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
- Lightweight == 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.

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.

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

RESULTS

Cyclic Load Ranges for Various Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Max Cyclic Load</th>
<th>Min Cyclic Load</th>
<th>Estimated Yield Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polypolymer</td>
<td>6 N</td>
<td>-6 N</td>
<td>[12 N]</td>
</tr>
<tr>
<td>Ultem 1000</td>
<td>10 N</td>
<td>-10 N</td>
<td>[20 N]</td>
</tr>
<tr>
<td>Ultem 2200</td>
<td>25 N</td>
<td>-25 N</td>
<td>[50 N]</td>
</tr>
<tr>
<td>30% Carbon</td>
<td>50 N</td>
<td>-50 N</td>
<td>[110 N]</td>
</tr>
<tr>
<td>40% Carbon</td>
<td>75 N</td>
<td>-75 N</td>
<td>[150 N]</td>
</tr>
</tbody>
</table>

- Single Voxel Instron Compression Testing
- Single Voxel Instron Tension Testing

**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.**

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.