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Title: PTW modeling in xRage

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PTW modeling in xRage

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Preston-Tonks-Wallace Model

- Viscoplastic material model for very high strain rates ($\sim 10^{11}/s$)
- Uses a Voce work hardening model.
- Strain rates above $10^9/s$ uses Wallace's model of overdriven shocks in metals
 - Novel implementation is to merge this high strain rate model with thermal activation models which are applicable for strain rates below $10^5/s$.
- PTW is applicable for broad range of strain rates ($10^{(-3)} - 10^{12}$)
- Dean Preston (XCP-5), Davis Tonks (XCP-5), and Duane Wallace (T-1) "Model of plastic deformation for extreme loading conditions", Journal of Applied Physics, **93**:211, 2003

Formulation

$$\sigma_y(\epsilon_p, \dot{\epsilon}_p, T) = \begin{cases} 2[\tau_s + \alpha \ln(1 - \varphi \exp(-\beta - \frac{\theta \epsilon_p}{\alpha \varphi}))] \mu(p, T) & \text{Thermal regime} \\ 2 \tau_s \mu(p, T) & \text{Shock regime} \end{cases}$$

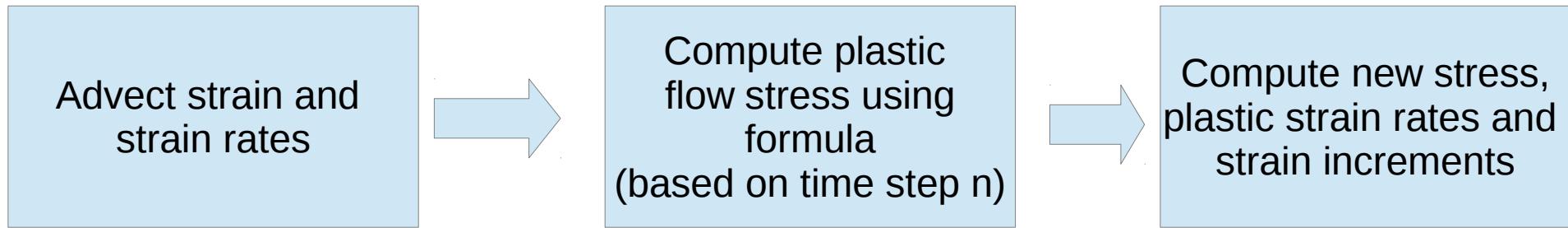
$$\tau_s = \max \left\{ s_0 - (s_0 - s_\infty) \operatorname{erf} \left[\kappa \hat{T} \ln \left(\frac{\gamma \dot{\xi}}{\dot{\epsilon}_p} \right) \right], s_0 \left(\frac{\dot{\epsilon}_p}{\gamma \dot{\xi}} \right)^{s_1} \right\}$$

$$\alpha = \frac{s_0 - \tau_y}{d} \quad \beta = \frac{\tau_s - \tau_y}{\alpha} \quad \varphi = \exp(\beta) - 1$$

$$\tau_y = \max \left\{ y_0 - (y_0 - y_\infty) \operatorname{erf} \left[\kappa \hat{T} \ln \left(\frac{\gamma \dot{\xi}}{\dot{\epsilon}_p} \right) \right], \min \left\{ y_1 \left(\frac{\dot{\epsilon}_p}{\gamma \dot{\xi}} \right)^{y_2}, s_0 \left(\frac{\dot{\epsilon}_p}{\gamma \dot{\xi}} \right)^{s_1} \right\} \right\}$$

$$\dot{\xi} = \frac{1}{2} \left(\frac{4\pi\rho}{3M} \right)^{\frac{1}{3}} \left(\frac{\mu(p, T)}{\rho} \right)^{\frac{1}{2}}$$

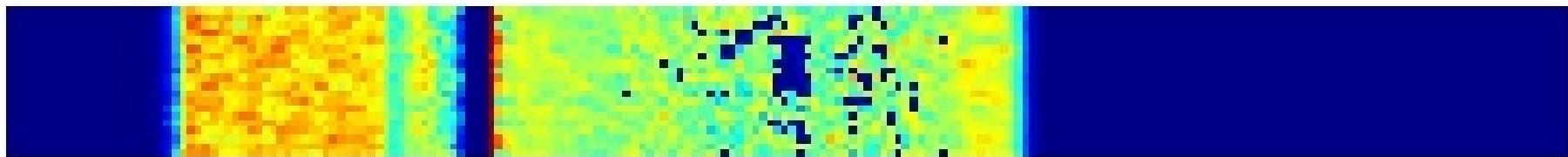
PTW in xRage



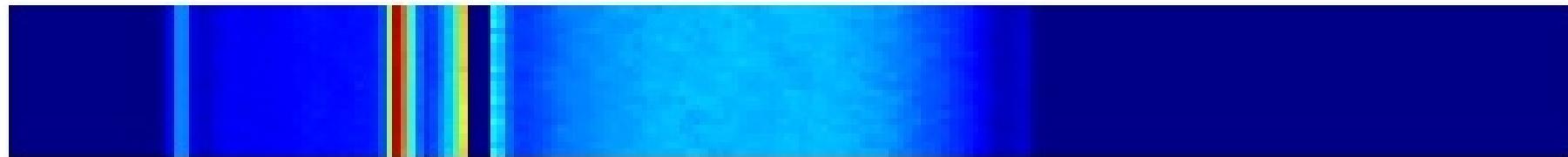
- Inconsistencies between plastic flow stress and plastic strain rates
- Solution: Iterate until new stress and plastic strain rates are consistent with plastic flow stress

Example – Flyer plate

Strain rate:



Strain:



Regula Falsi

- Use a false position method to determine consistent plastic flow stress and plastic strain rates
 - Bracketed method
 - Converges faster than bisection by using a linear fit on bracket endpoints to find zero point
- If solution is bracketed between points A and B, then we choose our next iteration point, C, as:

$$C = B - f(B) \frac{B - A}{f(B) - f(A)}$$

Regula Falsi and PTW

- Define a value 'Cy' to iterate on:
- Cy is in a known range, with a minimum of zero
 - Use Cy = 1.0e-4 for lower part of bracket. Compute Cy corresponding with zero plastic strain as upper bracket

$$C_y = \frac{\sigma_y}{\sigma_{eff}}$$

Compute plastic strain and strain rate using Cy

Compute plastic flow stress using computed plastic strain and strain rate

Compute strain and stain rates again based on plastic flow stress

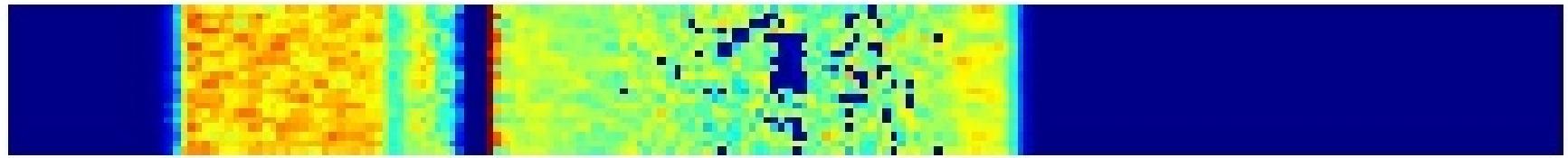
- Compute error based on strain rate discrepancy, update endpoints of bracket

Results

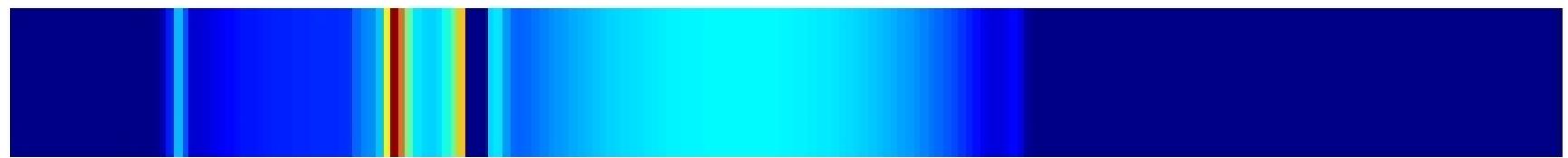
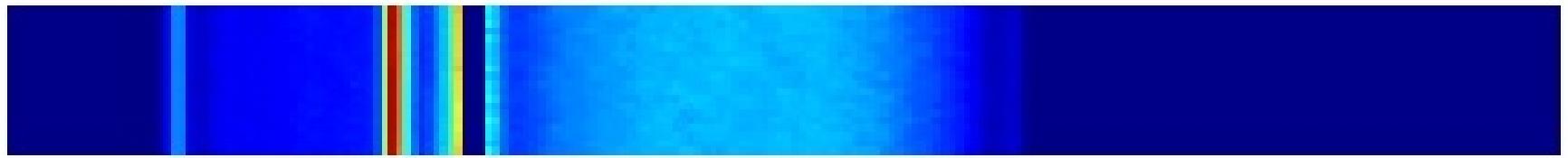
- Converges in usually ten iterations or less
- Eliminates 'noise' in numerical results

Results – Flyer Plate

Strain Rate

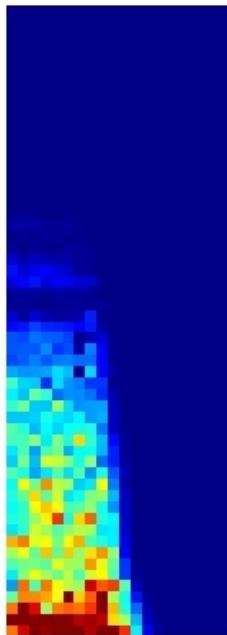


Total Strain

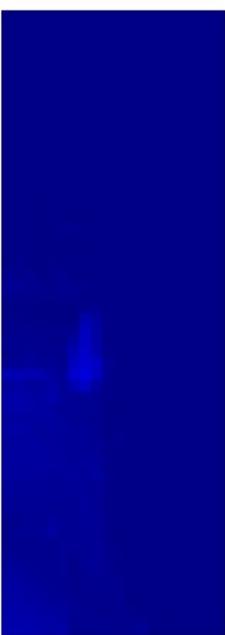


Results – Anvil Strain Rate

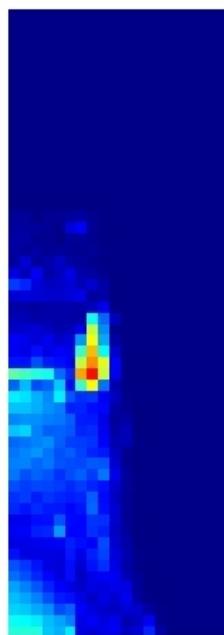
Before



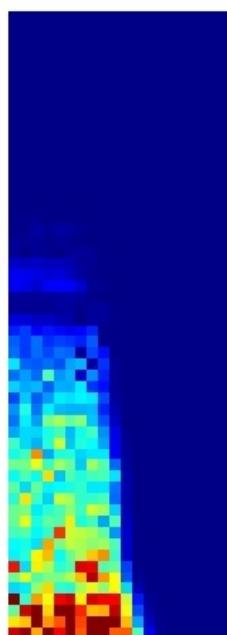
After



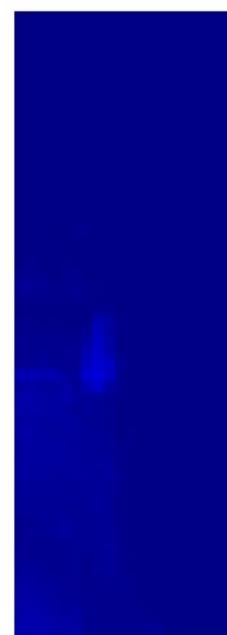
Rescaled



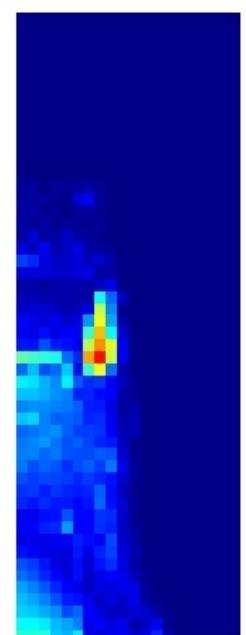
Before



After



Rescaled



PTW

PTW Mod 1

Other changes and future work

- Two distinct PTW yield stress routines are used for PTW and PTW_Mod1, despite being very similar methods
 - These have been merged into a single routine, saving several hundred lines of duplicate code
- Use Secant/Newton method, and keep false position available in case of convergence failure
 - Secant has been used in Roxane with success, can copy the approach used there
- More challenging and interesting 'test' problems are required to determine robustness of this approach