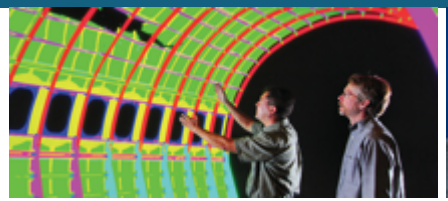
SAND2022-7723C

Sandia National Laboratories

Temperature- and Strain-Rate Dependent Mechanical Response of a 316 Stainless Steel



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SAND2022-XXXX

PRESENTED BY

Angela Ku, Bo Song

2022 SEM Annual Conference and Exposition on Experimental and Applied Mechanics
June 13-16, Pittsburgh, PA

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Outline

1. Background
2. Experimental Design
3. Tension & Compression Response
4. Summary

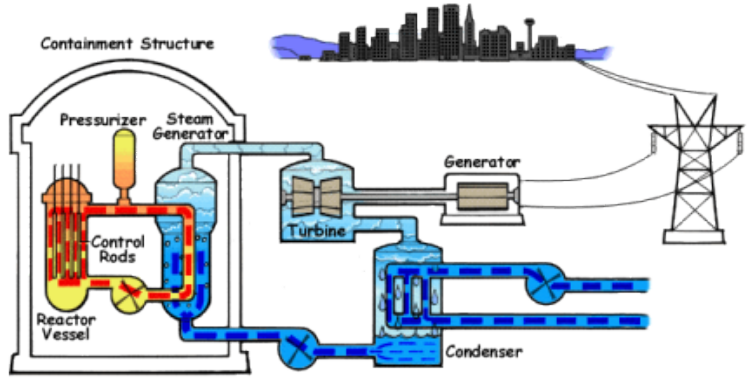
Background

- Stainless steels are a material of interest in a variety of industries (i.e. automotive, aerospace, medical, nuclear) due to its excellent corrosion resistance, machinability, and mechanical properties.
- Exhibit excellent strength and ductility at both cryogenic and elevated temperatures, which allows the material to be resistant against external impacts ranging from low-speed accidental crash to explosion.
- Mechanical response of 316 stainless steel have been studied previously, however there is little to no data on the tension and compression response in the intermediate and dynamic strain rate range.

- Complete characterization over a full spectrum of strain rates and temperatures is critical to understanding the material behaviors of 316 stainless steel over a broad range of thermomechanical environments.

https://www.avionalloys.com

https://www.meadmetals.com



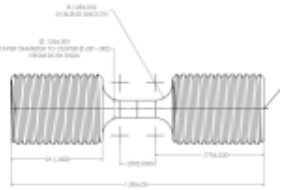
https://whatisnuclear.com

316 Stainless Steel

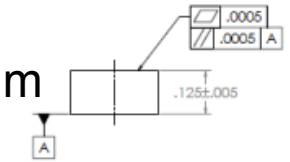
Reported Chemical Composition of 316 Stainless Steel (% wt)

C	Co	Cr	Cu	Mn	Mo	N	Ni	P	S	Si	Fe
0.015	0.41	16.53	0.36	1.29	2.024	0.030	10.51	0.031	0.026	0.27	Remainder

- Tension and compression specimens obtained from a 25.4 mm (1 in) cold-drawn round bar.
  - Tension Specimens: Diameter = 3.18 mm; Length = 6.35 mm



  - Compression Specimens: Diameter = 6.35 mm; Length = 3.18 mm



Test Matrix

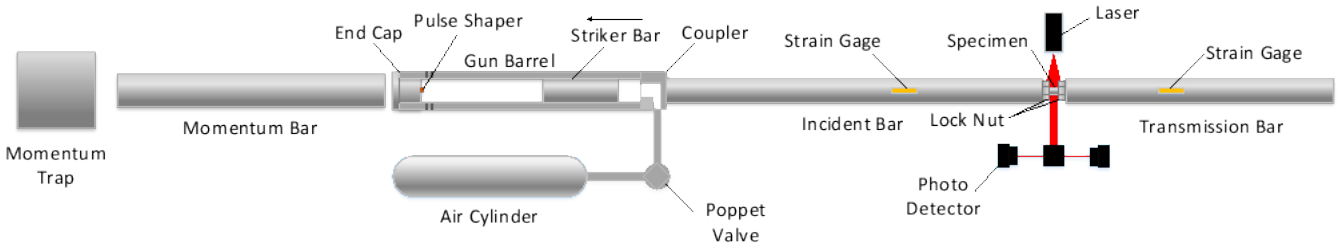
316 Stainless Steel

3-4 tests per experimental condition

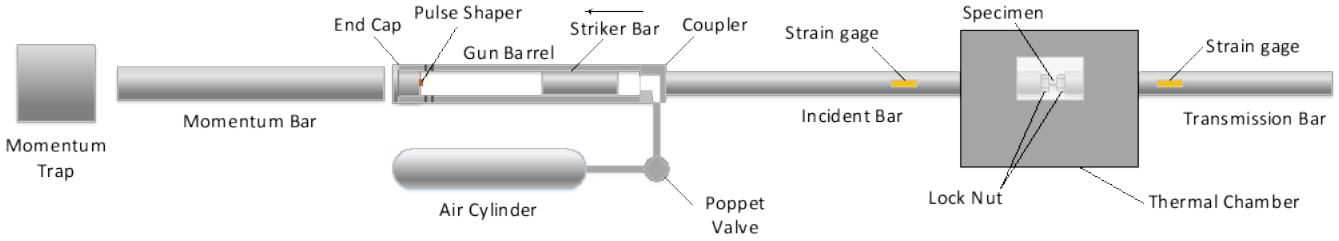
- Stress State
  - Tension
  - Compression
- Temperature
  - 22°C
  - 300°C
- Strain Rate
  - 200 s^{-1}
  - 500 s^{-1}
  - 1500 s^{-1}
  - 3000 s^{-1}

Tension & Compression Test Setup

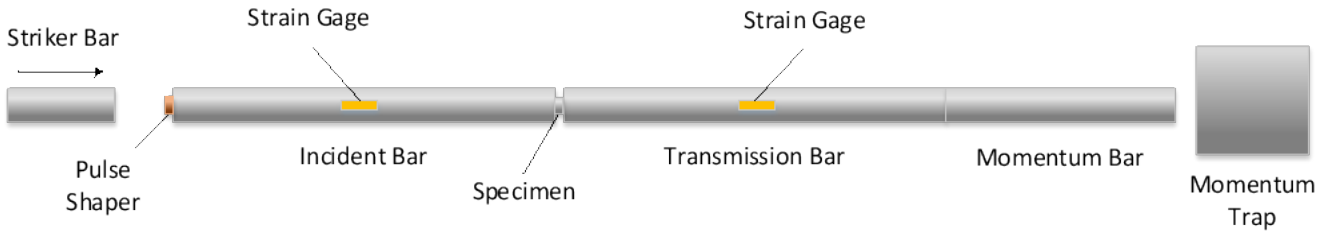
Dynamic Tension at 22°C



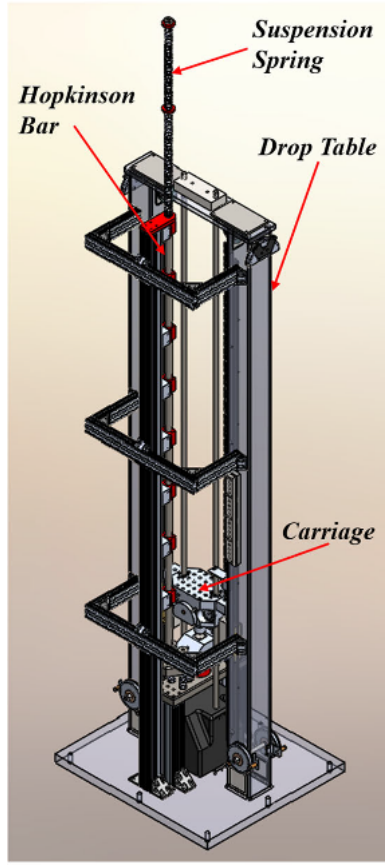
Dynamic Tension at 300°C



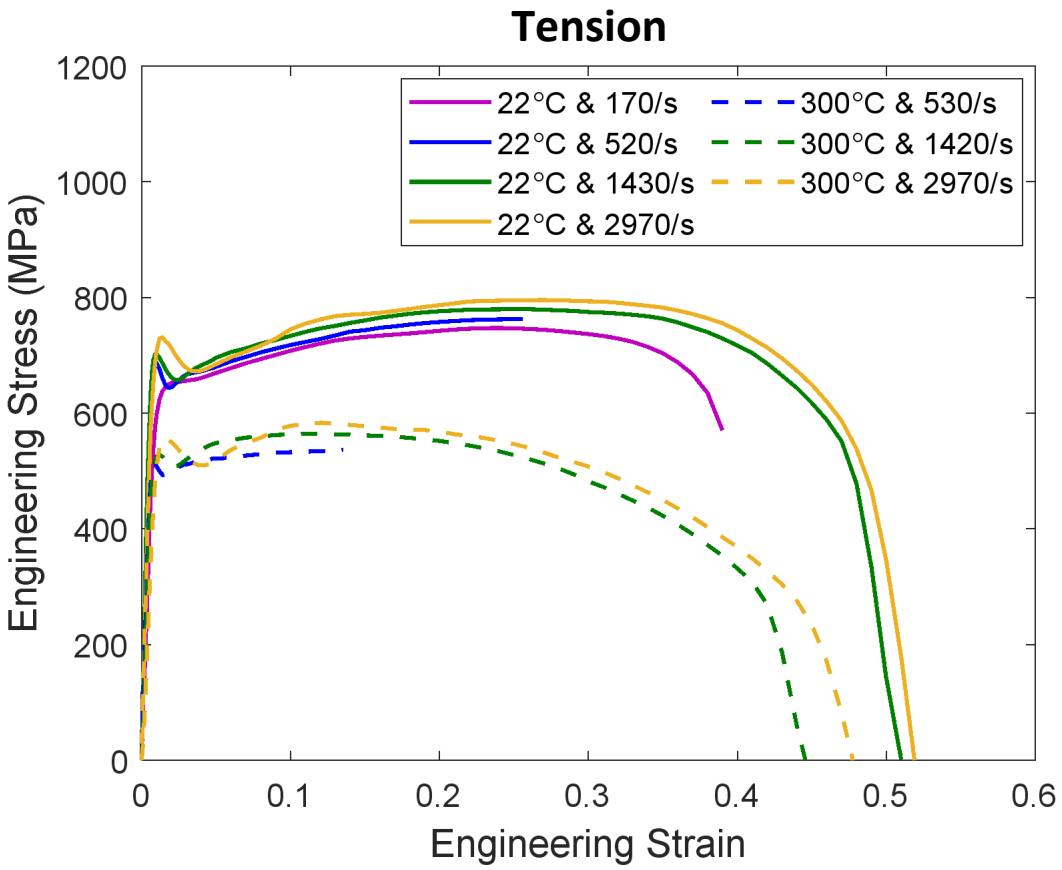
Dynamic Compression at 22°C

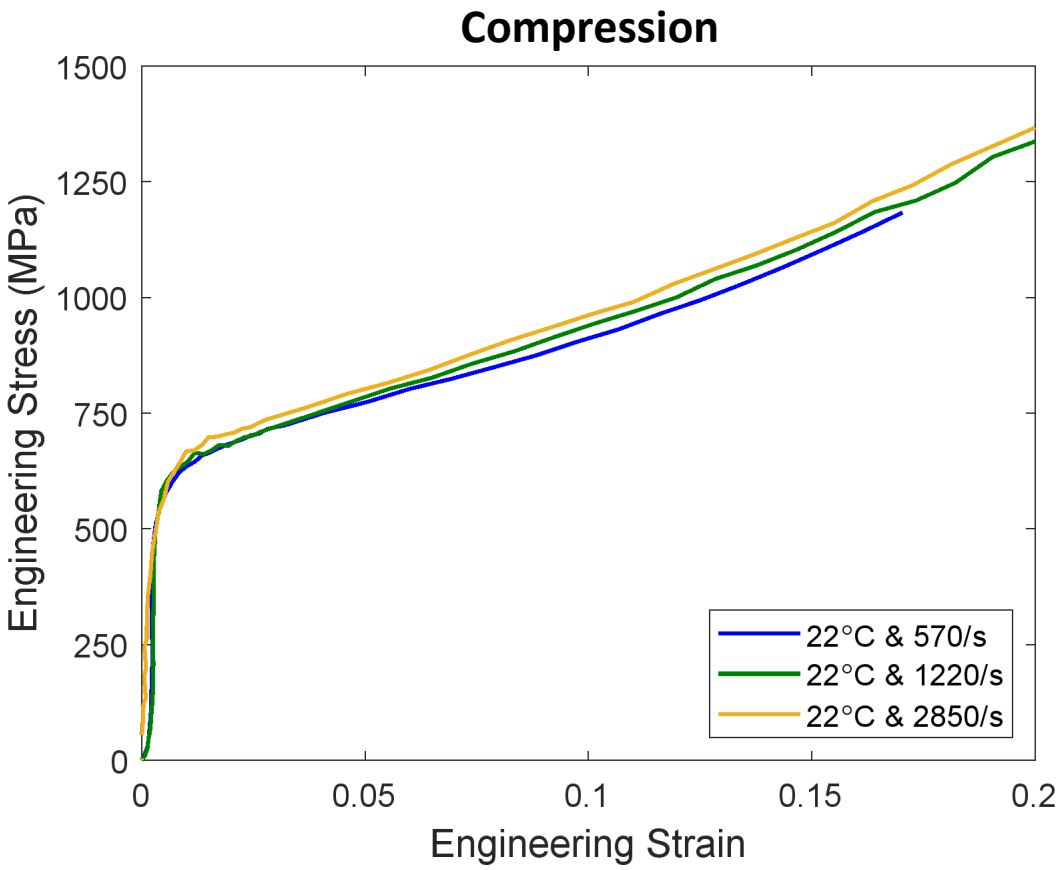


Intermediate Tension at 22°C



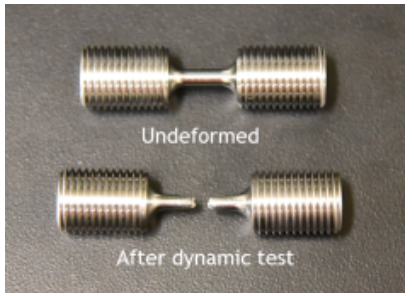
Tension & Compression Response at 22°C & 300°C



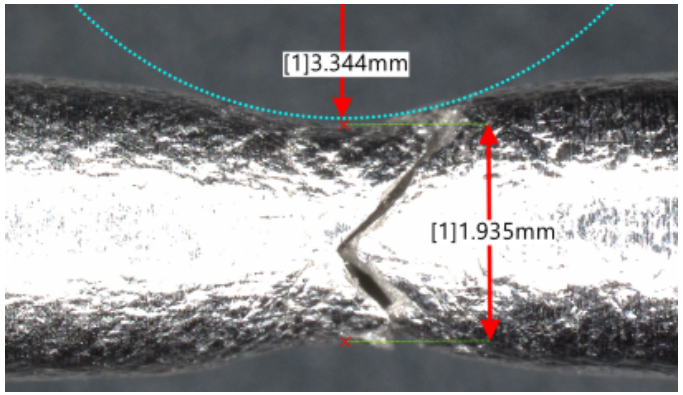


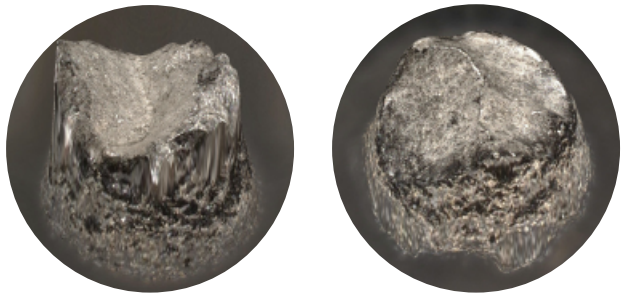
True Failure Strain at 22°C and 300°C

- True strain at failure is determined by measuring the minimum cross-sectional area of the post-test tension specimen.

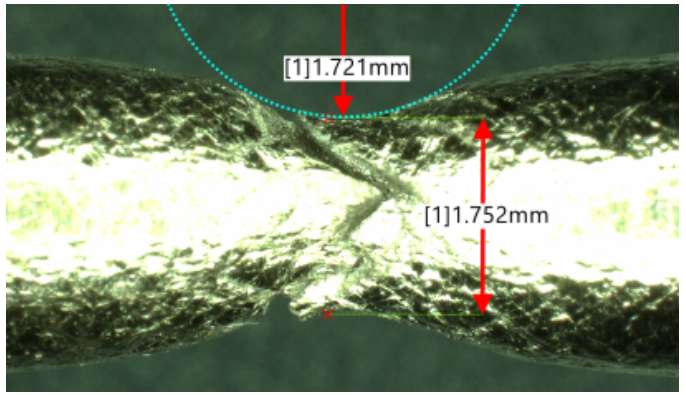


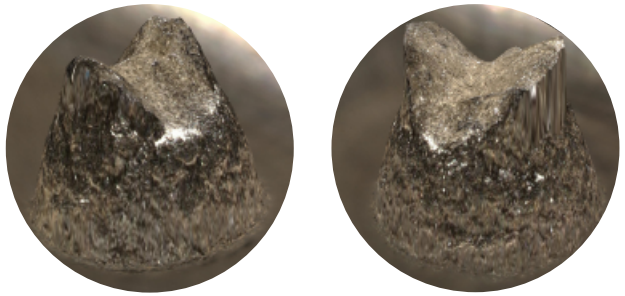
T = 22°C, $\dot{\varepsilon}$ = 1500 s^{-1}



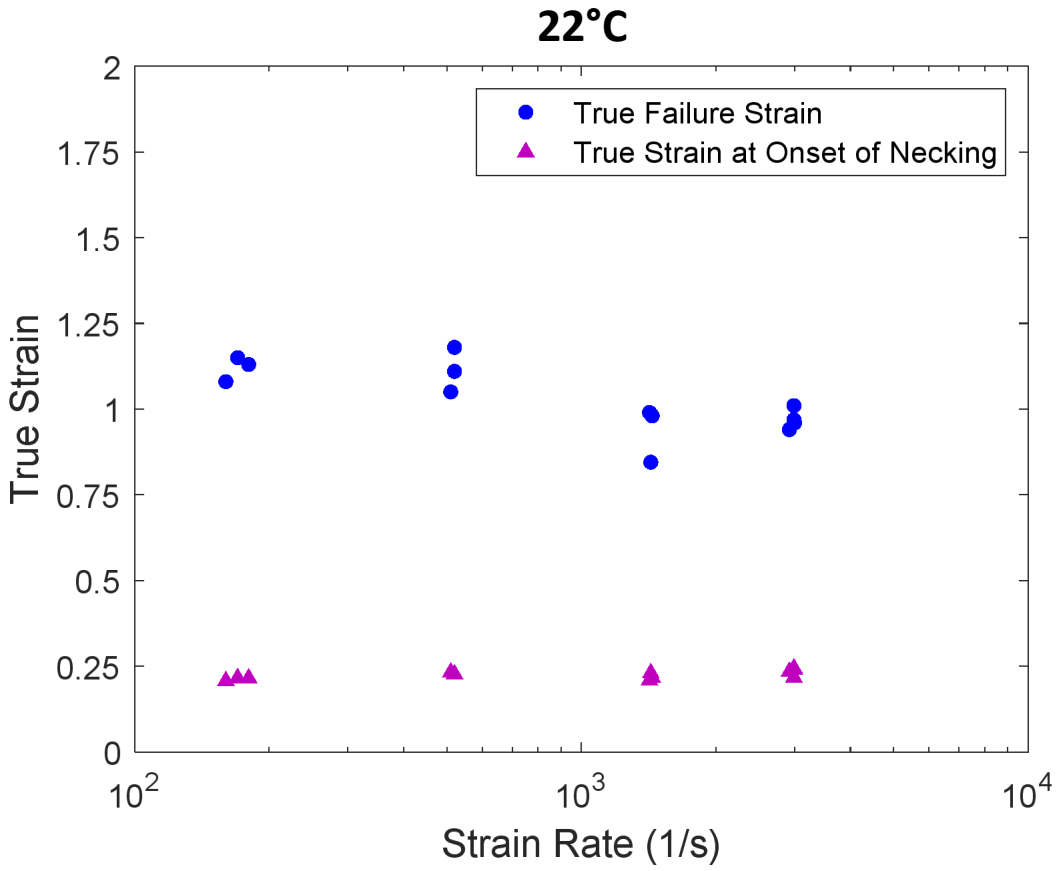


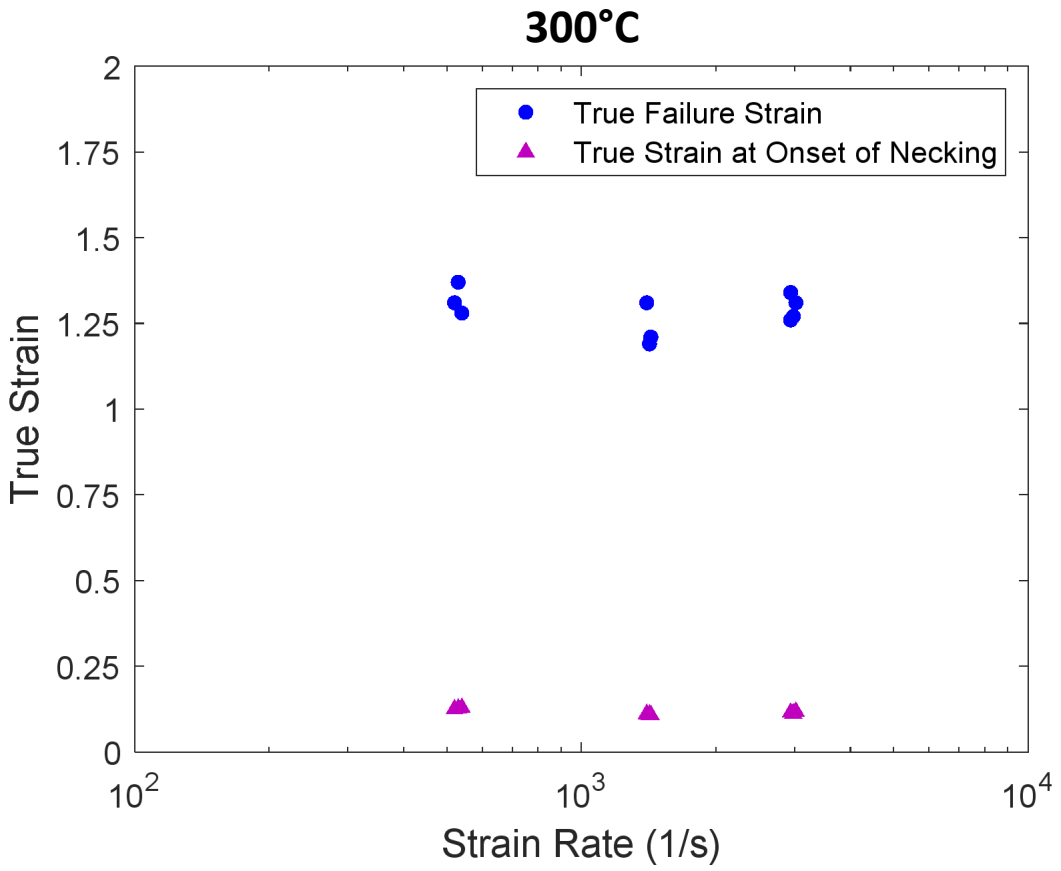
T = 300°C, $\dot{\varepsilon}$ = 1500 s^{-1}





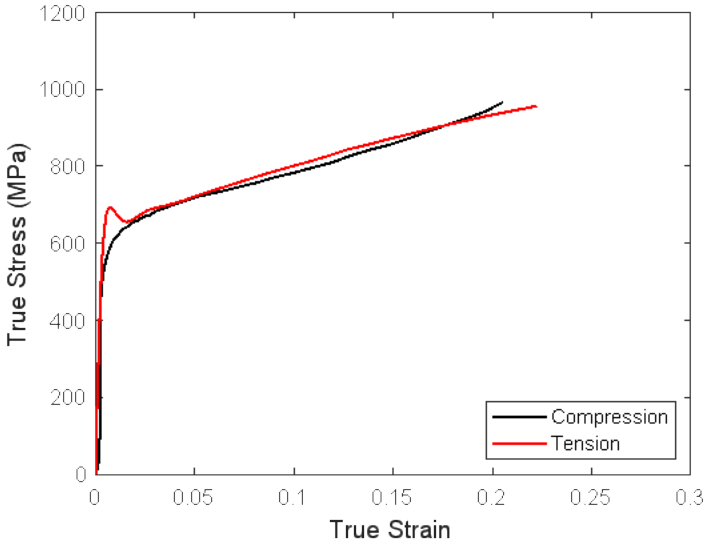
Strain Rate Effect – Tension True Strain



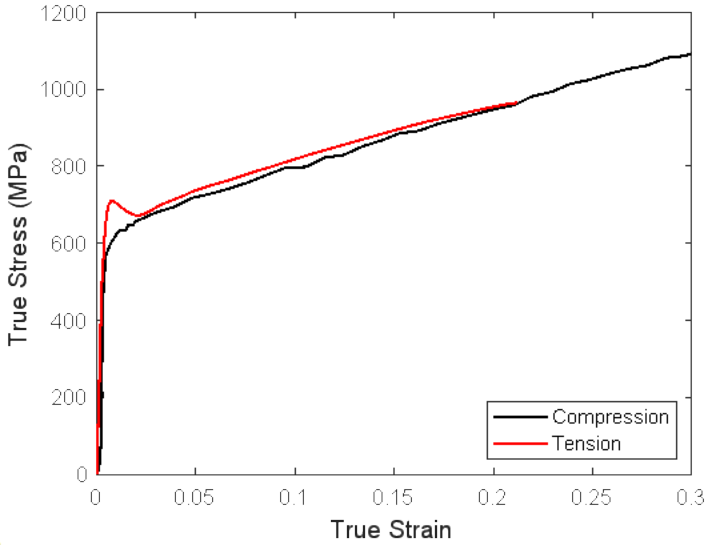


Tension-Compression Asymmetry at 22°C

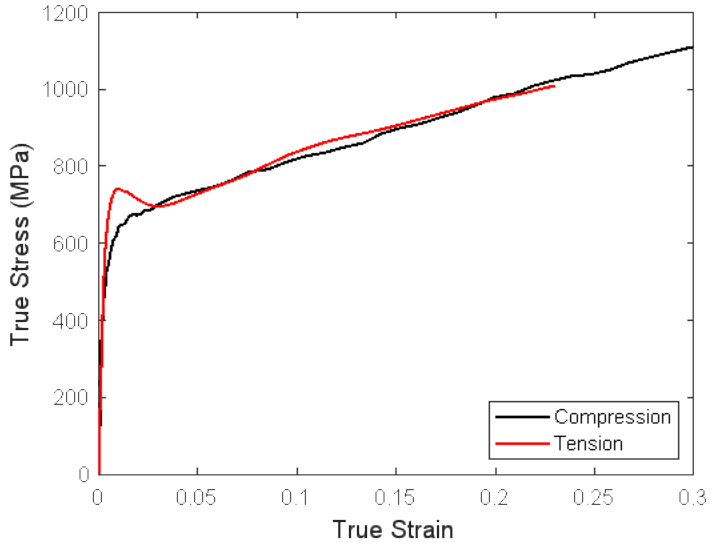
$\dot{\varepsilon}$ = 500 s^{-1}



$\dot{\varepsilon}$ = 1500 s^{-1}



$\dot{\varepsilon}$ = 3000 s^{-1}



Summary

General Conclusions

- Successfully characterized the tension and compression response of a 316 stainless steel at 22°C and 300°C, and at various strain rates between 200 s^{-1} and 3000 s^{-1}.
- Provide material data to develop a strain rate and temperature dependent failure criterion for high-fidelity numerical simulations.
- Improve safety and reduce cost in the design process.

316 Stainless Steel

- Flow stress exhibited positive strain rates sensitivity and is inversely dependent on temperature.
- True failure strain increased with increasing temperature and decreased with increasing strain rate.
- Tension and compression response is reasonably symmetric.