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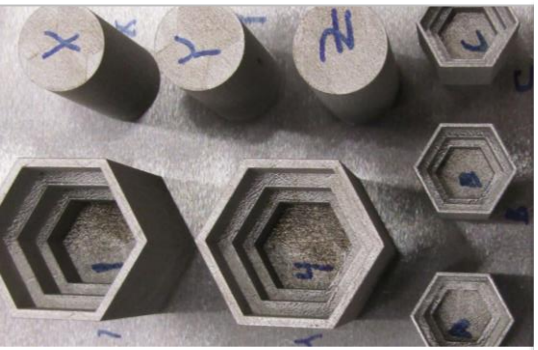

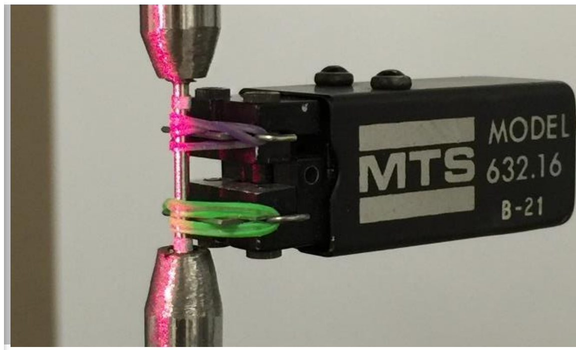

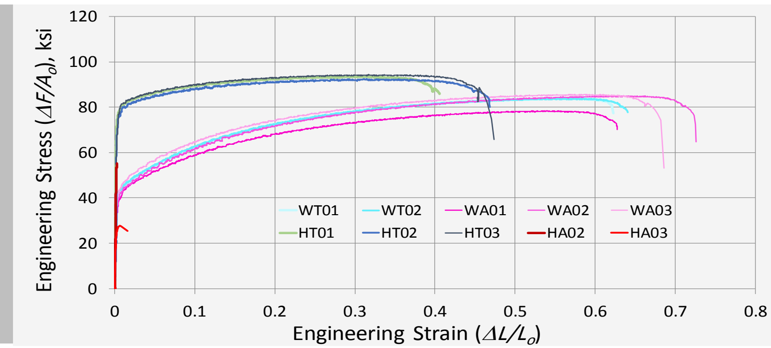

Characterization of Mechanical Properties of 3-D LENS and PBF Printed Prototypes

Wei-Yang Lu, Nancy Yang, Joshua Yee, Kevin Connelly

3rd AM Cross-JOWOG

April 24th-28th, 2017

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Introduction

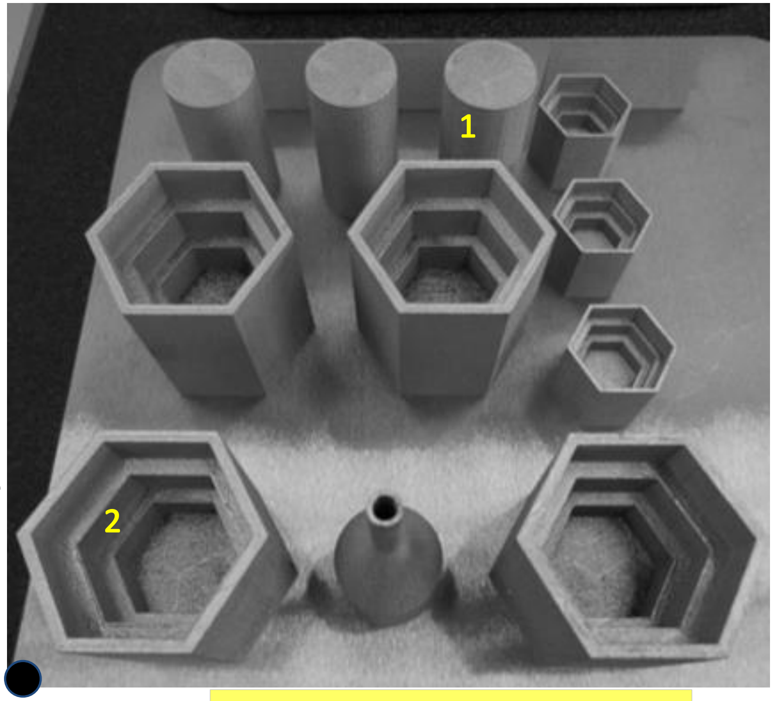
- AM material property is dependent on processing parameters
- Material consistency is a concern when qualifying AM parts for application
- Material properties are sensitive to localized thermal transport and heat distribution
  (Yang et al, JTST, April 2017, p.610)
- Specimens are taken from different locations and orientations of AM components
- LENS and PBF prototypes are considered

SS316L AM PBF Prototypes

PBF machine ProX300

Roller Direction

- Cylinder (1"D x 2"H)
- 3-tier hexagon (2"x2")
- Printed at SNL/CA (Josh Yee & Gary Hux)



Reference Frame

Y-axis

X-axis

Origin

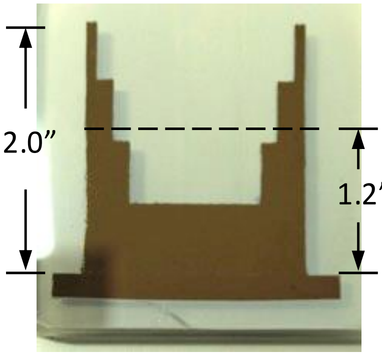
Z – Build Direction (BD)

Processing Parameters

Laser Power	Powder Layer thickness	Laser Scanning Speed
41% (of 500W)	40 um	1200 mm/s

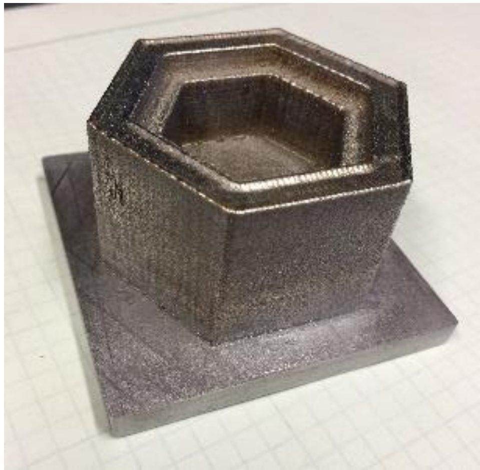
SS316L AM LENS Prototypes

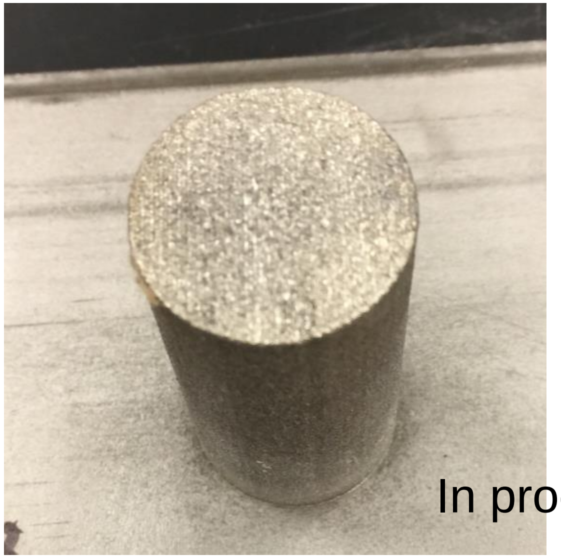
- LENS Hexagon-2 (2.0”x2.0”)
- LENS Short Hexagon (1.2”x2.0”)
- LENS Cylinder (1”D x 2”H)
- Printed at UC-Irvine

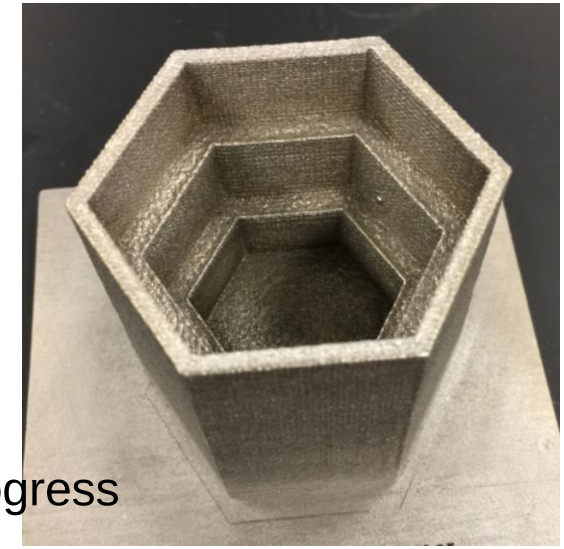


Processing Parameters

Laser Power	Speed
400 W	16.3 mm/s



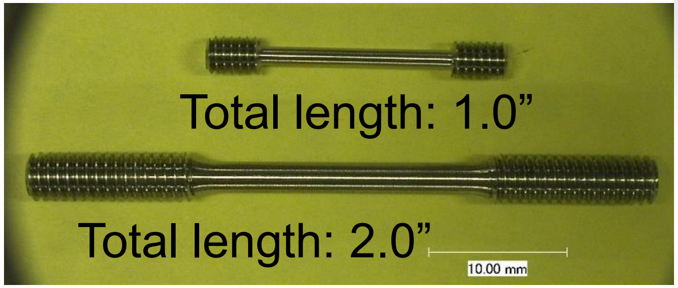


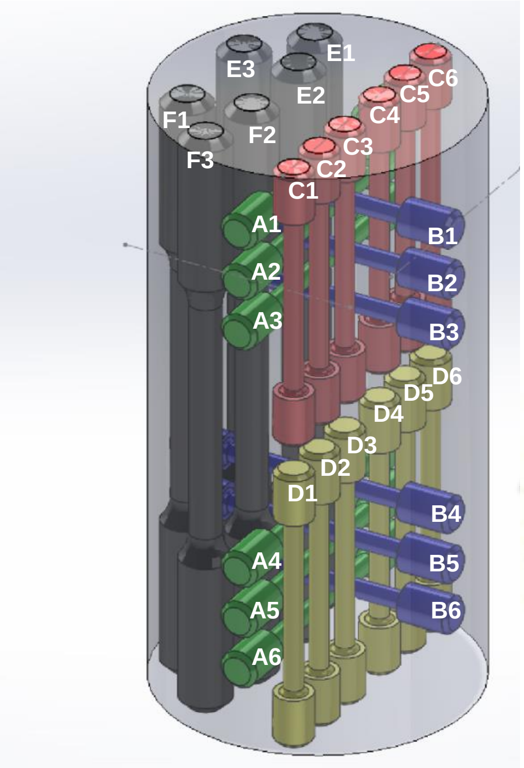


In progress

Tensile specimens from Cylinders

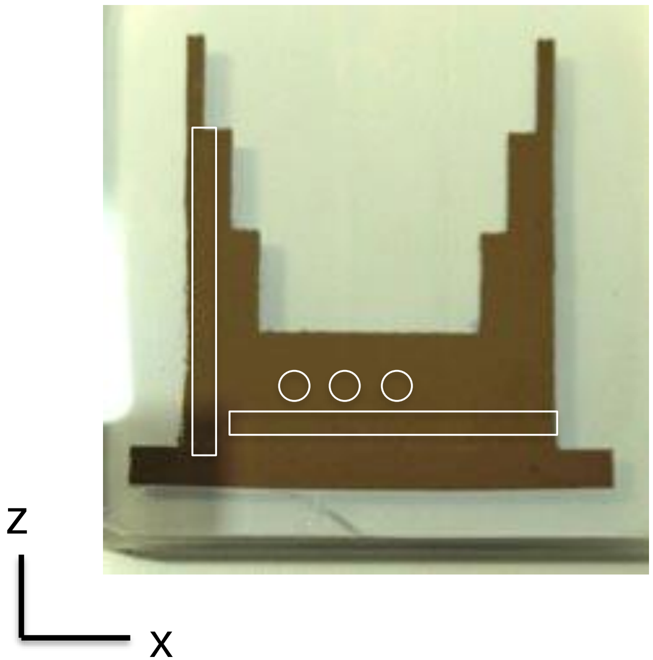
- Gage diameter: 0.06” or 0.10”

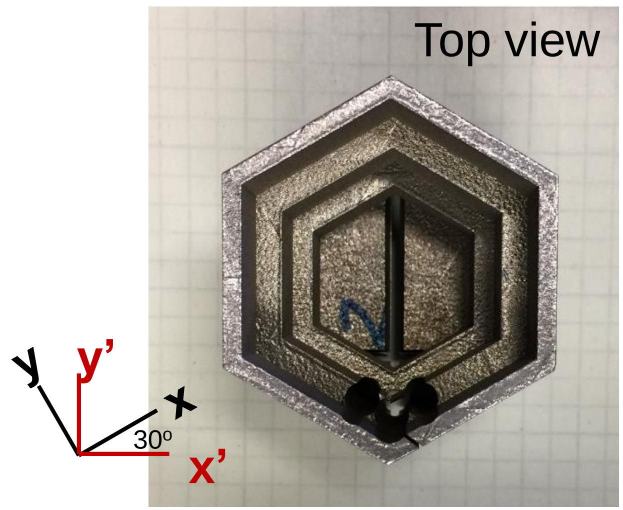




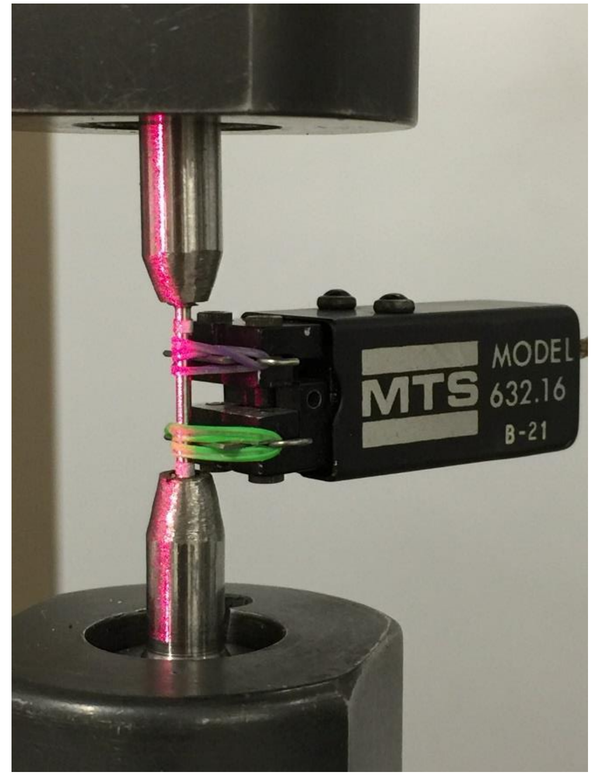
Tensile specimens from Hexagons

- Specimens oriented along x-, y- and z- axes.
- Off-axis specimens along x’ and y’.



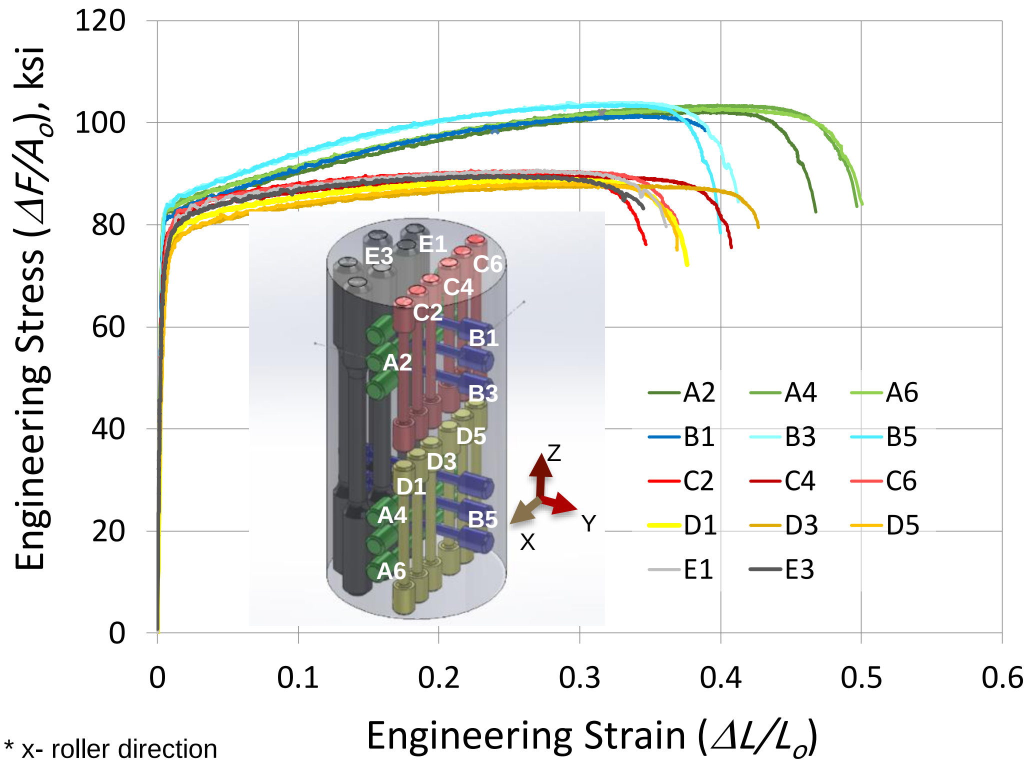


Experimental Setup



- Laser and mechanical extensometers are used to measure large and small deformations, respectively.

Tensile Properties – PBF Cylinder



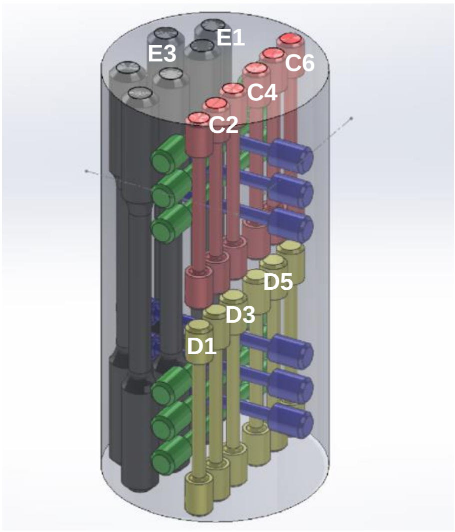
* x- roller direction

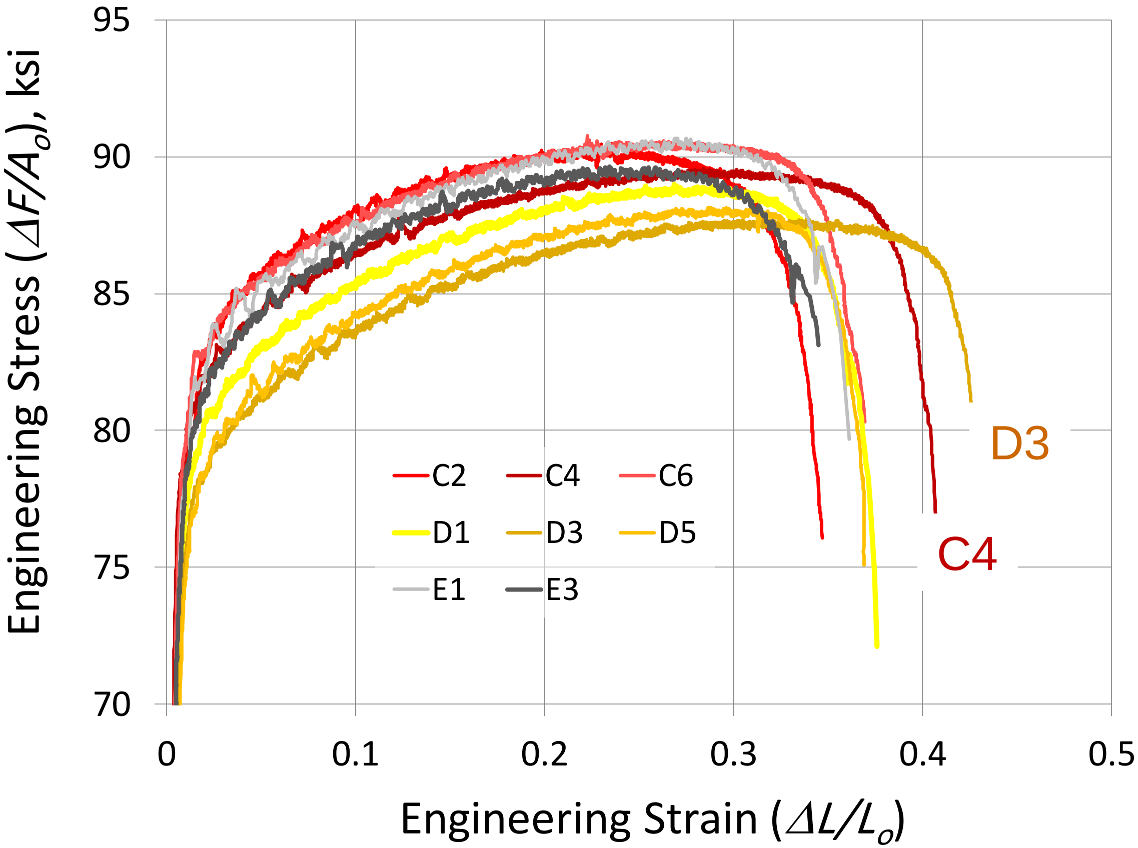
Specimen	Yield (Mpa)	Strength (Mpa)	Elongation (%)
2C	403	624	35
4C	507	617	41
6C	479	613	37
Average	463	618	37
1D	434	614	38
3D	429	605	43
5D	376	608	37
Average	413	609	39
1E	465	625	36
3E	471	618	35
Average	468	622	35
2A	548	705	47
4A	554	713	50
6A	567	709	50
Average	556	709	49
1B	551	699	39
3B	564	717	41
5B	556	714	40
Average	557	710	40

- Material anisotropy
  - The tensile strength in the z-direction is about 15% lower than the x- or y-direction.
  - The x-direction specimen set has the largest elongation.

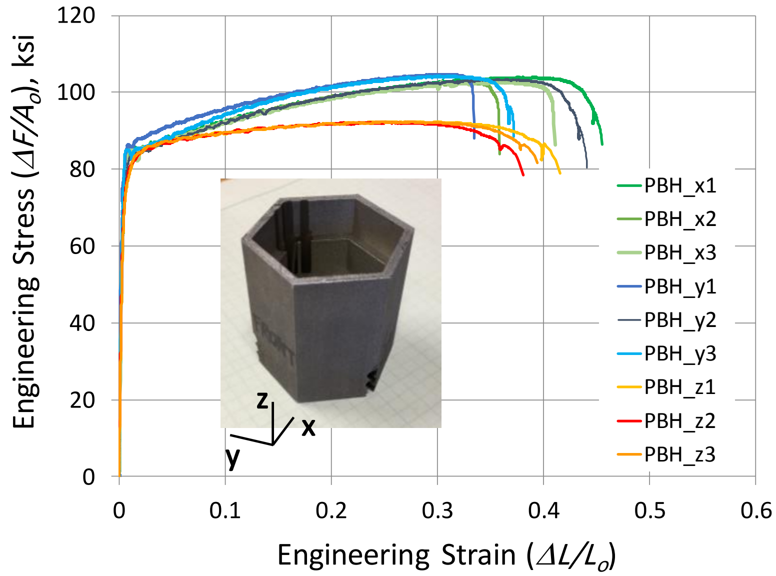
Observations

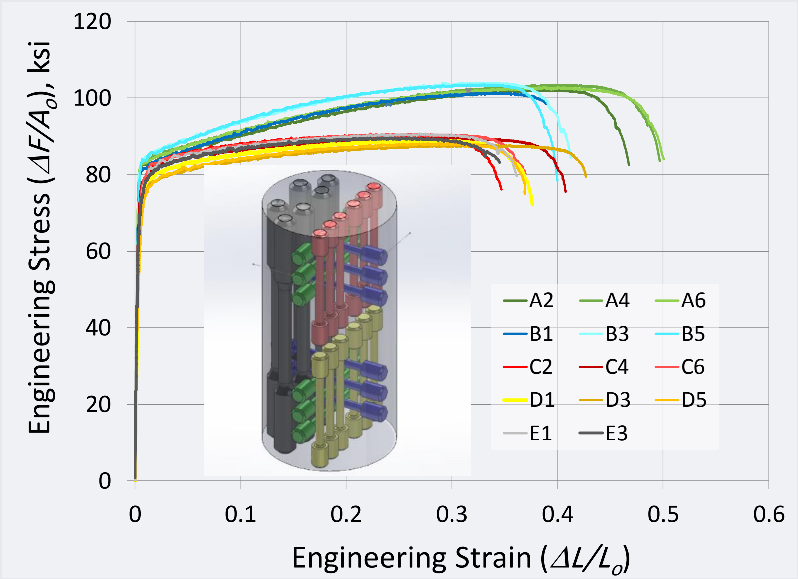
- Material anisotropy
- Specimen size
- Location
  - Top versus bottom
  - Center versus edge





PBF Hexagon: On-Axis Specimens

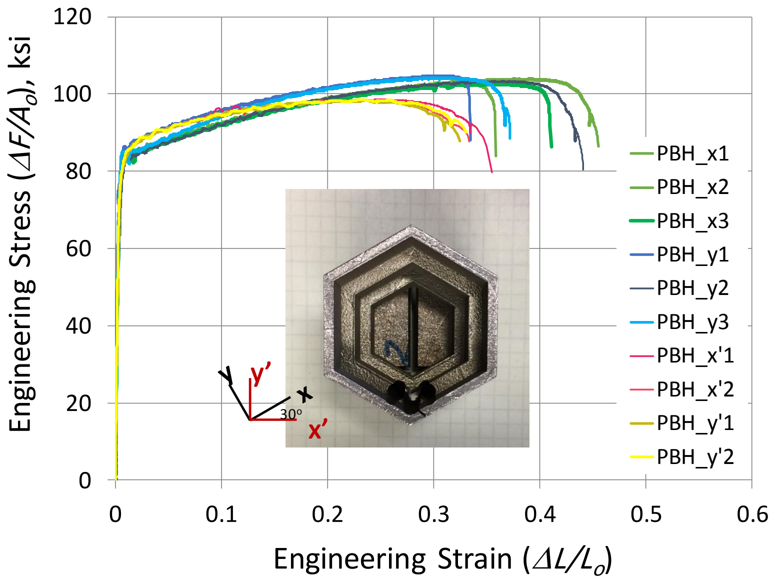


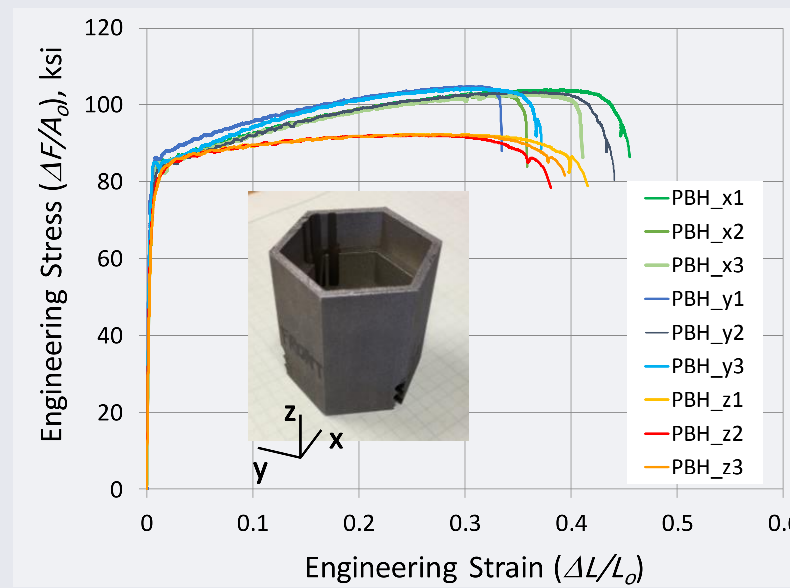


PBF-Cylinder

- Higher yield and strength in z.
- Shorter elongation in x and y

PBF Hexagon: Off-Axis Specimens

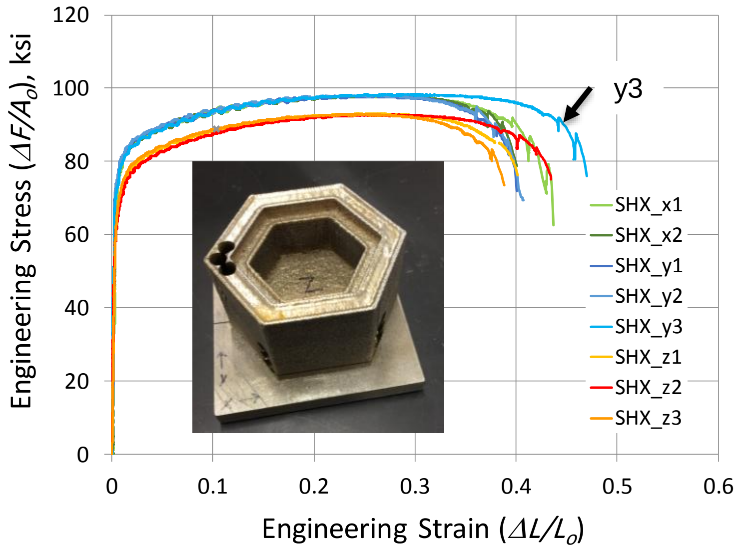




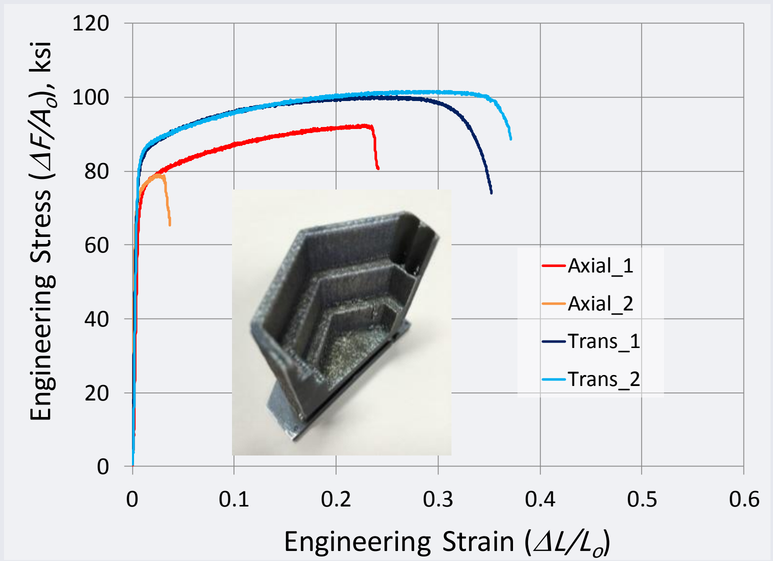
PBF-Cylinder: on-axis specimens

- Off-axis behaviors in x’ and y’ are about the same.

LENS Short Hexagon



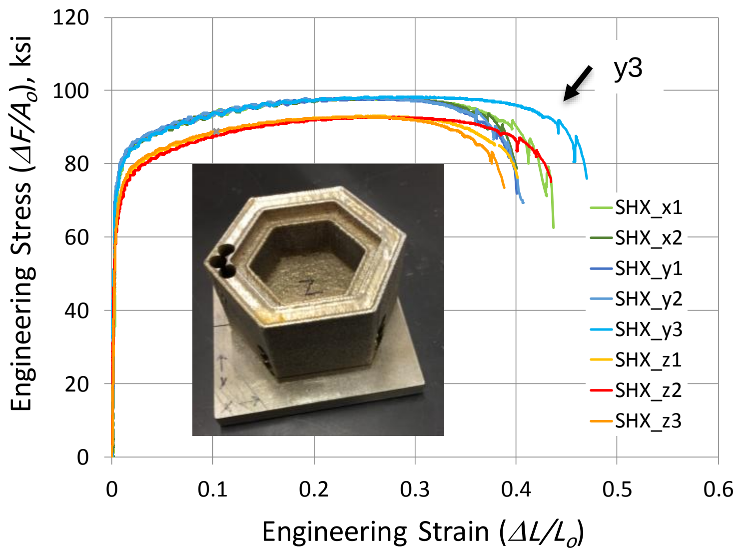
- Show better elongation in z direction

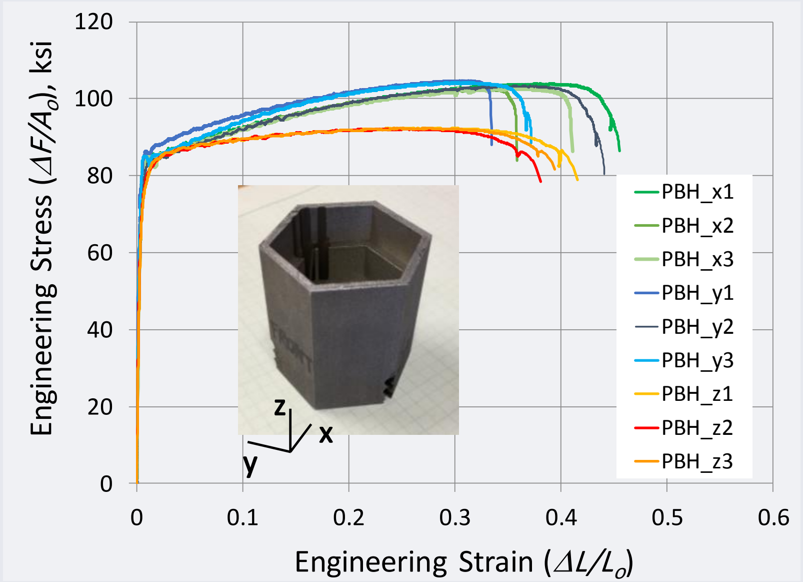


LENS Hexagon-1

Yang et al, JTST, April 2017

LENS Short Hexagon

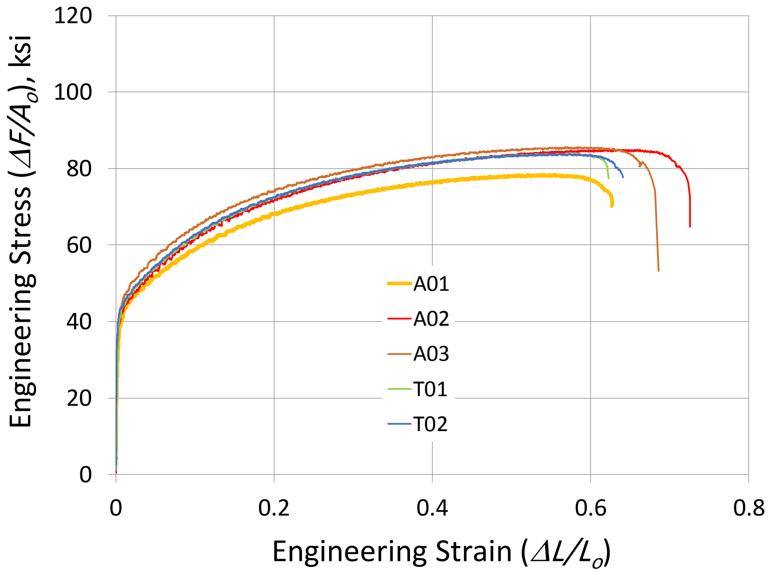


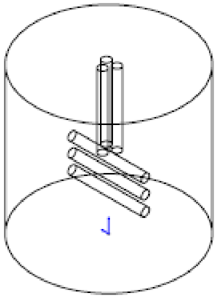


PBF-Hexagon

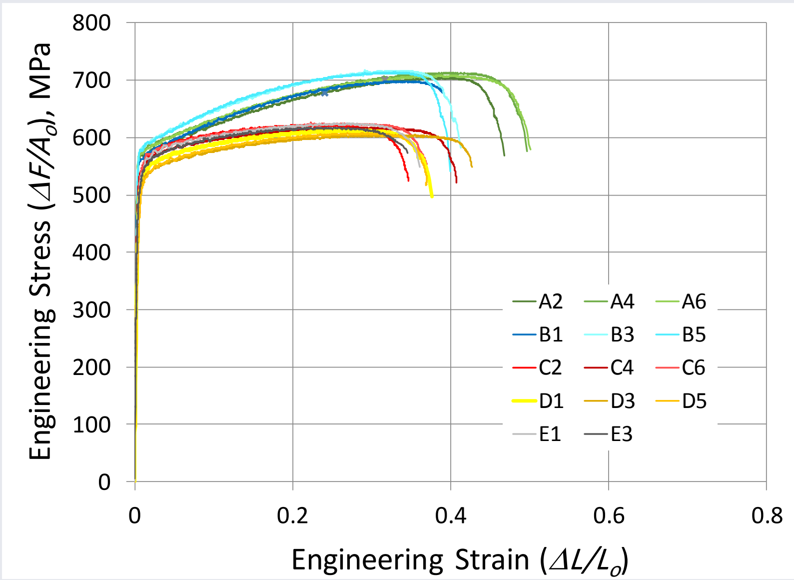
- Different hardening behavior

Wrought 316L





Certified annealed 316L 2” D Cylinder



PBF-Cylinder

Summary

- Tensile testing was conducted for specimens taken from PBF and LENS prototypes
- Depending on the process, AM SS316L shows various anisotropic behaviors
- Consistent results from two different specimen sizes indicate using the small size specimen is adequate
- Within a PBF cylinder, there are minor variations of mechanical properties with respect to location, which collaborate the suggestion it is “a result of the localized thermal transport and heat distribution” (Yang, 2017)
- More components are being studied.