National Aeronautics and Space Administration

Characterizing Material Scalability for Ultralight Lattice Design

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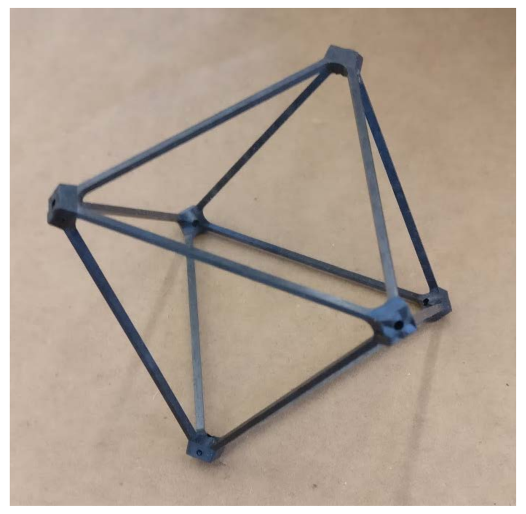
BACKGROUND

- Large Aero structures based on **ultralight lattice** structures are an alternative to large scale 3D printing and other manufacturing methods.
  - Digital materials made of **Voxels**
    - octahedron shaped unit cells
  - Lighter weight == **cost efficient** to launch into space
  - **Easy** robotic **assembly** in space
  - Easily **adaptable**
    - Lightweight airplane design
    - Economical space structures



MOTIVATIONS

It is desirable to determine the mechanical performance of octahedron voxel lattices when fabricated by different materials. The behavior of Ultem 2200 voxel, 40% carbon fiber voxel are already characterized.

Here we investigate the **convergence behavior** of homogeneous lattices as the size of the lattice assembly increases for various materials. We determine this behavior by comparing the elastic moduli and ultimate strengths of each voxel type.

Using **homogeneous** lattice behavior, **heterogeneous** lattices of different materials voxels can be designed to achieve target material properties for ultralight space applications.

MATERIALS

Cyclic Load Ranges for Various Materials

Material	Max Cyclic Load	Min Cyclic Load	Estimated Yield Load
Polypropylene	6 N	-6 N	[12 N]
Ultem 1000	10 N	-10 N	[20 N]
Ultem 2200	25 N	-25 N	[50 N]
30% Carbon	50 N	-50 N	[110 N]
40% Carbon	75 N	-75 N	[150 N]

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METHODS

The specimens were tested using an Instron 5982 Universal Testing System. A safe estimate of elastic range for cyclic load tests for each material is necessary to prevent premature failure. First, cyclic load tests were performed in the elastic range conducted to gain a hysteresis curve for determination of a modulus. Then, specimens were loaded until failure or until extreme plastic deformation to determine the break load and the fracture pattern.

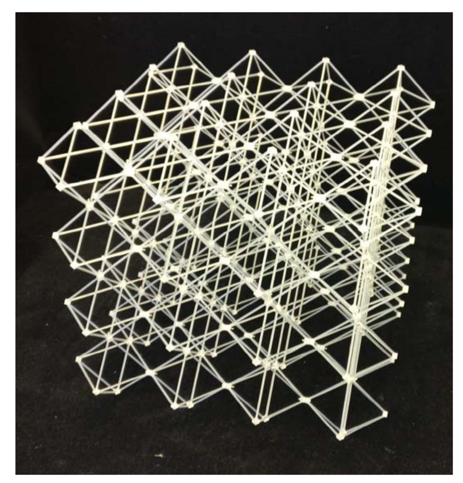
Instron Setup
Ultem 1000
Single Voxel

Single Voxel Testing

- Each voxel is manufactured in bulk through injection molding with a unit cell pitch of 76.2 mm.
- As a single unit cell, each voxel was fixtured to a load cell as well as a rigid bottom plate.
- Materials compared in tension and compression until failure
  - 3 failure trials for each test type and material

4x4x4 Voxel Constructions

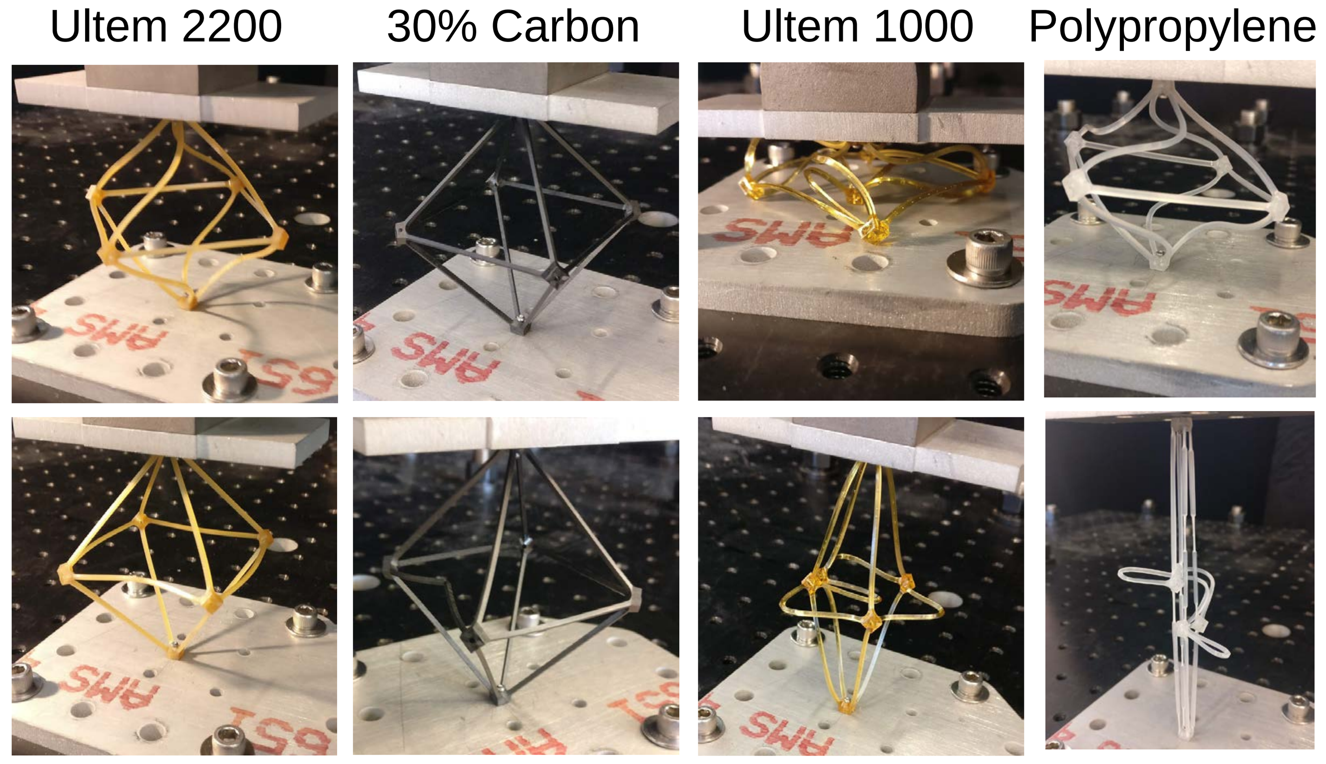
- Four 4x4x4 lattices constructed for each material
  - 2 tensile, 2 compressive
- Voxel materials tested: :
  - Ultem 1000
  - Polypropylene,
  - 30% Carbon Fiber
- Prior experimental data used for:
  - Ultem 2200, 40% Carbon Fiber



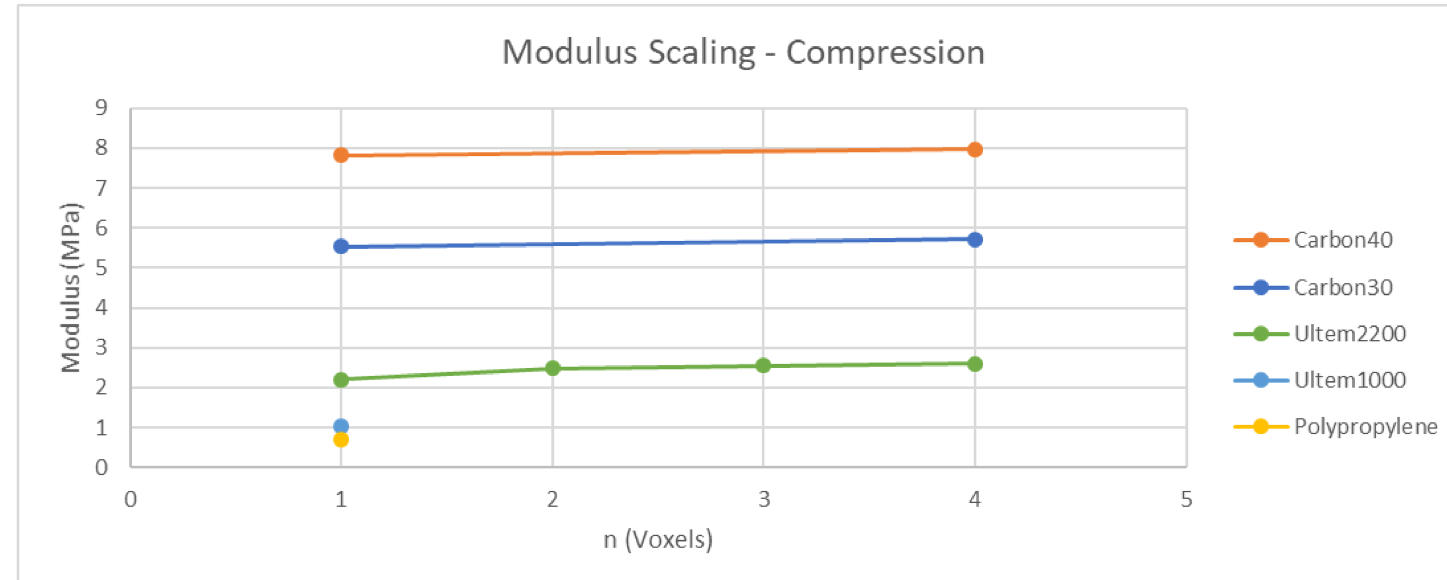
Before Fixturing
Polypropylene
4x4x4

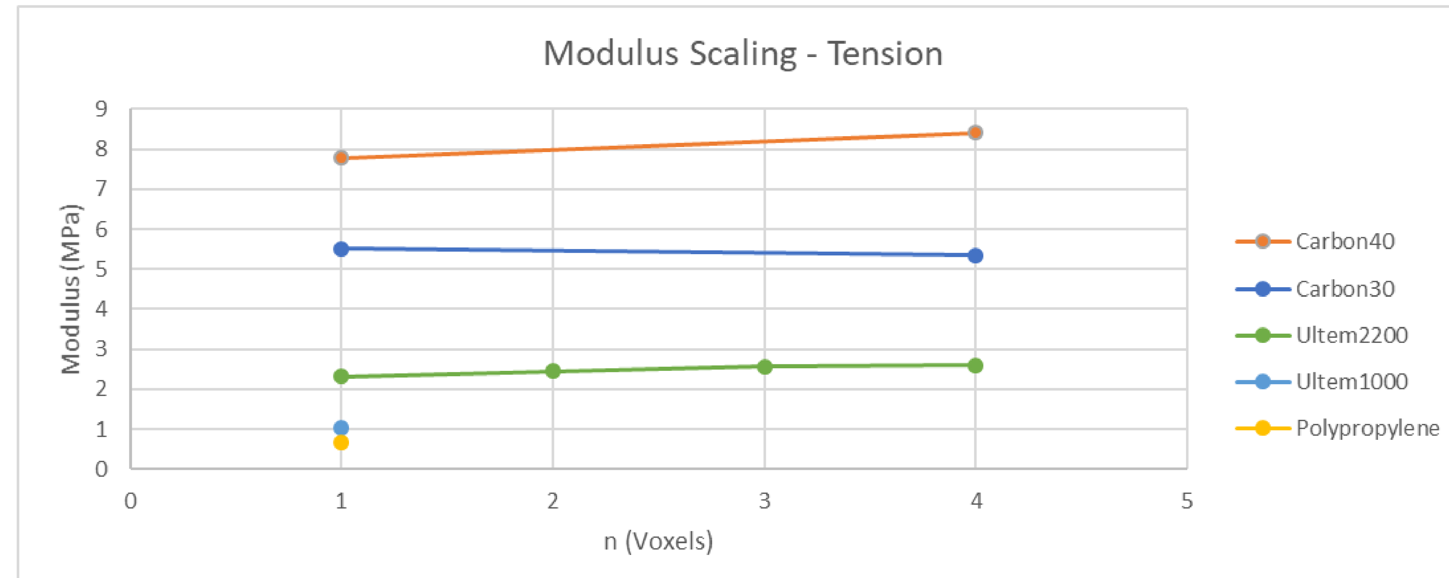
Instron Setup
30% Carbon
4x4x4

RESULTS

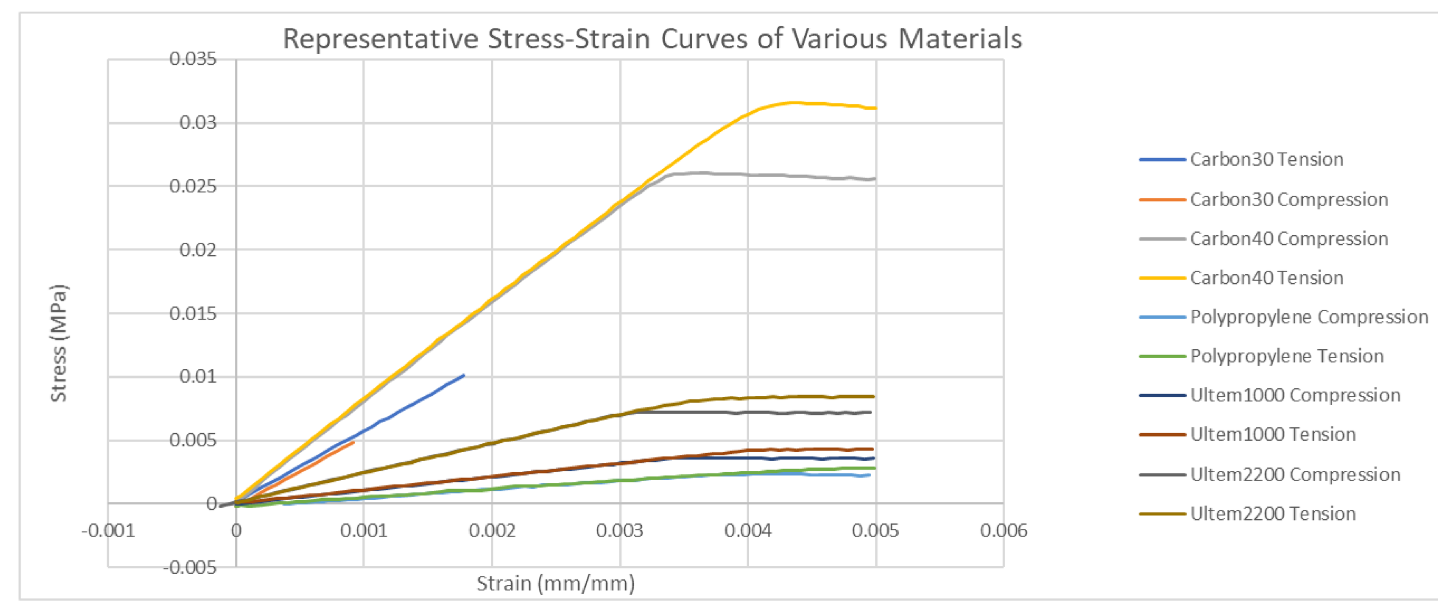


ANALYSIS





Comparative elastic modulus from compression and tension of voxels fabricated from various materials as a function of their assembly size, showing characteristic material convergence behavior. Reinforced polymer voxels perform with higher stiffness.



Representative stress-strain curves show a comparison of the linear elastic loading range and the structure's yield strength

CONCLUSIONS

- The convergence behavior of the materials tends to follow similar curves as the assembly size increases.
- Future work will investigate the properties of heterogeneous assemblies of compliant materials with stiff materials.