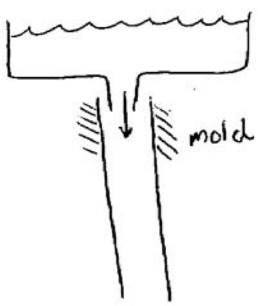
3.044 MATERIALS PROCESSING

LECTURE 18

Results from last time:



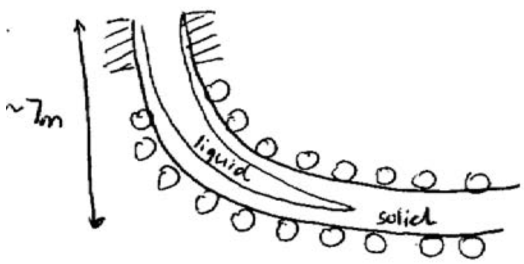
Fluid Flow

· the force of gravity is enough to deliver the metal into the mold

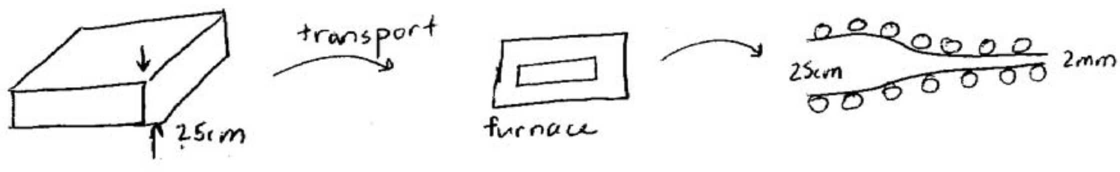
· turbulent flow → well mixed (good), but more aggressive on solid tube (bad)

Heat Transfer

· solidification takes $\sim$ 13min, $\sim$ 17m



Date: April 25th, 2012.



<u>Can this process be continuous?</u>

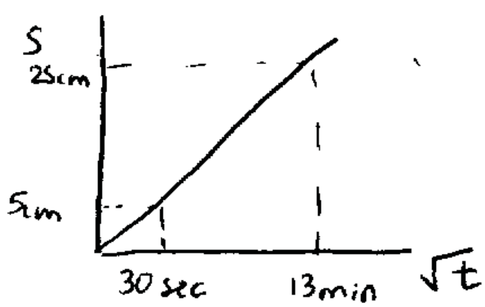
Conservation of Volume:

$$(0.25)(1)(1.3)\frac{m^3}{s} = (0.0005)(1)(V_{out})$$
$$V_{out} = 650\frac{m}{min} = 25\frac{m}{hr}$$

$\Rightarrow$ Such a high velocity is dangerous and requires an extremely long factory

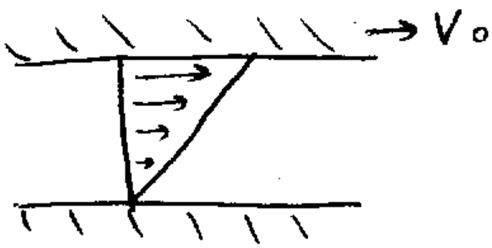
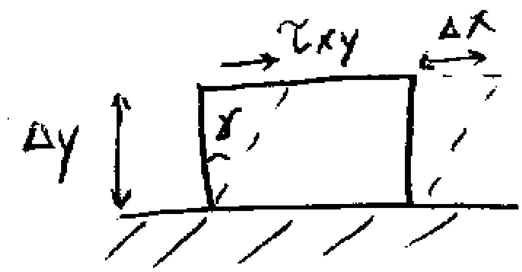
Therefore: The only path to fully continuous strip production is to cast even thinner
$\Rightarrow$ **strip casting**

- How do you maintain throughput?
  - parallelize $\Rightarrow$ multi-strand casting (requires **huge** capital investment)
- New processes: **mini-mills**
  - record thin casting $\sim$ 2mm
  - $s = 2\gamma\sqrt{\alpha t}$



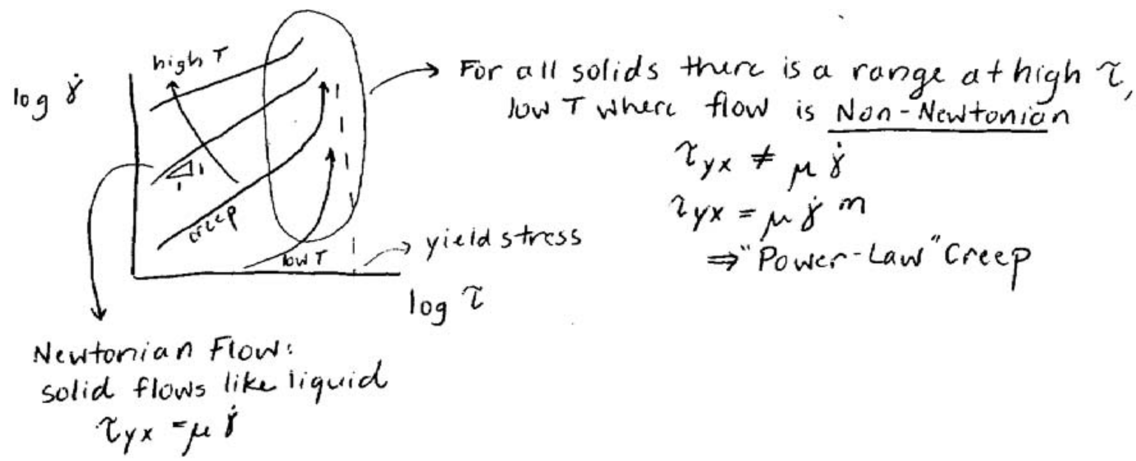
Solid State Shape Forming:

Hot solid material: must be high enough temperature to have viscous (fluid like) flow, but not so high that it melts

Newtons law of viscosity	Creep
 $$\tau_{xy} = -\mu \frac{\partial v_x}{\partial y}$$	 for small angles: $\gamma \approx \frac{\delta x}{\delta y} \approx \frac{\partial x}{\partial y}$ $\dot{\gamma} = \frac{\partial \gamma}{\partial t} = \frac{\partial}{\partial t}\left(\frac{\partial x}{\partial y}\right) = \frac{\partial}{\partial y}\left(v_x\right)$ $$\dot{\gamma} = \frac{\partial v_x}{\partial y}$$

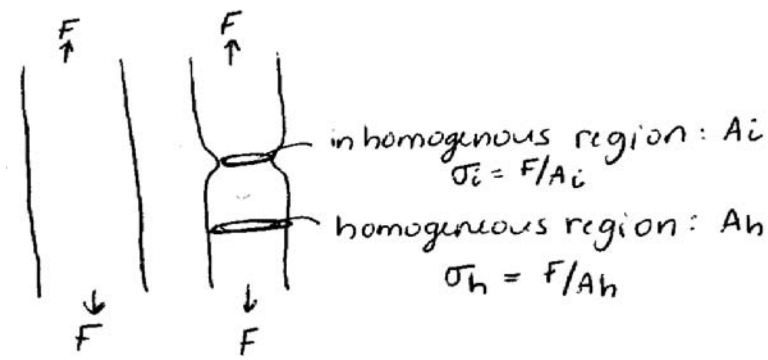
In conclusion: **Newton's law of viscosity** for fluids is same as the **creep law** for solids except for a factor of μ and the negative sign difference between solid and fluid mechanics

$$\tau_{xy} = \pm\, \mu \dot{\gamma}$$



m is defined as **strain rate sensitivity**
when m = 1, Newtonian ∼ fluid like
when m < 1, non-Newtonian

Stability of Tensile Flow:

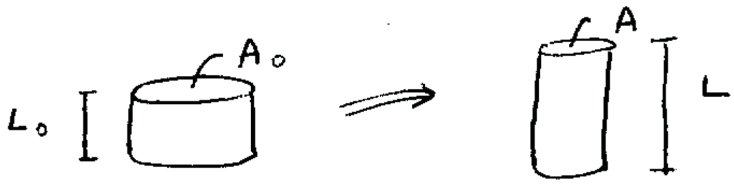


Will necking to failure occur? How far will it stretch?

$$\sigma_i \; A_i = \sigma_h \; A_h$$

$\Downarrow$ stress

$\Downarrow$ geometry relates to strain



General Power-Law Equation:

$$\sigma = \mu \dot{\Sigma}^m$$
$$\dot{\epsilon}_i^m A_i = \dot{\epsilon}_h^m A_h$$

Volume Conserved:

$$V_0 = V$$
$$A_0 L_0 = AL$$

True Strain:

$$\epsilon = \ln\left(\frac{L}{L_0}\right)$$
$$\epsilon = \ln\left(\frac{A_0}{A}\right)$$
$$A = A_0 \exp(-\epsilon)$$
$$\dot{\epsilon}_i^m A_{0,i} \exp(-\epsilon) = \dot{\epsilon}_h^m A_{0,h} \exp(-\epsilon)$$
$$\dot{\epsilon}_i \left(A_{0,i}^{\frac{1}{m}} \exp\left(-\frac{\epsilon_i}{m}\right)\right) = \dot{\epsilon}_h \left(A_{0,h}^{\frac{1}{m}} \exp\left(-\frac{\epsilon_h}{m}\right)\right)$$
$$\frac{d\epsilon_i}{dt} \left(A_{0,i}^{\frac{1}{m}} \exp\left(-\frac{\epsilon_i}{m}\right)\right) = \frac{d\epsilon_h}{dt} \left(A_{0,h}^{\frac{1}{m}} \exp\left(-\frac{\epsilon_h}{m}\right)\right)$$
$$d\epsilon_i \, A_{0,i}^{\frac{1}{m}} \, e^{-\frac{\epsilon_i}{m}} = d\epsilon_i \, A_{0,h}^{\frac{1}{m}} \, e^{-\frac{\epsilon_h}{m}}$$

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Spring 2013