Mechanical Design
K_t & K_{Ic}

Prof. Keun Ryu
Turbomachinery Laboratory
Hanyang University, Korea

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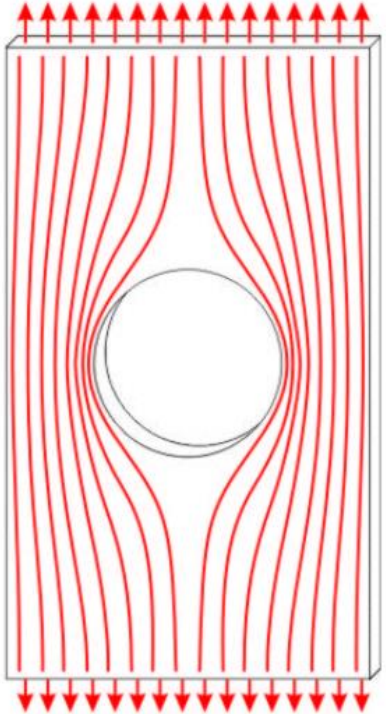
Review: Stress Concentration

- A stress concentration by a stress raiser is a location in an object where the stress is significantly greater than the surrounding region.
- Stress concentrations occur when there are irregularities in the geometry or material of a structural component that cause an interruption to the flow of stress.
- This arises from such details as holes, grooves, notches and fillets.



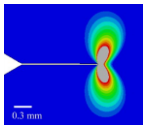
Internal force lines are denser near the hole

Review: Stress concentration factor

- Ratio of the highest stress to the nominal far field stress.
- For ductile materials, large loads can cause localized plastic deformation or yielding that will typically occur first at a stress concentration allowing a redistribution of stress and enabling the component to continue to carry load.
- Brittle materials will typically fail at the stress concentration.
- Repeated low level loading may cause a fatigue crack to initiate and slowly grow at a stress concentration leading to the failure of even ductile materials.
- Fatigue cracks always start at stress raisers, so removing such defects increases the fatigue strength.

Review: Fracture Mechanics (Ch. 6.3)

- Theoretically, the stress concentration factor at the base of a crack approaches infinity because the radius at the crack root approaches zero (as with r/d approaching zero in Figure 4.35).
- This means that if the material has any ductility, yielding will occur within some small volume of material at the crack tip, and the stress will be redistributed.
- Thus, the effective stress concentration factor is considerably less than infinity, and furthermore it varies with the intensity of the applied nominal stress.
- In the fracture mechanics approach, one does not attempt to evaluate an effective stress concentration per *se*; rather, a stress intensity factor, K, is evaluated.
- **The stress intensity factor is used to define the effect of a crack on the stresses in the region around a crack tip.**



Stress Intensity Factor, *K*

- A measure of the effective local stress at the crack root.
- *K* is used in fracture mechanics to predict the stress state ("stress intensity") near the tip of a crack or notch.
- The magnitude of *K* depends on specimen geometry, the size and location of the crack or notch, and the magnitude and the distribution of loads on the material.

Stress Intensity Factor, *K*

- Again, effective local stress at the crack root!
- *K* is then compared with a limiting value of *K* that is necessary for crack propagation in that material.
- This limiting value is a characteristic of the material, called fracture toughness, or critical stress intensity factor K_c , which is determined from standard tests.
- Failure is defined as whenever the stress intensity factor, *K*, exceeds the critical stress intensity factor, K_c.
- Thus, a safety factor, SF, for failure by fracture can be defined as K_c/K.

Stress intensity factor

- A parameter called the stress-intensity factor (K_I) is used to determine the fracture toughness of most materials.
- K_I : A Roman numeral subscript (I) indicates the mode of fracture.

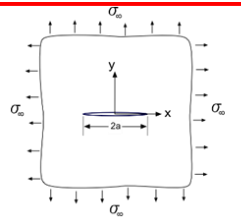
→ Stress intensity factor for mode I: K_I

Stress intensity factor

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

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

Crack in an infinite plate under mode I loading.



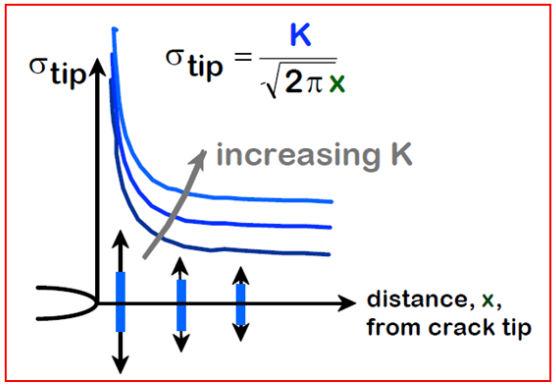
Crack tip stress is very large
→ Crack propagates when: the tip stress is large enough to make

Stress Intensity Factor: Depends on load & geometry

Fracture Toughness or Critical SIF: Material parameter, Depends on the material, temperature, environment, & rate of loading.

$$K_I \geq K_{Ic}$$

Crack is UNSTABLE!



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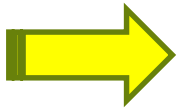
Stress intensity factor

- Fracture toughness: When the magnitude of the mode I stress intensity factor reaches a critical value (i.e., K_{Ic}), crack propagation initates!

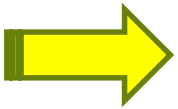
What does this mean????

$$K_I < K_{Ic}$$  Crack is STABLE!

K_{Ic}: Critical stress intensity factor = Fracture toughness

Stress intensity factor

- A properly determined value of K_{Ic} represents the fracture toughness of the material independent of crack length, geometry or loading system.
- K_{Ic} is a material property

$$K_I < K_{Ic}$$  Crack is STABLE!

K_{Ic}: Critical stress intensity factor = Fracture toughness


Thank you!