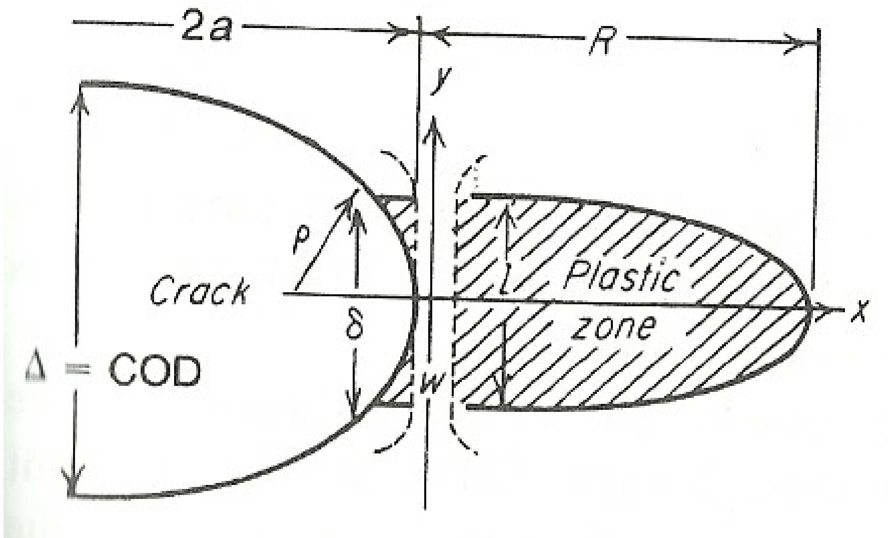
Crack-tip opening displacement (CTOD)

Crack opening displacement

LEFM approach works well for high strength materials (σ_o > 1400 MPa), but less applicable for low strength materials

The crack-tip displacement concept the material ahead of the crack contains a series of miniature tensile specimens having a gage length *l*, and a width *w*.



The length of the sample is determined by the root radius of the crack, ρ

If a thick plate is loaded in tension (mode I) (plane-strain), the displacement (deformation) of the miniature tensile specimen at the crack tip is

$$\delta = \varepsilon l = \varepsilon 2\rho$$

When the specimen adjacent to the crack tip reaches the ductility of the specimen ε_f, fracture will occur.

$$\delta_c = 2\rho\varepsilon_f$$

In plane-stress (thin plate) tensile loading the strain is distributed over the sheet thickness t, thus

$$\delta = \varepsilon l = \varepsilon t$$

The critical crack-opening displacement for fracture is

$$\delta_c = \varepsilon_f t$$

Using Dugdale crack model, CTOD for a crack length 2a in an infinite thin plate subjected to uniform tension σ, where plastic deformation occurs at the crack tip is given by

$$\delta = \frac{8\sigma_o a}{\pi E} \ln\left(\sec \frac{\pi\sigma}{2\sigma_o} \right)$$

Expanding secant term and keeping only the first term

$$\delta = \frac{\pi\sigma^2 a}{E\sigma_o}$$

From strain-energy release rate $$G = \frac{\pi a \sigma^2}{E}$$

Therefore, $$G = \sigma_o \delta$$

Unstable fracture occurs when, $$G_{1C} = \lambda \sigma_o \delta_c$$

Where λ depends on the exact location at which CTOD is determined
λ =2.1 for LEFM conditions, λ = 1.0 for extensive plasticity

Widespread plasticity at the crack tip enables the crack surfaces to move apart at the crack tip without an increase in crack length.

This relative movement of the two crack faces at a distance moved from the crack tip is called the crack-opening displacement (COD).

If the origin of measurement is at the center of a crack of length 2*a*, then

$$\text{COD} = \Delta = \frac{4\sigma}{E}\left[\left(a + r_p\right)^2 - x^2\right]^{1/2} \qquad (1)$$

Where x is the distance from the center of the crack toward the crack tip.

The CTOD is $\Delta = \delta$ and is measured at $x = a$.

When $r_p << a$

$$\delta = \frac{4\sigma}{E}\left(2ar_p\right)^{1/2}$$

By expanding eq 1 and substituting the above eq for ar_p term, we get

$$\Delta = \frac{4\sigma}{E}\left(a^2 - x^2 + \frac{E^2}{16\sigma^2}\delta^2\right)^{1/2}$$

- This equ can be used to determine δ_c from measured values of COD.
- Strain fields and COD vary with specimen geometry.
- Hence, it is difficult to define a single critical COD value for a material