

Chapter 8 Failure

Fracture

- ❑ Introduction
- ❑ Fundamentals of fracture
- ❑ Ductile fracture
- ❑ Brittle fracture
- ❑ Principles of fracture mechanics
- ❑ Impact fracture testing

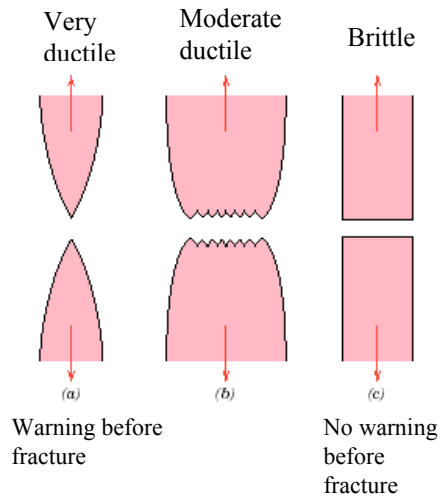
Introduction

❑ Failure modes

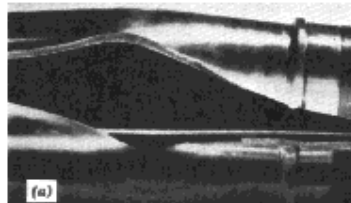
- fracture: a body is separated into two or more pieces in response to static imposed stress
- fatigue: material failures occur under repeated dynamic and fluctuating stresses
- creep: deformation occurs at elevated temperature

Fundamental of fracture

Fracture modes:

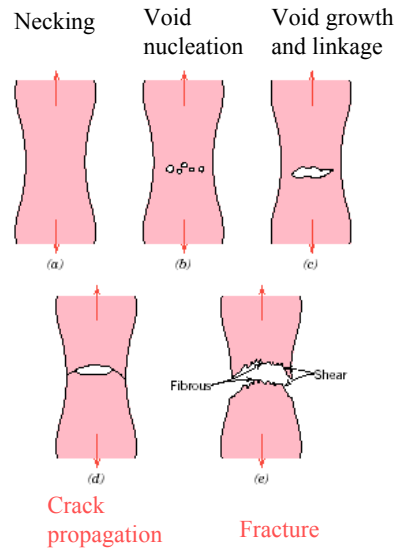


Examples: failure of a pipe



Ductile fracture

□ Evolution to failure



Ductile fracture (continue)

□ Cup-and-cone fracture

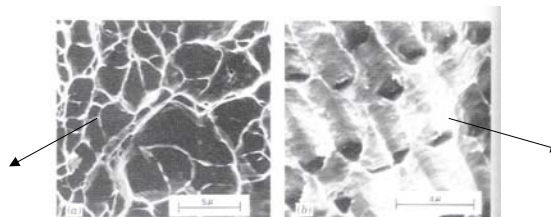
Aluminum
Ductile fracture



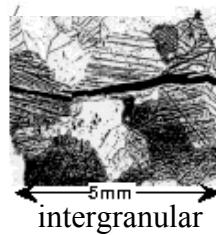
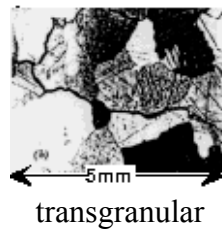
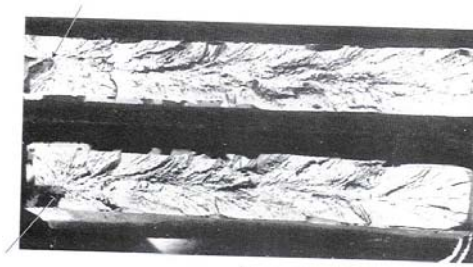
Mild steel
Brittle fracture



□ Scanning electron fractograph

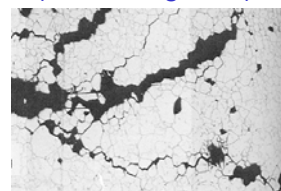


Brittle fracture

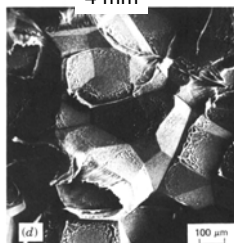


Brittle fracture surfaces

- Intergranular
(between grains)



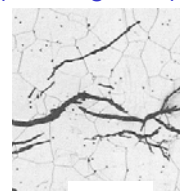
304 S. Steel
(metal)



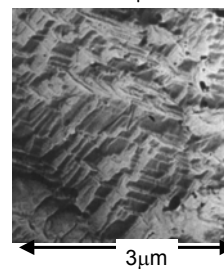
Polypropylene
(polymer)

- Intragranular
(within grains)

316 S.
Steel (metal)

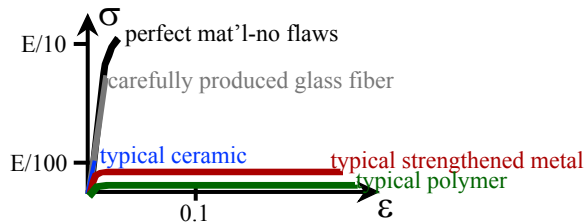


Al Oxide
(ceramic)



Ideal vs real materials

□ Stress-strain behavior (Room T):

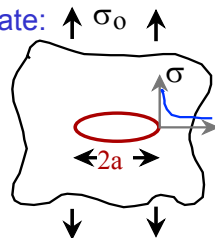


□ DaVinci (500 yrs ago!) observed...

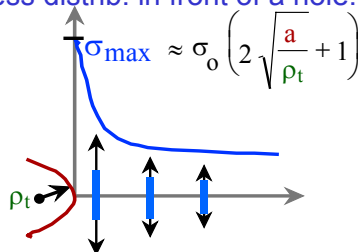
□ Reasons:

Flaws are stress concentrators

□ Elliptical hole in a plate:

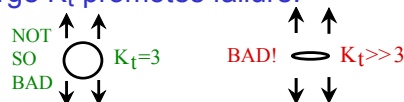


• Stress distrib. in front of a hole:



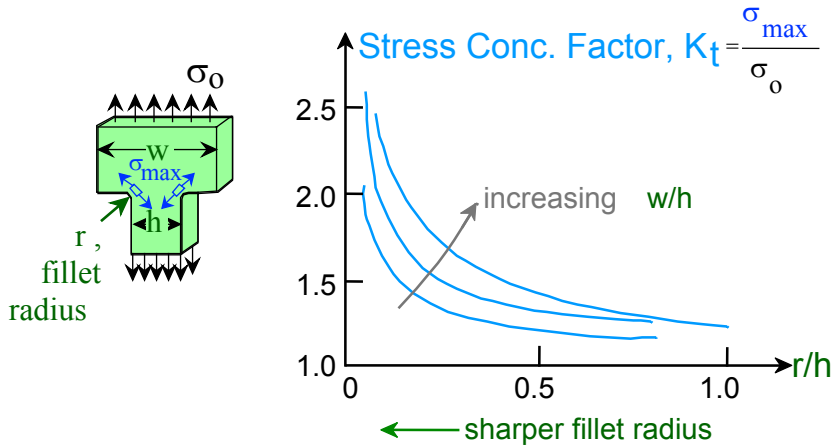
□ Stress conc. factor:

□ Large K_t promotes failure:

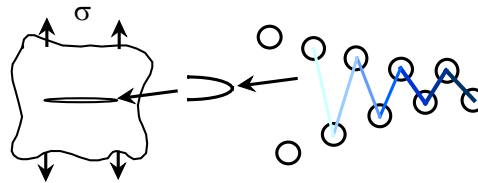


Engineering fracture design

❑ Avoid sharp corners!

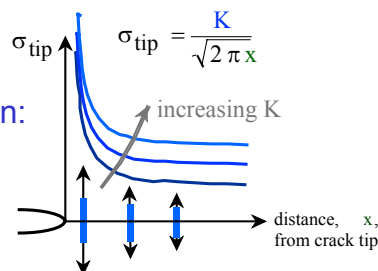


When does a crack propagate?



❑ Result:

❑ Crack propagates when:

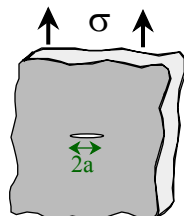


Geometry, load, &, material

Condition for crack propagation:

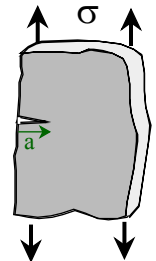
$$K \geq K_c$$

Values of K for some standard loads & geometries:



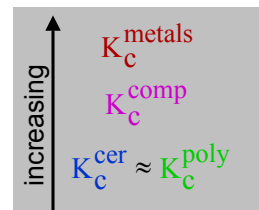
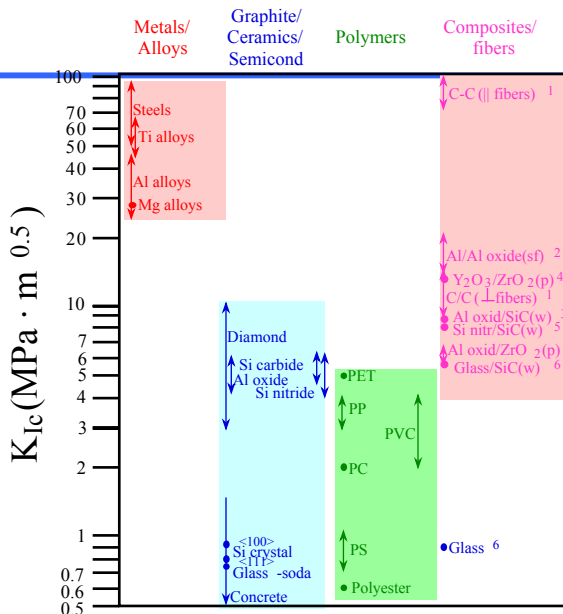
$$K = \sigma \sqrt{\pi a}$$

units of K :
MPa $\sqrt{\text{m}}$
or ksi $\sqrt{\text{in}}$



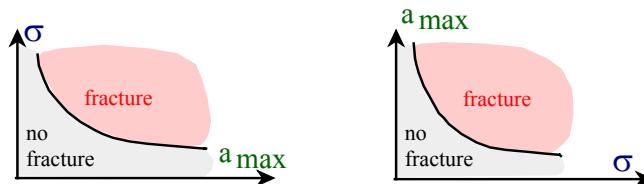
$$K = 1.1 \sigma \sqrt{\pi a}$$

FRACTURE TOUGHNESS



Design against crack growth

- ❑ Crack growth condition: $K \geq K_c$
- ❑ Largest, most stressed cracks grow first!



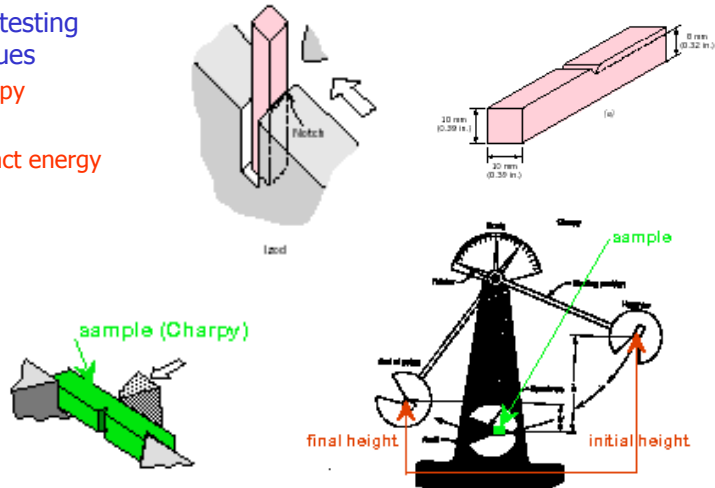
Design examples: Aircraft wing

- ❑ Material has $K_c = 26 \text{ MPa-m}^{0.5}$
- ❑ Two designs to consider...
- ❑ Use... $\sigma_c = \frac{K_c}{Y\sqrt{\pi a_{\max}}}$
- ❑ Key point: Y and K_c are the same in both designs.

Impact fracture testing

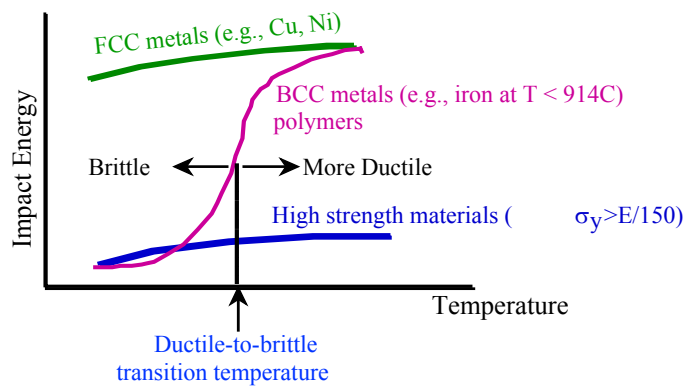
Impact testing techniques

- Charpy
- Izod
- impact energy



Ductile-to-brittle transition temperature (DBTT)

Increasing temperature...

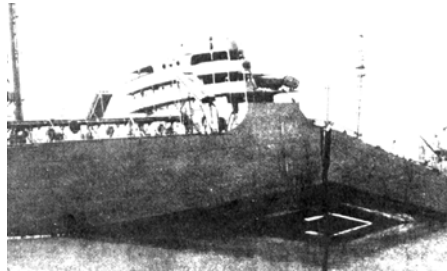


Design strategy: stay above the DBTT!

❑ Pre-WWII: The Titanic



❑ WWII: Liberty ships



❑ Problem: Used a type of steel with a DBTT ~ Room temp.

Summary

