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

Daevin Bhathal Hugh

Mentors: Thomas Gnäupel-Herold, Justin Milner

SURF 2016 Final Colloquium
Motivation

Rising fuel economy standards ➔ Need for lighter vehicles ➔ Need for mechanical properties of new metals ➔ Methods for determining formability outcomes
Neutron Diffraction Experiments

Neutron Diffraction

Distance Lattice Moves

Lattice Geometric Parameters

Strain

Modulus of Elasticity

Stress

Formability Outcomes

Representation of space lattice and unit cell
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 90° in plane.

- 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 360° in plane.
Preparation of Samples

1. Clean Sample
2. Apply White Coat
3. Spray Speckle Pattern
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

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:
\[ \varepsilon_{yy} = \varepsilon_{xx} \]

\[
\%error = \left| \frac{\varepsilon_{xx} - \varepsilon_{yy}}{\varepsilon_{yy}} \right| \times 100\%
\]

Strain control has lowest %error.
Octo-Strain: Plane Strain Test Results

Failed

Plane Strain

Major Strain vs Minor Strain Graph

Yon Masa Strain
0.0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
-0.2
-0.1
0
0.1
0.2
0.3
Minor Strain

Major Strain

Plane Strain Test Results

SURF 2016 Final Colloquium
Octo-Strain: Equi-Biaxial Test Results

x-direction strain

y-direction strain
Octo-Strain: Path Change Test Results
Octo-Strain: Pure-Shear Test Results

![Image of test results]

Diagram showing the relationship between major strain and minor strain for pure-shear tests. The diagram includes a color scale indicating strain levels and lines representing different strain paths.
In-Plane Shearing Device: Parameters Researched

Parameters:

- Planar sample geometry with the most homogeneity in strain.
**In-Plane Shearing Device: Homogeneity in Strain Results**

- **5mm high sample**: Less Pullout, More Homogeneity
- **9mm high sample**: More Pullout, Less Homogeneity
In-Plane Shearing Device: Homogeneity in Strain Results

Less Homogeneity
5mm high sample

More Homogeneity
5mm notched high sample
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:

- Dr. Thomas Gnäupel-Herold
- Dr. Justin Milner
- Dr. Julie Borchers
- Dr. Joseph Dura
- NCNR Director Dr. Robert Dimeo
- NIST Center for Neutron Research
- Center for High Resolution Neutron Scattering (CHRNS)
- SURF Program
Questions?