Institute for Predictive Performance Methodologies,

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ASC-40 Simulation Challenge Problem Statement

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Please refer all questions to the Chair of the 2025 ASC Student Simulation Challenge Competition,

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Background

Additively manufactured (AM) metamaterials are emerging material systems whose mechanical properties can be tailored through the design of their microstructures. In recent years, various AM metamaterial architectures have been developed to achieve mechanical performance and functionalities not typically available in conventional materials. Similar to fiber-reinforced composites, AM metamaterials can be designed with inherent anisotropy and heterogeneity to realize customized mechanical responses. Consequently, computational modeling approaches originally developed for composites, such as multiscale models and finite element (FE)-based simulations, have been adapted and extended for the modeling and design of AM metamaterials.

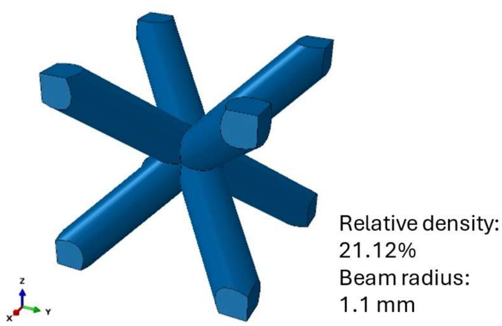
A key simulation challenge for AM metamaterials arises from material variability and process-induced uncertainty during fabrication. The mechanical properties of the base printing material can be significantly affected by process environment during printing (e.g., thermal history). Due to the complex geometries involved, the as-built properties of the printing material in the metamaterial often differ from those measured through standard coupon tests. As a result, calibration of the as-built material model of the base printing material is essential for accurate simulations. This simulation challenge requires students to:

1. **Calibrate the constitutive model** of the base printing material using stress-strain data from quasi-static compression tests of AM metamaterial specimens.
2. **Set up FE simulations** that incorporate appropriate modeling parameters, such as contact, friction, and geometric nonlinearity.
3. **Predict the stress-strain (SS) response** of AM metamaterials using the calibrated material model and modified simulation parameters.

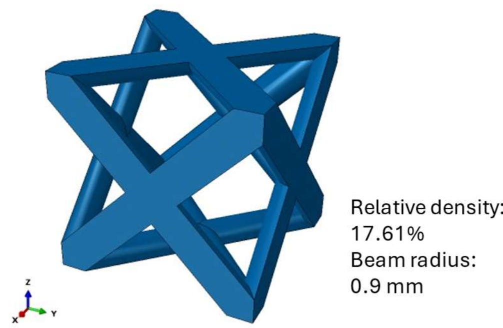
Simulation performance will be evaluated based on the accuracy of predicted SS curves relative to experimental data, as well as computational efficiency (e.g., total CPU hours used, CPUS settings, CPU numbers, etc.).

AM metamaterials

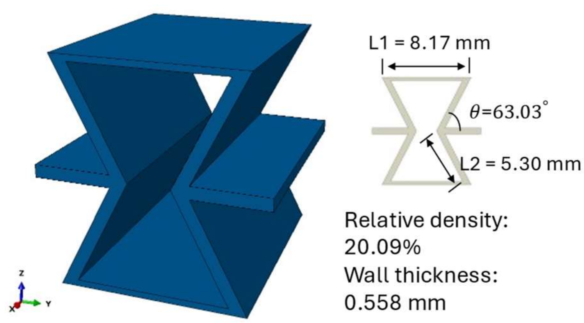
Three AM metamaterials are proposed in this simulation challenge: (1) Body-centered cubic (BCC) beam lattice, (2) Face-centered cubic (FCC) beam lattice, and (3) re-entrant honeycomb. The unit cells of the above metamaterials are shown in **Figure 1**.



(a) BCC beam lattice



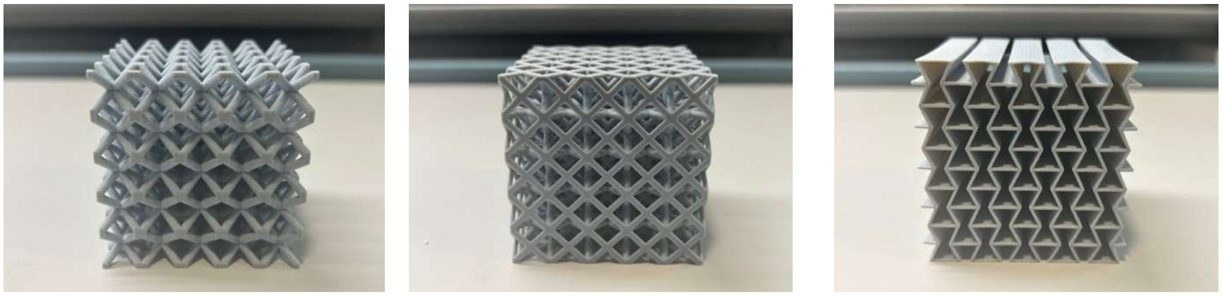
(b) FCC beam lattice



(c) Re-entrant honeycomb

Figure 1. Unit cell and key geometric parameters of the proposed AM metamaterials

Note that some geometric features (e.g., beams in FCC and walls in re-entrant) are cut due to the periodicity of the unit cell. The above unit cells are repeated 5 times in the xyz directions to construct the testing samples. The dimensions of the unit cell is 10 mm by 10 mm by 10 mm. As a result, the dimensions of the testing samples are 50 mm by 50 mm by 50 mm. The samples are printed using Stratasys J35 Pro 3D printer and the base material is **RGD8530-DM**[1]. The printed samples are shown in **Figure 2**.

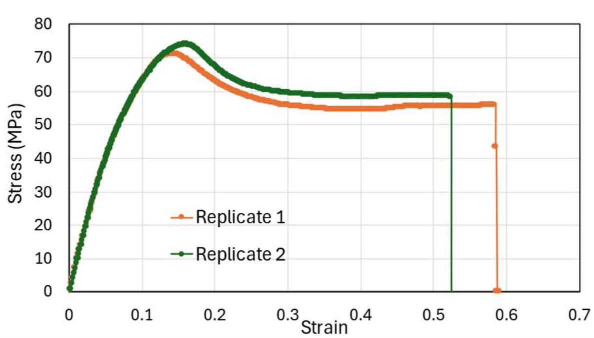


BCC sample FCC sample Re-entrant sample

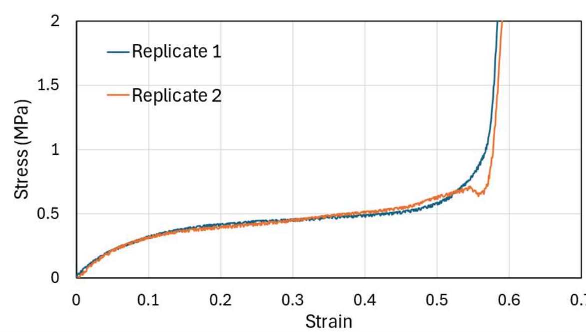
Figure 2. Printed metamaterial samples

Problem Statement

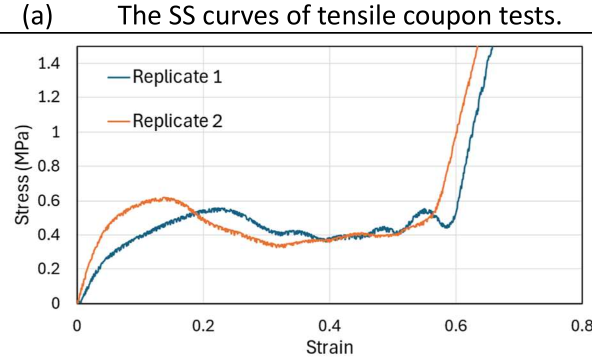
The SS curves of the coupon tensile tests and the above metamaterials under compression tests are given in **Figure 3**. The SS data can be downloaded from ASC Student Simulation Challenge website. The loading rate is 5 mm/min.



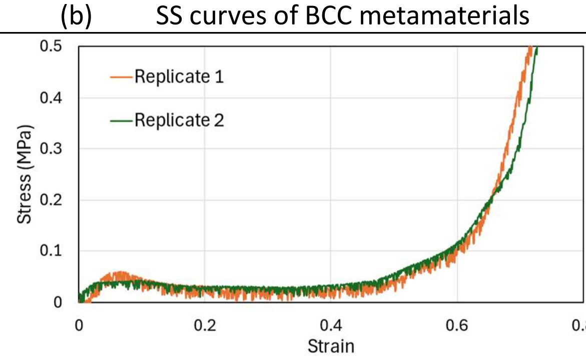
(a) The SS curves of tensile coupon tests.



(b) SS curves of BCC metamaterials



(c) SS curves of FCC metamaterials



(d) SS curves of re-entrant metamaterials

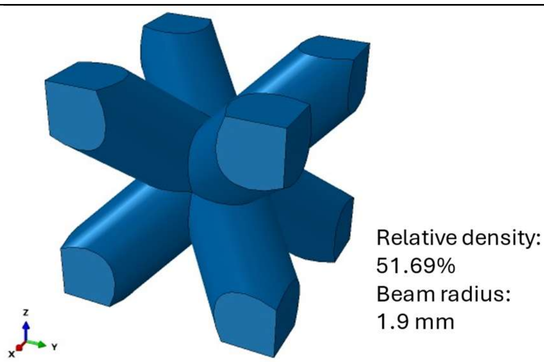
Figure 3. SS curves of the quasi-static compression tests.

Task 1 – Establish a FE model to reproduce the experimental results

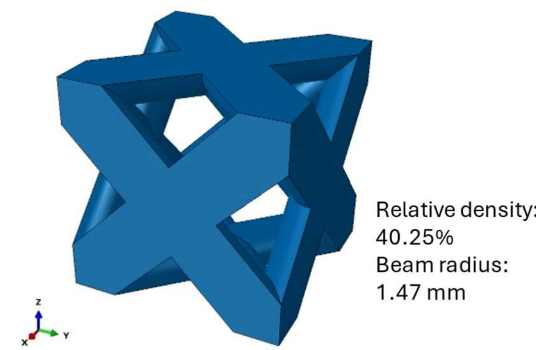
This task requires students to create a FE model for each of the three metamaterials. Based on the experimental SS curves, students need to calibrate the base material constitutive model and set up simulation parameters (e.g., contact, friction, and geometric nonlinearity). The FE models should be able to reproduce the experimental SS curves. Either solid elements or structural elements (e.g., beam and shell elements) can be used for the FE models, but structural elements are preferred given their computational efficiency.

Task 2 – Blind prediction using the developed FE models

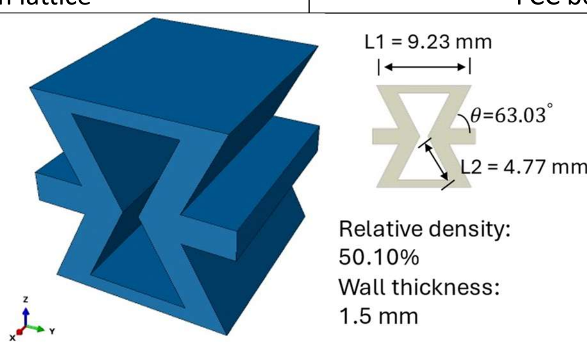
The metamaterials with different relative densities are also fabricated using the same manufacturing process. The quasi-static tests were performed to obtain the SS curves. The unit cell and key geometries of the new metamaterials are given in **Figure 4.**



BCC beam lattice



FCC beam lattice



Re-entrant honeycomb

Figure 4. unit cell design and the testing samples of the new metamaterials

Students are required to predict the SS curves of the new metamaterials under quasi-static compression loads, with the loading rate 5 mm/min. Students will need to modify the FE models in Task 1 to account for the potential variability in the as-built material properties and nonlinear deformations.

Evaluation Metrics

Items	Criteria	Weight
Task 1	The simulation model should be accurate and efficient. The **accuracy** will be evaluated based on the agreement of the predicted SS curves compared with the provided experimental SS curves. The accuracy will take 60% of the Task 1 weight. The model **efficiency** will be evaluated based on the CPU time, which will take 40% of the Task 1 weight.	30%
Task 2	The blind test simulation will be evaluated based on the model accuracy and efficiency. The **accuracy** will be evaluated based on the agreement of the predicted SS curves compared with the experimental SS curves. The accuracy will take 60% of the Task 2 weight. The model **efficiency** will be evaluated based on the CPU time, which will take 40% of the Task 2 weight.	70%
Note: Please also submit the spreadsheet with the data for the predicted SS curves in the two tasks.		

How to Submit

Zip everything, name the file LeadersLastname_Insitution.zip (e.g. smith_mit.zip) and

i) Email (if possible < 20 MB) to endel.iarve@uta.edu by **October 6, 2024**. Use "ASC-40 Simulation Challenge" as a subject line.

ii) If needed, email endel.iarve@uta.edu and Prof. Iarve will arrange for drop site. Use "ASC-40 Simulation Challenge" as a subject line.

Reference:

[1] https://www.stratasys.com/siteassets/materials/materials-catalog/polyjet-materials/digital-abs-plus/mss_pj_digitalmaterialsdatasheet_0617a.pdf