Structural Repair of Aluminum Alloy 7050-T7451 using Cold Spray Repair

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Program Goals and Objectives

- Show that cold spray can be used to improve fatigue life in repaired aluminum alloy 7050-T7451
- Determine if using different screening sample geometries affect the determination on if a repair process is acceptable
- Demonstrate a cold spray repair can be used for structural repair of aluminum alloys

Fatigue Sample Geometries

15% Blend Geometry

Pristine

Baseline

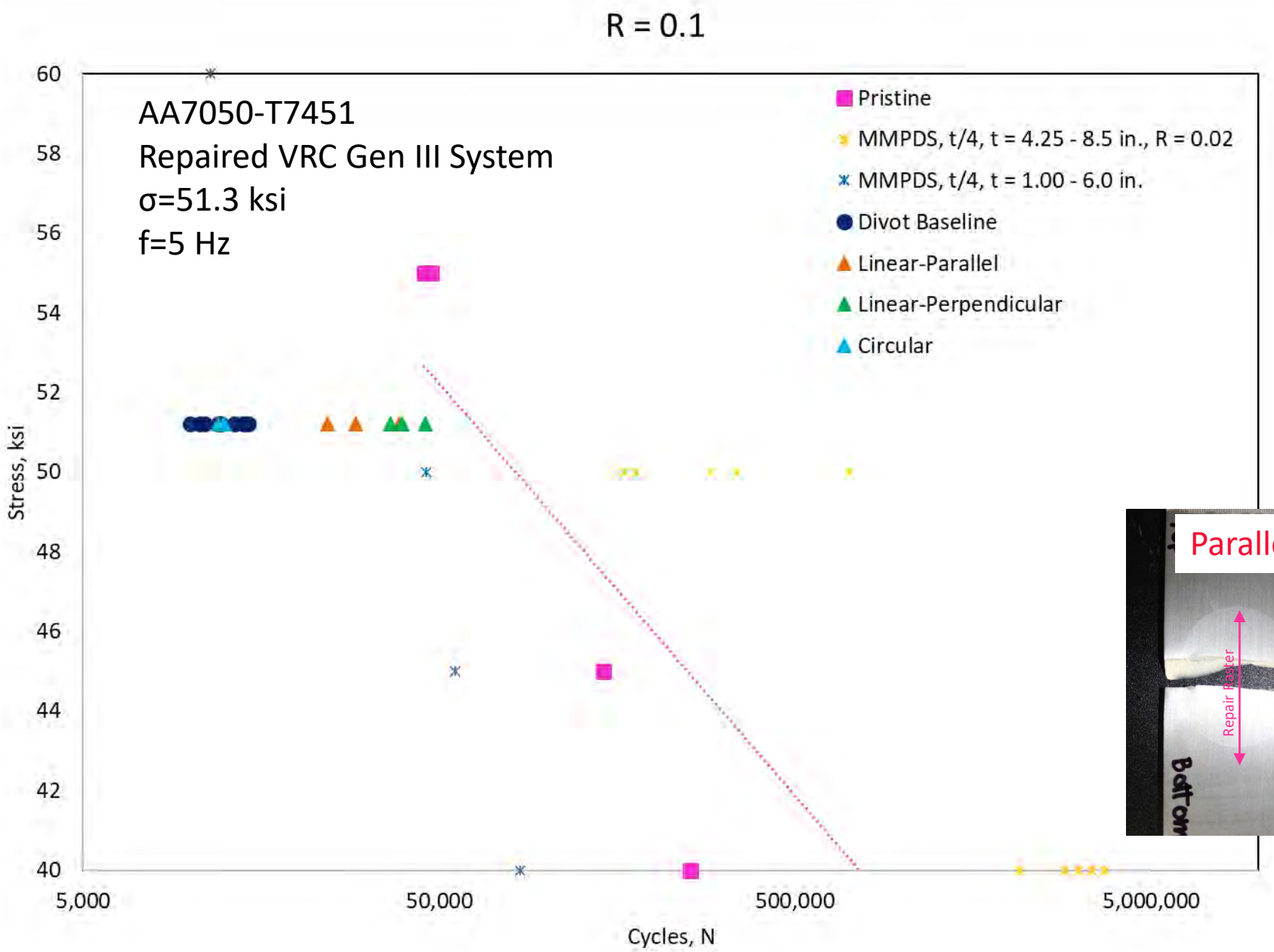
Repair

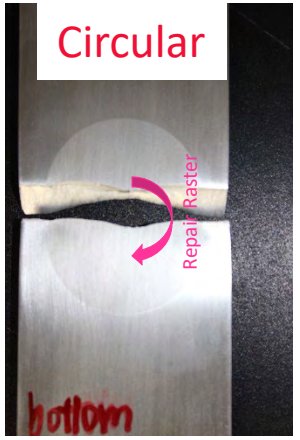
30% Blend Geometry

Baseline

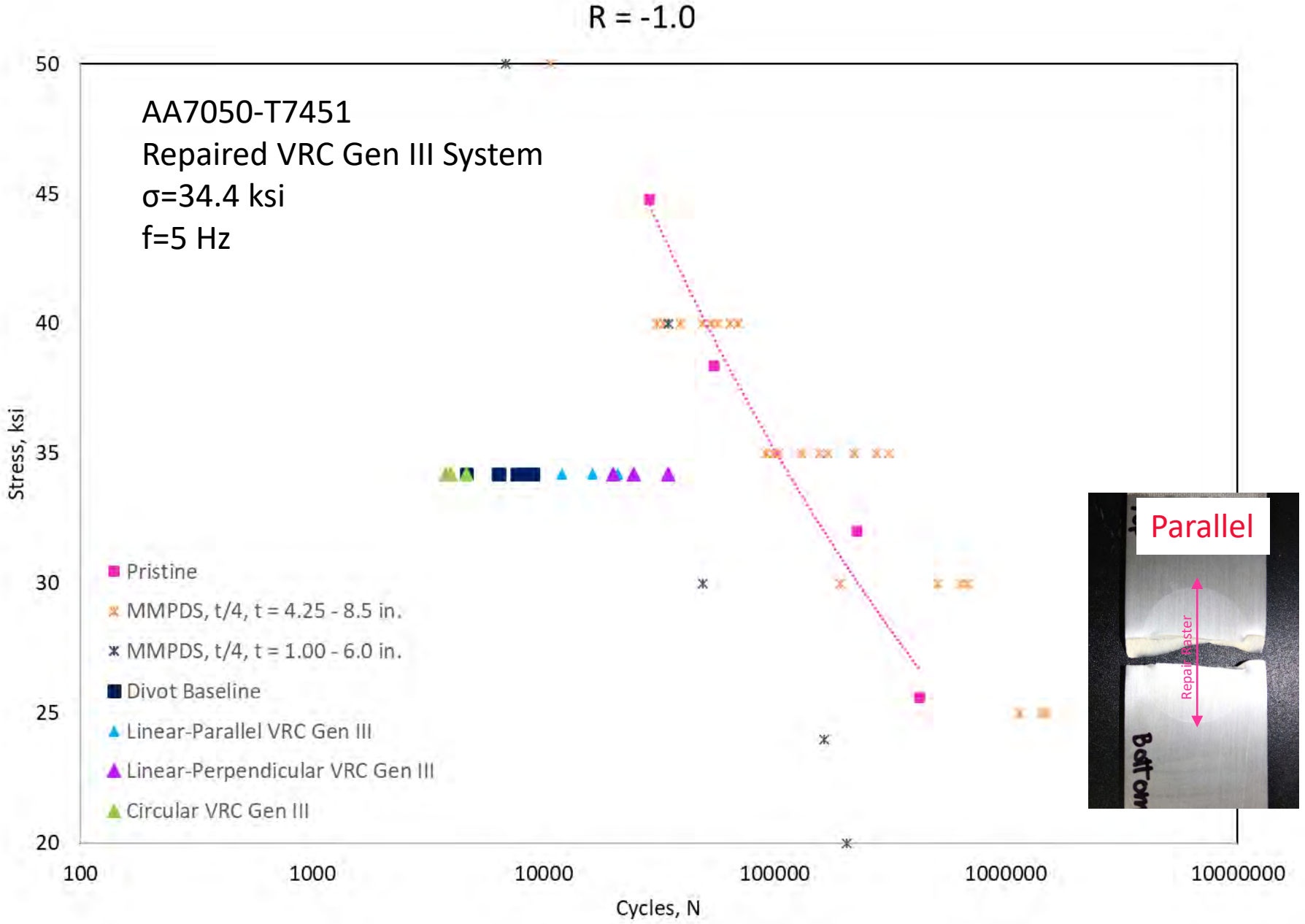
Repair

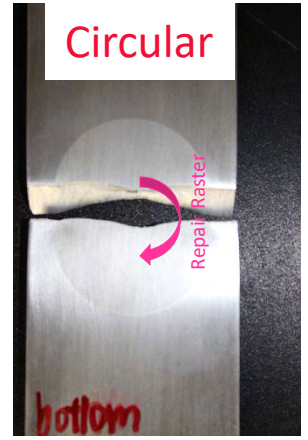
30% Divot Geometry



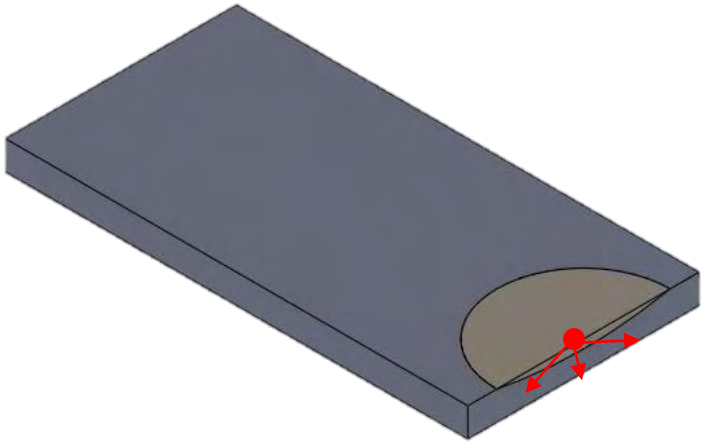


30% Divot Geometry



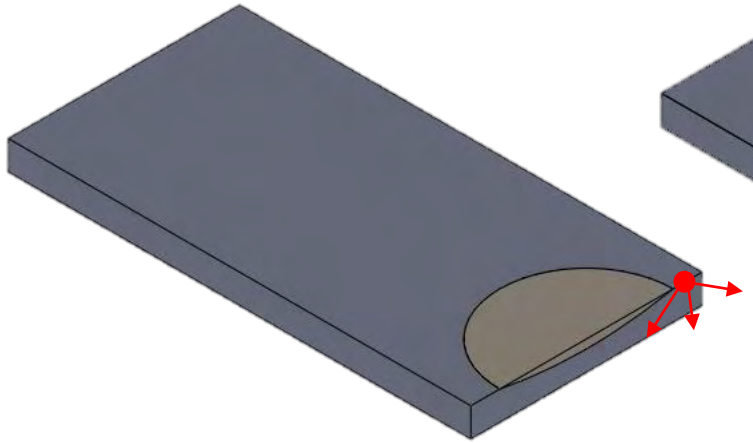


Fracture Nucleation Location



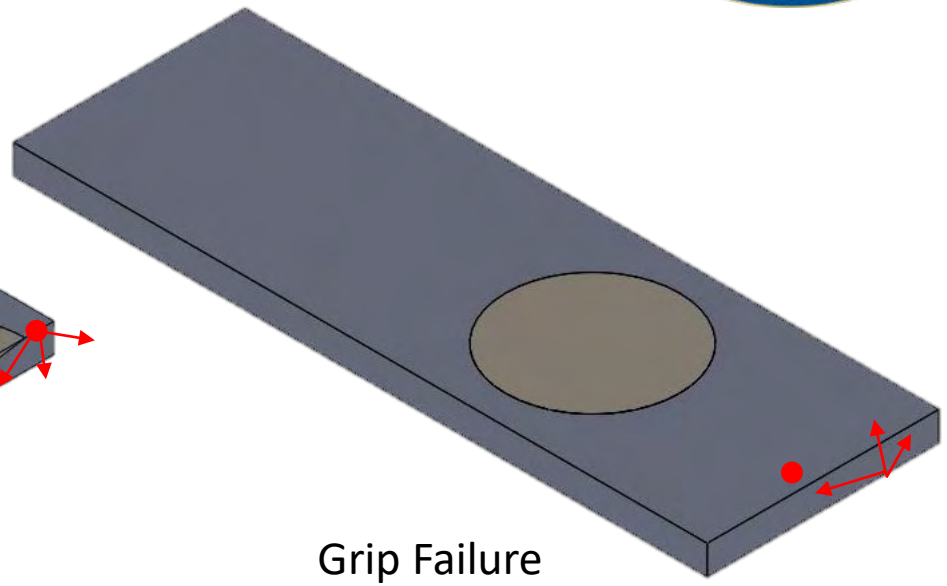
Divot Failure

Fracture nucleation at the center of the divot, where the Cold Spray is thickest.



Edge Failure

Fracture nucleation at one or both sides of the divot, completely in the wrought material. Not noted in these samples.

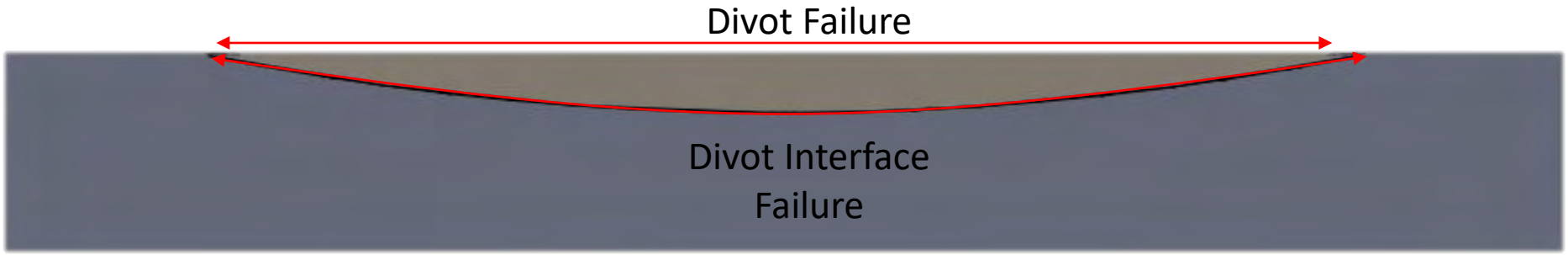


Grip Failure

Fracture can nucleate from any location, in any direction.

Failure nucleation location can highlight information about how the load is being transferred between the cold spray and wrought material. For an unrepaired sample, the failure should start near the base of the divot due to the highest stress localization. If the cold spray is able to carry load equivalent to the wrought material the nucleation location could move into the cold spray or to other locations within the sample. Other features such as porosity, limited particle deformation or other features can also influence these events.

Fracture Nucleation Location - Thickness



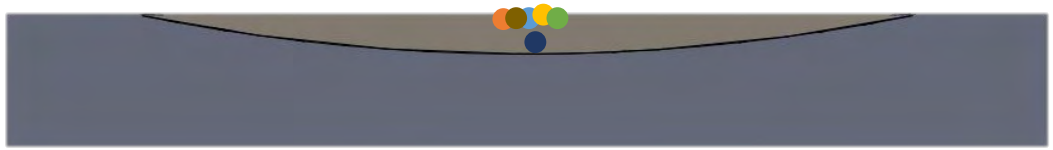
Divot Failure

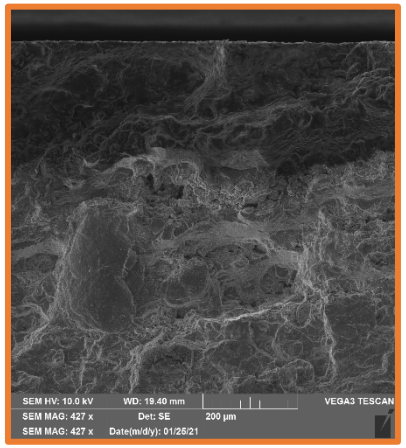
Occurs within the cold spray, generally at or near the surface

Divot Interface Failure

Occurs at the bond between the wrought and cold spray.

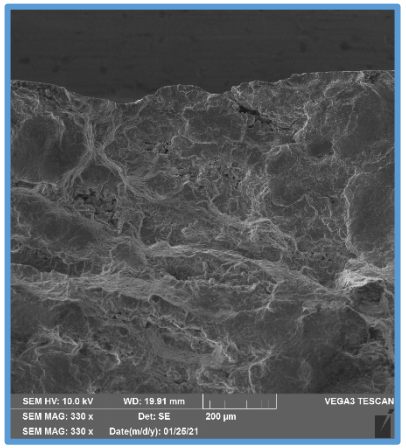
Crack Nucleation-Circular Repair



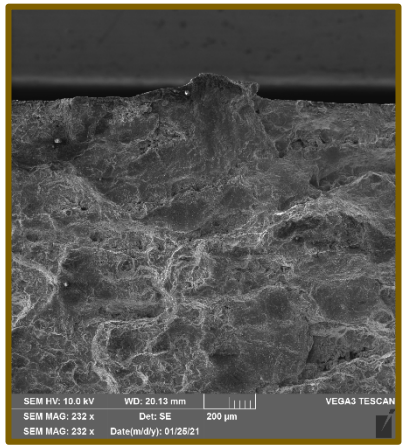


Divot Failure
R= -1
N= 3,785 cycles

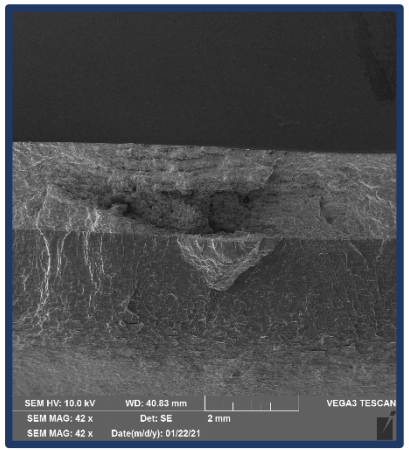
1.65mm from interface



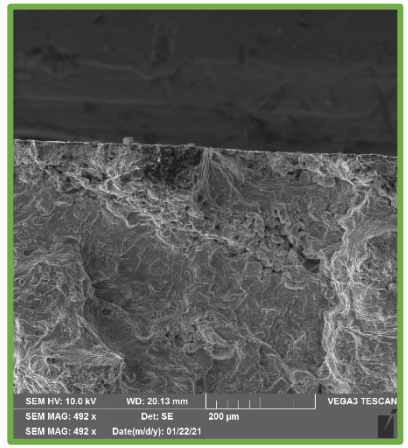
Divot Failure
R= -1
N= 3,964 cycles



Divot Failure
R= -1
N= 4,661 cycles

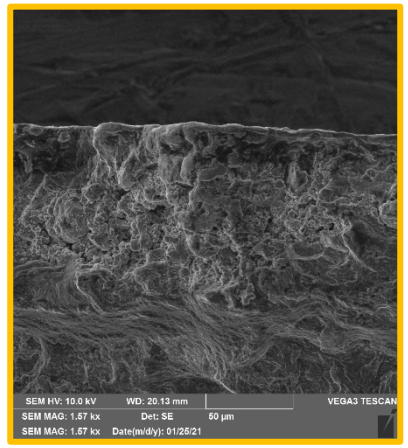


Divot Failure
R= 0.1
N= 1,298 cycles



Divot Failure
R= 0.1
N= 11,991 cycles

1.75mm from interface

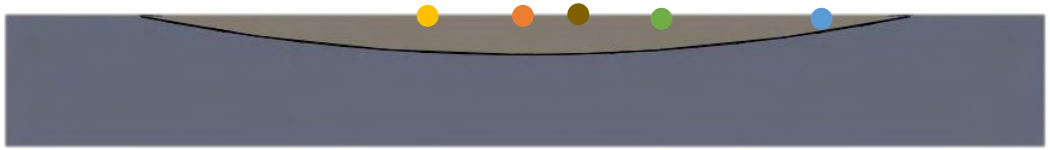


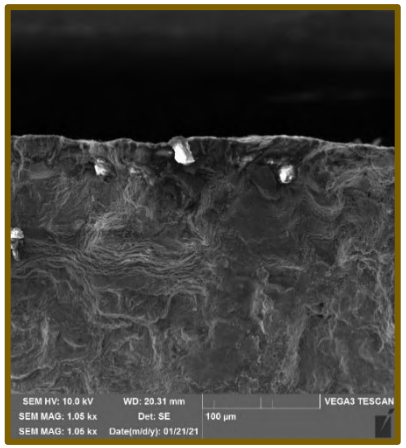
Divot Failure
R= 0.1
N= 12,458 cycles

1.80mm from interface

- In all six circular samples, fracture nucleated within the cold spray due to incomplete bonding of cold spray particles.
- Distance from initiating feature to interface measurements were not taken for three samples due to incomplete bonding of cold spray particles throughout the coating and multiple initiation sites.

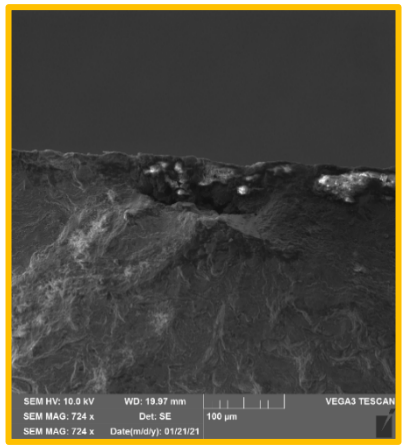
Crack Nucleation Linear – Parallel





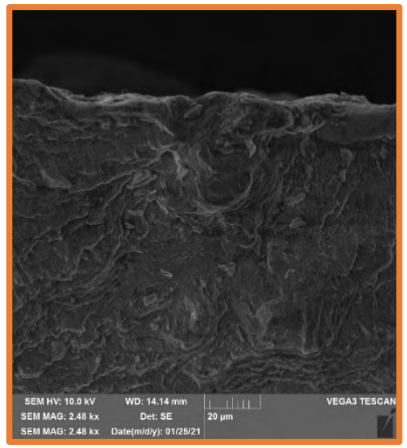
Divot Failure
R= -1
N= 11,997 cycles

1.75 mm from interface



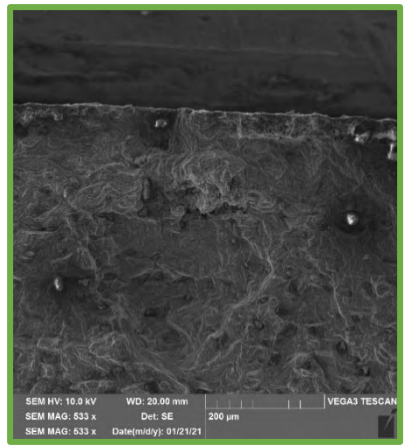
Divot Failure
R= -1
N= 15,343 cycles

1.55 mm from interface



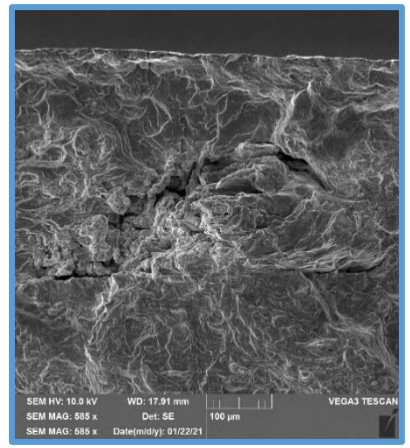
Divot Failure
R= -1
N= 21,033 cycles

1.40 mm from interface



Divot Failure
R= 0.1
N= 24,348 cycles

1.50 mm from interface



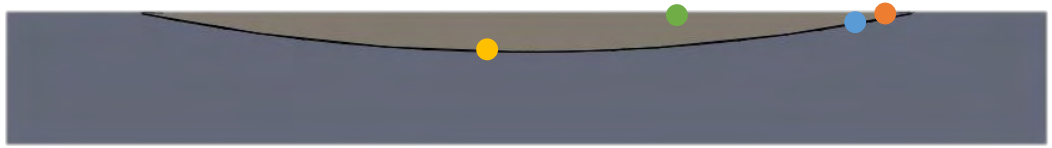
Divot-Edge Failure
R= 0.1
N= 29,197 cycles

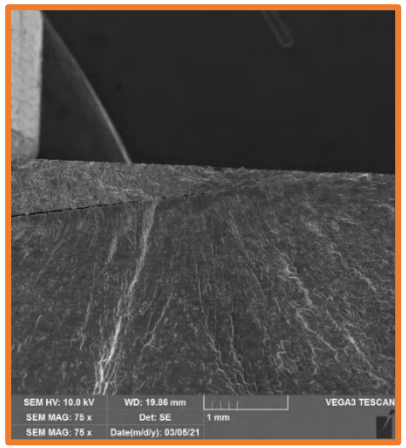
0.35mm from interface

Grip Failure
R= 0.1
N= 38,524 cycles

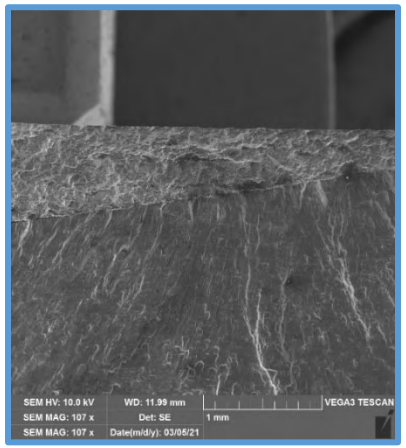
- In most of the linear-parallel samples, sprayed parallel to the length of the coupon, fracture initiated within the cold spray. No obvious signs of consistent porosity within the cold spray were noted in center cold spray. The correlates with the increased cycles to failure over the baseline.

Crack Nucleation Linear – Perpendicular Repair



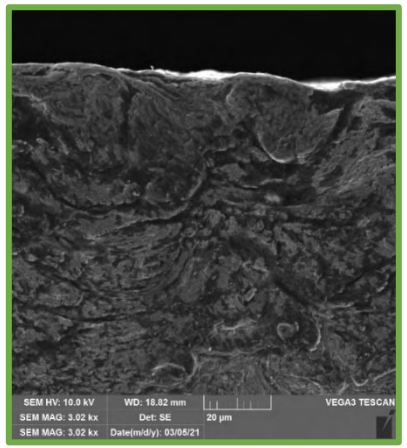


Divot-Edge Interface Failure
R= -1
N= 20,060 cycles



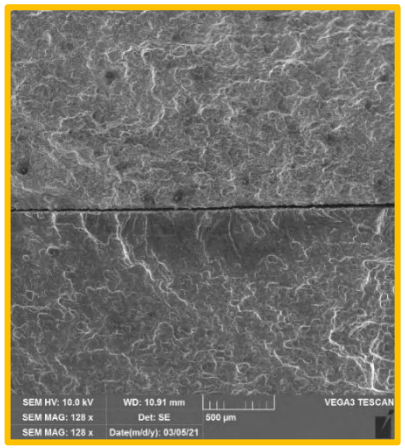
Divot-Edge Failure
R= -1
N= 24,590 cycles

0.36mm from interface

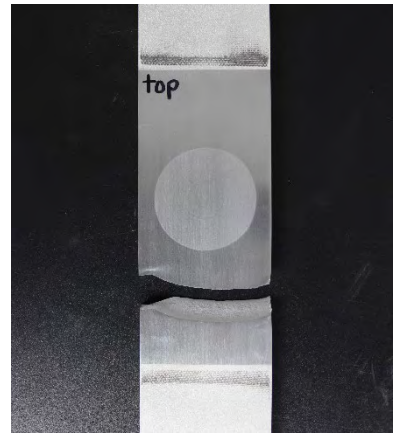


Divot Failure
R= -1
N= 34,693 cycles

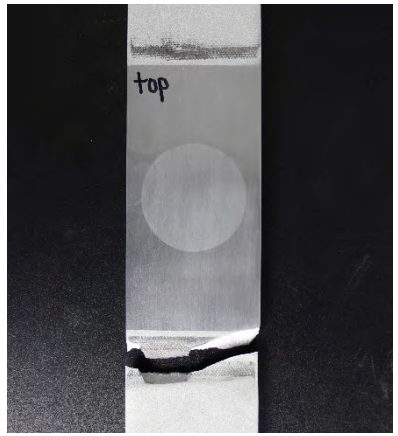
1.45mm from interface



Divot Interface Failure
R= 0.1
N= 39,202 cycles



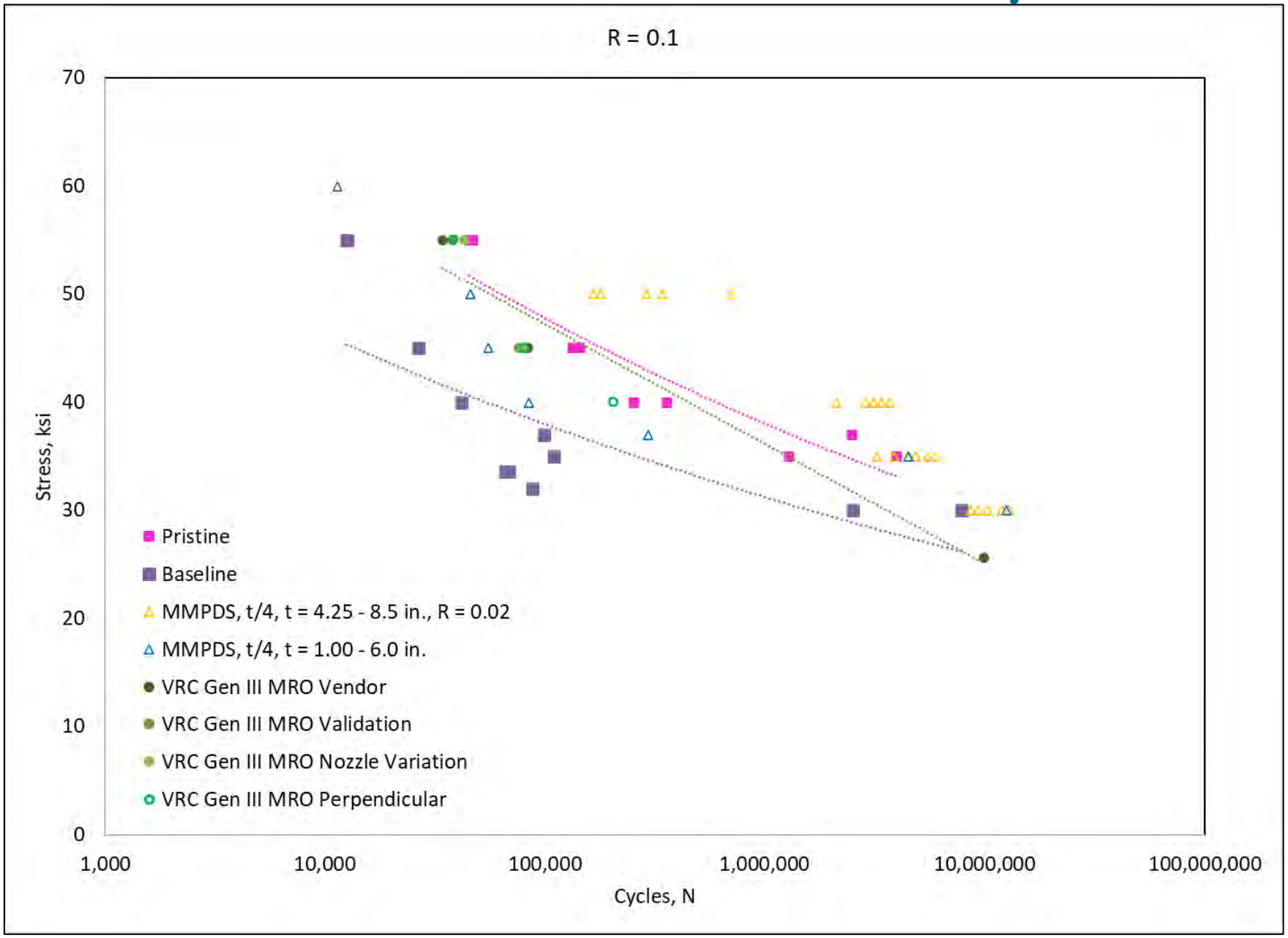
Grip Failure
R= 0.1
N= 35,611 cycles



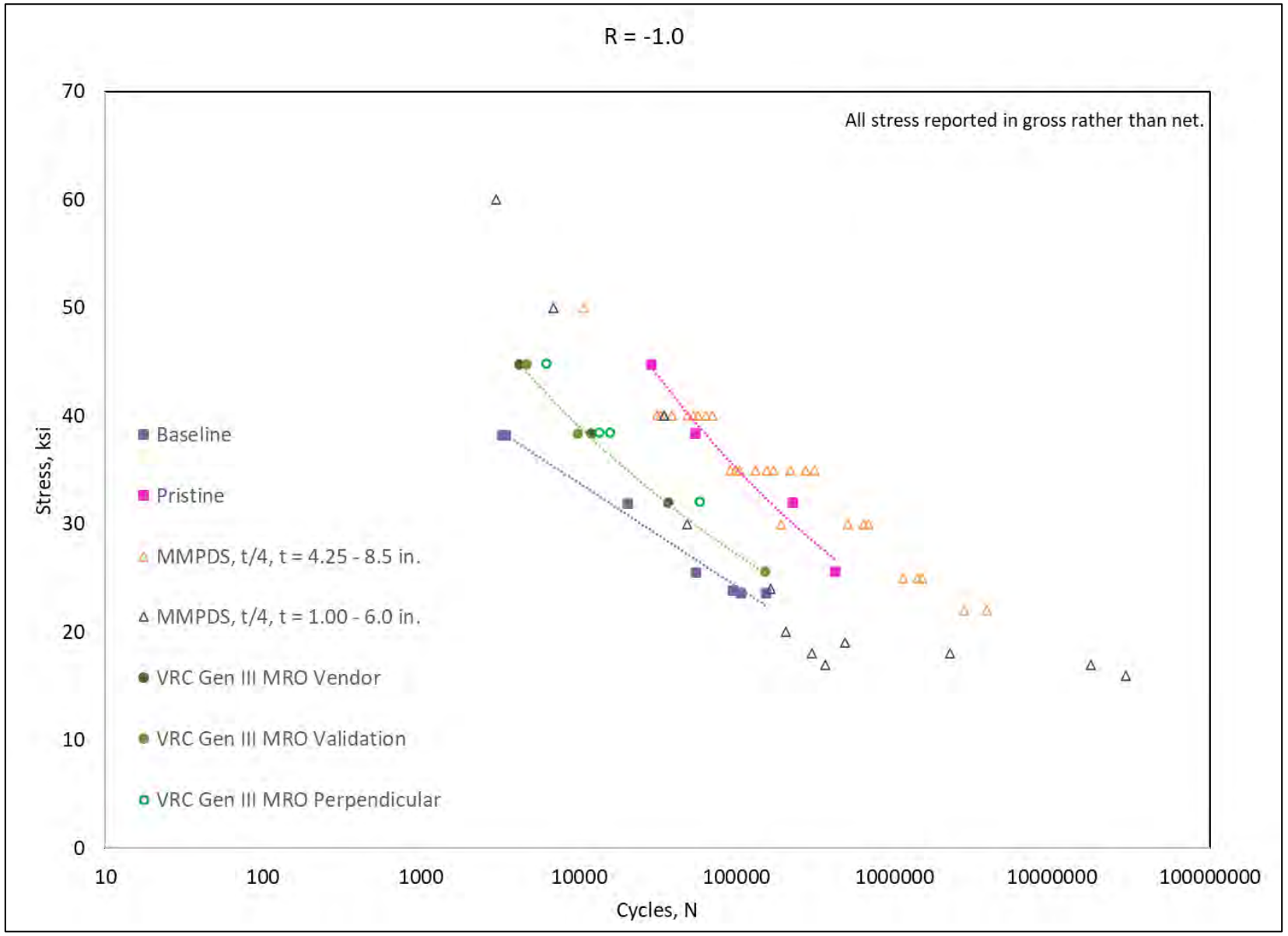
Grip Failure
R= 0.1
N= 45,580 cycles

- Linear samples sprayed perpendicular to the length of the coupon performed better than the other raster patterns. This led to a range of initiation locations.
- Two samples initiated in the divot center (one at the CS surface and one in the interface), two broke at the divot-edge (one higher and one at the interface), and two broke within the grip section.

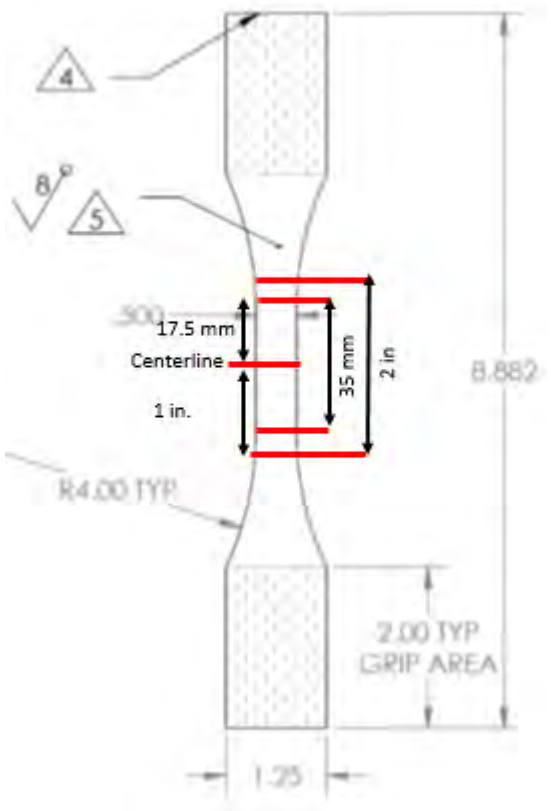
15% Blend Geometry

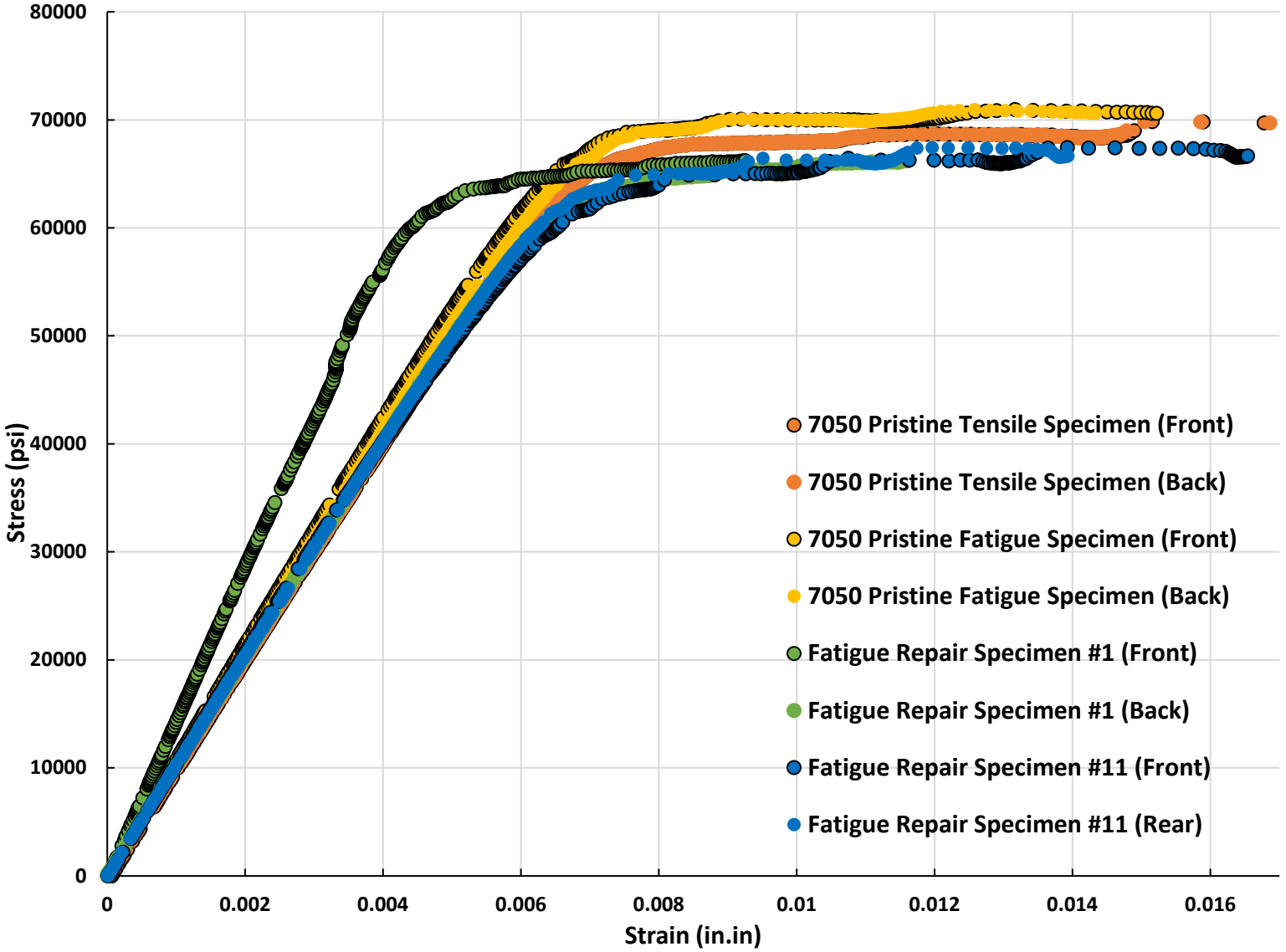


15% Blend Geometry

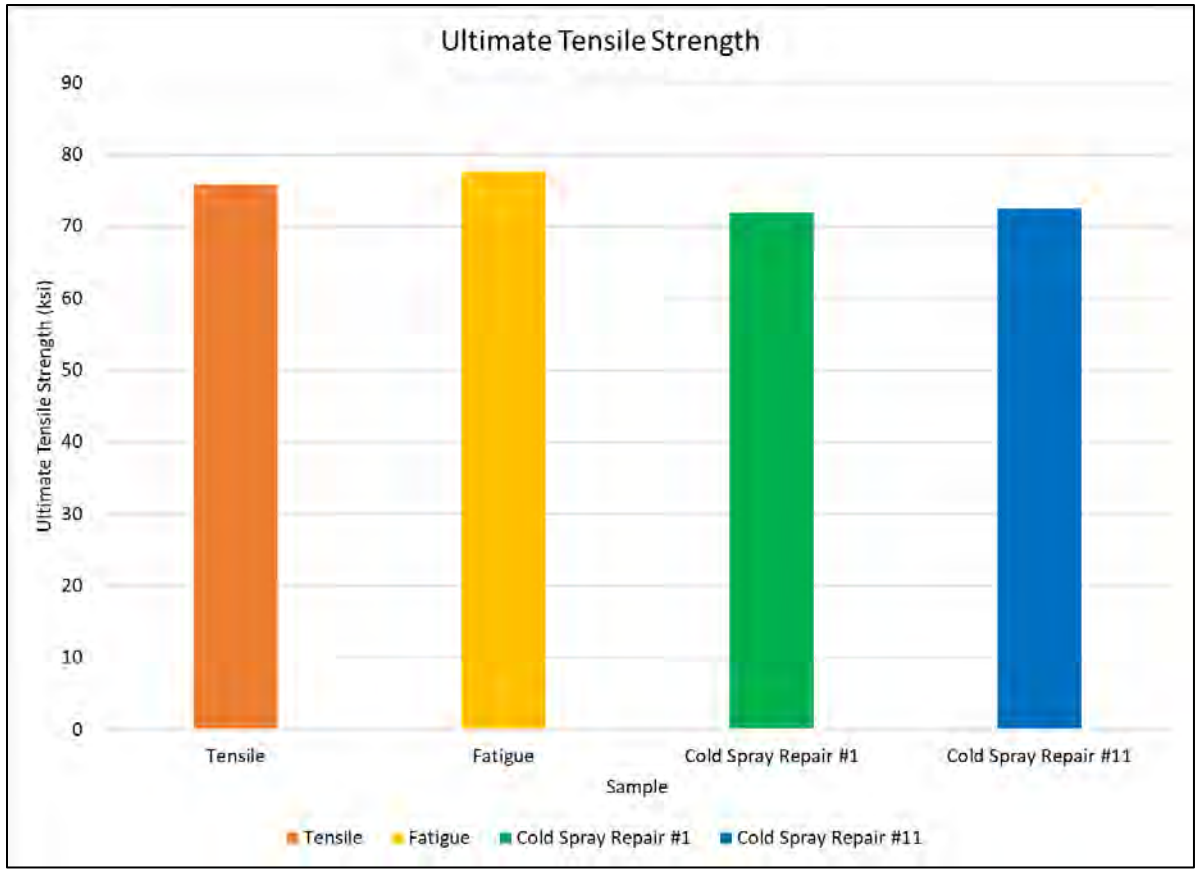


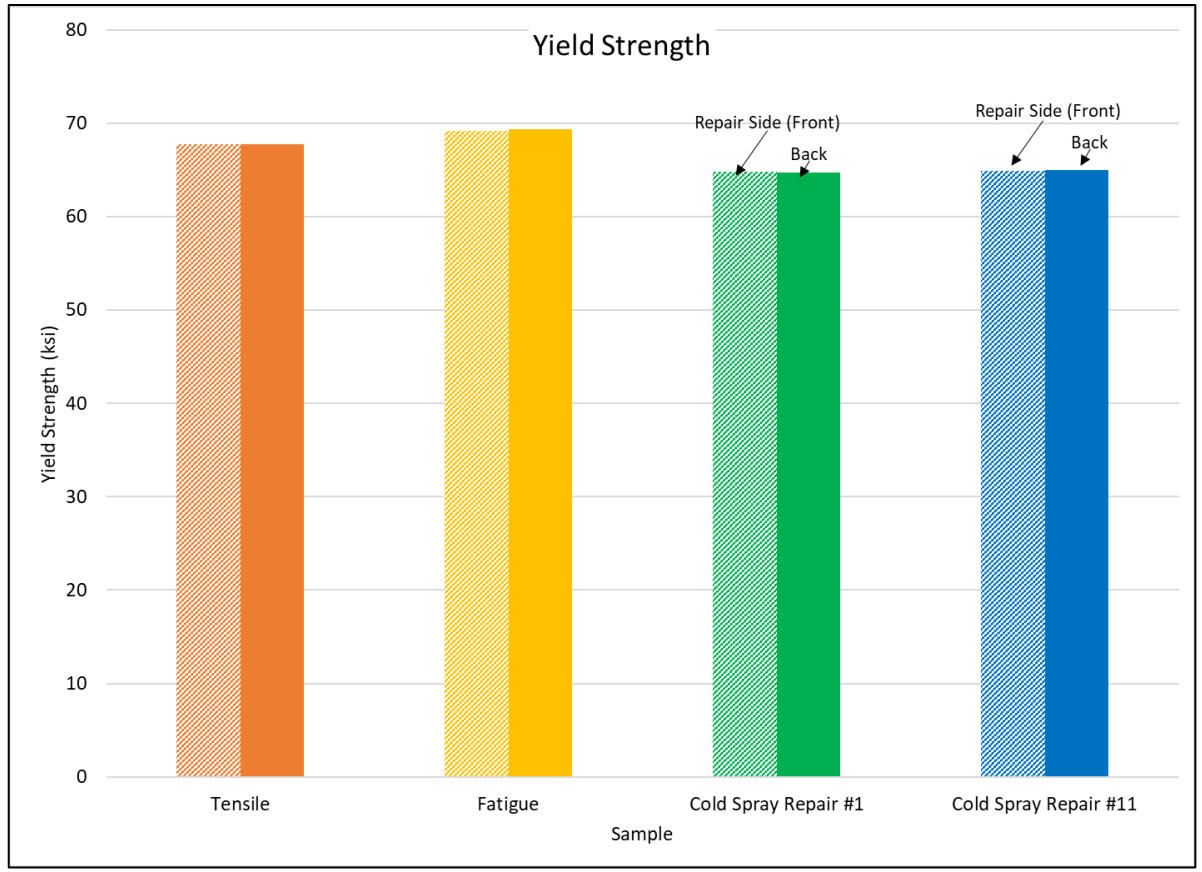
Tensile Testing



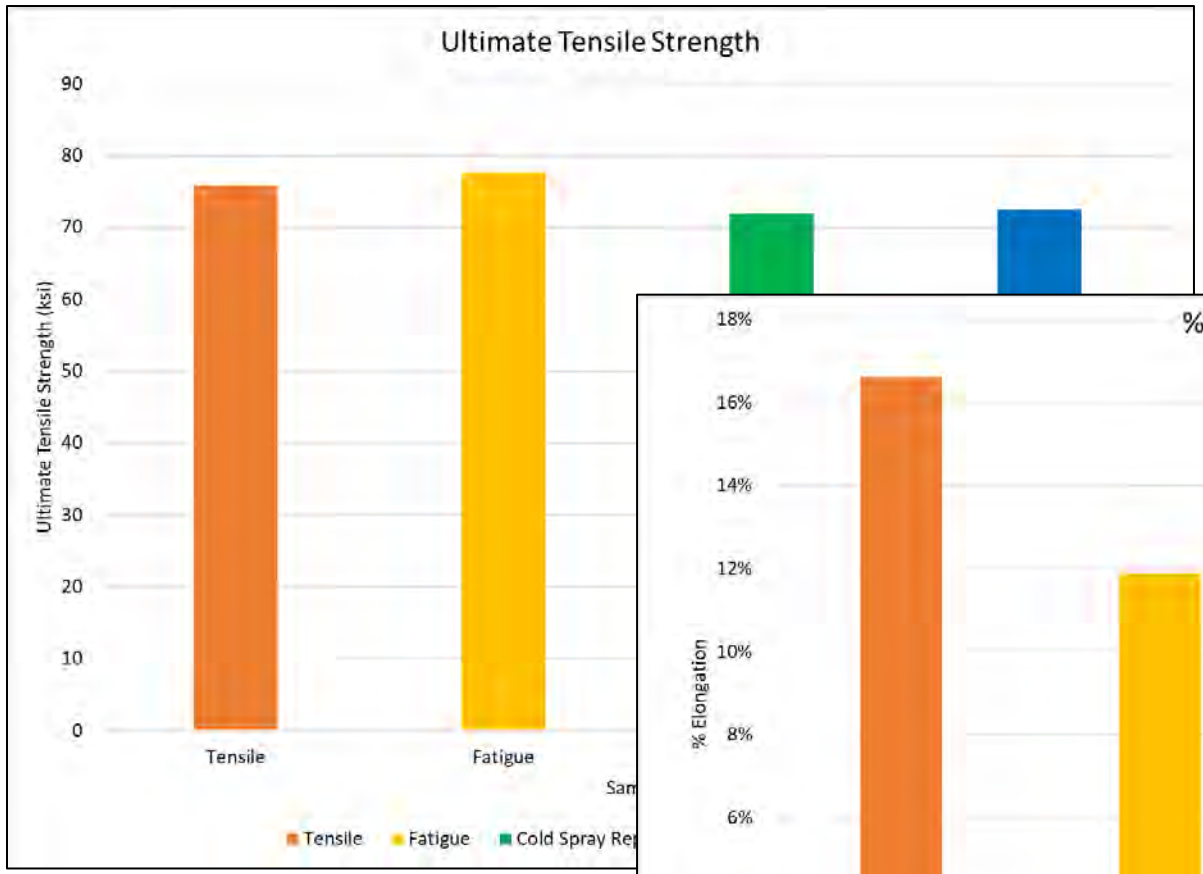


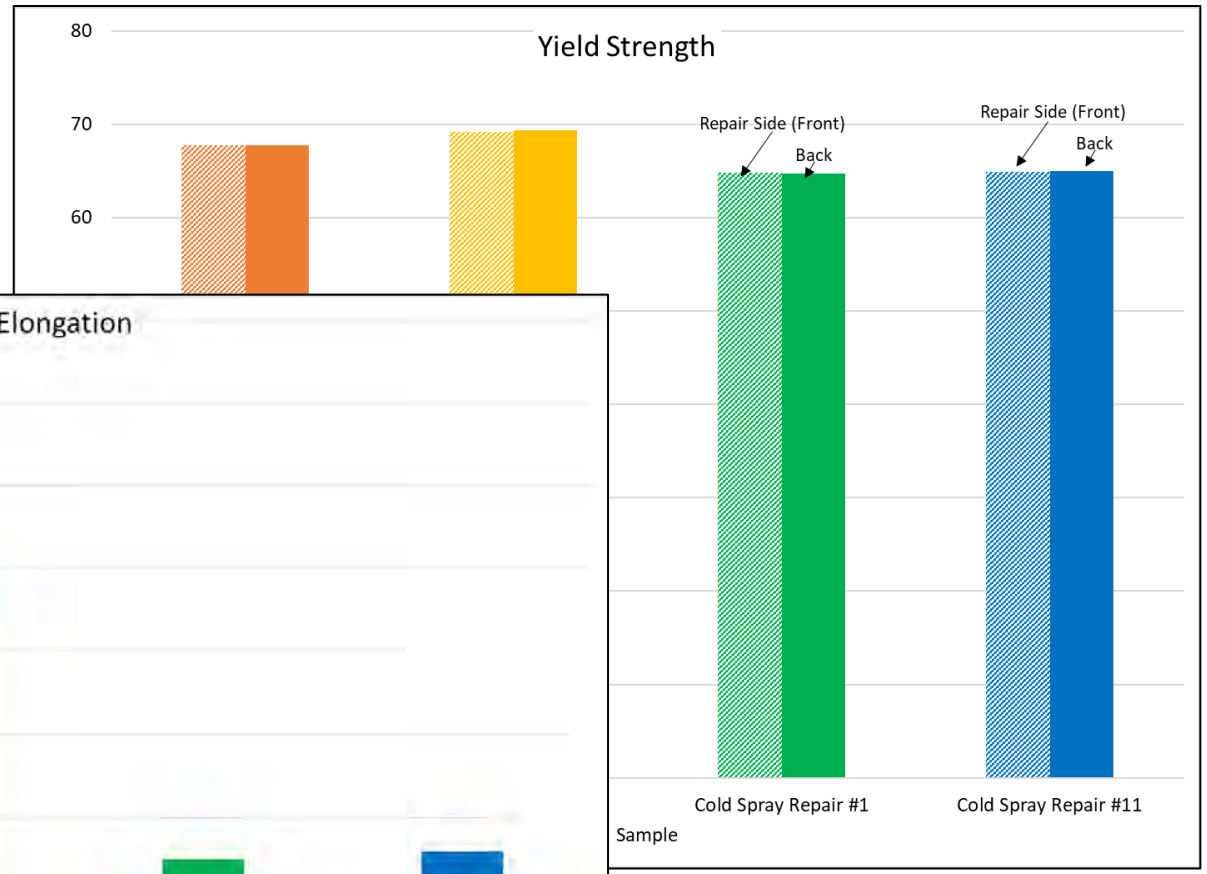
Tensile Properties

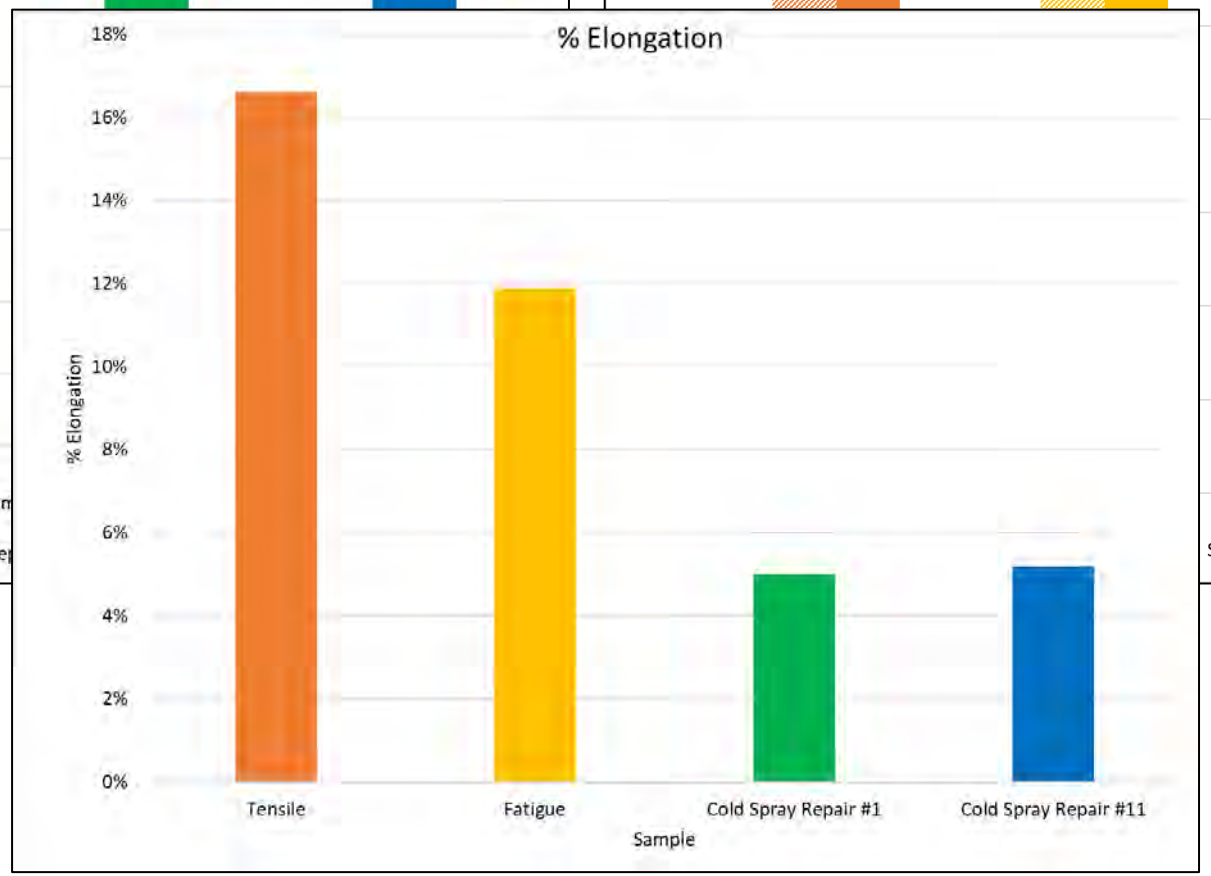




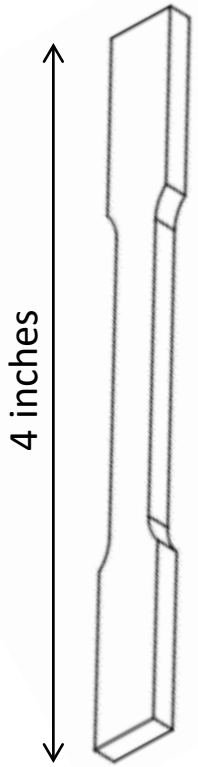
Tensile Properties

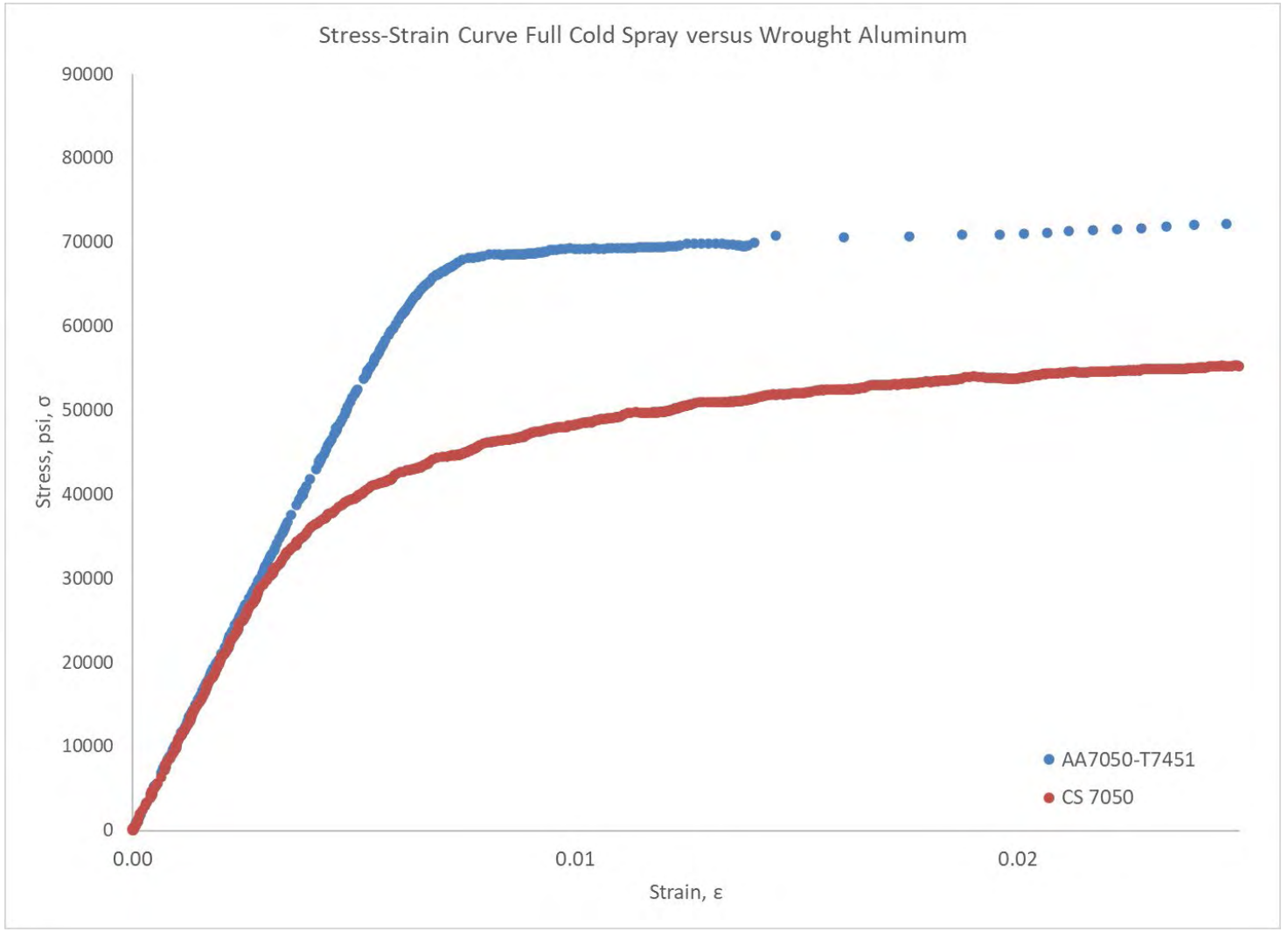




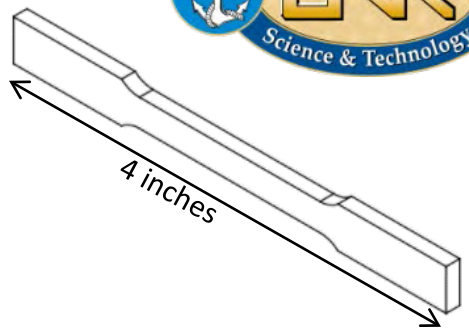


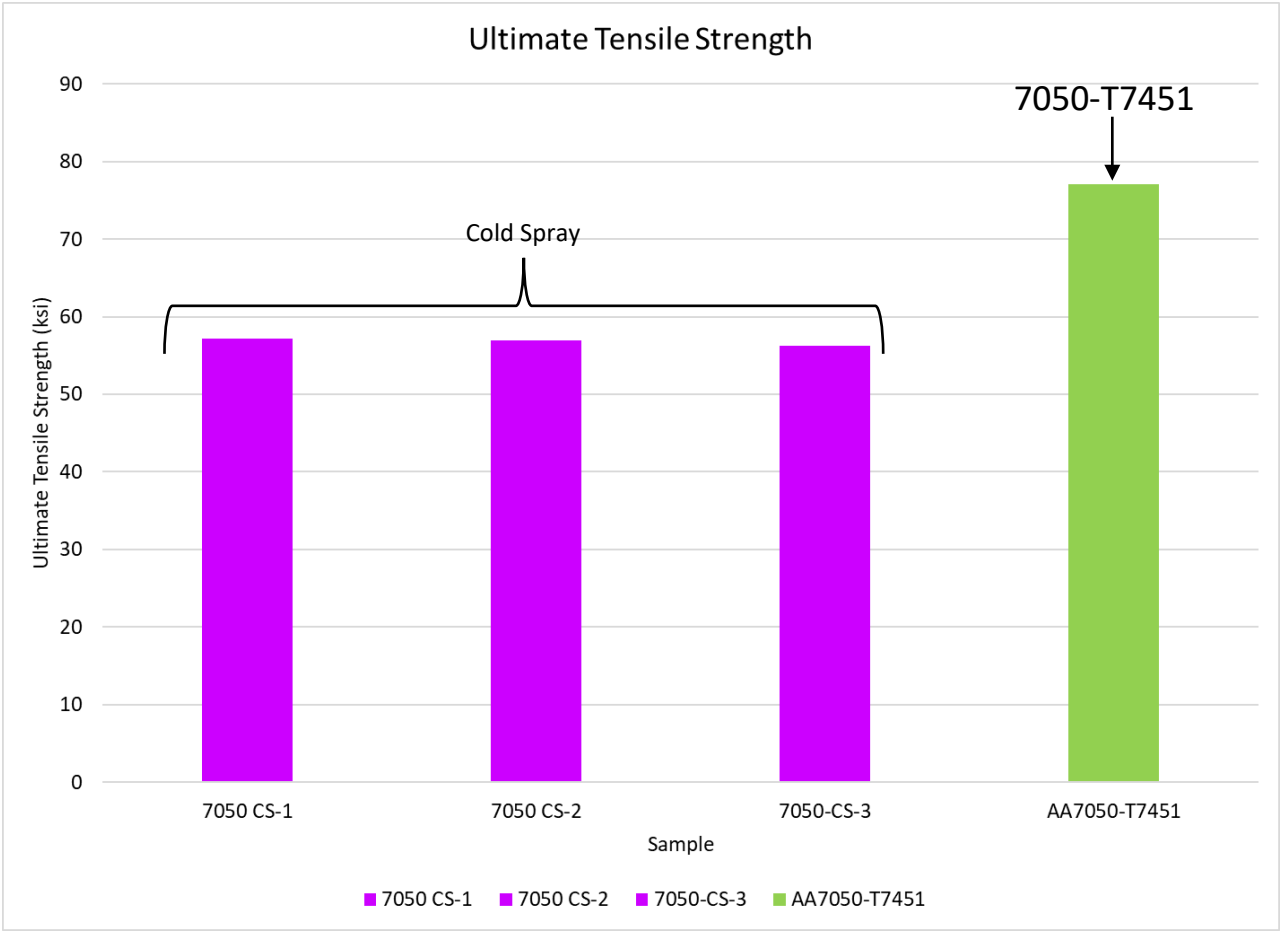
Tensile Testing Full 7050 CS Samples

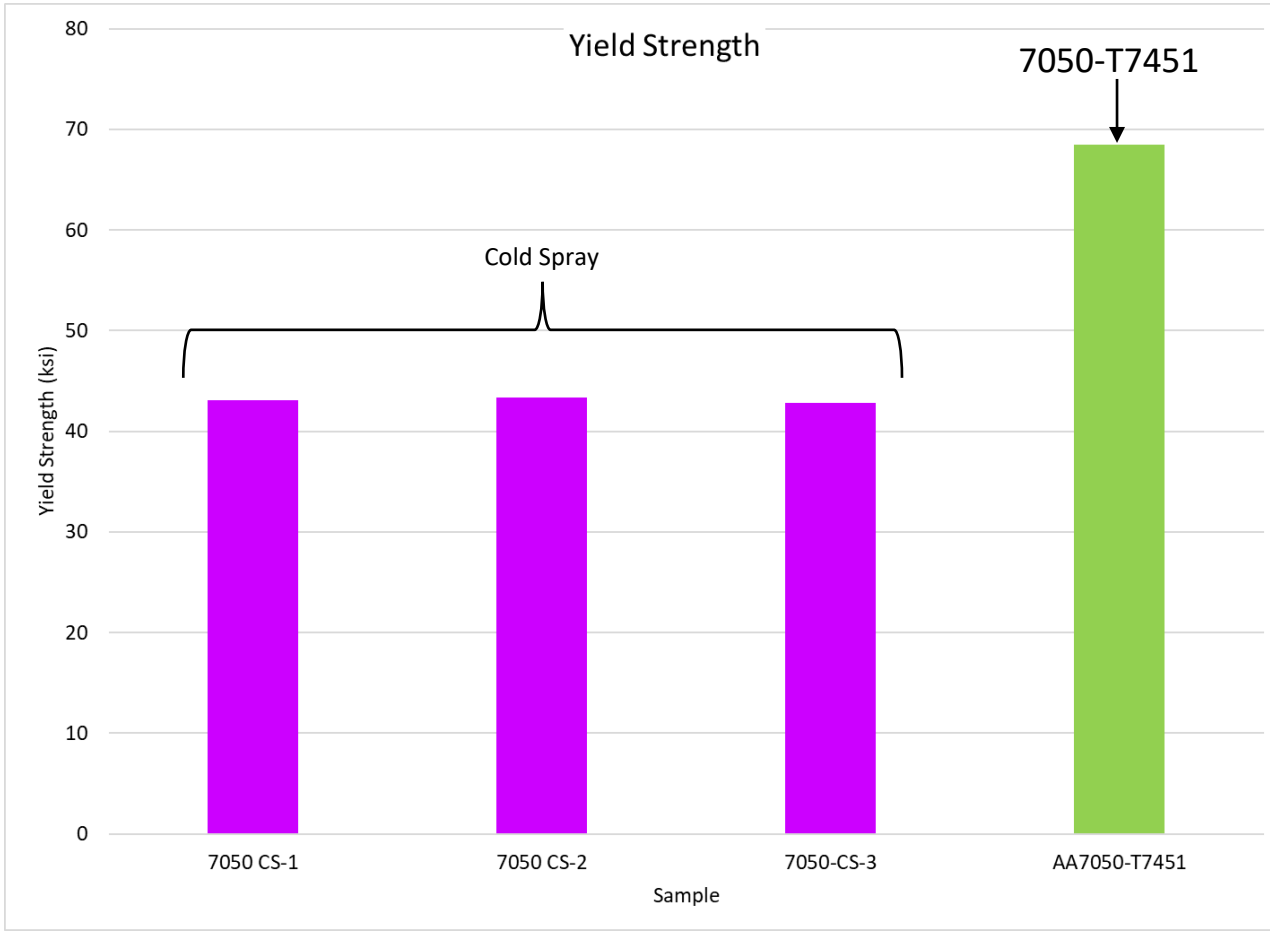




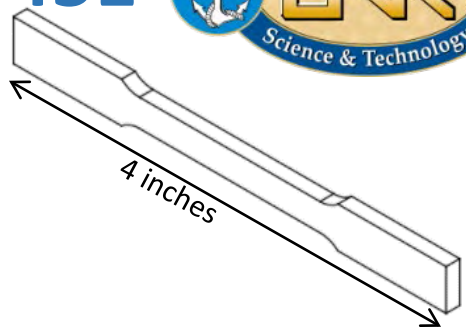
Tensile Testing Full Cold Spray AA7050-T7451

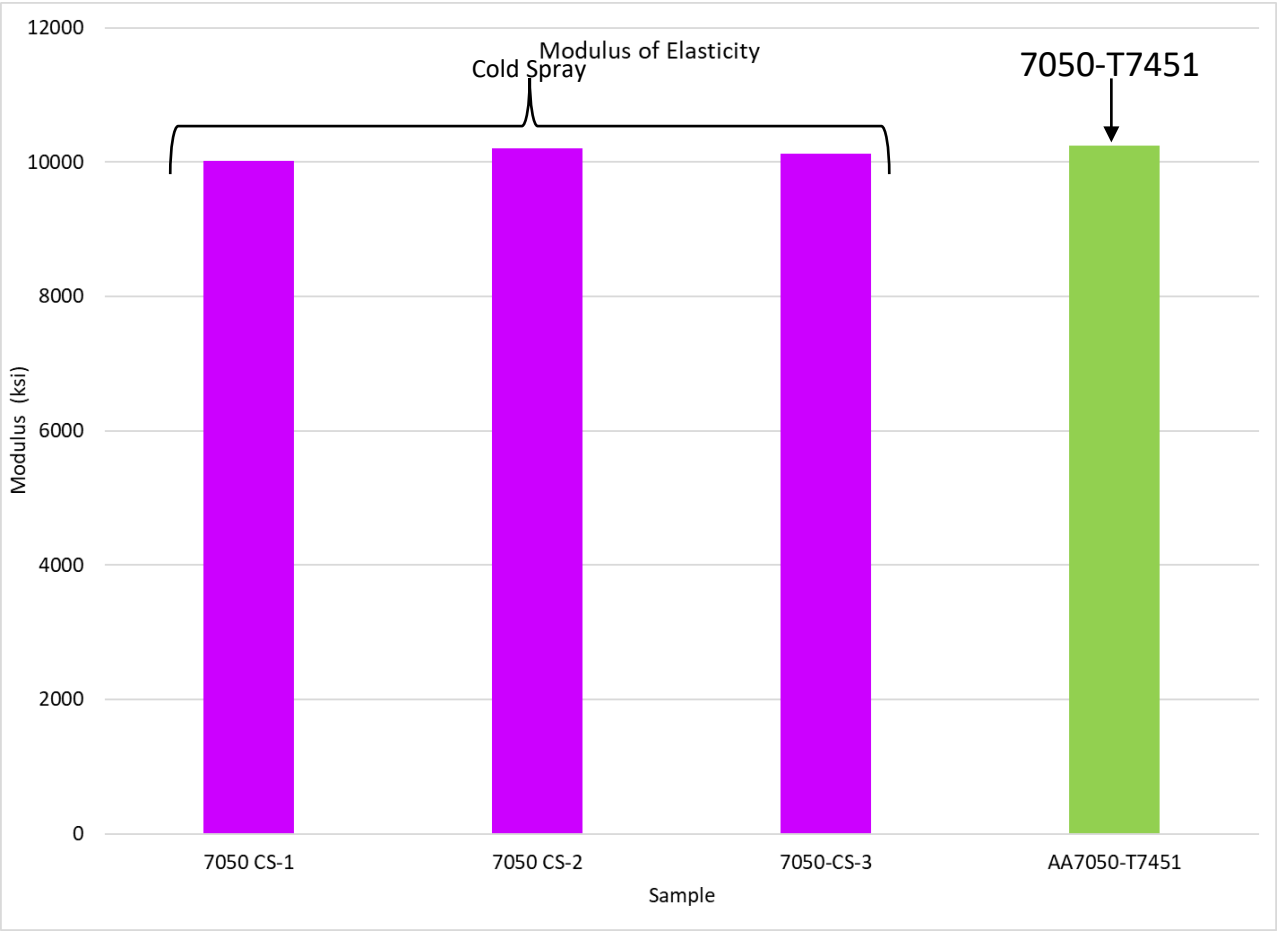


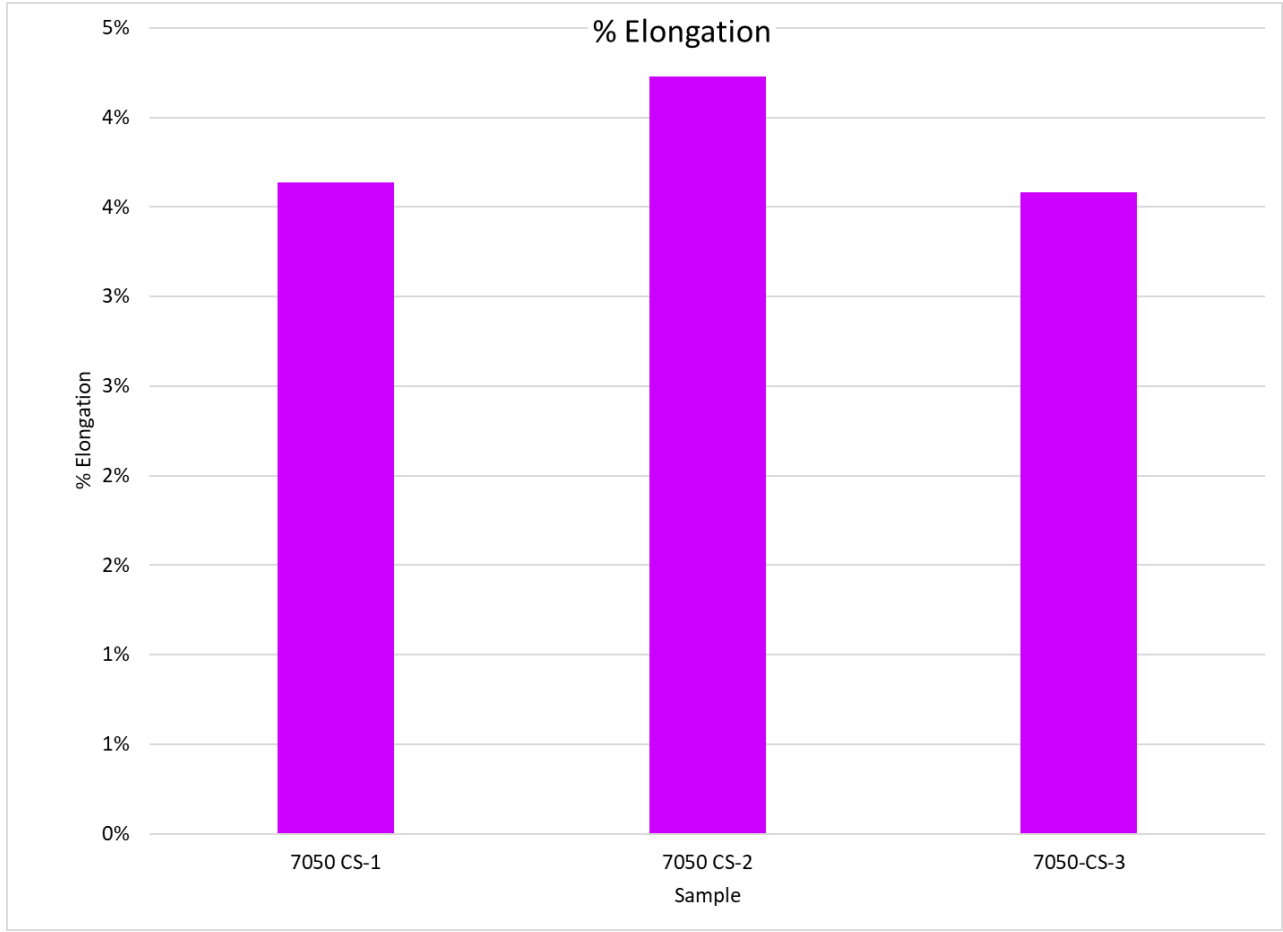




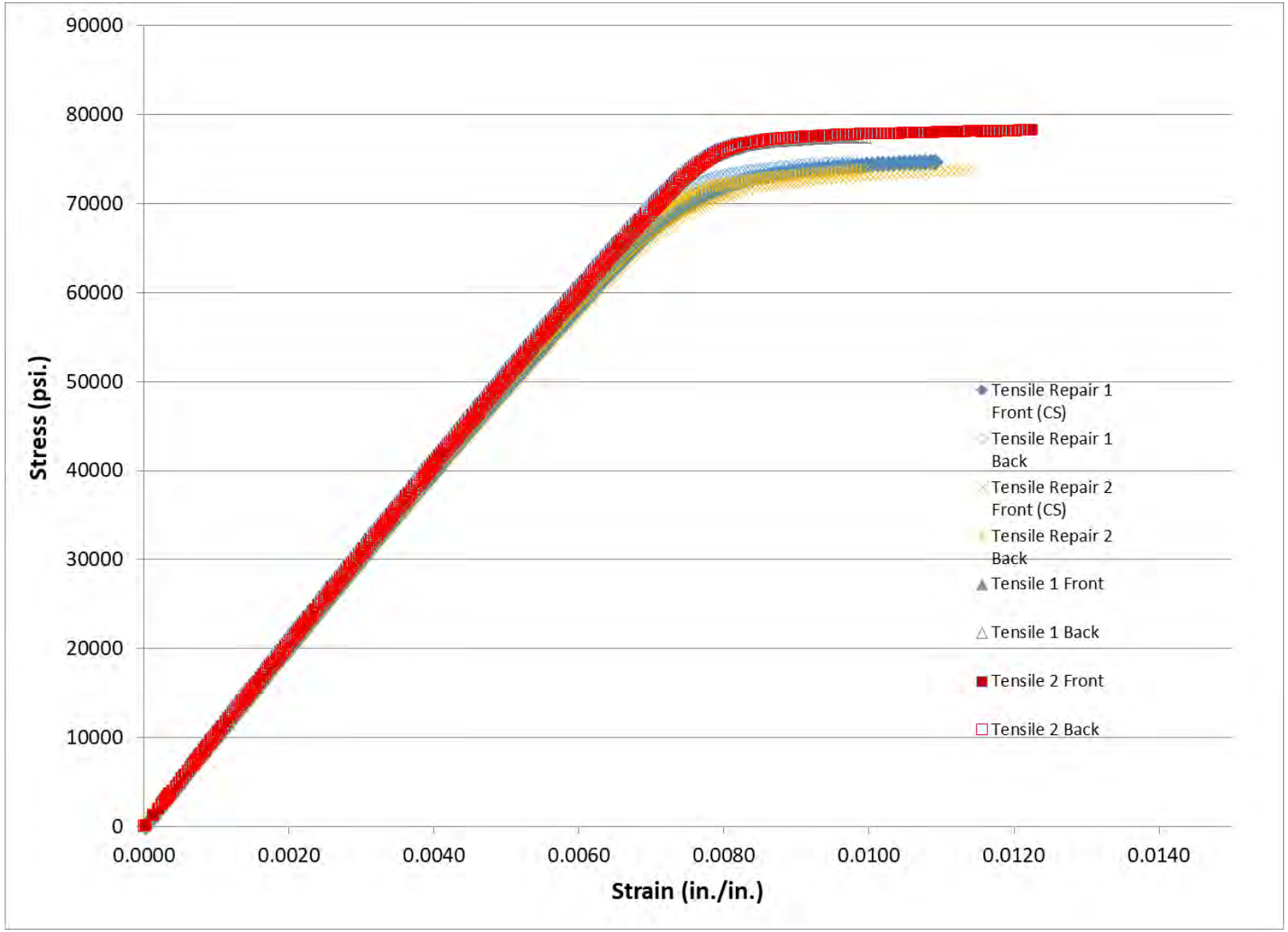
Tensile Testing Full Cold Spray AA7050-T7451



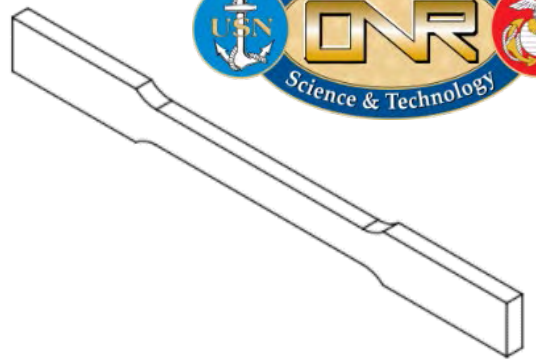


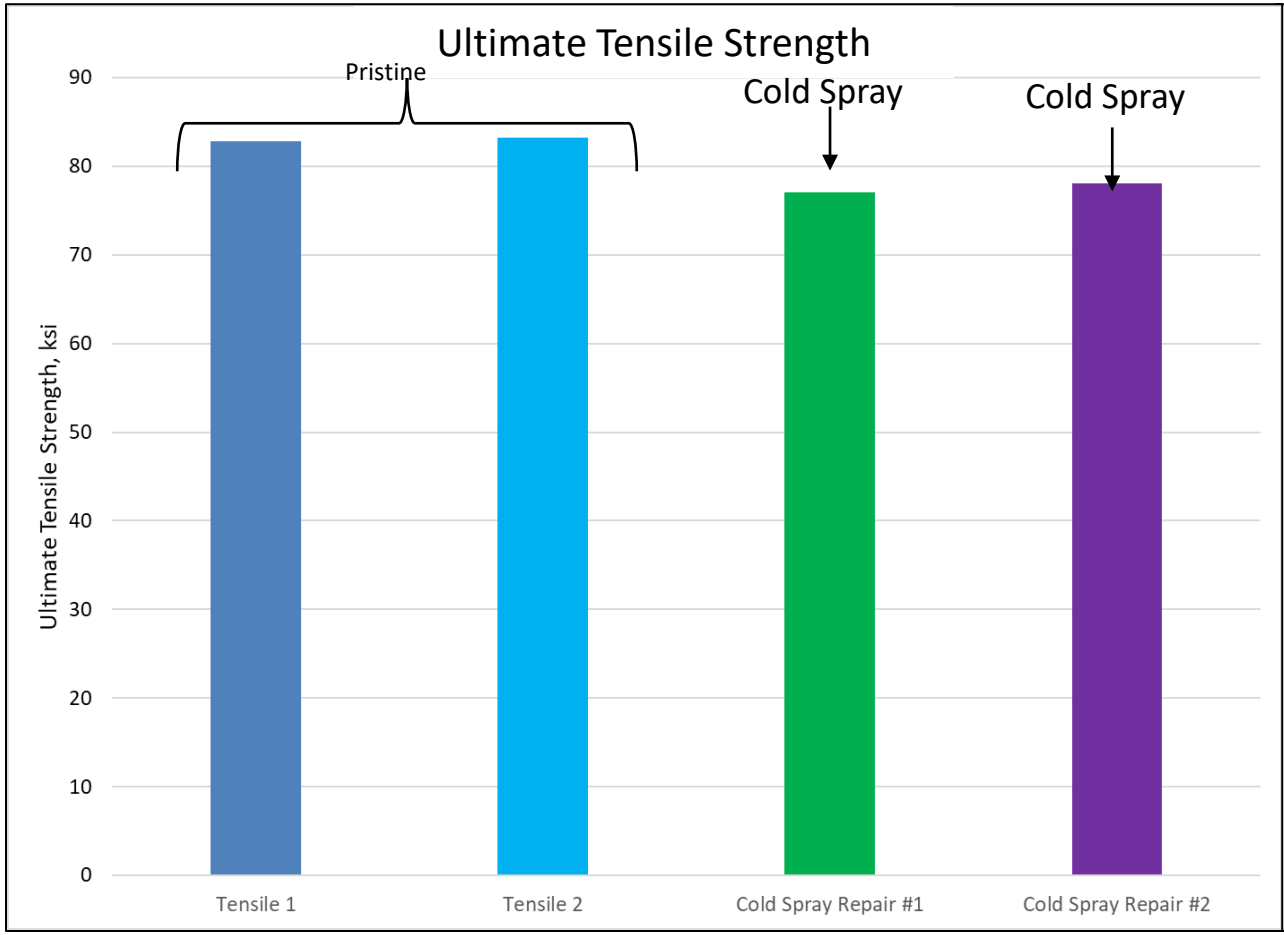


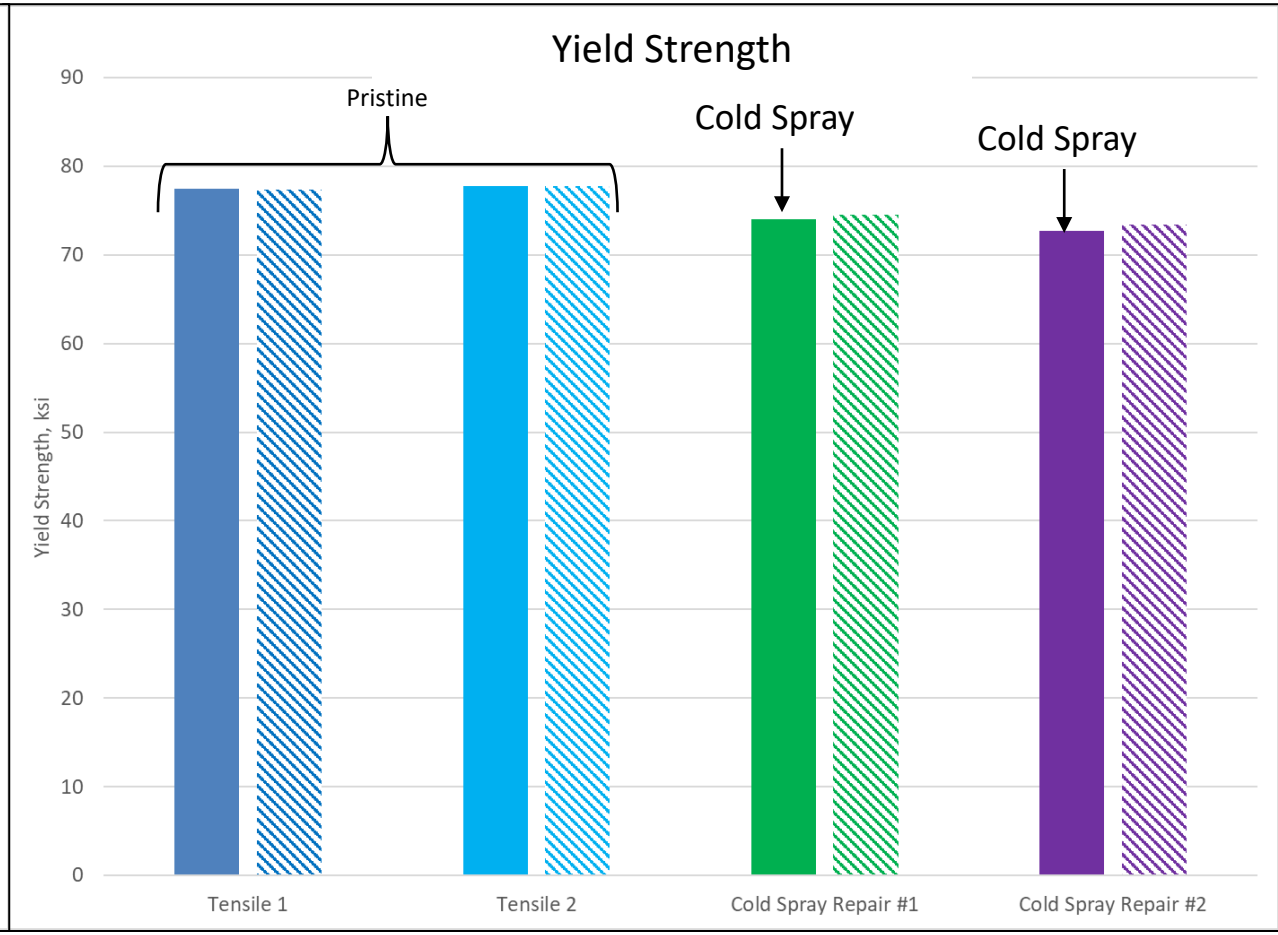
Stress-Strain Curves for AA7075-T651 CS Repair



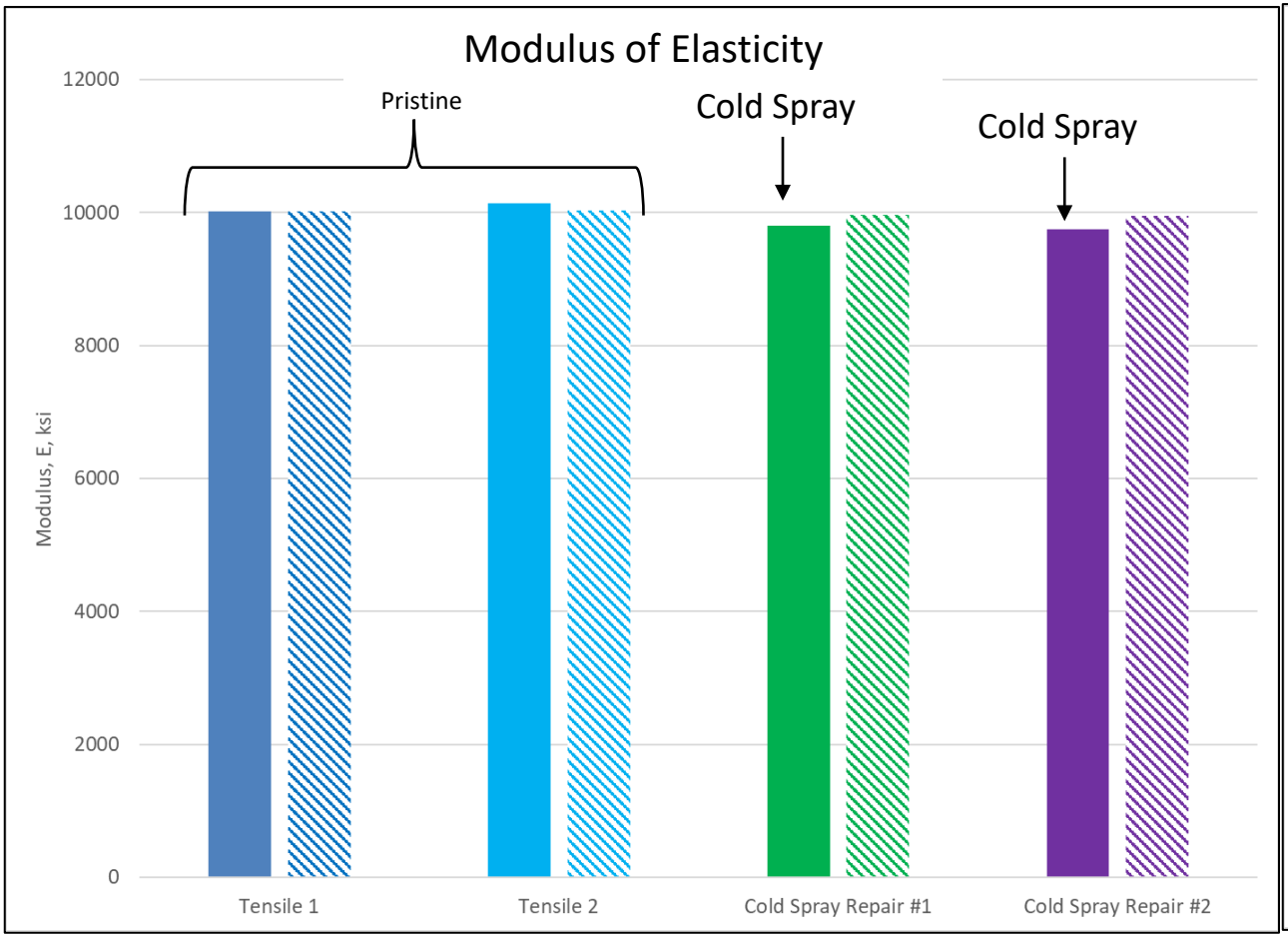
Tensile Testing AA7075-T651

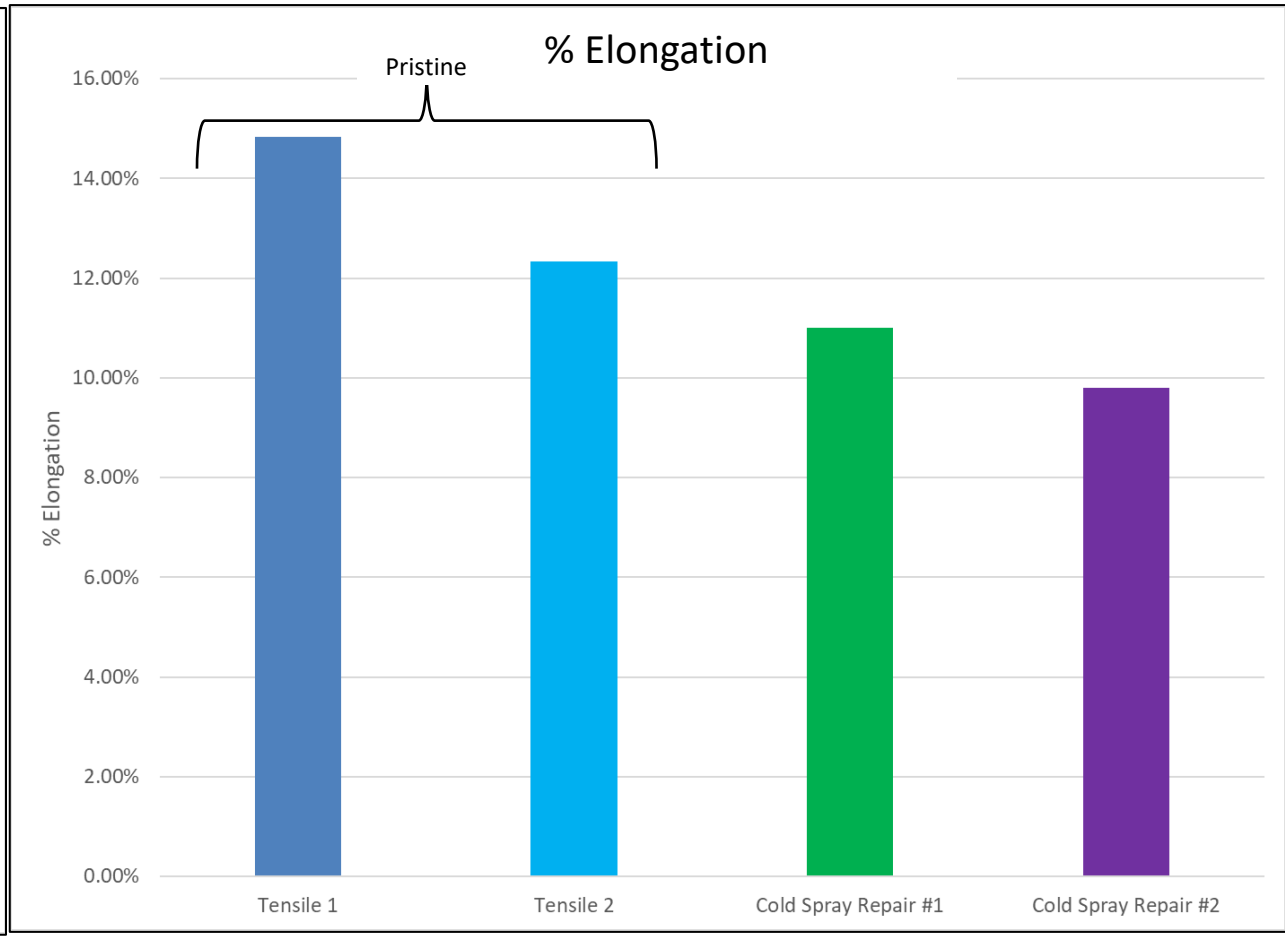




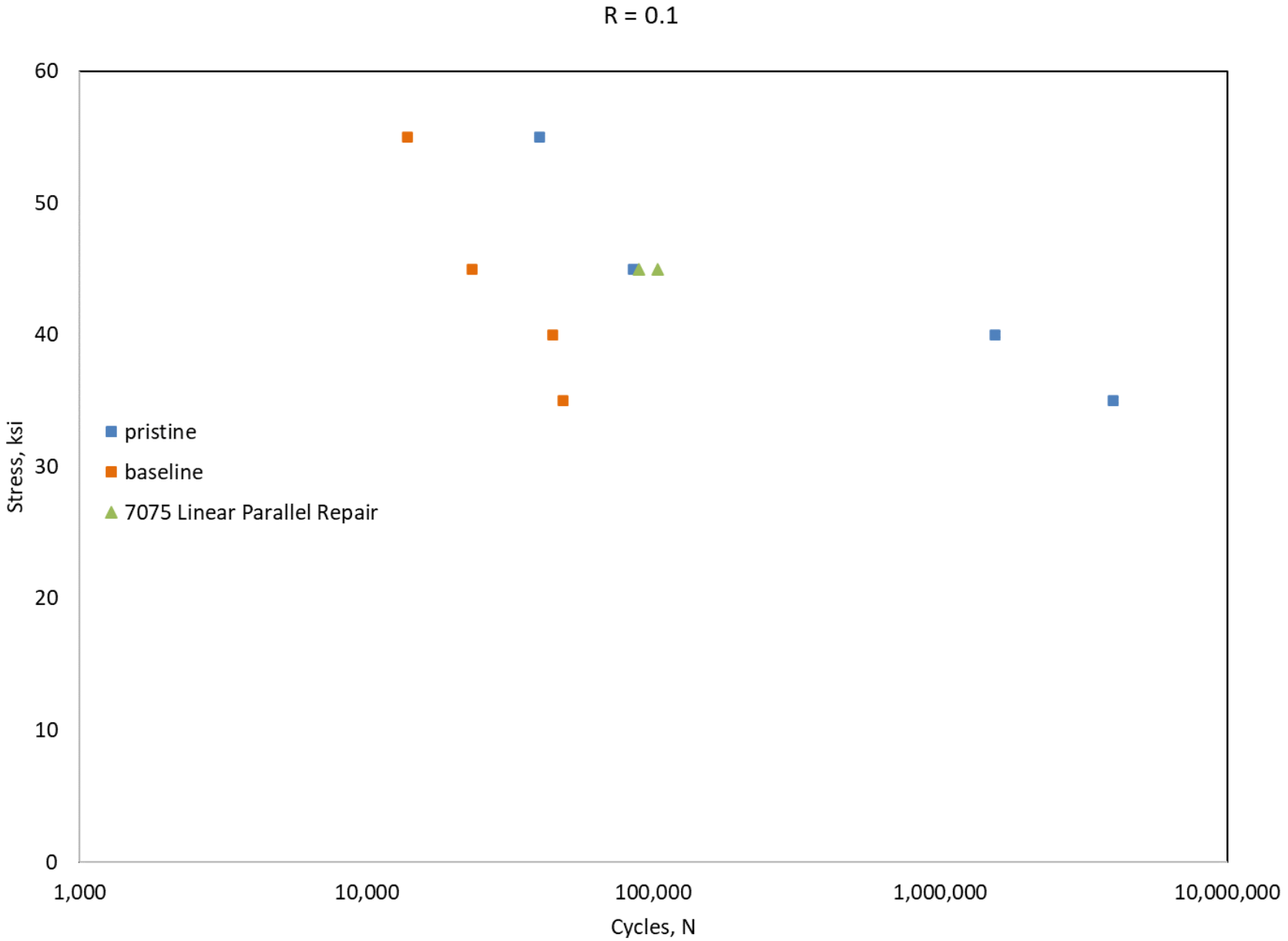


Tensile Testing AA7075-T651

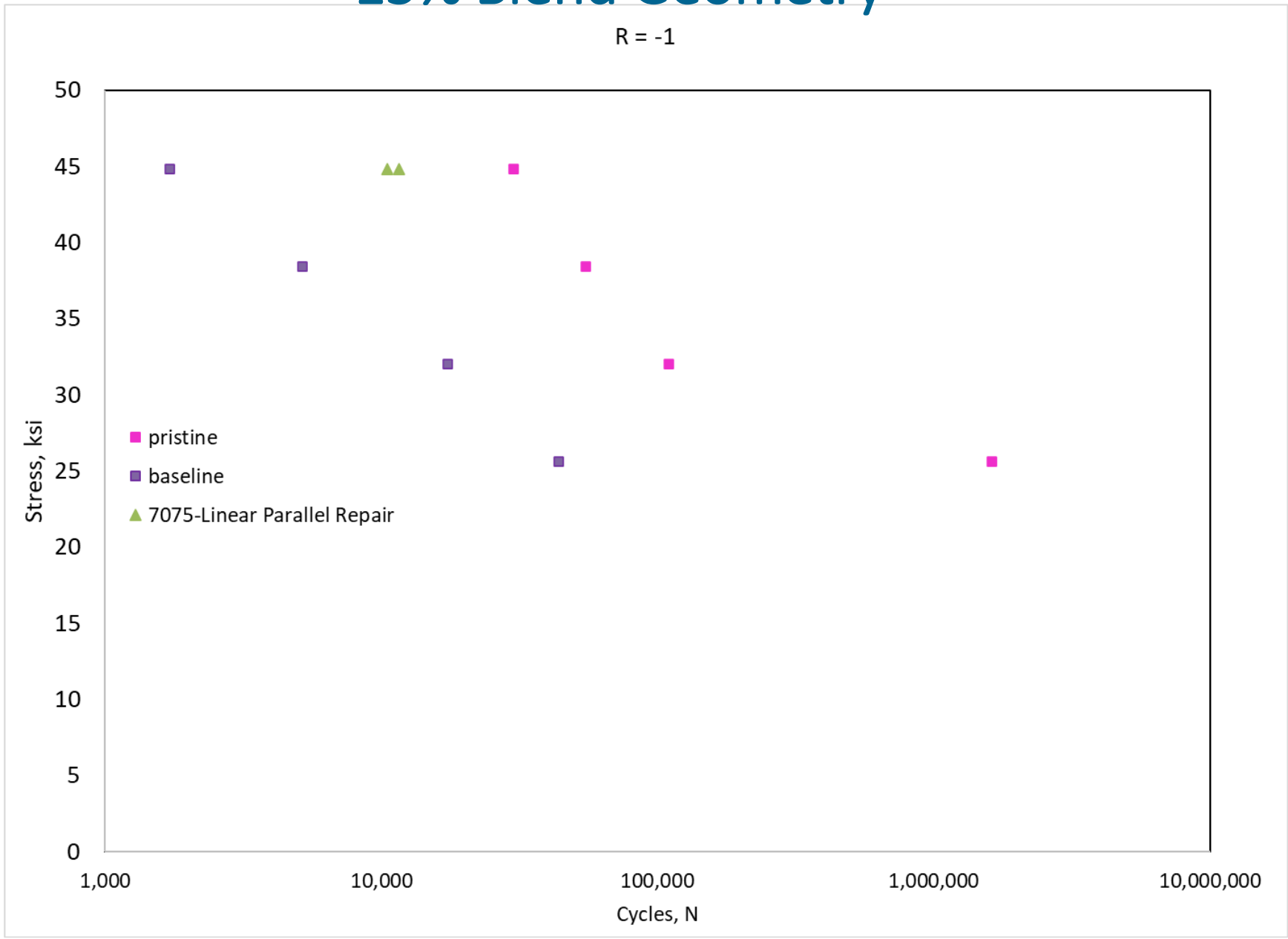




Process Transfer AA7075-T651 (Preliminary Data)
15% Blend Geometry



Process Transfer AA7075-T651 (Preliminary Data)
15% Blend Geometry



Conclusions

- AA7050-T7451 was repaired using high pressure cold spray
- The 15% repair had ultimate and yield strength approximately 95% of the wrought material
  - Two repair depths were investigated 15% and 30%; both showed an improvement in fatigue life at R=0.1 and R=-1 over unrepaired samples
  - The spray raster that showed the greatest improvement in fatigue life was perpendicular to the loading direction of the sample
    - This fatigue life improvement based on raster direction was greater for samples with wrought material surrounding the repair compared to the repairs with free cold spray edges
    - The majority of the fatigue crack initiated within the cold spray and propagated across the interface into the wrought material
- Early fatigue data shows that the AA7050-T7451 process results can be reproduced
- Full CS AA7050 shows an ultimate strength near 73% and yield strength of approximately 63% of AA7050-T7451
- Use of a similar process with AA7075-T651 shows excellent fatigue and tensile properties based on preliminary results.

Questions

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- The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the official policies and endorsements, either expressed or implied of the US Air Force Academy or the US Government.