What is Failure?

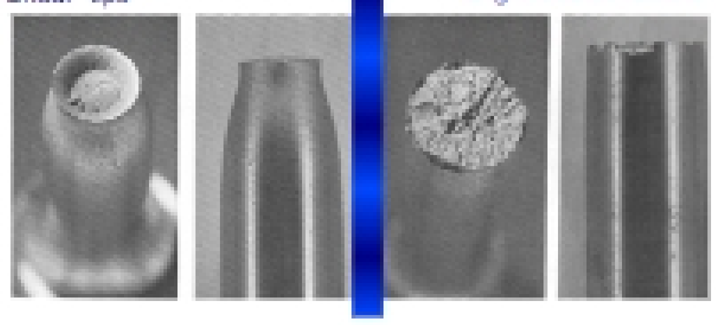
Examining Failures

Ductile

Necking or bending
Dull, fibrous fracture
Shear "lips"

Brittle

Little or no distortion
Flat Fracture
Bright/coarse texture



Conclusion: ductile and brittle materials fail differently

How do parts fail?

- static loading
- dynamic loading
- wear
- corrosion
- embrittlement
- temperature effects
- heat affected zones
- …

In this class (static loading, dynamic loading)

Static Failure

parts fail only when stresses are greater than S_y or S_{ut}… right??

well, it depends…

OK… Here's the truth…

All that we have are HYPOTHESES about why parts fail!

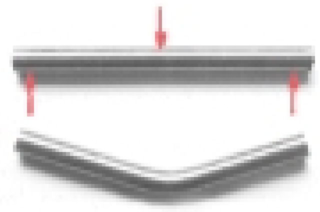
*with possible exception of Distortion Energy

(your book calls these THEORIES)

and we will discuss these hypotheses over the next few days

Ductile Failure

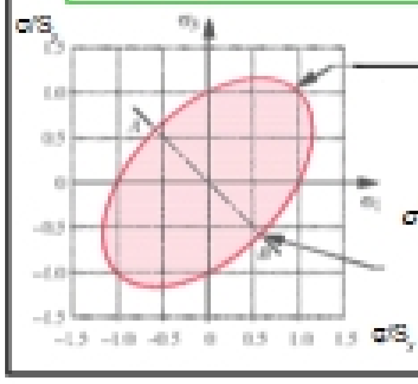
where Failure=Yielding



Distortion Energy Theory

Distortion Energy Theory (von Mises-Hencky)

failure occurs iff the total strain energy in a unit volume reaches or exceeds the strain energy in the same volume corresponding to the yield strength



$$\sigma' \geq S_y$$

$$\sigma' = \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}}$$

$$N = \frac{S_y}{\sigma'}$$

Distortion Energy Derivation Cont.

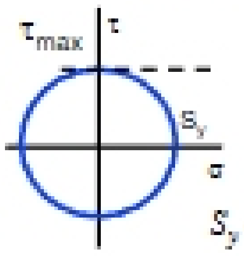
- Von Mises Stress σ'
  - the uniaxial tensile stress that would cause the same distortion energy as created by the actual stresses

$$\sigma' = \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}}$$

In terms of applied stresses:

$$\sigma' = \sqrt{\frac{(\sigma_x-\sigma_y)^2+(\sigma_y-\sigma_z)^2+(\sigma_z-\sigma_x)^2+6(\tau_{xy}^2+\tau_{yz}^2+\tau_{zx}^2)}{2}}$$

Distortion Energy: Pure Shear



$$\sigma_1 = \tau_{max}$$
$$\sigma_2 = 0$$
$$\sigma_3 = -\tau_{max}$$

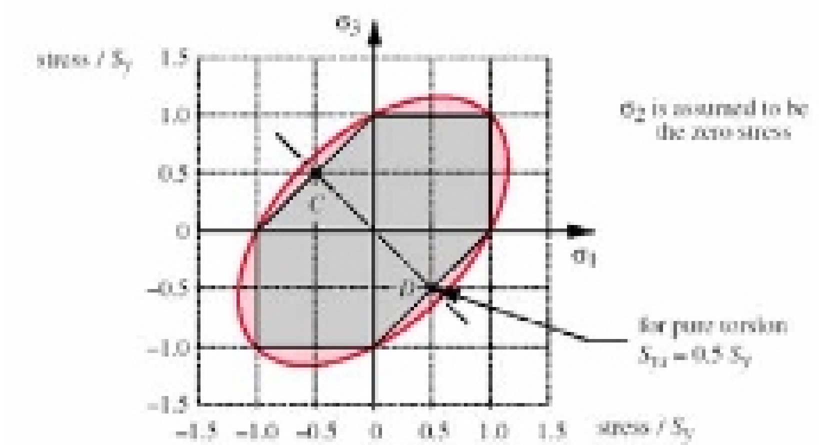
$$S_y = \sigma' = \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}}$$

$$S_y = \sqrt{\frac{(\tau_{max})^2+(\tau_{max})^2+(2\tau_{max})^2}{2}}$$

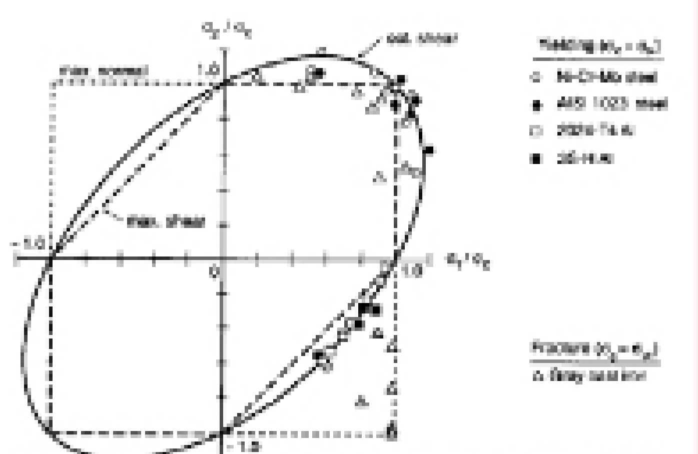
$$S_y = \sqrt{3\tau_{max}^2}$$

$$\tau_{max} = \frac{S_y}{\sqrt{3}} = 0.577 S_y$$

Distortion vs. Max Shear



The Empirical Support



Reproduced from Fig. 7.11, p. 252, in Mechanical Behavior of Materials by N. E. Dowling, Prentice-Hall, Englewood Cliffs, NJ, 1993)

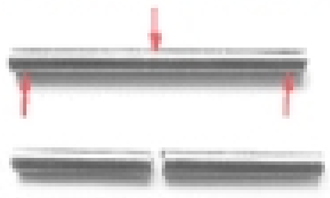
Ductile Failure Conclusions

"Both the distortion-energy theory and the maximum shear theory are acceptable as failure criteria in the case of *static loading* of *ductile*, *homogenous*, *isotropic* materials whose *compressive and tensile strengths are of the same magnitude*."

(from Norton, Machine Design, 2nd edition)

Brittle Failure

where Failure=Fracture



Brittle Failure

While ductile failure tends to be due to shear stresses and the sliding of atoms in the lattice of the material, normal stresses play some role in the failure of brittle materials

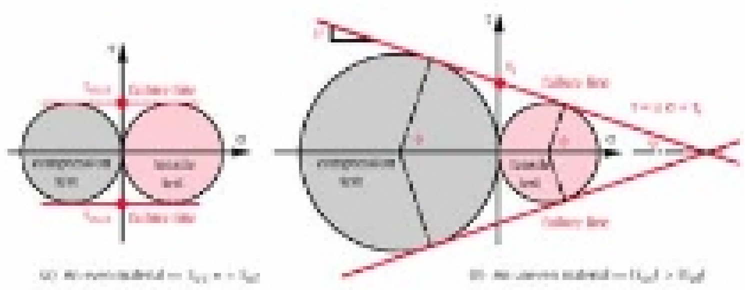
In tension: brittle materials fail due to normal tensile stress alone – what theory is appropriate?

In compression: some combination of compressive normal and shear stresses cause failure

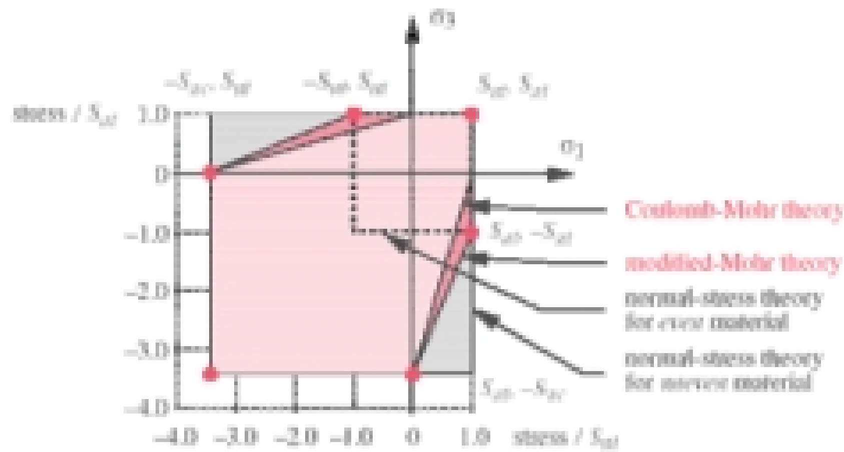
→ Coulomb –Mohr & Modified Mohr

On Brittle Materials…

- Many brittle materials are *UNEVEN* (especially cast brittle materials)
- Some cast, brittle materials have shear strengths greater than tensile strengths

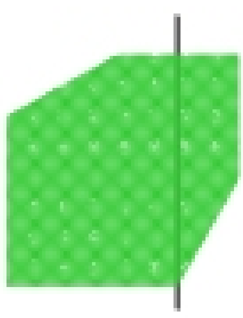


Modified Mohr



Modified Mohr

- Quadrant I – max normal stress
  - $N = S_{ut}/\sigma_1$
- Quadrant IV – connect with straight lines



$$N = \frac{S_{ut}|S_{uc}|}{|S_{uc}|\sigma_1 - S_{ut}(\sigma_1 + \sigma_3)}$$