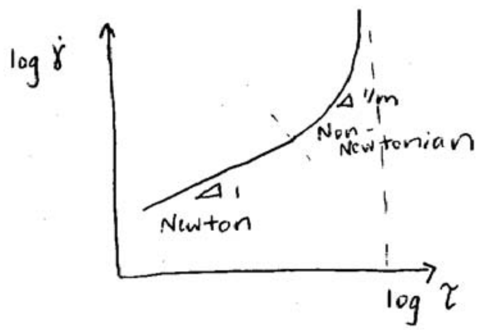
3.044 MATERIALS PROCESSING

LECTURE 19

At $T < T_m$ is it fluid flow?

Generalized Flow Law:

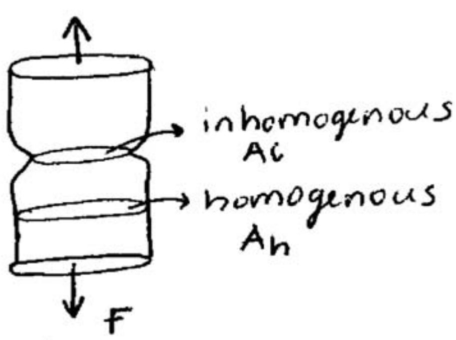


$$\tau = \mu \dot{\gamma}^m$$

$$\text{at } m = 1 \quad \text{Newtonian}$$

$$\underbrace{\text{at } m < 1}_{\text{usually for solids}} \quad \text{Non-Newtonian}$$

Homogeneous vs. Inhomogeneous Area:



Date: April 30th, 2012.

Force Balance: i ↔ h

$$d\varepsilon_i \, A_{0,i}^{\frac{1}{m}} \exp\left(-\frac{\varepsilon_i}{m}\right) = d\varepsilon_h \, A_{0,h}^{\frac{1}{m}} \exp\left(-\frac{\varepsilon_h}{m}\right)$$

$$\int_0^\infty A_{0,i}^{\frac{1}{m}} \exp\left(-\frac{\varepsilon_i}{m}\right) \, d\varepsilon_i = \int_0^{\varepsilon_{\text{fracture}}} A_{0,h}^{\frac{1}{m}} \exp\left(-\frac{\varepsilon_h}{m}\right) \, d\varepsilon_h$$

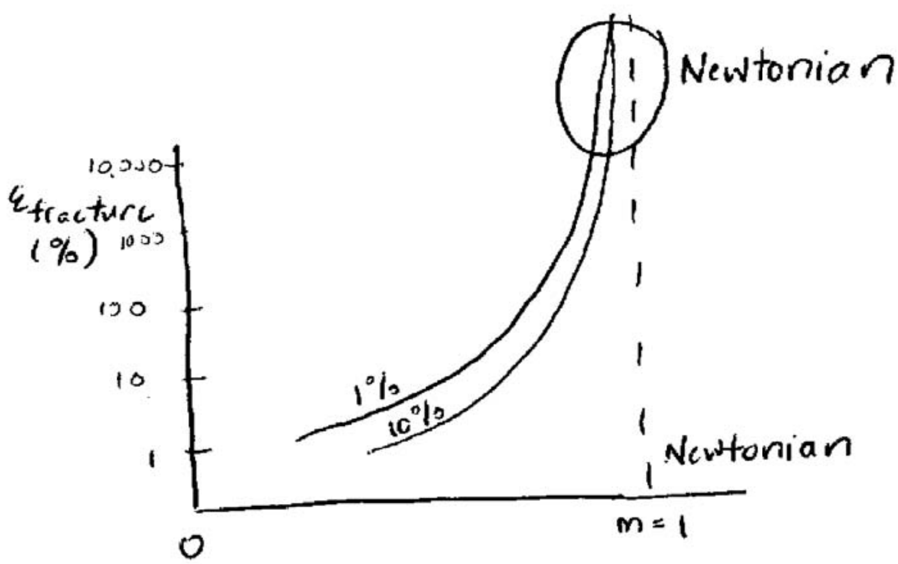
$$\boxed{\varepsilon_{\text{fracture}} = -m \ln\left(1 - \left(\frac{A_{0,i}}{A_{0,h}}\right)^{\frac{1}{m}}\right)}$$

· where m is a material property: strain rate sensitivity

· where $\left(\frac{A_{0,i}}{A_{0,h}}\right)^{\frac{1}{m}}$ is the size of inhomogeneity

⇒ if = 1 no roughness, no perturbation

⇒ if < 1 (0.99) there is 1% area fluctuation



· Newtonian Flow is stable: resists necking, voiding, etc.
· Non-Newtonian flow is unstable

⇒ Shape forming in net tension must strive for Newtonian conditions ($m < 0.5$)

Bottle Production

- glass blowing ∼ 1500
- plastic / polymers ∼ 1940-1960
- bottles ∼ 1980
- monolithic bottle ∼ 2000
- superplastic forming ∼ 1990, metals ∼ 2000, now: ceramics

Deformation Mechanism Map