

# Crack Propagation

## Lecture 12

Engineering 473  
 Machine Design



### Evidence of Crack Growth



Crack Growth Striations in shaft with keyway

Crack Growth Striations in crankshaft

Norton, Fig. 6-4

### Crack Propagation Striations

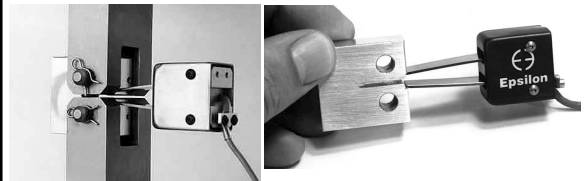


Concentric pattern is characteristic of fatigue failures in which a crack propagates (grows) under cyclic loading.

Norton, Fig. 6-3

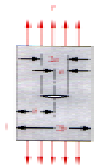
### Crack Opening Displacement (COD) Tests

COD Tests are used to determine the change in crack size in compact tension specimens subjected to cyclic loads.



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### Stress Intensity Factor Range



#### Stress Intensity Equation

$$K = Y \sigma_{nom} \sqrt{\pi \cdot a}$$

(Refer to Class 7 Notes)

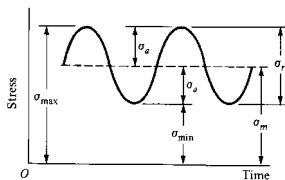
#### Stress Intensity Factor Range

$$K_{max} = Y \sigma_{max} \sqrt{\pi \cdot a}$$

$$K_{min} = Y \sigma_{min} \sqrt{\pi \cdot a}$$

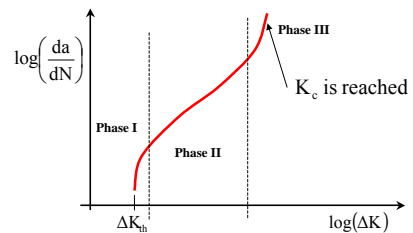
$$\Delta K = Y \sqrt{\pi \cdot a} \cdot (\sigma_{max} - \sigma_{min})$$

$$\text{If } K_{min} < 0, \Delta K = K_{max}$$



Norton, Fig. 5-15

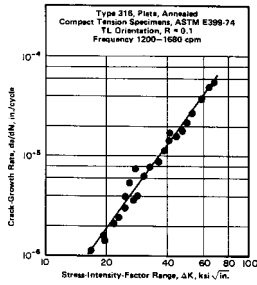
### Crack Growth Rate Curve



Phase I: Crack initiation  
 Phase II: Stable crack-growth  
 Phase III: Unstable crack-growth (fracture)

## Example da/dN Curve

Fe  
18 Cr  
13 Ni  
+ Mo  
Type 316  
Type 317



Phase II crack growth data for 316 and 317 stainless steel at  $-452^{\circ}\text{F}$ .

Stainless steels are used extensively at cryogenic temperatures.

FIGURE 3.0632. FATIGUE CRACK-GROWTH RATE OF ANNEALED ALLOY AT  $-452^{\circ}\text{F}$  (1111)

## Griffith-Irwin Formula

Empirical equation used to fit da/dN data

$$\frac{da}{dN} = \frac{C(\Delta K - \Delta K_{th})^m}{(1-R)K_c - \Delta K}$$

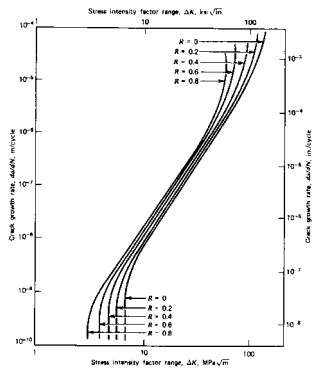
$C, m \equiv$  empirical constants

$$R \equiv \text{stress amplitude ratio} = \frac{\sigma_{\min}}{\sigma_{\max}}$$

$K_c \equiv$  Fracture toughness

$\Delta K_{th} \equiv$  threshold value, crack growth is not expected for values of  $\Delta K$  less than  $\Delta K_{th}$ .

## Griffith-Irwin Formula Plots



Norton, Fig. 6-20

## Stable Crack Growth Regime

$$\frac{da}{dN} = \frac{C(\Delta K - \Delta K_{th})^m}{(1-R)K_c - \Delta K} \quad \text{Griffith-Irwin formula}$$

$$\frac{da}{dN} = C \cdot \Delta K^m \quad \text{Phase II simplified formula}$$

These equations can be integrated (usually numerically) to obtain the number of cycles to failure. There are several commercially available programs containing material libraries that make this a fairly straight forward process. NASA uses a program called FLAWGRO.