SAND2020-0611PE

Munson-Dawson Recalibration to Fit Constant Strain Rate and Constant Stress Tests

Benjamin Reedlunn

Computational Material Mechanics Department

Sandia National Laboratories

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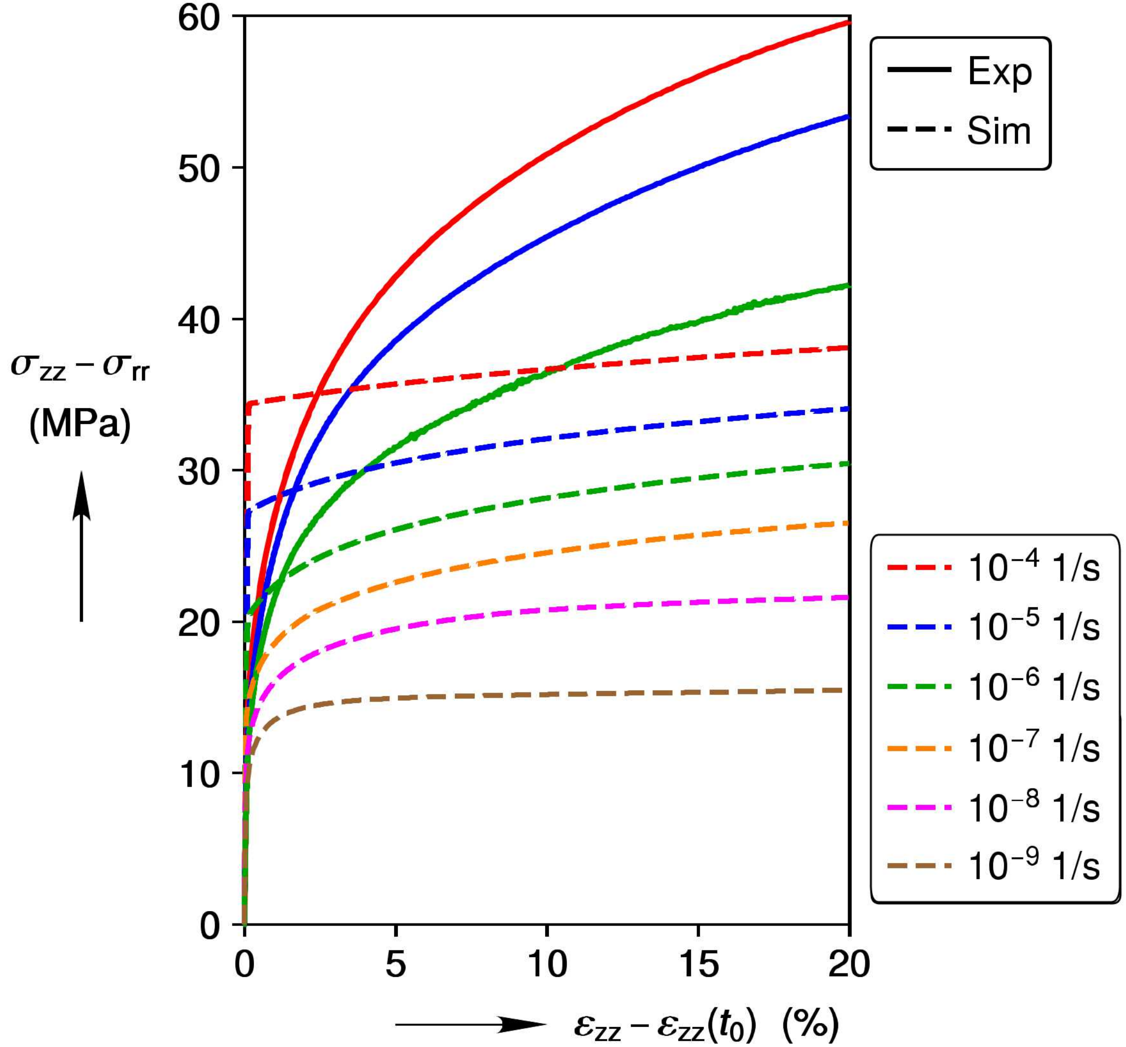
SAND2020-XXXX PE

Outline

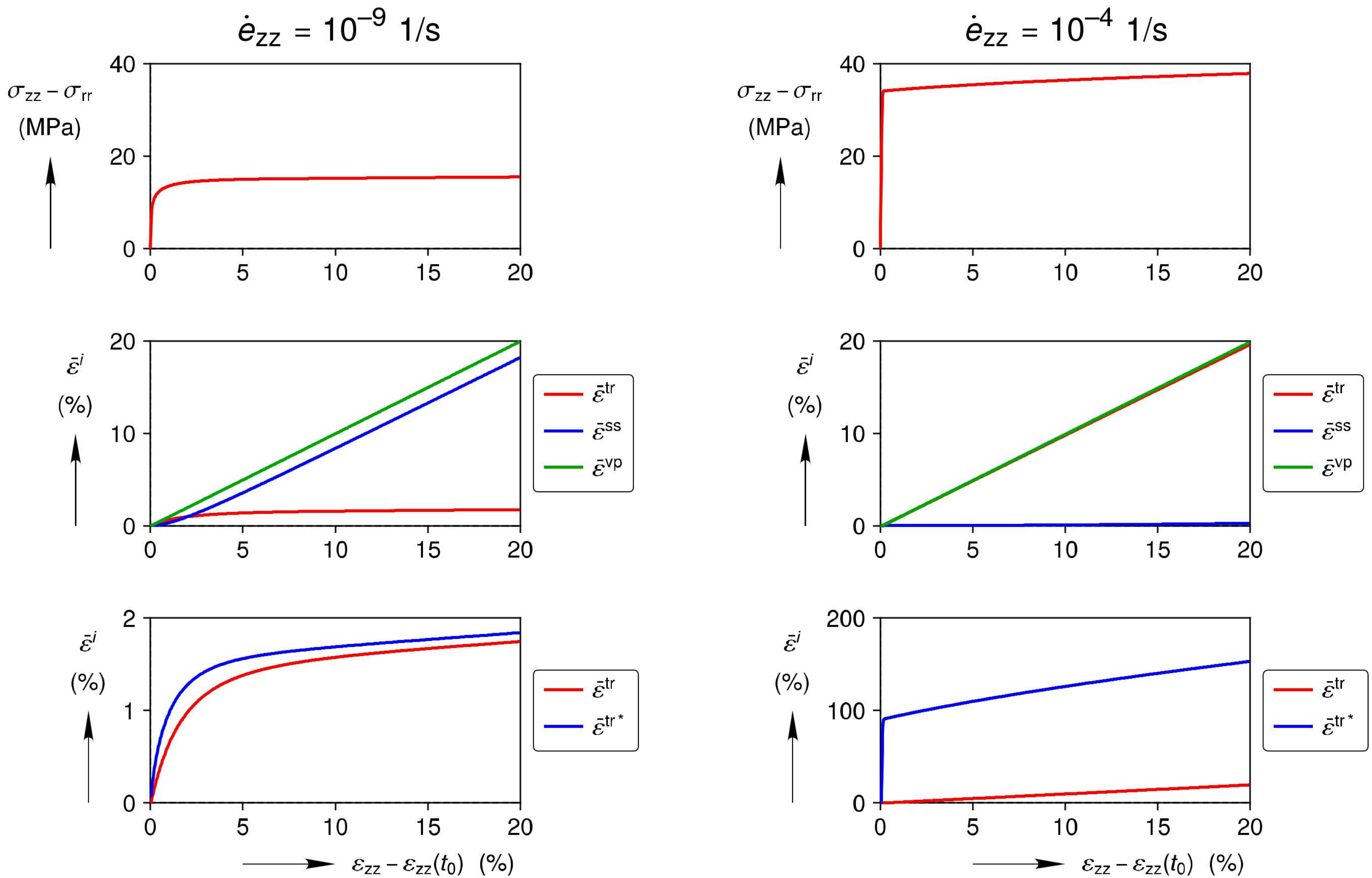
1. Initial Predictions of Constant Strain Rate Tests
2. Manual Calibration Adjustments
3. Optimization of Parameters
4. Summary

Initial Predictions of Constant Strain Rate Tests

Calibration 3A Predictions of CSR Tests



Closer Look at Calibration 3A CSR Behavior

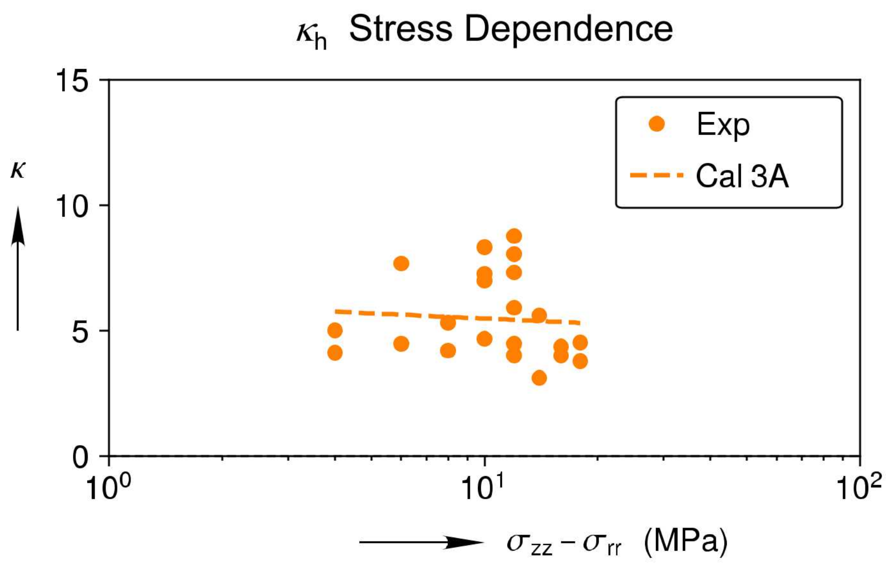


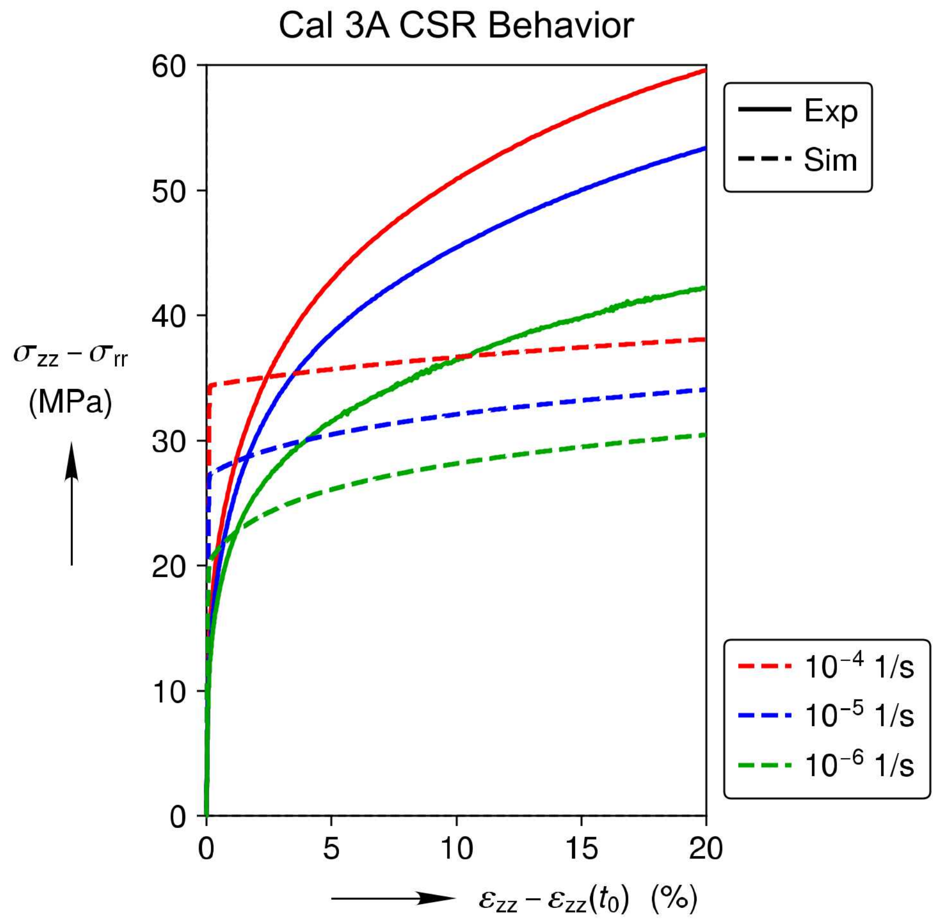
Manual Calibration Adjustments

Manual Adjustment of κ

Transient Strain Evolution Eqn.

$$\dot{\bar{\varepsilon}}^{\mathrm{tr}} = \left\{ \exp\left[\kappa \left(1 - \frac{\bar{\varepsilon}^{\mathrm{tr}}}{\bar{\varepsilon}^{\mathrm{tr}*}} \right)^2 \right] - 1 \right\} \dot{\bar{\varepsilon}}^{\mathrm{ss}}$$





Manual Adjustment of κ_h

Transient Strain Evolution Eqn.

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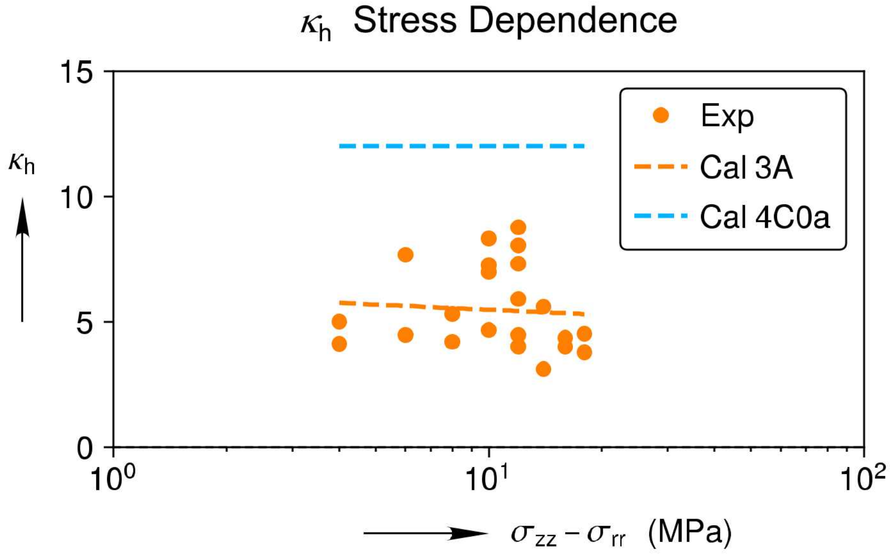

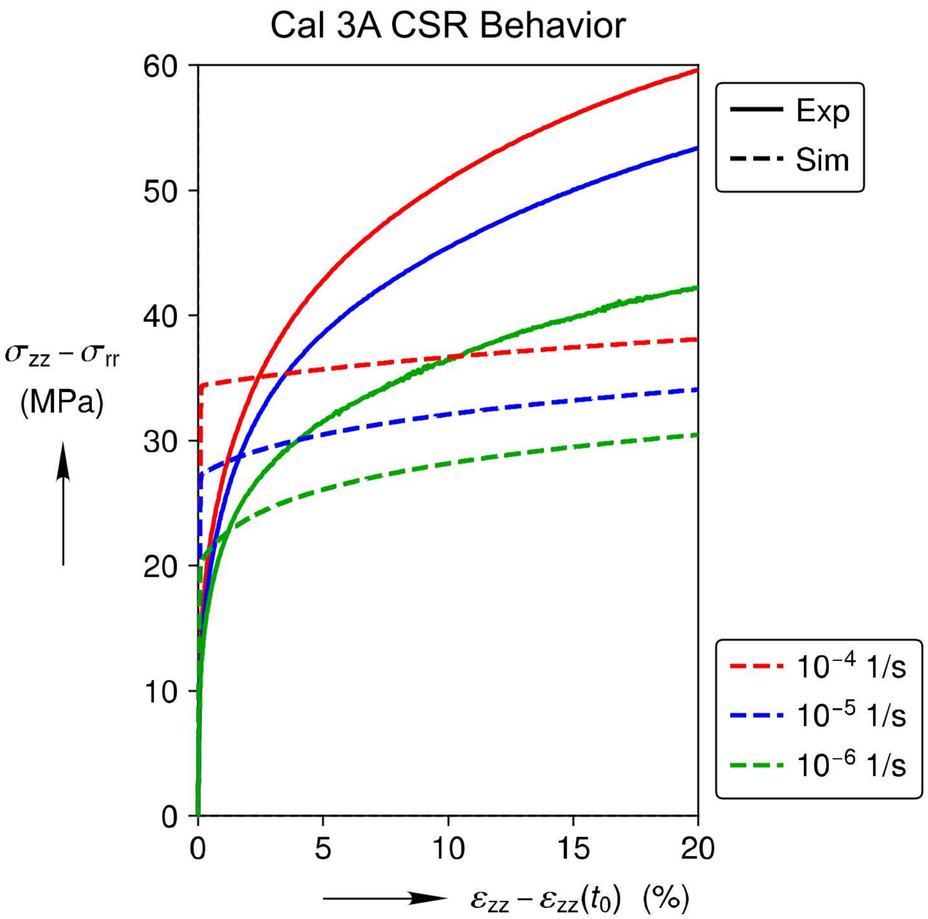

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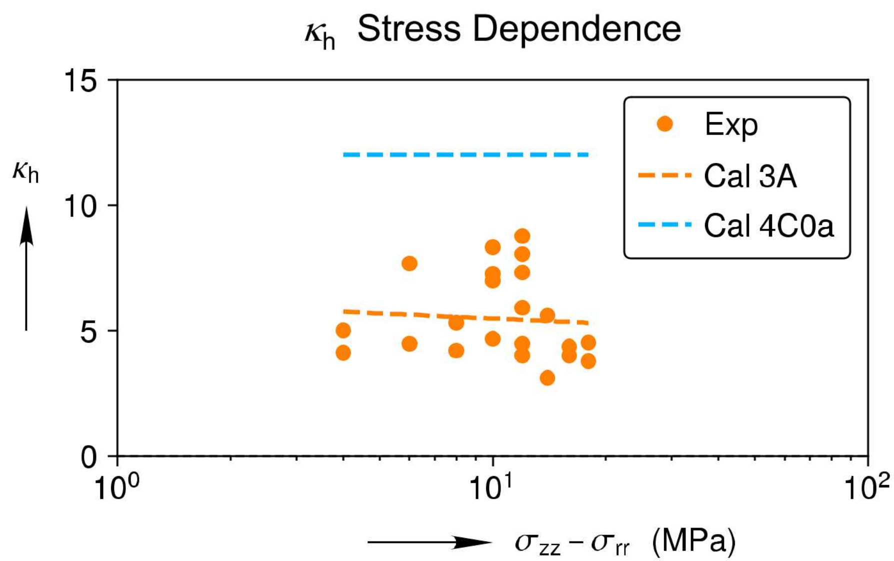
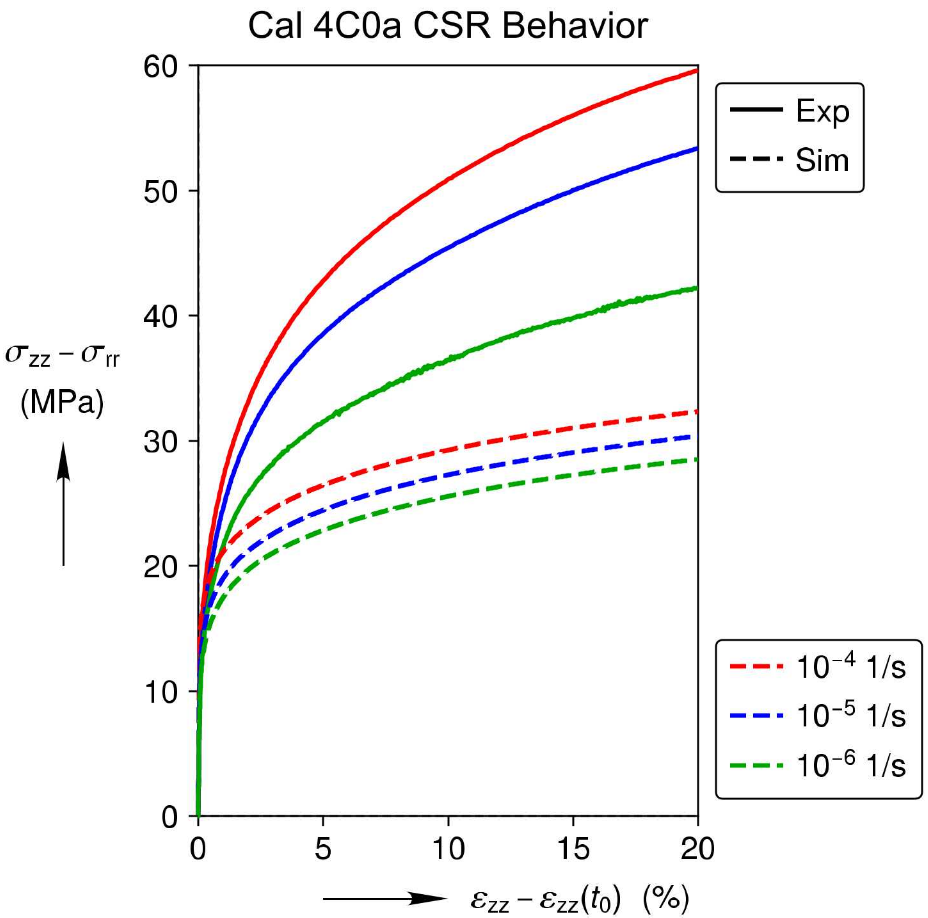
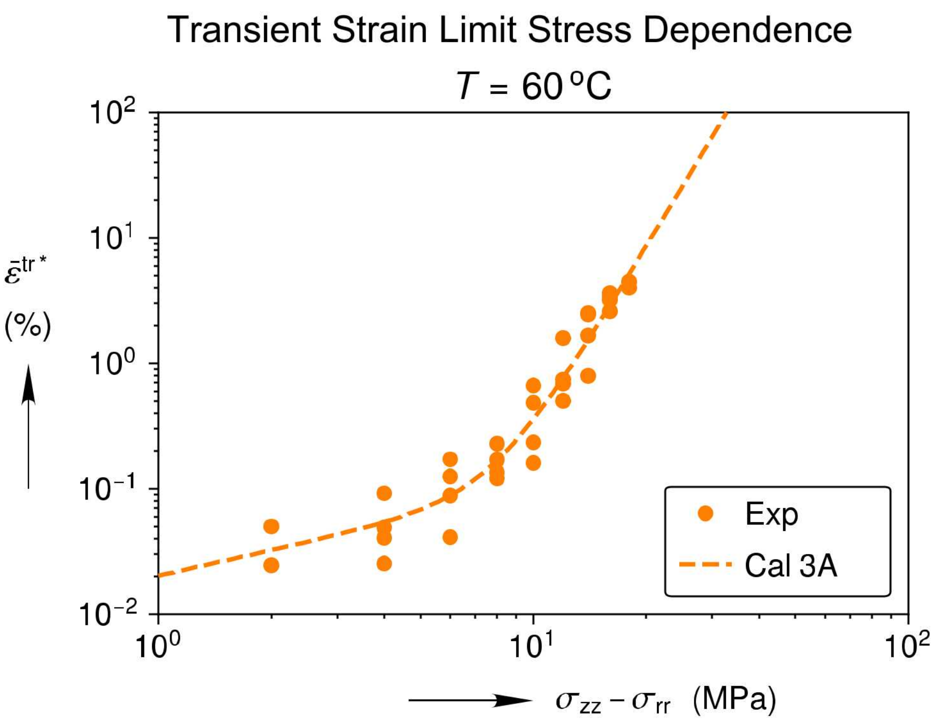


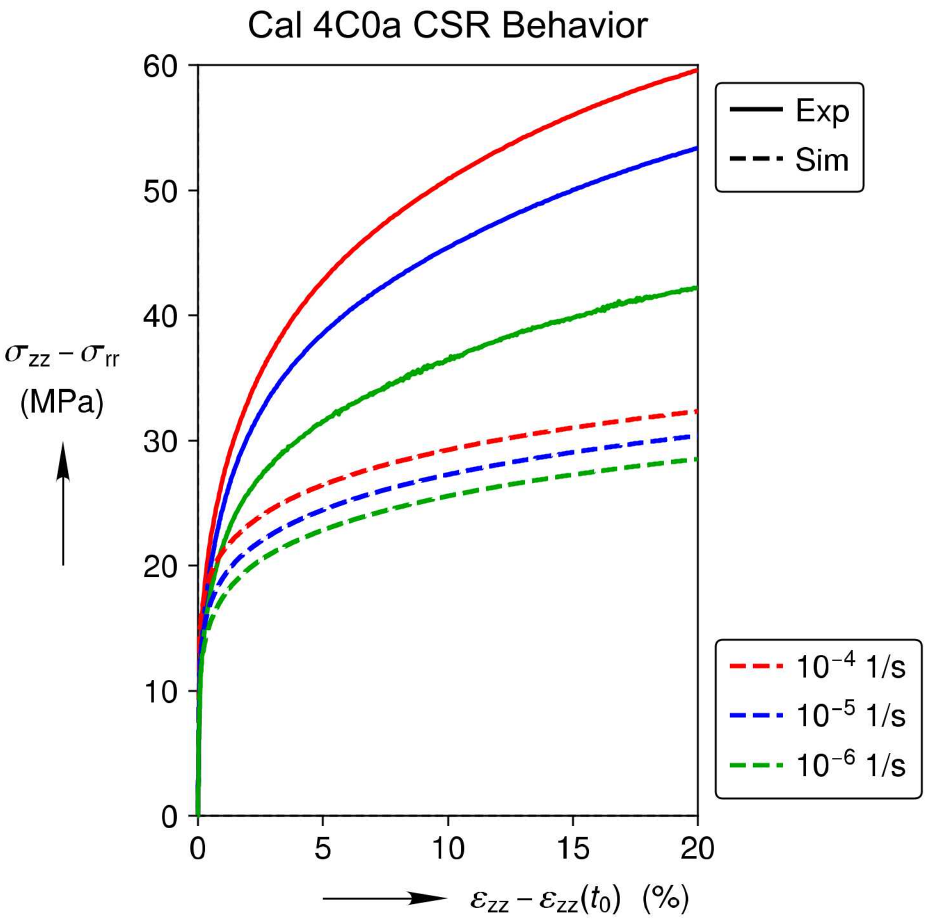


Manual Adjustment of Transient Strain Limit

Transient Strain Evolution Eqn.

$$\dot{\bar{\varepsilon}}^{\mathrm{tr}} = \left\{ \exp\left[\kappa \left(1 - \frac{\bar{\varepsilon}^{\mathrm{tr}}}{\bar{\varepsilon}^{\mathrm{tr}*}} \right)^2 \right] - 1 \right\} \dot{\bar{\varepsilon}}^{\mathrm{ss}}$$





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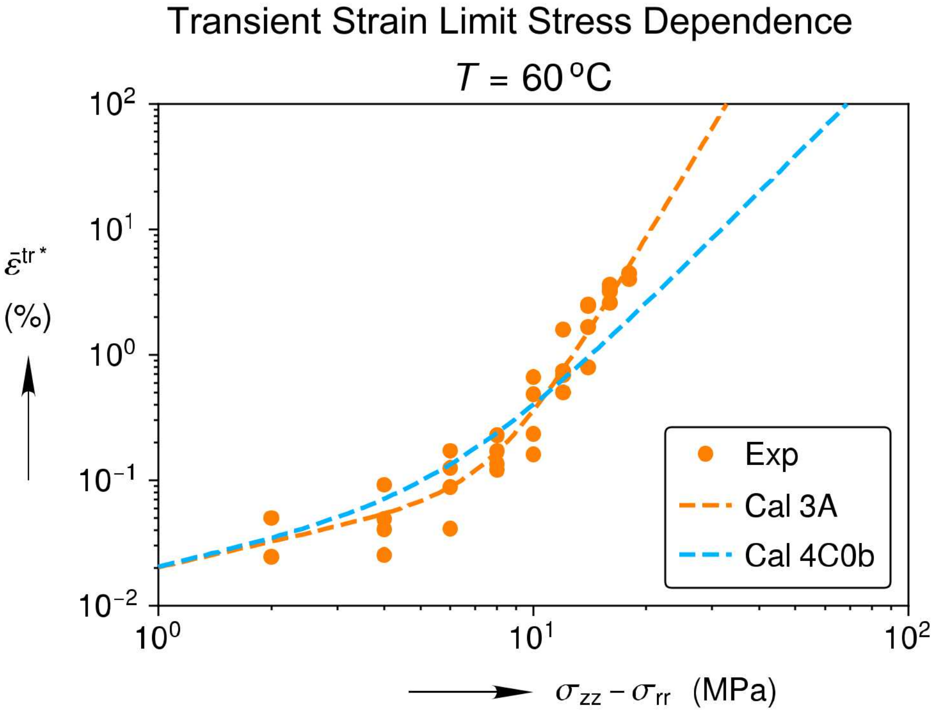

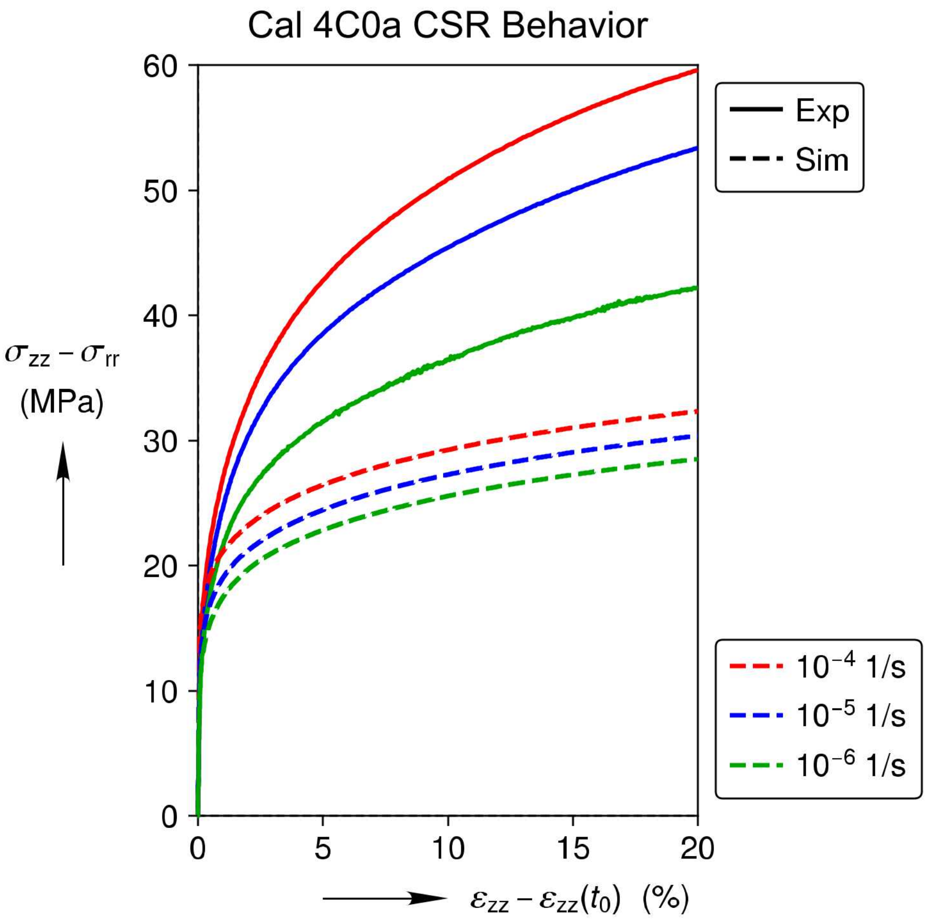

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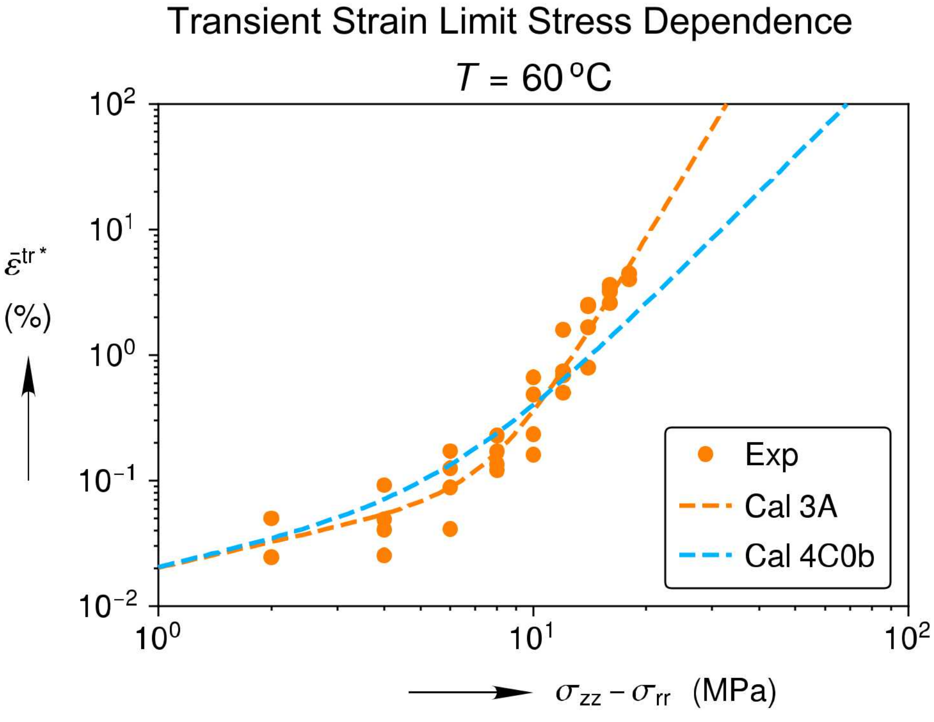
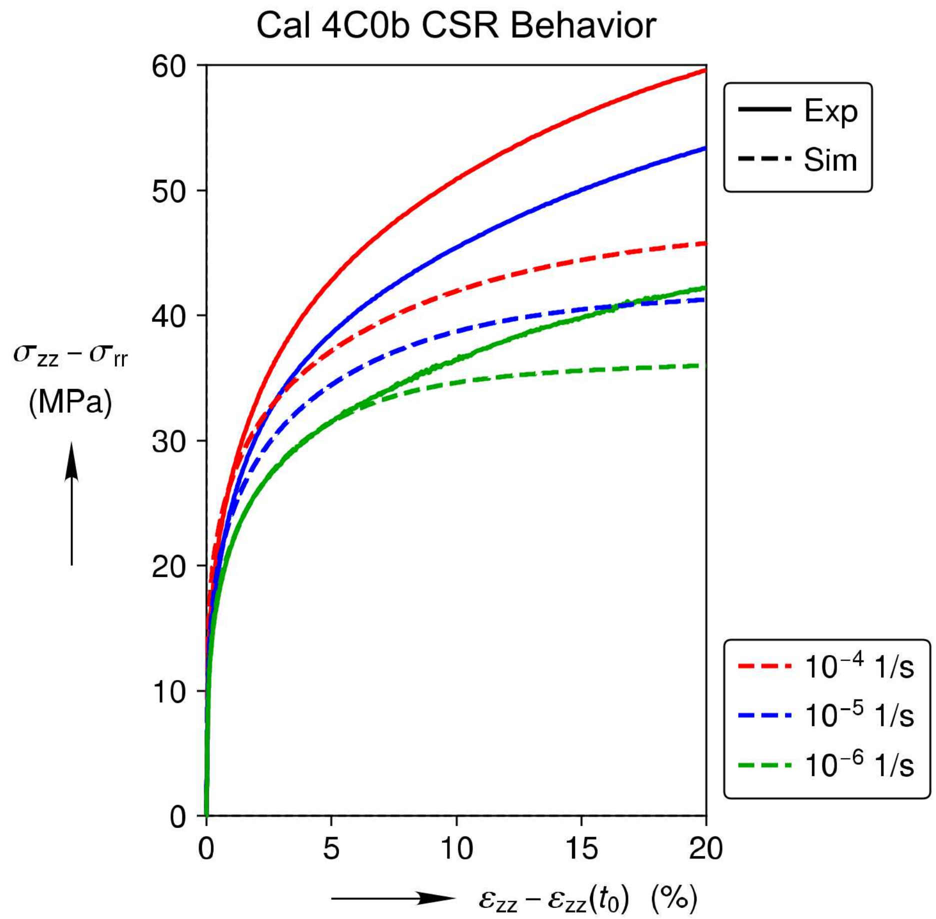
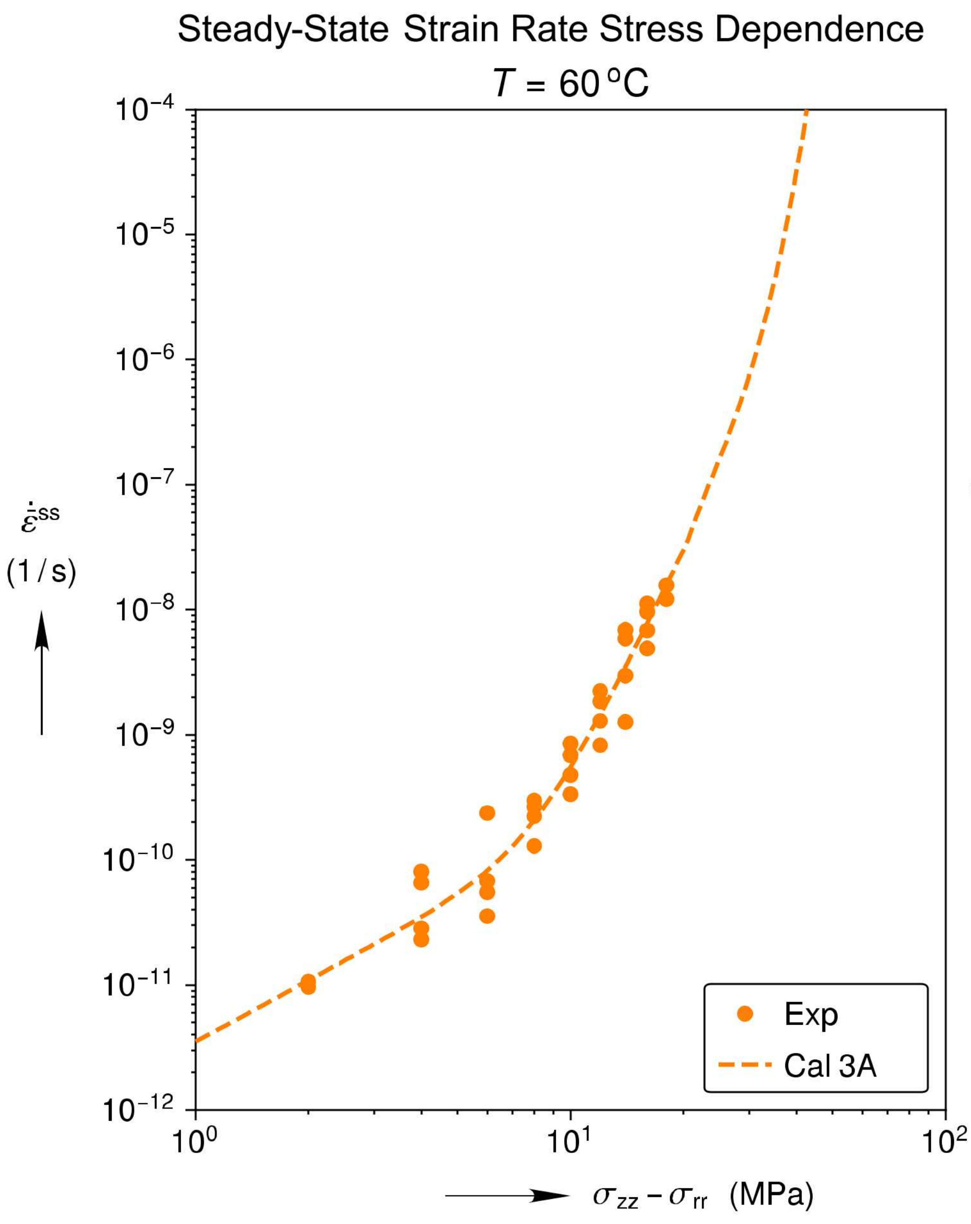
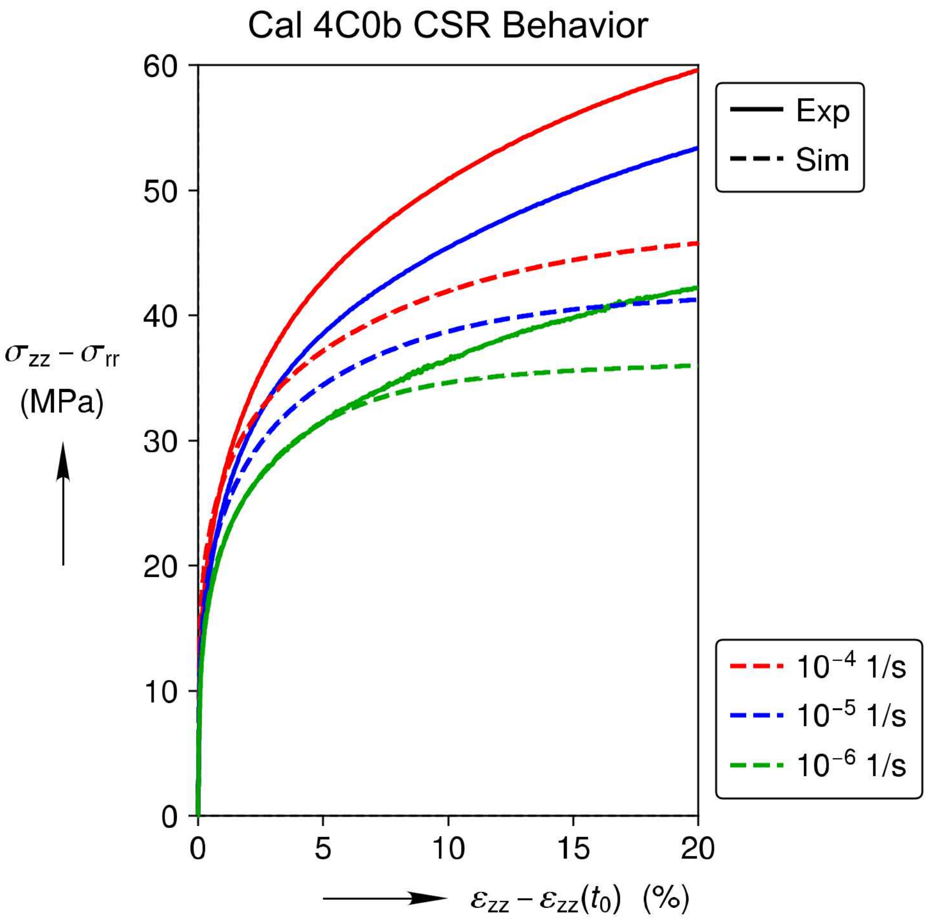




Manual Adjustment of Steady-State Rate





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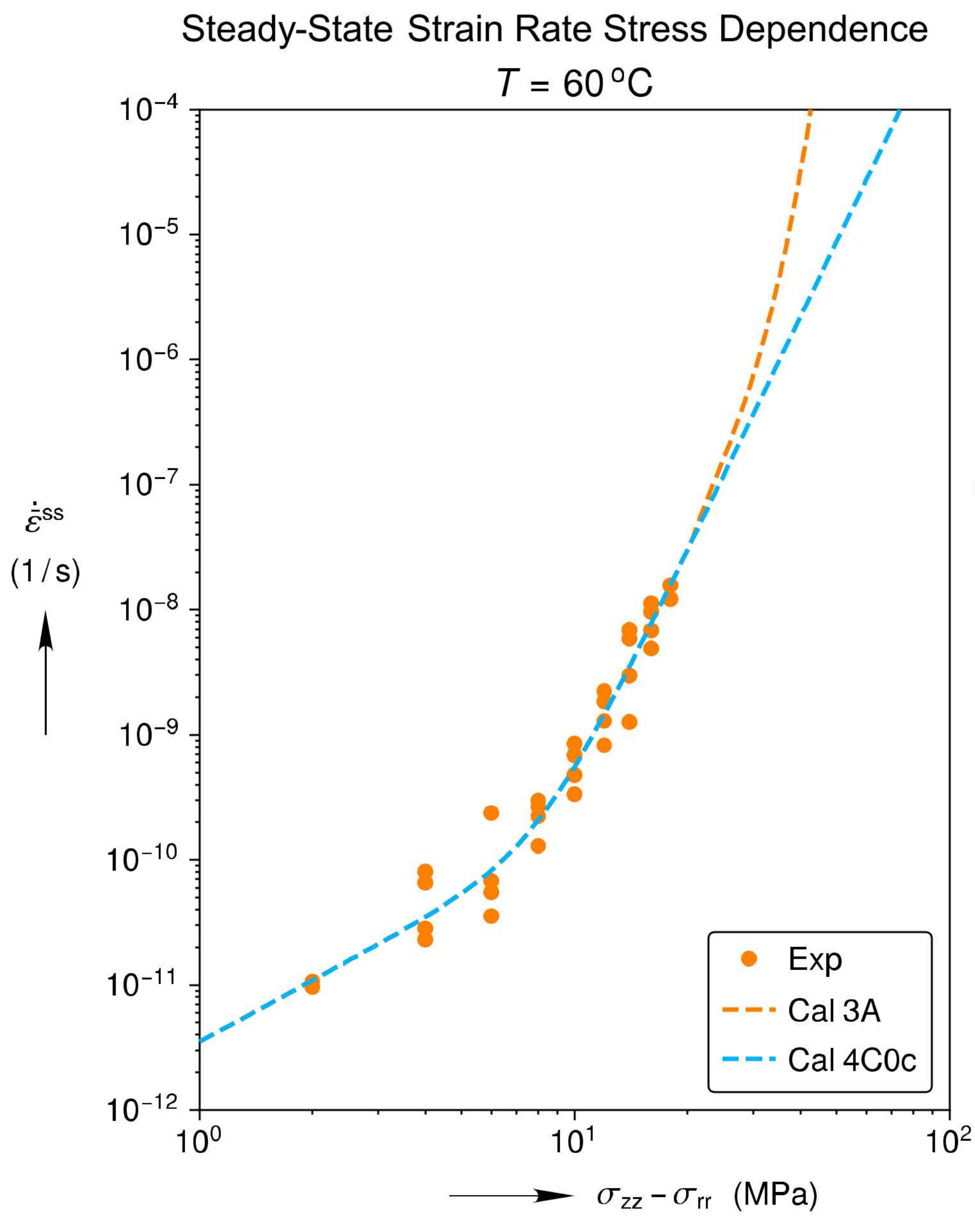

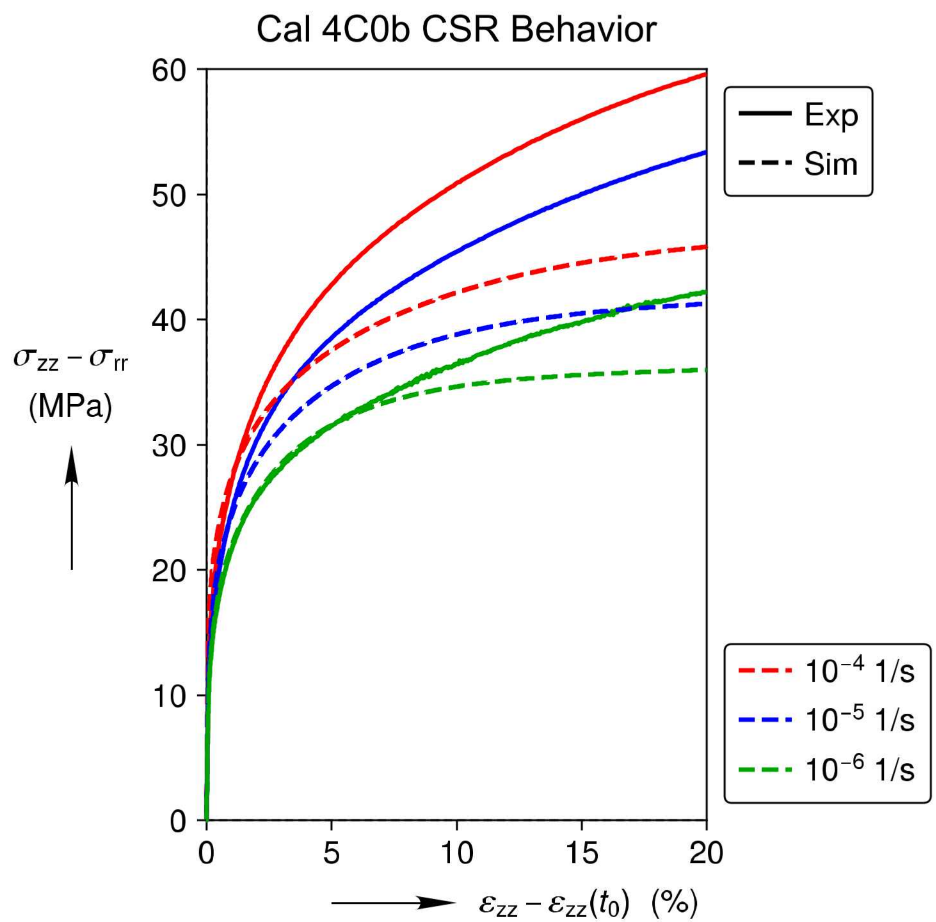

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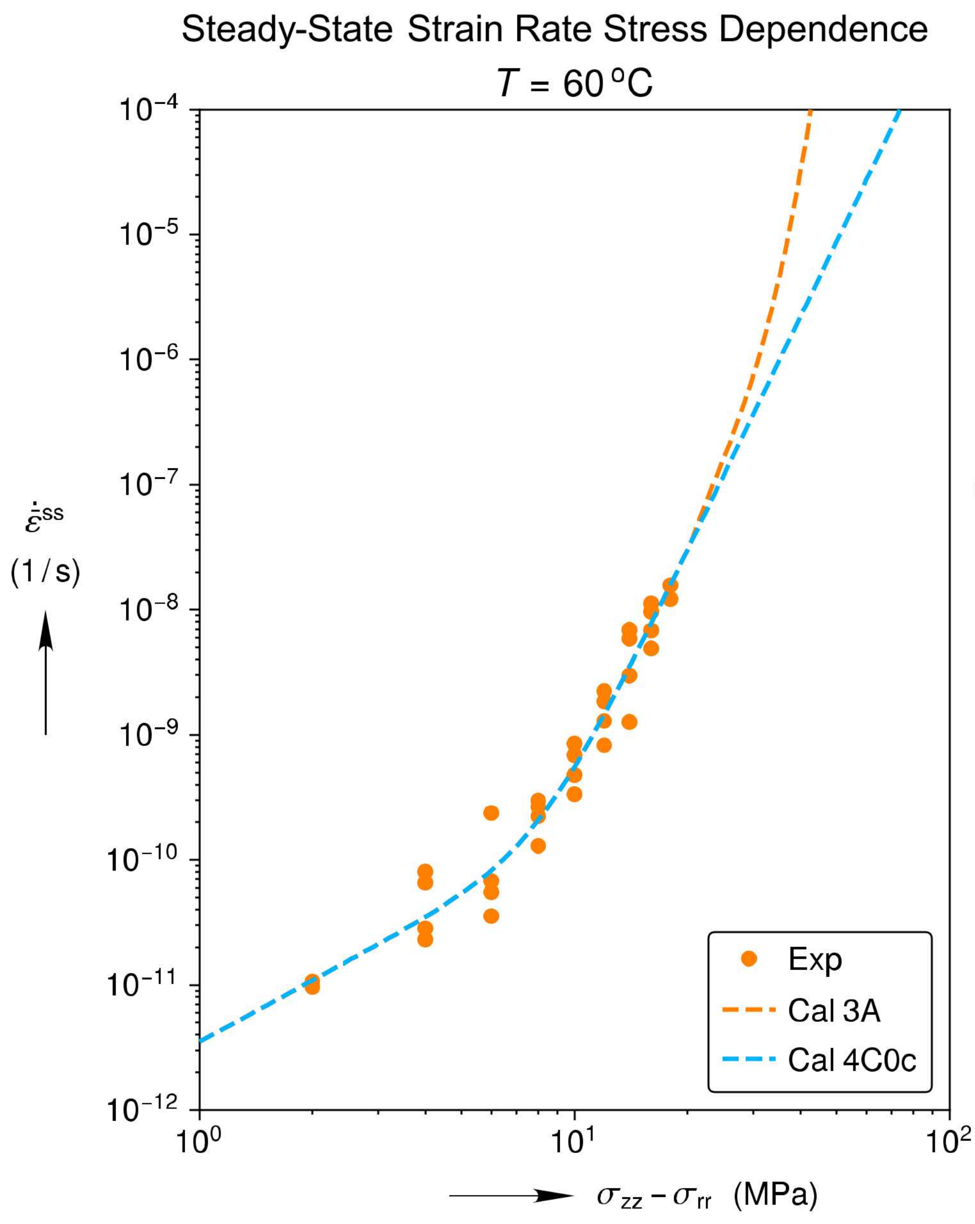
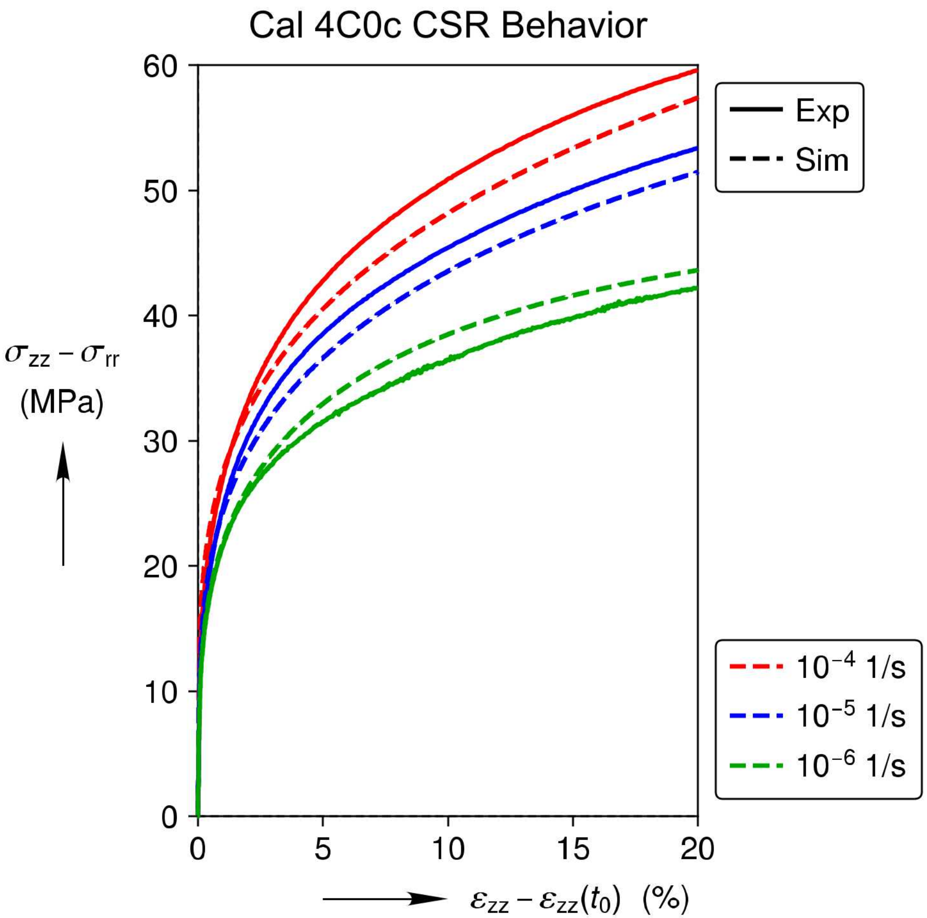
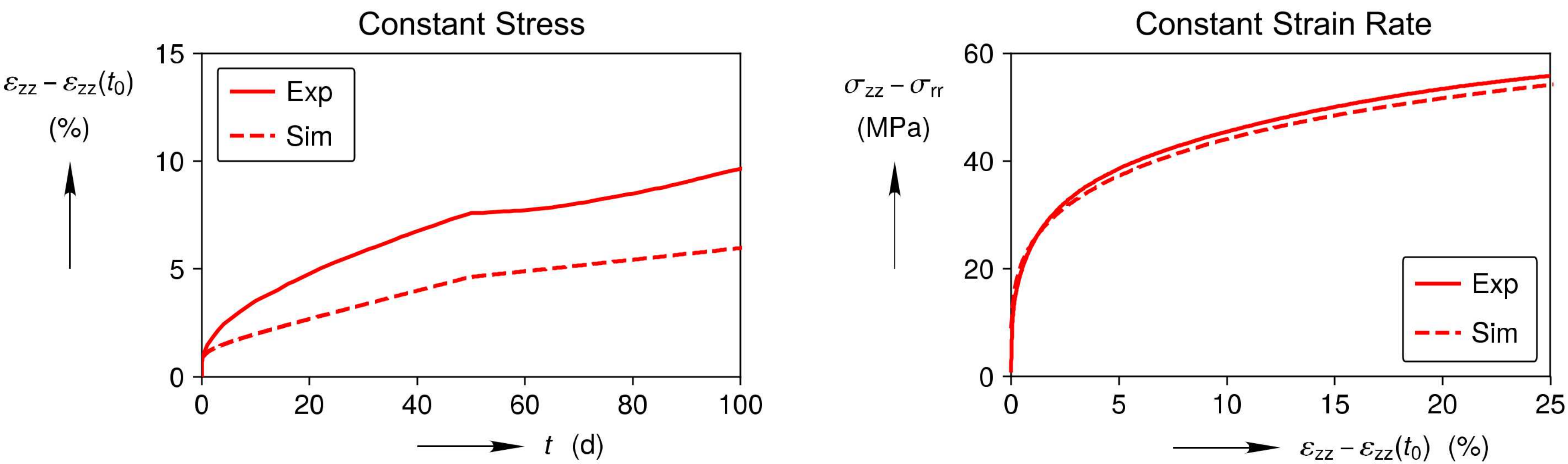




Optimization of Parameters

Residual Construction



$$r_i^{\mathrm{cs}} = \left\{ \frac{1}{t_2 - t_0} \int_{t_0}^{t_2} \left[\frac{(\varepsilon_{zz} - \varepsilon_{zz}(t_0))^{\mathrm{sim}} - (\varepsilon_{zz} - \varepsilon_{zz}(t_0))^{\mathrm{exp}}}{\max\,(\varepsilon_{zz} - \varepsilon_{zz}(t_0))^{\mathrm{exp}}} \right]^2 \mathrm{d}t \right\}_i$$

$$r_i^{\mathrm{csr}} = \left\{ \frac{1}{\varepsilon_{zz}(t_1) - \varepsilon_{zz}(t_0)} \int_{\varepsilon_{zz}(t_0)}^{\varepsilon_{zz}(t_1)} \left[\frac{(\sigma_{zz} - \sigma_{rr})^{\mathrm{sim}} - (\sigma_{zz} - \sigma_{rr})^{\mathrm{exp}}}{\max\,(\sigma_{zz} - \sigma_{rr})^{\mathrm{exp}}} \right]^2 \mathrm{d}\varepsilon_{zz} \right\}_i$$

$$r = w^{\mathrm{cs}} \sum_i^{I^{\mathrm{cs}}} r_i^{\mathrm{cs}} + w^{\mathrm{csr}} \sum_i^{I^{\mathrm{csr}}} r_i^{\mathrm{csr}}$$

Calibration Procedure

1. Turn off steady-state mechanism 3 (sinh term)
2. Fit remaining steady-state mechanisms against direct measurements of steady-state slopes
3. Set $\beta_h = 0$ for simplicity
4. Vary m_i, K_i, and α_h to minimize r

Transient Strain Evolution

$$\dot{\bar{\varepsilon}}^{tr} = \left\{ \exp\left[\kappa \left(1 - \frac{\bar{\varepsilon}^{tr}}{\bar{\varepsilon}^{tr*}} \right)^2 \right] - 1 \right\} \dot{\bar{\varepsilon}}^{ss}$$

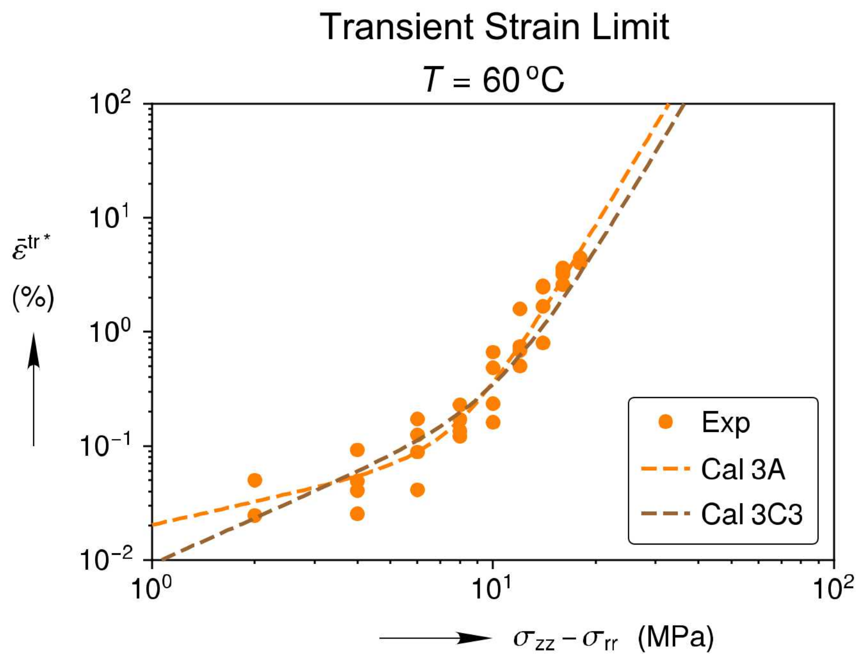
Transient Strain Limit

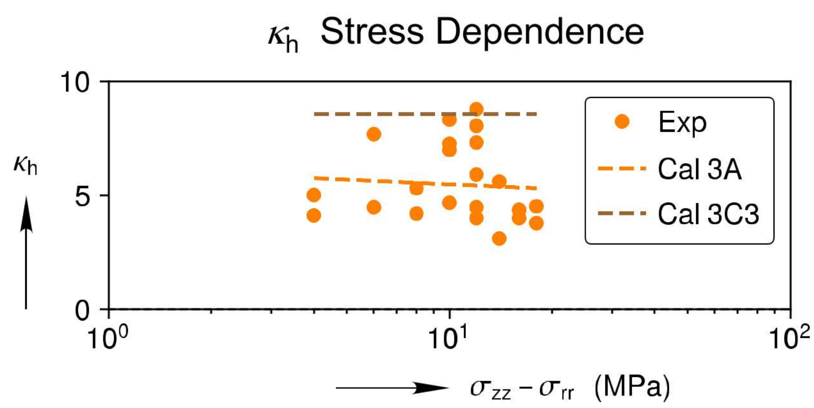
$$\bar{\varepsilon}_i^{tr\,*} = K_i \exp(c_i T) \left(\frac{\bar{\sigma}}{\mu} \right)^{m_i}$$

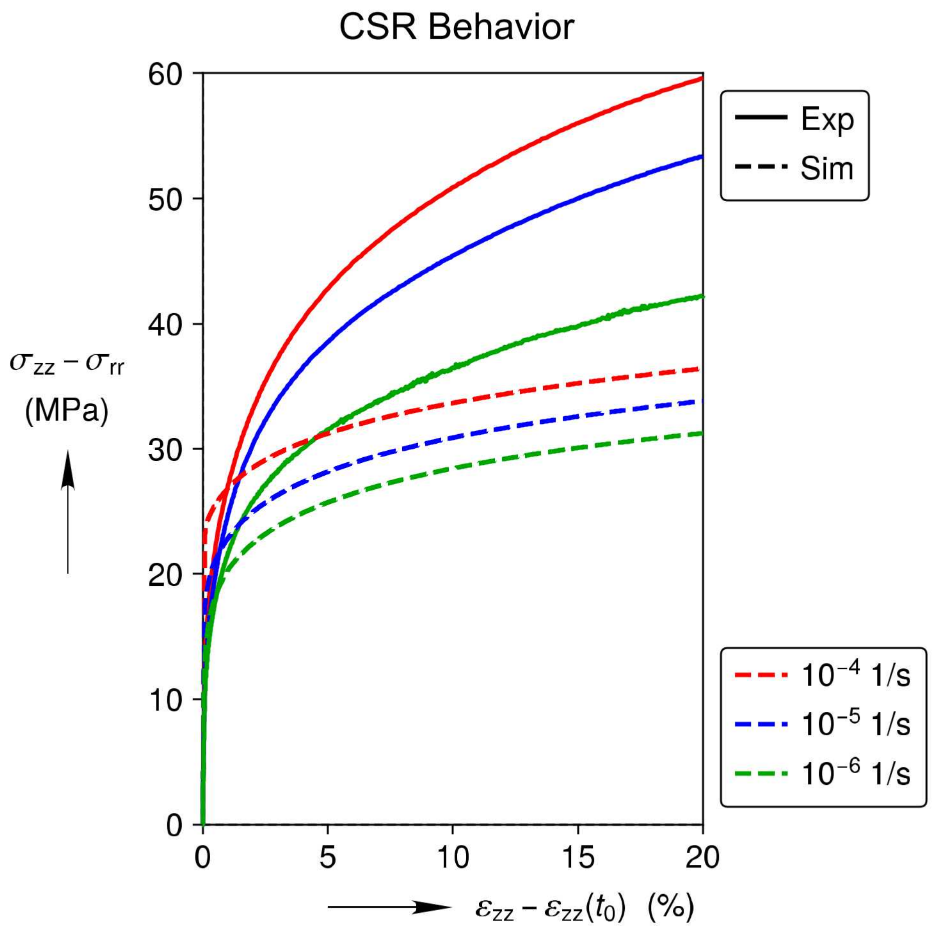
κ_h Stress Dependence

$$\kappa_h = \alpha_h + \beta_h \log_{10}\left(\frac{\bar{\sigma}}{\mu} \right)$$

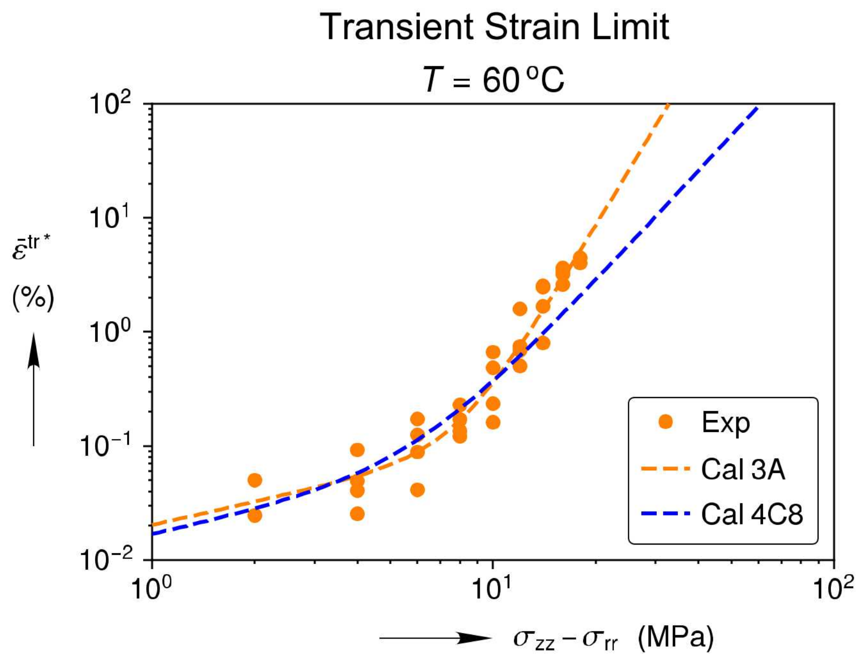
Trial Run of Optimization Routine

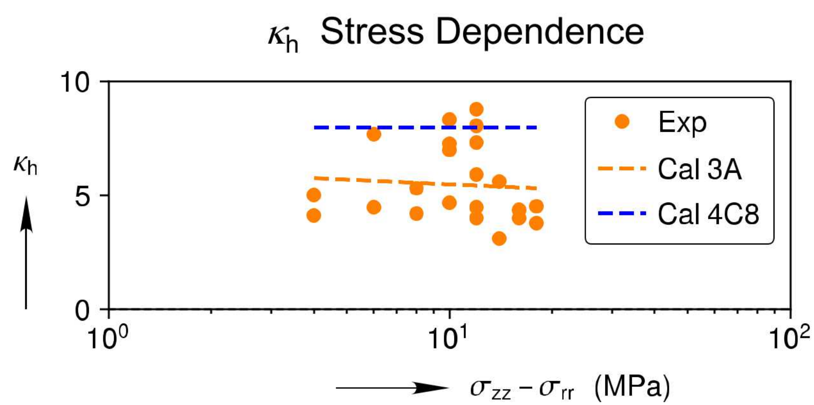


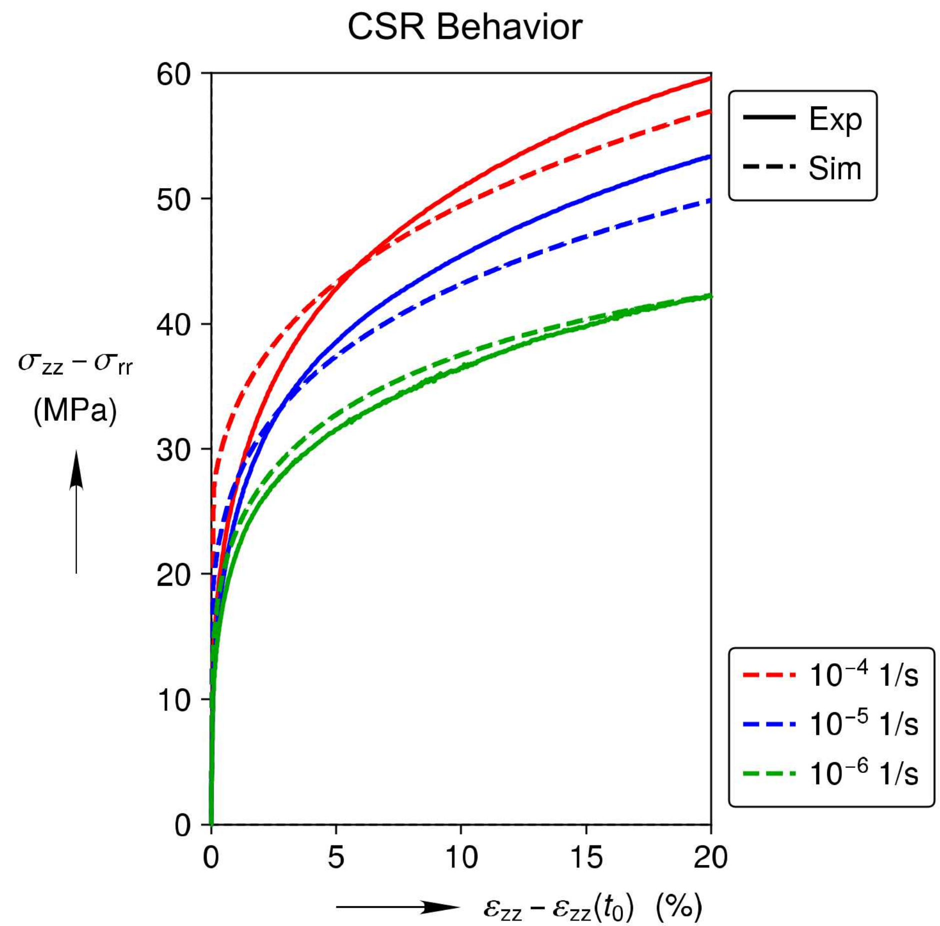




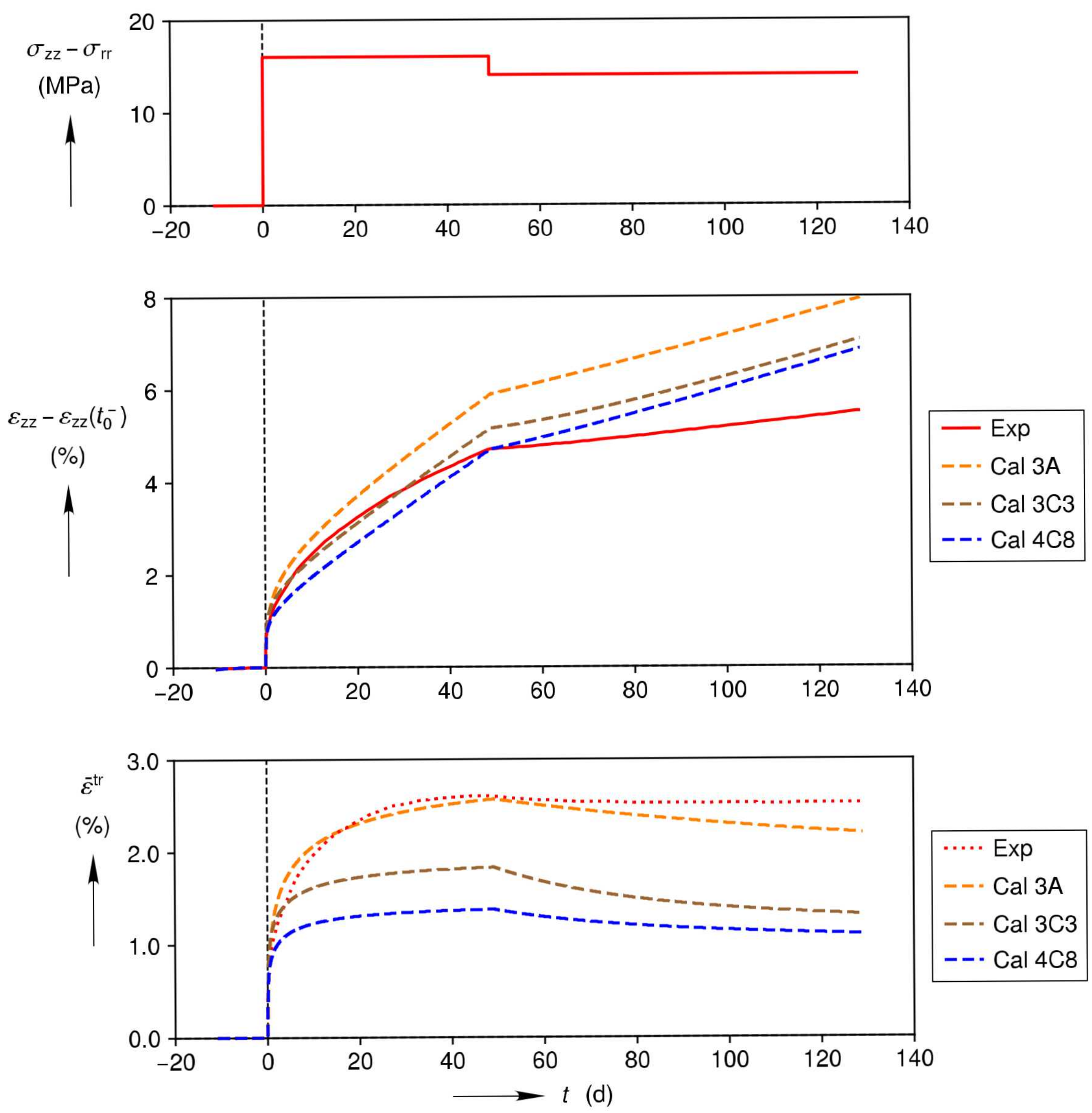
New Calibration







Different Measures of Quality



Summary

Summary

1. Calibrating only against constant stress tests leads to poor constant strain rate predictions.
   a. Transient strain evolves too slowly at first and then too quickly later.

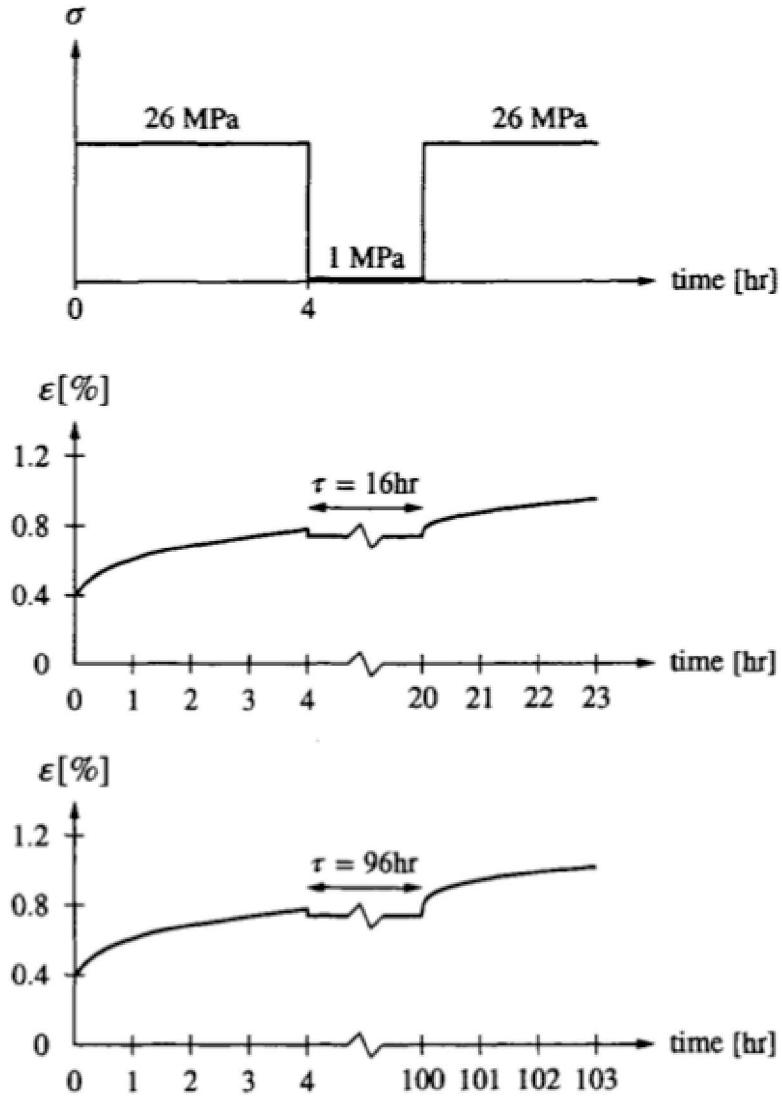
2. Manually adjusting the parameters captured constant strain rate tests, but appeared to harm the constant stress predictions.

3. Optimized parameters to acceptably capture both types of tests.
   a. Different measure of quality

Extra Slides

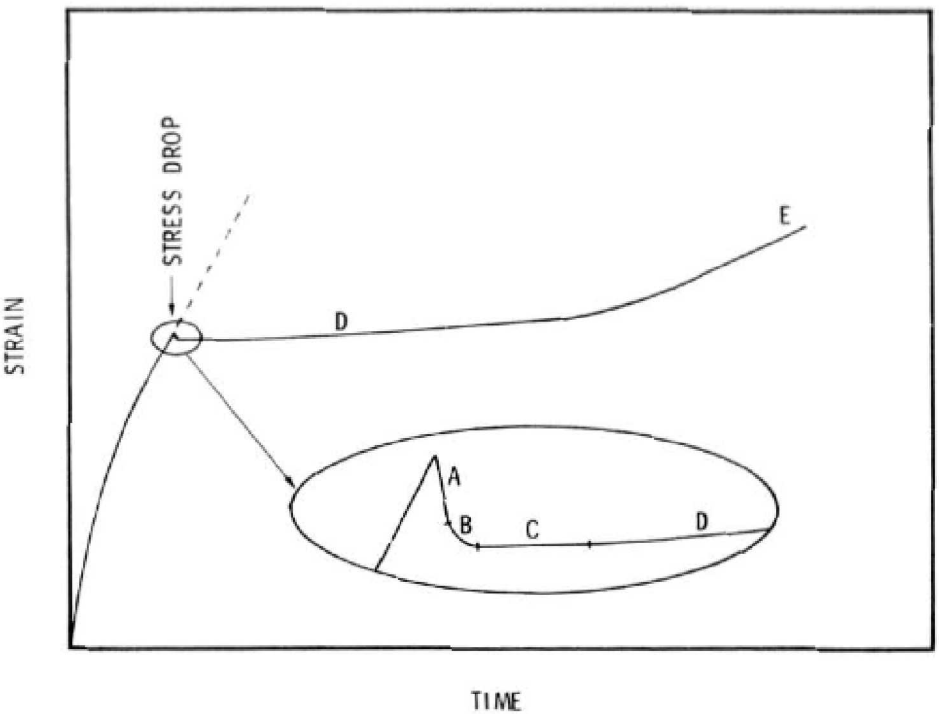
Examples of Thermal (Static) Recovery

Aluminum 1100 at 300°F



Wang, T. T. and Onat, E. T. (1968). Nonlinear mechanical behavior of 1100 aluminum at 300F. *Acta Mechanica*, vol. 5, pg. 54-70

Salt Behavior (Schematic)



Munson, D.E. and Dawson, P.R. (1982). Transient creep model for salt during stress loading and unloading. Sandia National Laboratories. SAND82-0962

Thermal (Static) Recovery

1. Add a term to hardening evolution equations

$$\dot{h} = H_r \left(\dot{\bar{\varepsilon}}^{vp} - \frac{h}{h^s} \dot{\bar{\varepsilon}}^{vp} \right) - H_{tr}\, h^{H_{te}}$$

or

$$\dot{h} = H_r \left(\dot{\bar{\varepsilon}}^{vp} - \frac{h}{h^s} \dot{\bar{\varepsilon}}^{vp} \right) - H_{tr} \left\langle h - h^s \right\rangle^{H_{te}}$$

2. Internal state variable conjugate to h is no longer $\bar{\varepsilon}^{vp}$

3. Responsible for higher secondary creep rate above 80°C ?

4. Is it negligible at room temperature over long times?