

Amputee Advanced Donning Device

BME 400

October 2nd, 2026

Client: Dr. Daniel Kutschera

Advisor: Dr. Justin Williams

Team: Freyja Heggeland, Adam Bauer, Megan Pearson, Carl Assmus



Overview

I. Introduction

- A. Background
- B. Problem Statement
- C. Competing Designs

II. Product Design Specifications

- A. Client Requirements
- B. Size
- C. Materials and Cost

IV. Matrices

- A. Design Ideas
- B. Materials

V. Final Design

VI. Testing

VII. Future Work



Background

- 300-500 amputations performed each day [1]
- Transtibial amputations account for 82% of all amputations [2]
- 80% of lower limb amputations are due to complications with diabetes
- Many amputees have low dexterity due to peripheral artery disease or diabetes [3]
- Compressive shrinker socks used to reduce swelling and shape the limb [4]
- Client is a physical therapist who works with amputee patients in rehabilitation



Figure 1. Transtibial amputee wearing shrinker sock [5].

Problem Statement

During rehabilitation, amputee patients must wear a shrinker sock to shape the residual limb, prepare for prosthetic fitting, and reduce postoperative complications. Current application methods rely on donning tubes and require patients to manually stretch the sock, which can be challenging for individuals with limited strength or dexterity. The goal is to design an advanced donning device that automatically stretches a shrinker sock to 25.4 cm (10 in), simplifying application and eliminating the need for manual stretching.



Competing Designs



Figure 2. Donning tubes currently used by amputee patients [6].



Figure 3. Doff N' Donner and Rolly Combo by sigvaris, typically used for compression sock application [7].

Product Design Specifications

Client Requirements:

- Maintain sufficient force to open shrinker sock
- Device needs to be sterilizable with a disinfectant wipe or bleach solution
- Bear more stress than previous design

Cost:

- \$500

Size:

- Weight: < 5 kg
- Expanded diameter: 20-25.4cm (8-10")

Materials:

- Easily sterilized
- Durable attachments
- Sturdy design



Design Ideas

Expanding Pulley System

- Interlocking vertical parts
- Mechanical pulley system
- Integrate electronics and reinforce vertical structure
- Simplest design considered

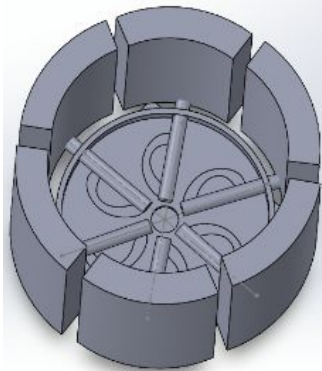


Figure 4. Previous team's final design.

Expanding Rail System

- Non-interlocking vertical parts with force sensors
- Rail system for expansion
- Base houses electronic components and motor

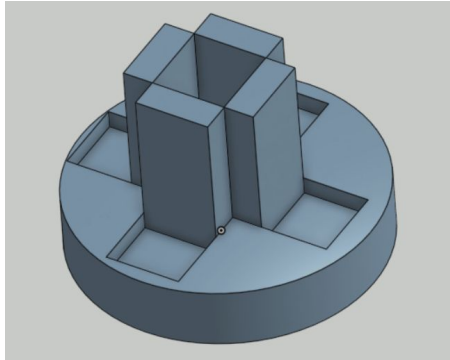


Figure 5. Expanding Rail System model.

Hoberman Design

- Hoberman Mechanism
- Radial expansion from linear motion
- Mechanically complex

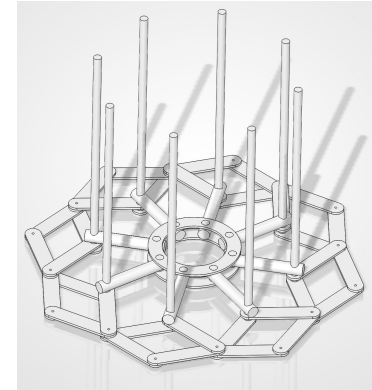


Figure 6. Hoberman model.

Design Matrix

<i>Designs</i>		Expanding Pulley Mechanism		Expanding Rail System		Hoberman Design	
Rank	Criteria (Weight)	Score (_/5)	Weighted Score	Score (_/5)	Weighted Score	Score (_/5)	Weighted Score
1	Ease of Donning (25)	3	15	4	20	3	15
2	User Comfort (20)	5	20	2	8	3	12
3	Safety (20)	4	16	5	20	4	16
4	Ease of Fabrication (15)	3	9	2	6	1	3
5	Durability (15)	4	12	3	9	3	9
6	Cost (5)	4	4	2	2	3	3
Total:	100	76	/100	65	/100	58	/100

Table 1. Design matrix.



Materials

Aluminum Alloy

- Established use in medical devices
- Highly machinable
- Elastic Modulus: 10-10.8 GPa [8]
- Shear Modulus: 3.75-4 GPa [8]
- Cost: \$0.0065/gram [9]



Figure 7. Aluminum alloy rod [10].

PLA

- Very low skin irritation and toxicity [11]
- Unable to withstand shrinker sock compressive force
- Cost: \$0.02/gram



Figure 8. PLA filament spools [12].

Nylon

- Established use with sutures
- Elastic Modulus: 1.6 GPa [13]
- Shear Modulus: 0.5 GPa [14]
- Cost: \$0.045/gram [15]



Figure 9. Nylon filament spools [16].

Material Matrix

<i>Materials</i>		Aluminum Alloy		PLA		Nylon	
Rank	Criteria (Weight)	Score (_/5)	Weighted Score	Score (_/5)	Weighted Score	Score (_/5)	Weighted Score
1	Biocompatibility (30)	5	30	5	30	4	24
2	Durability (25)	4	20	1	5	5	25
3	Weight (20)	3	12	4	16	5	20
4	Ease of Fabrication (15)	4	12	5	15	5	15
5	Cost (10)	5	10	5	10	2	4
Total:	100	84	/100	76	/100	88	/100

Table 2. Material matrix.



Final Design

- User-friendly
- Motor integration for enhanced usability
- Durable with protected components
- Lightweight hybrid construction using aluminum and nylon
- Cost-effective
- Easy to manufacture



Figure 10. (A) Side view of Expanding Pulley System CAD model. (B) Expansion of CAD model.

Testing

- Material Properties
 - MTS testing of material components
 - Strength and elastic modulus characterization
 - Load capacity of 30-40 N
- Functional Performance
 - Shrinker sock expansion testing
 - Donning capability assessment



Figure 11. Shrinker donning [17].

Future Work

Short Term:

- Fabrication:
 - Preliminary fittings and attachments in PLA
 - Transition to nylon
- Testing and potential design iterations
- Electronics

Long Term:

- Receive client feedback/usage
- Improve portability by making device more compact
- Optimize electronic components
- Pressure sensors for safety



Acknowledgments

Thank you to everyone who has contributed to this project thus far including:

- Dr. Daniel Kutschera
- Dr. Justin Williams
- BME Faculty
- UW Makerspace and TEAMLab



References

- [1] "Guide Amputation Statistics: US States With Most Amputees - Liv Hospital," *Liv Hospital*, Dec. 30, 2025. <https://int.livhospital.com/amputation-statistics/>.
- [2] T. Powelson and J. J. Yang, "Prosthetics for Transtibial Amputees: A Literature Survey," *Volume 3: 2011 ASME/IEEE International Conference on Mechatronic and Embedded Systems and Applications, Parts A and B*, Jan. 2011, doi: 10.1115/detc2011-47024.
- [3] "Preventing diabetes-related amputations," *Centers for Disease Control and Prevention*, Mar. 07, 2024. <https://www.cdc.gov/diabetes/diabetes-complications/preventing-diabetes-related-amputations.html>.
- [4] A. Lin, "Stump Sock vs Shrinker Sock: What's the Difference and When to Use Each?," *Max Hosiery*, Sep. 08, 2026. https://www.icompressionsocks.com/stump-sock-vs-shrinker-sock-whats-the-difference-and-when-to-use-each/#elementor-toc__heading-anchor-1.
- [5] "Medical Compression Stump Shrinkers," *TruformStore*, 2018. <https://truform.com/products/stump-shrinkers>.
- [6] "Thuasne, LLC," *Thuasne, LLC*, 2025. <https://www.knitrite.com/shrinker-donning-tube>.
- [7] "Doff N' Donner and Rolly® Combo," *Shop Sigvaris*, 2026. <https://www.shopsigvaris.com/products/doff-n-donner-and-rolly-combo-kit>.
- [8] "Aluminum Alloys - Mechanical Properties," *Engineeringtoolbox.com*, 2014. https://www.engineeringtoolbox.com/properties-aluminum-pipe-d_1340.html.
- [9] "Aluminium Cost Guide 2025: Comparing 3003, 5052, 6061, 6063, and 7075," *TBK Metal Co., Ltd.*, Nov. 20, 2025. <https://www.tbkmetal.com/aluminium-cost-guide/>.
- [10] "Aluminum alloy rod - All industrial manufacturers," *Directindustry.com*, 2026. <https://www.directindustry.com/industrial-manufacturer/aluminum-alloy-rod-230367.html>.
- [11] "Is PLA Body Safe for Skin and Food Contact? - Biology Insights," *Biology Insights*, Aug. 20, 2025. <https://biologyinsights.com/is-pla-body-safe-for-skin-and-food-contact/>.
- [12] "What Is 3D Printer Filament PLA? A Complete Guide to the Most Popular 3D Printing Material," *pixenib3d.com*, Oct. 21, 2025. <https://www.pixenib3d.com/what-is-pla-filament/>.
- [13] "Technical Data Sheet - Nylon," *Laminated Plastics*. <https://laminatedplastics.com/nylon.pdf>.
- [14] "AZoM," *AZoM*, 2026. <https://www.azom.com/properties.aspx?ArticleID=753>.
- [15] F. Arbex, "PrintCalc," *PrintCalc*. <https://print-calc.com/filament/nylon>.
- [16] "Nylon Filament for 3D Printer - Industrial 3D printer solution expert," *Industrial 3D printer solution expert*, June 09, 2021. <https://www.dreambot3d.com/nylon-filament-for-3d-printer/>.
- [17] "Using an Amputee Sock Donner," *UW Health*, Apr. 2023. <https://patient.uwhealth.org/healthfacts/7679>.



Questions?

