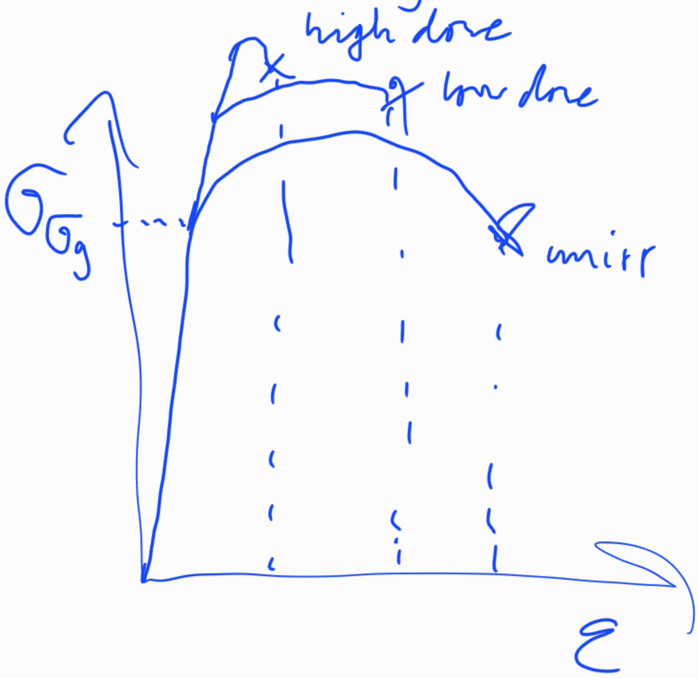
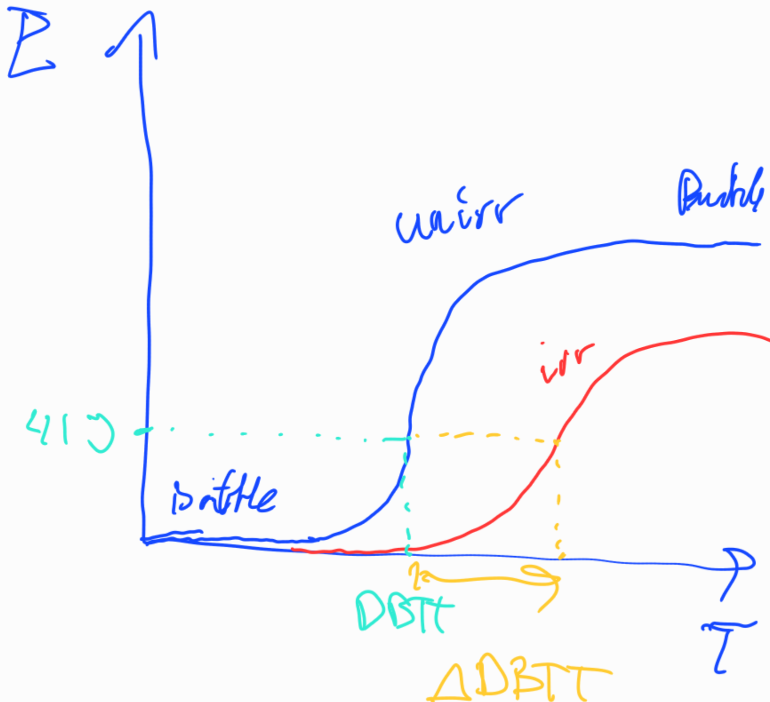
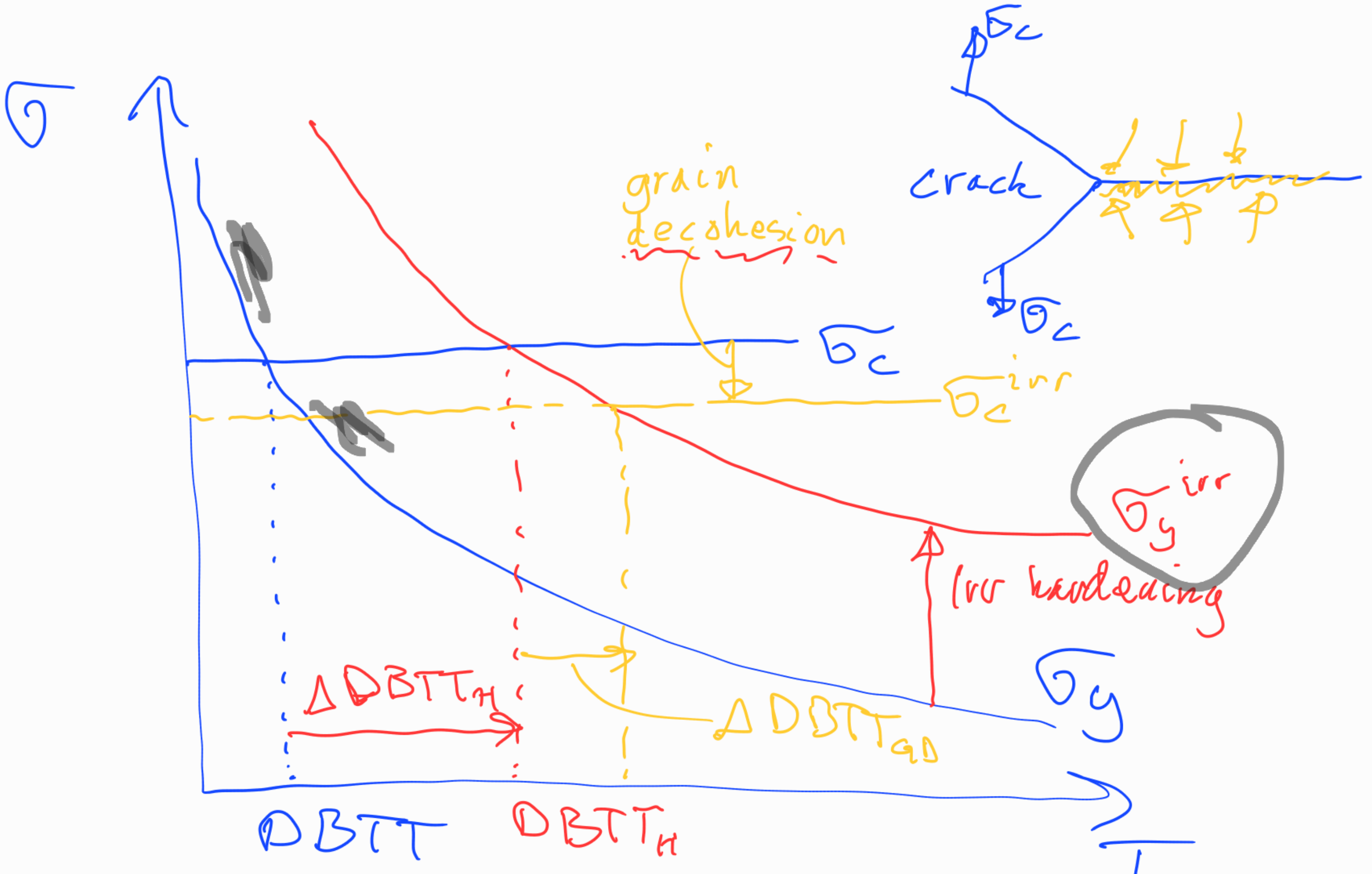
Hardening



Embrittlement





$$\Delta DBTT = \Delta DBTT_H + \Delta DBTT_{qD}$$

Burgers' vector b

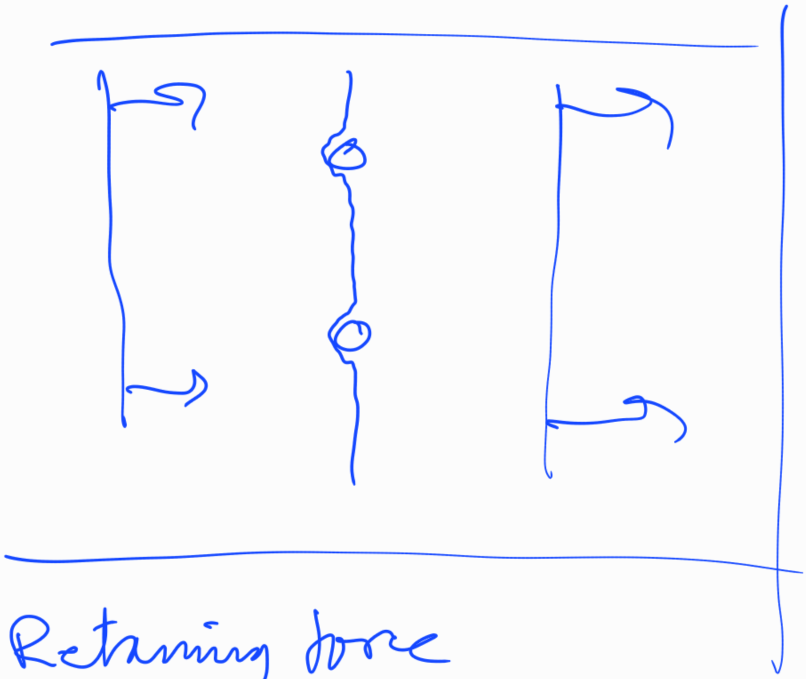
Dislocations elast and

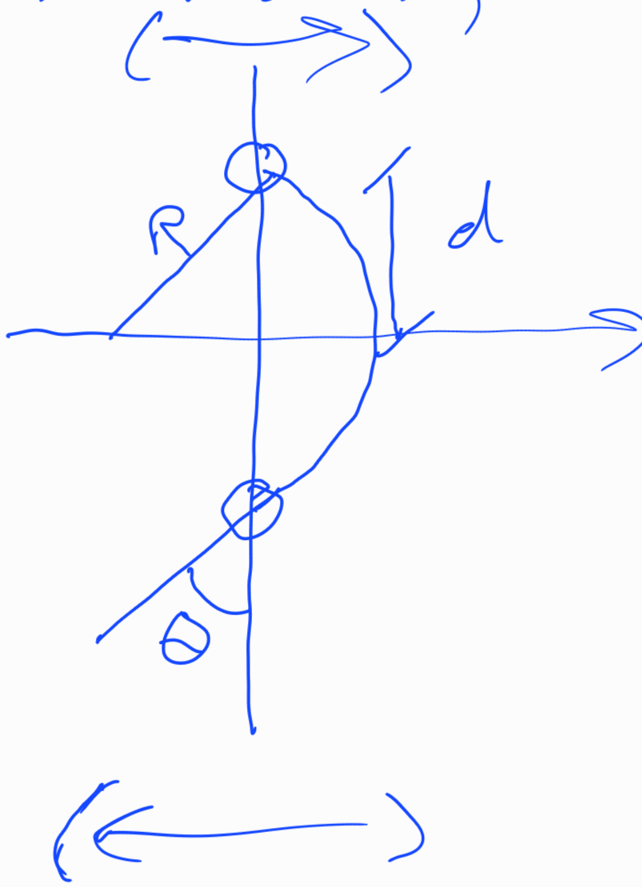
end in defects.

l - dislocation length

Line tension = energy per unit length

$$T \simeq \frac{Gb^2}{2}$$ (G - shear modulus)





Retaining force

$$F_r \simeq 2T\sin\theta = 2T\frac{d}{R}$$
$$= Gb^2\frac{d}{R}$$

Applied force

$$F_s = \tau l b$$

Applied shear stress

$$\tau = \frac{Gb}{2d}\sin\theta$$

Orowan (impenetrable) object $\Rightarrow$

Critical shear stress (Orowan loop forms)

$$\tau_c = \frac{Gb}{2d}$$

Hardening from different sources

Friction hardening

$$\sigma_F = \sigma_{LR} + \sigma_{SR} = \sigma_{LR} + (\sigma_{ppt} + \sigma_{void} + \sigma_{loop} + \dots)$$

σ_{LR}: long range dislo-dislo interaction

σ_{SR}: short range

LR: $$F_{LR} = \frac{G b^2 \sqrt{\pi \rho d}}{\frac{4}{3}\pi} \approx 0{,}44\, G b^2 \sqrt{\rho d}$$

$$\Rightarrow \sigma_{LR} = \frac{F_{LR}}{b} = 0{,}44\, G b \sqrt{\rho d}$$

SR: PPT: Line tension $$\tau \approx \frac{G b^2}{4\pi} \ln\left(\frac{d}{r_c}\right)$$

d = half-spacing

r_c = dislo core radius

Resolved stress: $$\sigma_s = \frac{\tau}{b d} = \frac{G b}{2d} \frac{1}{2\pi} \ln\left(\frac{2d}{2 r_c}\right)$$

$\sigma_y = M \sigma_s$

$$\Rightarrow \sigma_{PPT} = \underbrace{\frac{1}{2\pi} \ln\left(\frac{d}{r_c}\right)}_{\alpha_{ppt}} M G b \sqrt{N_{ppt} d_{ppt}} =$$

spacing

N_{ppt}: density ppt

d_{ppt}: av. ppt size

$$= \alpha_{ppt} M G b \sqrt{N_{ppt} d_{ppt}}$$

Voids: $\Rightarrow \ldots \Rightarrow \sigma_{void} = \alpha_v M G b \sqrt{N_v d_v}$

Loops: $\Rightarrow \sigma_{loop} = \alpha_l M G b \sqrt{N_l d_l}$

$$\left(\sigma_{SR_x} = \alpha_x M G b \sqrt{N_x d_x} \right)$$

$$\begin{cases} \alpha_v \sim 0{,}15 \\ \alpha_l \sim 0{,}1 \\ \alpha_{ppt} \sim 0.3 \end{cases}$$