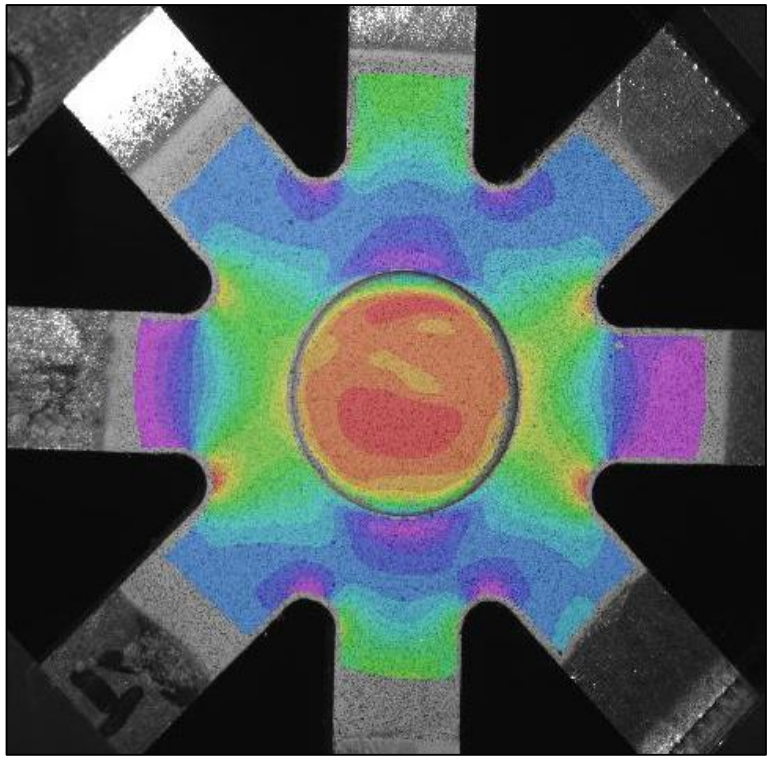
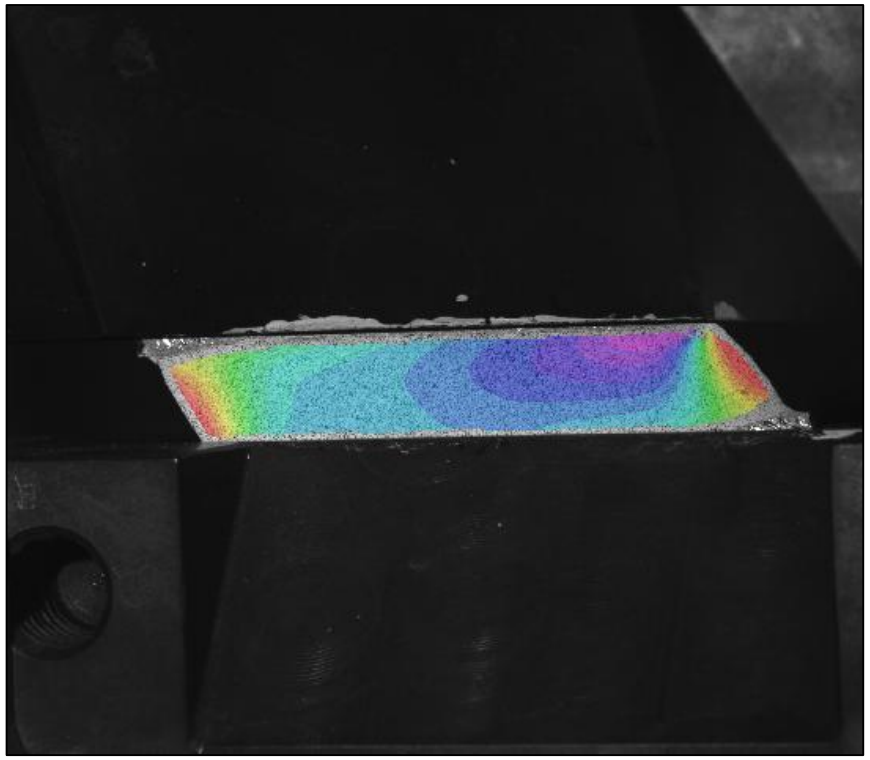
Characterizing and Verifying Parameters for Two New Mechanical Systems Through the Multiaxial Deformation of Automotive Sheet Metal





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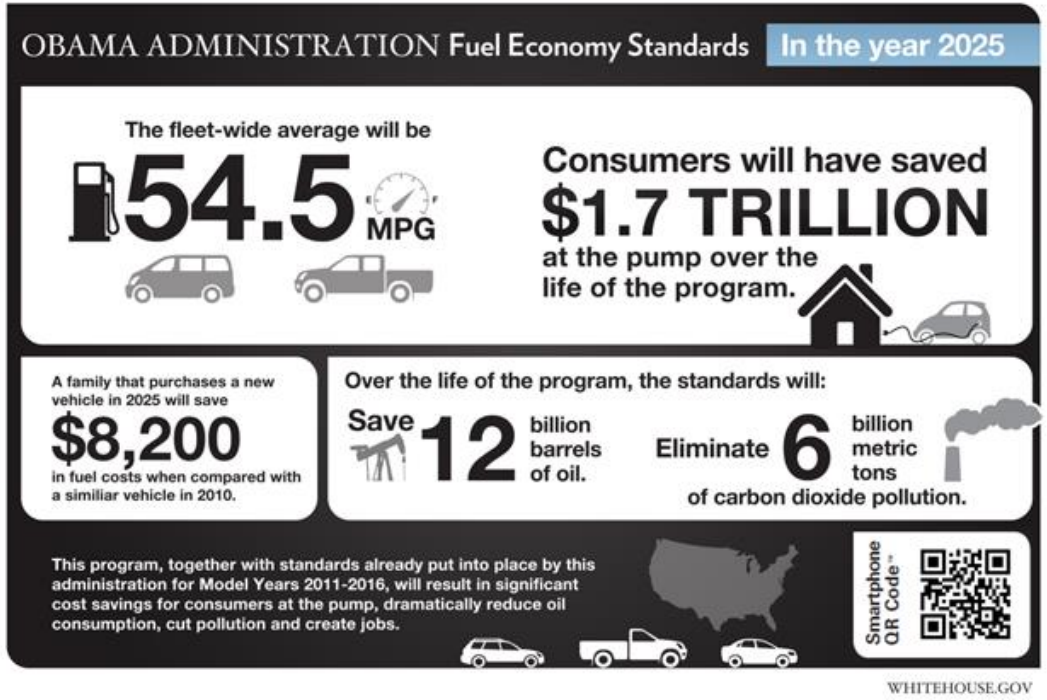
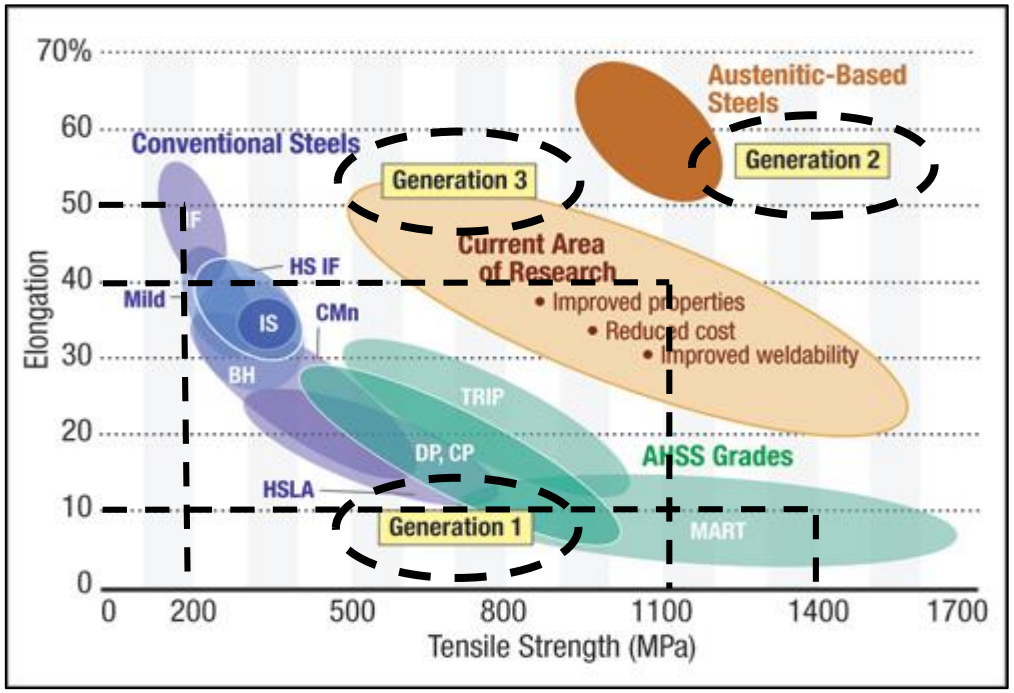
Motivation



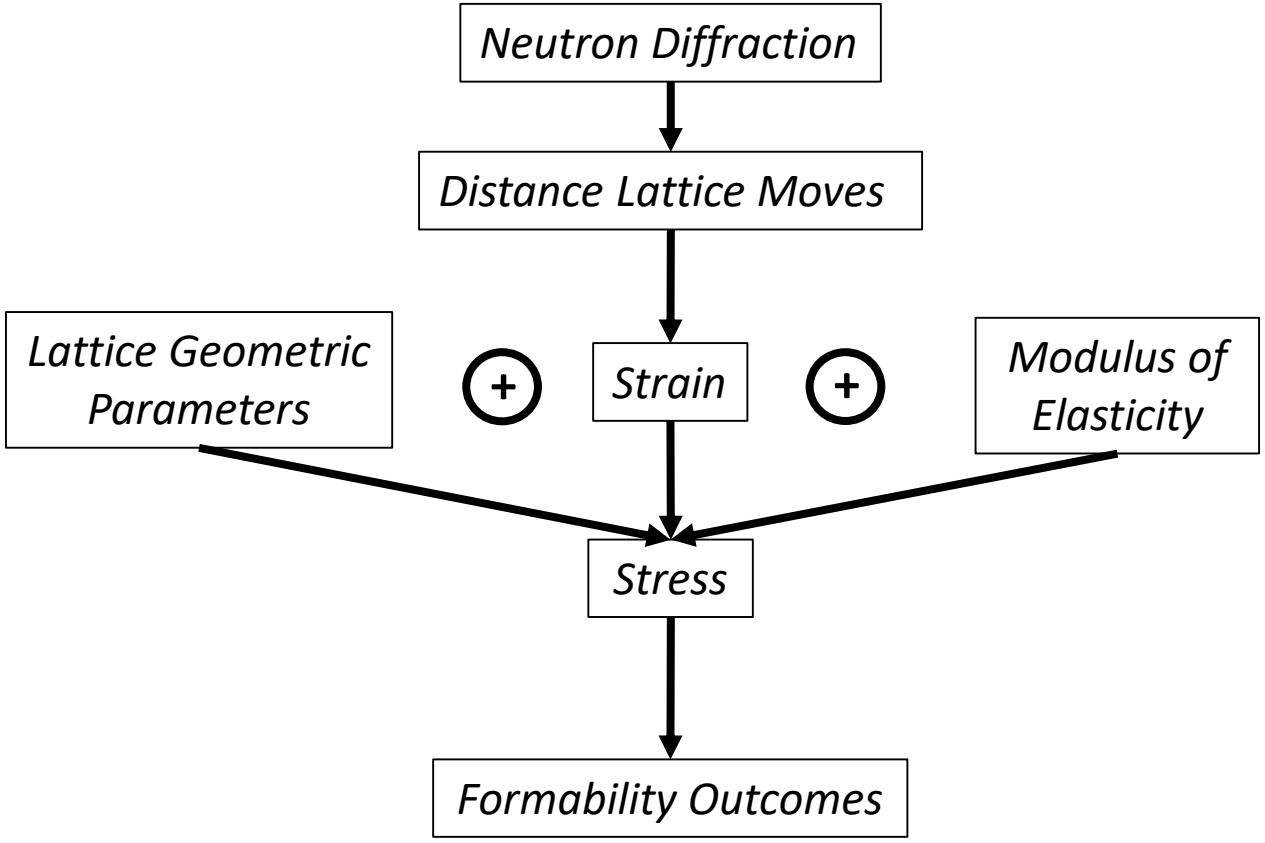


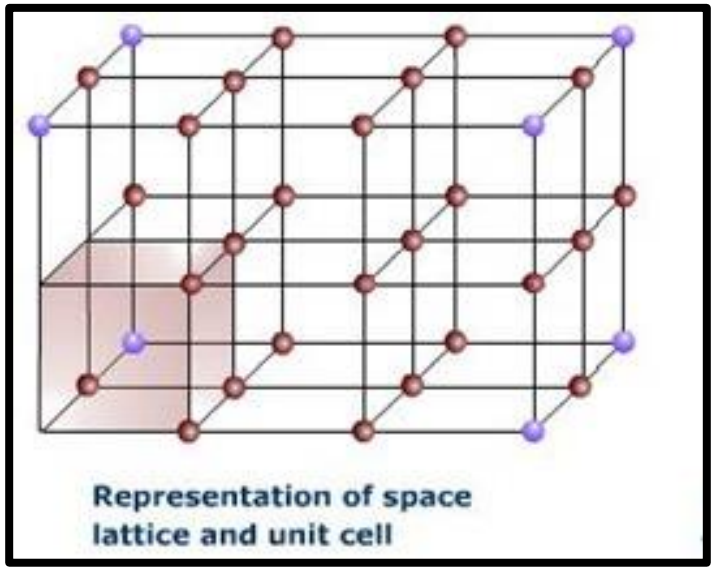
Classes and Properties of Automotive Sheet Metals

(Courtesy of *WorldAutoSteel)*

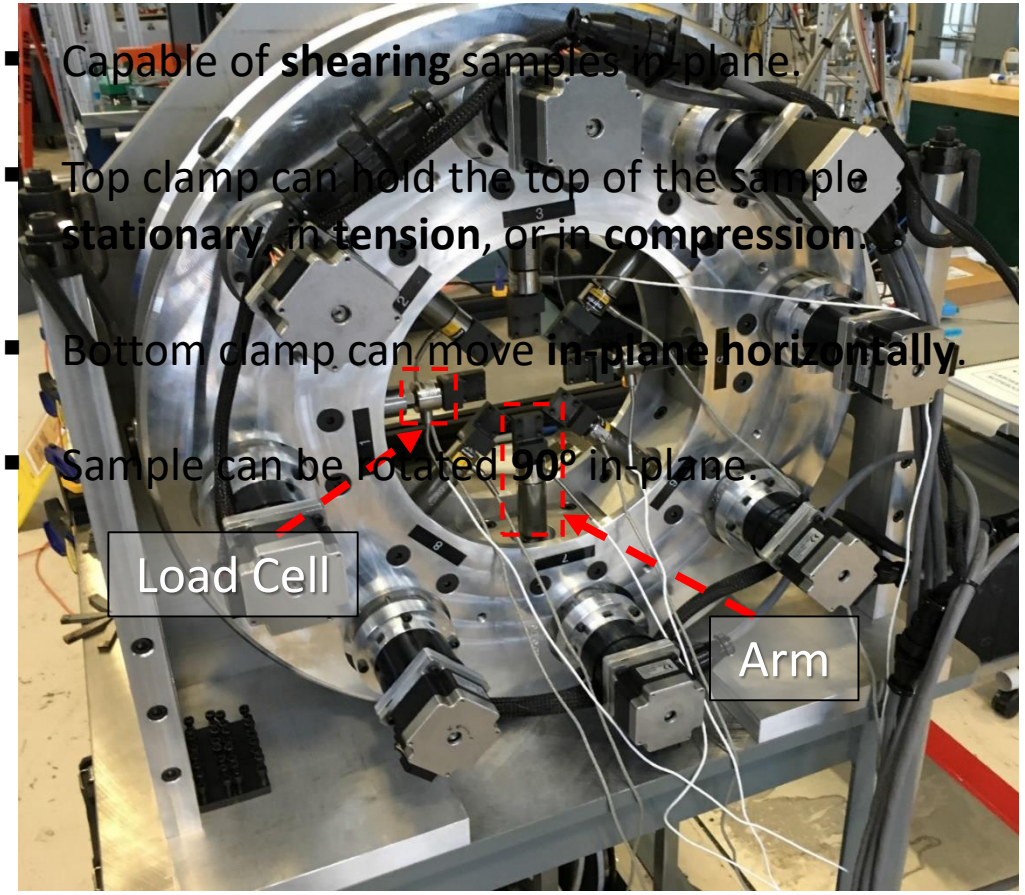
Rising fuel economy standards → Need for lighter vehicles → Need for mechanical properties of new metals → Methods for determining formability outcomes

Neutron Diffraction Experiments



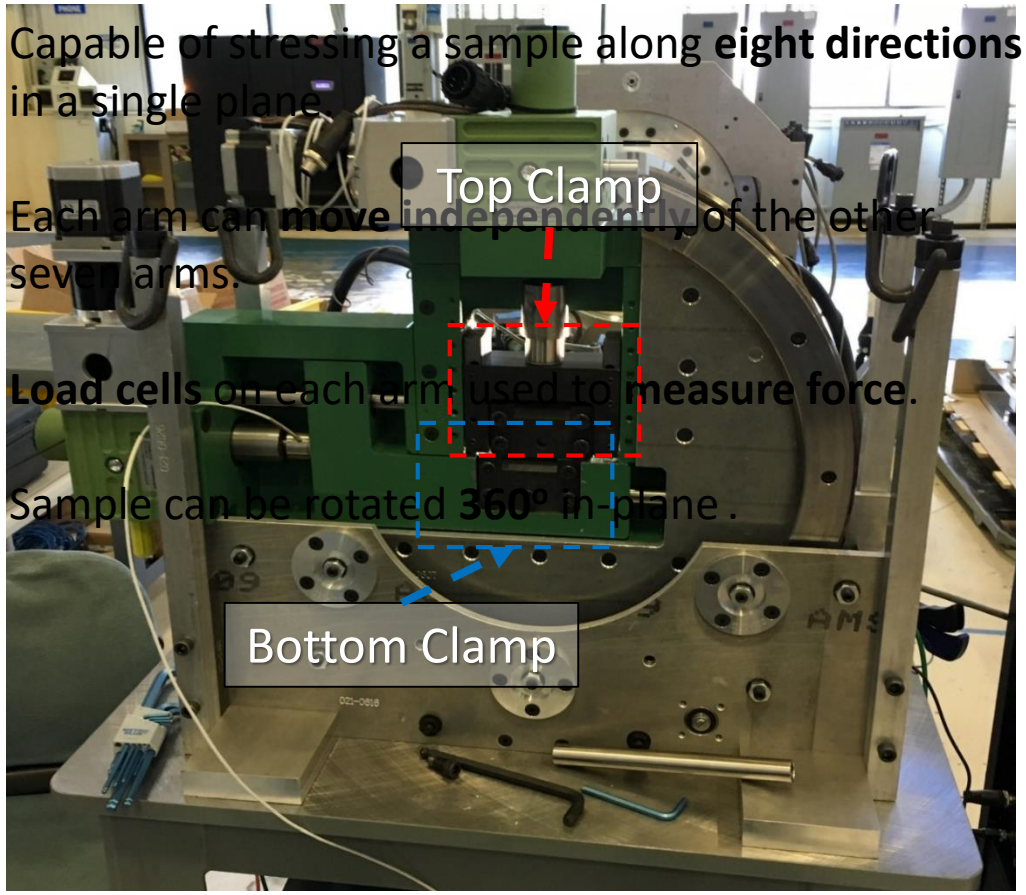


The Mechanical Systems



- Capable of **shearing** samples in-plane.
- Top clamp can hold the top of the sample **stationary**, in **tension**, or in **compression**.
- Bottom clamp can move **in-plane horizontally**.
- Sample can be rotated **90º** in-plane.

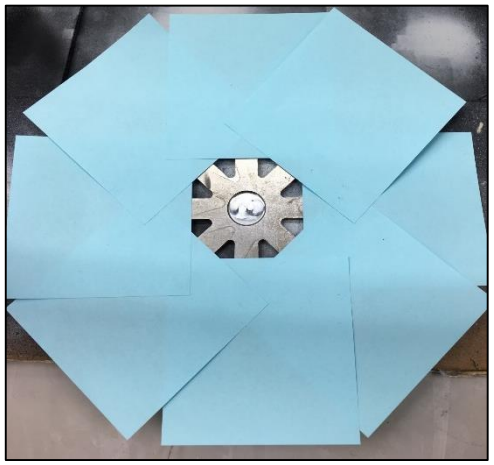
Octo-Strain



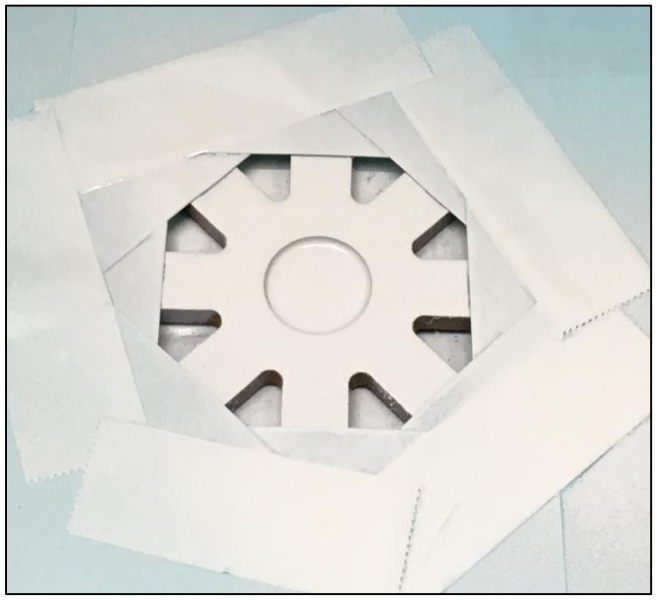
- Capable of stressing a sample along **eight directions** in a single plane.
- Each arm can **move** independently of the other seven arms.
- **Load cells** on each arm used to **measure force**.
- Sample can be rotated **360º** in-plane .

In-Plane Shearing Device

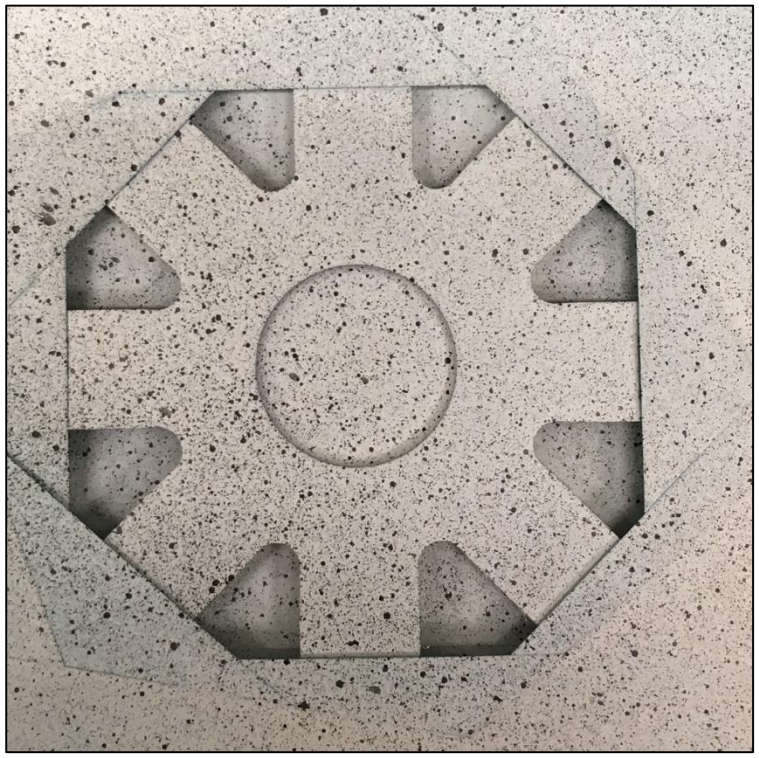
Preparation of Samples

1. 

Clean Sample

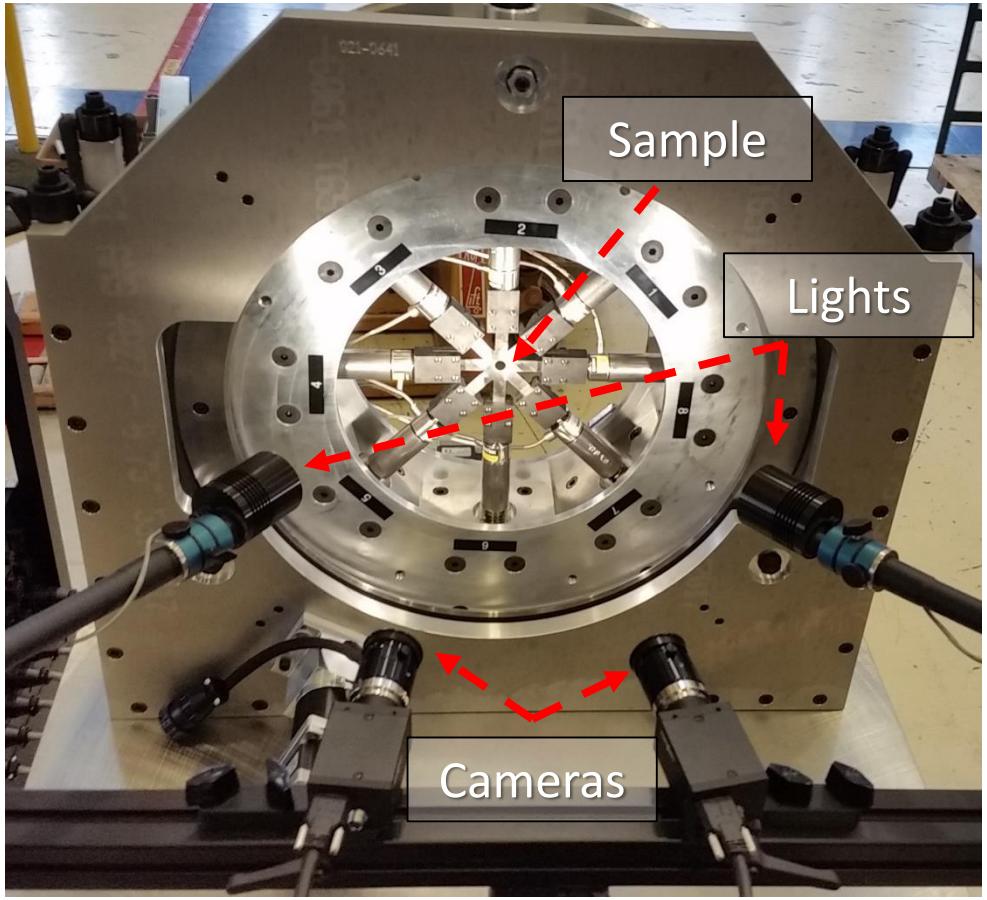
2. 

Apply White Coat

3. 

Spray Speckle Pattern

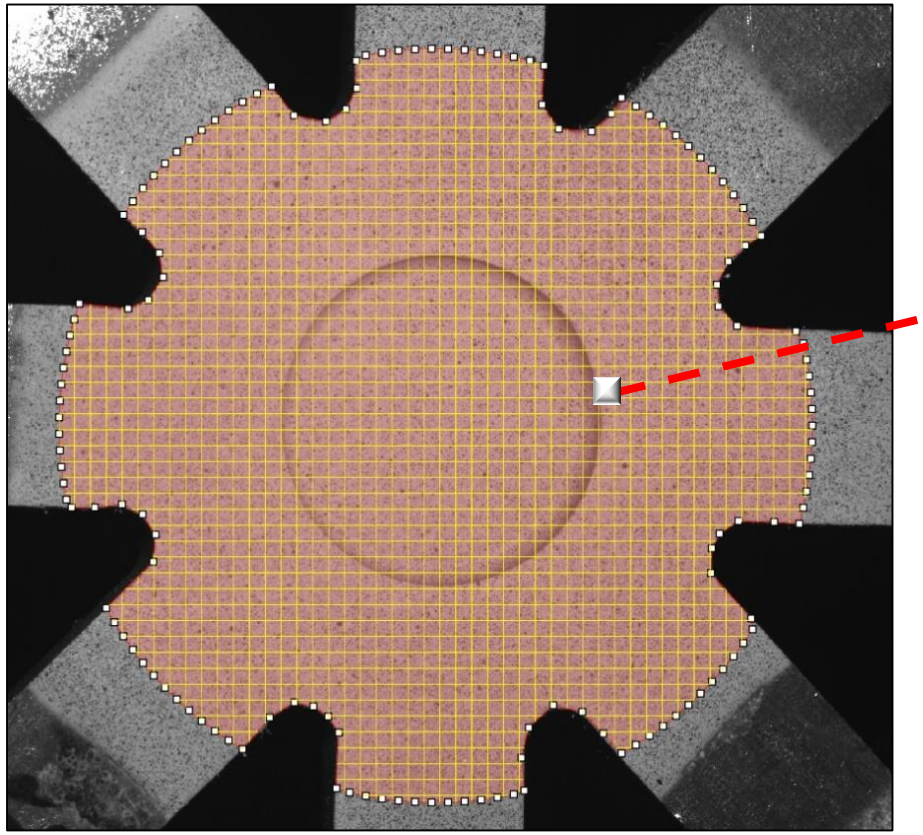
Digital Image Correlation Setup



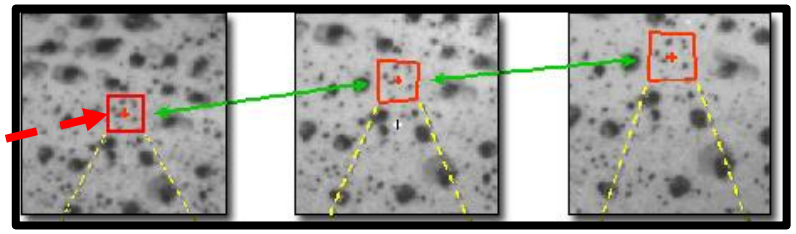
Digital Image Correlation Setup

- Sample placed in mechanical system.
- Cameras positioned to provide an appropriate field of view of the sample.
- Lights rotated and positioned to provide even lighting.

Basics of Digital Image Correlation



Typical Number of Subsets in One Image

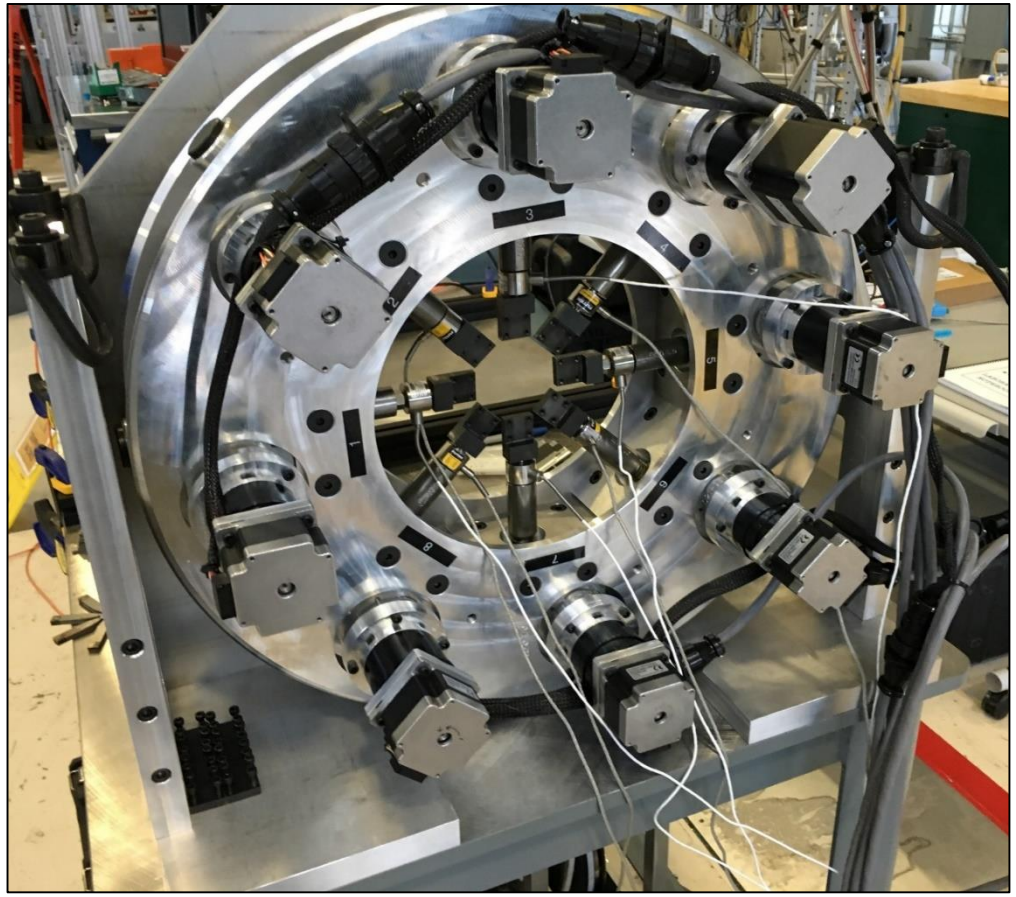


Movement of a Subset
During Tracking

(correlatedsolutions.com)

$$\varepsilon = \frac{l_f - l_o}{l_o}$$

Octo-Strain:
Parameters Researched



Octo-Strain

Parameters:

- **Strain Control**
  - Allows more **complex strain paths.**
  - **No user input** required during testing.
  - **More accurate** than current control methods.

- Testing **Strain Paths**

Octo-Strain:
Control Methods

Two Current Control Methods:

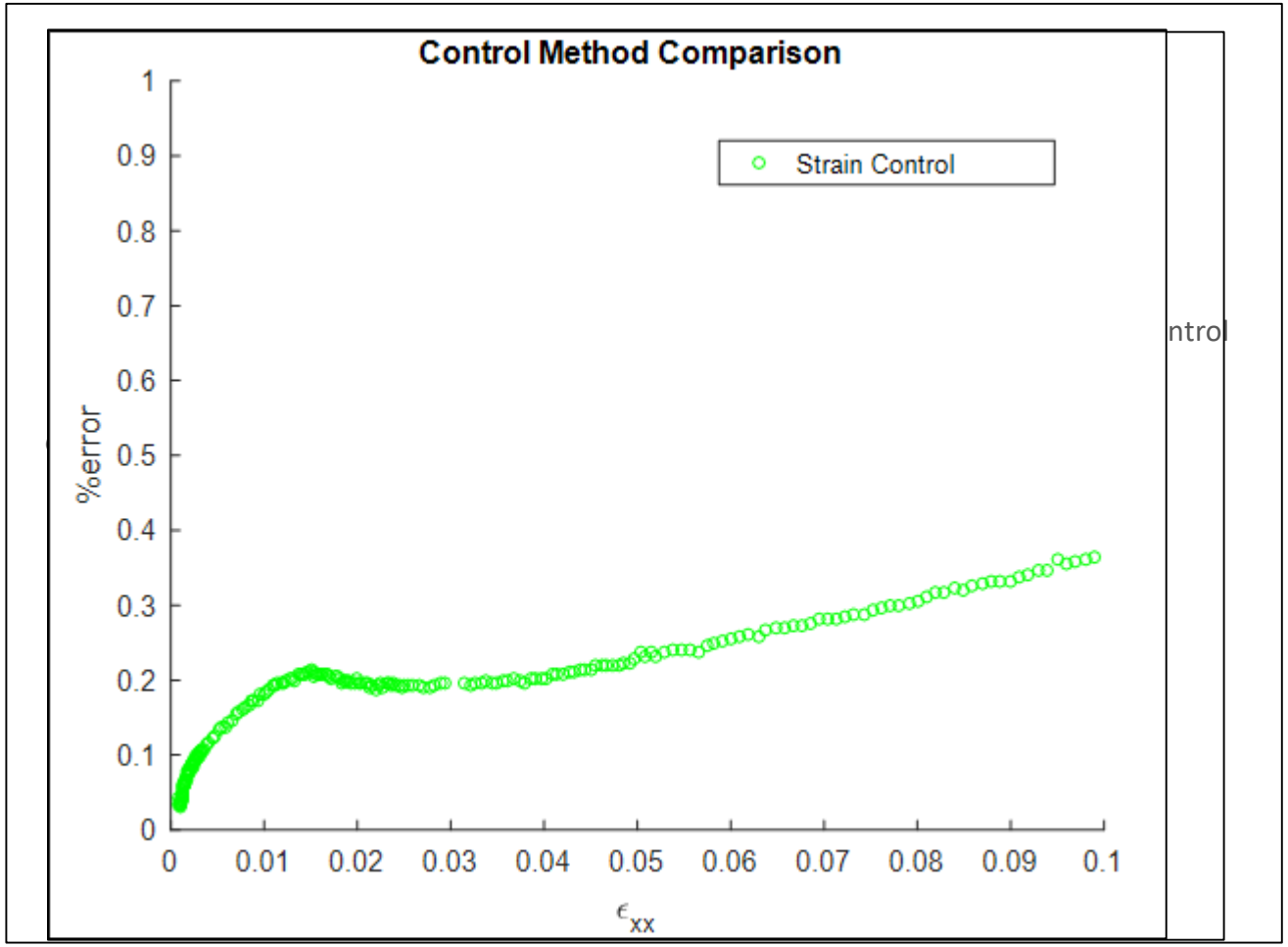
- **Force Control:**
  - Load cells read forces exerted on each arm.
  - Computer code changes speed of motors to approach the arm forces that the user has defined.

- **Displacement Control:**
  - Computer code sets speed of motors based on user defined strain targets and rates.

New Control Method:

- **Strain Control:**
  - Digital Acquisition (DAQ) setup reads strain from Digital Image Correlation (DIC) system.
  - Code changes speed of motors based on comparing a user defined strain path to the DAQ strain readings.

Strain Control: Results



All tests were run to be **equi-biaxial**.

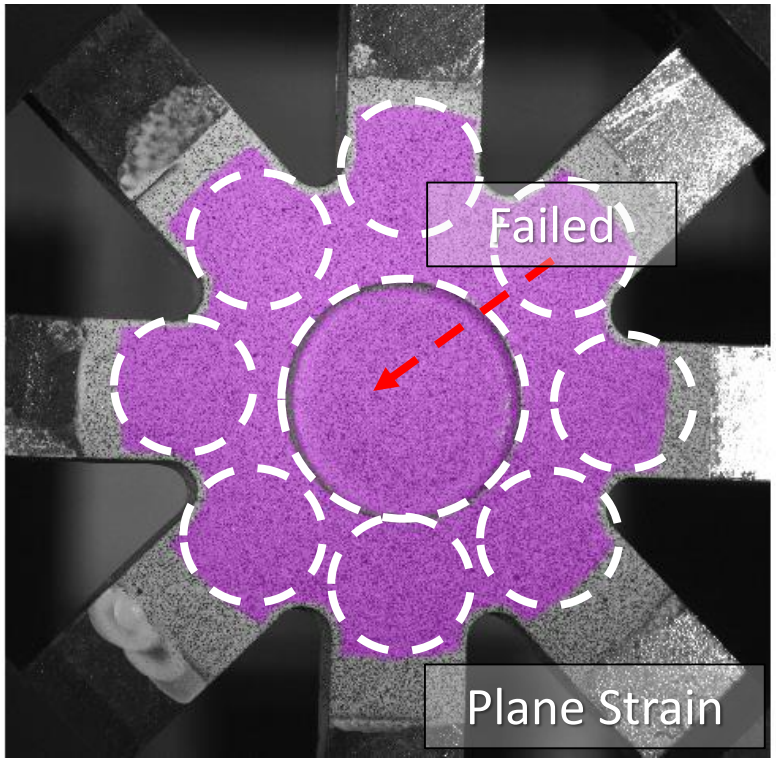
Equi-biaxial means that at each point:

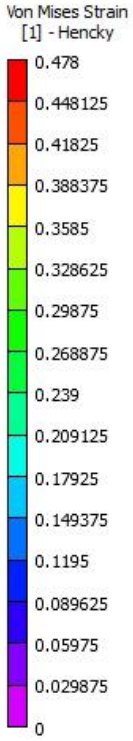
$\varepsilon_{yy} = \varepsilon_{xx}$

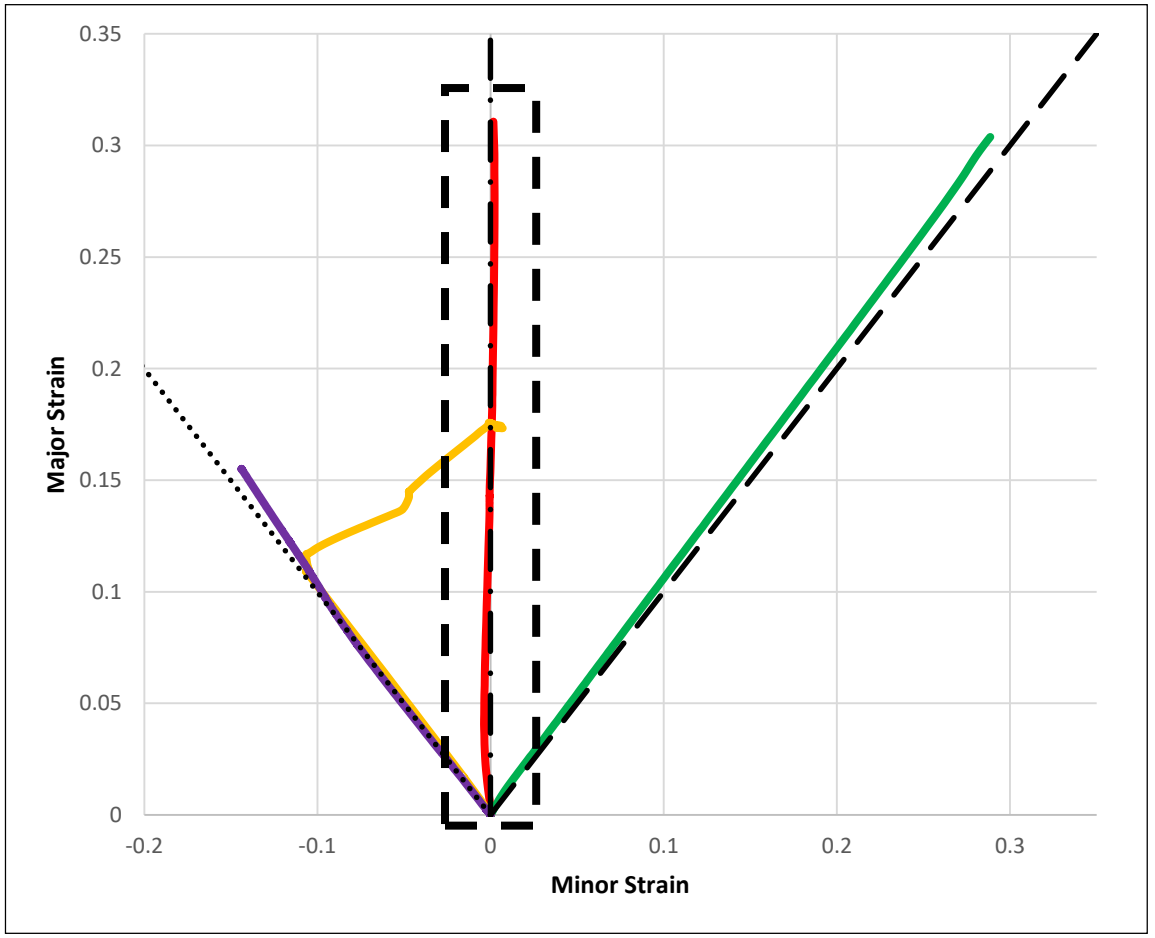
$$\%\text{error} = \frac{|\varepsilon_{xx} - \epsilon_{yy}|}{\varepsilon_{yy}} * 100\%$$

Strain control has **lowest %error.**

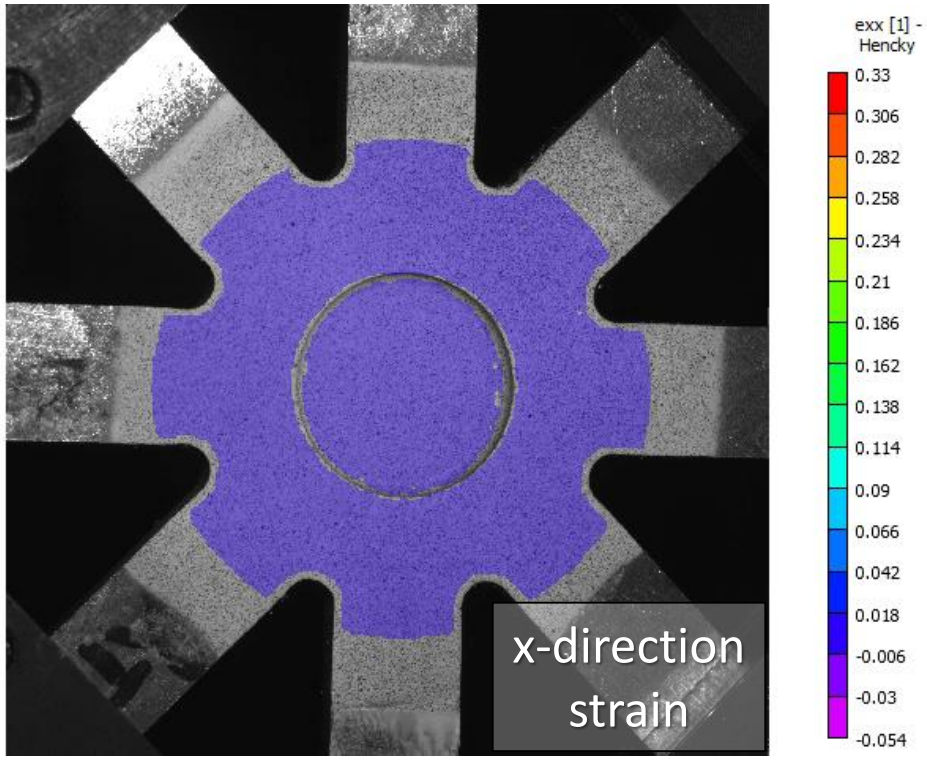
Octo-Strain:
Plane Strain Test Results

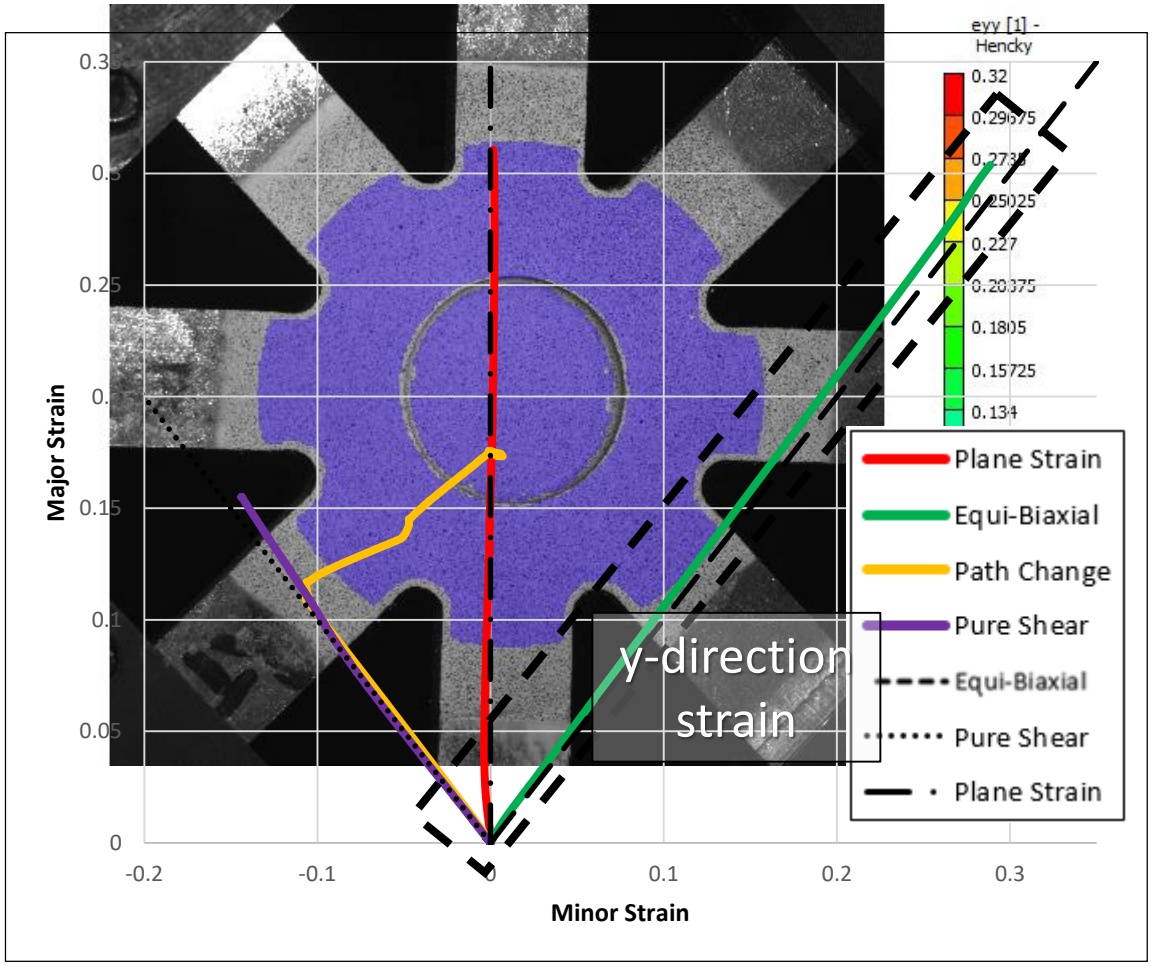




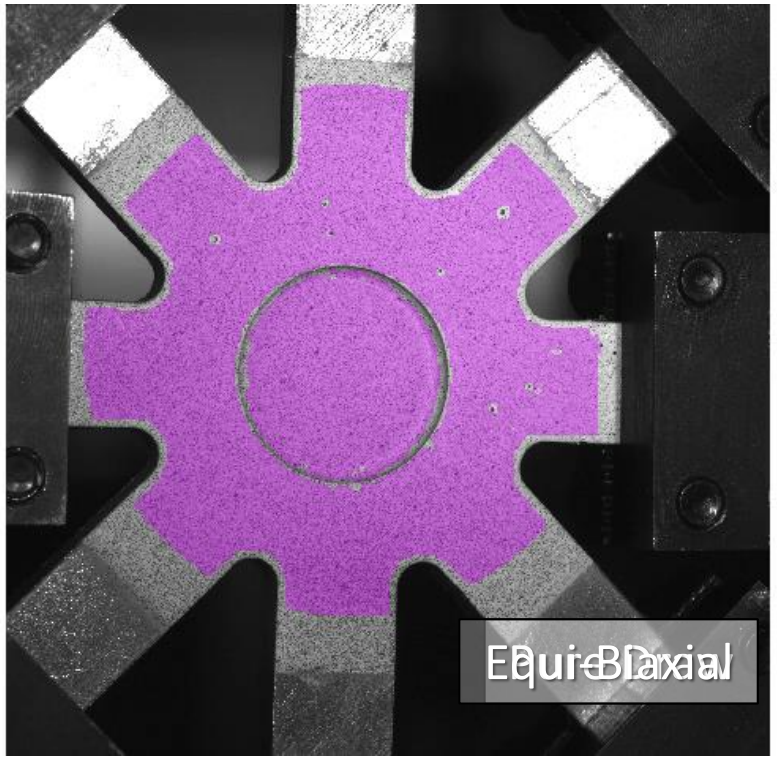


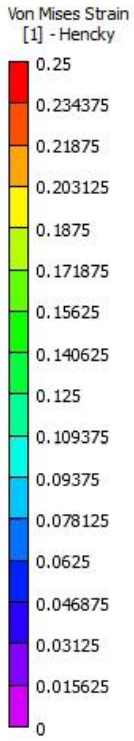
Octo-Strain:
Equi-Biaxial Test Results

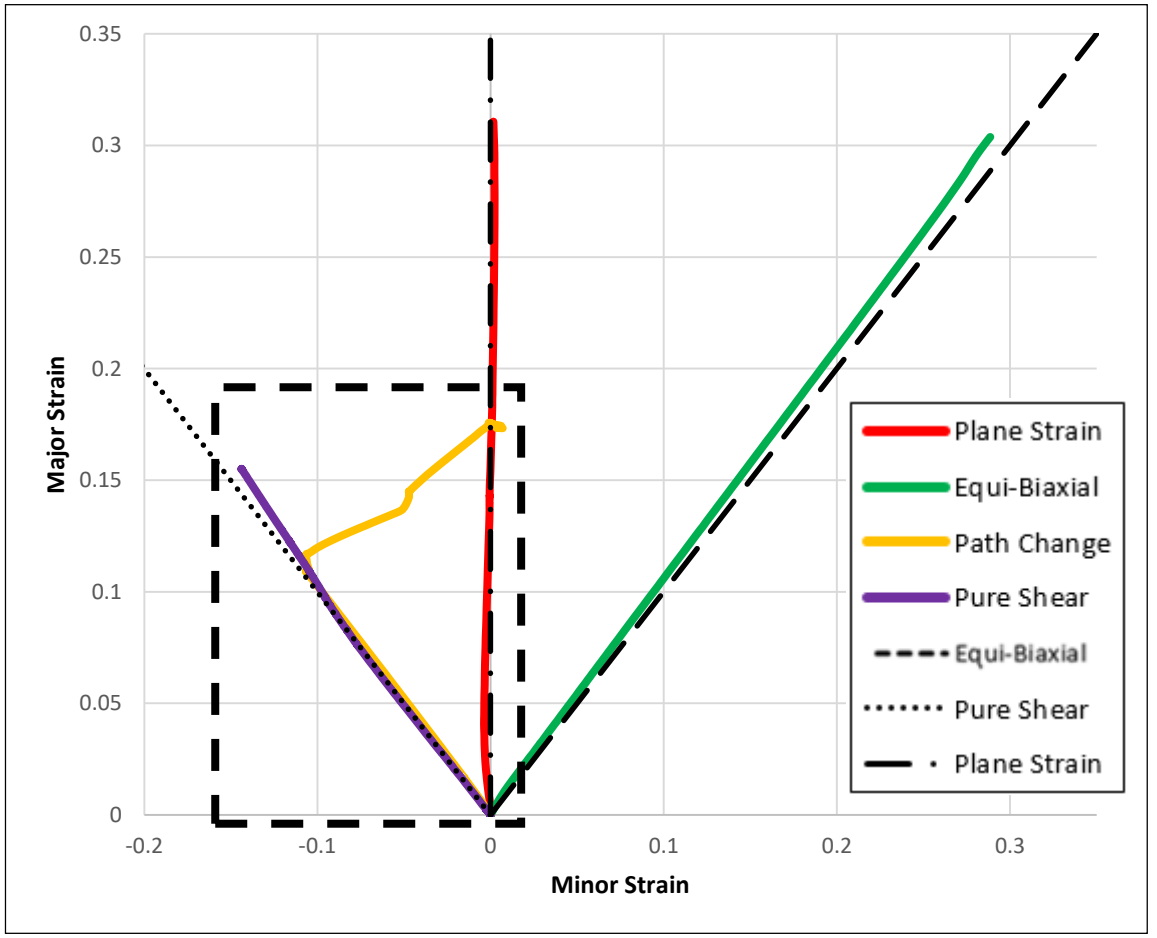




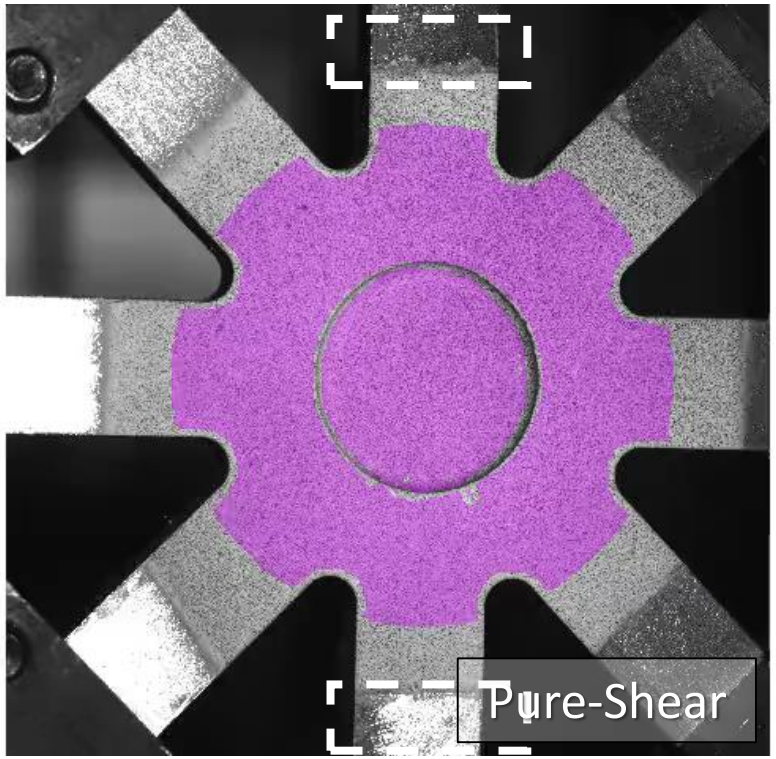
Octo-Strain:
Path Change Test Results

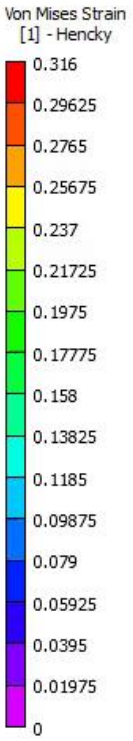


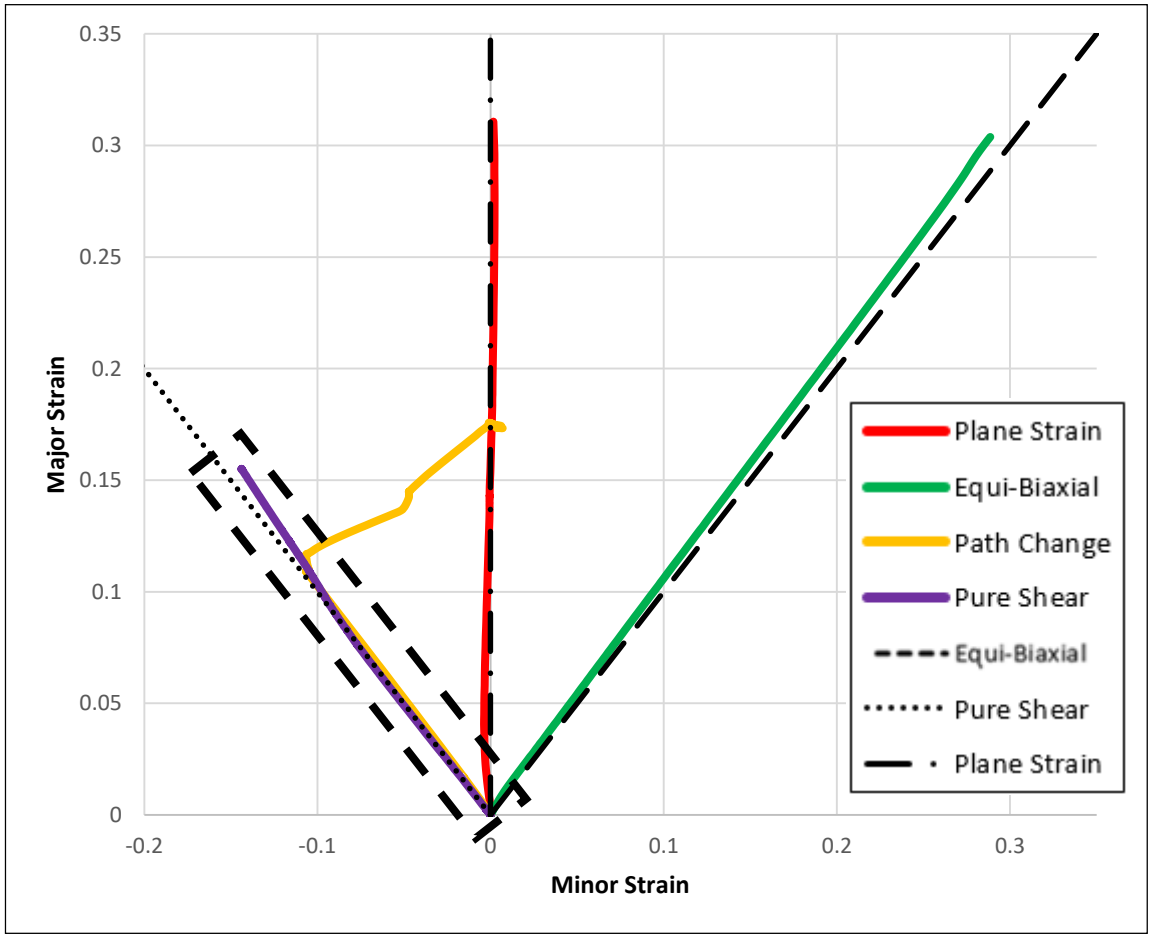




Octo-Strain:
Pure-Shear Test Results







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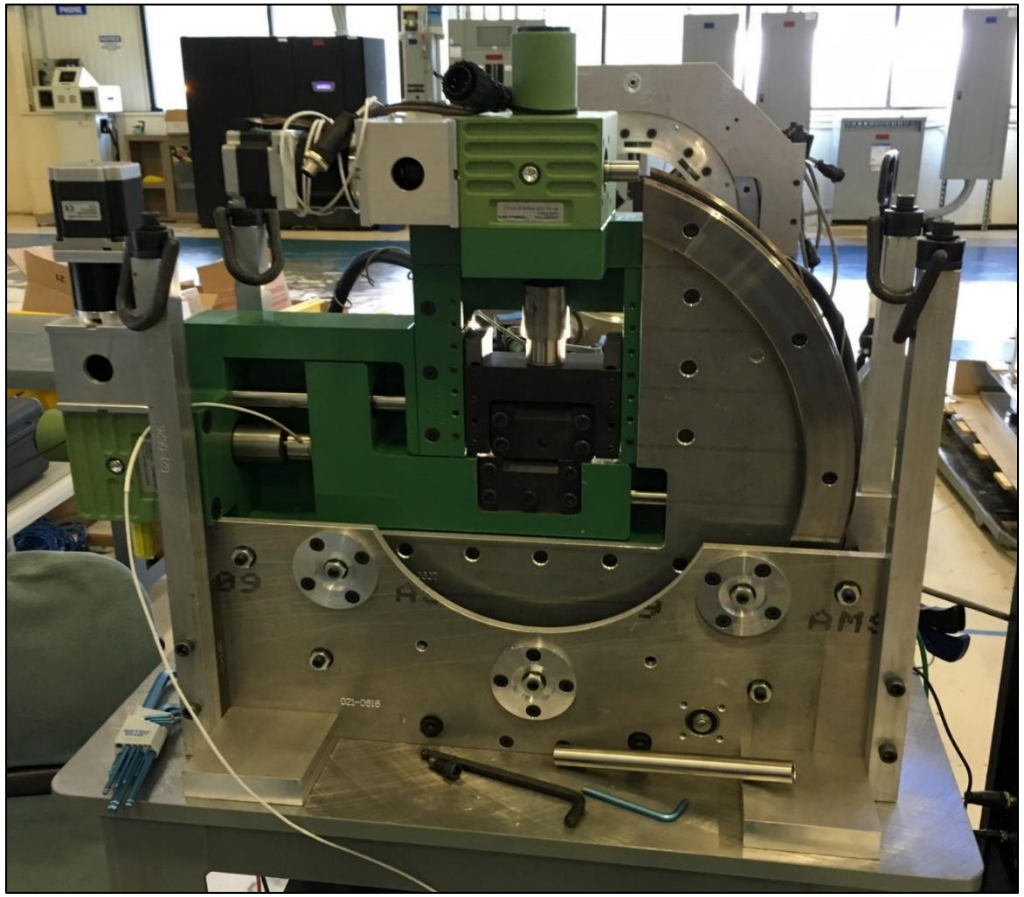
In-Plane Shearing Device:
Parameters Researched

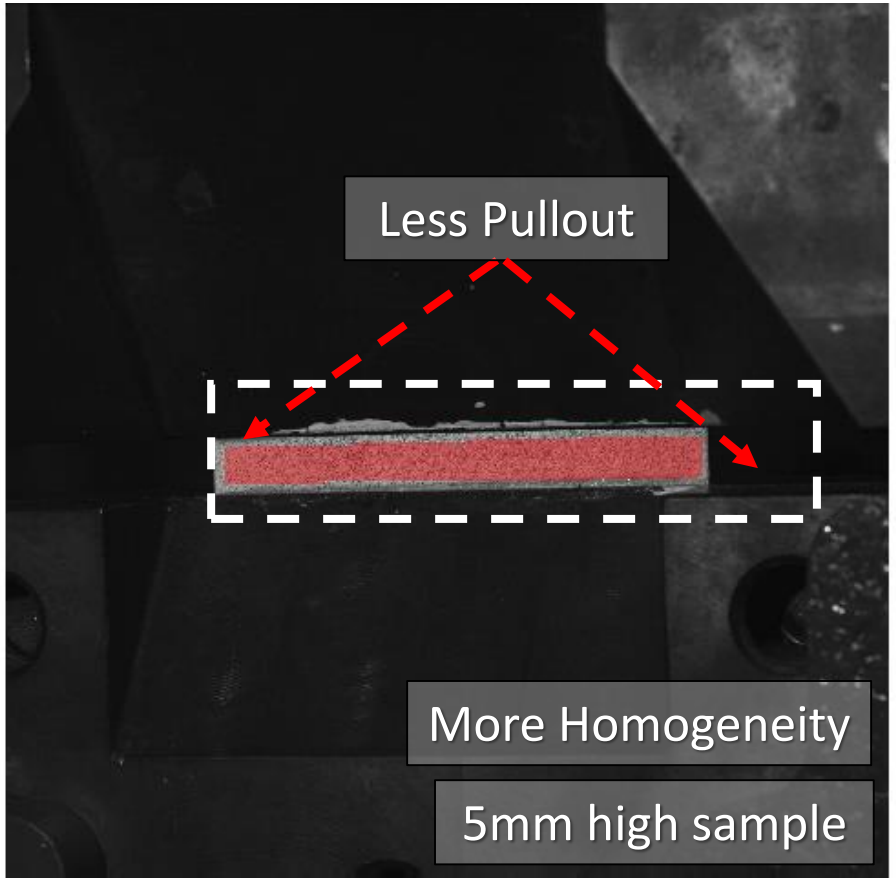
Parameters:

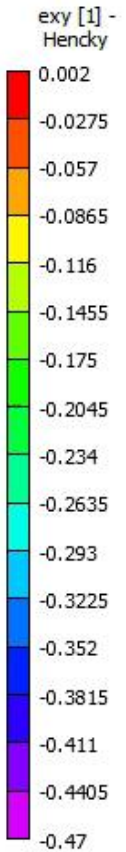
- Planar sample **geometry** with the most **homogeneity in strain**.

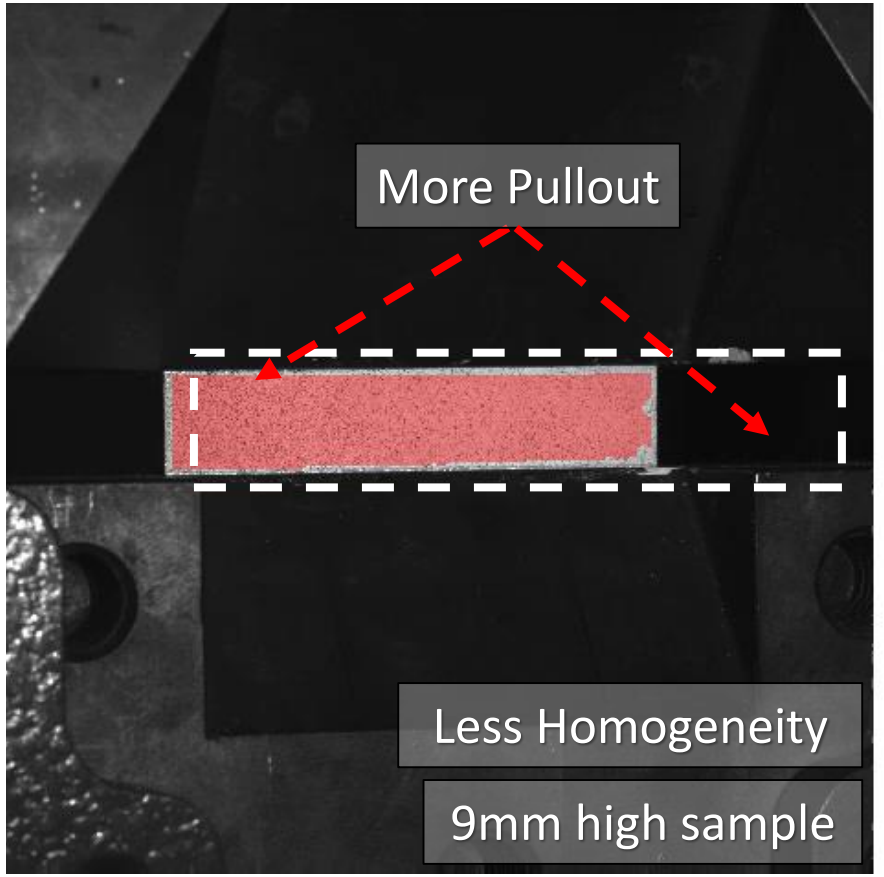


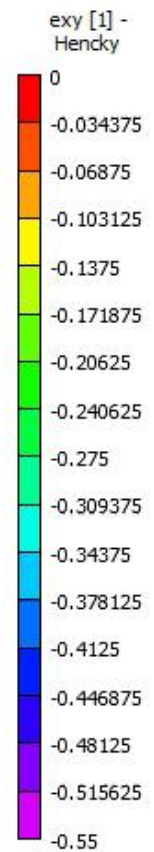
In-Plane Shearing Device

In-Plane Shearing Device:
Homogeneity in Strain Results

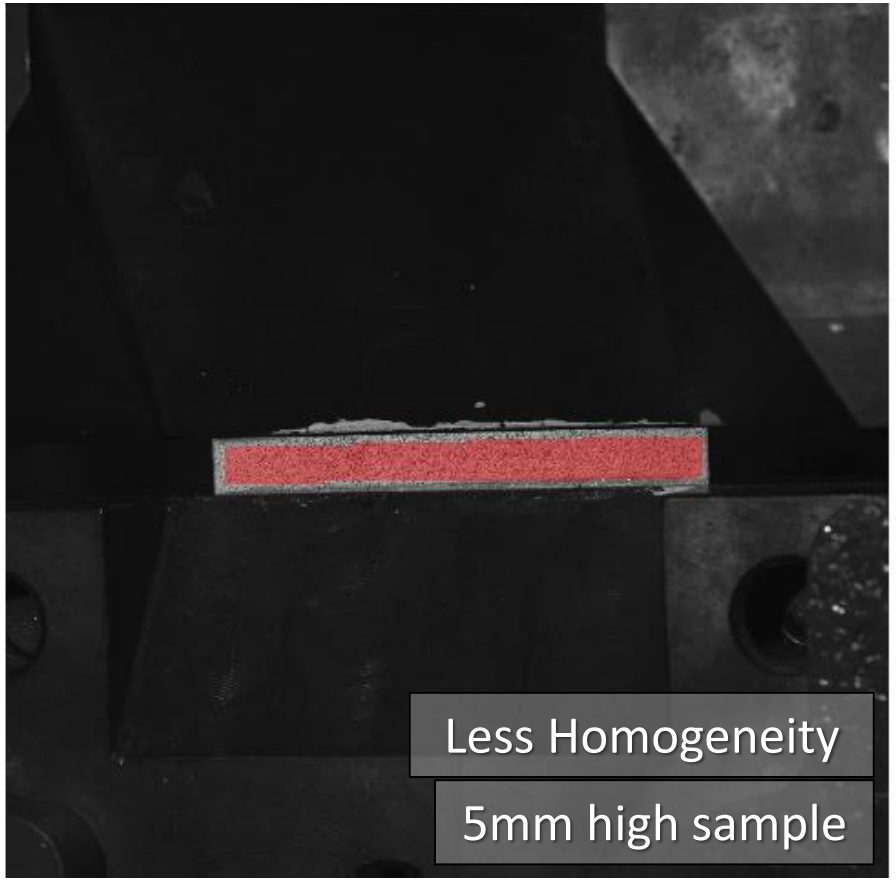


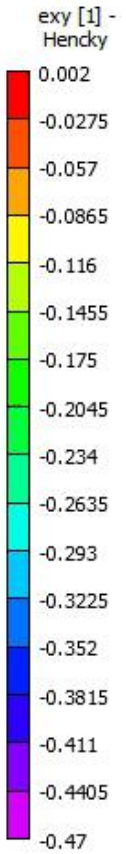


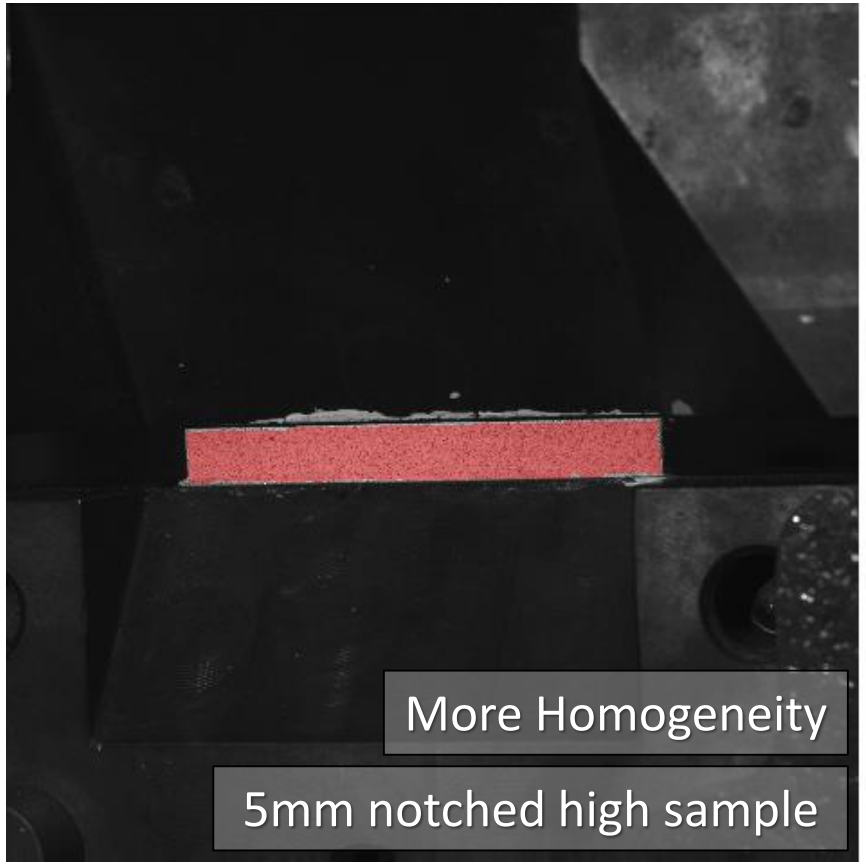


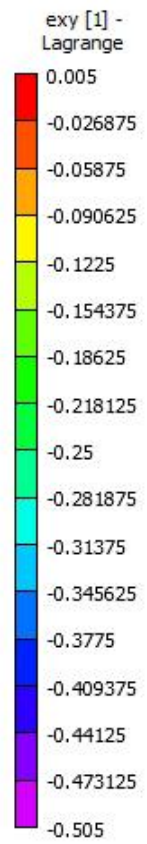


In-Plane Shearing Device:
Homogeneity in Strain Results









Summary of Results

- A new control method, **strain control**, has been developed.
  - Advantages:
    - **Complex strain paths** can be defined easily in Excel.
    - **No user input** required during testing.
    - **More accurate** strain tests.

- Geometric parameters to achieve the highest homogeneity in strain for planar samples have been determined.
  - **Smaller Height = Greater Homogeneity**
  - **Notches = Greater Homogeneity**

Acknowledgements

Special Thanks To:

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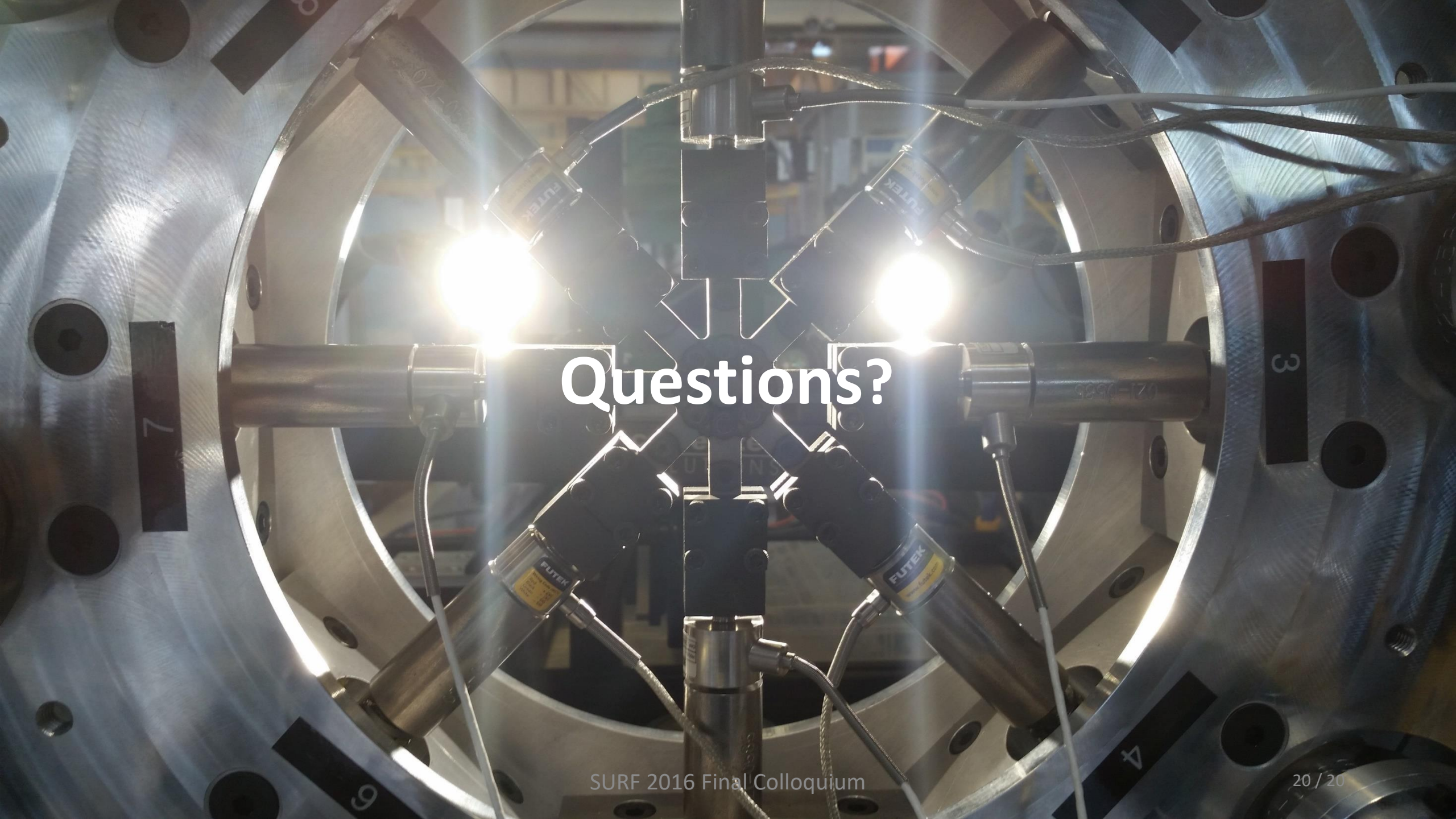
- Center for High Resolution Neutron Scattering (CHRNS)
- SURF Program


Questions?