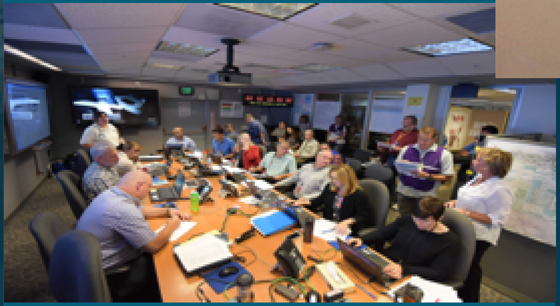
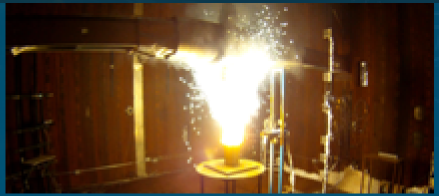
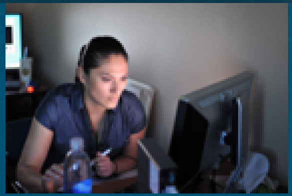
SAND2021-8580C

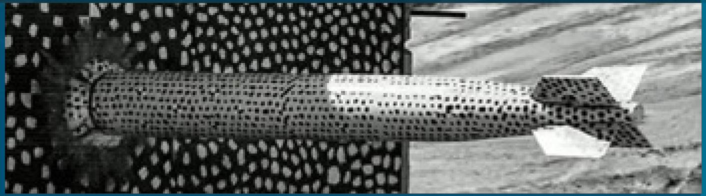
Sandia National Laboratories

A Study of Process Parameters and Mechanical Performance of Lattices using Powder Bed Fusion of Stainless Steel 316L









Presented by

Scott Jensen

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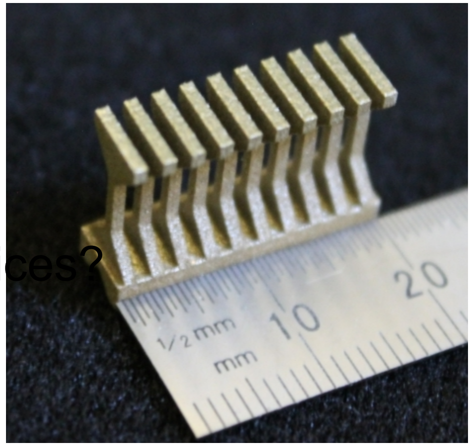
Motivation

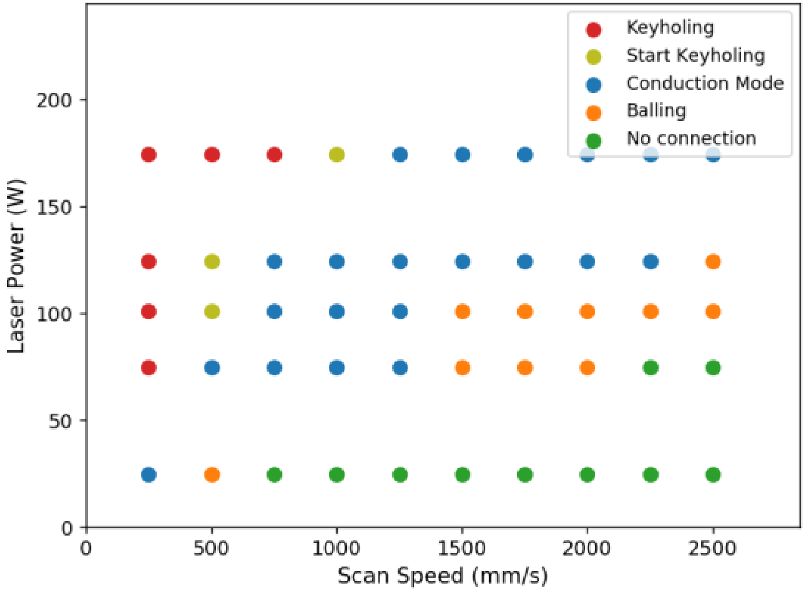
Additive manufacturing is driven by process

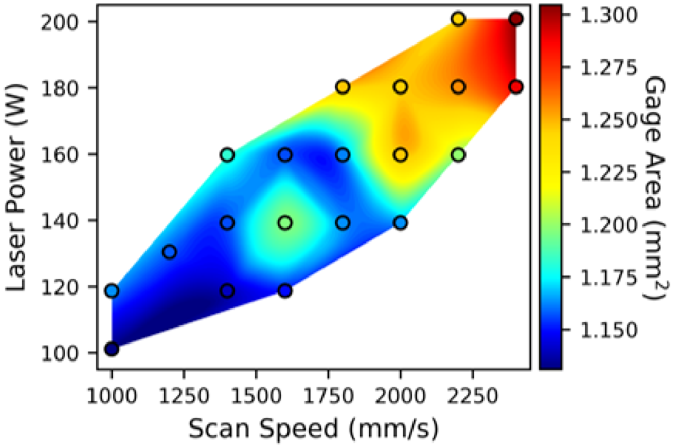
Process changes are impacted by feature size

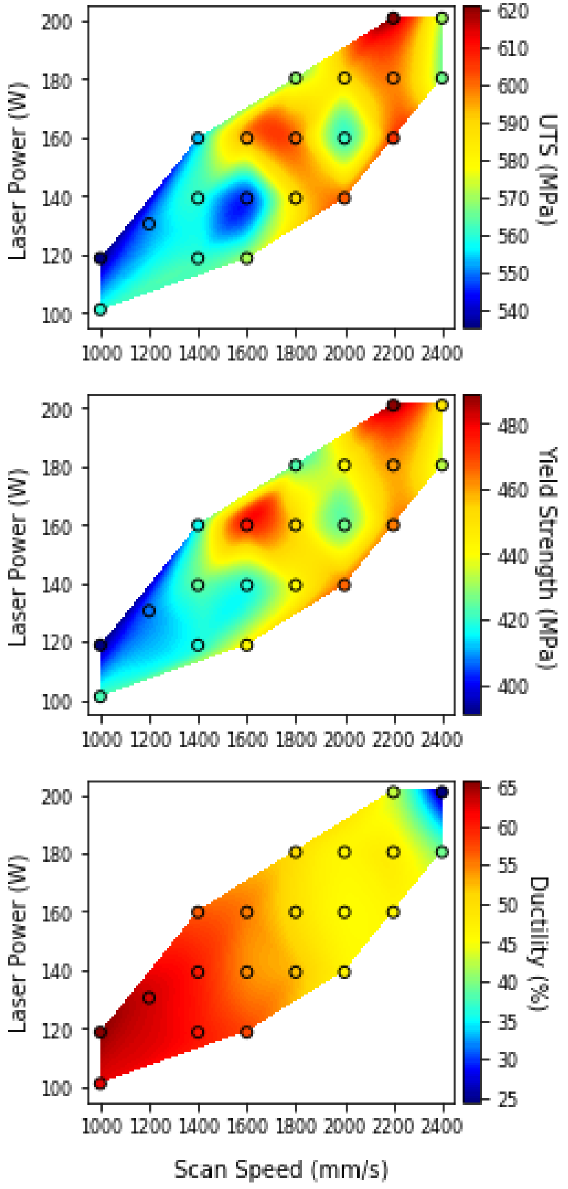
What does performance mapping look like for lattices?



Melt-pool Behavior

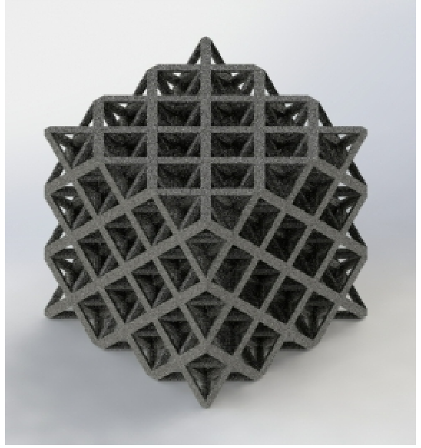




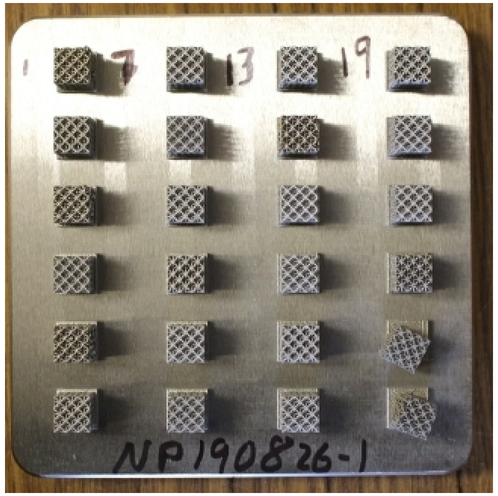


Process Parameter Study

Lattices:
- 42 octet truss lattices
- 3x3x3 unit cell
- 10.5 mm side (3.5 mm unit cell)
- Nominal strut thickness of 0.5 mm
- 2 plates



Build parameters (ProX 200)
- Laser diameter: ($1/e^2$) of 50 μm
- Layer thickness: 30 μm
- Hatch Spacing 50 μm
- Varied laser power and scan speed

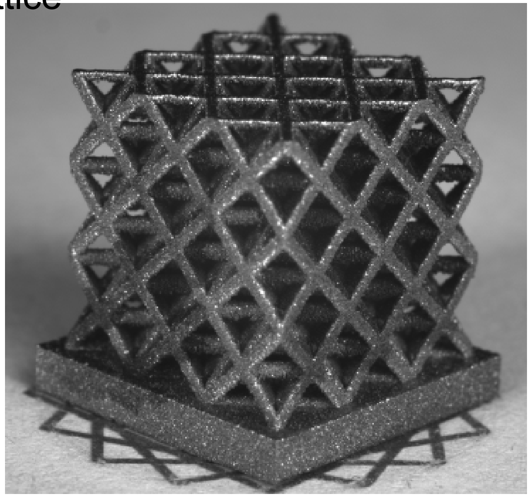


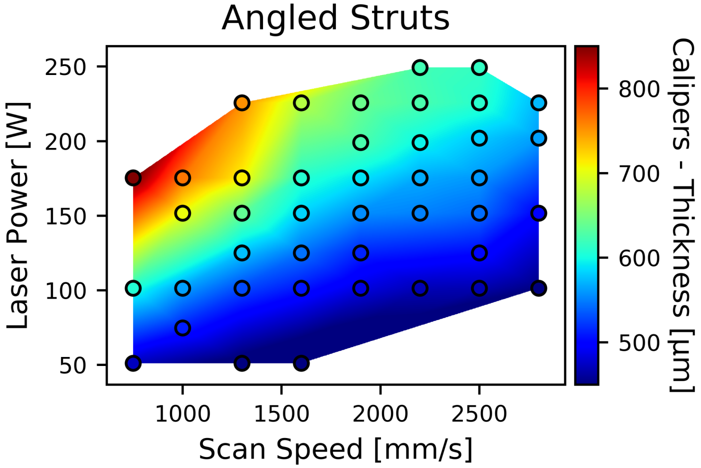
Geometric Variations of Lattices

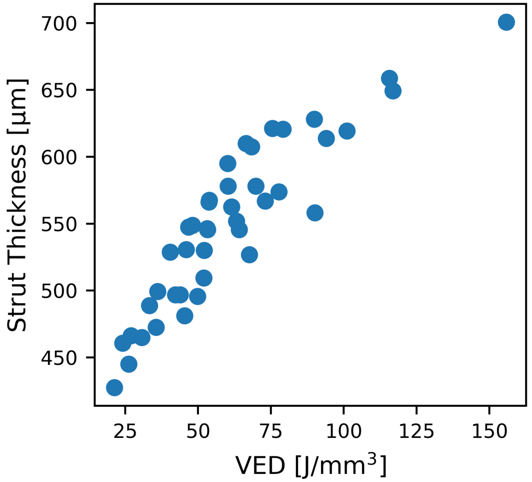
Angled Struts
Average 2 measurements each side

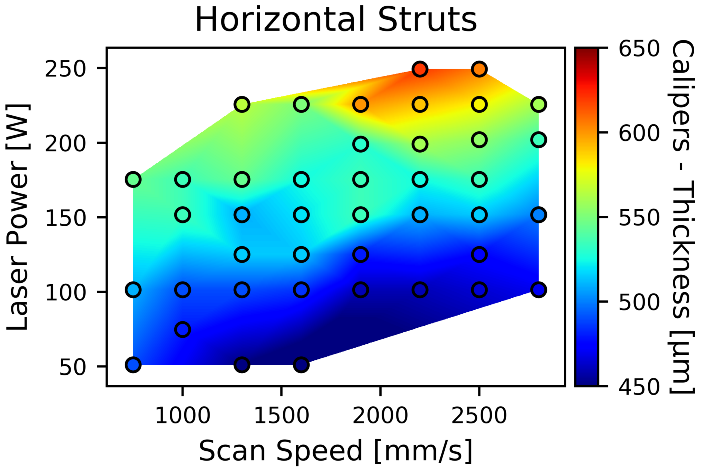
Horizontal Struts
Average of two perpendicular struts

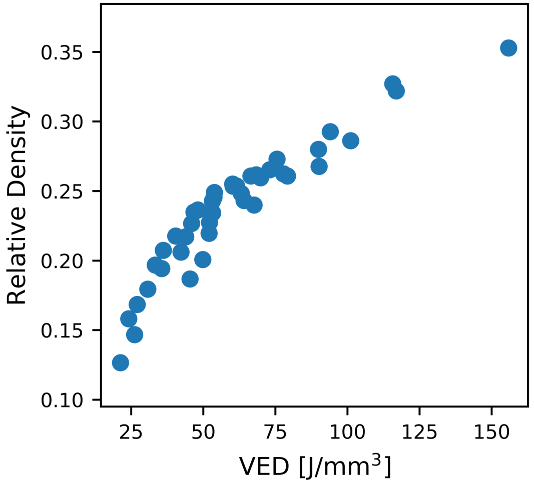
Relative Density
Volume that is material / Volume of lattice











VED = P/vdh

P = Laser Power   v = Scan speed

d = beam diameter ($1/e^2$)   h = hatch spacing

Compression Tests

Definition of mechanical properties

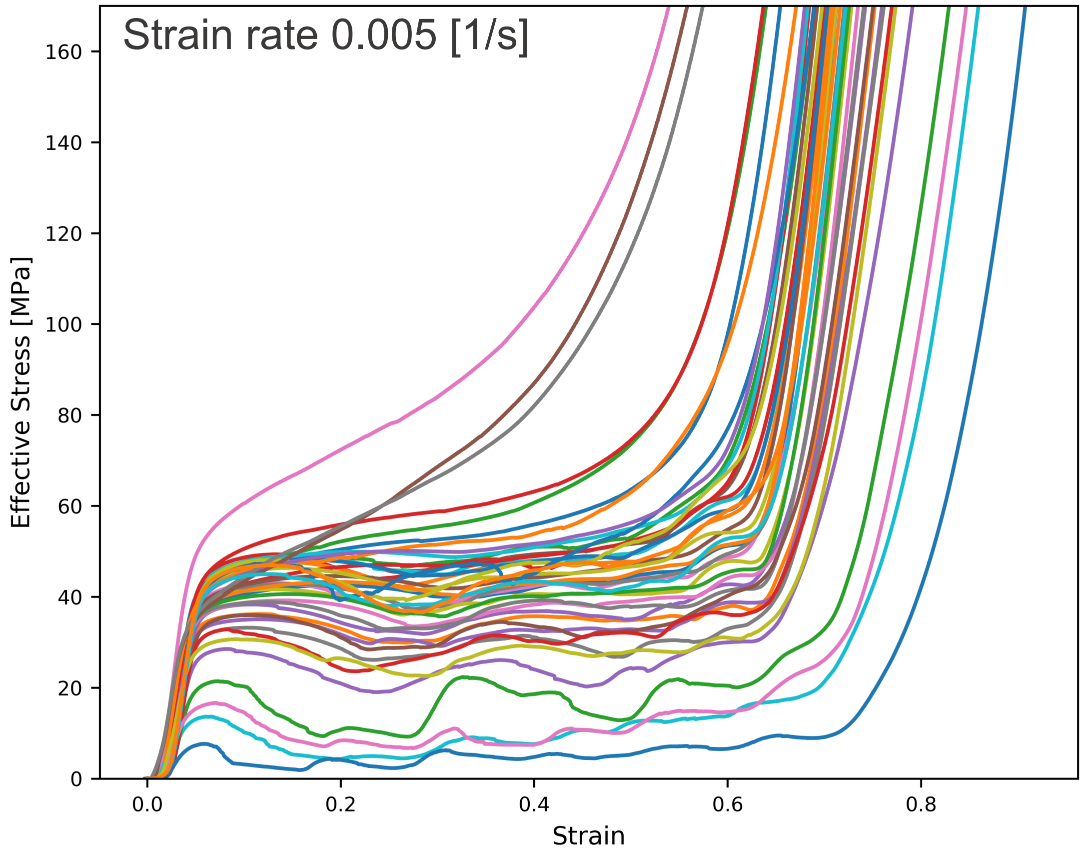
Stress (Effective Stress) – Load / Nominal cross section of lattice

Elastic modulus – Max Slope on Stress/Strain curve

Yield Stress – Found at 0.005 strain

Deformation Work – Area under the load displacement curve (Up until densification)

Relative Density – Volume of material / Nominal volume of lattice



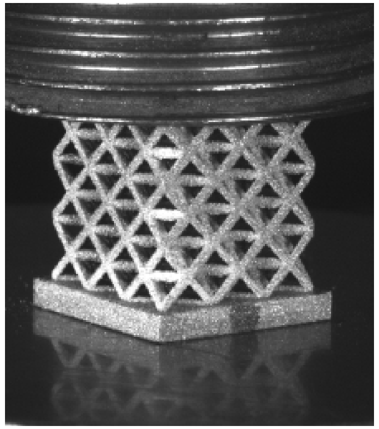
Mechanical Properties

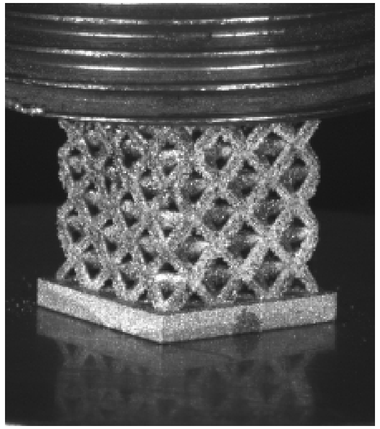
<u>Mechanical properties</u>

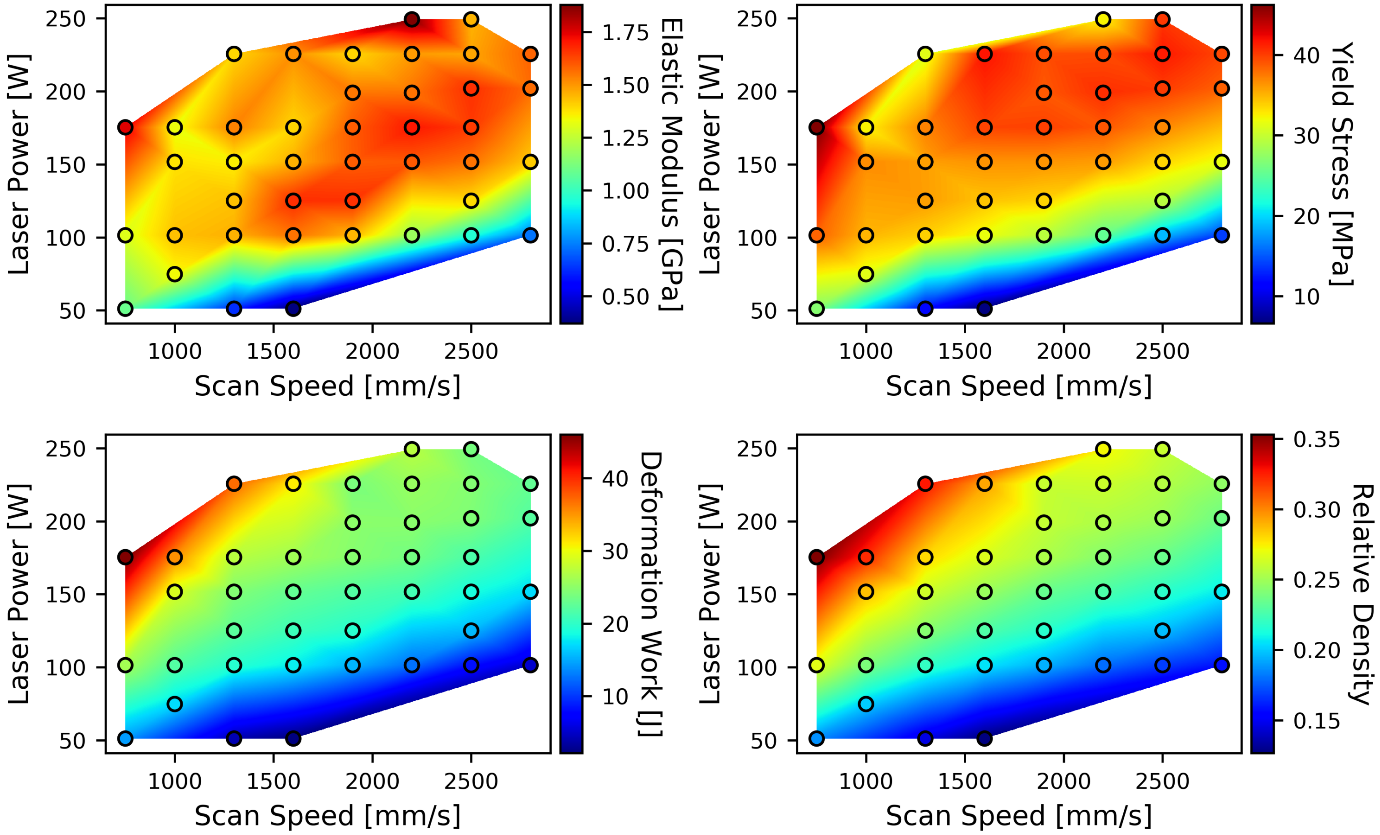
Elastic modulus – Variable with larger values in center

Yield Stress – Similar to strain with only a few outliers

Deformation Work – Similar to relative density with strong increase with slower scan speed and laser power







Mechanical Property Relations

Effective Modulus [GPa]

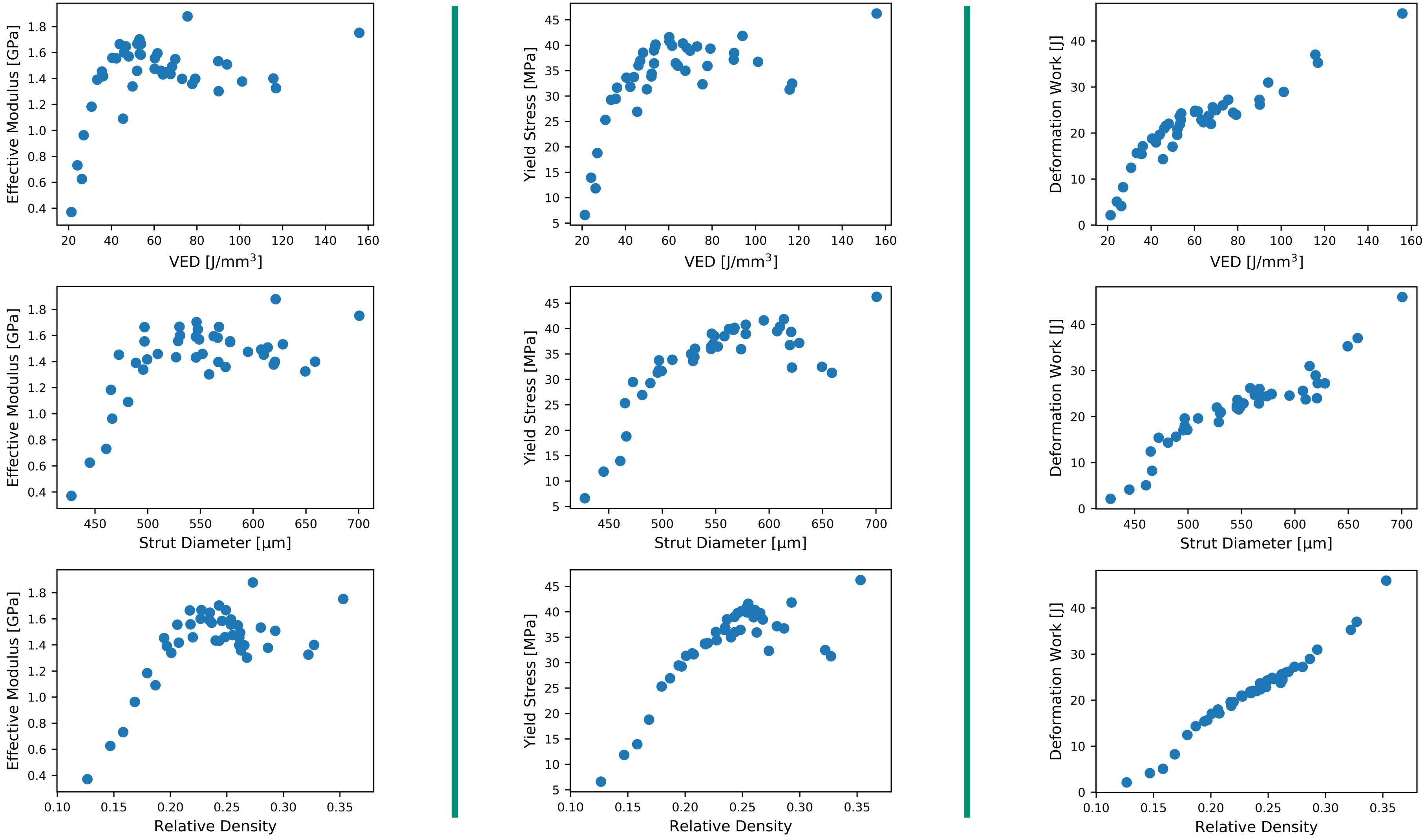
Yield Stress [MPa]

Deformation Energy [J]

VED [J/mm^3]

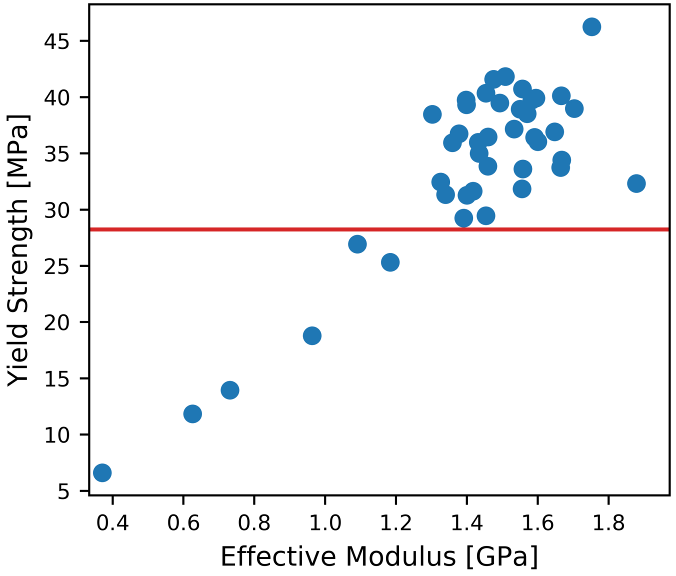
Strut Diameter [μm]

Relative Density

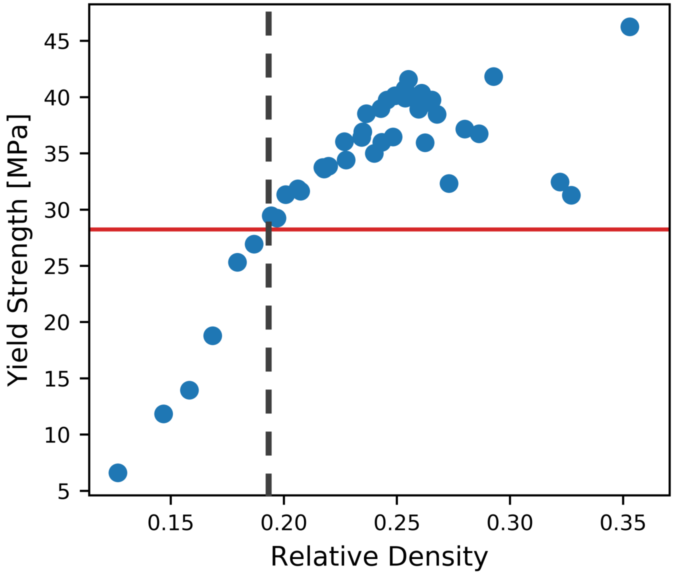


Mechanical Property Relationships

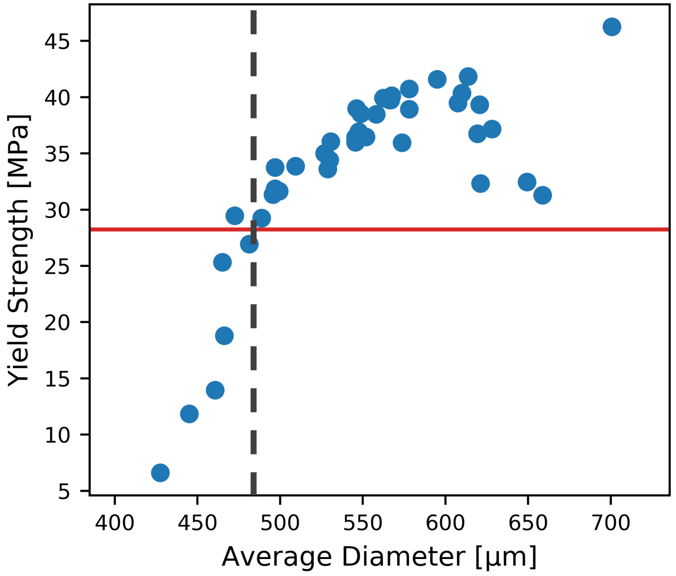
Yield Stress and Elastic Modulus -



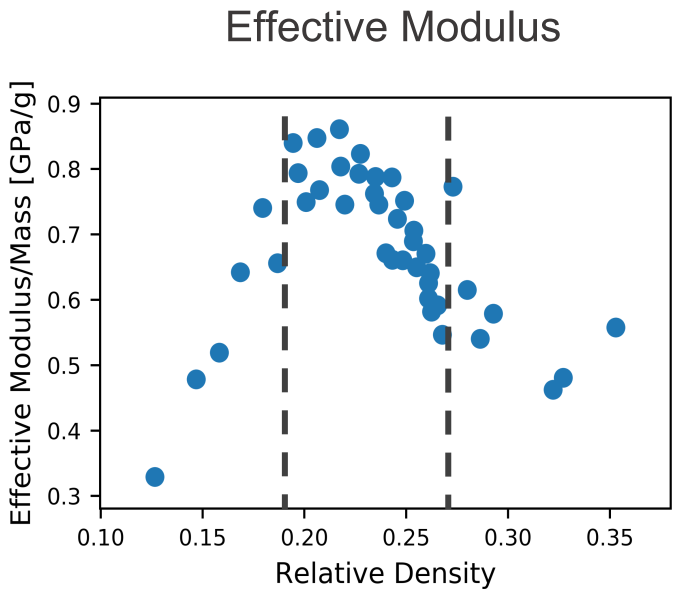
Predicting “Stability” Relative Density

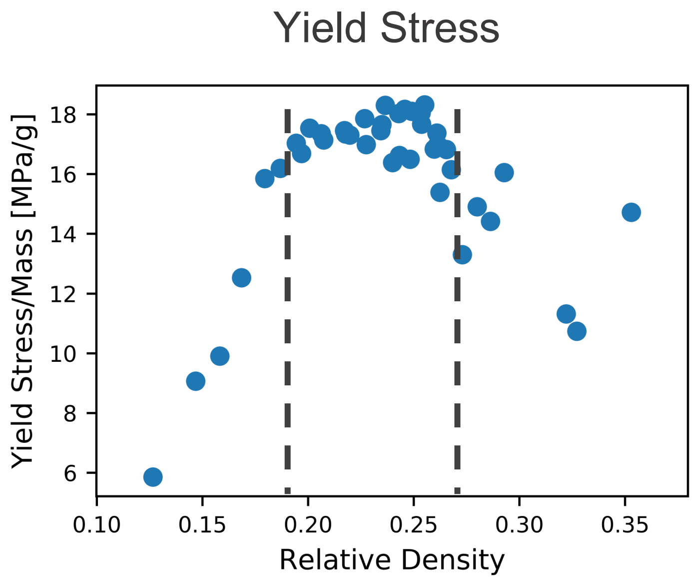


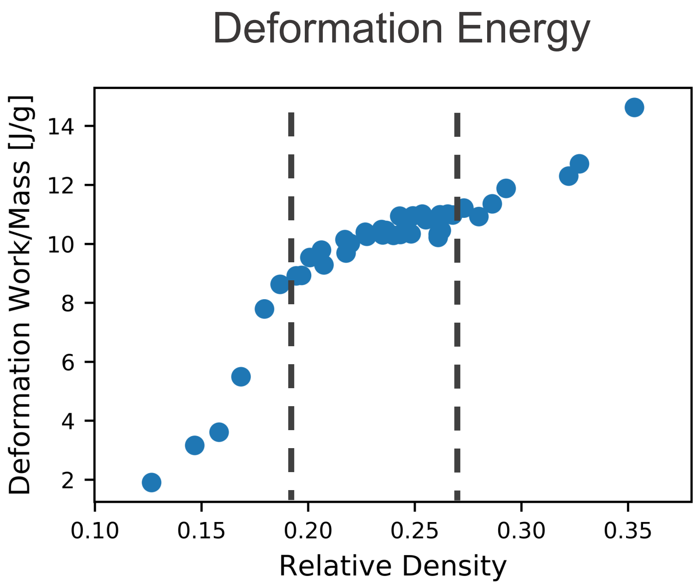
Predicting “Stability” Calipers



Mass Normalized Mechanical Properties

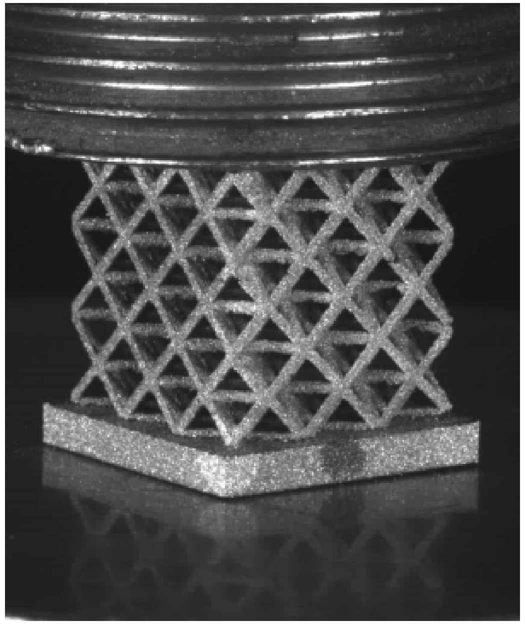




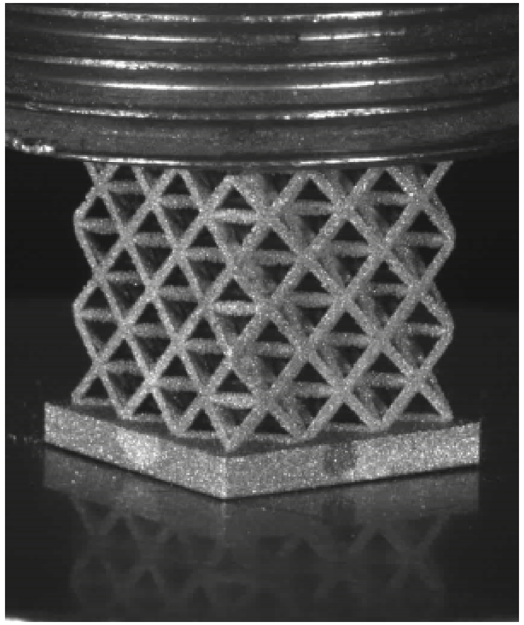


Octet Lattice Deformation Modes

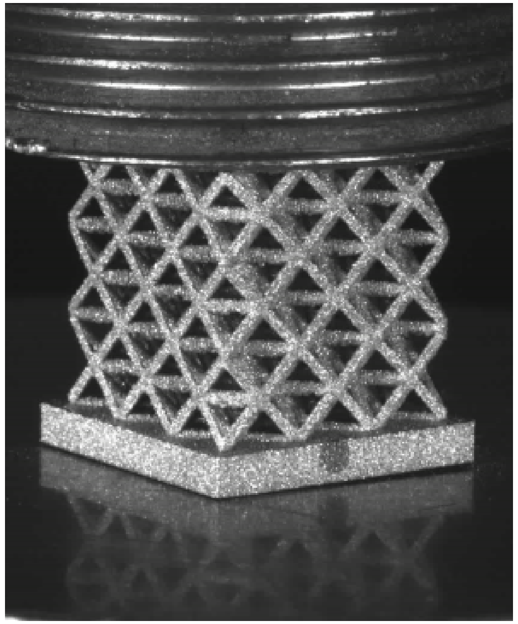
Shear Banding



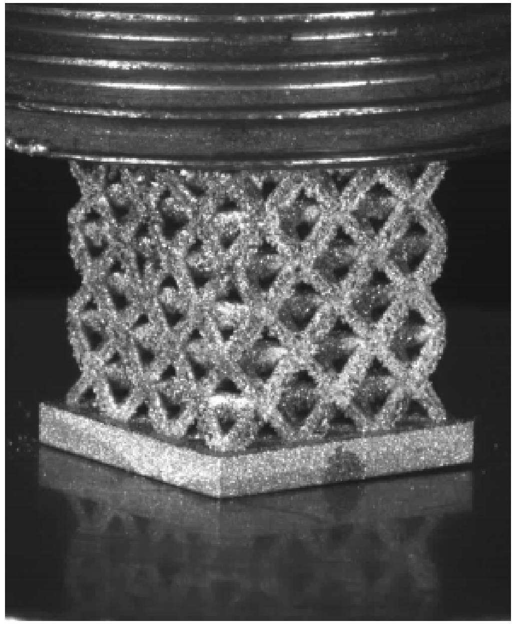
Localized failure



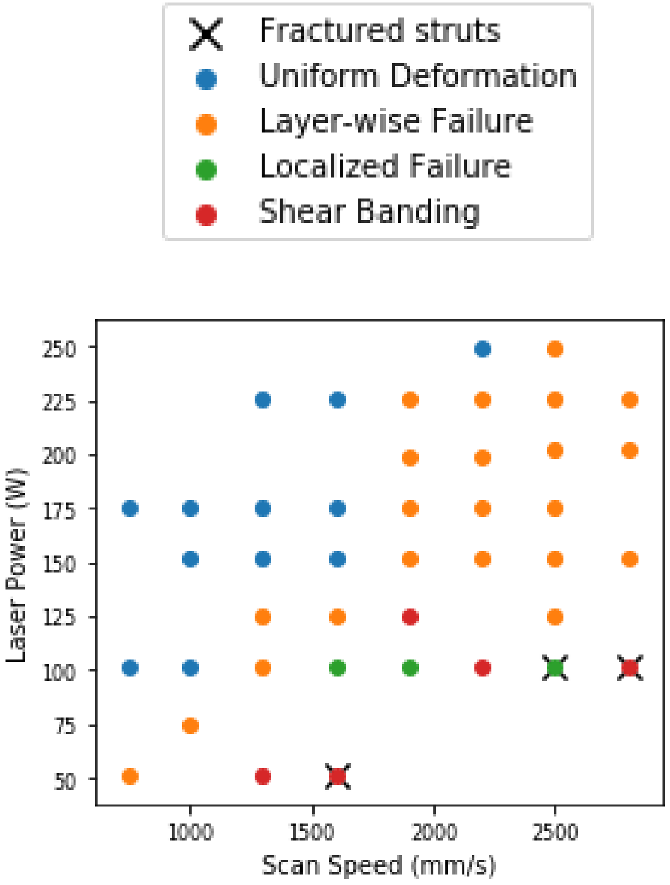
Layer Wise Failure

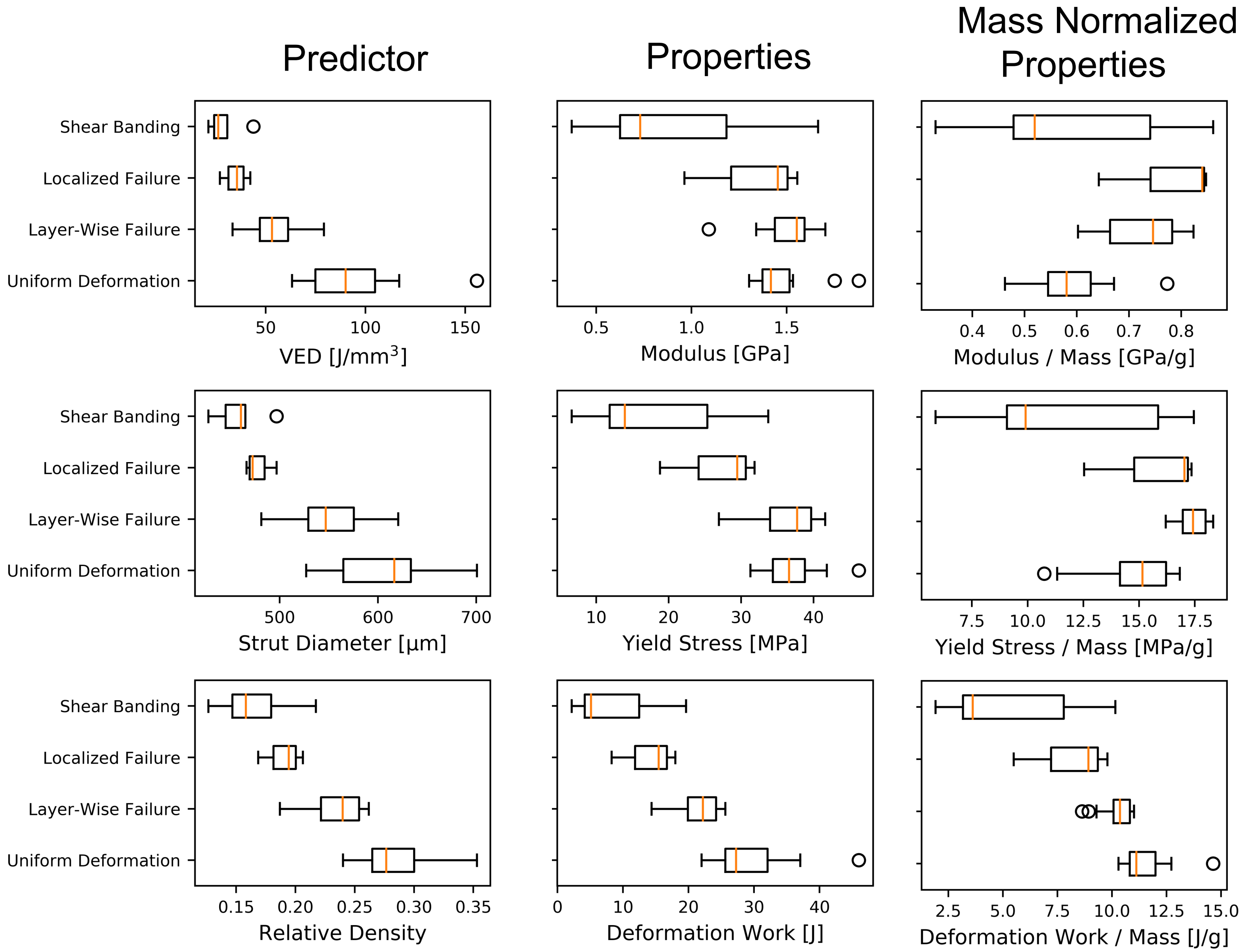


Uniform Deformation



Failure Modes





Conclusions

Deformation Work
- Correlates well to density (Non-linear dependence)

Elastic Modulus and Yield Strength
- Non-linear relationship with density/Strut Size
- Stabilize after a certain range (above baseline Properties)
  - Predicted by density or strut size

Failure Mode
- Different modes have small overlap in VED/Density/Struts Size
- Shear Banding / Localized Failure
  - Lower average properties, lower density/strut size
  - Layer by layer collapse and uniform deformation
    - Similar elastic modulus and properties but different density
  - Optimization per unit weight yields different results

Predicting Performance
- Density/Strut diameter are sensitive across the process space
  - Can be good indicators of the “stable” region for lattices and predicting failure mode

Questions?

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