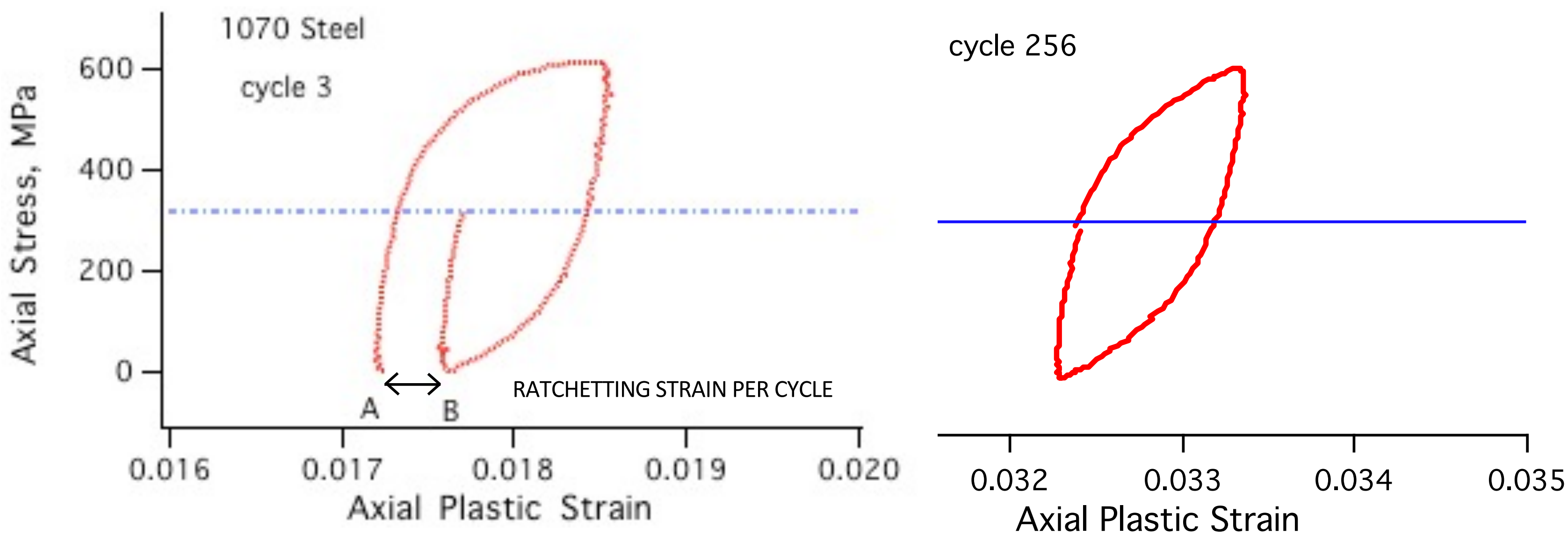
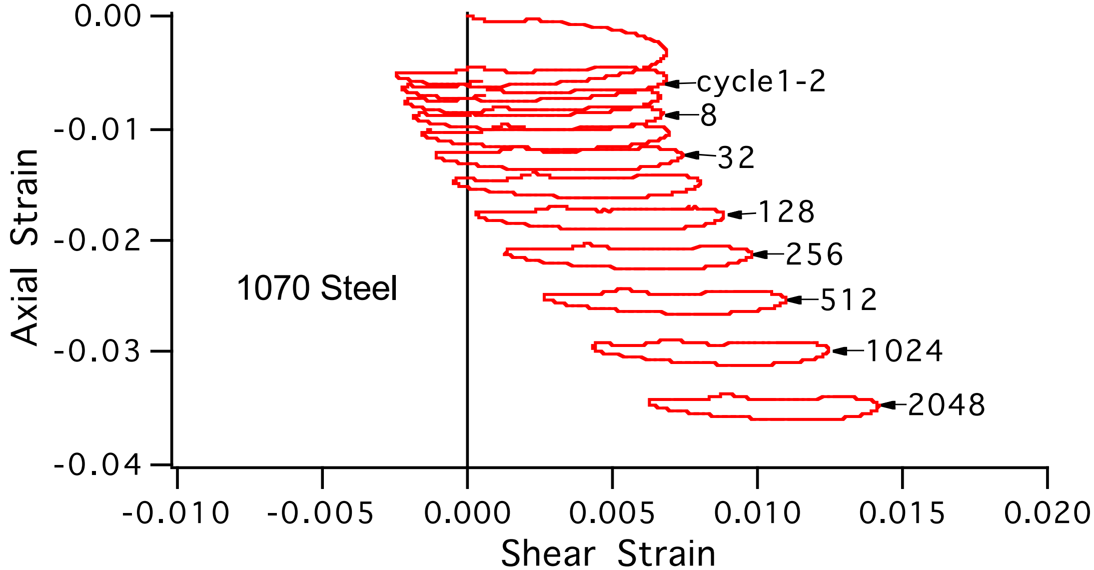
# DEFINITION OF RATCHETTING : INCREMENT OF STRAIN PER CYCLE DUE NONCLOSURE OF THE HYSTERESIS LOOP



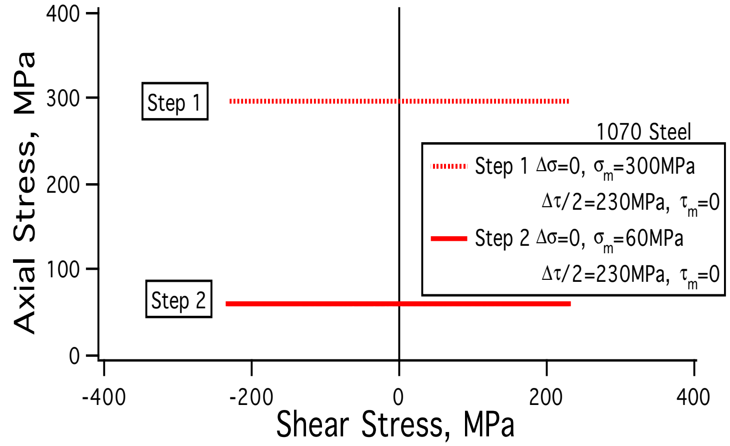
# EXPERIMENTAL RATCHETTING FOR A NOPROPORTIONAL AXIAL-TORSIONAL LOADING PATH

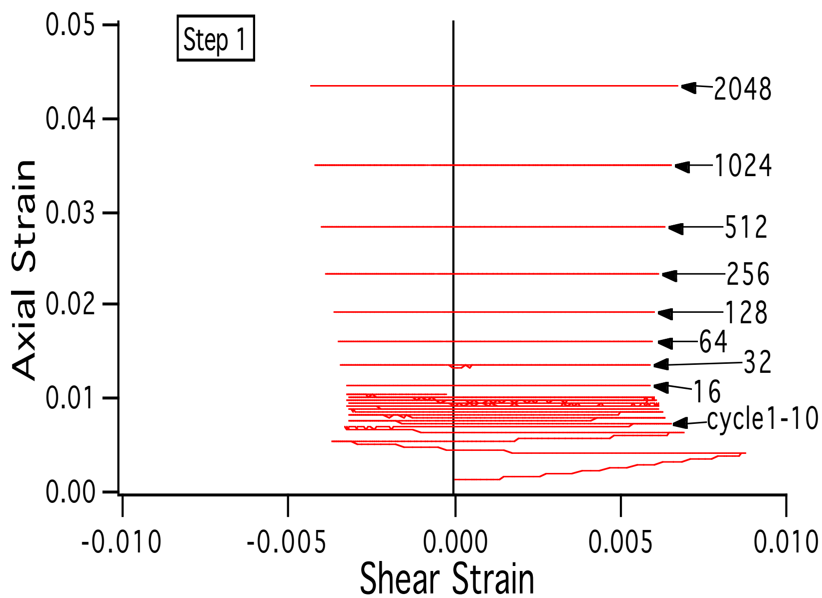
Jiang, Y. and H. Sehitoglu, *ASME JAM*, 63, 726-733, 1996.

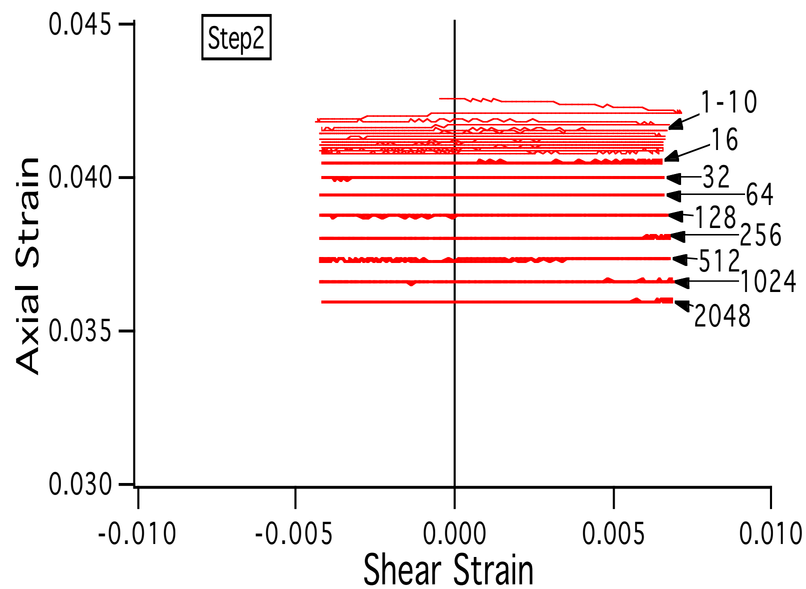
Jiang, Y. and H. Sehitoglu, *ASME JAM*, 63, 720-725, 1996.

# EXPERIMENTAL RATCHETTING FOR A TWO-STEP NONPROPORTIONAL LOADING HISTORY



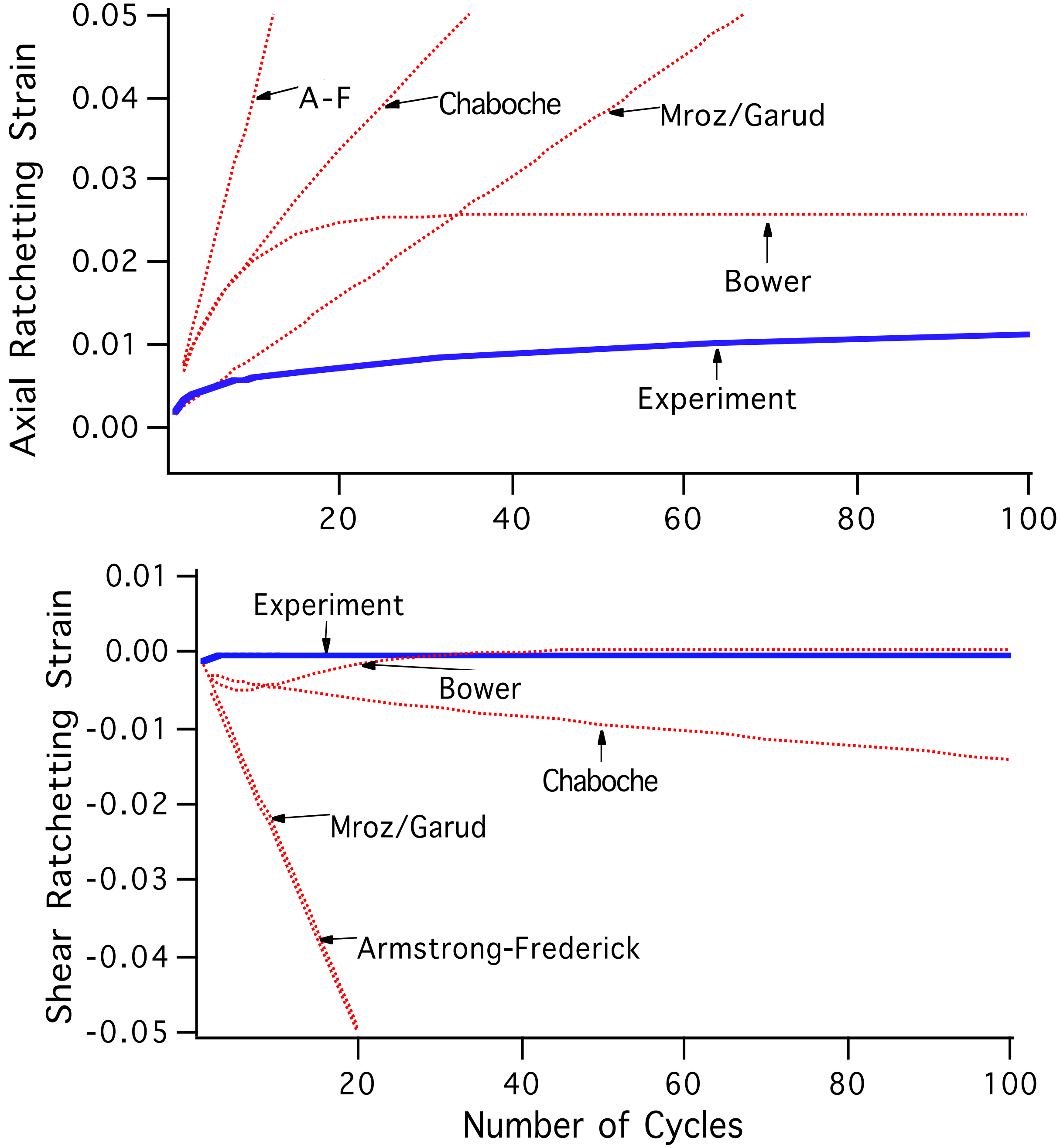



# EXPERIMENTAL OBSERVATIONS

- The ratchetting direction is coincident with the mean stress direction under single-step proportional loading.
- For 1070 Steel, the ratchetting rate decreases with increasing number of loading cycles for both proportional and nonproportional loadings.
- Under multiple-step loadings, the material exhibits a memory of the previous loading history.

# PREDICTION OF THE "ELLIPSE" PATH



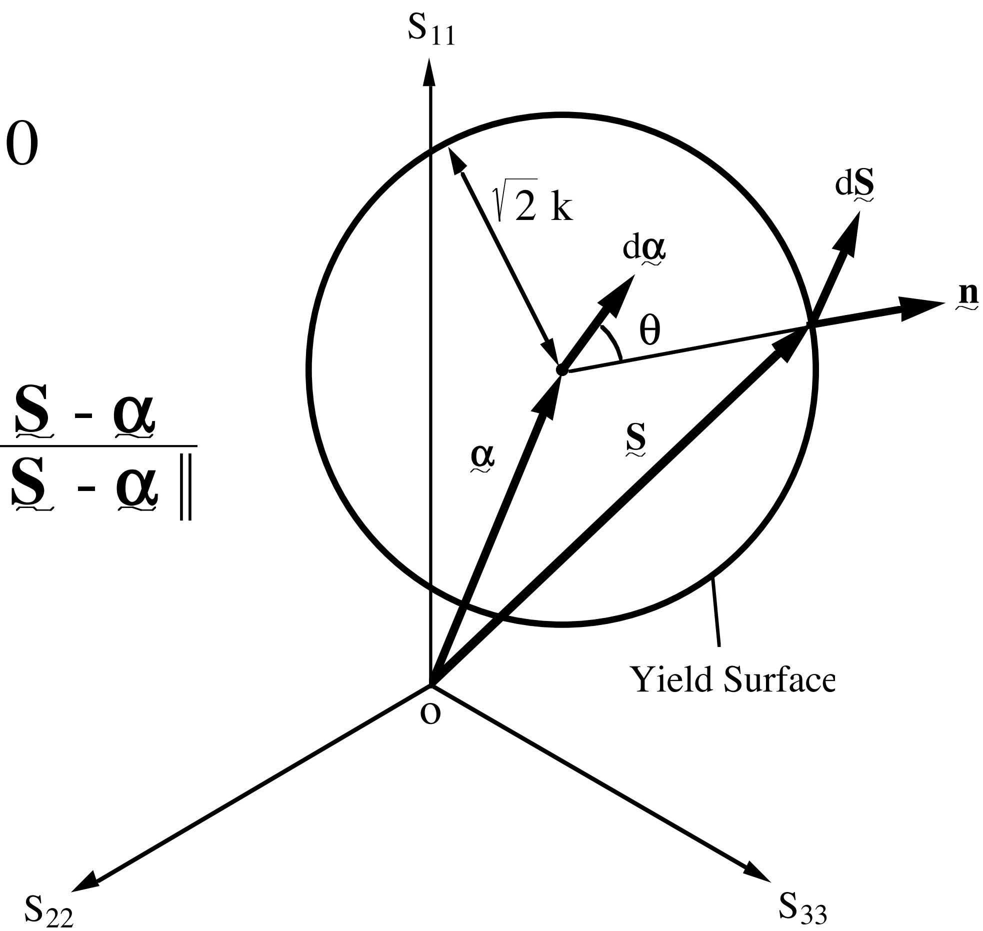
# Plasticity Fundamentals

$$f = (\underset{\sim}{\mathbf{S}} - \underset{\sim}{\boldsymbol{\alpha}}):(\underset{\sim}{\mathbf{S}} - \underset{\sim}{\boldsymbol{\alpha}}) - 2k^2 = 0$$

$$d\underset{\sim}{\boldsymbol{\varepsilon}}^p = \frac{1}{h} \left\langle d\underset{\sim}{\mathbf{S}}:\underset{\sim}{\mathbf{n}} \right\rangle \underset{\sim}{\mathbf{n}} \qquad \underset{\sim}{\mathbf{n}} = \frac{\underset{\sim}{\mathbf{S}} - \underset{\sim}{\boldsymbol{\alpha}}}{\left\| \underset{\sim}{\mathbf{S}} - \underset{\sim}{\boldsymbol{\alpha}} \right\|}$$

$$df = 0$$

$$d\underset{\sim}{\mathbf{S}}:\underset{\sim}{\mathbf{n}} - d\underset{\sim}{\boldsymbol{\alpha}}:\underset{\sim}{\mathbf{n}} - 2k\, dk = 0$$



# EVOLUTION OF BACK STRESS

$$d\underset{\sim}{\boldsymbol{\alpha}}^{(i)} = f_1^{(i)} \left( \underset{\sim}{\mathbf{n}} - f_2^{(i)} \underset{\sim}{\mathbf{L}}^{(i)} \right) dp \qquad (\, i=1, 2, ..., M)$$

$$M=1 \qquad f_1^{(1)} = a_a \qquad f_2^{(1)} = \frac{c_a}{a_a} \| \underset{\sim}{\boldsymbol{\alpha}} \|$$

$$f_1^{(i)} = c^{(i)} r^{(i)} \qquad f_2^{(i)} = \frac{\| \underset{\sim}{\boldsymbol{\alpha}}^{(i)} \|}{r^{(i)}} \qquad (\, i=1, 2, ..., M)$$

$$f_1^{(i)} = c^{(i)} r^{(i)} \qquad f_2^{(i)} = \left( \frac{\| \underset{\sim}{\alpha}^{(i)} \|}{r^{(i)}} \right)^{\chi^{(i)}+1} \langle \underset{\sim}{n} : \underset{\sim}{L}^{(i)} \rangle$$

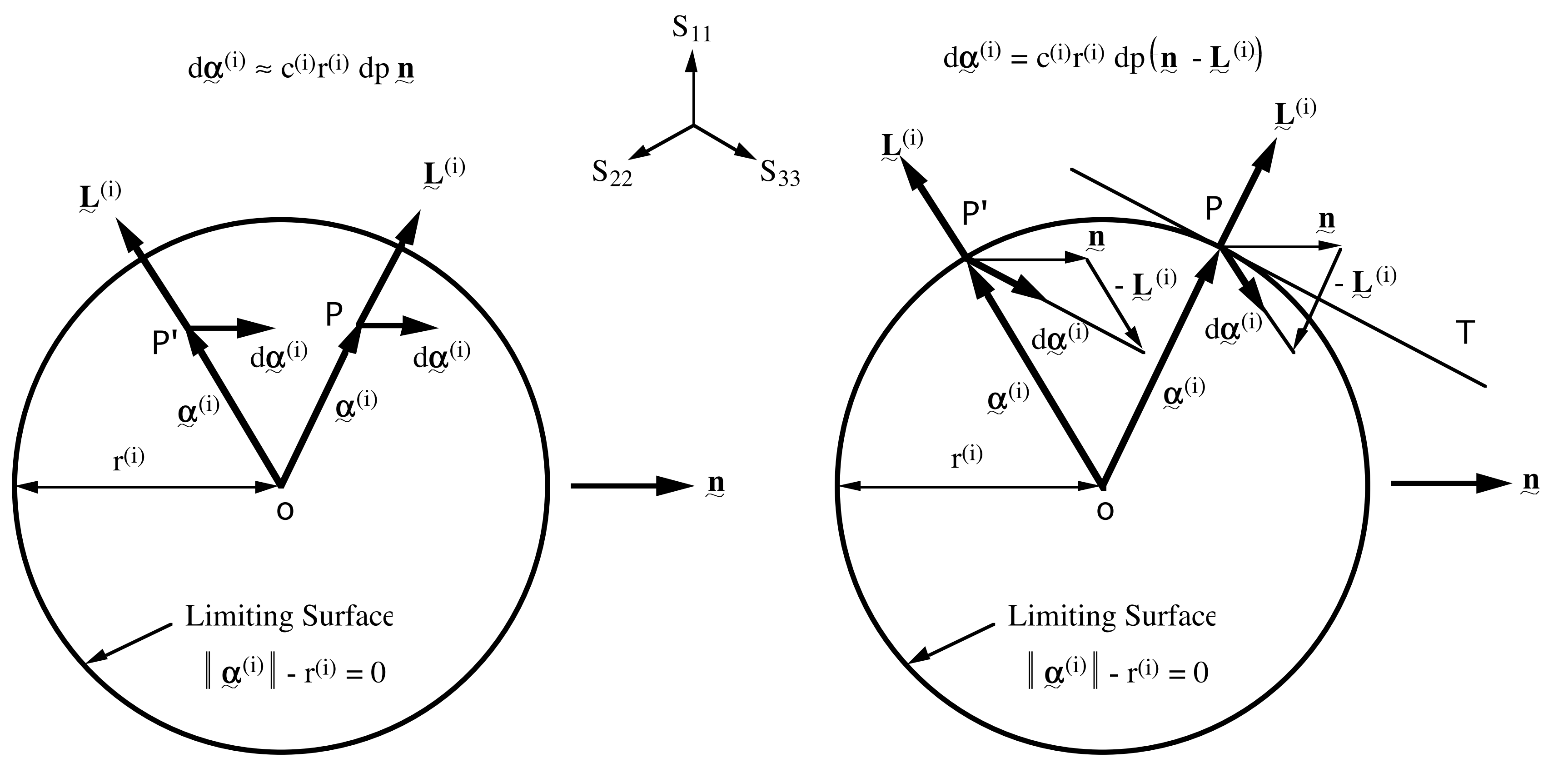
$$(\, i=1, 2, ..., M)$$

# NEW PLASTICITY MODEL

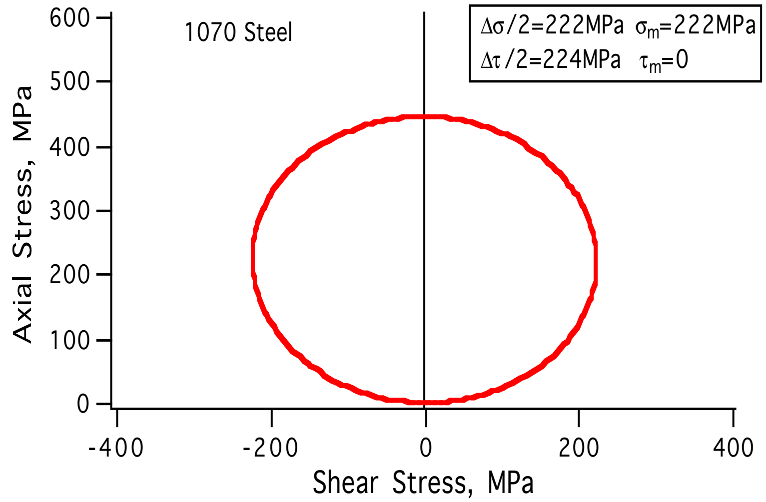
Jiang, Y. and H. Sehitoglu, *ASME JAM*, 63, 726-733, 1996.
Jiang, Y. and H. Sehitoglu, *ASME JAM*, 63, 720-725, 1996.

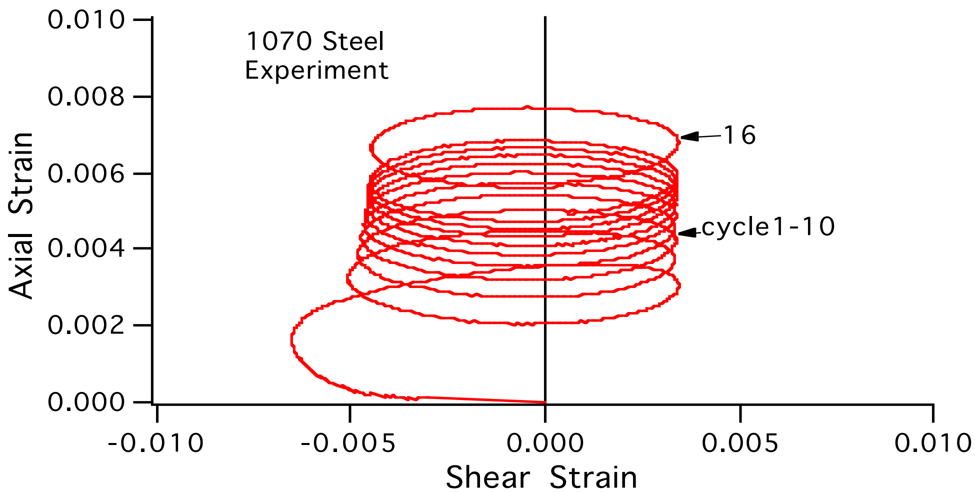
$$\underset{\sim}{\boldsymbol{\alpha}} = \sum_{i=1}^{M} \underset{\sim}{\boldsymbol{\alpha}}^{(i)} \qquad d\underset{\sim}{\boldsymbol{\alpha}}^{(i)} = c^{(i)} r^{(i)} \left( \underset{\sim}{\mathbf{n}} - \left( \frac{\left\| \underset{\sim}{\boldsymbol{\alpha}}^{(i)} \right\|}{r^{(i)}} \right)^{\chi^{(i)} + 1} \underset{\sim}{\mathbf{L}}^{(i)} \right) dp$$

$$(\, i=1, 2, \ldots, M)$$

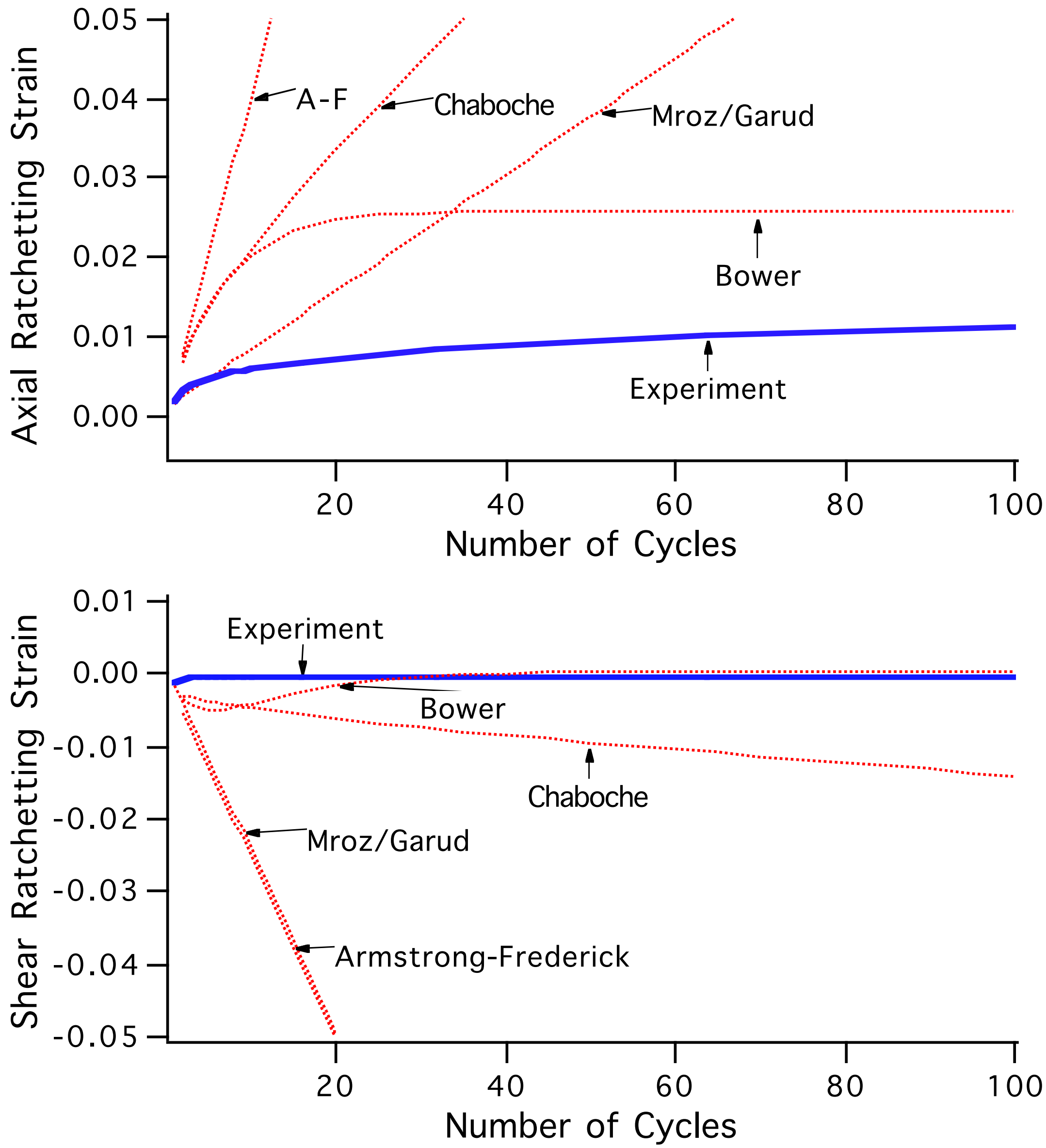


# EXPERIMENTAL “ELLIPSE PATH”

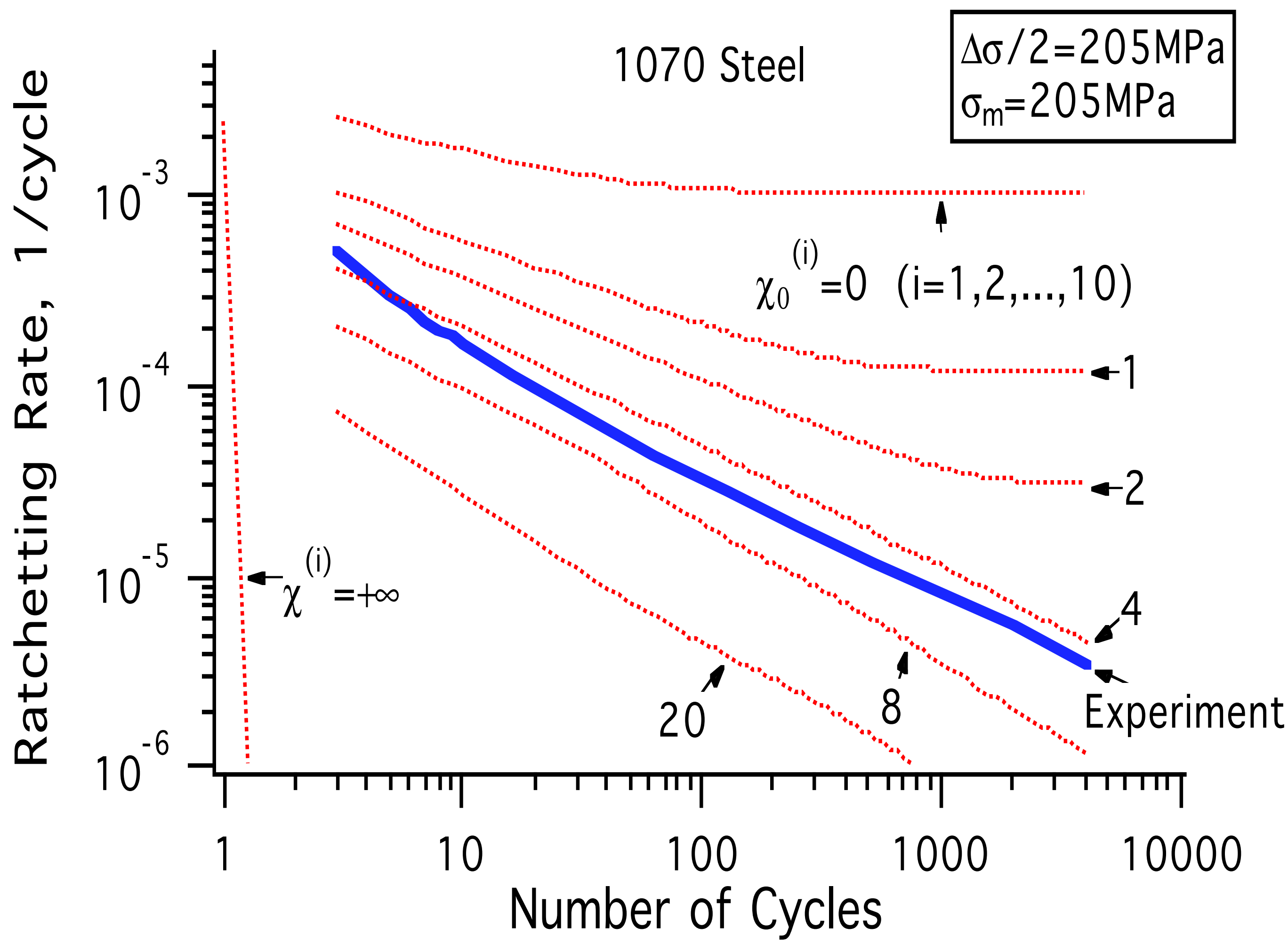


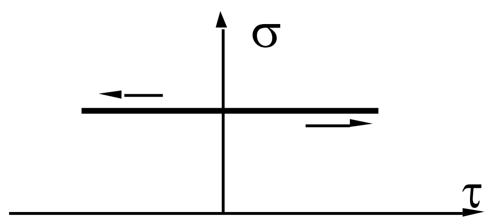
# PREDICTION OF THE "ELLIPSE" PATH

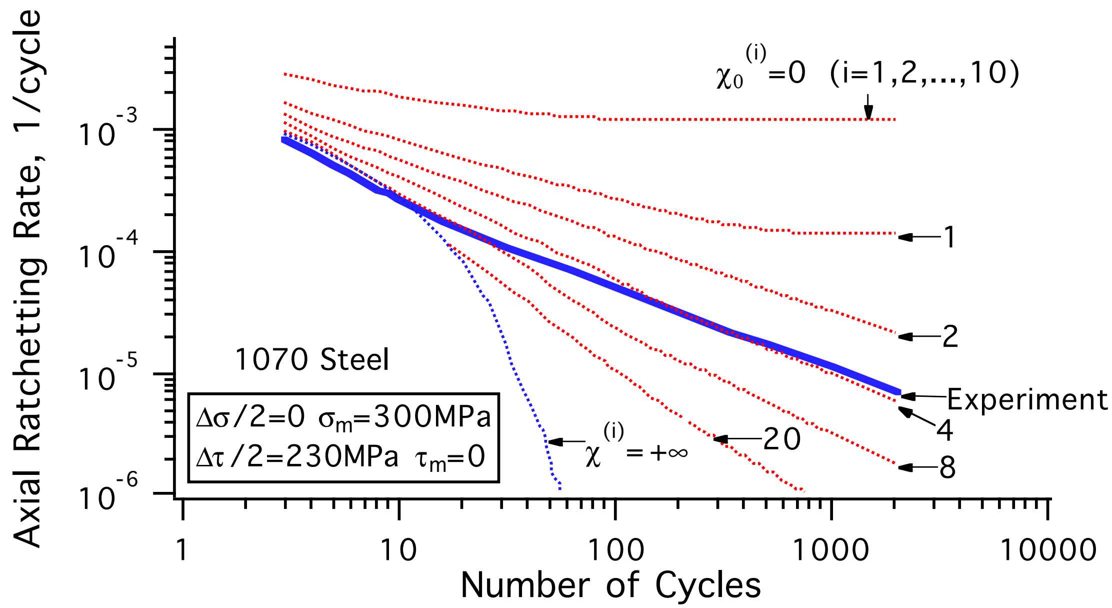


# CAPABILITY OF PROPOSED MODEL IN UNIAXIAL LOADING

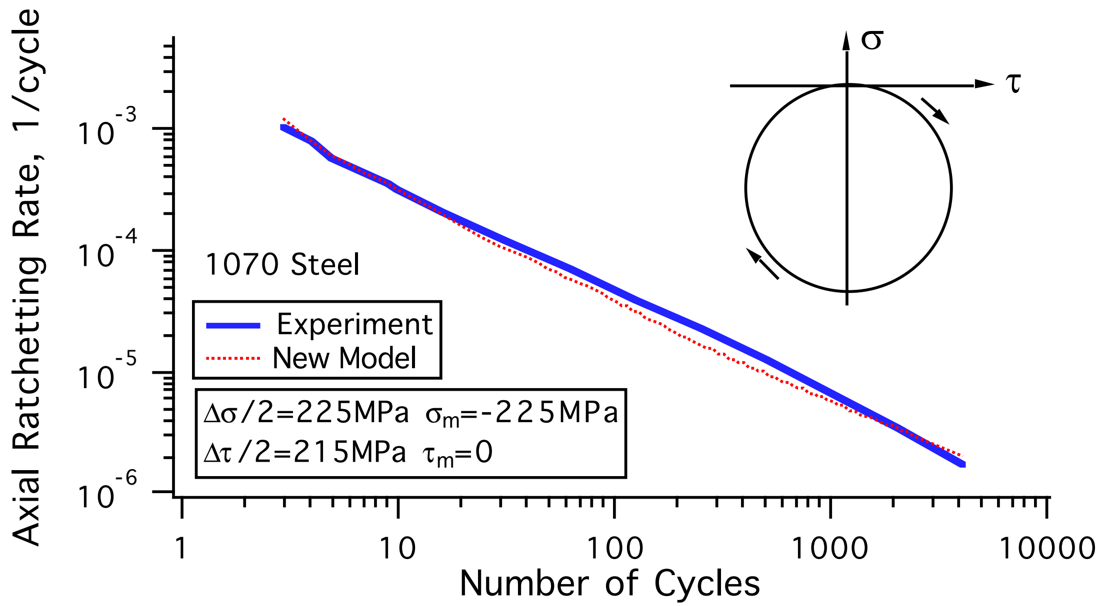


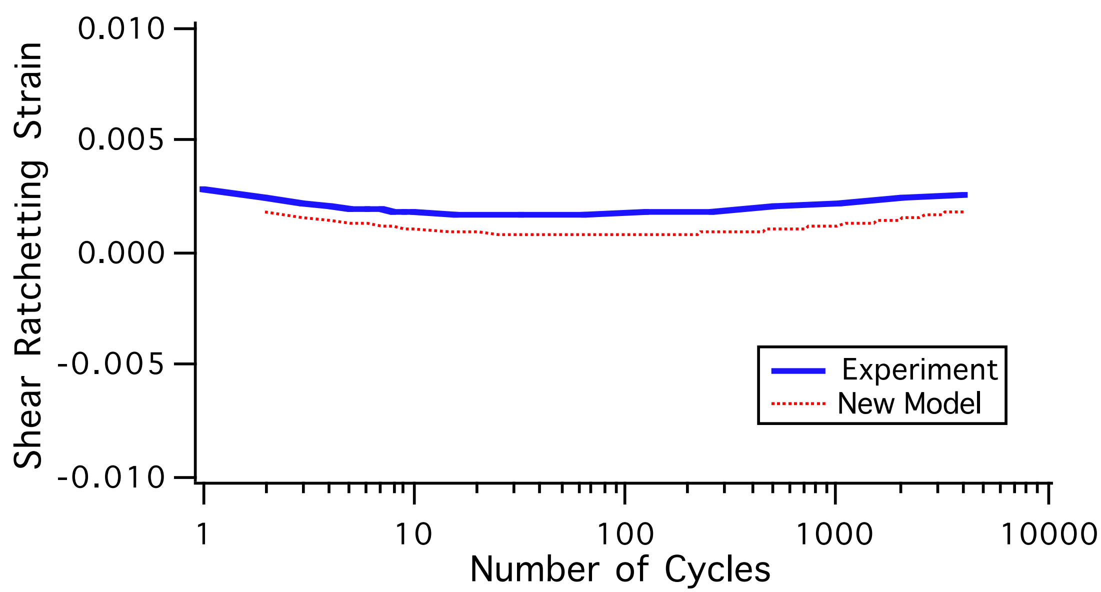
# CAPABILITY OF PROPOSED MODEL IN NONPROPORTIONAL LOADING



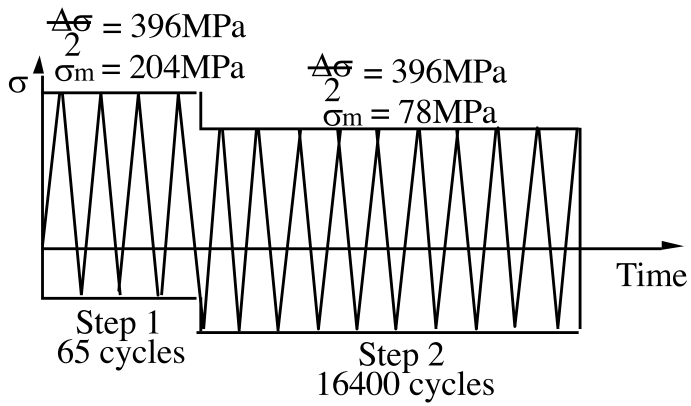



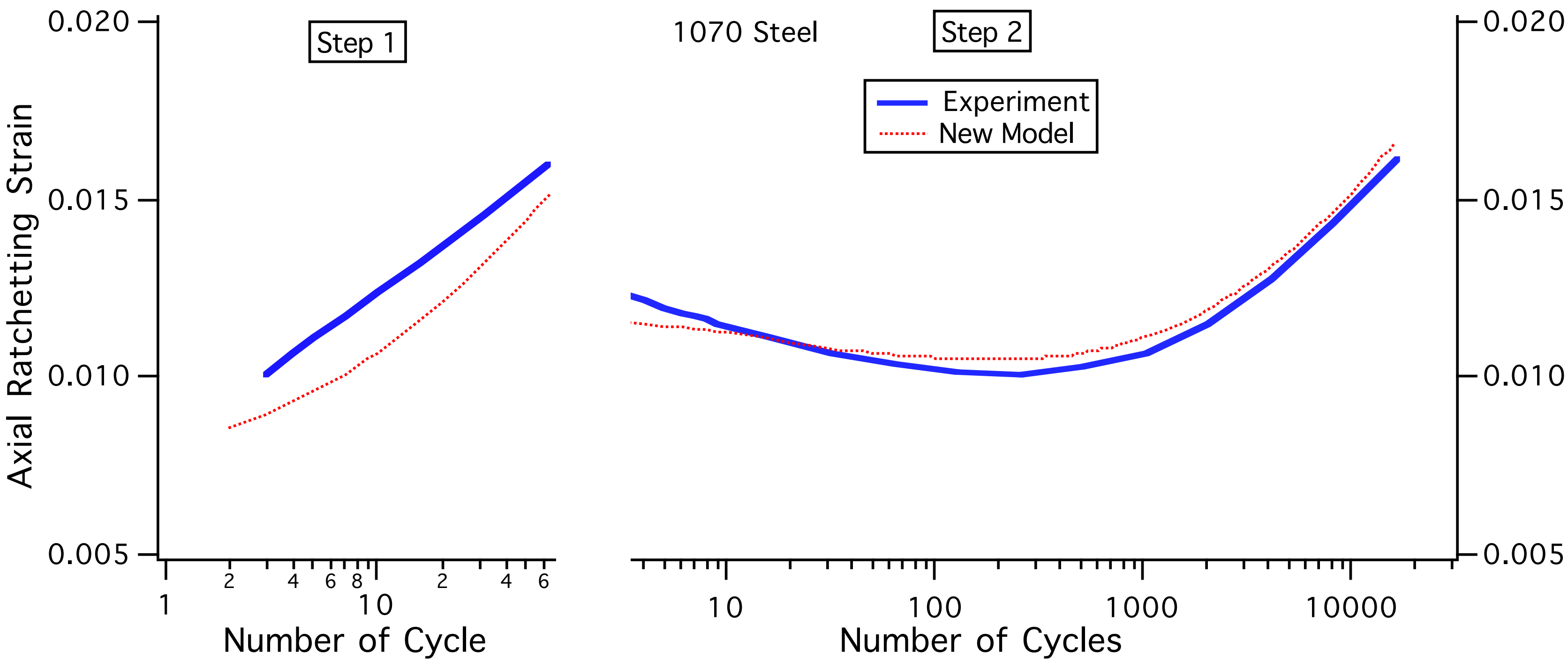
# CAPABILITY OF PROPOSED MODEL IN NONPROPORTIONAL LOADING



# PREDICTION OF RATCHETTING RATES IN TWO STEP PROPORTIONAL LOADING



# Jiang-Sehitoglu (JS) Plasticity Model

- Only model that can predict ratcheting under complex loading scenarios
- Backstress is divided into multiple components
- Translation of the backstress is not constricted to the direction of the normal
- Elastic stress state is computed first, and a relaxation procedure is implemented to determine the final stress state

# JS Plasticity Model

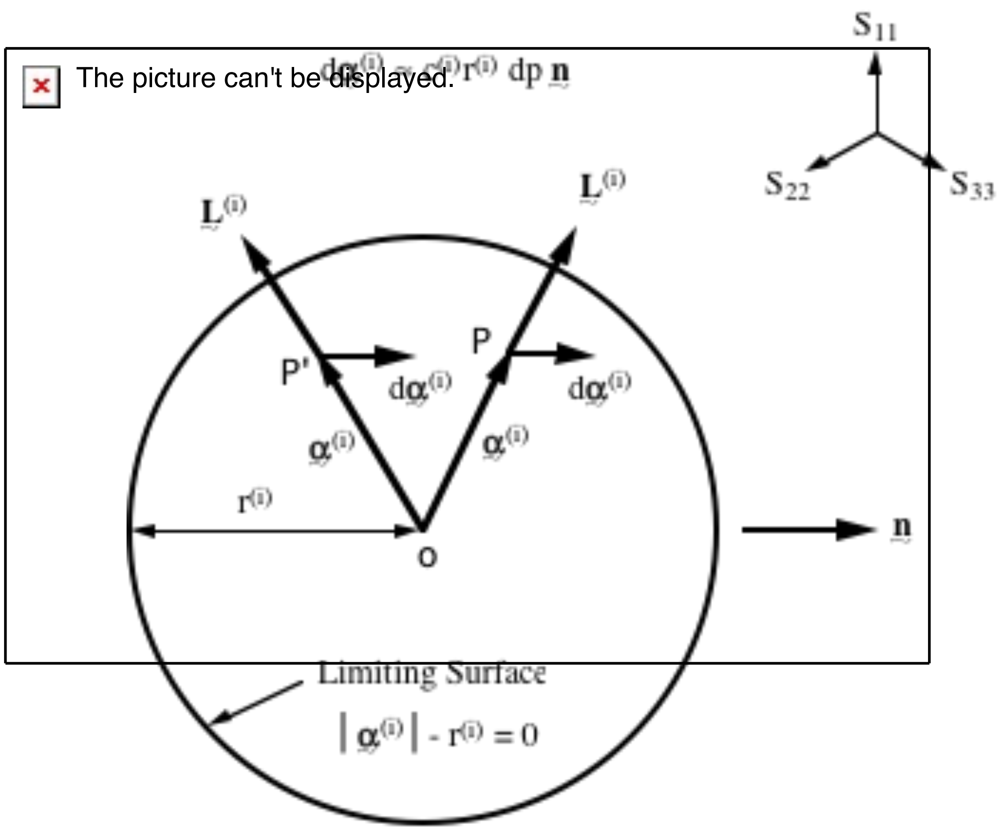
Jiang, Y. and H. Sehitoglu, *ASME JAM*, 63, 726-733, 1996.

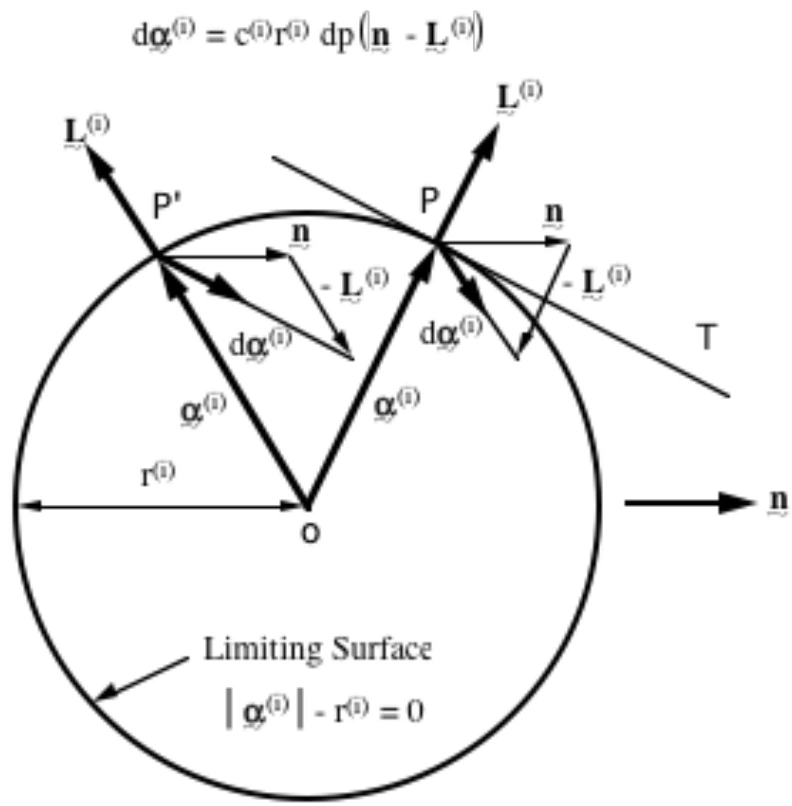
Jiang, Y. and H. Sehitoglu, *ASME JAM*, 63, 720-725, 1996.

3 Constant Sets Are Needed

$$\underset{\sim}{\alpha} = \sum_{i=1}^{M} \underset{\sim}{\alpha}^{(i)} \qquad d\underset{\sim}{\alpha}^{(i)} = c^{(i)} r^{(i)} \left( \underset{\sim}{n} - \left( \frac{\|\underset{\sim}{\alpha}^{(i)}\|}{r^{(i)}} \right)^{\chi^{(i)}+1} \underset{\sim}{L}^{(i)} \right) dp$$

$(i=1, 2, \ldots, M)$



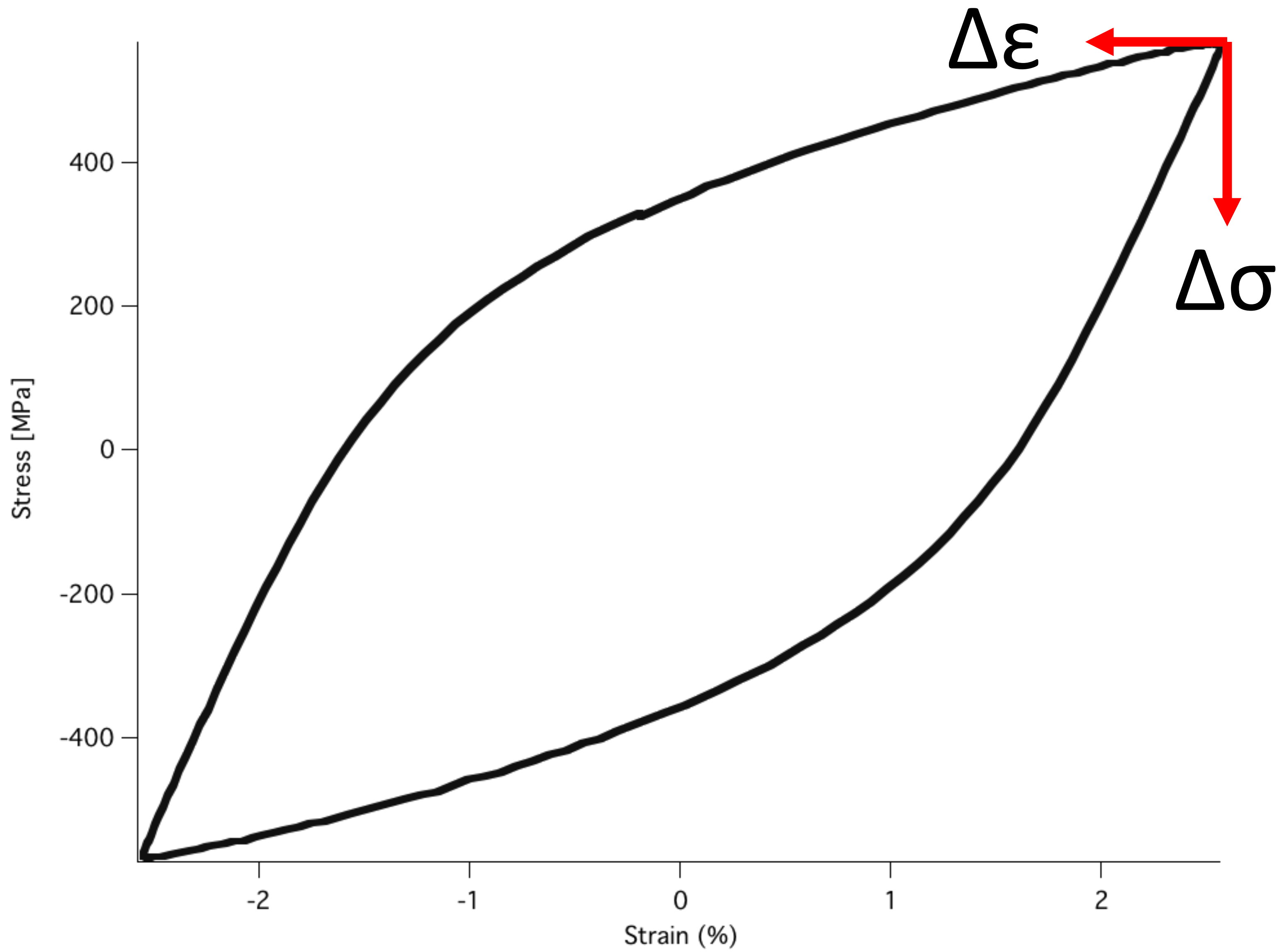



# Material Constant Sets

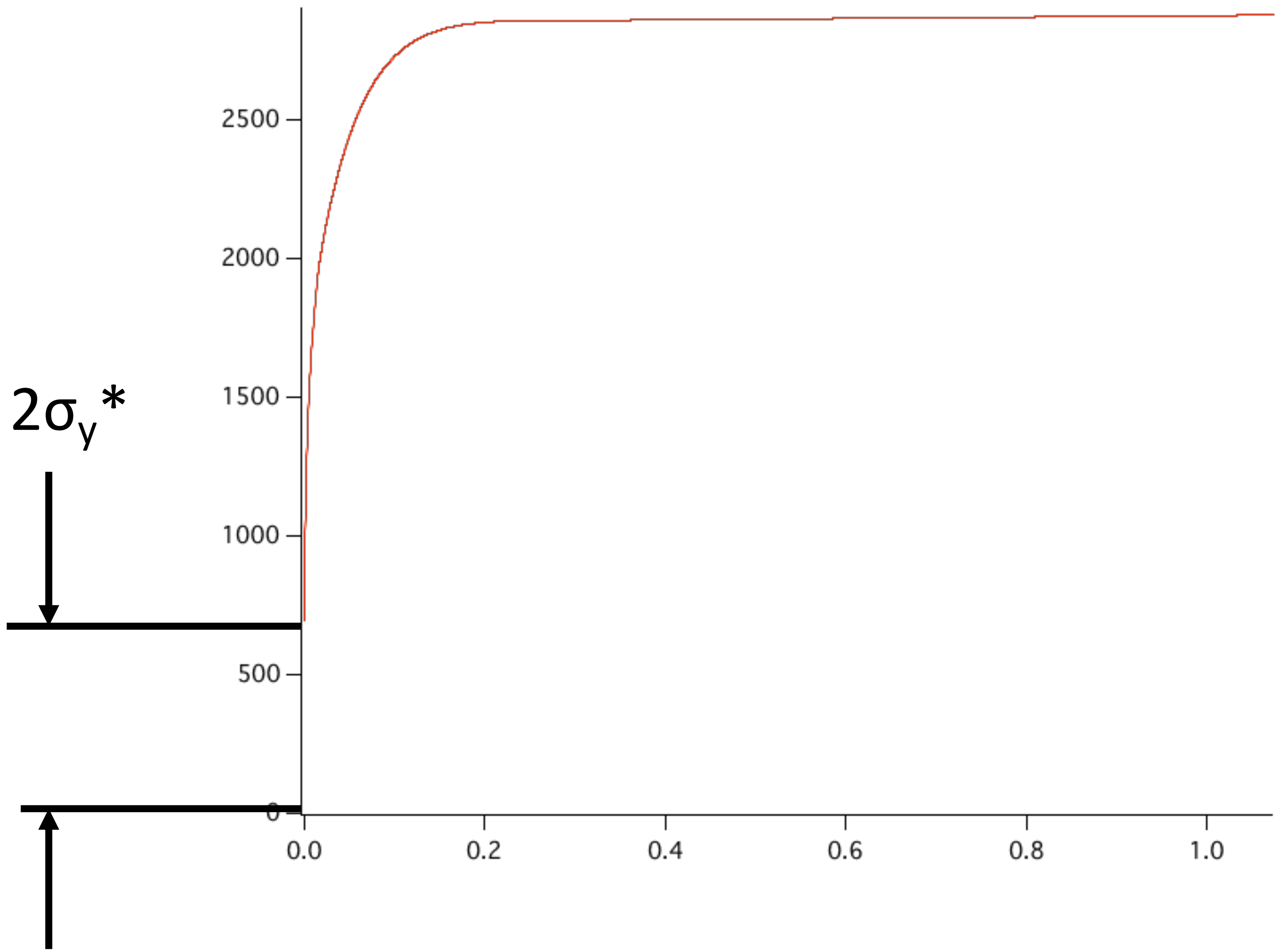
- $r^{(i)}$ and $c^{(i)}$
  - Define the stress-strain behavior of the material in a linear piece-wise manner
  - Determined from fully reversed stress-plastic strain data

- $\chi^{(i)}$
  - Defines the ratcheting rate decay of the material
  - Determined from uniaxial ratcheting experiments

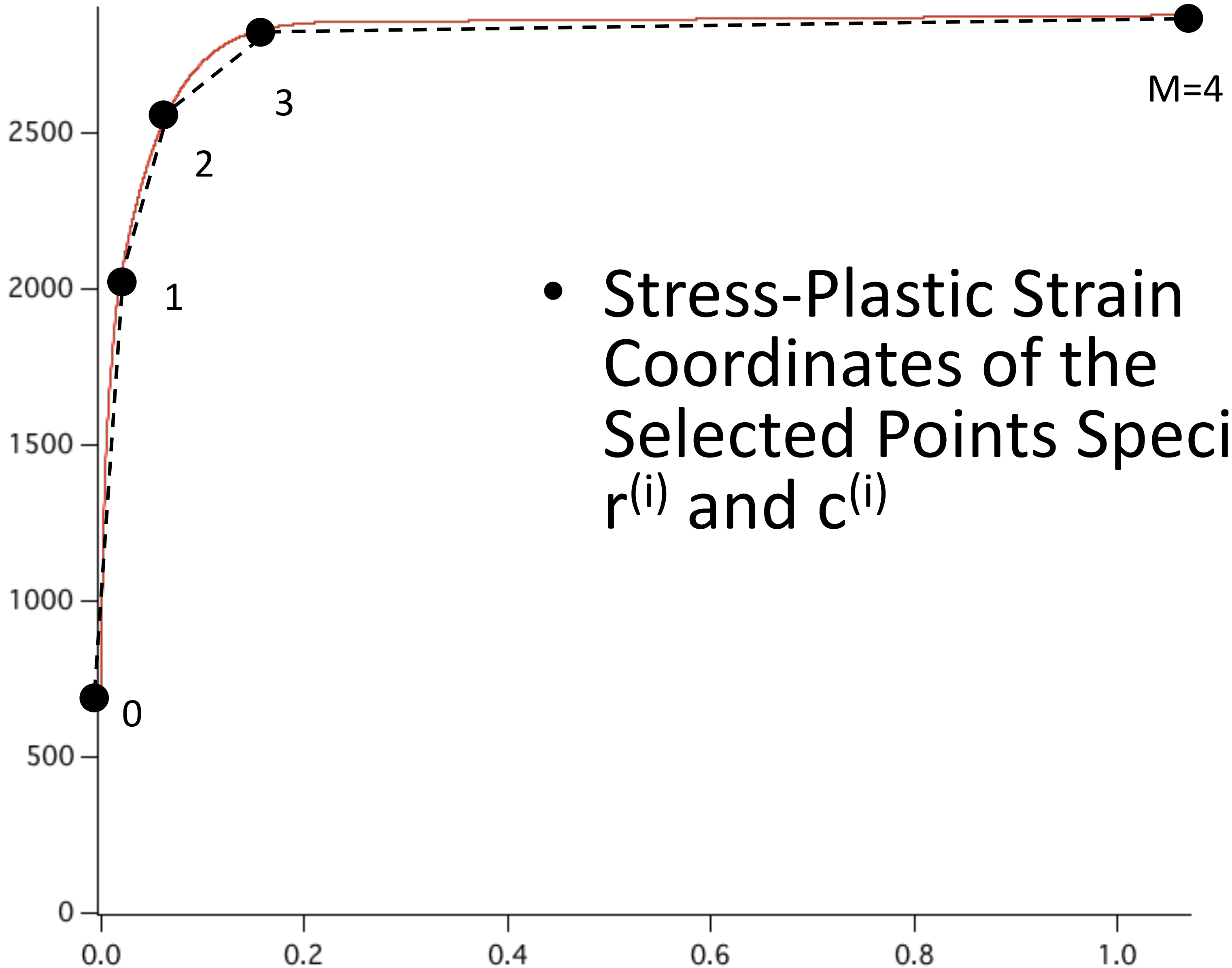
# Pearlite Stress-Strain Data



# Eliminate the Elastic Strain



# Select Piece-Wise Linear Segments




- Stress-Plastic Strain Coordinates of the Selected Points Specify $r^{(i)}$ and $c^{(i)}$

# Determining X

- Plot uniaxial ratcheting rate from experimental data
- Simulate ratcheting rate from JS model
  - Use $r^{(i)}$ and $c^{(i)}$ determined above
  - Guess a value for X
- Trial and Error until the simulated curve equals the experimental curve