Tutorial Class 4 – Week 5

Aims:

Upon successfully completing these tutorial exercises, students should be able to:

- Understand relationships between crack size, applied stress and fracture toughness
- Perform calculations relating to fracture toughness of materials
- Understand relationships between stress amplitude, mean stress, fatigue lifetime and fatigue strength
- Perform calculations relating to fatigue behavior of materials

Fracture Toughness

Additional Crack characteristic information

Characteristics of Cracks

Cracks can be characterized looking into the following aspects.

- Its connection with the external free surface:
  (i) completely internal,
  (ii) internal cracks with connections to the outer surfaces,
  (iii) Surface cracks.
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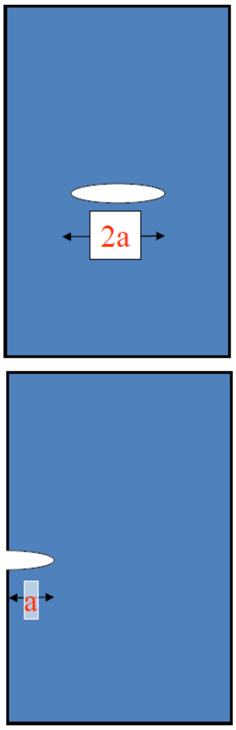
  • Cracks with some contact with external surfaces are exposed to outer media and hence may be prone to oxidation and corrosion (cracking).
- Crack length
- Crack tip radius Crack tip radius is dependent of the type of loading and the ductility of the material.
- Crack orientation with respect to geometry and loading.

$$\boxed{K_{Ic} = Y\sigma\sqrt{\pi a}}$$



Exercise 4.1 A 50mm wide sample plate of 7074-T8 aluminium alloy contains a central through-crack of length 2a. For 7074-T8: $K_c = 22.2$ MN m$^{-3/2}$; $\sigma_y = 520$MPa

a) an applied stress of 200 MPa, determine if the plate will fail by fracture with a crack half-length a of:
   - 1 mm; 5 mm; 10 mm

b) Determine the limiting crack size 2a below which the plate will fail by yielding (assume Y = 1)

Exercise 4.2 In a component σ_y =800 MPa, K_{1C} =85 Mpa.m$^{0.5}$.
What is the maximum allowable size of a fully internal crack (Assume Y=0.95)?

Note: For a fully internal crack, the crack size is 2a.
Brittle fracture occurs when $K_{Ic} = Y\sigma\sqrt{\pi a}$

Exercise 4.3 A rotating shaft in a gearbox is to be made from AISI 4340 quenched and tempered steel which has a tensile strength of $\sigma_{TS} = 1820\ MPa$. Using the information in the following figure, determine:

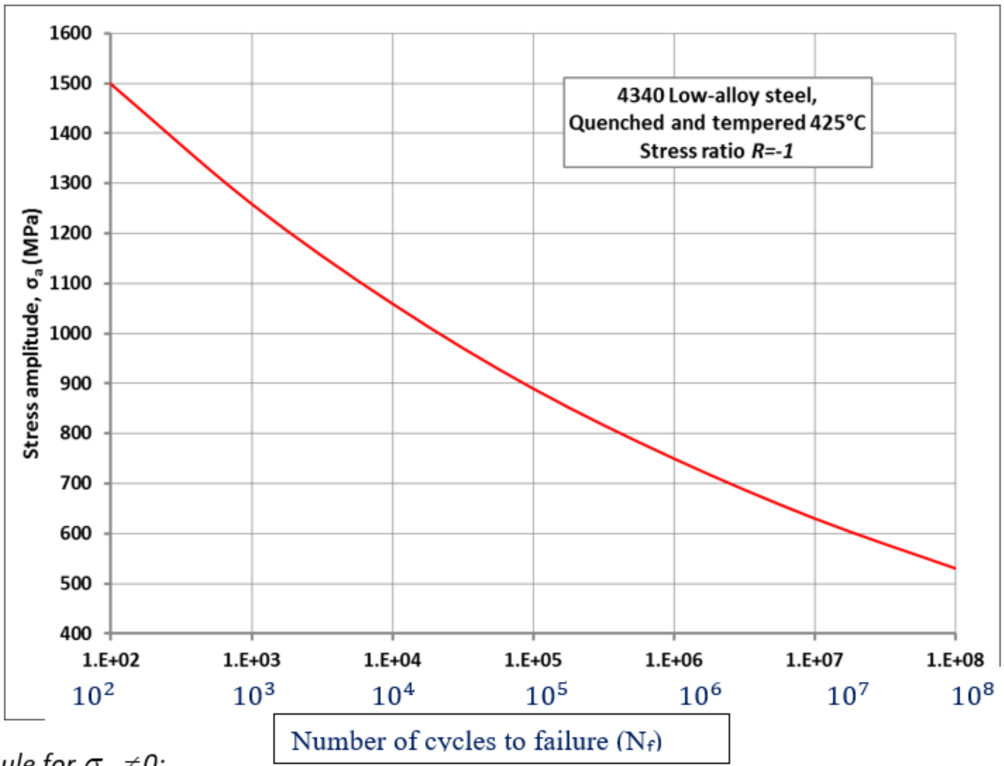
a) What is the fatigue strength σ_f at 10^7 cycles?

b) Will the shaft fail by fatigue if it is subjected to 100 cycles with amplitude of 1200 MPa and zero mean stress?

c) Will the shaft fail by fatigue if it is subjected to 100 000 cycles with amplitude of 900 MPa and zero mean stress?

d) Will the shaft fail by fatigue if it is subjected to 100 000 cycles with amplitude of 800 MPa and mean stress of 300 MPa?

e) If cycled between -100 MPa and 1100 MPa, how many cycles will the shaft survive? If the rotation frequency is 8 Hz, how long (in hours) will the shaft survive? (*Hertz = cycles per second)*



Goodman Rule for $\sigma_m \neq 0$:

$$\Delta\sigma_{\sigma_m} = \Delta\sigma_{\sigma_0}\left(1 - \frac{\sigma_m}{\sigma_{TS}}\right)/$$

Exercise 4.4 A small actuator is made from a polymer material with an ultimate tensile strength of σ_{ts} = 28 MPa. The loading of the actuator is fully reversed with a stress amplitude of σ_a = 11 MPa . If the loading cycles at a frequency of 3.0 Hz, how many hours would the actuator be expected to survive before failing due to fatigue? The SN curve for the polymer material is shown below.

1 Hz = 1 cycle per second

3600 Hz = 1 cycle per hour

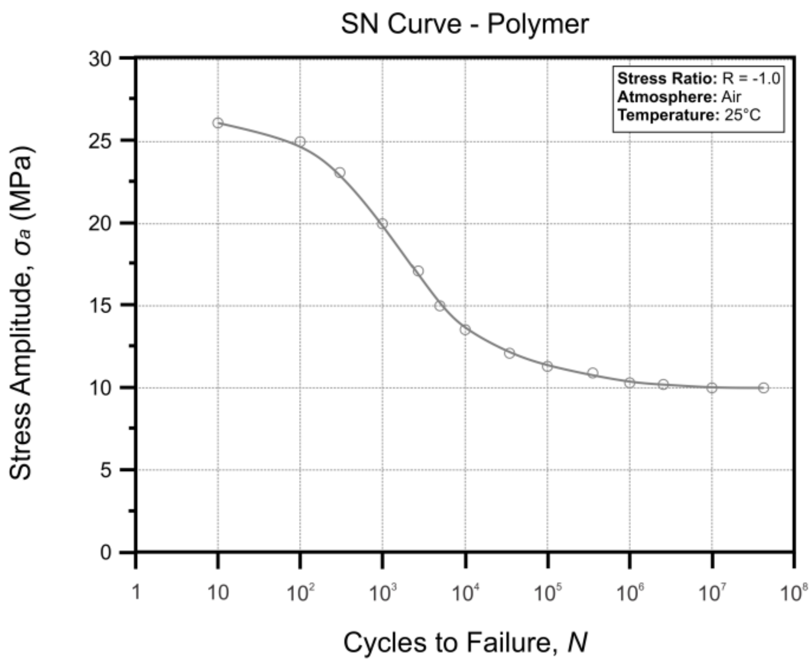


Figure 2. Fatigue behaviour of the polymer material.