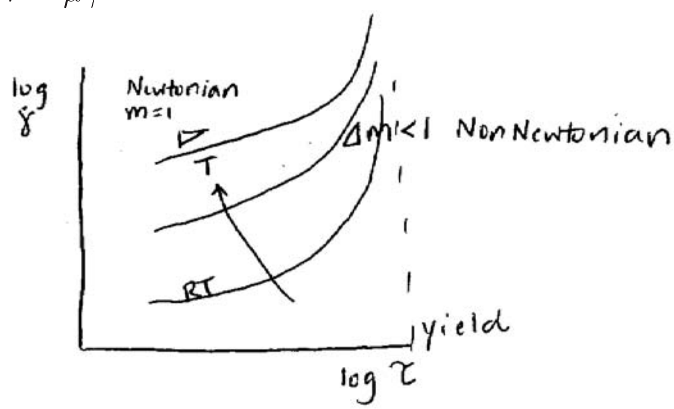
3.044 MATERIALS PROCESSING

LECTURE 20

Non-Newtonian Rheology

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



Newtonian Flow ($m \rightarrow 1$) is desirable for flow stability against necking and voiding/cavitation

So far we have talked about **net tension**. However, many processing operations are in **net compression**:

· extrusion
· rolling } continuous

· injection molding
· forging } batch

What about flow stability?

· more forgiving, less concerned about m in compression

$m > 0.5$ tension

$m > 0.2$ compression

$\Rightarrow$ faster processing is possible

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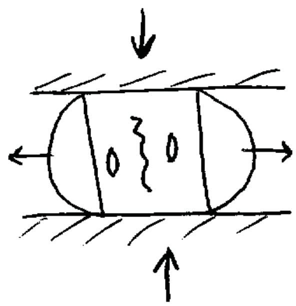
But we can't completely ignore m, there are some instabilities:

- barrelling (but it doesn't really matter)
- recrystallization
- cracks } open on directions of tension
- voids }



How to process high T_m materials?

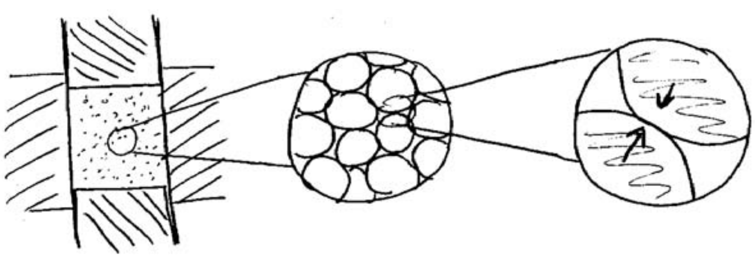
e.g. Refractory metals (W, Ta, Mo), $T_m = 3000 - 4000°C$, ceramics Al_2O_3

Casting: too hot

- hard to melt
- what material do you use as a mold?
  - → must withstand the heat and not react
  - → containerless process, powder

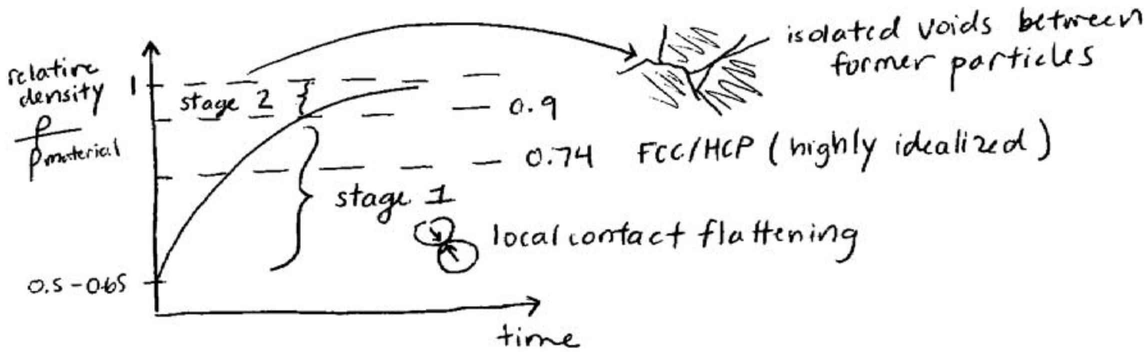
Viscous shape forming: need a solid block of material to begin with

Powder Processing and Consolidation: volume reducing and forging



- Spray atomization and other containerless processes
  - → mostly for metals (few ceramics)
- Wet chemical processing
  - → e.g. Bayer process to make alumina
  - → clean powders, distributed sizes

Consolidation (Sintering)



<u>Mechanics of powder compaction are complex but well modeled:</u>

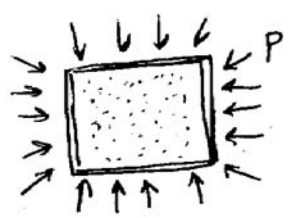
Driving Force

$$P = P_{\text{applied}} + \underbrace{\frac{2\gamma}{r}}_{\substack{\text{capillary}\\ \text{pressure}}} - \underbrace{P_i}_{\substack{\text{internally trapped}\\ \text{gas pressure}}}$$

Sintering: $P_{\text{app}} \to 0$, if sintering in a vacuum $P_i = 0$

Pressing: $P_{\text{app}} \neq 0$

- · uniaxial ⇒ fast, but very limited in shapes
- · isostatic, HIP (hot isostatic pressing) ⇒ very good for closing small pores
  ⇒ expensive, limited in shape



<u>Uses of Powder Production</u>

(1) ceramics processing

(2) powder metallurgy

(3) thermoset polymers

(4) pharmaceuticals