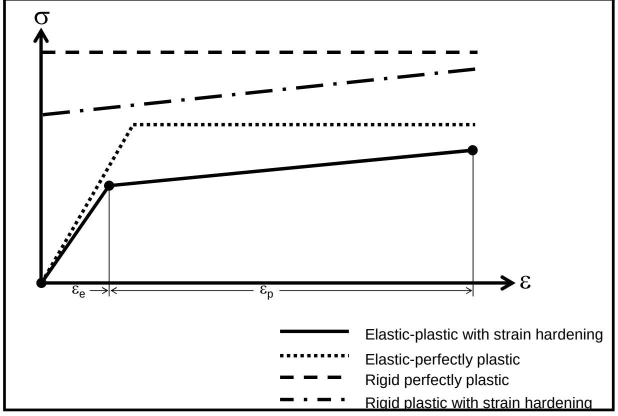
DEFORMING

Stress strain behavior of ductile materials



Topics for today's lecture

Deformation processes

- Deforming process characteristics
- Deforming physics
- Common deforming processes
- DFM

Process characteristics

Material/continuum changes during processing

- Machining = Local, concentrated
- Deforming = Over large volume

Force

- Machining: ~10s - 100s of lbs
- Stamping: ~10s - 100s of tons

Materials - Virtually all ductile materials

Shapes - Limited by strain/flow

Size - Limited by force/equipment

Advantages and disadvantages

Advantages

- Parallel process: rapid bulk formation
- Overall material properties improved

Disadvantages

- Cost of equipment and dies
- Limited flexibility in shapes and sizes (i.e. compared to machining)
- Accuracy
- Repeatability

Important physics

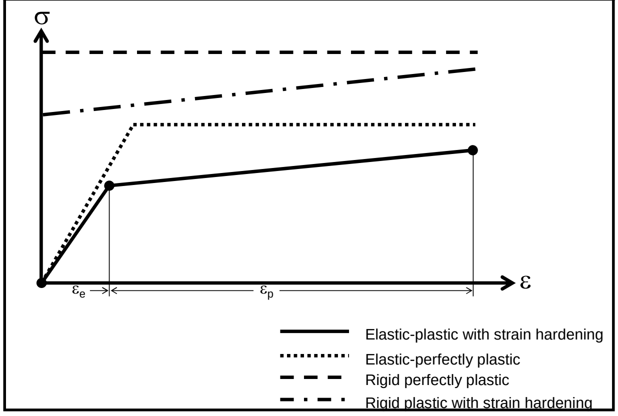
Stress/strain

- Affect CQFR
- Affect deforming force -> equipment & energy requirements

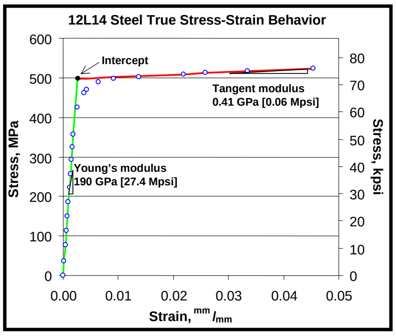
Friction

- Affect on deforming force -> equipment & energy requirements
- Why lubrication is needed and can help
- Friction is not repeatable… quality….

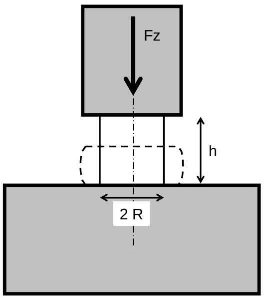
Stress strain behavior of ductile materials



Example: 12L14 Steel in Duratec



Forging force and friction



Axisymmetric upsetting

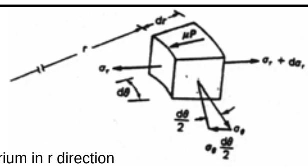
Purpose

- Find $F_z(\mu)$
- Sensitivity

Assumptions:

- Tresca flow
- Constant friction coefficient
- Plastic deformation

Forging force and friction



Eqxn: A – Equilibrium in r direction

$dF_{inner\ arc}$, $dF_{friction\ top\ \&\ bottom}$, dF_{hoop}, $dF_{outer\ arc}$

$$\Sigma dF_r = 0 = -\sigma_r \cdot h \cdot r \cdot d\theta - 2\cdot\mu\cdot p\cdot r\cdot d\theta\cdot dr - 2\cdot\sigma_\theta\cdot h\cdot dr\cdot\frac{d\theta}{2} + (\sigma_r + d\sigma_r)\cdot(r+dr)\cdot h\cdot d\theta$$

$$\frac{d\sigma_r}{dr} = \frac{2\cdot\mu\cdot p}{h} = -\frac{2\cdot\mu\cdot\sigma_z}{h}$$

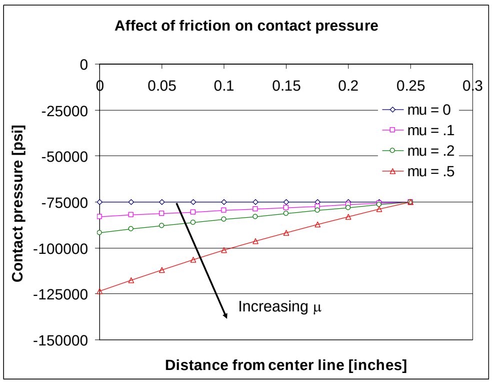
Eqxn: B - Tresca Yield Criterion

$$\sigma_r - \sigma_z = Y$$

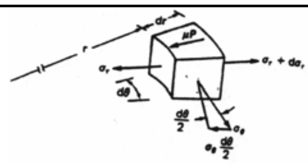
$$\sigma_z = -Y\cdot\exp\left[\frac{2\mu}{h}(R-r)\right]$$

Forging force and friction

Y=75000 psi
h = ½ inch



Forging force and friction cont.



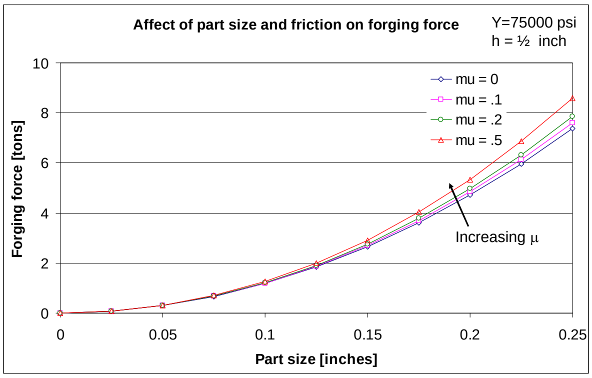
$$F_z = \int_0^R \sigma_z\cdot 2\cdot\pi\cdot r\cdot dr = (\pi\cdot R^2)\cdot\frac{1}{2}\cdot\left(\frac{h}{\mu\cdot R}\right)^2\cdot Y\cdot\left[\exp\left(\frac{2\cdot\mu\cdot R}{h}\right) - \left(\frac{2\cdot\mu\cdot R}{h}\right) - 1\right]$$

Now use Taylor's series expansion (3 terms) to approximate the exponential function

Expand about 0, makes this approximation valid for small values of $2\mu R/h$

$$|F_z| = (\pi\cdot R^2)\cdot Y\cdot\left[1 + \left(\frac{2}{3}\cdot\frac{\mu\cdot R}{h}\right)\right]$$

Forging force and friction



Common processes

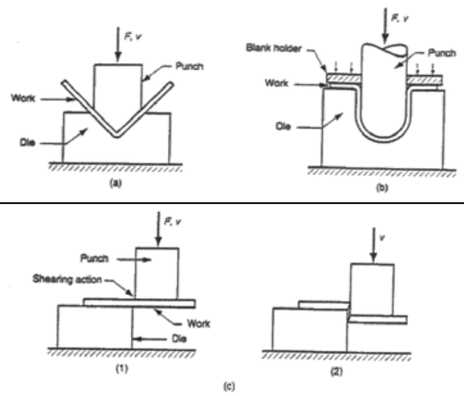
Sheet metal

Forging

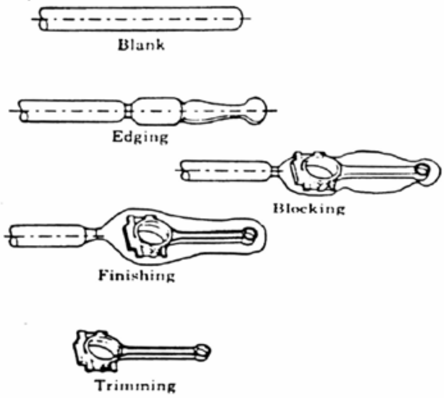
Extrusion

Rolling

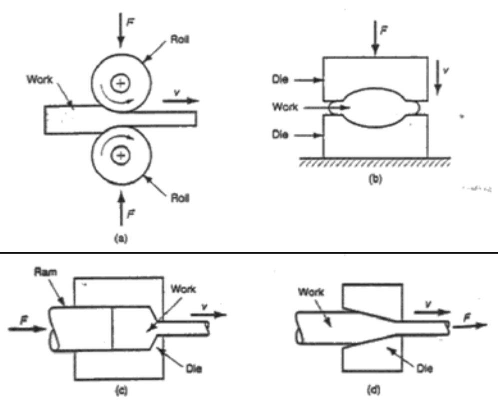
Bending and shearing



Forging



Rolling and extrusion



Affect of grain size

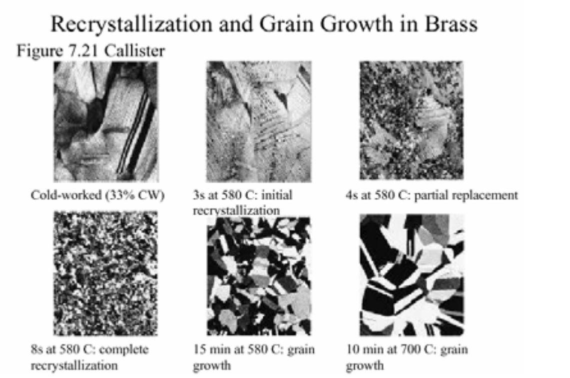
Properties affected by grain size

- **Strength**
- **Hardness**
- **Ductility**
- **For example (Ferrite)**

$$\sigma_y = \sigma_o + \frac{k_y}{\sqrt{d_{grain}}}$$

We desire smaller grains for better properties

Recrystallization



http://www.mmat.ubc.ca/other/courses/apsc278/lecture11.pdf

DFM for deforming processes

Parting line and flash

Draft angle

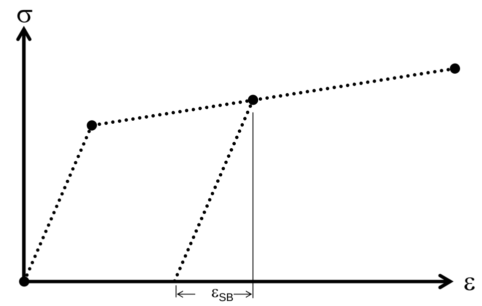
Radii

Lubrication

Mechanics of spring back

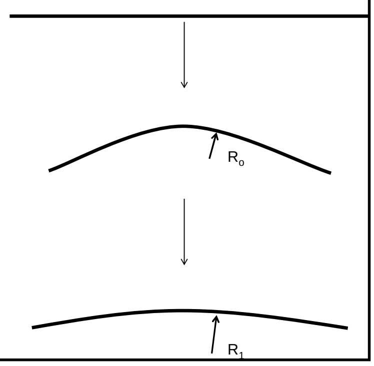
Q: Why do we see spring back?

A: Elastic recover of material



Example: Elastic spring back

Example: Bending wire



$$R_o < R_1 \Rightarrow \frac{1}{R_o} > \frac{1}{R_1}$$

Quantifying elastic spring back

Elastic recovery of material leads to spring back

- Y = Yield stress E = Young's Modulus t = thickness
- $\frac{R_i}{R_f} = 4 \cdot \left(\frac{R_i}{t} \cdot \frac{Y}{E}\right)^3 - 3 \cdot \left(\frac{R_i}{t} \cdot \frac{Y}{E}\right) + 1 \longrightarrow \frac{1}{R_i} - \frac{1}{R_f} = \frac{3}{t} \cdot \left(\frac{Y}{E}\right) - \frac{4R_i^2}{t^3} \cdot \left(\frac{Y}{E}\right)^3$
- With increase in R_i / t or Y OR decrease in E spring back increases