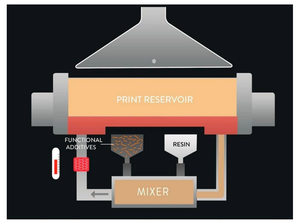
Team Members
Alexandra Light
Drew Craven
Spencer Scarber

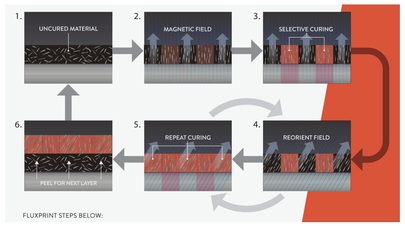
Sponsor Contact
Eric Versluys

Faculty Advisor
Mahdi Norouzi, Ph.D.

Project Additie

Introduction / Technology

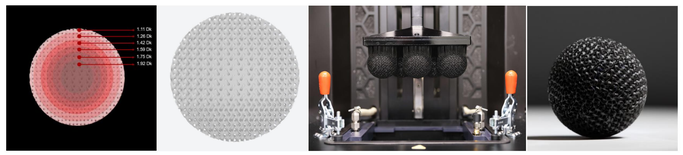


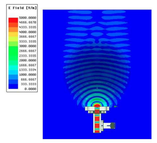


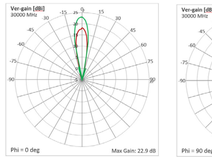
One of the challenges for integrating additively manufactured materials into aerospace products is the lack of necessary statistical data on the mechanical and environmental properties of new additive materials. In this project, the mechanical properties of newly introduced additive materials are measured, and the statistical data are reported according to relevant engineering standards.

Applications

Gradient Index Lenses / Tunable Dielectric Permittivity







Green: Fortify Printer With Rogers Radix
Red: Commercially Available Photopolymer

Concept

By changing the density of the lattice and effectively increasing the lattice air fraction from core to perimeter, a radially continuous spatially graded index of refraction can be realized. The mixing of dielectric material and air is used to control the designed effective permittivity, but it also introduces incredible advantages to the overall loss of a device.

Radomes and Other Components

Project Findings

ASTM D790: Flexural Properties

Orientation A

Flexural Stress: 137.96 MPa

Flexural Strain: 0.0397 mm/mm

Chord Modulus: 636.13 MPa

Elastic Modulus: 760 MPa

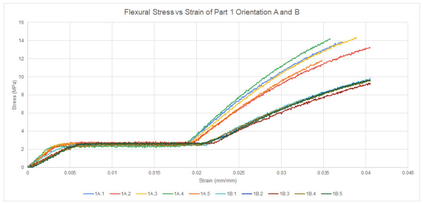
Orientation B

Flexural Stress: 108.83 MPa

Flexural Strain: 0.0470 mm/mm

Chord Modulus: 327.74 MPa

Elastic Modulus: 331 MPa



ASTM D5961-17: Bearing Properties

Orientation A

Ultimate Bearing Strength: 102 MPa

Ultimate Bearing Strain: 0.029 microstrain

Failure Force: 2428 N

Modulus: 1310 MPa

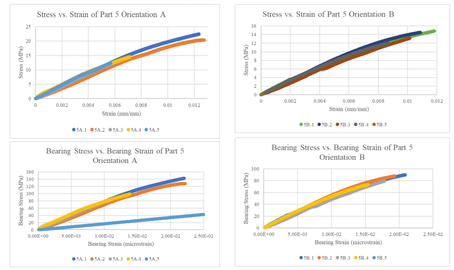
Orientation B

Ultimate Bearing Strength: 64 MPa

Ultimate Bearing Strain: 0.013 microstrain

Failure Force: 1886 N

Modulus: 892 MPa



ASTM D638-14: Tensile Properties

Orientation A

Load at Rupture: 1021.59 N

Extension at Rupture: 2.38 mm

Tensile Strength: 23.04 MPa

Percent Elongation at Break: 4.76%

Normal Strain: 2.07 mm/mm

Modulus: 2524.90 MPa

Orientation B

Load at Rupture: 1080.01 N

Extension at Rupture: 2.95 mm

Tensile Strength: 24.01 MPa

Percent Elongation at Break: 4.72%

Normal Strain: 2.57 mm/mm

Modulus: 1654.68 MPa

Orientation C

Load at Rupture: 620.34 N

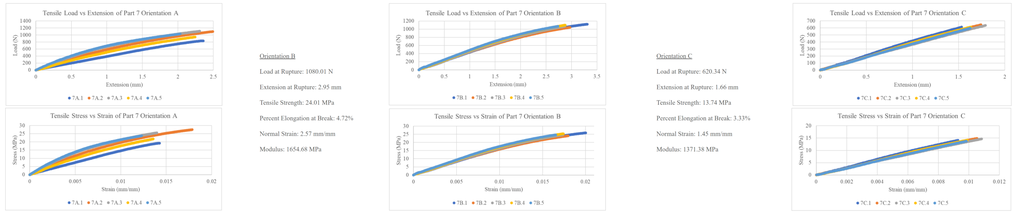
Extension at Rupture: 1.66 mm

Tensile Strength: 13.74 MPa

Percent Elongation at Break: 3.33%

Normal Strain: 1.45 mm/mm

Modulus: 1371.38 MPa



ASTM D695-15: Compressive Properties

Orientation A

Compressive Strength: 48.72 MPa

Compressive Yield Strength: N/A

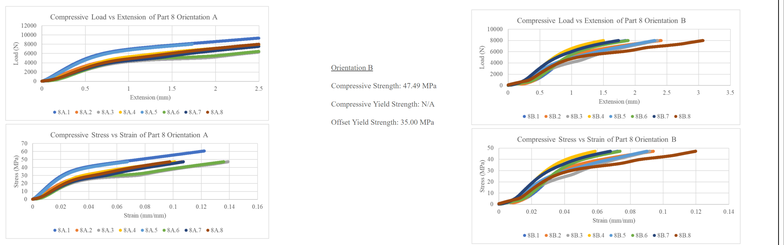
Offset Yield Strength: 26.43 MPa

Orientation B

Compressive Strength: 47.49 MPa

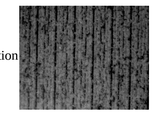
Compressive Yield Strength: N/A

Offset Yield Strength: 35.00 MPa

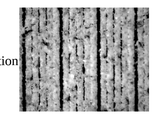


Photomicrograph Analysis

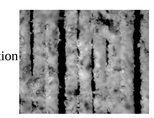
x50 Magnification



x100 Magnification



x200 Magnification



ASTM D5379-19: Shear Properties

Orientation A

Ultimate Strength: 39.76 MPa

Ultimate Shear Strain: 6860.5 μm/μm

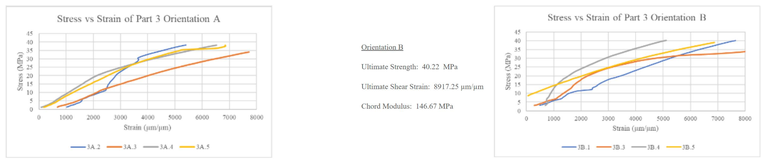
Chord Modulus: 167.9 MPa

Orientation B

Ultimate Strength: 40.22 MPa

Ultimate Shear Strain: 8917.25 μm/μm

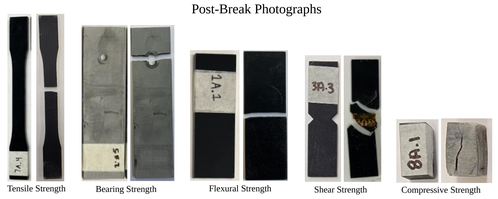
Chord Modulus: 146.67 MPa



Conclusions

- The material exhibited brittle behavior across all tests.
- Print orientation impacted part strength across all tests.
- Exposure to sea water decreased part strength regardless of print orientation.

Post-Break Photographs



Tensile Strength | Bearing Strength | Flexural Strength | Shear Strength | Compressive Strength

Thank You!

Roy Visser
Wendy Reffeor, Ph.D.
Brian Krug, Ph.D.
Chris Weber
Costa Kury
Jason Ehrich
Rachel Muench
Trevor Polidore
Ryan Aldridge
GVSU School of Engineering
Lockheed Martin Skunk Works

ASTM E831-19: Linear Thermal Expansion of Solid Materials by Thermomechanical Analysis

Orientation A Coefficient of Expansion

-50°C to 50°: 82.07 ppm/°C

-50°C to 240°: 148.8 ppm/°C

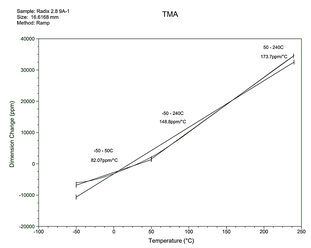
50°C to 240°: 173.7 ppm/°C

Orientation B Coefficient of Expansion

-50°C to 50°: 69.39 ppm/°C

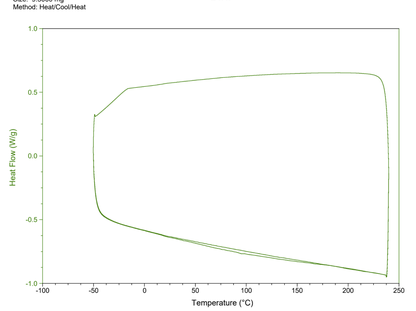
-50°C to 240°: 126.5 ppm/°C

50°C to 240°: 148.4 ppm/°C



ASTM D3418-15: Transition Temperatures and Enthalpies of Fusion

Sample: 2A-5
Size: 9.3000 mg
Method: Heat/Cool/Heat



Post-Submersion Tensile Testing

Orientation A, Diesel

Load at Rupture: 1015.23 N

Extension at Rupture: 4.37 mm

Tensile Strength: 23.30 MPa

Percent Elongation at Break: 8.74%

Normal Strain: 3.80 mm/mm

Modulus: 71.16 MPa

Orientation A, Seawater

Load at Rupture: 912.54 N

Extension at Rupture: 2.85 mm

Tensile Strength: 20.46 MPa

Percent Elongation at Break: 5.70%

Normal Strain: 2.48 mm/mm

Modulus: 74.27 MPa

Orientation B, Seawater

Load at Rupture: 877.90 N

Extension at Rupture: 2.86 mm

Tensile Strength: 19.59 MPa

Percent Elongation at Break: 5.72%

Normal Strain: 2.49 mm/mm

Modulus: 68.41 MPa

Orientation B, Diesel

Load at Rupture: 1023.67 N

Extension at Rupture: 4.52 mm

Tensile Strength: 23.17 MPa

Percent Elongation at Break: 9.04%

Normal Strain: 3.93 mm/mm

Modulus: 68.45 MPa