FEB 0 5 2018

Fracture Mech Day 1

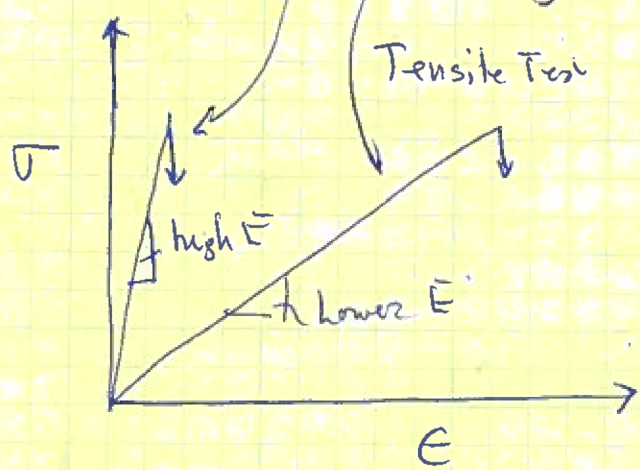
What is fracture?

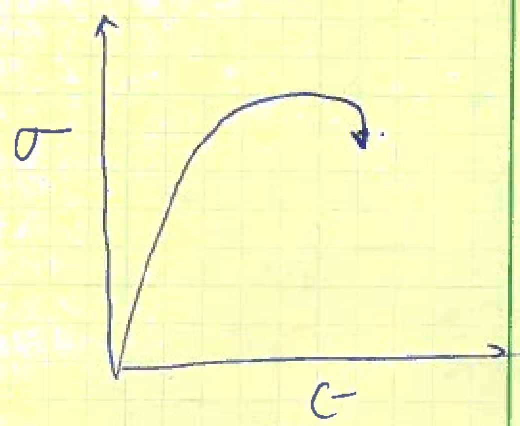
Brittle — Ceramics.

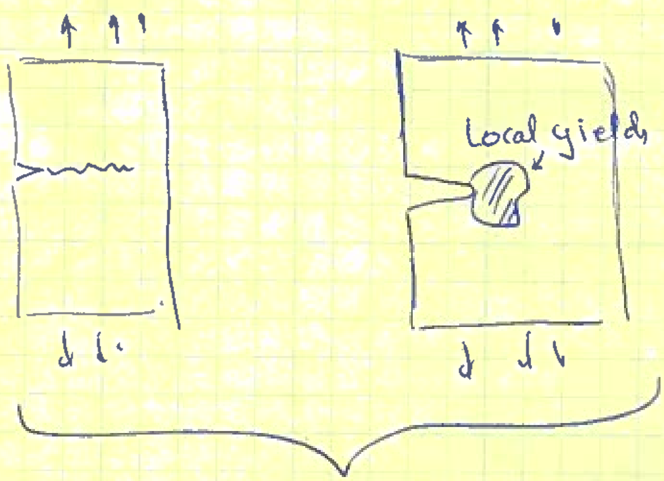
Semi-Brittle — Tool steel. Polymers (Polycarbonate)

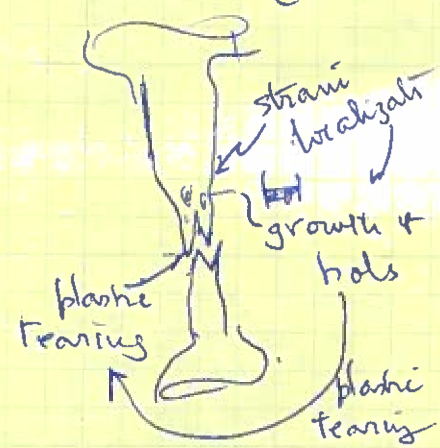
Ductile — Aluminum.

Tensile Test







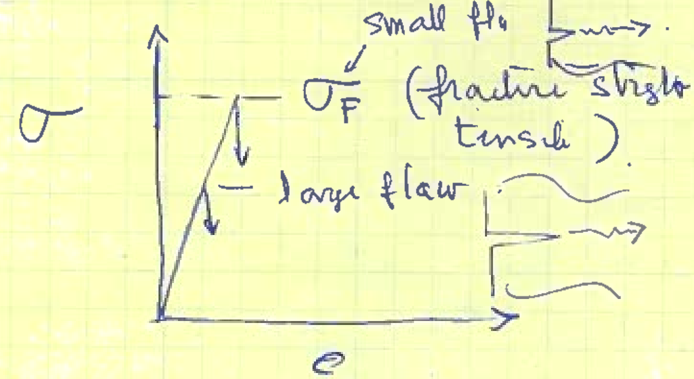


Topics of Discussion

BRITTLE FRACTURE

σ_F is NOT a material property → depends on the "flaw size")

└ microcrack



Question

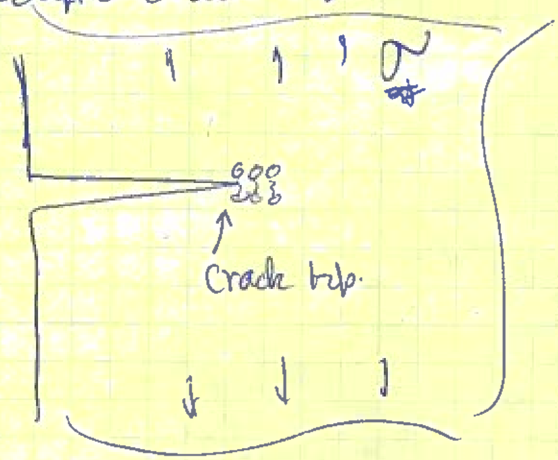
Mechanics — Material Sci

- A parameter that couples fracture stress to the flaw size.
- Probabilistic value of failure. prediction of failure (Weibull) ↔ proof testing)

Effective Value Work of Fracture

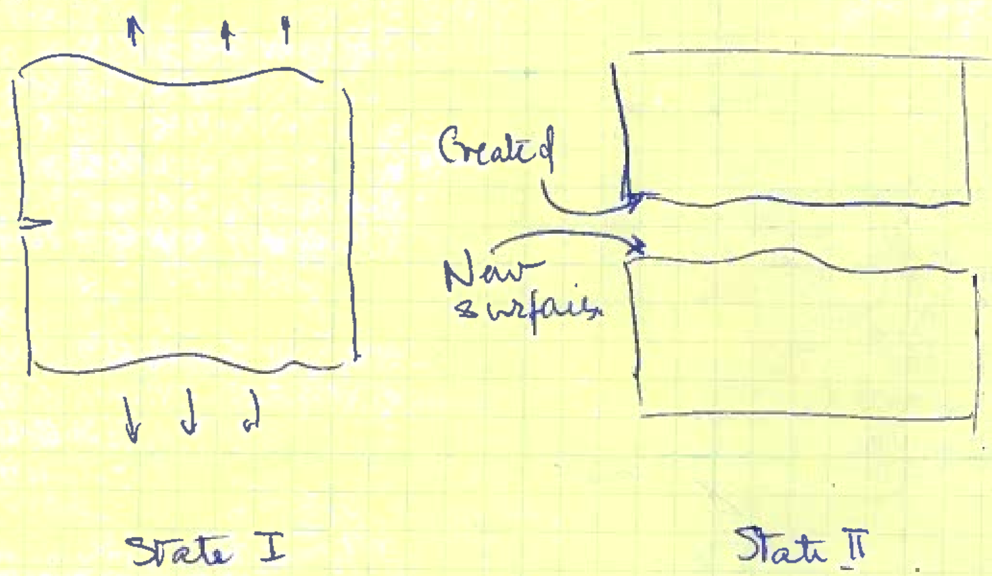
A thermodynamic approach to fracture.

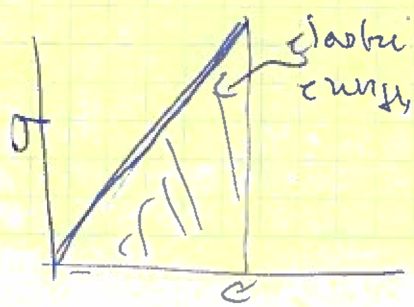
~~Couple crack tip~~



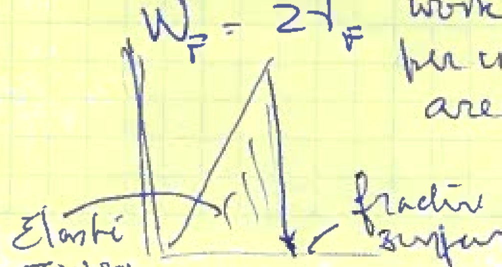
Couple the local fracture criterion at the crack tip with the applied stress.

The Work of Fracture

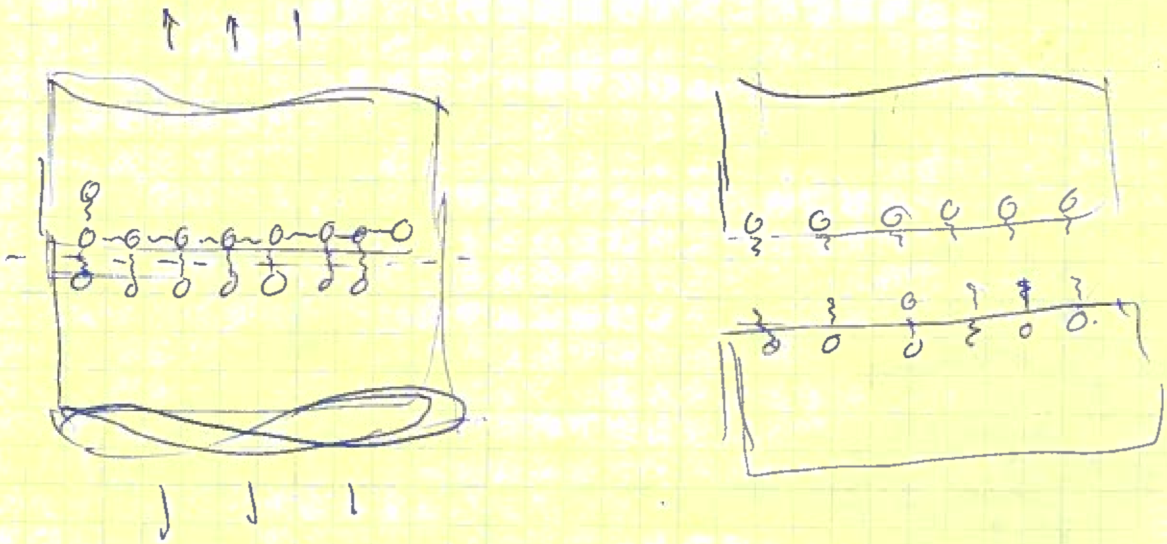




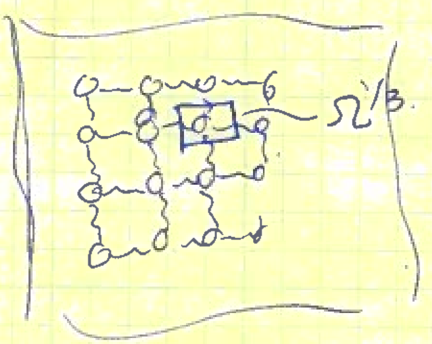
$W_F = 2\gamma_F$ work done per unit area.

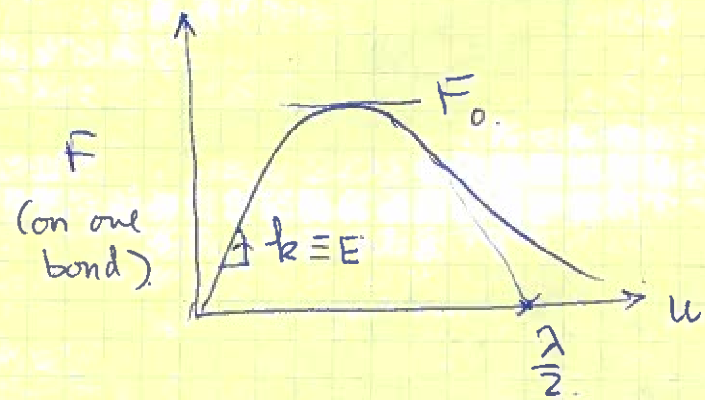


Conceptualize a simple bond breaking model in an ideal crystal i.e. without any defects:



Plan View





$$F = F_0 \sin \frac{2\pi u}{\lambda}$$

$$k = \left(\frac{dF}{du}\right)_{u \to 0} = \frac{2\pi F_0}{\lambda}$$

$$\frac{\lambda}{4} = 0.25\,\Omega^{1/3} \qquad \sigma_F = \frac{F_0}{\Omega^{2/3}} \qquad E = \frac{k}{\Omega^{1/3}} = \frac{2\pi F_0}{\lambda\,\Omega^{1/3}}$$

$$\sigma_F = \frac{E\ \lambda\,\Omega^{1/3}}{2\pi\,\Omega^{2/3}} = \frac{E}{2\pi} \sim \frac{E}{10} \quad (*)$$

$$\epsilon_f = 10\%$$

Work of fracture (per bond). Define γ_F.

$$\cancel{2}\cancel{F}\Omega^{\cancel{2/3}}2\gamma_F = \int_0^{\lambda/2} F\,du.$$

$$= \int_0^{\lambda/2} F_0 \sin\frac{2\pi u}{\lambda}\,du$$

$$= -\frac{\lambda}{2\pi}\times F_0\left[-1-(1)\right]$$

$$= \frac{\lambda F_0}{\pi}.$$

$$\lambda = \Omega^{1/3}$$

$$F_0 = \frac{E\lambda\,\Omega^{1/3}}{2\pi}$$

$$2\gamma_F\,\cancel{\Omega^{2/3}} = \frac{\cancel{\lambda}}{\pi}\times\frac{E\,\cancel{\lambda}\,\cancel{\Omega^{1/3}}}{2\pi}. \qquad \Omega^{1/3} = a$$

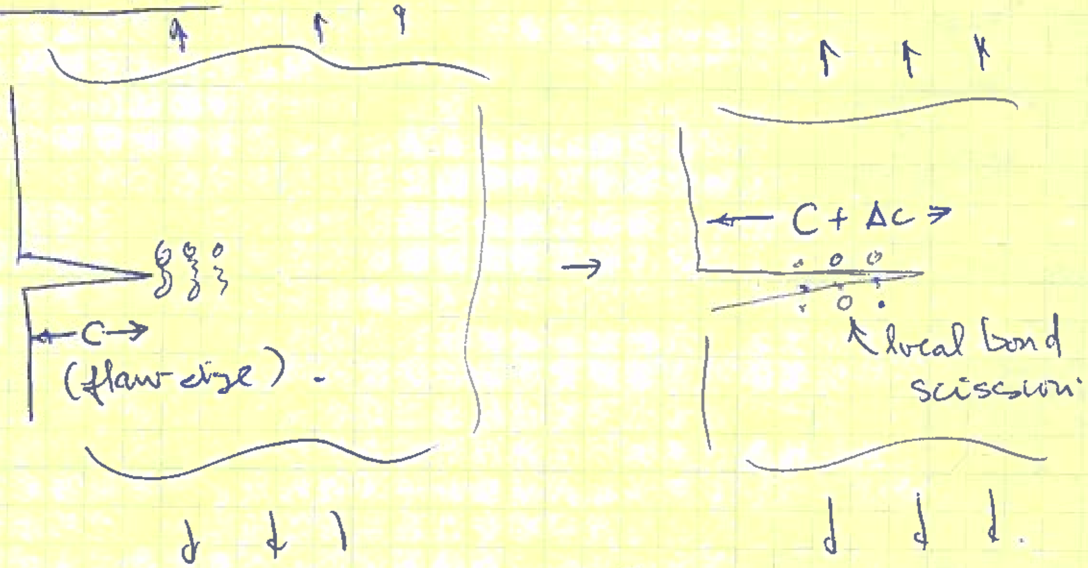
lattice parameter

$$\boxed{\gamma_F = \frac{Ea}{4\pi^2}} \text{ — } (*)$$

~~$\gamma_F = \frac{1}{2}\,\sigma_F^2 \times 2a$~~

Ideal crystal → no flaws → ideal fracture strength

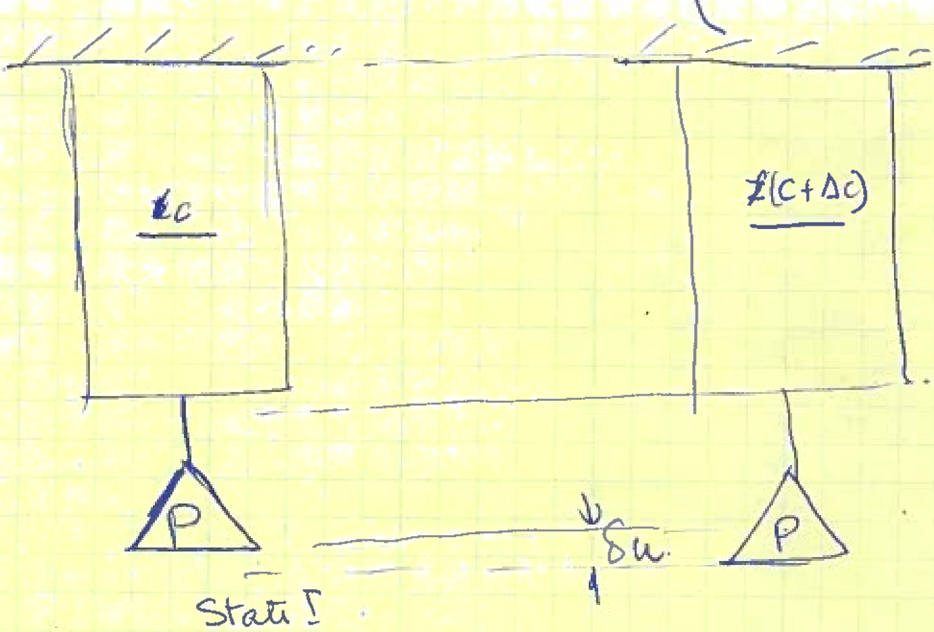
More realistically



Thermodynamic Approach to fracture.

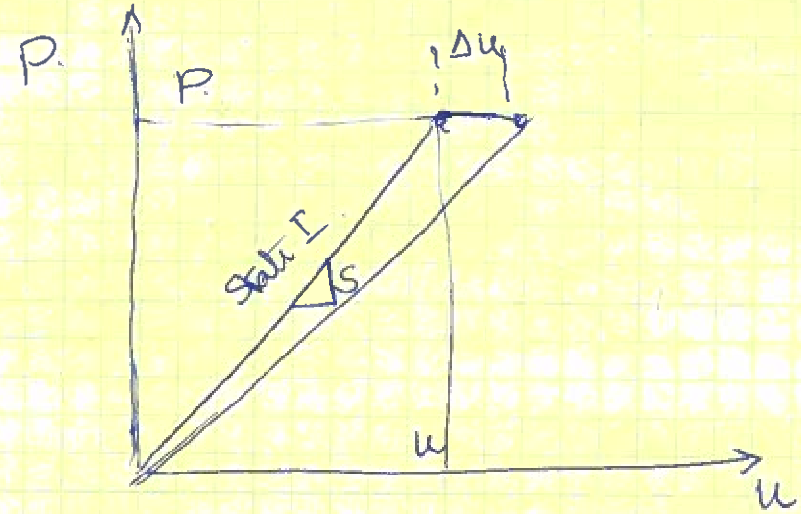
Global → work is done by the applied stress.

Local → Work of fracture related to bonds breaking.



2D problem

→ a ribbon shaped flaw



Change in Mechanical Energy

~~Work done by the system on the~~ ~~Reduction in the~~

Change in the Potential Energy.

Change in The Stored Elastic Energy

State I → State II $\quad - P\Delta u. \quad \frac{1}{2}P(u+\Delta u) - \frac{1}{2}Pu.$

$$= \frac{1}{2}P\Delta u.$$

Note the total change →

$= -\frac{1}{2}P\Delta u = -$ |Change in the stored elastic energy| $= -$ |Change in the potential energy|

$$2\gamma_F \cdot \Delta c \leq \frac{1}{2} P \Delta u.$$

$$S = \frac{u}{P}$$

$$\Delta S = \frac{\Delta u}{P}$$

$$\leq \frac{1}{2} P^2 \cdot \Delta S$$

$$\boxed{2\gamma_F \leq \frac{P^2}{2} \frac{dS}{dc}.}$$

<u>Gibbs Free Energy Approach</u>

$$\Delta G = -2\gamma_F c + \frac{1}{2} P u.$$

$$\frac{d\Delta G}{dc} = -2\gamma_F + \underbrace{\frac{1}{2} P \frac{du}{dc}}_{\frac{P^2}{2}\frac{dS}{dc}} \leq 0.$$

$$S = \frac{u}{P}$$

$$\frac{du}{dc} = P \frac{dS}{dc}$$

→ same result obtained by differentiation.