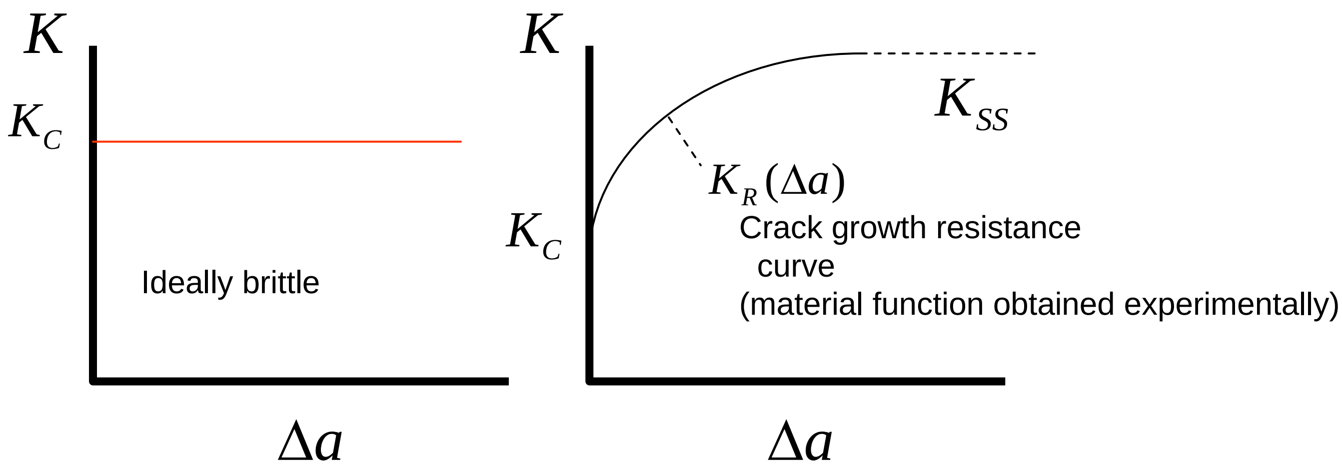
Crack Growth Resistance and Crack Stability (pgs. 19-27 of nonlinear fracture notes)



Stress intensity factor as a function of a and loading parameter L : $K(a, L)$
(the loading may be prescribed load or prescribed displacement)

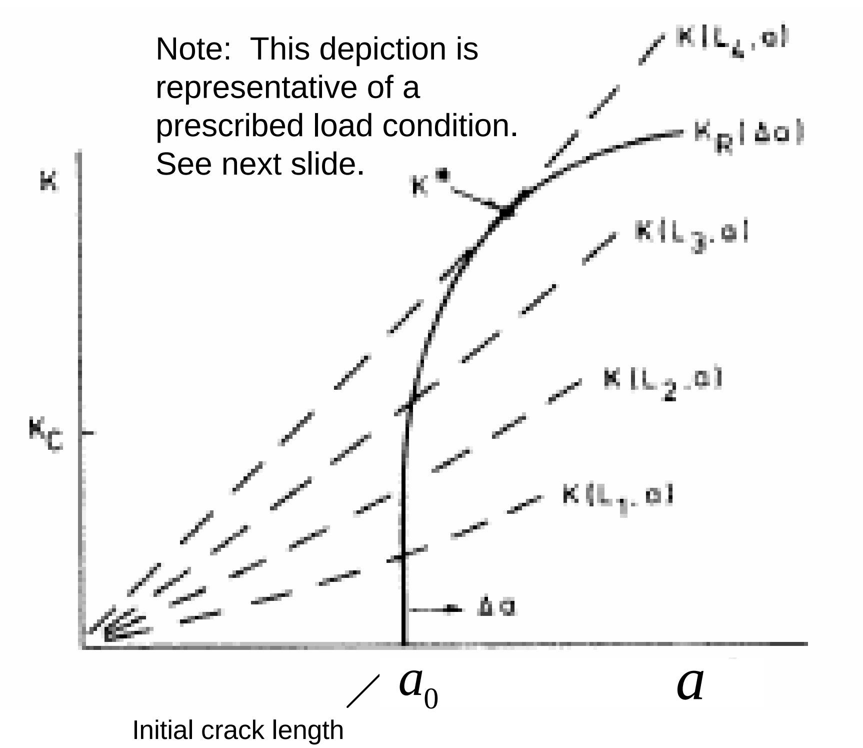
Criterion for continued crack advance: $K(a, L) = K_R(\Delta a)$

Criterion for **stability** of crack: $\left(\dfrac{\partial K(a, L)}{\partial a}\right)_L = \dfrac{dK_R(\Delta a)}{d\Delta a}$

The crack begins to advance for $L \cong L_3$

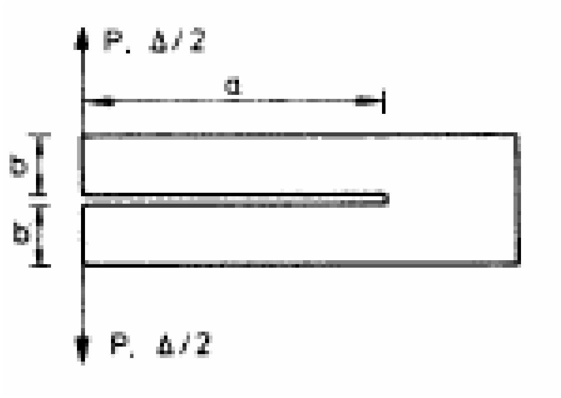
In the plot to the right the crack is stable for $L < L_4$

It becomes unstable and will begin to advance dynamically for $L = L_4$ and $K = K^*$



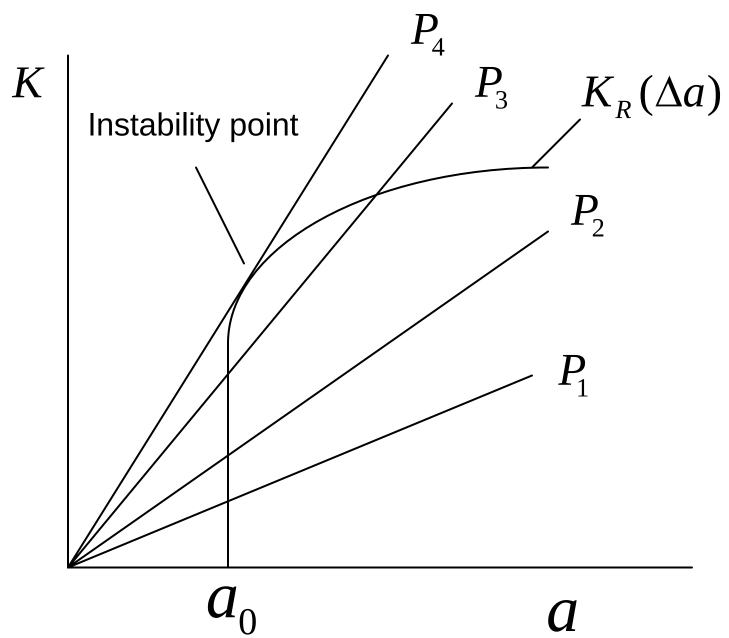
Crack Growth Resistance and Crack Stability—Role of loading conditions

Recall results for DCB specimen under prescribed load and prescribed displacement

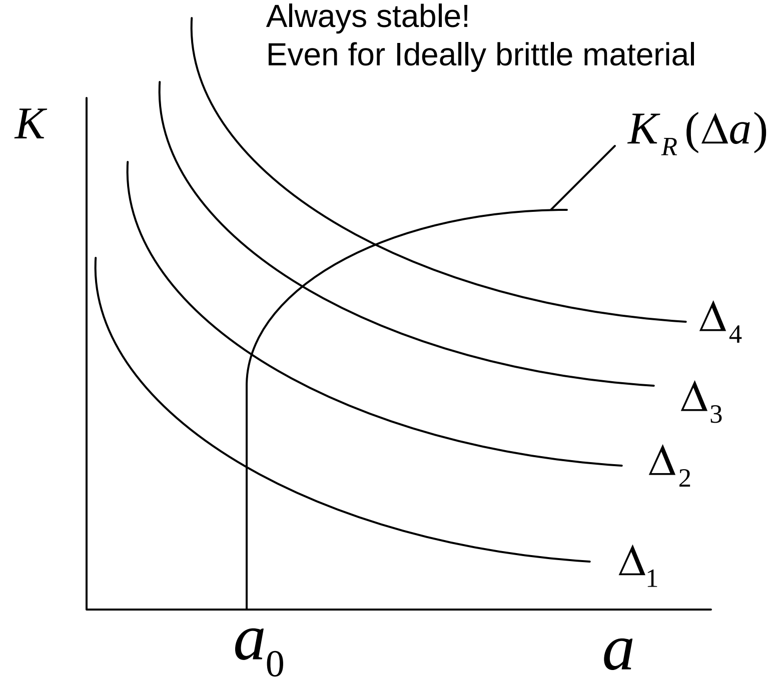


$$K = 2\sqrt{3}\frac{Pa}{b^{3/2}}, \quad \Delta = \frac{4Pa^3}{\bar{E}b^3} \quad (P \text{ is the force/thickness})$$

$$K = \frac{\sqrt{3}\bar{E}b^{3/2}}{2a^2}\Delta$$



Prescribed load



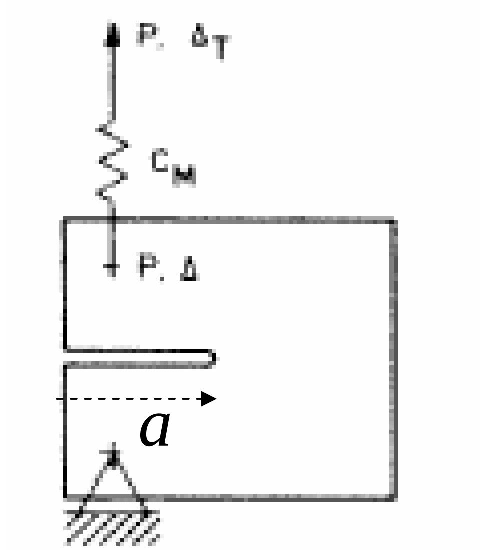
Prescribed displacement

Crack Growth Resistance and Crack Stability—Role of compliance

For generic cracked body loaded in series with compliant "spring":

$$K = f(a)P$$

$$\Delta_T = \Delta + C_M P = \left(C(a) + C_M\right)P$$



Consider an increment of crack advance **with Δ_T fixed**.

$$dK = f(a)dP + f'(a)daP \qquad (\ )' = d(\ )/da$$

$$d\Delta_T = \left(C(a) + C_M\right)dP + C'(a)daP$$

$$\Rightarrow \left(\frac{\partial K}{\partial a}\right)_{\Delta_T} = \left(f' - \frac{f\,C'}{C + C_M}\right)P$$

Example: DCB specimen on previous slide $f(a) = 2\sqrt{3}\,b^{-3/2}a$

Two limiting cases:

Prescribed P ($C_M \rightarrow \infty$).

$$\left(\frac{\partial K}{\partial a}\right)_{\Delta_T} = f'P$$

Prescribed Δ ($C_M \rightarrow 0$).

$$\left(\frac{\partial K}{\partial a}\right)_{\Delta_T} = \left(f' - \frac{C'}{C}f\right)P = CP\left(\frac{f}{C}\right)' = \Delta\left(\frac{f}{C}\right)'$$

$$\left(\frac{\partial K}{\partial a}\right)_{\Delta_T} = 2\sqrt{3}Pb^{-3/2}\left[1 - \frac{3}{1 + C_M/C}\right] = \frac{K}{a}\left[1 - \frac{3}{1 + C_M/C}\right]$$

For, $C_M \rightarrow \infty$,

$$\left(\frac{\partial K}{\partial a}\right)_{\Delta_T} = \frac{K}{a}$$

For, $C_M \rightarrow 0$,

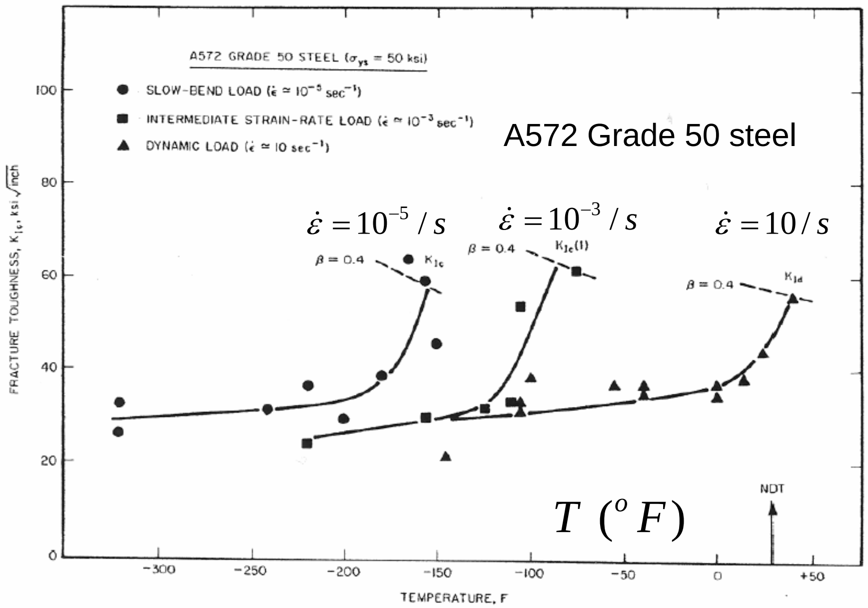
$$\left(\frac{\partial K}{\partial a}\right)_{\Delta_T} = -2\frac{K}{a}$$

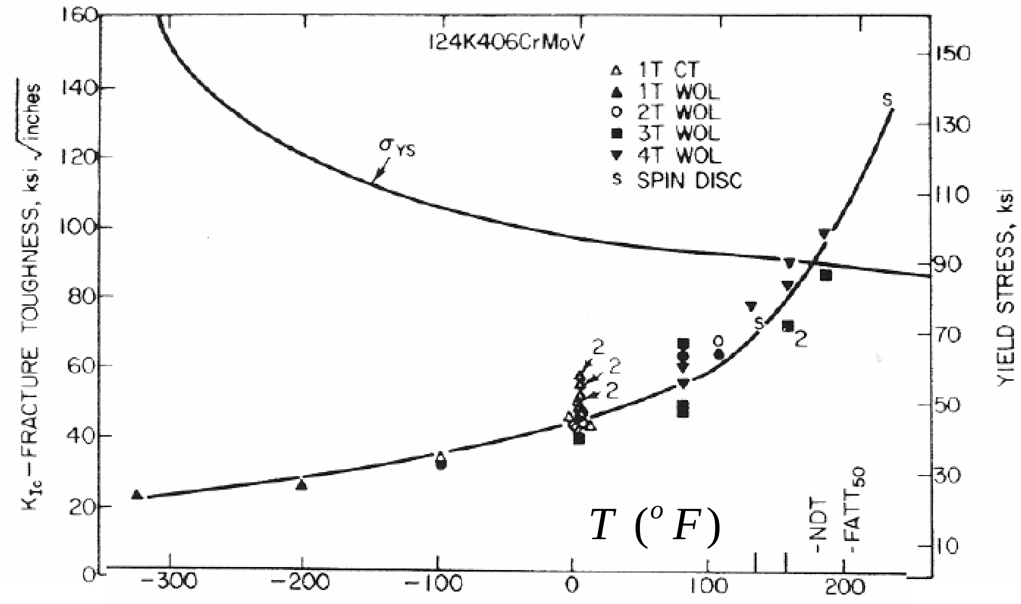
Additional compliance destabilizes crack growth

Temperature and rate dependence of fracture toughness of two steels

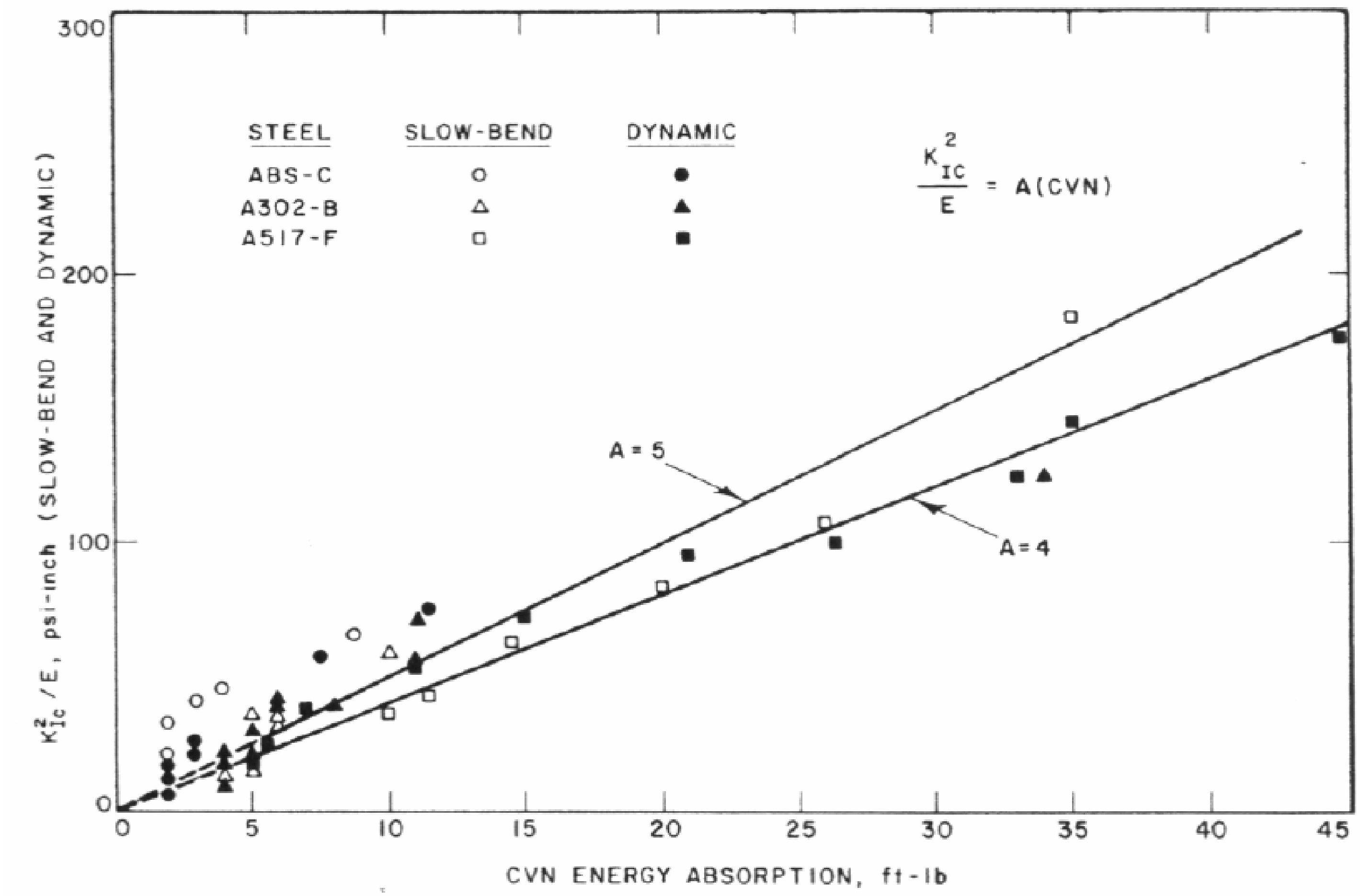
Reference:
Barsom and Rolfe
Fracture and Fatigue Control
In Structures, Englewood Cliffs,
1987.

Excellent text on practical
aspects of fracture testing
and application



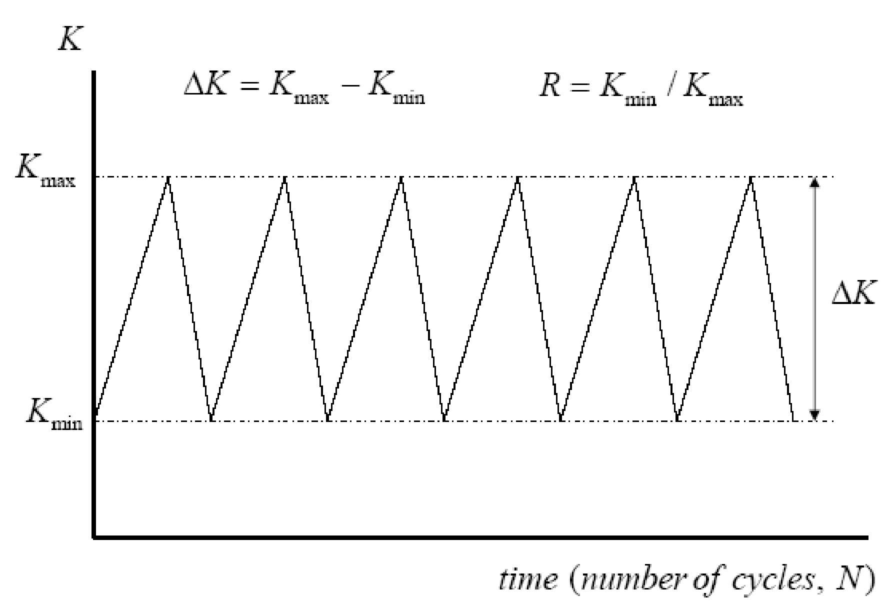


Correlation between KIC and Charpy Energy

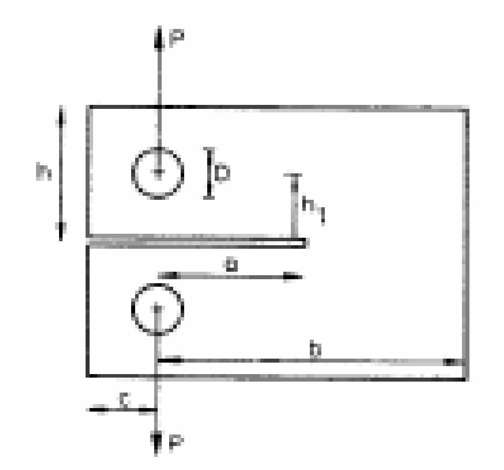


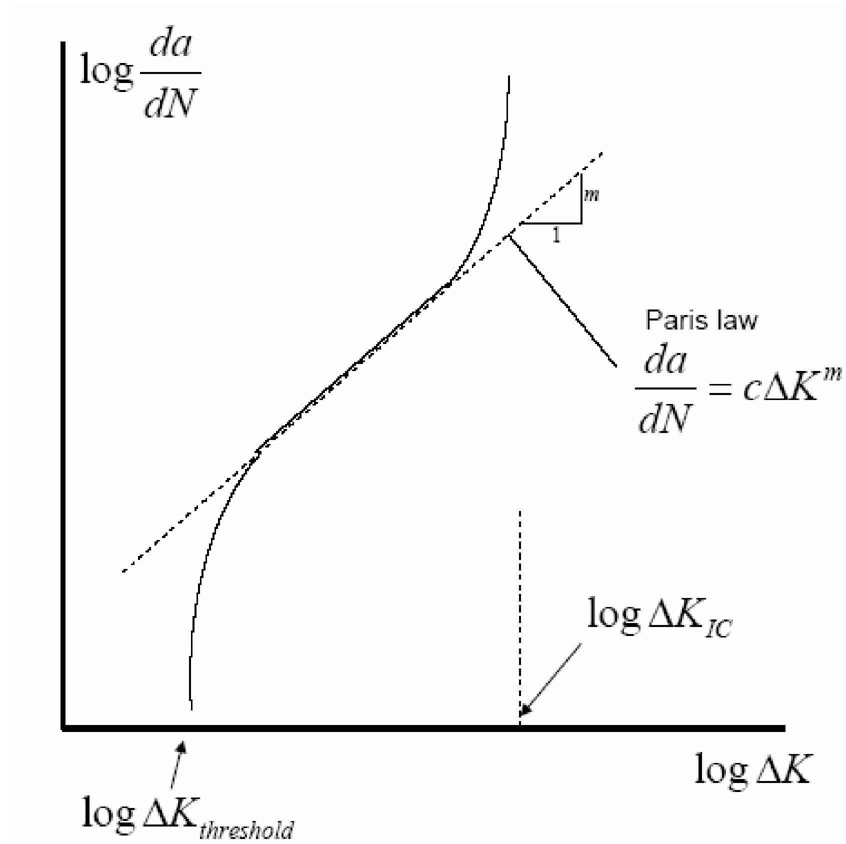
Reference:
Barsom and Rolfe

Characterization of mode I fatigue crack growth rate using K



Cyclic loading

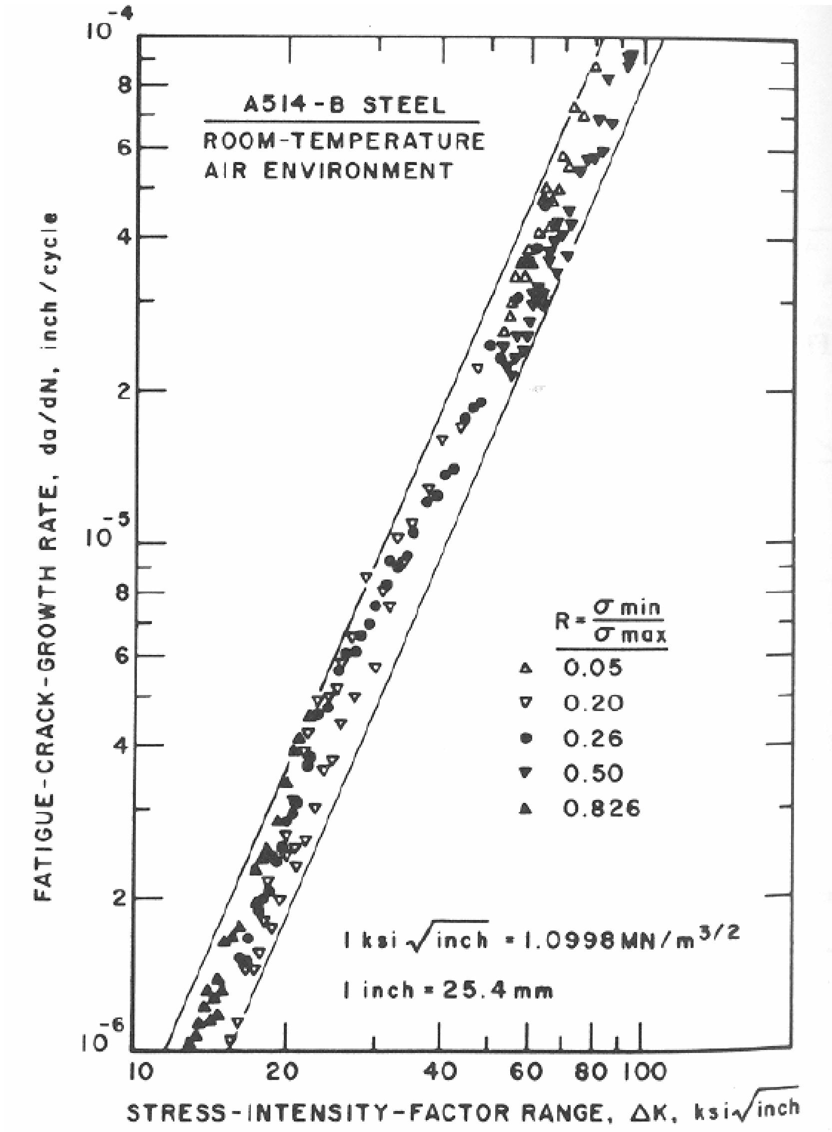


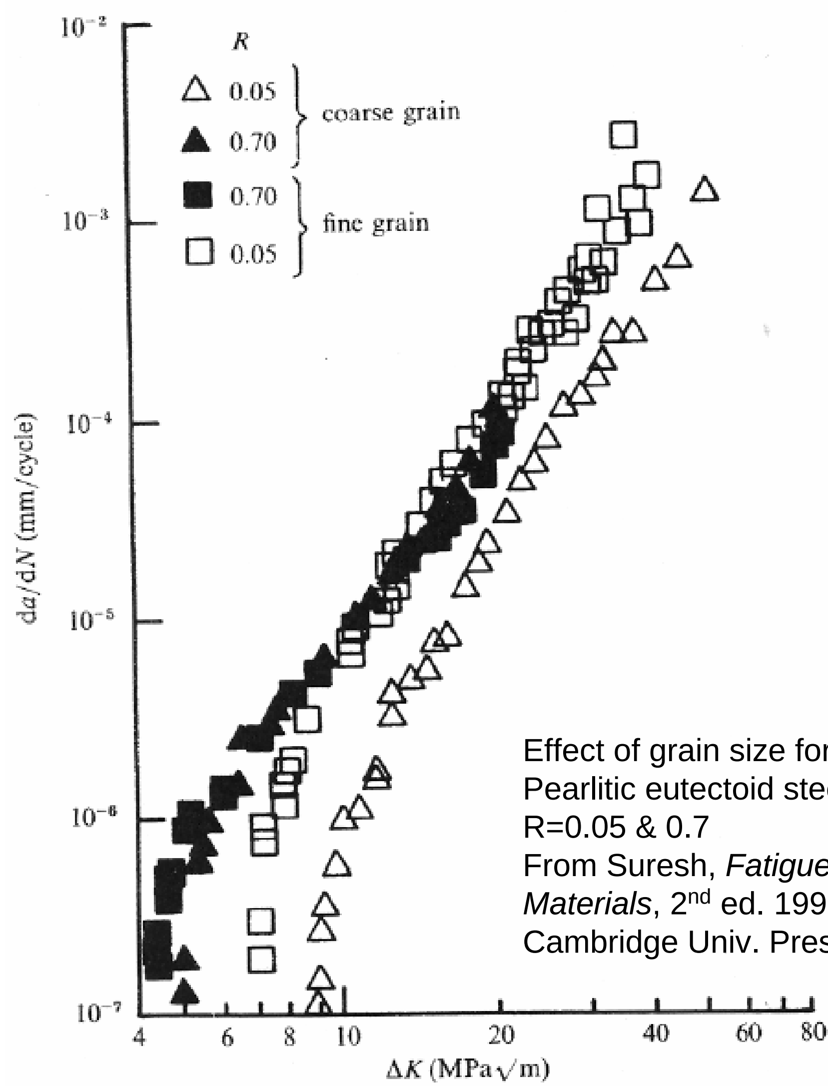


Schematic of crack growth/cycle

Representative Fatigue Crack Growth Data for Some Steels

Reference:
Barsom and Rolfe





Effect of grain size for Pearlitic eutectoid steel
R=0.05 & 0.7
From Suresh, *Fatigue of Materials*, 2nd ed. 1998
Cambridge Univ. Press

Influence of environment on fatigue crack growth rate and threshold

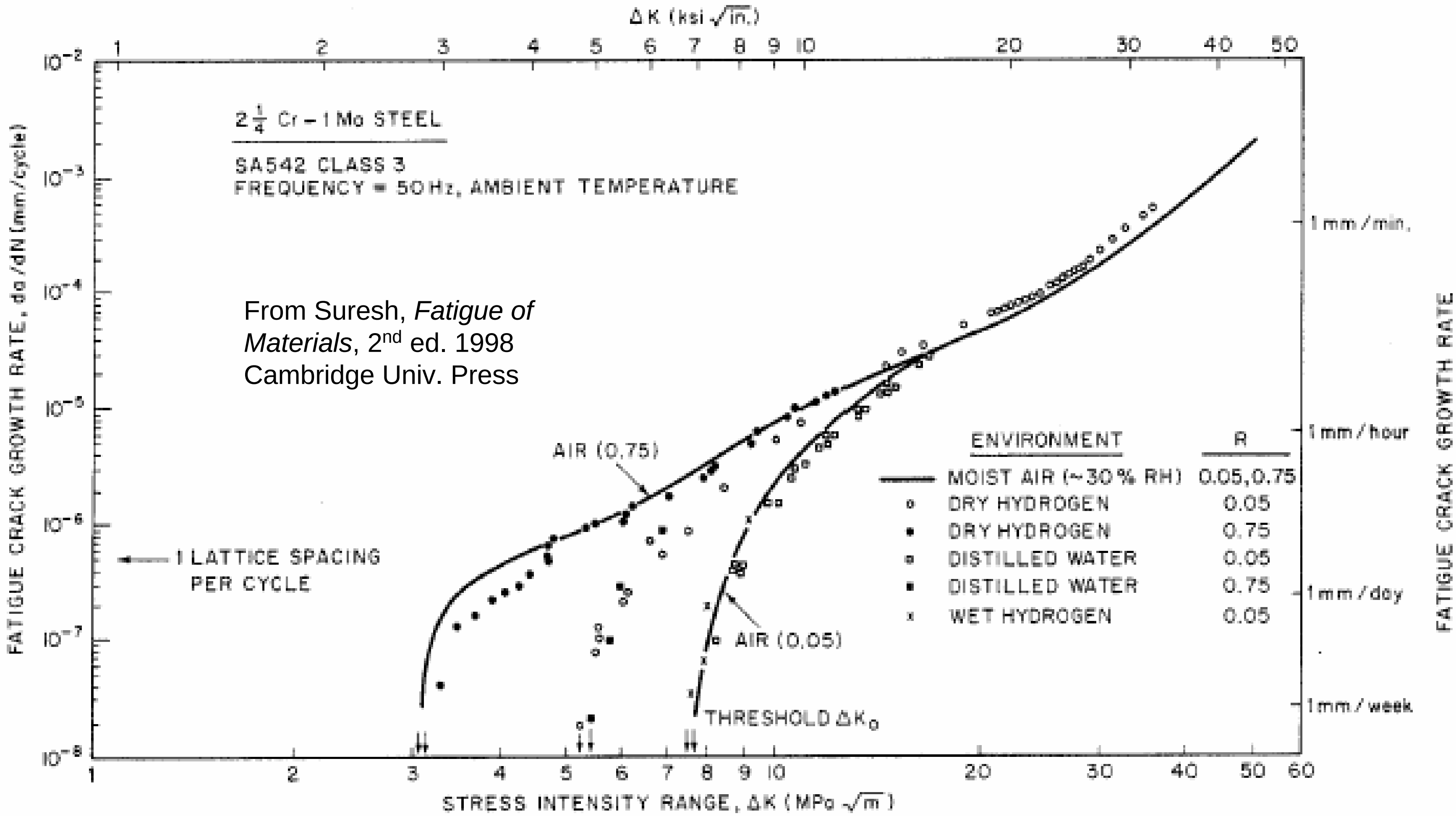
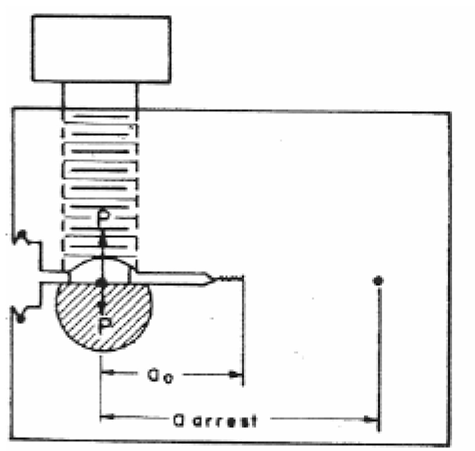
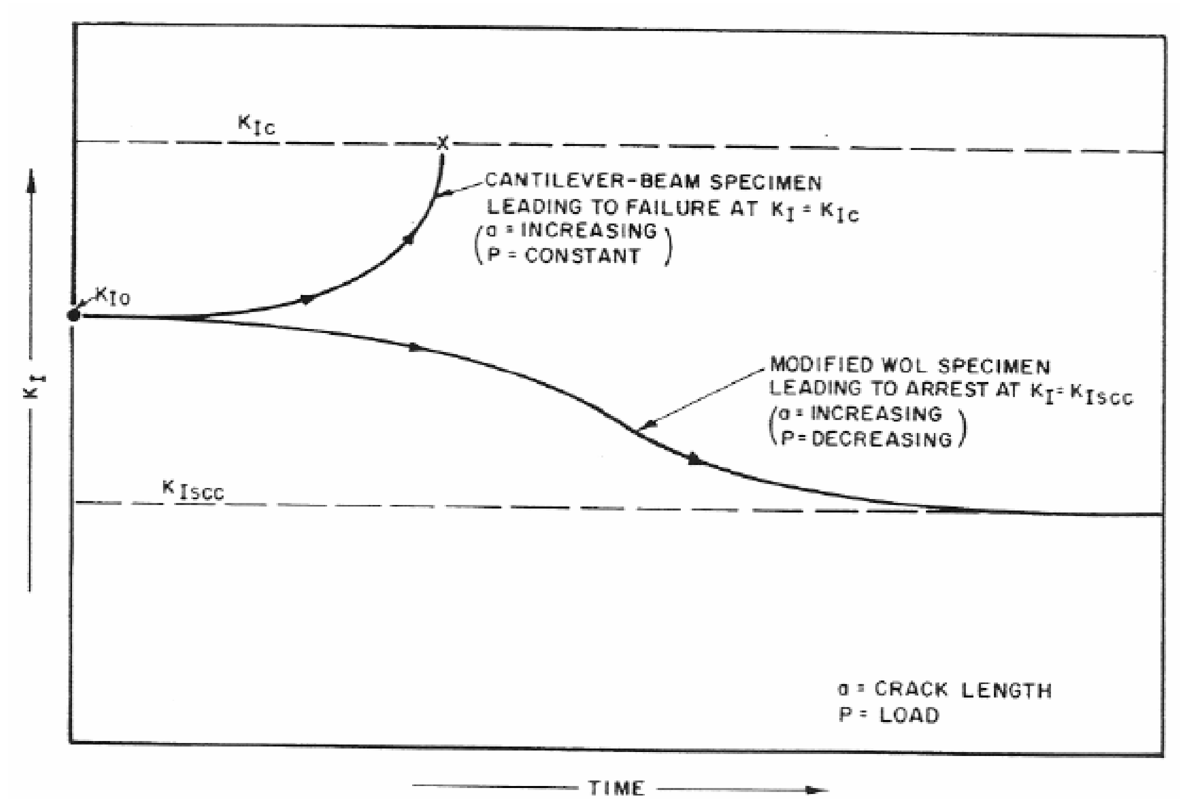


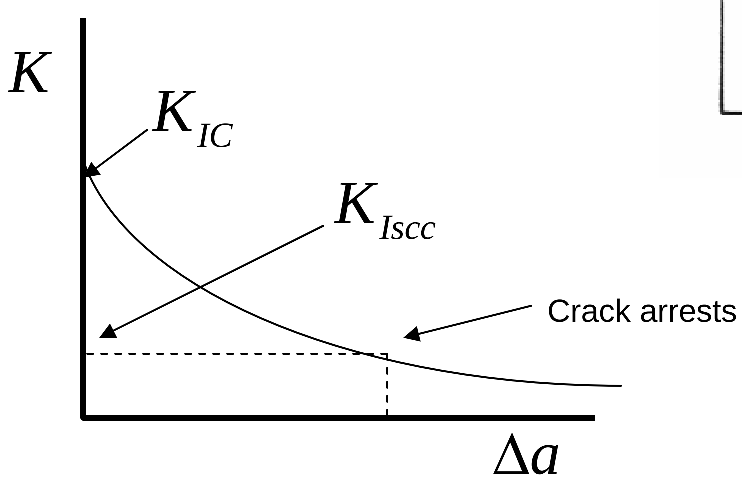
Figure 13.3 Influence of environment on near-threshold fatigue-crack growth in SA542-3 tested at $R = 0.05$ and 0.75. Room temperature moist-air data are compared with data for wet and dry gaseous hydrogen and distilled water environments.

Use of K to characterize cracking in corrosive environments





"Rigid" bolt is tightened to the point where K=KIC. Then specimen is immersed in corrosive environment and crack advance is monitored.



K_{Iscc} Is the critical stress intensity factor for stress corrosion cracking

No crack advance if $K < K_{Iscc}$