Additive Manufacturing

Course Number: MANE 6962 — Graduate Level

Instructor: Dr. Semih Akin — **Email:** akins@rpi.edu

Semester: Spring 2026 — **Location/Time:** JEC 4309 Mon-Thr 2:00-3:20 pm

Office: JEC 5038 — **Office Hours:** By appointment

Final Project Overview

Imagine that you are an engineer working in a footwear innovation team, and your group has been assigned a project to develop a **patient-specific foot–heel cushion**. The design must maximize impact energy absorption while minimizing overall weight for performance. Building on this scenario, the **objective of this final project** is to **design, model, simulate, and fabricate an additively manufactured foot-heel cushion**. The primary engineering goals are to **maximize impact energy absorption** while **minimizing total mass**, leveraging the design freedoms of additive manufacturing.

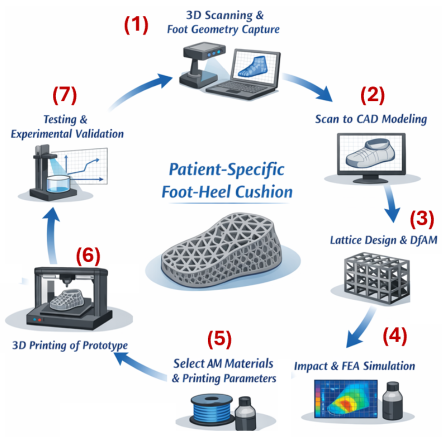

Fig.1 Conceptual illustration of the final project.

To achieve this, the project will integrate the complete additive manufacturing workflow, including 3D scanning, STL-to-CAD conversion, design for AM (DfAM), computational modeling, consideration of process–structure–property relationships, material selection, and fabrication using AM technologies.

Engineering Problem Statement

Design a lightweight, high-performance **personlized foot-heel cushion** capable of absorbing maximum mechanical energy during compressive loading associated with human stepping. The cushion must satisfy the following requirements:

1. Maximize energy absorption (primary objective).
2. Minimize total mass (secondary objective).
3. Fit within a specified geometric envelope.
   Note: You will be provided with the STL scan data of a foot-heel
   The CAD model will be standardized for all teams
4. Be manufacturable with available lab resources.

Project Requirements

1. Conceptual Design

- Conduct a literature review on impact-absorbing structures (lattices, auxetics, etc.).

- Conduct a literature review on AM of impact-absorbing structures
- Propose candidate concepts (e.g., honeycombs, graded lattices, auxetic structures).
- Select one concept using engineering justification.

2. CAD Modeling

- Generate the initial CAD model from the provided STL data
- Construct a parametric CAD model using SolidWorks, NX, or a similar software.
- Include tunable parameters (cell size, wall thickness, etc.).

3. Simulation and Analysis

Perform finite element simulations to predict structural performance:
→ There is no restriction on the FEA software; teams may use any simulation tool.

- Static compression analysis.
  Note: Dynamic loading is optional and can be included depending on the team's approach
- Stress/strain distribution and failure prediction.
- Force–displacement response and energy absorption.

Students must analyze **at least five (10) design iterations** and demonstrate measurable improvement.

4. Optimization Study

Conduct a design optimization using either (i) an iterative refinement approach or (ii) a systematic optimization framework (e.g., multi-objective optimization models).

→ Teams may develop a Design of Experiments (DoE) for trial-and-error optimization; however, the use of a multi-objective optimization approach will be considered a plus.

5. Fabrication

Produce a physical prototype using polymer material(s) and AM process selected by the group.
→ Document material considerations.

6. Experimental Testing

Propose an experimental testing plan and analysis methodology, including how FEA predictions will be compared against experimental data and how discrepancies will be evaluated.

→ Note: Physical experimental testing is not mandatory; however, teams that explore available facilities and incorporate experimental validation will receive positive consideration.

Final Deliverables

1. Final Report

The report must include:

1. Problem definition and requirements
2. Literature survey
3. Concept selection and justification
4. CAD and simulation workflow
5. Optimization model and results
6. Fabrication process and prototype documentation
7. Achieved metrics, such as energy absorbed per unit mass
8. Experimental testing proposal
9. Limitations and future improvements

2. Final Presentation

Teams will deliver a 20-25 minute presentation summarizing:

- Design strategy
- Simulation–experiment correlation
- Prototype demonstration
- Key findings and outlook

Learning Objectives

By completing this project, you will be able to:

- 3D-scanning, STL-to-CAD conversion
- Apply mechanics of materials and impact modeling to energy-absorbing structures
- Create parametric CAD models of compliant geometries
- Perform static and/or dynamic finite element simulations
- Optimize structural parameters
- Rapid prototyping using an AM process
- Proposes mechanical testing to assess structural performance

Note: A design competition will be held during the final project presentations, and the winning team will be selected based on which group delivers the highest-performing and most innovative heel-cushion design according to the evaluation criteria.