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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 (~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

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

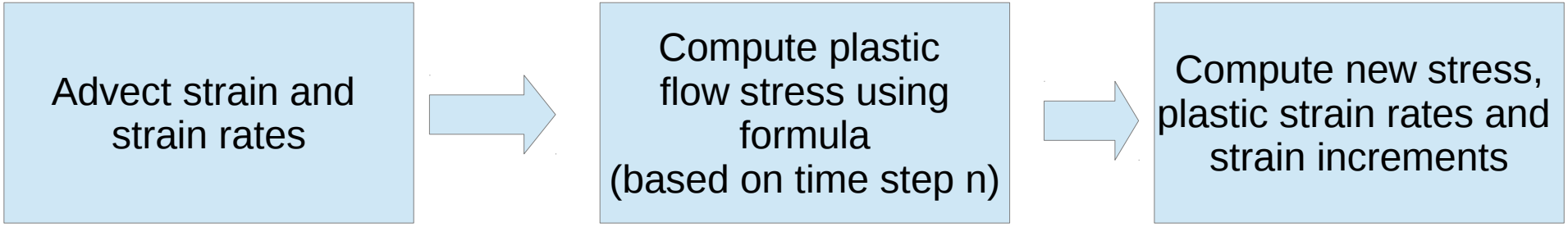
$$\tau_s = max\left\{ s_0 - (s_0 - s_\infty) erf[\kappa \hat{T} \ln(\frac{\gamma \dot{\xi}}{\dot{\epsilon}_p})], s_0 (\frac{\dot{\epsilon}_p}{\gamma \dot{\xi}})^{s_1} \right\}$$

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

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

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

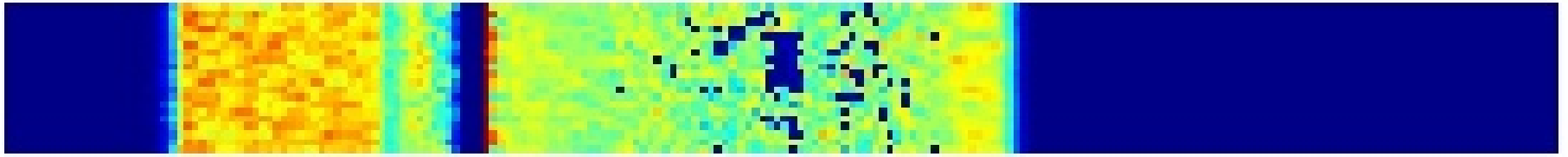
PTW in xRage



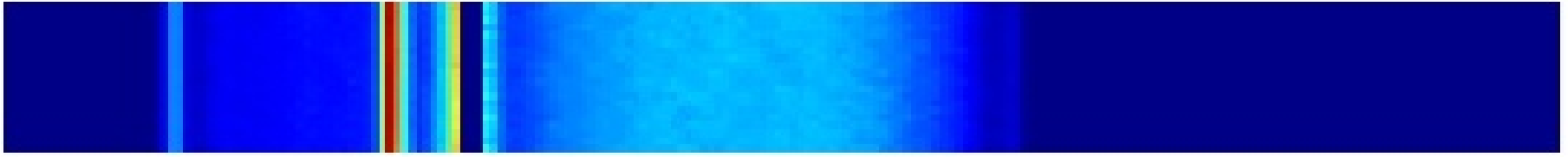
- Inconsistencies between plastic flow stress and plastic strain rates
- Solution: Iterate until new stress and plastic strain rates are consistent with plastic flow stress

Example – Flyer plate

Strain rate:



Strain:



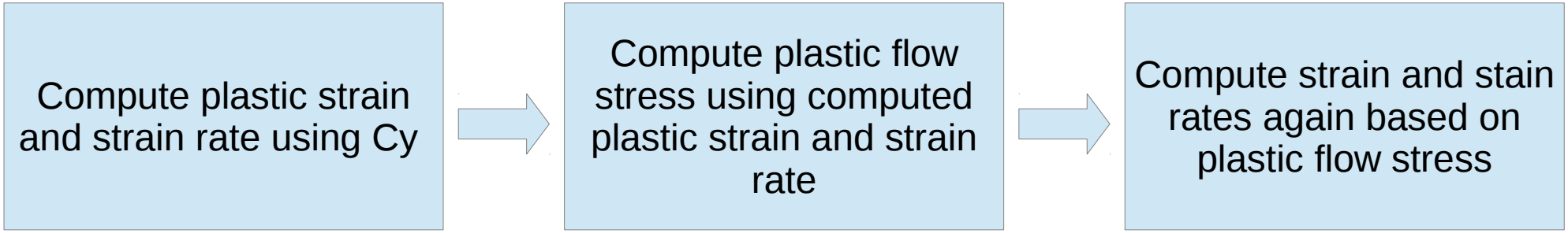
Regula Falsi

- 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: $C_y = \frac{\sigma_y}{\sigma_{eff}}$
- Cy is in a known range, with a minimum of zero
  - Use Cy = 1.0e-4 for lower part of barcket. Compute Cy corresponding with zero plastic strain as upper bracket



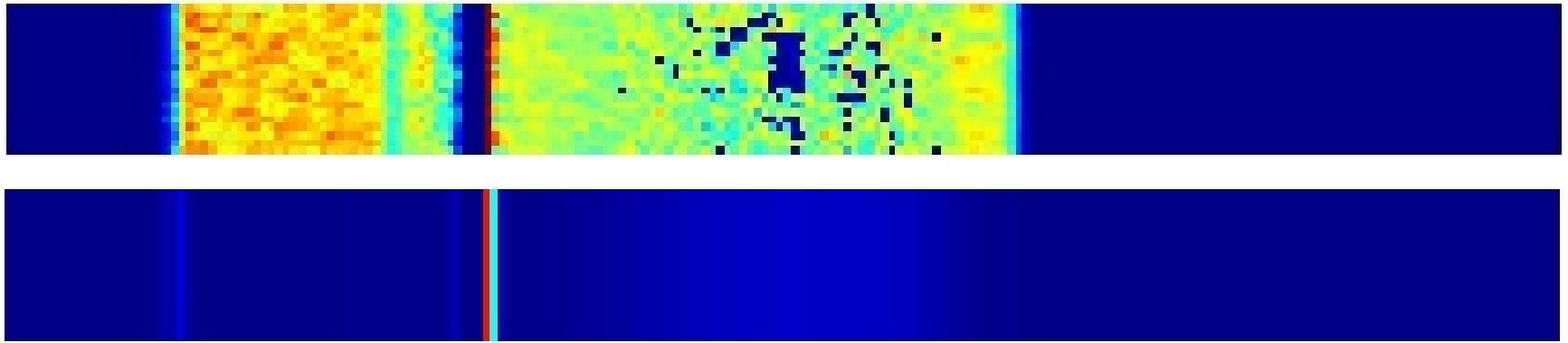
- Compute error based on strain rate discrepency, update endpoints of bracket

Results

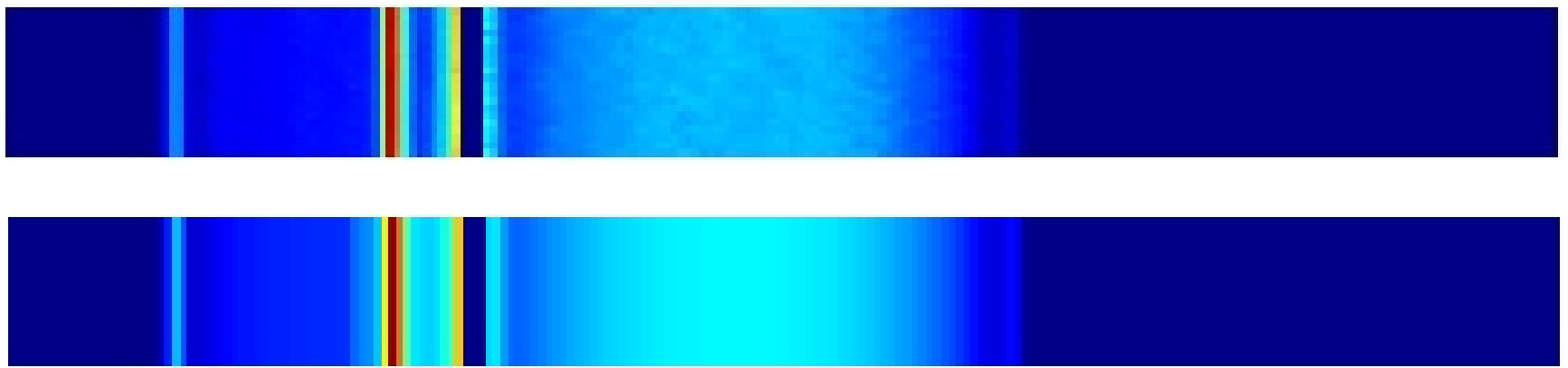
- Converges in usually ten iterations or less
- Eliminates 'noise' in numerical results

Results – Flyer Plate

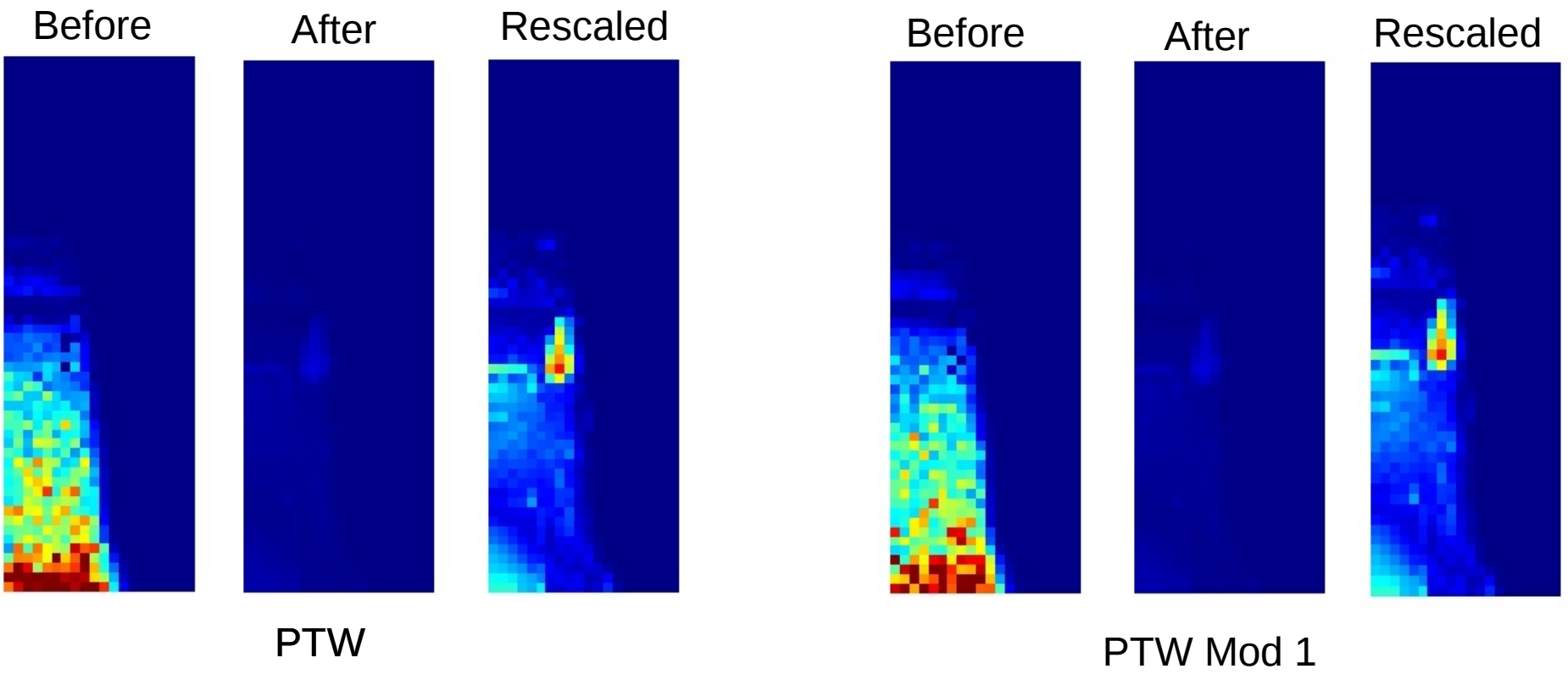
Strain Rate



Total Strain



Results – Anvil Strain Rate



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