Plastic Deformation of Metallic Foam

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INTRODUCTION: Metallic foams can be plastically deformed to dramatically alter the material's mass density, microstructure, and bulk mechanical properties. The goals of this work are to

- Construct 3D of metallic foam from micro-CT scans
- Construct 2D unit cell models of simplified geometry
- Simulate plastic deformation of the structures
- Look at the effects of applied boundary conditions as well as resulting properties of the structures

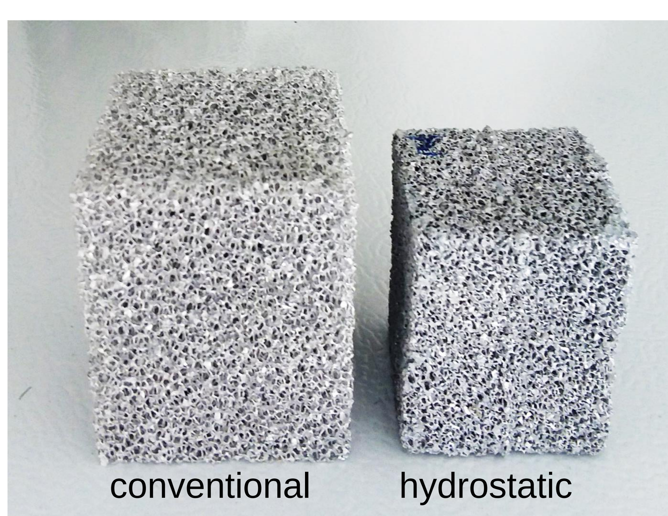


Figure 1. Conventional aluminum metallic foam (right) and a similar sample that was plastically deformed due to 1500 PSI (10 MPa) hydrostatic pressure

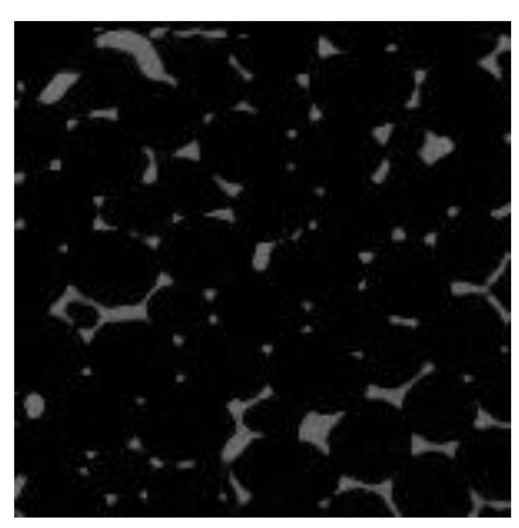


Figure 2. Cross sectional image (approx. 12 mm x 12 mm) of metallic foam from micro-CT scan (gray is aluminum)

COMPUTATIONAL METHODS: Structural mechanics module including nonlinear geometry, plasticity, and contact

1. 3D model: prescribed displacement on X, Y, Z faces backed by roller

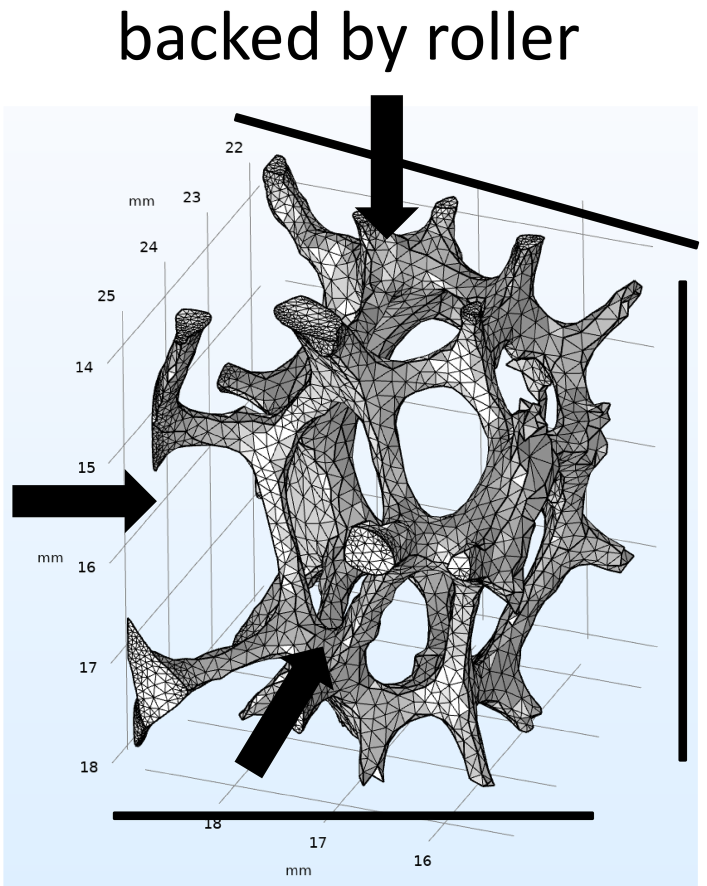


Figure 3. 3D model of a pore of an aluminum metallic foam

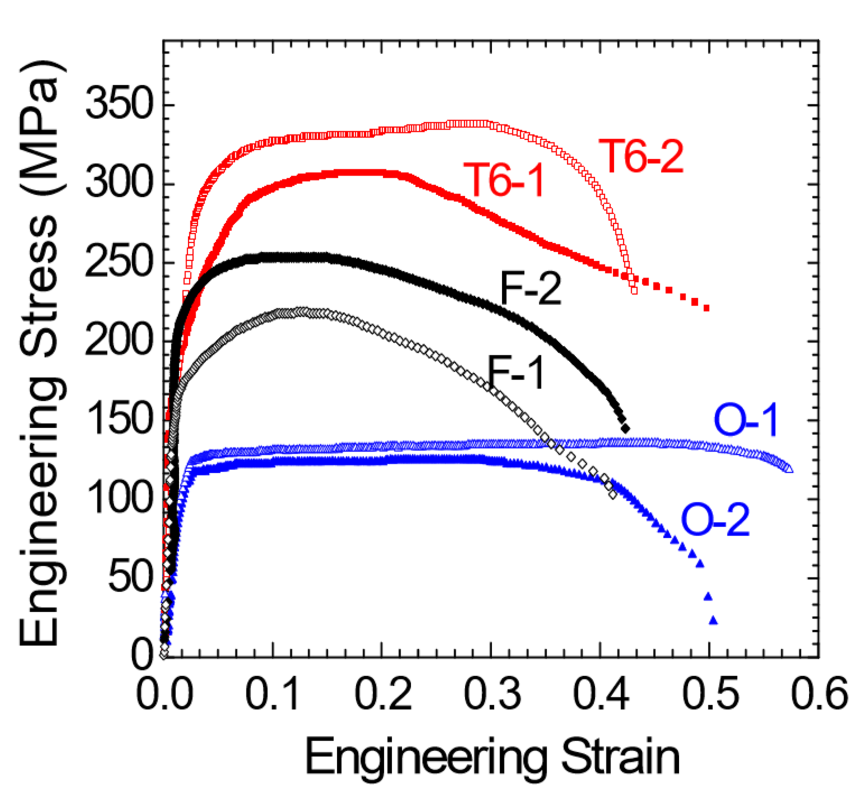


Figure 4. Aluminum plasticity data of different tempers taken from Ref. 1

2. 2D model: unit cell box beam model

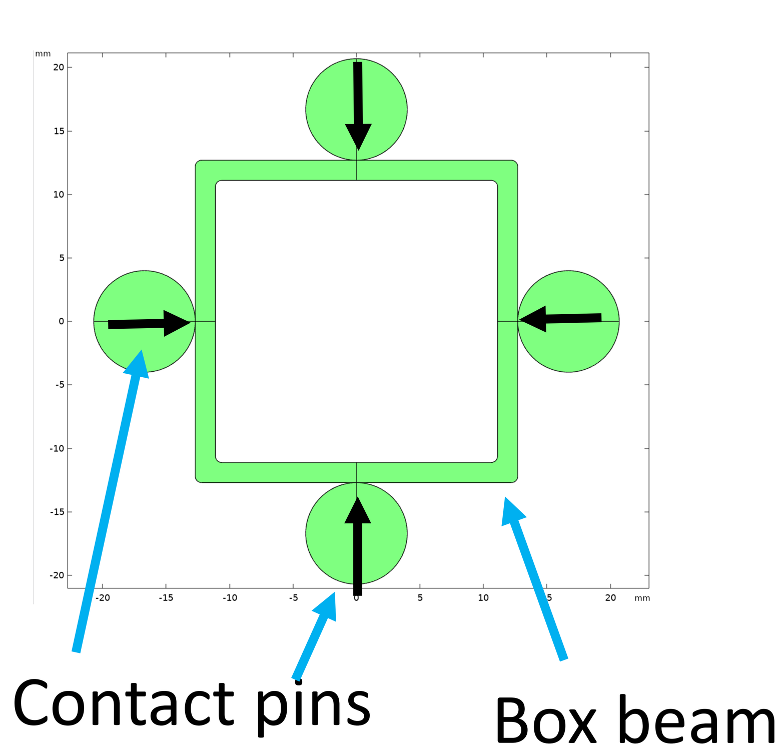


Figure 5. Plastic compression step with contact pins

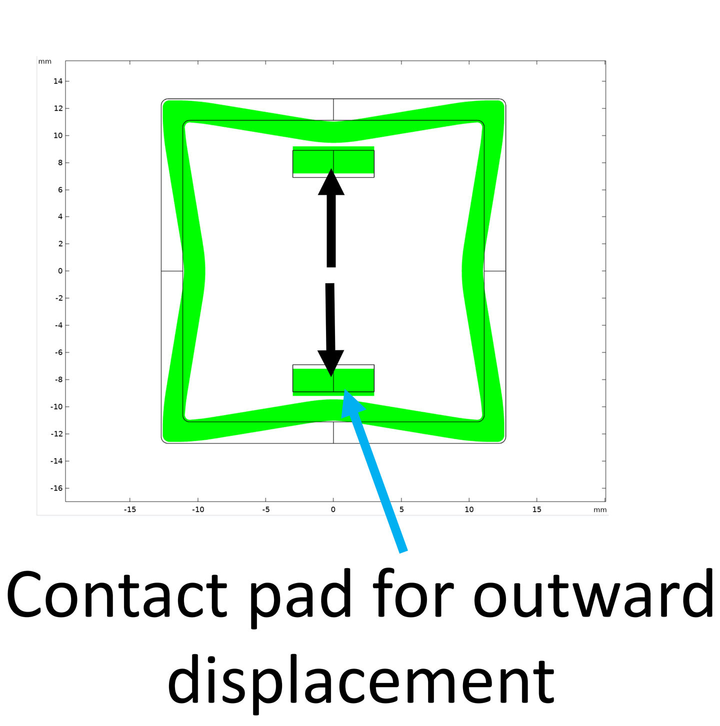


Figure 6. Loading step with prescribed outward displacement

RESULTS:

1. 3D model

- Deformation is due to combined compression and bending
- Struts with the most severe deformation form local "plastic hinges"

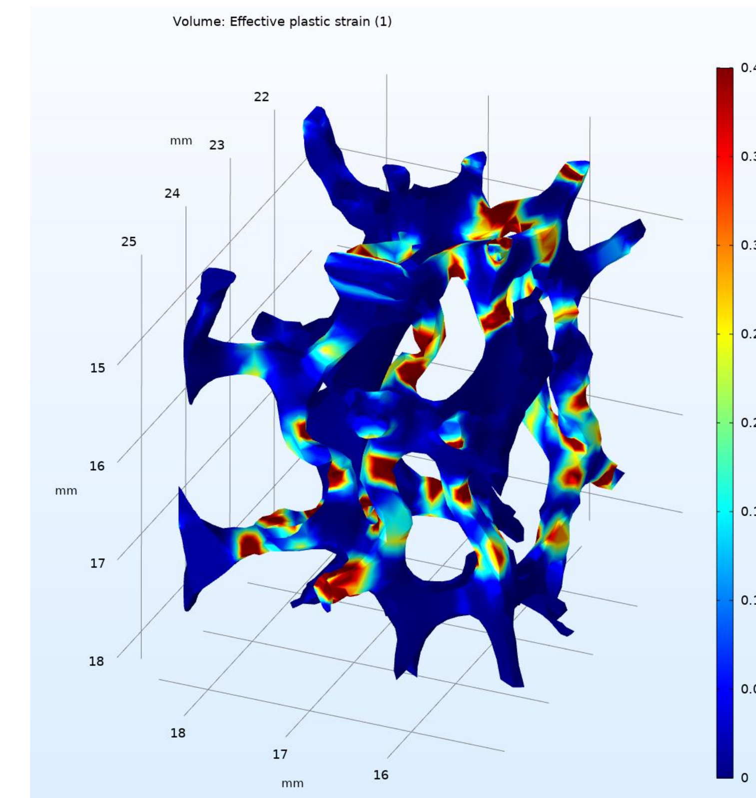


Figure 7. Effective plastic strain after 1.5 mm compression

2. 2D model

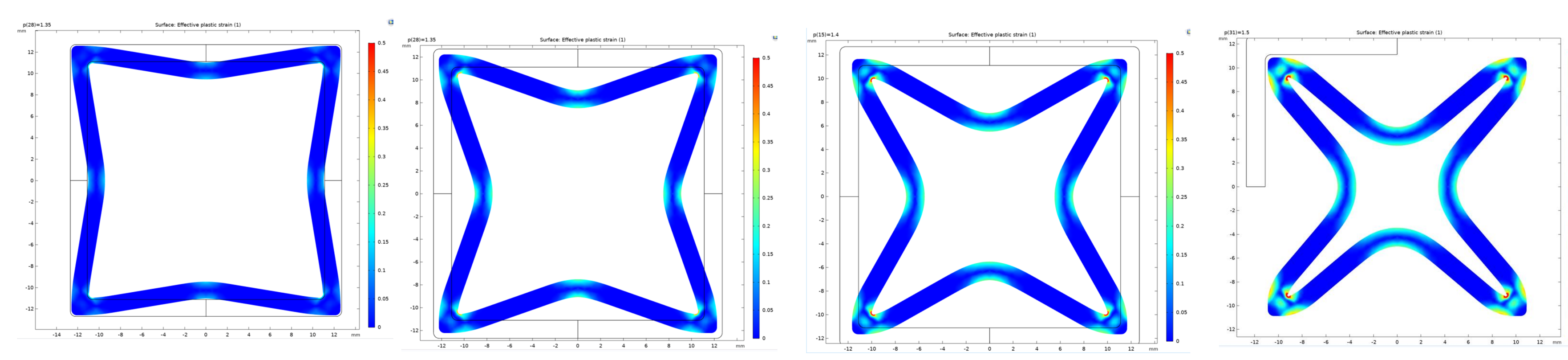
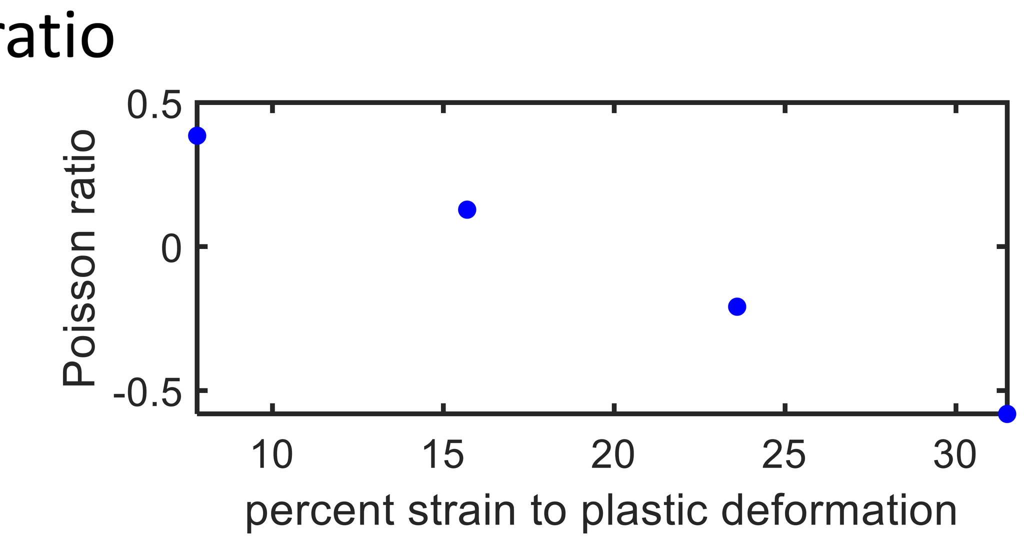


Figure 8. Plastic deformation change with increasing applied displacement

- The formation of plastic hinges along with the deformed geometry can be used to tune the structure's Poisson ratio



Initial porosity, Volume of gas:

$$\emptyset = \frac{v_g}{v_g + v_l}$$

Total volume

Final porosity, Compression ratio:

$$\emptyset' = \frac{\emptyset}{\emptyset + \alpha(1-\emptyset)}$$

Figure 9. Poisson ratio of plastically deformed 2D models

Table 1. Summary of simulations

Model	Boundary Condition	Value	Initial porosity	Final porosity	Compression ratio
3D pore	Prescribed displacement	.5 mm	.8992	.8458	1.53
2D unit cell	Prescribed displacement with contact	2 mm	.9414	.9370	1.07
2D unit cell	Prescribed displacement with contact	4 mm	.9414	.9297	1.2
2D unit cell	Prescribed displacement with contact	6 mm	.9414	.9189	1.38
2D unit cell	Prescribed displacement with contact	8 mm	.9414	.9030	1.66

CONCLUSIONS: Plastic deformation of metallic foams not only alters the material's mass density, but also changes the microstructure of the material through deformed geometry and spatial variation of stiffness by formation of plastic hinges. Future work includes benchmarking models with experiments for an aluminum square channel

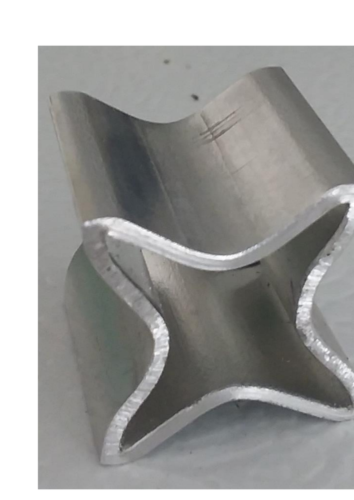


Figure 10. Deformed Al square channel

REFERENCE: Zhou, J., S. Allameh, and W. O. Soboyejo. "Microscale testing of the strut in open cell aluminum foams." *Journal of Materials Science* 40.2 (2005): 429-439

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