Heterogeneous Stresses at Bimaterial Interfaces

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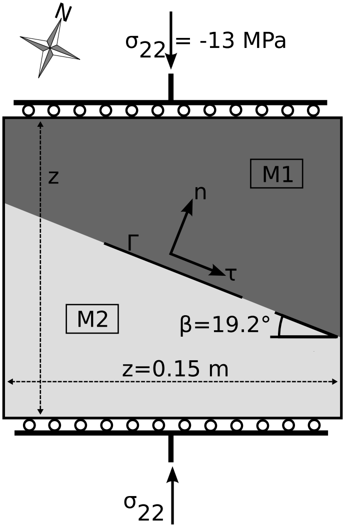
Web version without backup slides.

Questions and suggestions to s.langer@uq.edu.au

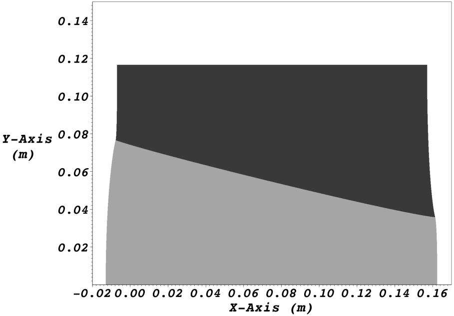
Outline

1. Heterogeneous stresses in laboratory experiments
2. Methods to remove or reduce heterogeneity of stresses
3. Numerical dynamic rupture studies

Experimental Setup

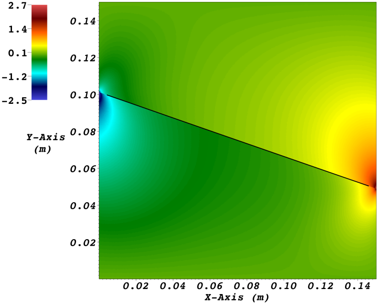


Xia et al., Science, 2005
Bhat et al., Tectonophysics, 2010
Biegel et al., Tectonophysics, 2010

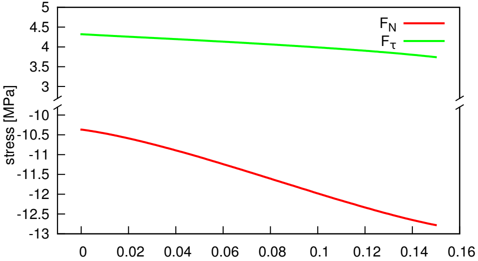


Stress and Strain Heterogeneities

Shear strain distortion



Stress distortion



Values for homogeneous case

Shear strain: $\epsilon_{12} = 0$

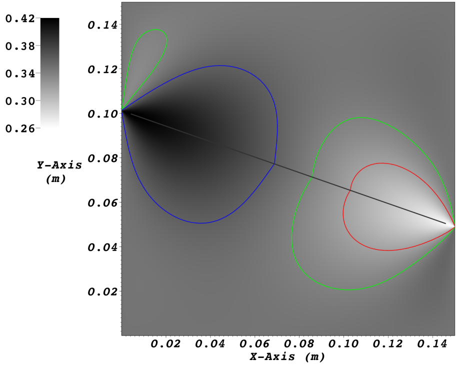
Normal stress: $F_N = -11.6\,\mathrm{MPa}$

Tangential stress: $F_\tau = 4.0\,\mathrm{MPa}$

Reducing and Removing Stress Heterogeneities

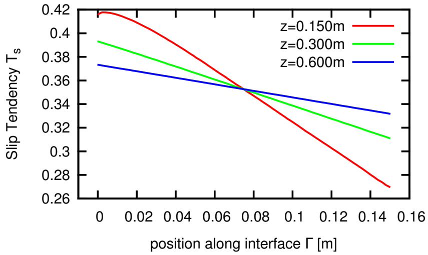
Slip tendency [Morris et al., 1996] as criterion for stress heterogeneity:

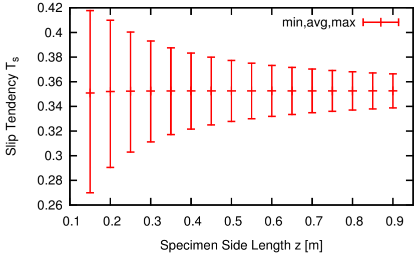
$$T_s = \frac{F_\tau}{F_N}$$



Method 1: Long Specimen Border

Analytical value for homogeneous material interface: $T_s = 0.345$





+ Can be used in laboratory experiments
– Slip tendency constant only for infinitely large specimen

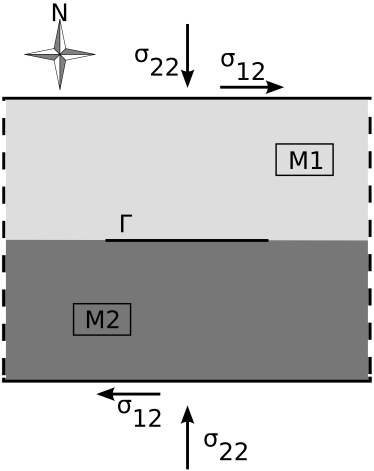
Method 2: Equal Elastic Moduli

$$C_{S2} = (1+\gamma)\, C_{S1}$$
$$C_{P2} = (1+\gamma)\, C_{P1}$$
$$\rho_2 = (1+\gamma)^{-2}\, \rho_1$$
$$\mu_2 = \mu_1$$
$$\lambda_2 = \lambda_1$$

γ	...	Wave speed contrast
C_{Sx}, C_{Px}	...	Wave speeds
λ, μ	...	Lamé parameters

- \+ Constant slip tendency
- \+ Arbitrary fault orientations and complex geometry possible
- – Can only be used in numerical work
- – Bimaterial Effect of rigidity contrast can not be observed

Method 3: Periodic Boundary Conditions



- \+ Constant slip tendency
- \+ Arbitrary material properties possible
- − Can only be used in numerical work
- − Fixed geometry

Case studies

Elastoplastic dynamic rupture model

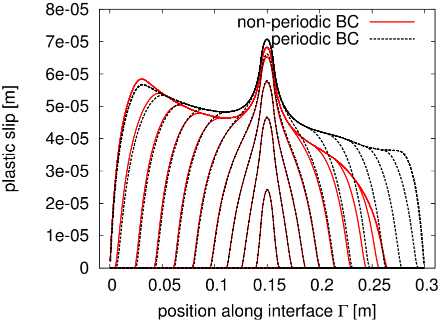
Velocity-weakening friction law [Ampuero et al., 2008]:

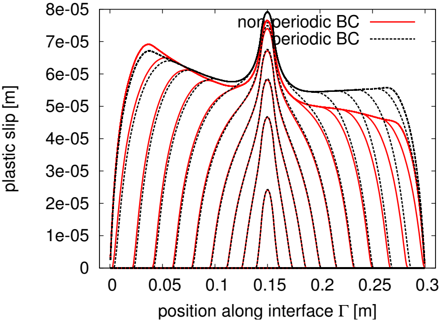
$$\mu_f = \mu_s + \alpha \frac{V}{V + V_C} - \beta \frac{\Theta}{\Theta + V_C}$$

$$\dot{\Theta} = \frac{V - \Theta}{\tau_C}$$

V_c determines if rupture mode is pulse-like and crack-like

Case 1: Homalite-100 / Polycarbonate



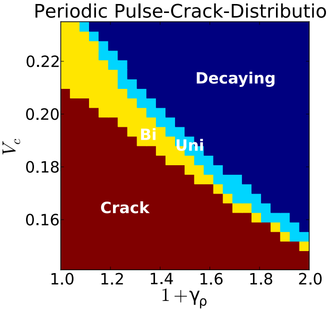


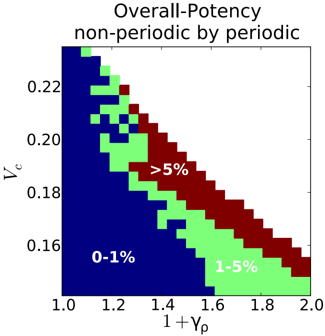
Unilateral pulses

Nonperiodic Boundaries
25 ouf 36 (69%)

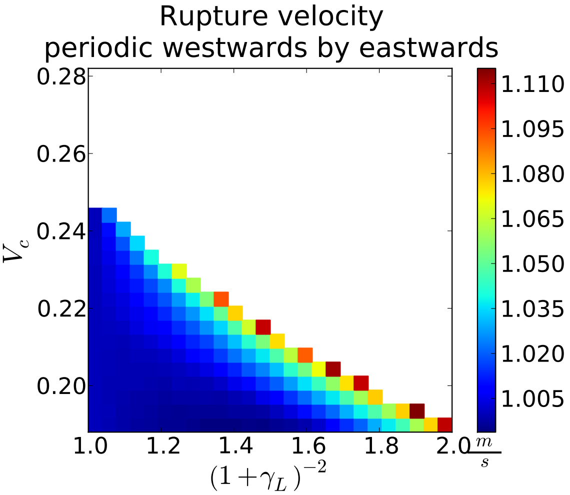
Periodic Boundaries
16 out of 30 (53%)

Case 2: Equal Density





Case 3: Equal Elastic Moduli



Conclusions

- Loading of bimaterial interfaces causes heterogeneous stresses
- Three methods to reduce or remove heterogeneities
  - Larger boundary for laboratory experiments or numerical models
  - Equal elastic moduli or periodic boundary conditions for numerical models only
- Case studies reveal
  - Nonperiodic boundary conditions lead to higher potency asymmetries
  - Directivity is weaker for periodic boundaries
  - Wave speed contrast influences rupture direction preference even when no rigidity contrast exists
  - Potency and moment of rupture event are exaggerated for nonperiodic boundary conditions