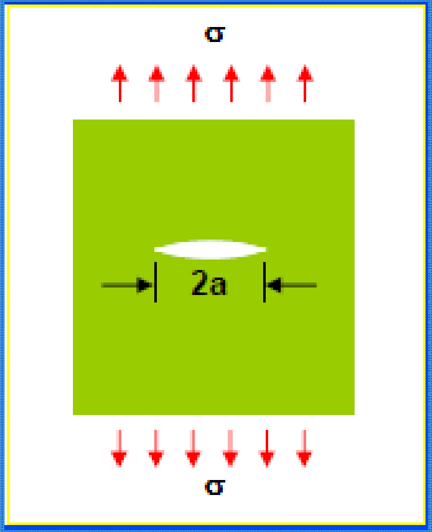
# Griffith theory of brittle fracture:

- Observed fracture strength is always lower than theoretical cohesive strength .
- Griffith explained that the discrepancy is due to the inherent defects in brittle materials leading to stress concentration implies lower the fracture strength of the materials.

**Crack propagation criterion:**

- Consider a through thickness crack of length 2a, subjected to a uniform tensile stress σ, at infinity.




- Crack propagation occurs when the released elastic strain energy is at least equal to the energy required to generate new crack surface.

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- The stress required to create the new crack surface is given as follows :

$$\sigma = \left( \frac{2E\gamma_s}{\pi a} \right)^{1/2}$$

- In plane strain condition, the equation becomes :

$$\sigma = \left( \frac{2E\gamma_s}{(1-\upsilon^2)\pi a} \right)^{1/2}$$

# Modified Griffith equation

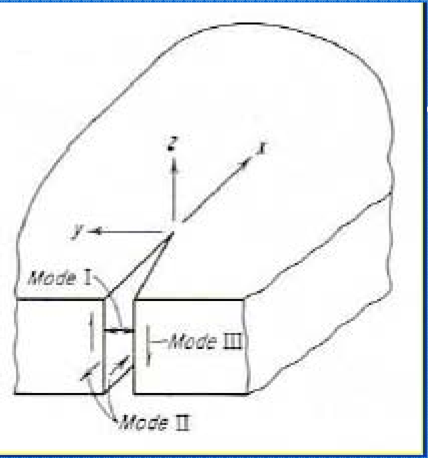
- The Griffith equation is strongly dependent on the crack size a,and satisfies only ideally brittle materials like glass.
- However, metals are not ideally brittle and normally fail with certain amounts of plastic deformation, the fracture stress is increased due to blunting of the crack tip.
- Irwin and Orowan suggested Griffith's equation can be applied to brittle materials undergone plastic deformation before fracture by including the plastic work, γp, into the total elastic surface energy required to extend the crack wall, giving the modified Griffith's equation as follows :

$$\sigma_f = \left[\frac{2E(\gamma_s + \gamma_p)}{\pi(1-\upsilon^2)a}\right]^{1/2} \approx \left(\frac{E\gamma_p}{(1-\upsilon^2)a}\right)^{1/2} ,when\ \gamma_p >> \gamma_2$$

# Stress intensity factor

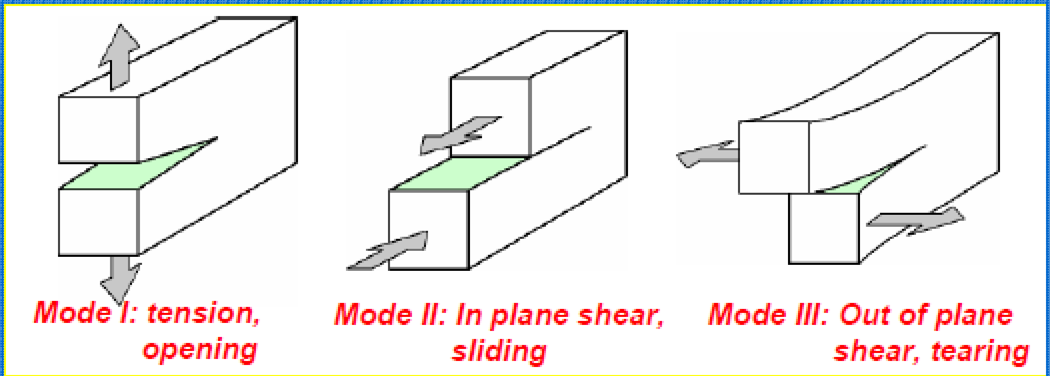
- In mode I failure and plane-strain condition, the relationship between GIC an KIC can be shown by an expression as follows :

$$G_{IC} = \frac{K_{IC}^2 (1 - \upsilon^2)}{E}$$




re $K_{IC}$ is the critical stress intensity factor

Crack deformation mode.




Fracture modes

- Stress intensity factor KIC can be described as fracture toughness of materials (material resistance to crack propagation) under conditions of :

1) brittle fracture

2) in the presence of a sharp crack

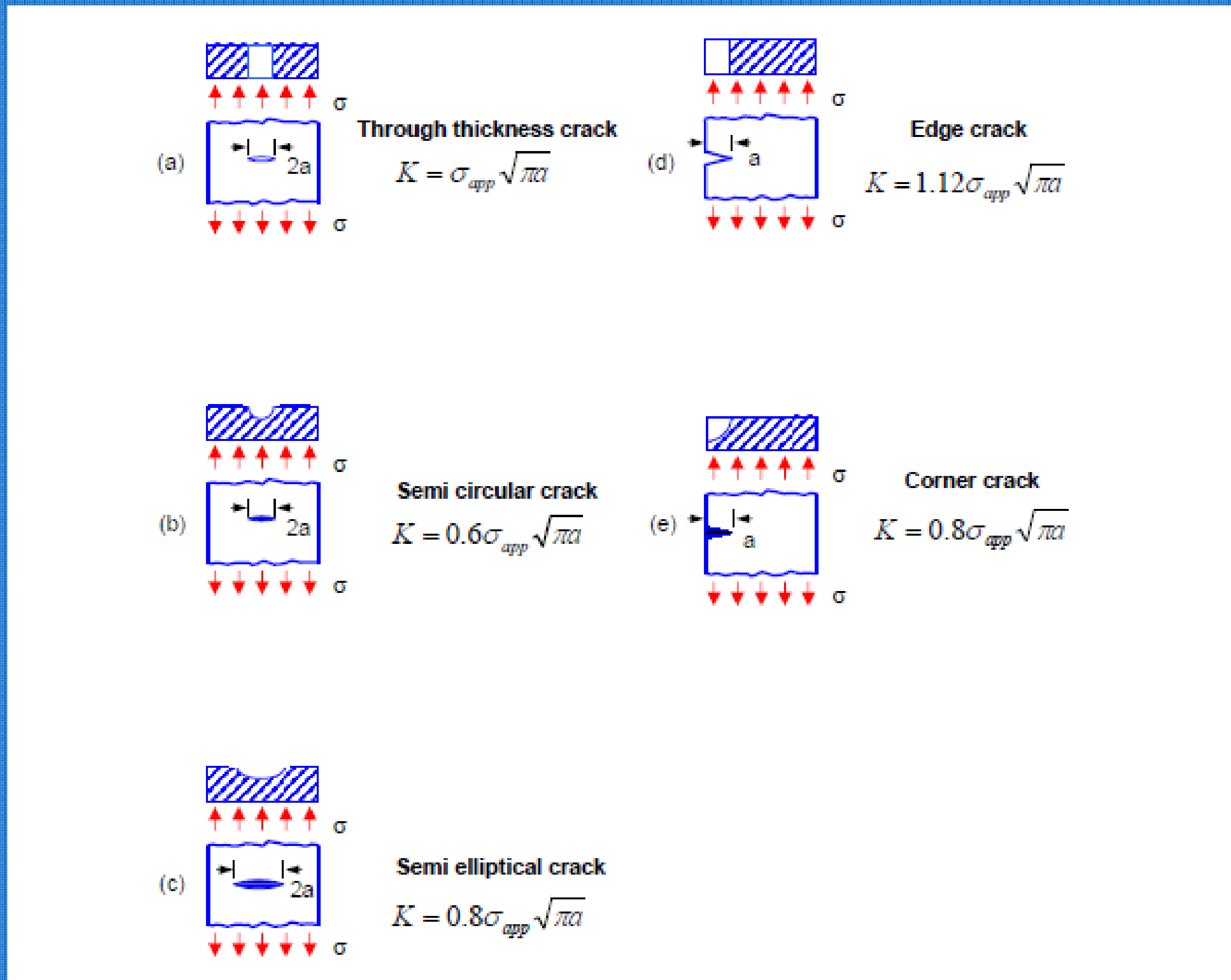
3) under critical tensile loading

$$K_{IC} = \alpha \sigma_{app} \sqrt{\pi a_c}$$

Where

- $K_{IC}$ is the critical stress intensity factor for plane strain condition in mode failure.
- $a_c$ is the critical crack length in an infinite plate
- $\sigma_{app}$ is the applied stress
- $\alpha$ is a parameter dependent on specimen and crack geometry

# K values of various crack geometries:



# Determination of fracture toughness

- Fracture toughness of material can be determined according to LEFM analysis

1) KIC fracture toughness :

works well for very high strength materials.

→ exhibiting brittle fracture

2) Crack tip opening displacement CTOD :

Used for lower strength materials ($\sigma o < 1400$ MPa), exhibiting small amount of plastic deformation before failure.

3) J-integral ($J_{IC}$) :

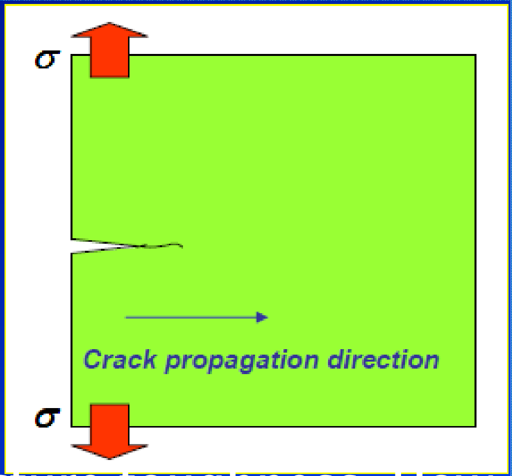
Used for lower strength materials, exhibiting small amount of plastic deformation before failure.

4) R-curve :

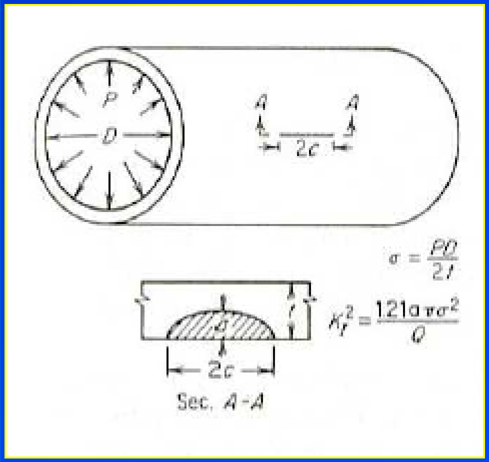
The resistance to fracture of a material during slow and stable crack propagation

# $K_{IC}$ fracture toughness

- $K_{IC}$ fracture toughness of material is obtained by determining the ability of material to withstand the load in the presence of a sharp crack before failure.
- Fracture toughness is required in the system of high strength and light weight, i.e., high strength steels, titanium and aluminium  alloys.



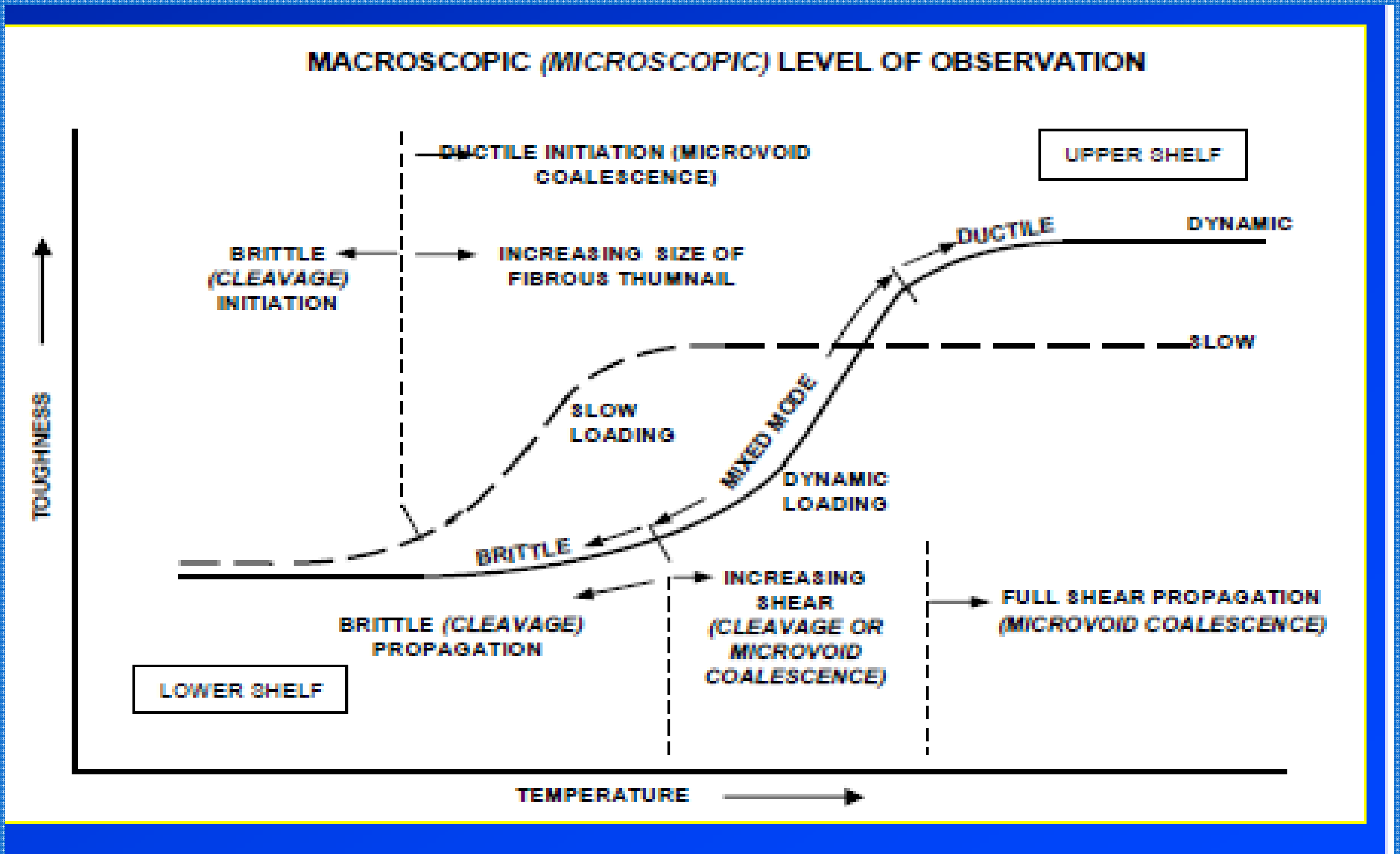

Fracture toughness  How long the existing crack will grow until the specimen fails




Flaw geometry and design of cylindrical pressure vessel

# Ductile to brittle transition behaviour

- BCC structure metals experience ductile-to-brittle transition behaviour when subjected to decreasing temperature, resulting from a strong yield stress dependent on temperature.



- BCC metals possess limited slip systems available at low temperature, minimising the plastic deformation during the fracture process.
- Increasing temperature allows more slip systems to operate, yielding general plastic deformation to occur prior to failure .

## Theory of the ductile to brittle transition :

- The criterion for a material to change its fracture behaviour from ductile to brittle mode is when the yield stress at the observed temperature is larger than the stress necessary for the growth of the microcrack indicated in the Griffith theory.

- Cottrell studied the role of parameters, which influence the ductile to-brittle transition as follows;

$$\left(\tau_i D^{1/2} + k'\right)k' = G\gamma_s \beta$$

- $\tau_i$ is the lattice resistance to dislocation movement
- k' is a parameter related to the release of dislocation into a pile-up
- D is the grain diameter (associated with slip length).
- G is the shear modulus
- β is a constant depending on the stress system.