3D-Printed Hands-Free Shoe Mechanism

K.Y.S.O. (Knock Your Socks Off)

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1. Introduction

Putting on and taking off shoes remains an everyday task, often performed multiple times daily. To address the limitations of current solutions, this project aimed to develop a universal, hands-free shoe mechanism that can be integrated into various types of footwear.

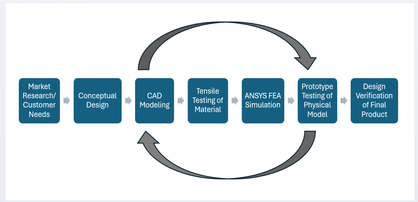


Figure 1: Design Process Flow Chart

2. Customer Research

To gauge customer needs and wants, a survey was conducted amongst 48 participants.

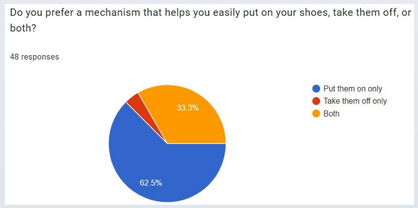


Figure 2: Pie chart showing percent of respondents preferences for mechanism functionality.

3. Concept Generation & Selection

Concept generation is used at early phases of product design and development. The team aimed to generate a broad variety of innovative ideas or possible solutions to customer needs. The team produced 17 different concepts.

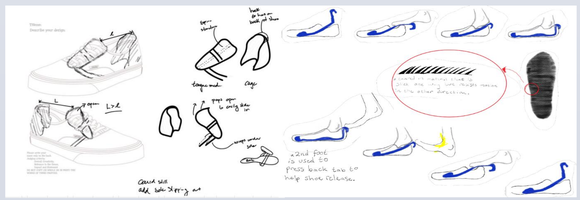
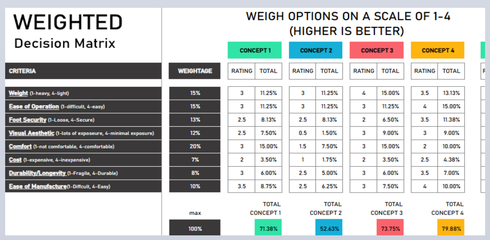


Figure 3: Scoring Matrix used to narrow down the teams' selected ideas.

After the initial brainstorming phase, the group used selection criteria and a scoring matrix to narrow down our options till a unanimous decision was made.



WEIGHTED Decision Matrix

WEIGH OPTIONS ON A SCALE OF 1-4 (HIGHER IS BETTER)

CRITERIA	WEIGHTAGE	CONCEPT 1 RATING	CONCEPT 1 TOTAL	CONCEPT 2 RATING	CONCEPT 2 TOTAL	CONCEPT 3 RATING	CONCEPT 3 TOTAL	CONCEPT 4 RATING	CONCEPT 4 TOTAL
Weight (1-heavy, 4-light)	15%	3	11.25%	3	11.25%	4	15.00%	3.5	13.13%
Ease of Operation (1-difficult, 4-easy)	15%	3	11.25%	3	11.25%	3	11.25%	4	15.00%
Foot Security (1-Loose, 4-Secure)	13%	2.5	8.13%	2.5	8.13%	2	6.50%	3.5	11.38%
Visual Aesthetic (1-lots of exposure, 4-minimal exposure)	12%	2.5	7.50%	0.5	1.50%	3	9.00%	3	9.00%
Comfort (1-not comfortable, 4-comfortable)	20%	3	15.00%	1.5	7.50%	3	15.00%	2	10.00%
Cost (1-expensive, 4-inexpensive)	7%	2	3.50%	1	1.75%	2	3.50%	2.5	4.38%
Durability/Longevity (1-Fragile, 4-Durable)	8%	3	6.00%	2.5	5.00%	3	6.00%	3.5	7.00%
Ease of Manufacture (1-Difficult, 4- Easy)	15%	3.5	8.75%	2.5	6.25%	3	7.50%	4	10.00%
max			TOTAL CONCEPT 1		TOTAL CONCEPT 2		TOTAL CONCEPT 3		TOTAL CONCEPT 4
100%			71.38%		52.63%		73.75%		79.88%

Figure 4: Scoring Matrix used to narrow down the teams' selected ideas.

4. Testing

Prototype Functionality Test

Physical prototypes were built from the concepts chosen for the final selection out of simple materials and then tested for basic operation and efficacy.



Figure 5: Testing conditions for initial prototypes.

Dog-Bone Testing

Tensile testing was performed on 3 types of TPU (Thermoplastic Polyurethane) dog-bones to determine what shore hardness (stiffness/flexibility) was appropriate for a given part.



PolyFlex™ TPU95 A SpiderMaker ™ TPU75 A Bambu Labs™ TPU68 D

FEA Modeling and Simulation Setup

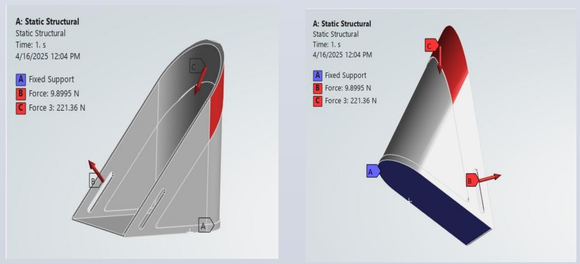


Figure 6: Boundary conditions

Further testing was done on the CAD models of each piece in ANSYS® Mechanical, using the Young's Modulus ε, obtained from the tensile testing.

5. Modeling & Design

The initial prototype built off the cardboard prototype and its dimensions. The group initially started with an additive design approach where the components were individually extruded into each other.

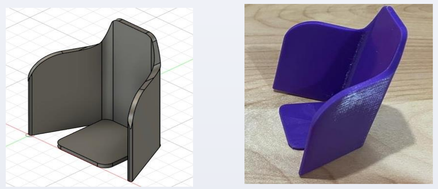


Figure 7: Initial CAD and printed model of first prototype.

Due to low performance of the initial prototypes the group decided to revisit their design and optimize their design process to subtracting from a solid rather than additive extrusion.

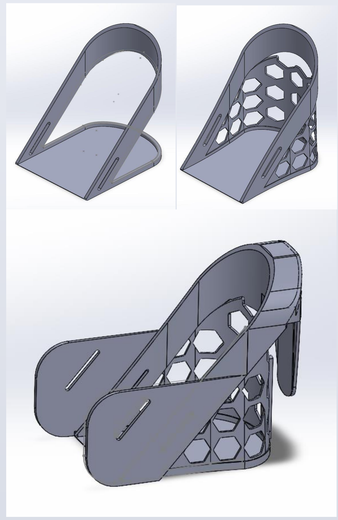


Figure 8: Pathway to final design using subtractive modeling.

The tongue followed a similar design path as the cage, with early prototypes proving too uncomfortable. To address this, the team removed material to reduce pressure, but this made the structure too flimsy. A balanced, middle-ground design was ultimately developed.

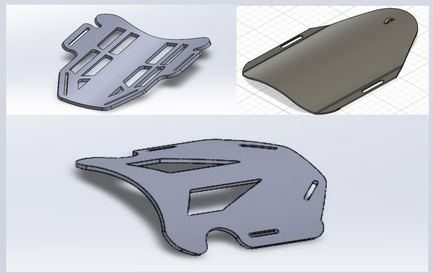


Figure 9: Pathway to final tongue design over multiple test iterations.

6. Results and Analysis

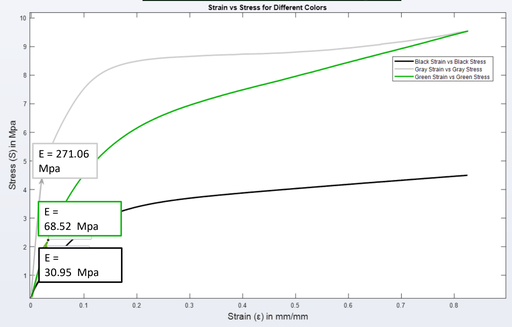


Figure 10: Plot of stress vs strain to find Young's Modulus

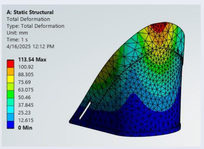


Figure 11a: Ansys Mechanical set for stress and strain analysis on heel cage.

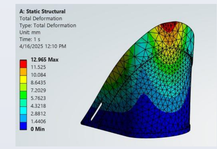


Figure 11b: Ansys Mechanical set for stress and strain analysis on heel cage.

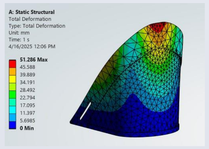


Figure 11c: Ansys Mechanical simulated structural deformation on heel cage.

Due to its flexibility and rebound, the **black (75A)** TPU was selected for the heel cage. The **gray (68D)** was selected for the tongue portion due to its increased rigidity. The **green (95A)** was considered for the heel but was not used in the final design. (See Modeling and Design panel for respective part models).

7. Conclusion

Through a structured process of problem identification, design, and testing, a hands-free shoe-assist mechanism was developed with a focus on compatibility, comfort, and ease of use. Future work will explore design refinement for broader 3D-printed shoe compatibility and potential for mass production.



Figure 12: Final product

Acknowledgments

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