Effect of Pre-Strain on Nitinol Fatigue Life

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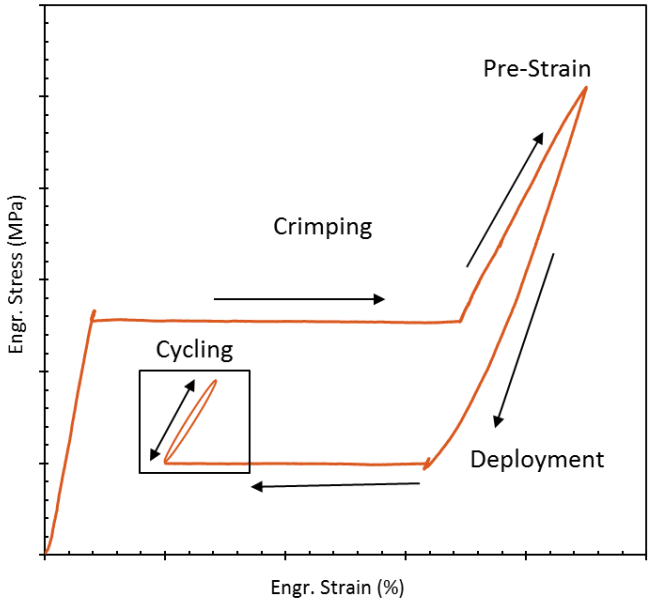
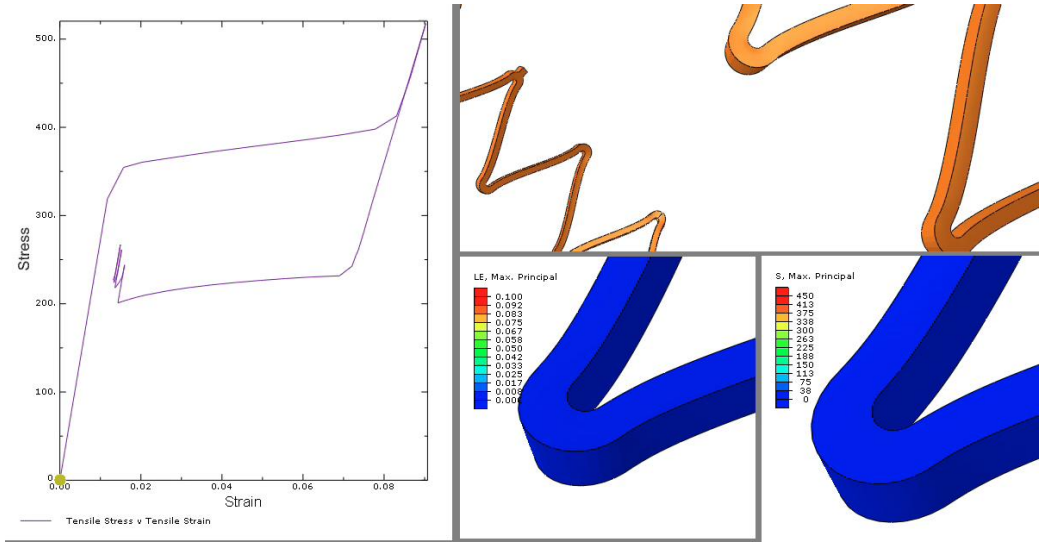
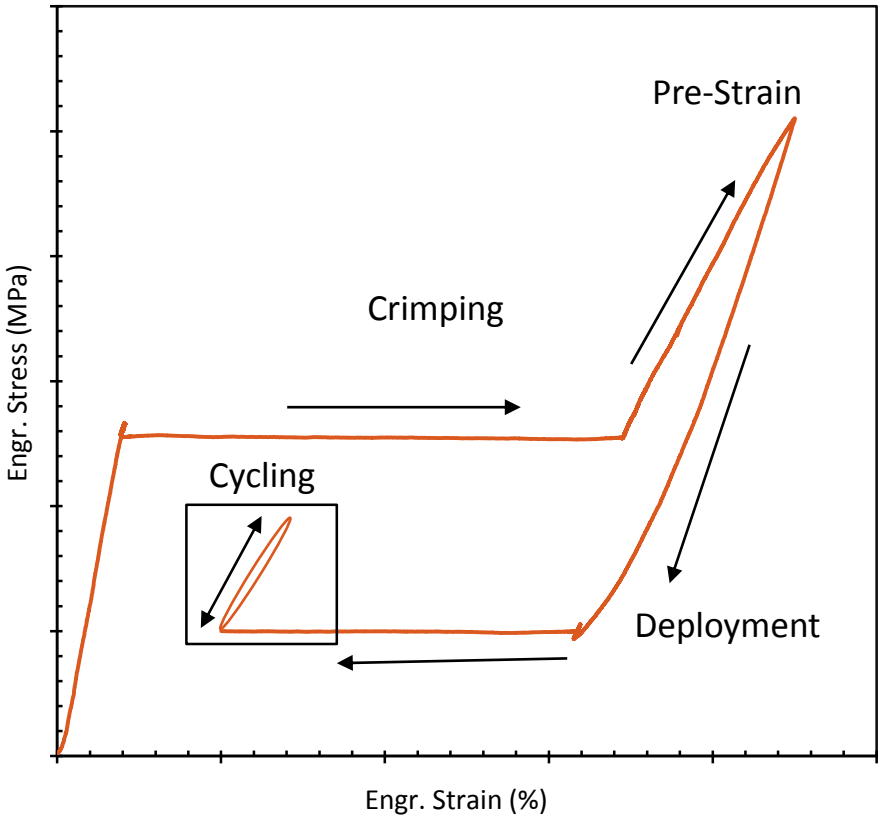
Duty Cycle – Crimp, Deploy, and Pulse

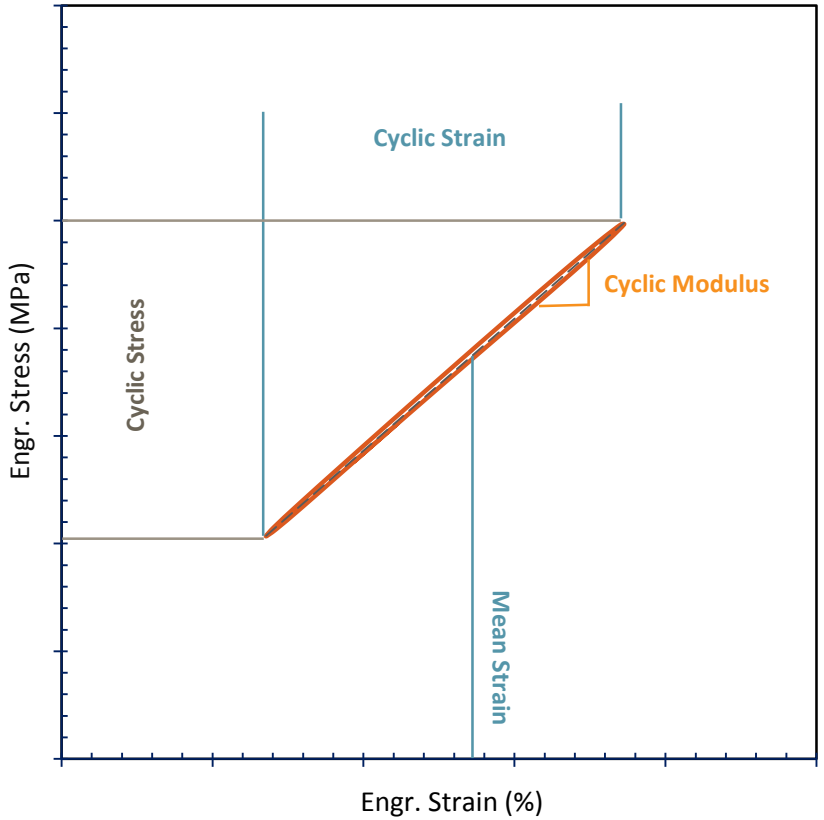




Credit: Craig Bonsignore

Duty Cycle – Definition of Pre-, Mean, and Cyclic



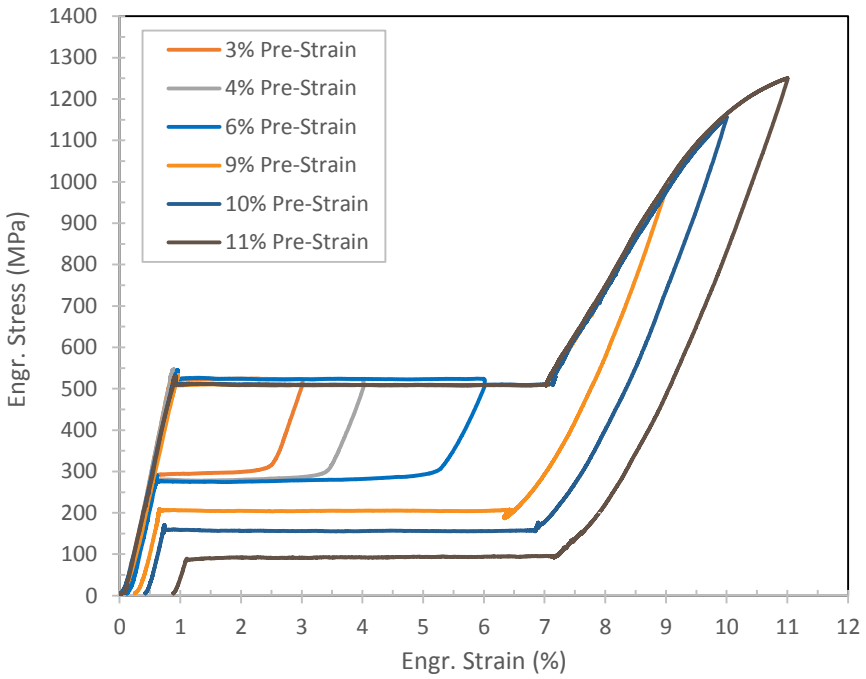


Outline

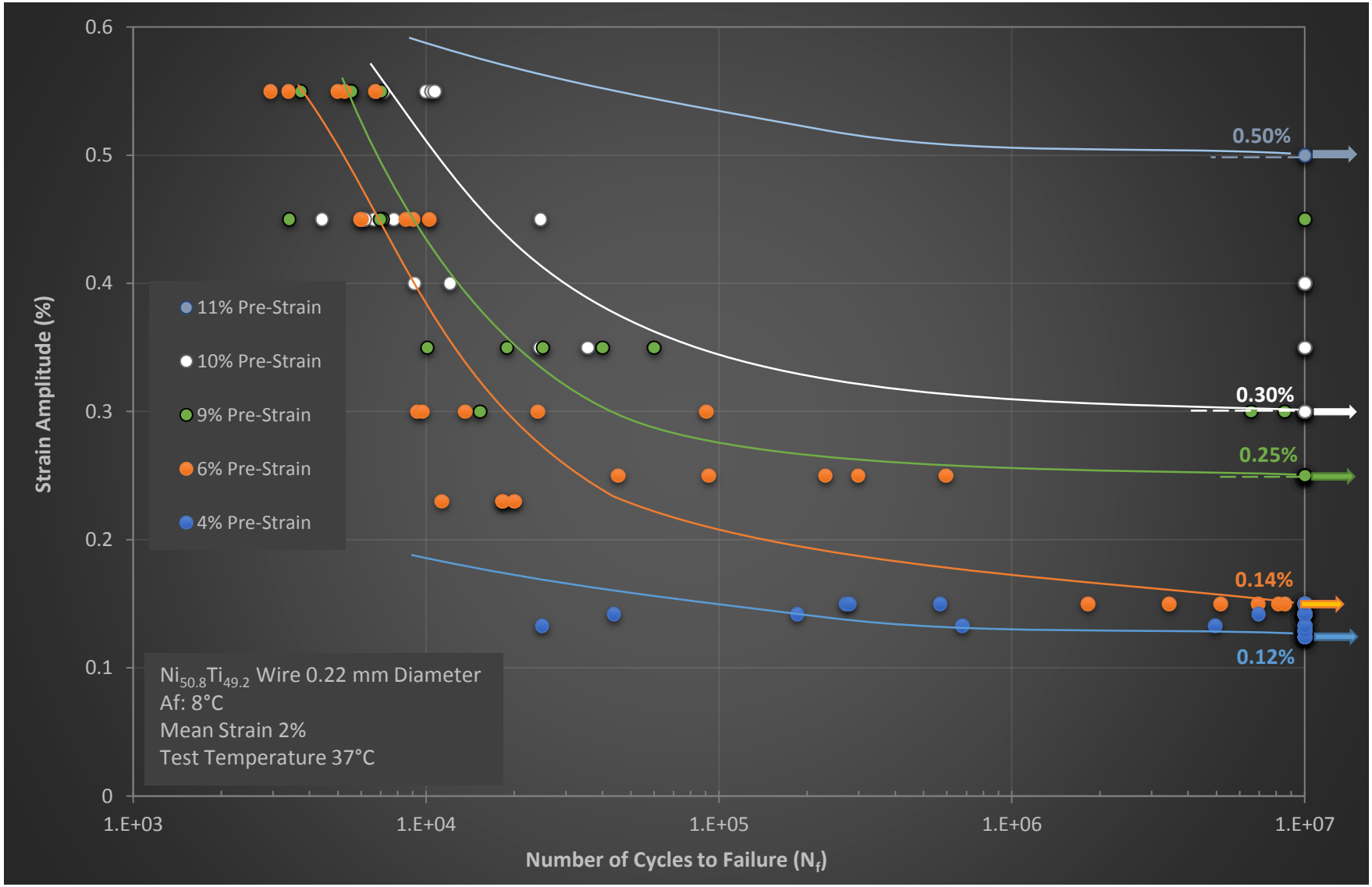
- Pre-Strain and ε – N Plot
- Macroscopic Changes
- Microscopic Changes
- Possible Mechanisms
- Punch Line

Fatigue Test – Parameters

- Material: $Ni_{50.8}Ti_{49.2}$ Wire ; Af: 8°C
- Dogbone Samples
  - Diameter: 0.22 mm
  - Gauge Length: 27 mm
- Loading Type: Tension – Tension
- Mean Strain: 2%
- Test Temperature: 37°C
- Sample Size: ≥ 5
- Run out: 10M Cycles



Fatigue Results – Effect of Pre-Strain on ε – N

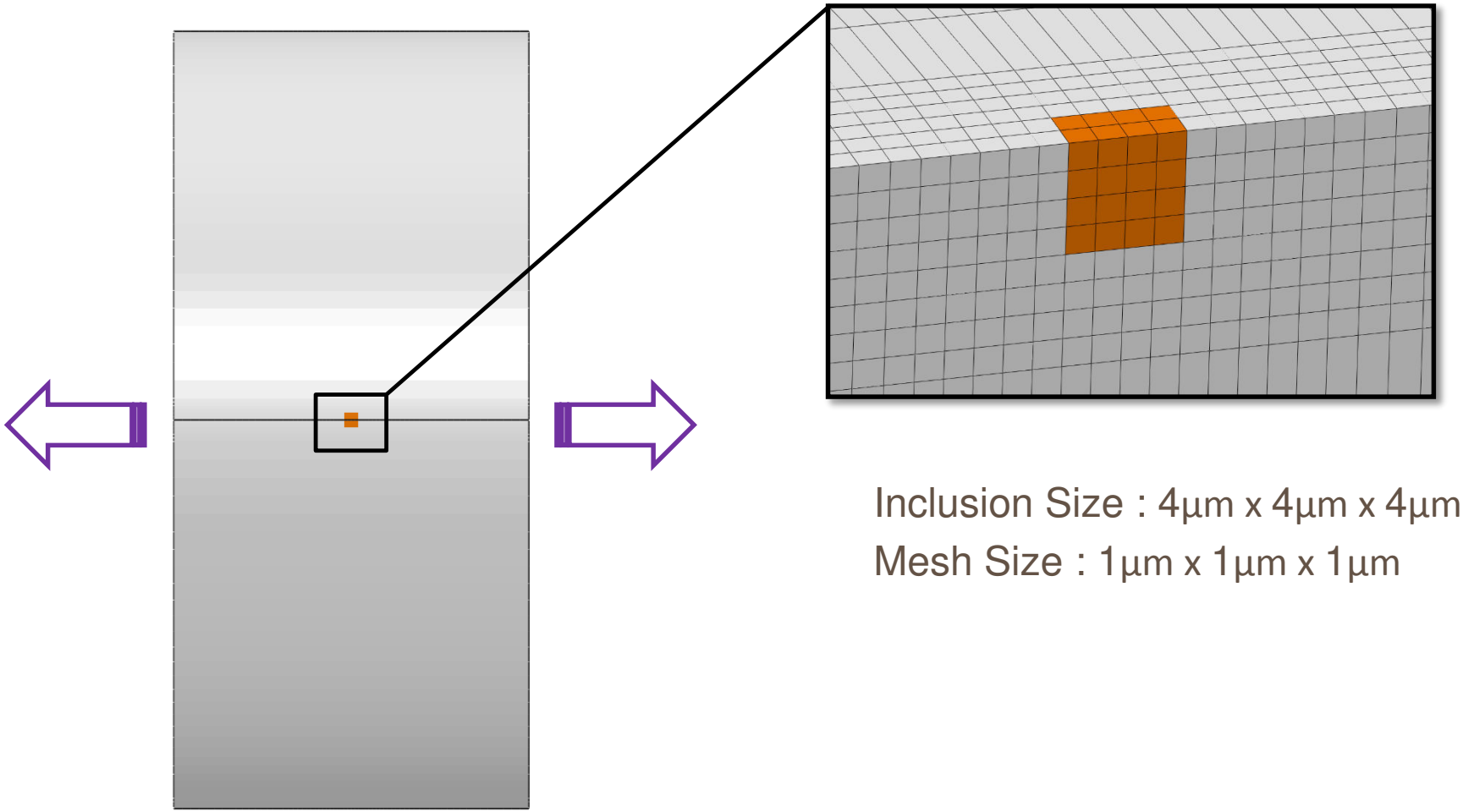


Shamimi et al., Unpublished Data, 2015

Fatigue Improvement – Possible Mechanisms

- Change in Residual Stress
  - Stress State
  - Inclusions
- Change in Properties
  - Hysteresis
  - Cyclic Modulus
  - Mean Stress

Possible Mechanisms – Change in Residual Stresses

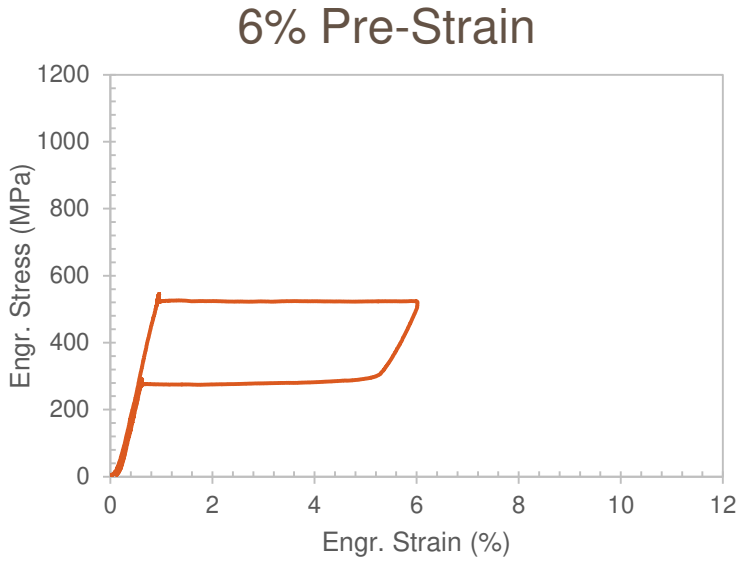


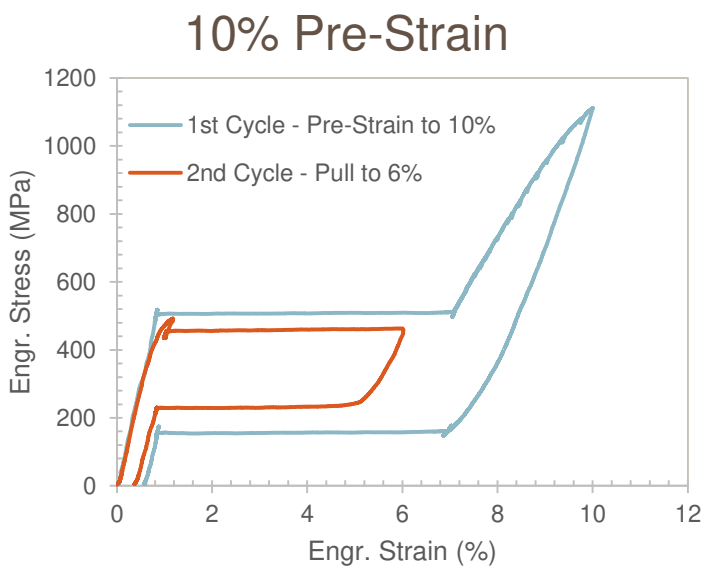
Inclusion Size : 4µm x 4µm x 4µm

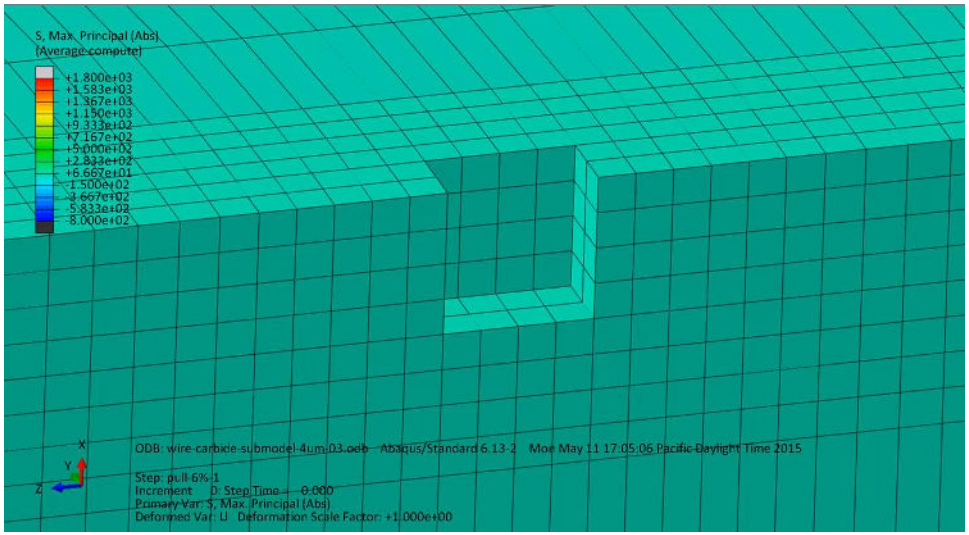
Mesh Size : 1µm x 1µm x 1µm

Credit: Karthikeyan Senthilnathan

Change in Residual Stresses - Comparison

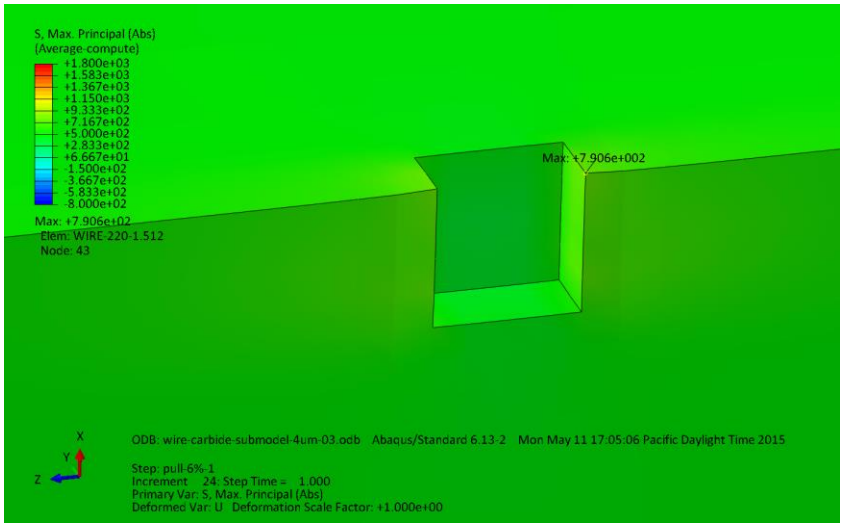




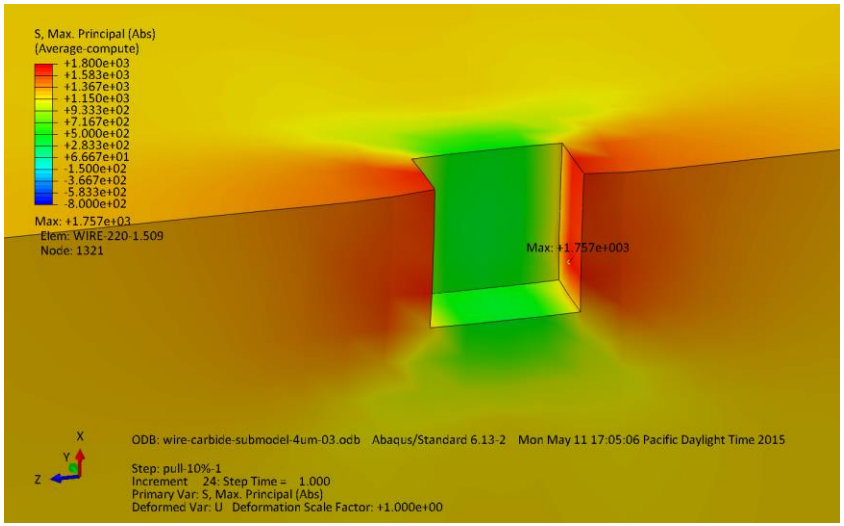


Change in Residual Stresses – Pre-Strain

6% Pre-Strain



10% Pre-Strain



Max. Stress

790 MPa

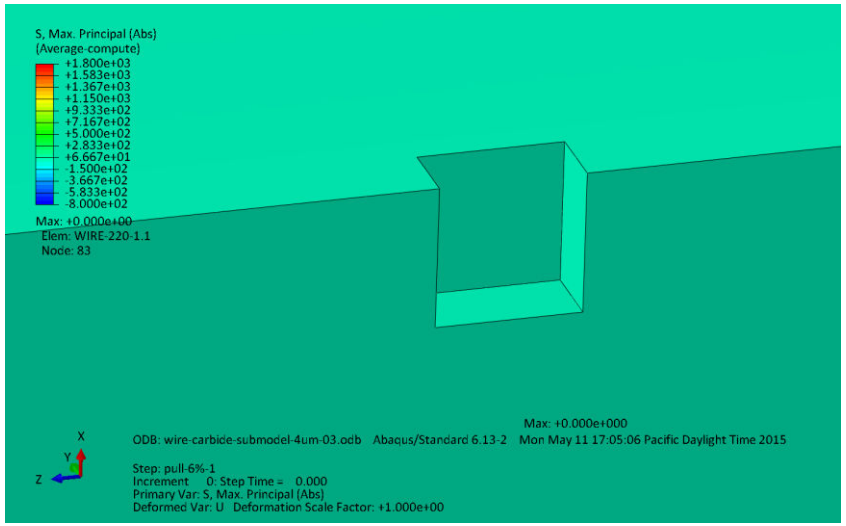
Max. Stress

1757 MPa

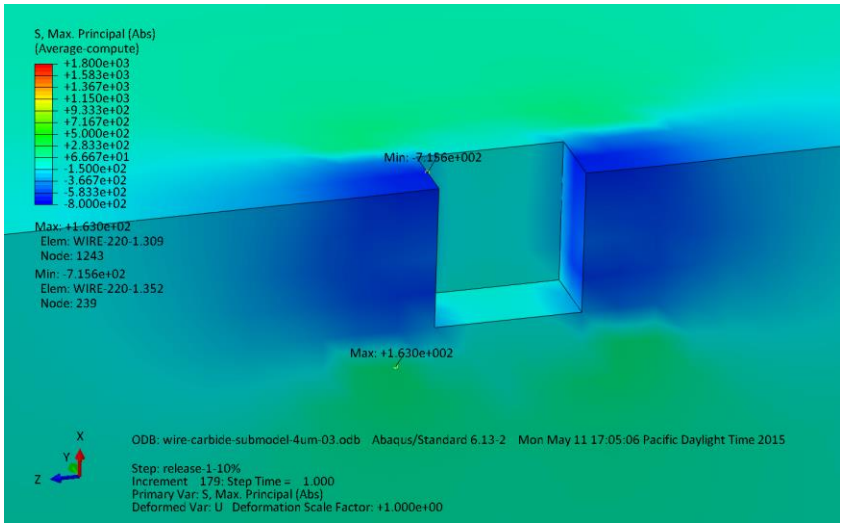
Shamimi et al., Unpublished Data, 2015

Change in Residual Stresses – Released

6% Pre-Strain



10% Pre-Strain



Max. Stress

0 MPa

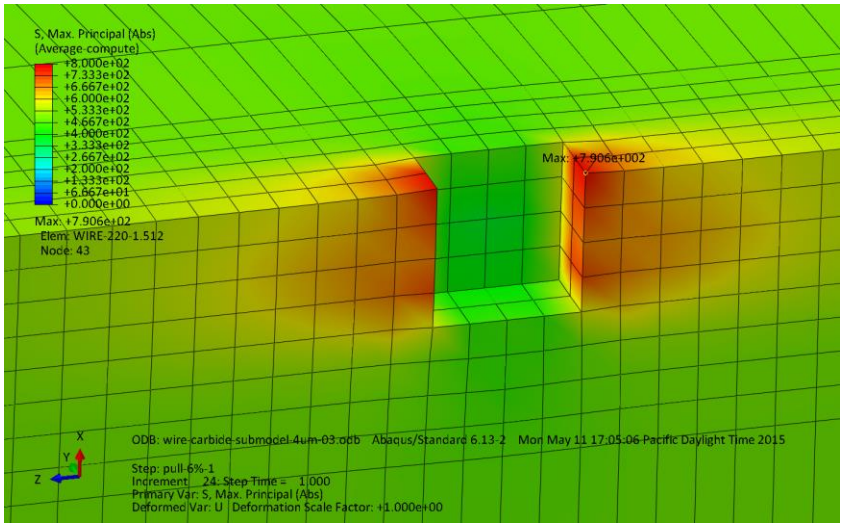
Max. Stress

-715 MPa

Shamimi et al., Unpublished Data, 2015

Change in Residual Stresses – Pull to 6%

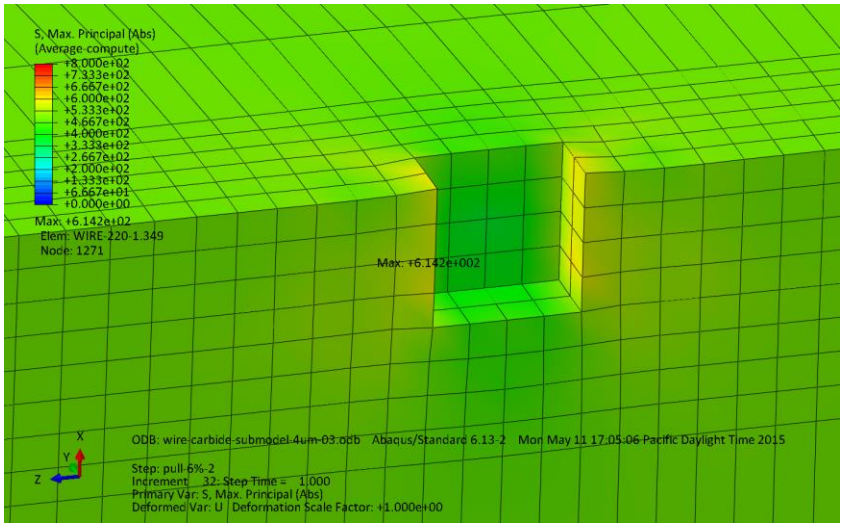
6% Pre-Strain



Max. Stress

790 MPa

10% Pre-Strain

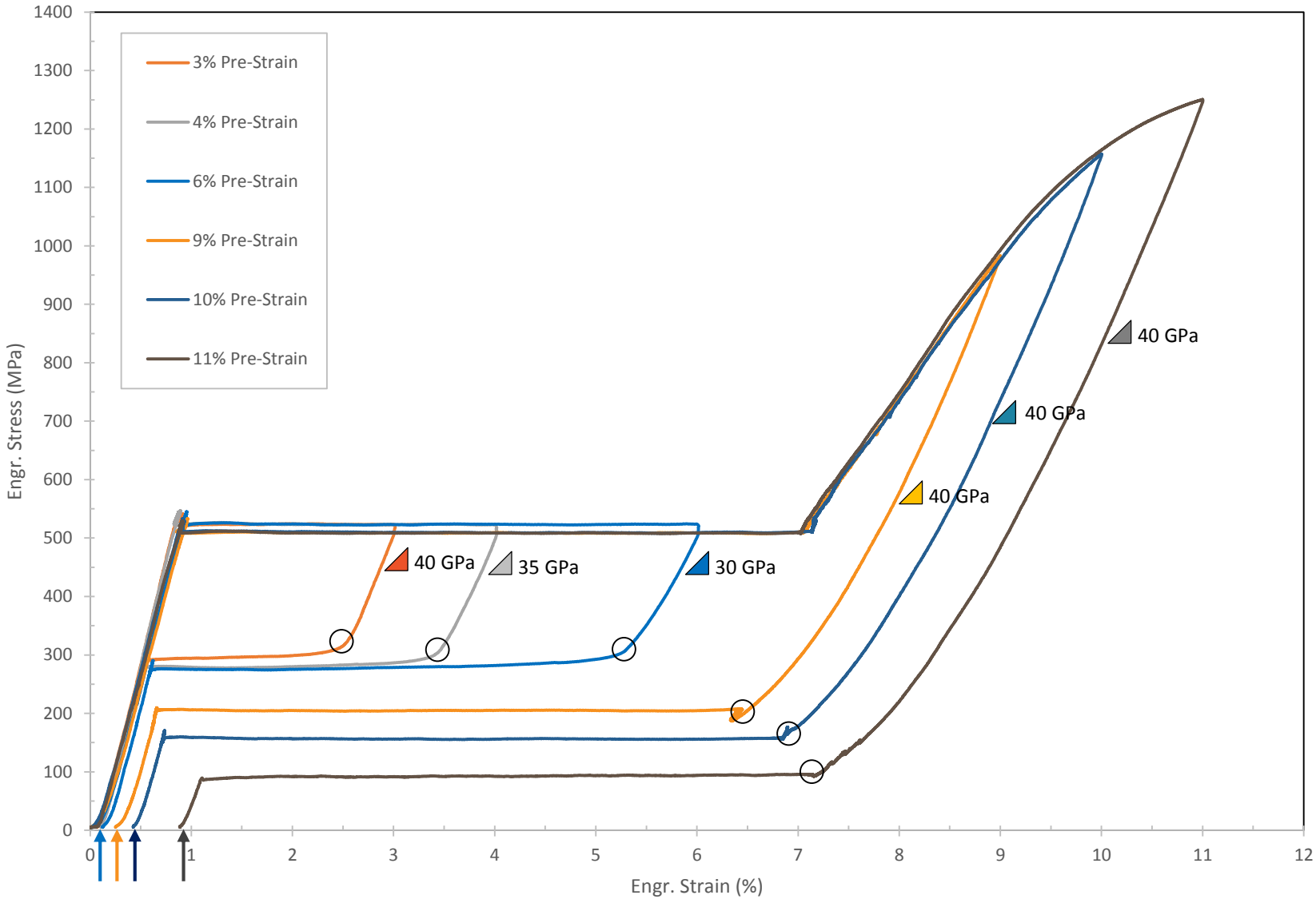


Max. Stress

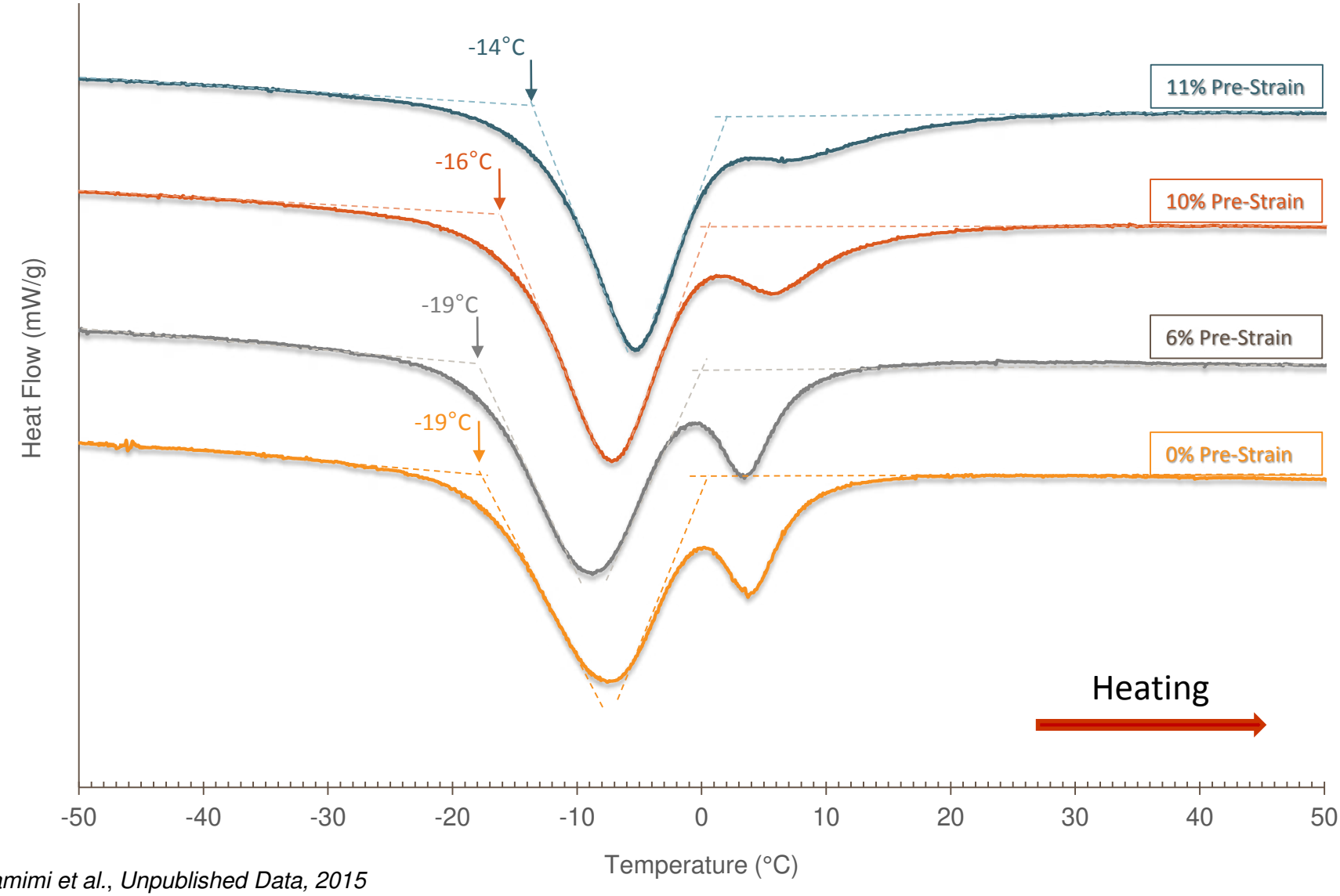
614 MPa

Shamimi et al., Unpublished Data, 2015

Possible Mechanisms – Change in Properties

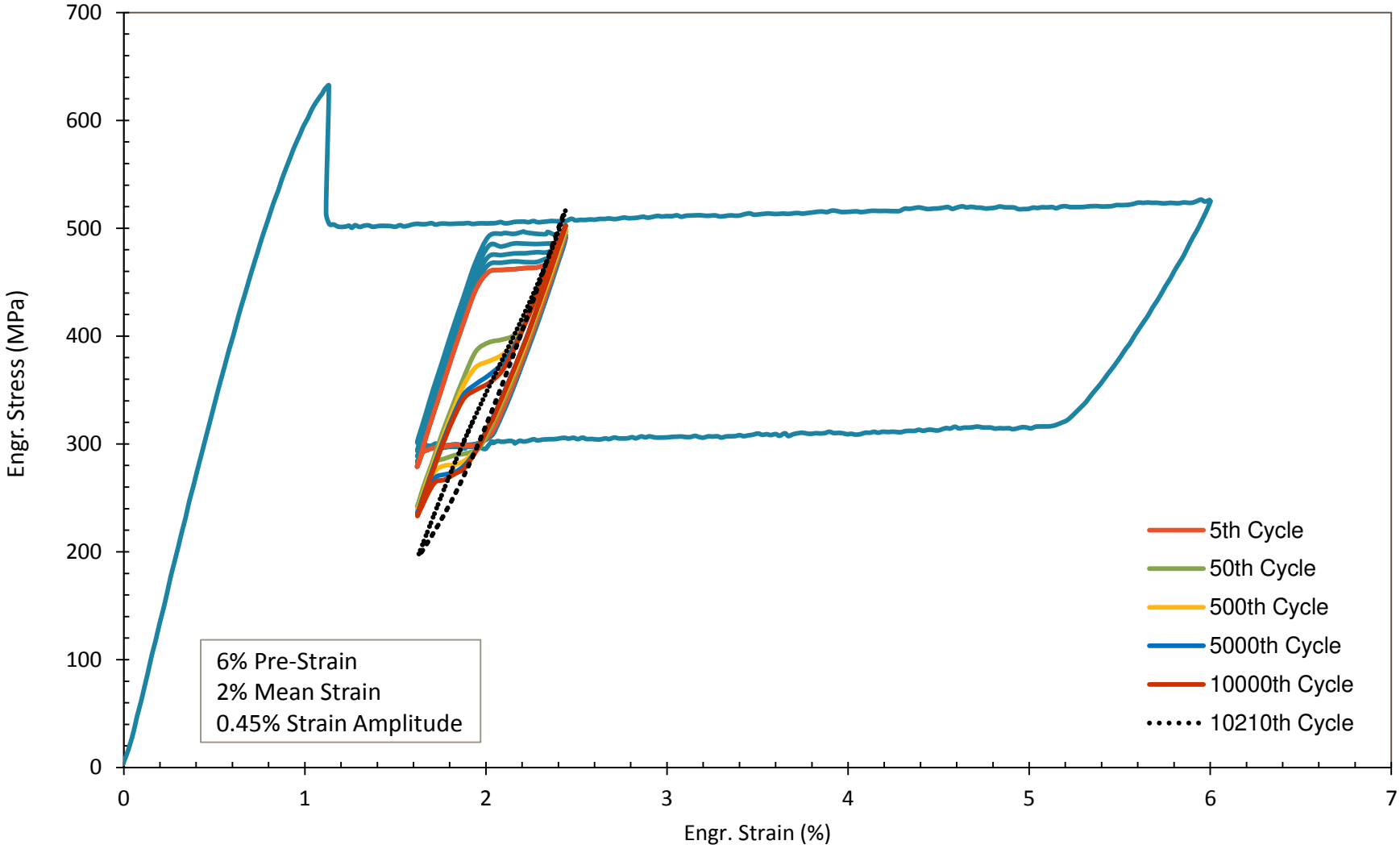


DSC – Effect of Pre-Strain



Shamimi et al., Unpublished Data, 2015

Cyclic Hardening – Strain Controlled



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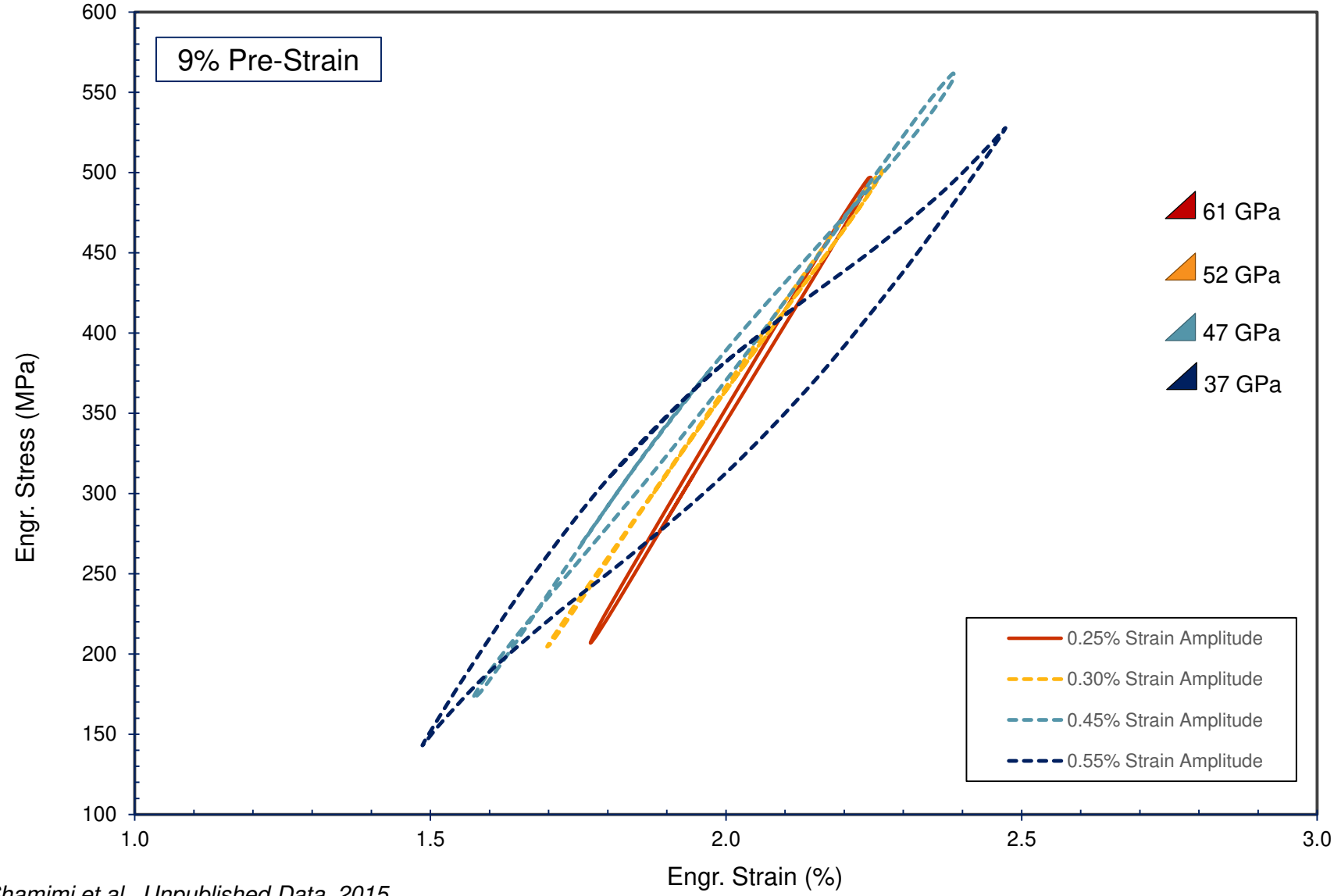
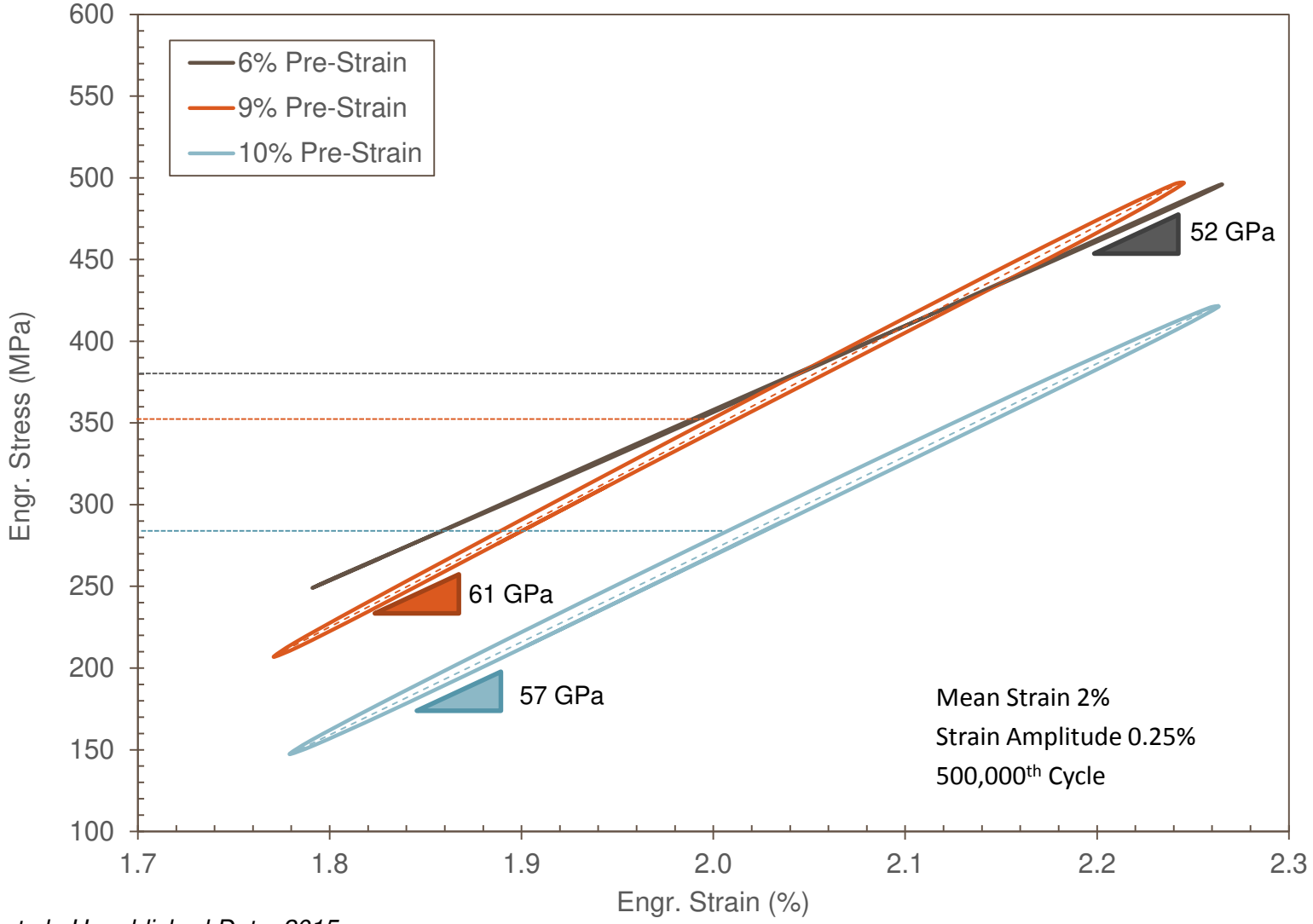
Cyclic Modulus – Effect of Strain Amplitude



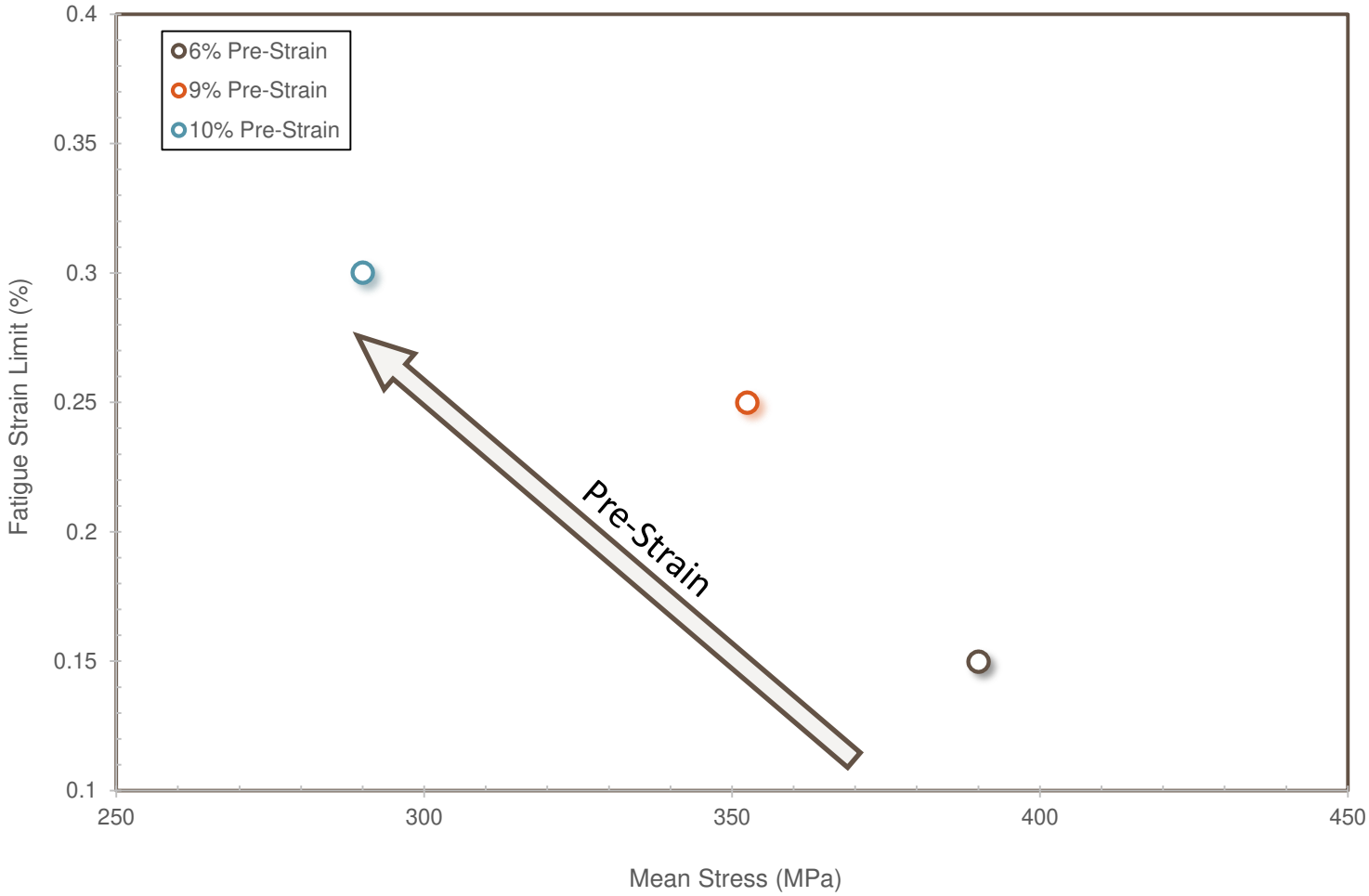
Shamimi et al., Unpublished Data, 2015

Mean Stress– Effect of Pre-Strain



Shamimi et al., Unpublished Data, 2015

Mean Stress– Effect of Pre-Strain

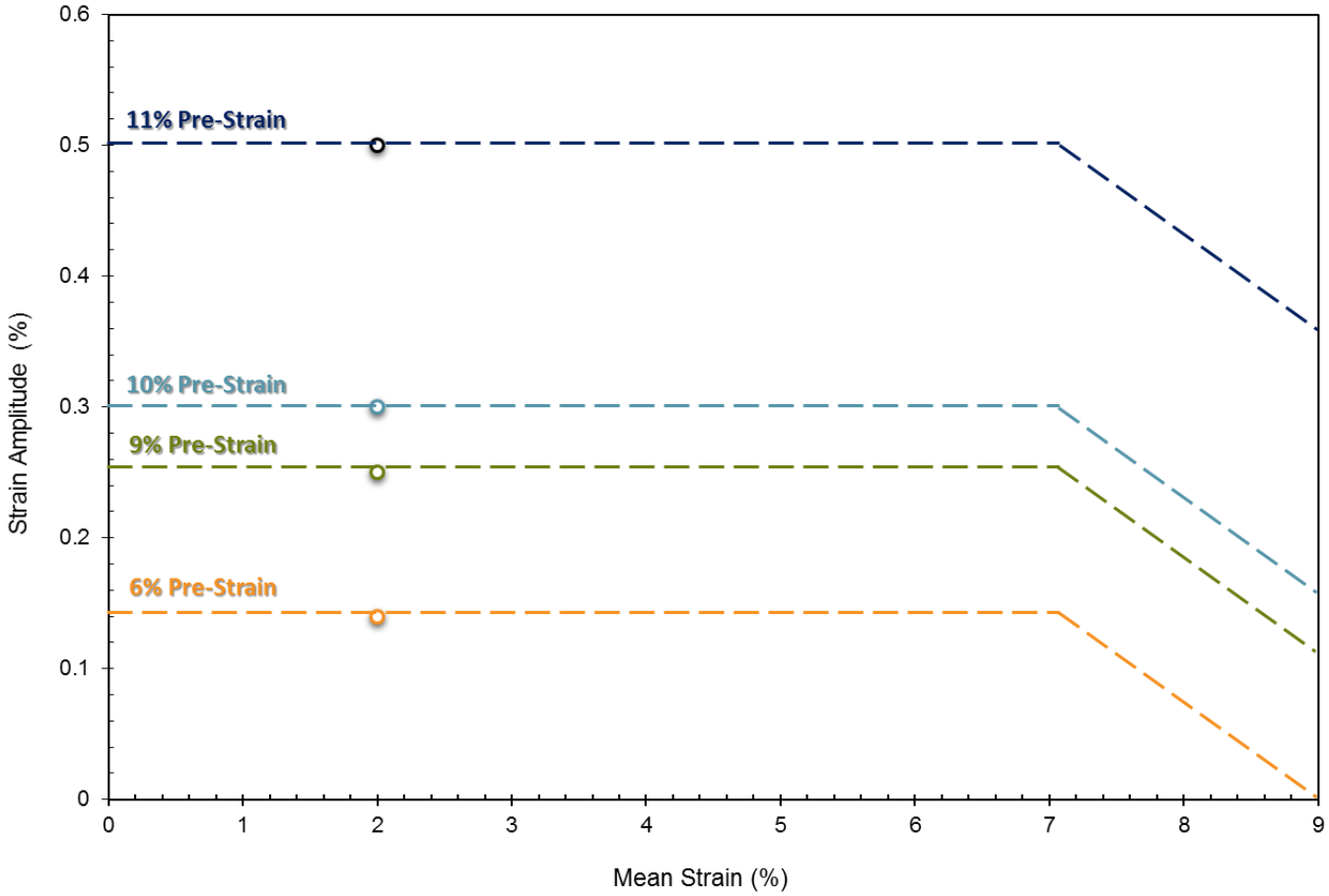


Shamimi et al., Unpublished Data, 2015

Conclusion

- Pre-Straining (up to 11%) Improves Fatigue life in Tension-Tension
- Pre-Straining Generates Compressive Residual Stresses around Inclusions Resulting in a Reduced Stress State, Hence Delaying Crack Initiation Process
- Pre-Straining Decreases the Mean Stress

Pre Straining Significantly Affects the Strain Limit Diagram



Stay Tuned!…."Sensitivity of Nitinol Fatigue Strain on Material Inputs in Finite Element Analysis" On Wednesday @ 12:00