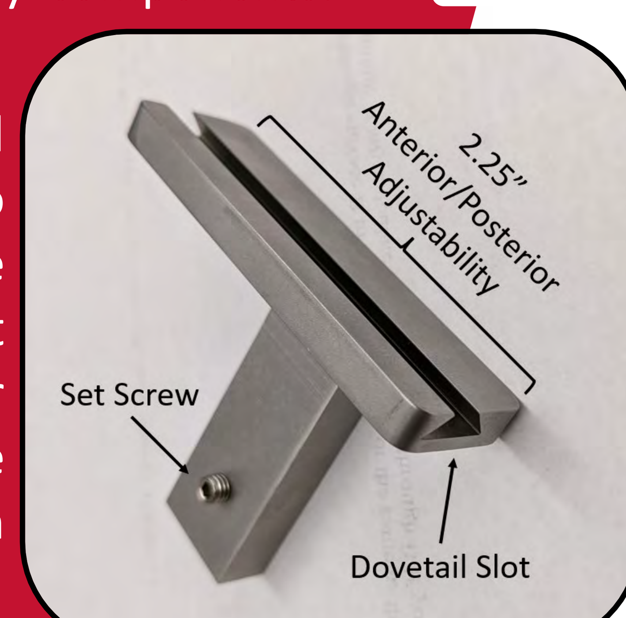
A pair of fully-assembled brakes weighs approximately 1.5 lbs.



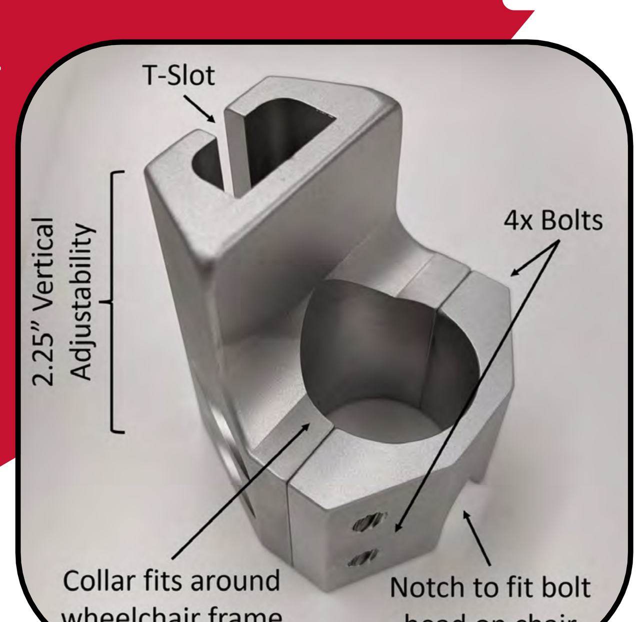
Fender (aluminum)



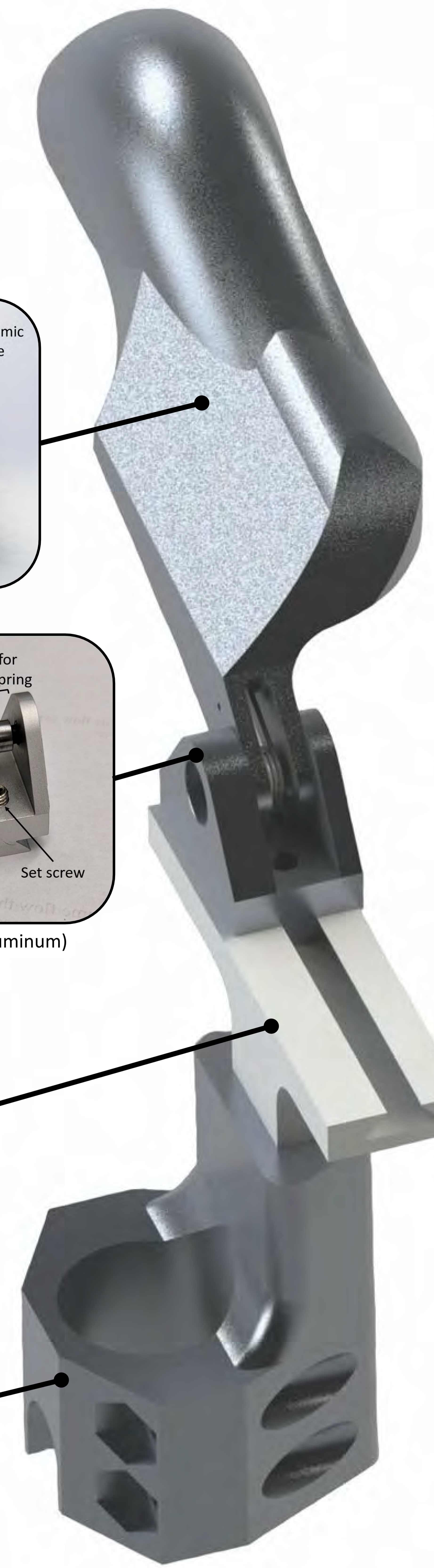
Spring Base (aluminum)



T-Bracket (stainless steel)



Collar (aluminum)


Full assembly render of final design

Experimental and Analytical Results

Coefficient of Friction

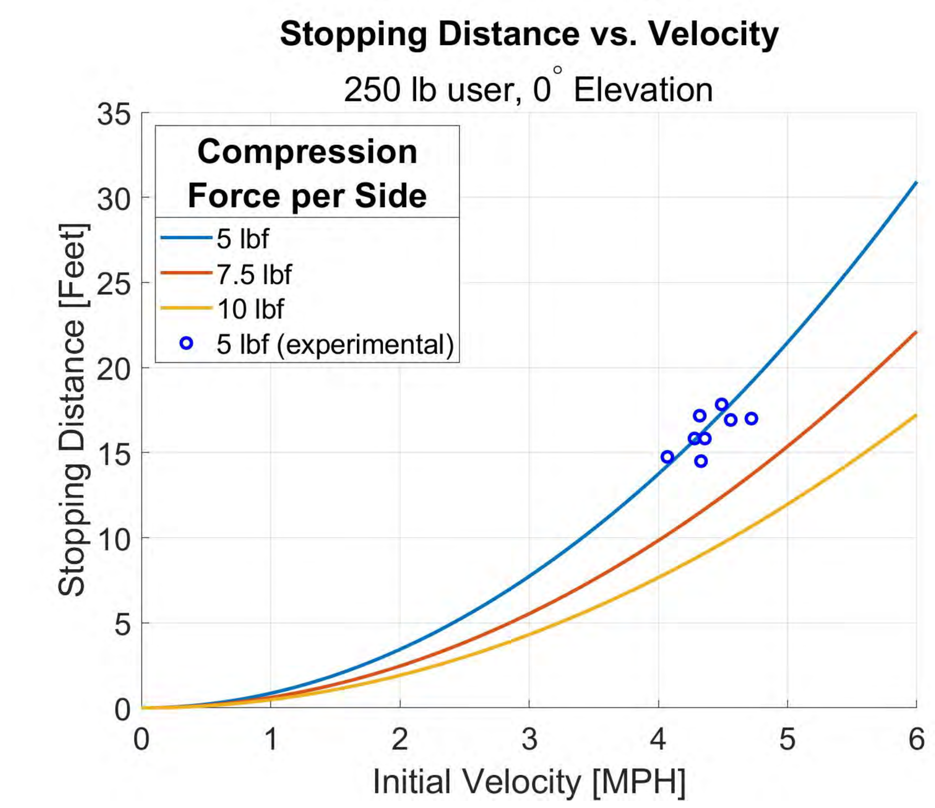
The coefficient of friction for the fender brake is a critical design component. The target metric was 0.7. We conducted an experiment to determine the coefficient of friction between tire rubber and several possible brake materials. All materials passed this target metric. Aluminum was chosen for the final design .

Kinetic Friction Coefficients with Rubber

Material	μ_k
Steel	0.81
Plastic	0.90
Rough Leather	0.76
Smooth Leather	0.81
Rubber	0.93

Stopping Distance Experiment

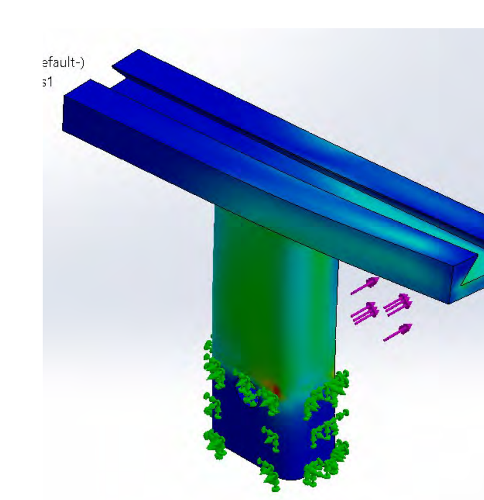
We conducted an experiment, as described in ISO 7176-3 [2], to determine how the brake prototype functions empirically. Our target metric was for the brake to stop a user within 20 ft when moving on a horizontal surface at 4 mph. The brake should require less than 13.5 lbf to activate. A mathematical model showed the brake could meet these metrics and experimental data confirmed.

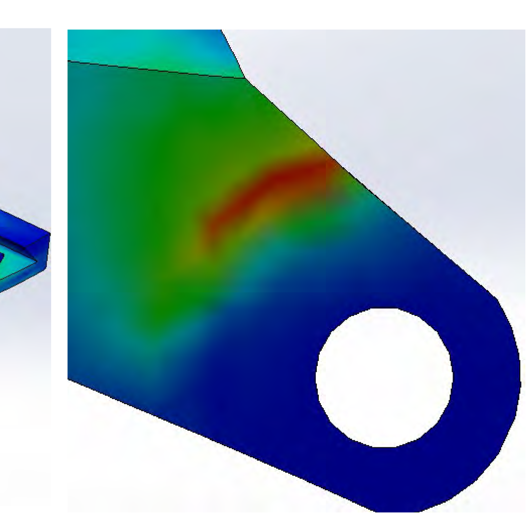


$$\Delta x = \frac{v_0^2}{2a}, \quad a = \frac{(\mu_R mg + \mu_B F_c)}{m}$$

Finite Element Analysis

Two FEAs were run to verify the strength of the prototype. The first FEA investigated the effects of impact on the T-bracket if the wheelchair fell out of a vehicle. The 3/8 in. T-bracket resists torsional stresses up to 600 lbf, which is enough to survive a fall from most heights. The second FEA investigated the strength of the fender connection tabs. The fender will resist a horizontal force up to 75 lbf before yielding.


T-Bracket FEA


Fender FEA

Conclusions

This hand brake device provides a dynamic braking solution for manual wheelchairs. A pair of these brakes attached to a wheelchair provide additional control and stability for the user on hills or uneven terrain. This will increase accessibility for people who use manual wheelchairs.


Final design prototype installed on a wheelchair

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Our Friends at TRAILS

References
[1] Fridén, J., & Gohritz, A. (2015). Tetraplegia Management update. *The Journal of Hand Surgery, 40*(12), 2489–2500. https://doi.org/10.1016/j.jhsa.2015.06.003
[2] International Organization for Standardization. (2012). *Wheelchairs – Part 3: Determination of Effectiveness of Brakes.* (ISO/DIS Standard No. 7176-3). Retrieved from https://www.iso.org/standard/53816.html