SAND2014-17940PE

Various Topics in Plasticity and Ductile Failure

Benjamin Reedlunn

Computational Solid Mechanics

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Outline

- Introduction
  - My background
  - My impressions of Sandia
- Mechanical Response of Additively Manufactured Stainless Steel
- Sandia Fracture Challenge (“X-Prize”) – Post Competition Investigation

Sandia National Laboratories

INTRODUCTION

My Background

Sandia National Laboratories

- Born in California
  - B.S. Mechanical Engineering, Cal Poly SLO
  - 2.5 years at Medtronic Vascular doing stent design
- Graduate school at University of Michigan—Ann Arbor
  - Ph.D. Mechanical Engineering
  - Thesis Advisors: John Shaw (Aero.) and Sam Daly (Mech.)
  - Thesis Topic: Thermomechanical Behavior of Shape Memory Alloy Cables and Tubes
- Sandia National Labs
  - ~ 2 years in the Solid Mechanics department

My impressions of Sandia

Sandia National Laboratories

- Sandia wants to invest in you
  - Experimentalist --> Modeler
  - Matlab --> Python
  - Conferences
- Sandia has more experts in engineering fields than most universities
  - Helpful and team oriented culture
- Facilities
  - In-house modeling codes and 20k core compute servers
  - State of the art experimental equipment
- Work – life balance

SANDIA FRACTURE CHALLENGE – POST COMPETITION INVESTIGATION

Problem Statement

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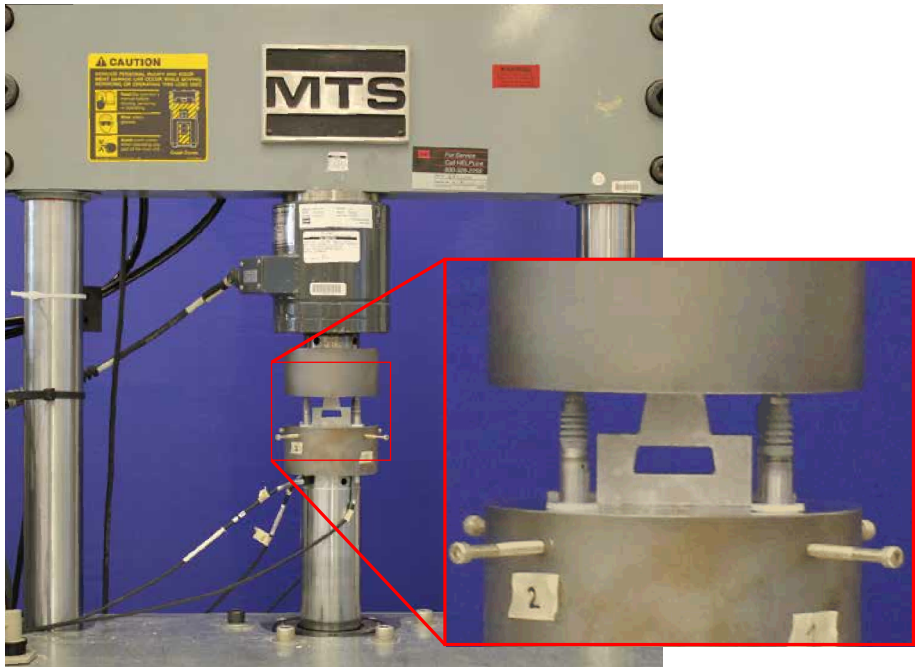
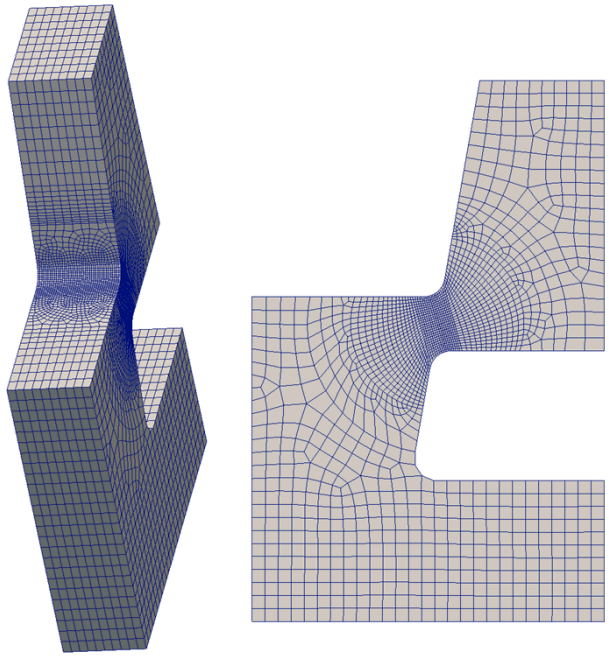
Experimental Setup

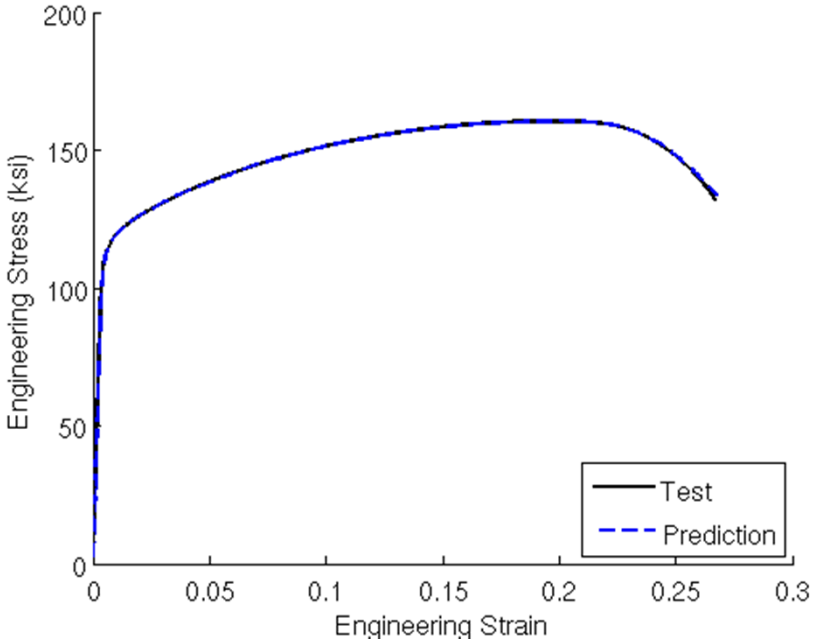


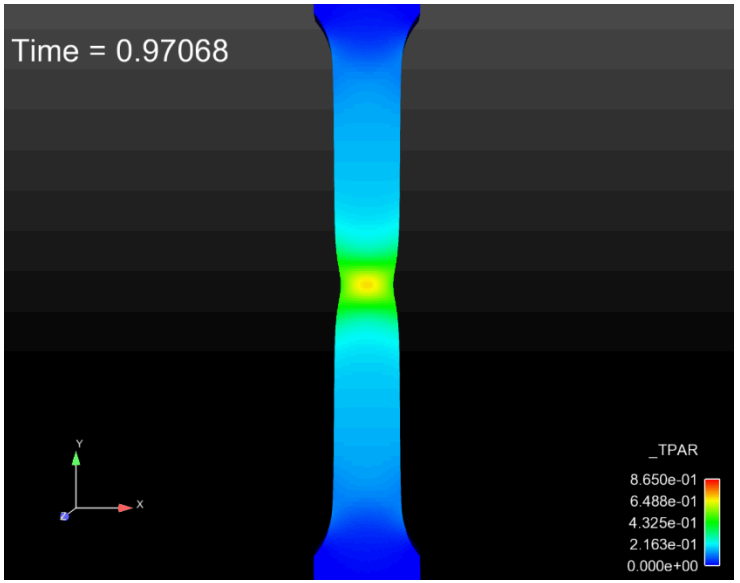
Finite Element Mesh



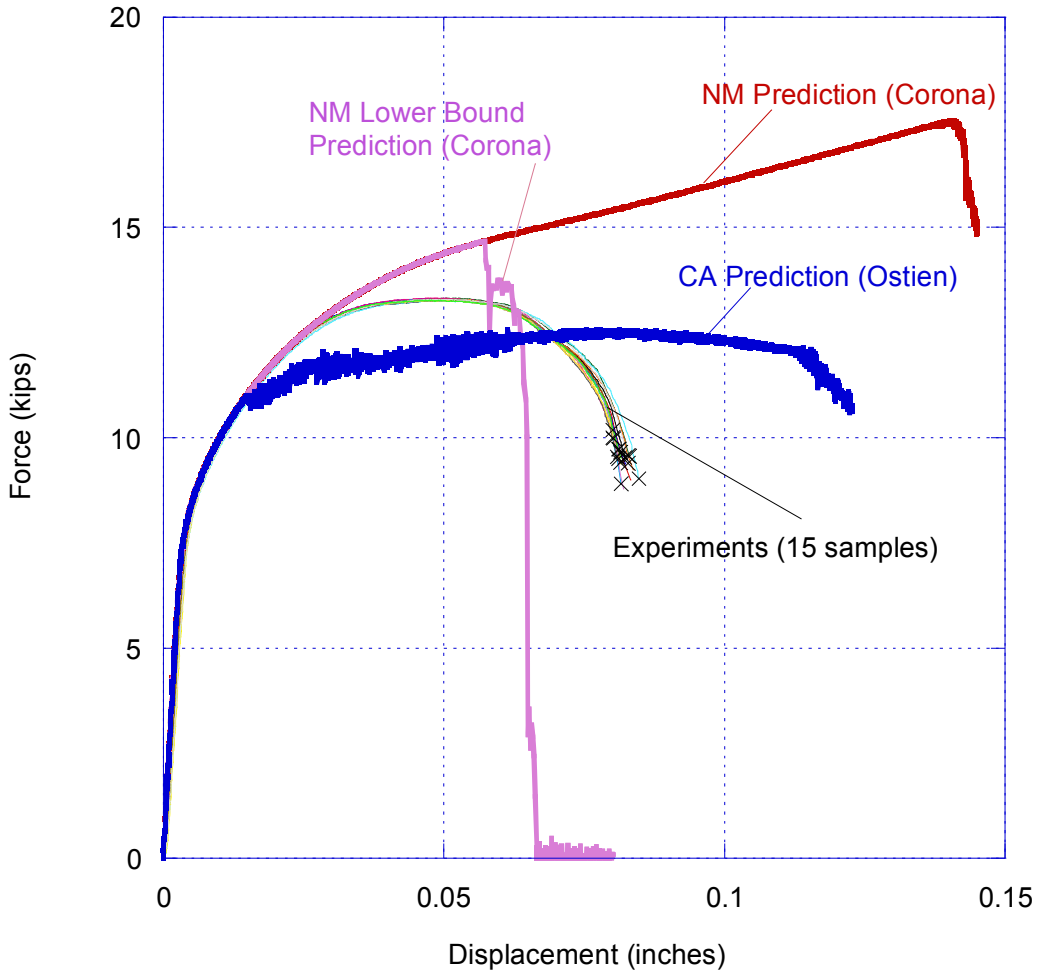
Quarter Symmetry

Model Calibration





Model Predictions

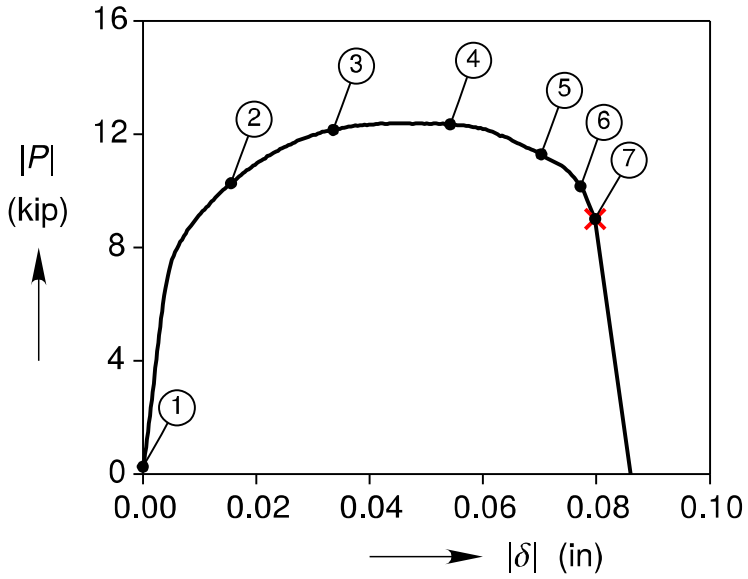


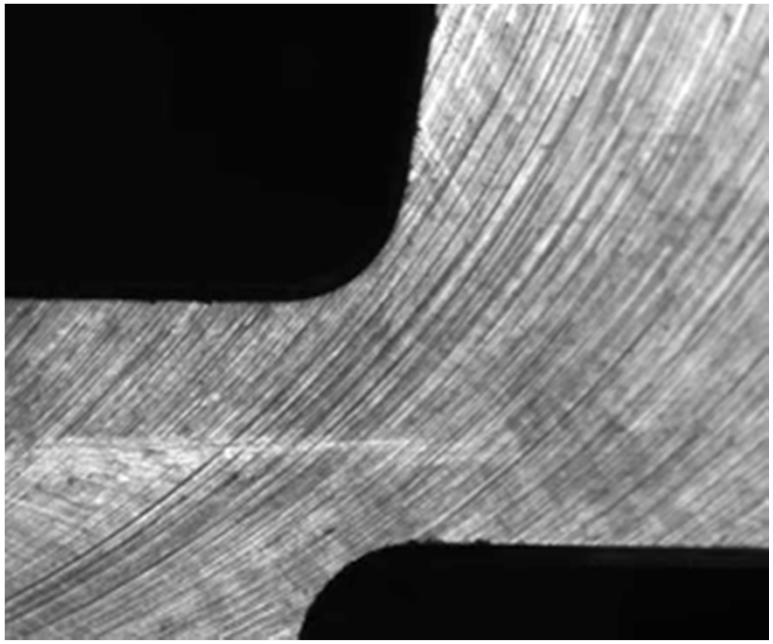
J. Koester and E. Corona. 2013 Shear-dominated failure x-prize, post challenge investigations. Technical report, Sandia National Laboratories, September 2013. Internal Sandia Memo.

Digital Image Correlation Results

Sandia National Laboratories

Images of the Machined Surface





Microscopy Results

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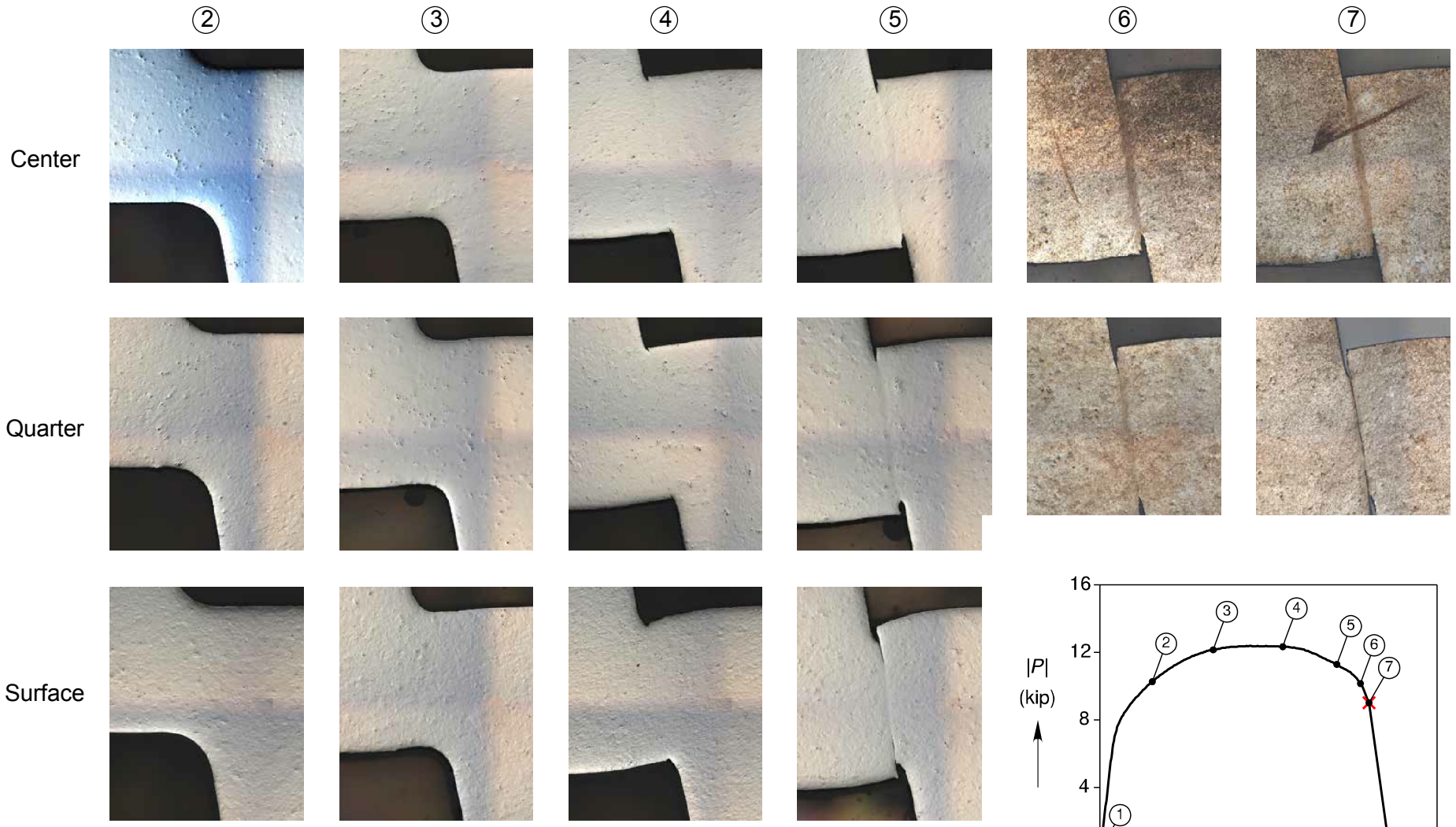
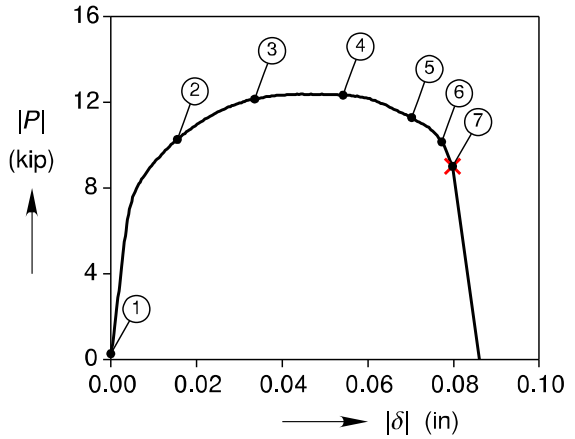
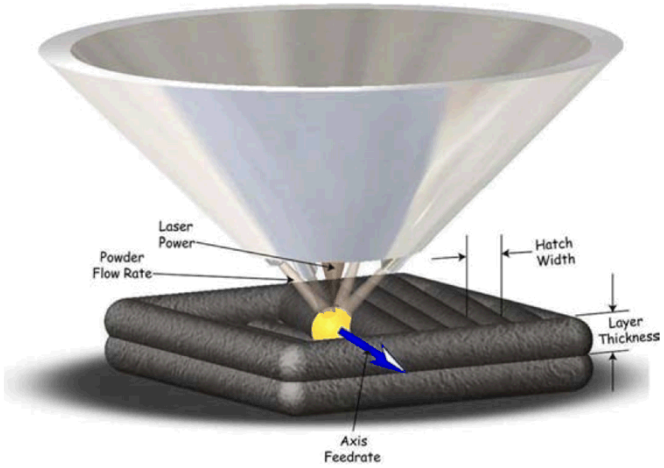




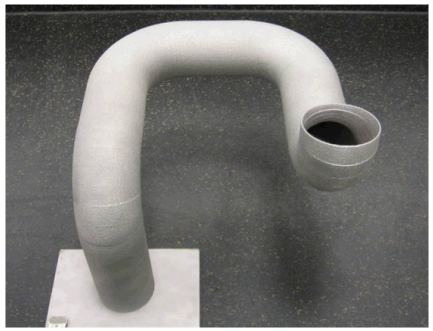
MECHANICAL RESPONSE OF ADDITIVELY MANUFACTURED STAINLESS STEEL

Additive Manufacturing

- Build parts layer by layer, rather than removing material from a large block
  - Also known as 3D printing or Rapid Prototyping



Gill, D. *et. al.,* 2006. LENS Repair and Modification of Metal NW Components, SAND 2006-6430, Unlimited Release



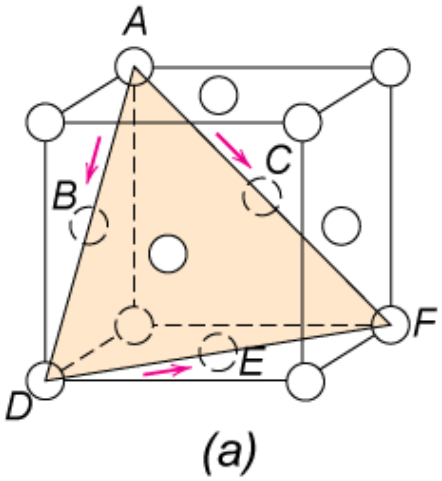
www.rpm-innovations.com

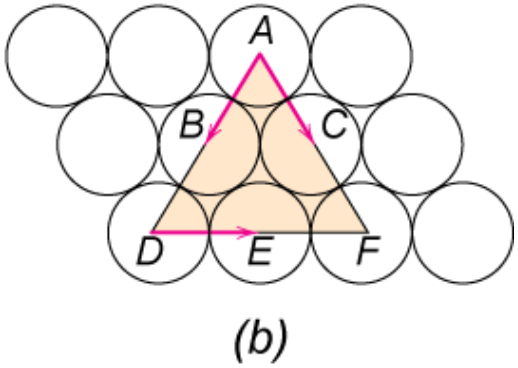
www.withinlab.com

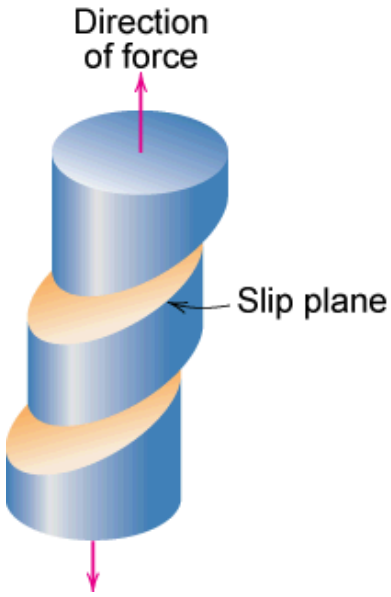
- LENS – Laser Engineered Net Shaping
- Goal: Predict the mechanical response of LENS processed stainless steel

Crystal Plasticity

- Single crystal

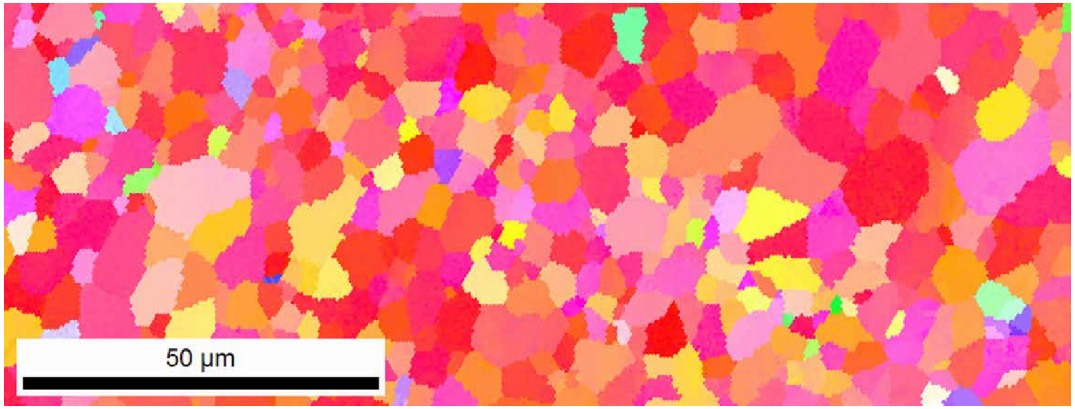


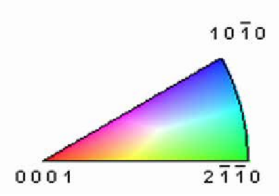




Adapted from Fig. 7.8, *Callister 7e.*

- Polycrystal

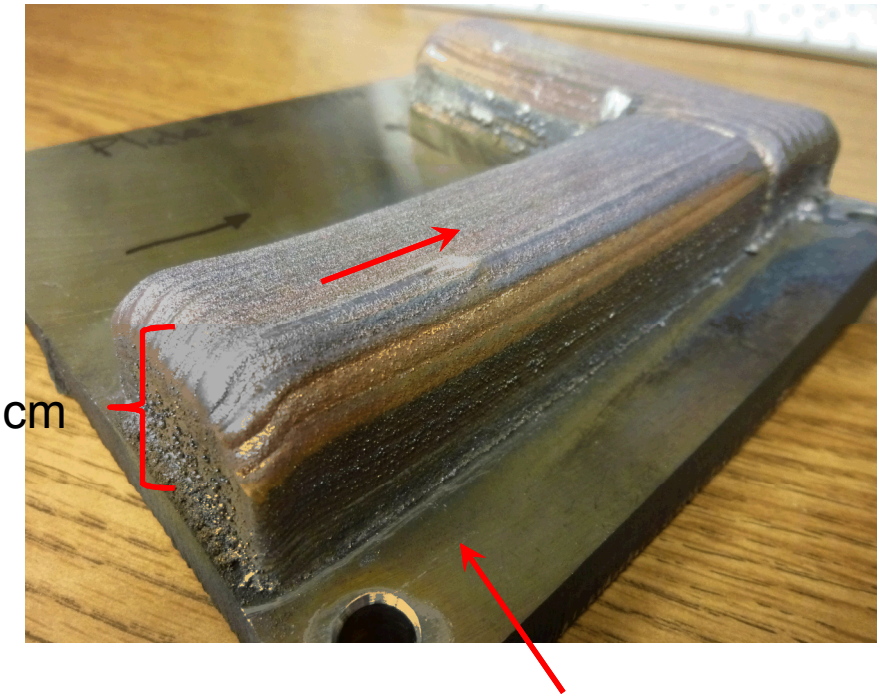


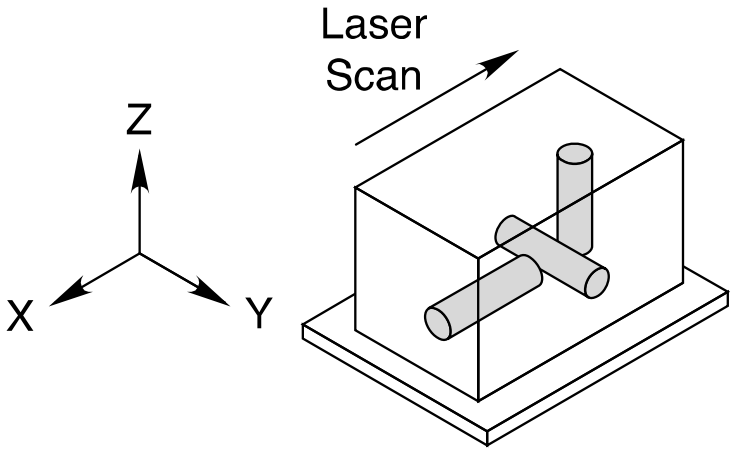


Baird, J.C., et. al. 2012. Localized twin bands in sheet bending of a magnesium alloy, Scripta Materialia, Vol. 67, Iss 5 (Modified)

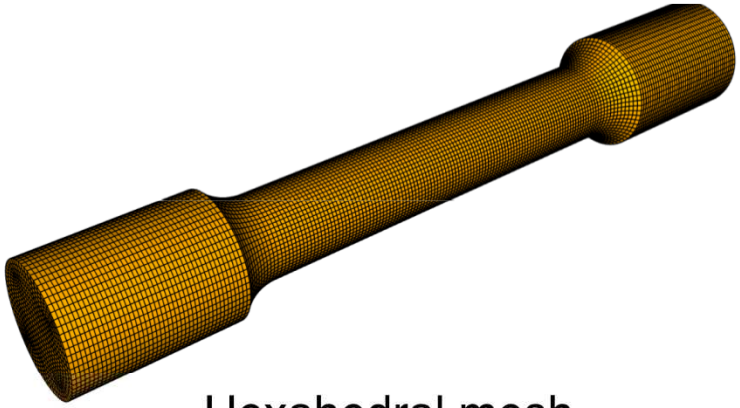
Tensile Specimens

304L SS by LENS

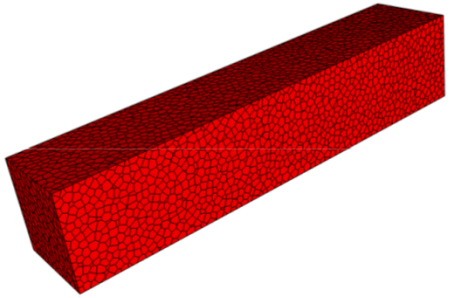




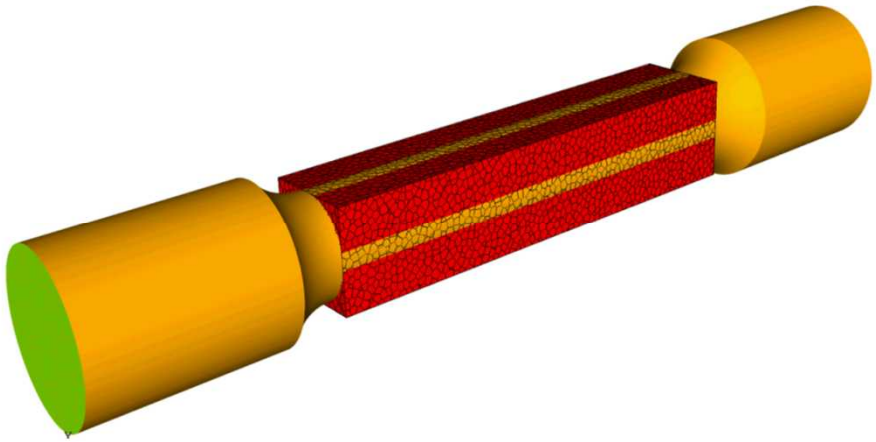
Voronoi Overlay



Hexahedral mesh



Voronoi model of grain structure



Voronoi overlay of hex mesh

Resultant grain structure embedded in hex mesh

Images courtesy of Joe Bishop, Solid Mechanics Dept.

Wrought vs. LENS Microstructure

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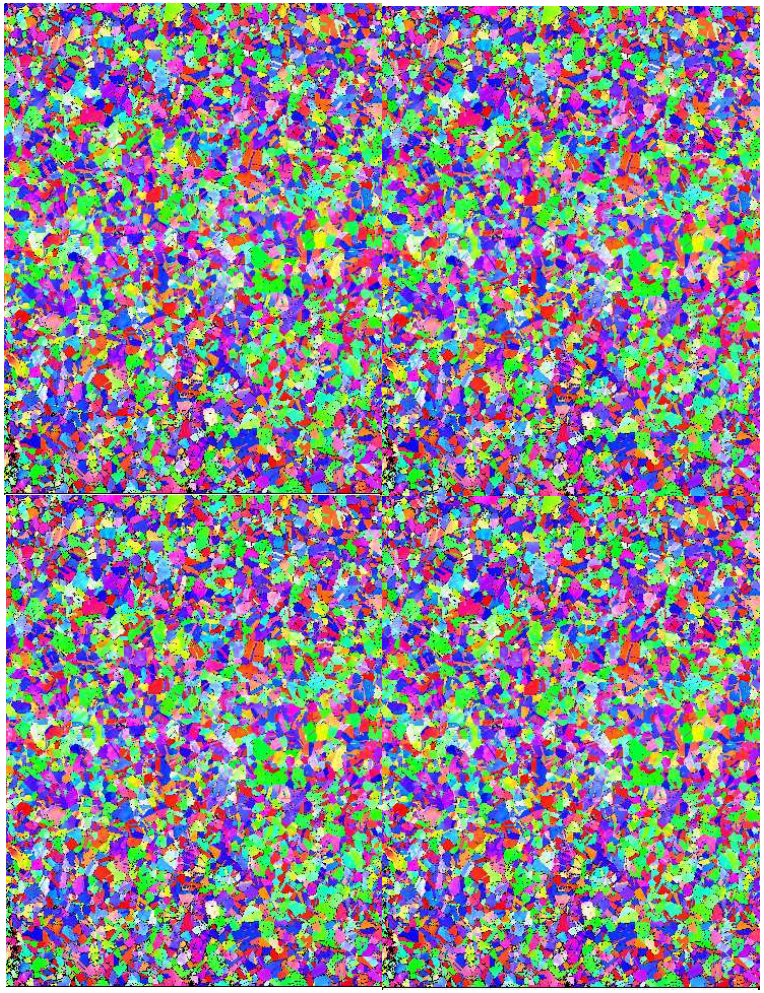
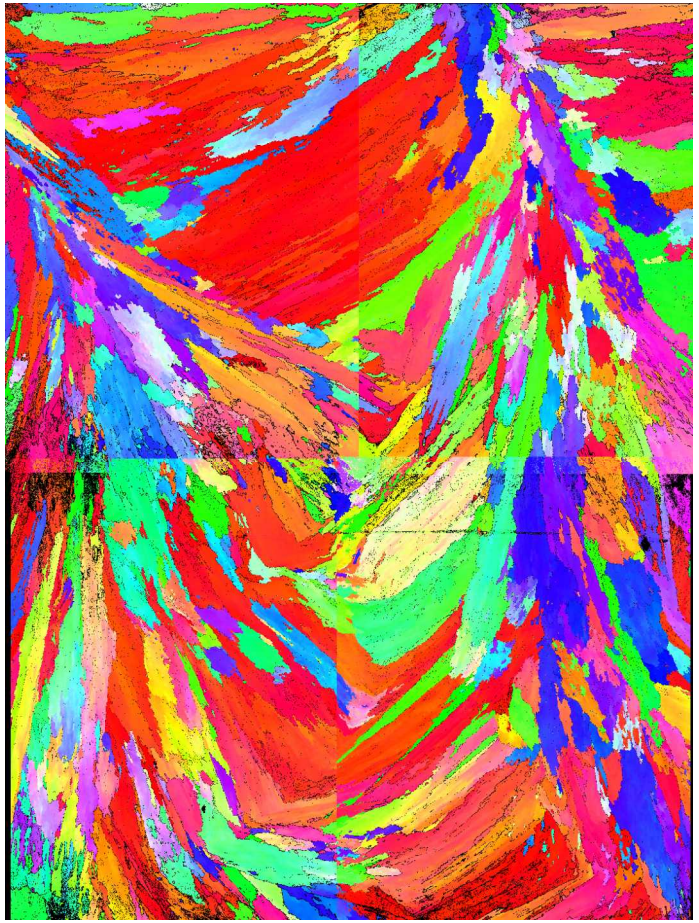
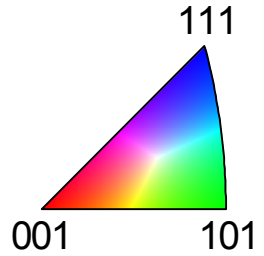
Wrought, SS 304L

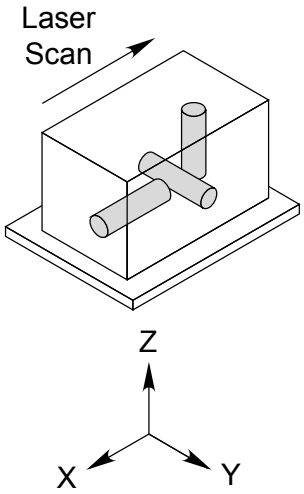
LENS, SS 304L
(3.8 kW Laser Power)





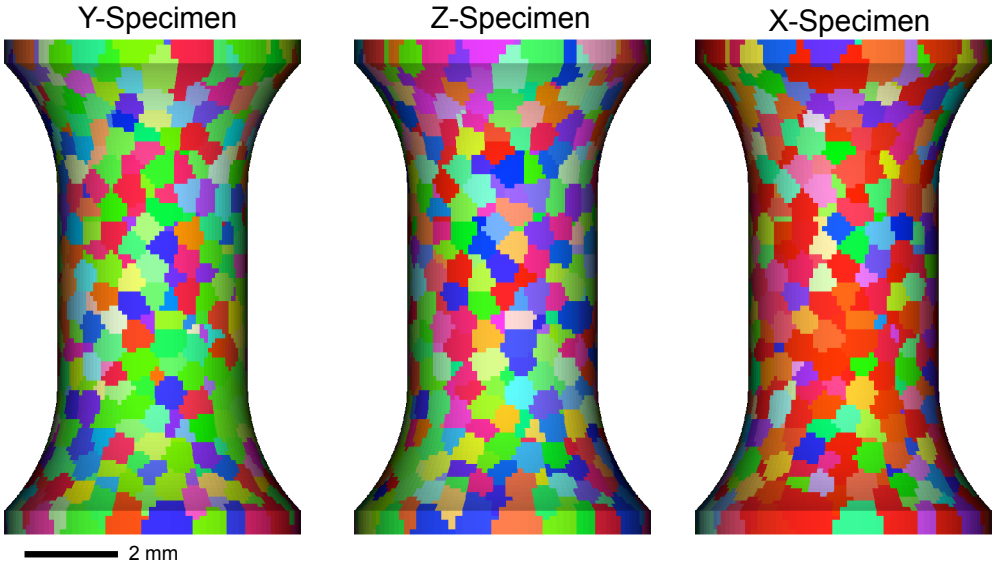


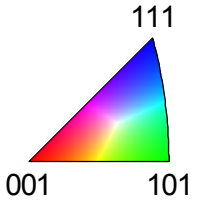
Texture Modeling



EBSD Orientation Maps

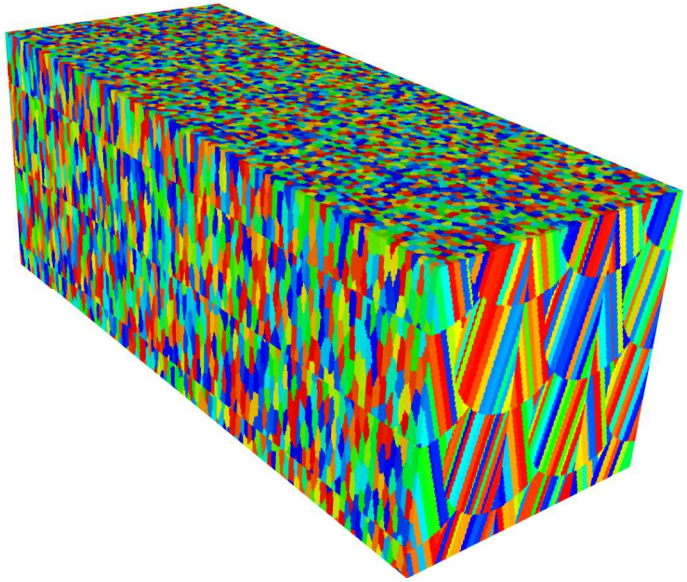
Tensile Specimens

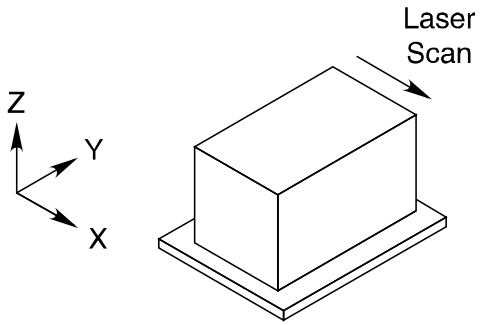




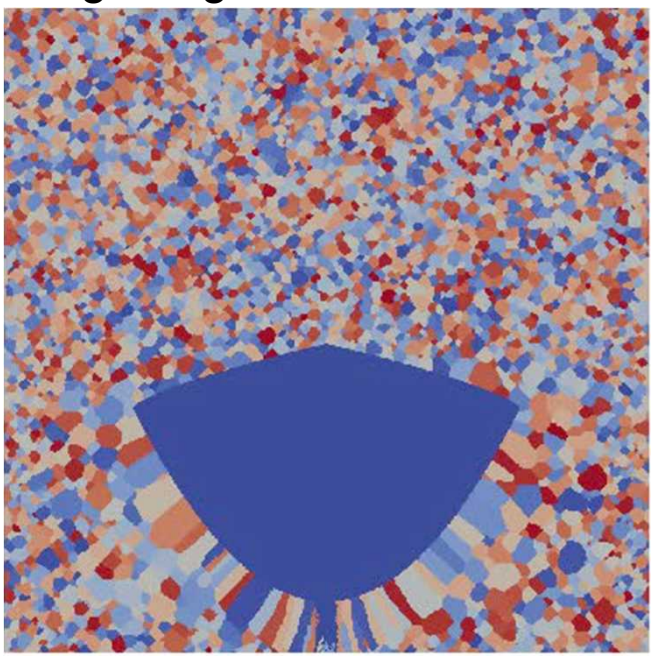
Microstructure Generation

Current method:
idealized LENS microstructure

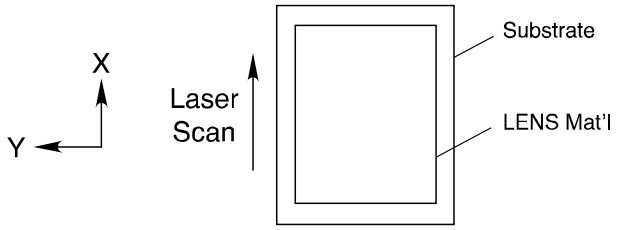




Future method:
grain growth simulation

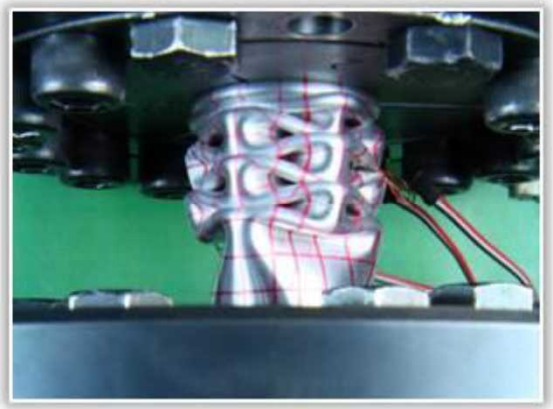
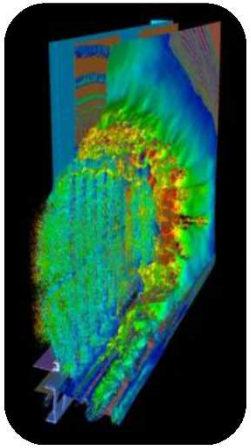
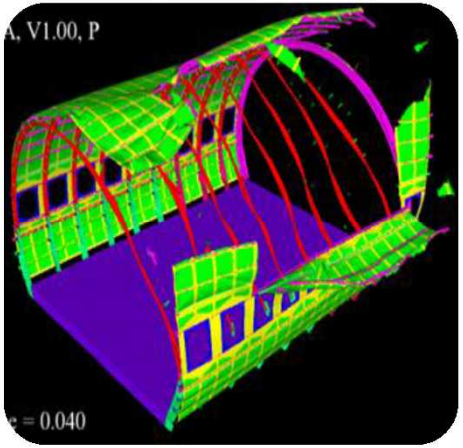


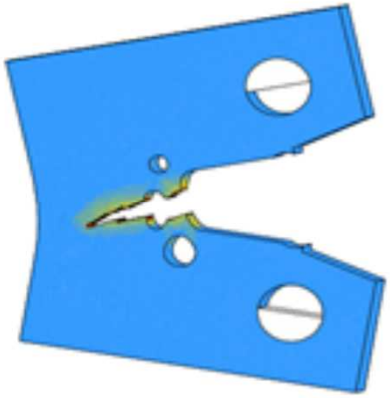
Video courtesy of Veena Tikare,
Multiscale Science Dept.



Summary

- Great people and exciting problems



- Open positions
  - Go to http://www.sandia.gov/careers
  - Internship postings 647130 (Graduate) and 647131 (Undergraduate) in the Solid Mechanics and Shock Physics departments. We expect to bring on 3 to 6 people over the summer.