Lecture 2.2

Testing Requirements

Crack tip plasticity and R curves

Fracture Criteria

1. For fracture: K --> K_{cr}
2. Ideal picture of fracture:
   - Load a structure (specimen) with a crack and monitor K
   - When K = K_{cr}, sudden unstable failure occurs
3. Two problems that cause difficulty with this fracture picture
   a) Crack tip plasticity
   b) R curve behavior

Limits of Linear Elastic Fracture

1. Crack-tip stress solution has a singularity

$$\sigma_y = \frac{K_I}{\sqrt{2\pi r}} f(\theta)$$

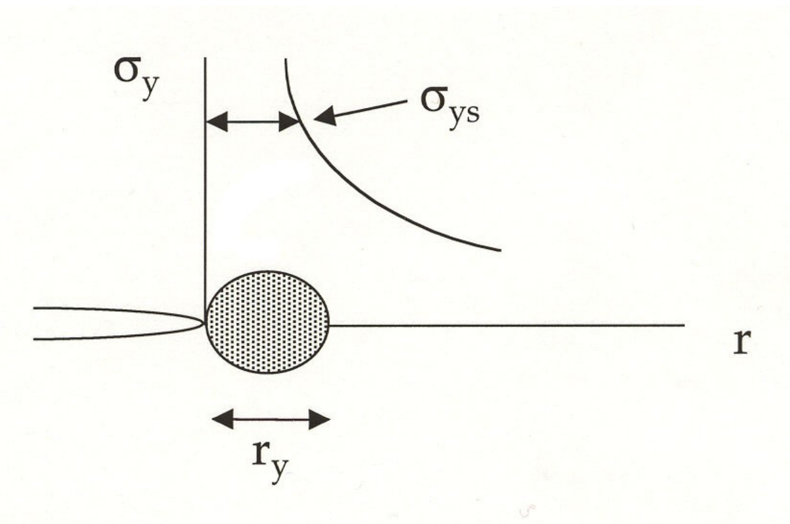
As r -> 0, σ_y -> ?

2. Any loading makes a plastic zone at the crack tip

Limits of Linear Elastic Fracture, Cont'd

3. When the plastic zone is small the K field dominates
4. When the plastic zone is large, K no longer characterizes the crack-tip field
5. Another parameter is needed

Crack-tip plastic zone estimate



$$\sigma_y = \frac{K_I}{\sqrt{2\pi r_y}} = \sigma_{ys}$$

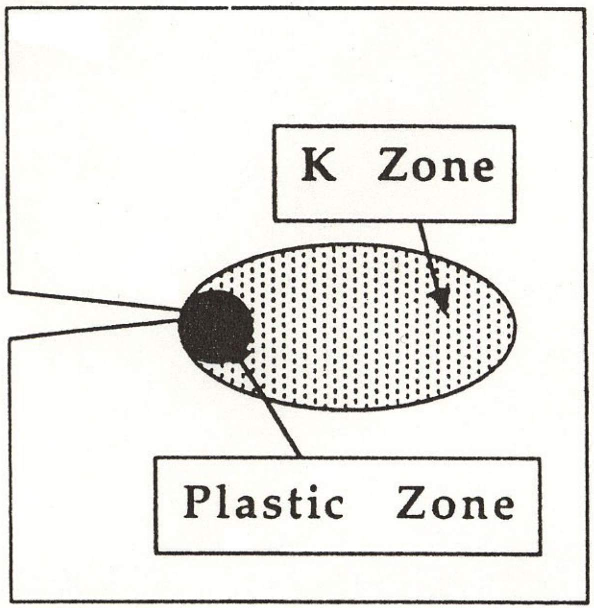
$$r_y = \frac{1}{2\pi}\left(\frac{K}{\sigma_{ys}}\right)^2$$

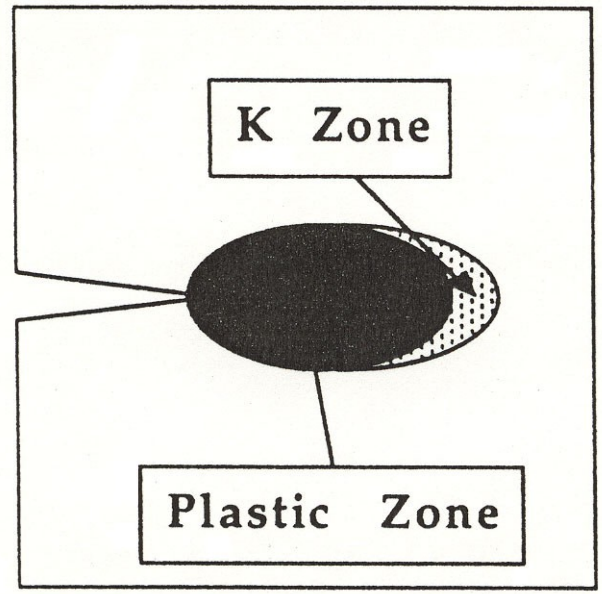
This is usually taken for plane stress

Plane strain

$$r_y = \frac{1}{6\pi}\left(\frac{K}{\sigma_{ys}}\right)^2$$

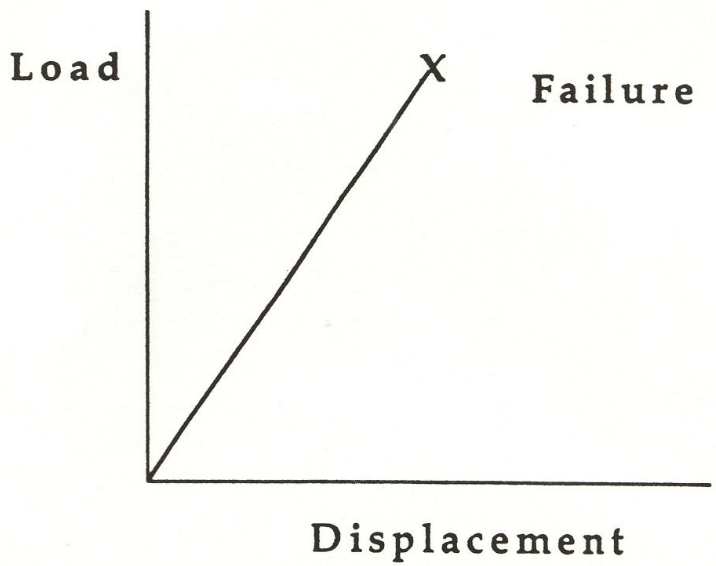
Problem with LEFM



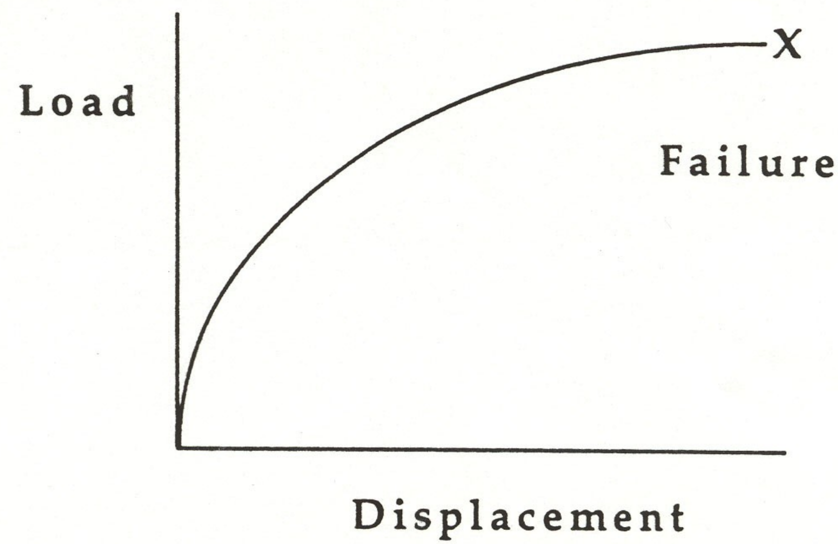


Small scale plasticity
LEFM is valid

Large scale plasticity
LEFM no longer valid

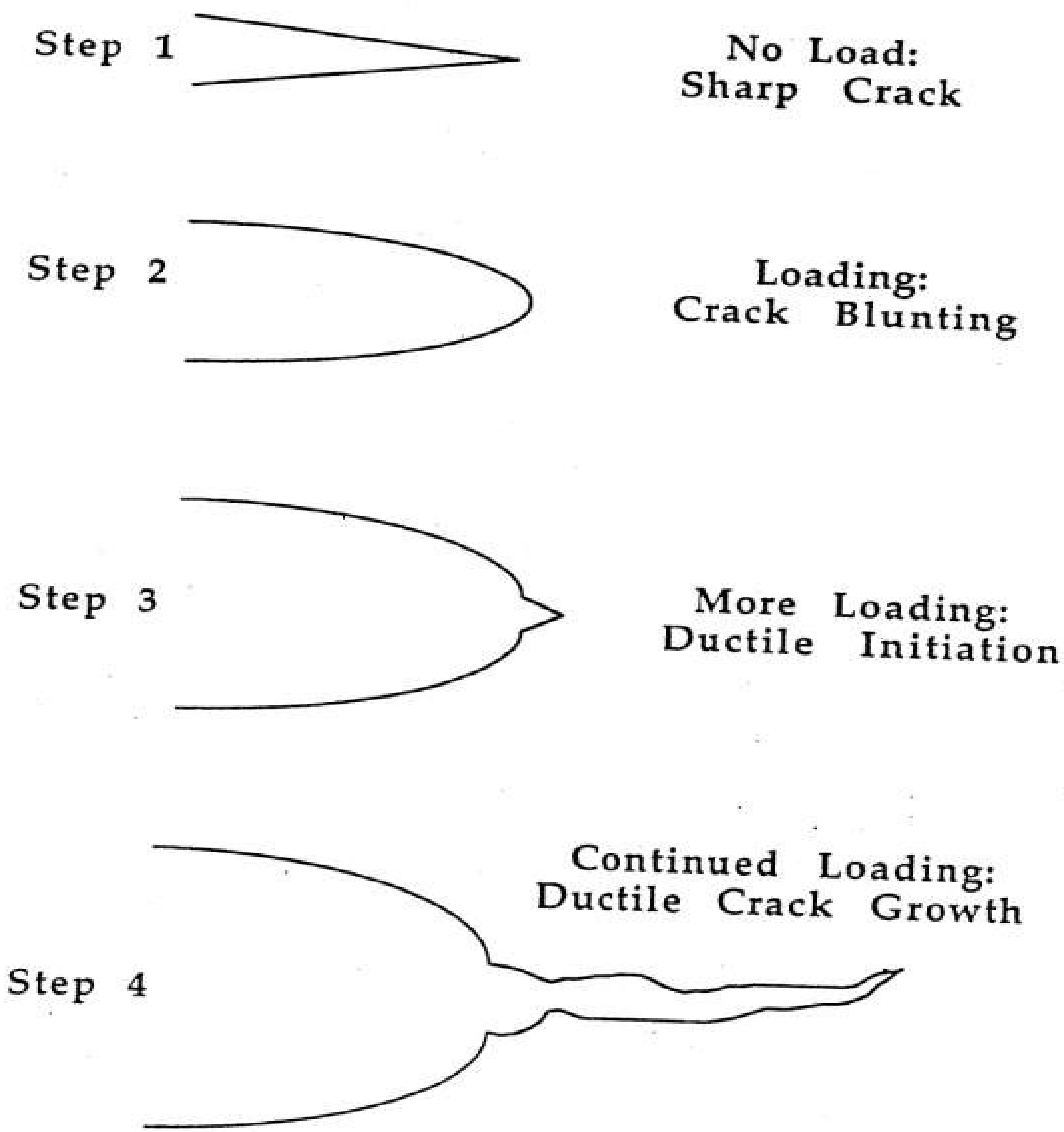


Load versus displacement
LEFM behavior



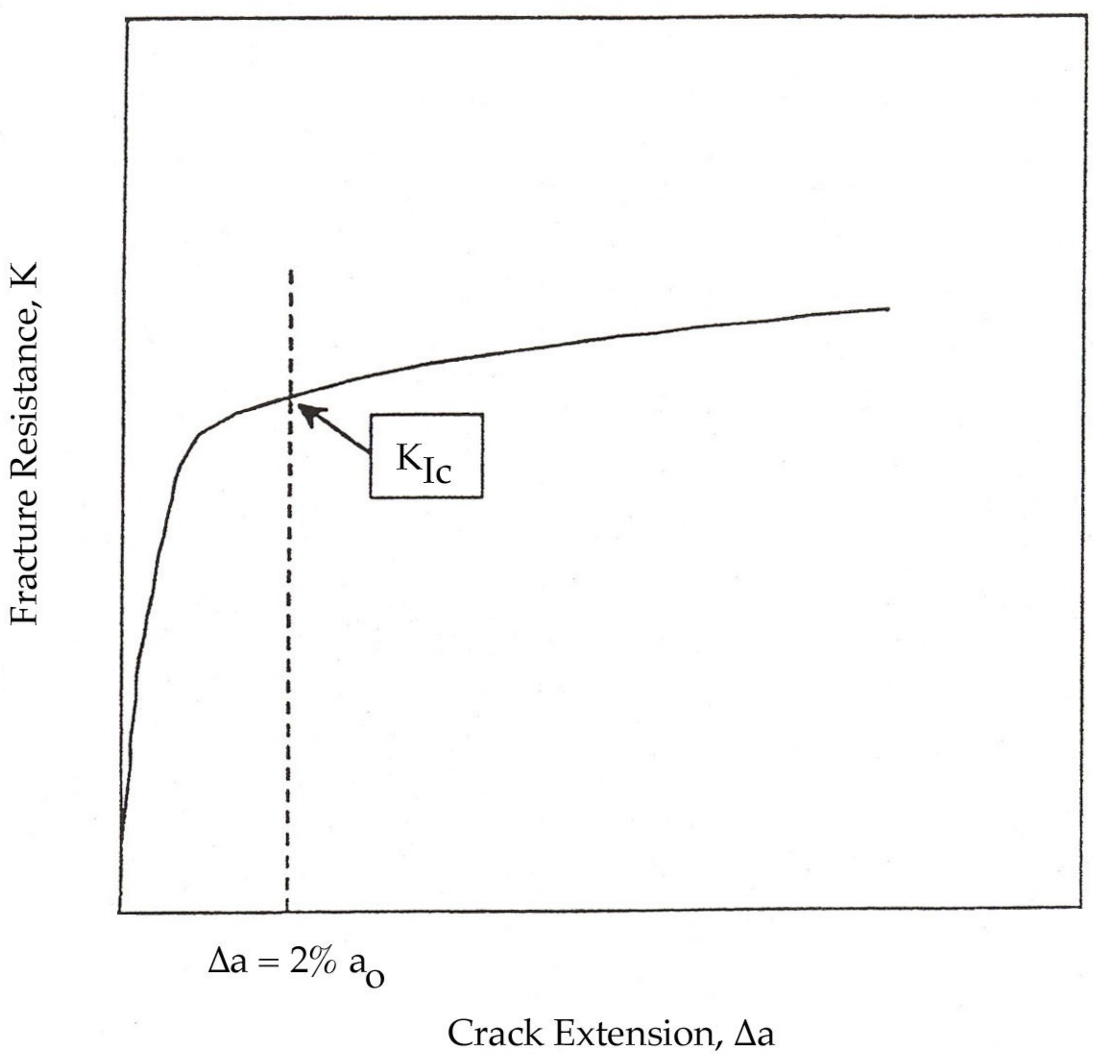
Load versus displacement
EPFM behavior

Ductile Fracture Process



R Curve Behavior

1. Ductile fracture does not occur at a single point
2. The crack extends in a stable manner
3. Plots of a fracture parameter versus crack extension form an R curve
4. Typically K versus Δa is plotted


Fracture Resistance, K
K_Ic
Δa = 2% a_o
Crack Extension, Δa