Modeling FDM-Printed TPU Energy Absorption for Impact-Resistant Armor in Combat Robotics

Problem Statement

- Develop a Python-based discrete simulation to visually simulate FDM-printed TPU components for impact-resistant combat-robot armor and bridge theory of discrete elastic structures from MAE 263F with real-world soft armor applications

Background

- Combat robots experience repeated high-energy impacts that fracture rigid armor and transmit shocks to electronics.
- To mitigate such, TPU (Thermoplastic Polyurethane) 's unique flexibility, high elongation, superior abrasion resistance properties + FDM tunability (through infill, density, and wall thickness) allow for performance optimization under strict weight constraints, where every ounce affects energy efficiency and impact mitigation.

Motivation

- Further understanding TPU's deformation behavior enables design optimization of lightweight, resilient, and repairable armor systems for competitive robotics at lower weight classes ≤ 30lbs.
- Aim to visualize and quantify the energy absorption capabilities of various TPU geometries and print configurations to guide design choices in combat robotics.

ASME at UCLA FLAGSHIP 2023 15 lb Flywheel Flipper Combot

Literature Review

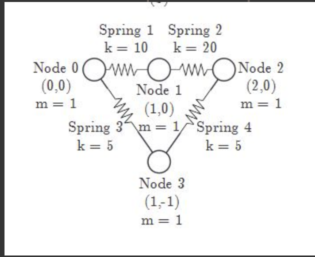
- FDM-Printed TPU Printing Parameters & Mechanical Properties
  - Bruère V. M. et al. (2023) - The influence of printing parameters on the mechanical properties of 3D printed TPU-based elastomers
  - Birosz M. T. et al. (2022) - Effect of FDM infill patterns on mechanical properties
- Hyperelastic and Constitutive Modeling of TPU
  - Reppel T. et al. (2018) - Experimental Determination of Elastic and Rupture Properties of Printed Ninjaflex
  - Gallup L. et al. (2023) - Predicting the Bending of 3D Printed Hyperelastic Polymer Components
- Energy Absorption and Lattice Design
  - Khatri N. R. et al. (2024) - Energy Absorption of 3D Printed ABS and TPU Multimaterial Honeycomb Structures

Anticipated Contributions

- Establish a computational framework for predicting deformation and damping in FDM-printed TPU armor, building design intuition for flexible protection.
- Analyze design optimizations and weight trade-offs between simple infill structures; quantify how infill topology (grid vs hex) affects impact absorption.
- Provide practical guidelines/insights for creating soft, modular, and printable energy-absorbing components in combat robotics.

Proposed Approach

- Begin with wall simulation with fixed beam ends and point load
- Extend to explore incorporation of simple internal infill patterns (grid,hex) to study how topology affects deformation and damping.
- Implement all stages in Python using energy-based formulation.



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5. Khatri, N. R., Zhou, J., & Parthasarathy, T. (2024). Energy absorption of 3D-printed ABS and TPU multimaterial honeycomb structures. 3D Printing and Additive Manufacturing, 11(2), 123–135. https://doi.org/10.1089/3dp.2023.0056