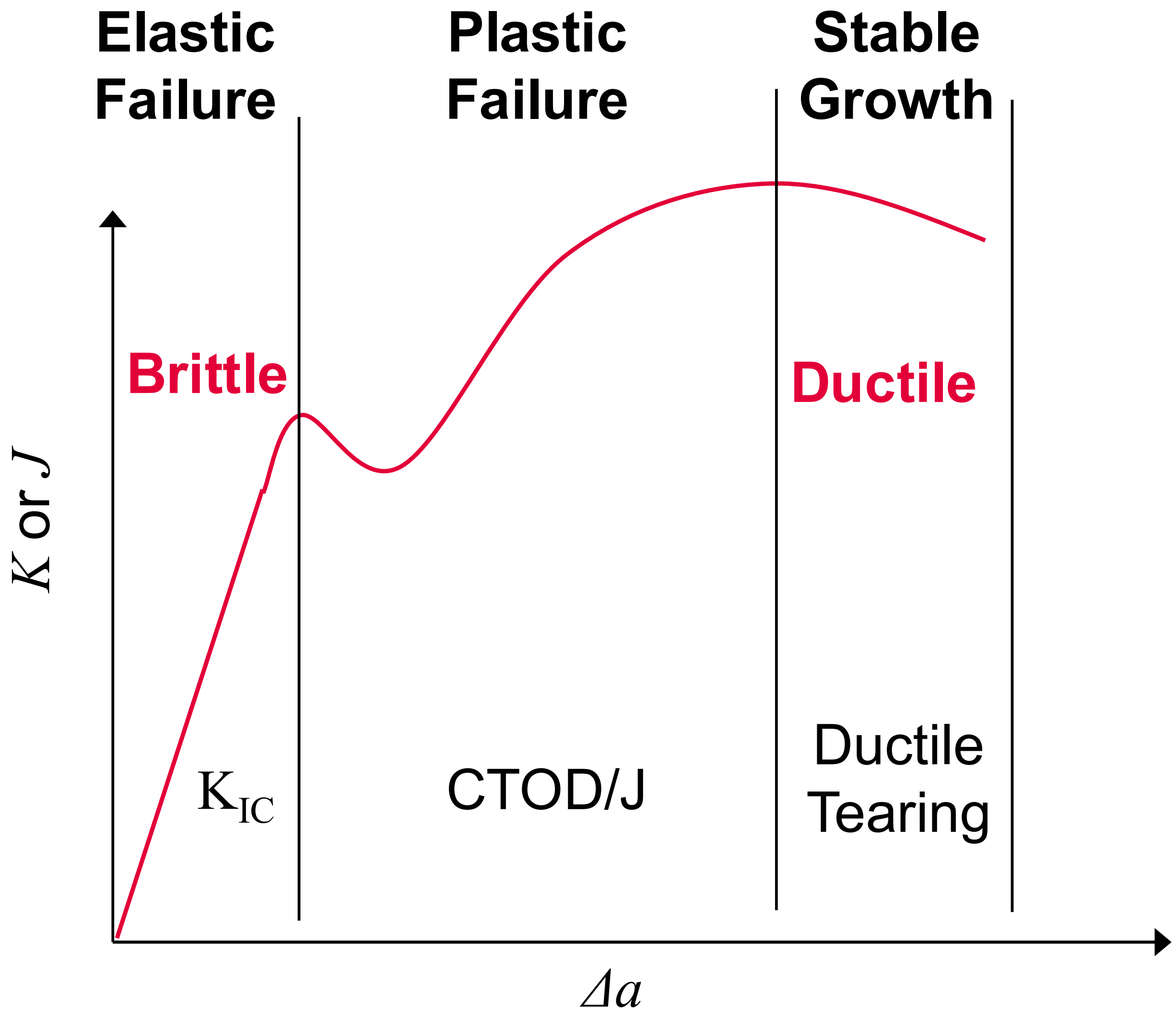
Ductile Fracture vs. Brittle Fracture



Elastic-Plastic Fracture Mechanics

- **LEFM** is suitable for conditions that the plastic zone around the crack tip is sufficiently small.

- When the plastic zone size becomes significantly large, the stress intensity factor cannot characterise stress distribution at the crack tip under SSY conditions any longer.

- For an elastic-plastic material with relatively large plastic zone size, the **non-linear fracture mechanics parameter**, *J*, may describe the stress and strain distribution around the crack tip.

Ramberg-Osgood Material Model

- Many of the **non-linear fracture mechanics parameters solutions** are based on Ramberg-Osgood material model constants.

- The tensile behaviour of a strain hardening material may be described using Ramberg-Osgood material model (in uniaxial form) by

$$\varepsilon = \frac{\sigma}{E} + A_p \sigma^N$$

or in non-dimensional form by

$$\frac{\varepsilon}{\varepsilon_{p0}} = \frac{\sigma}{\sigma_{p0}} + \alpha \left(\frac{\sigma}{\sigma_{p0}} \right)^N$$

The first term on the RHS represents linear elastic deformation and the second term non-linear plastic deformation.

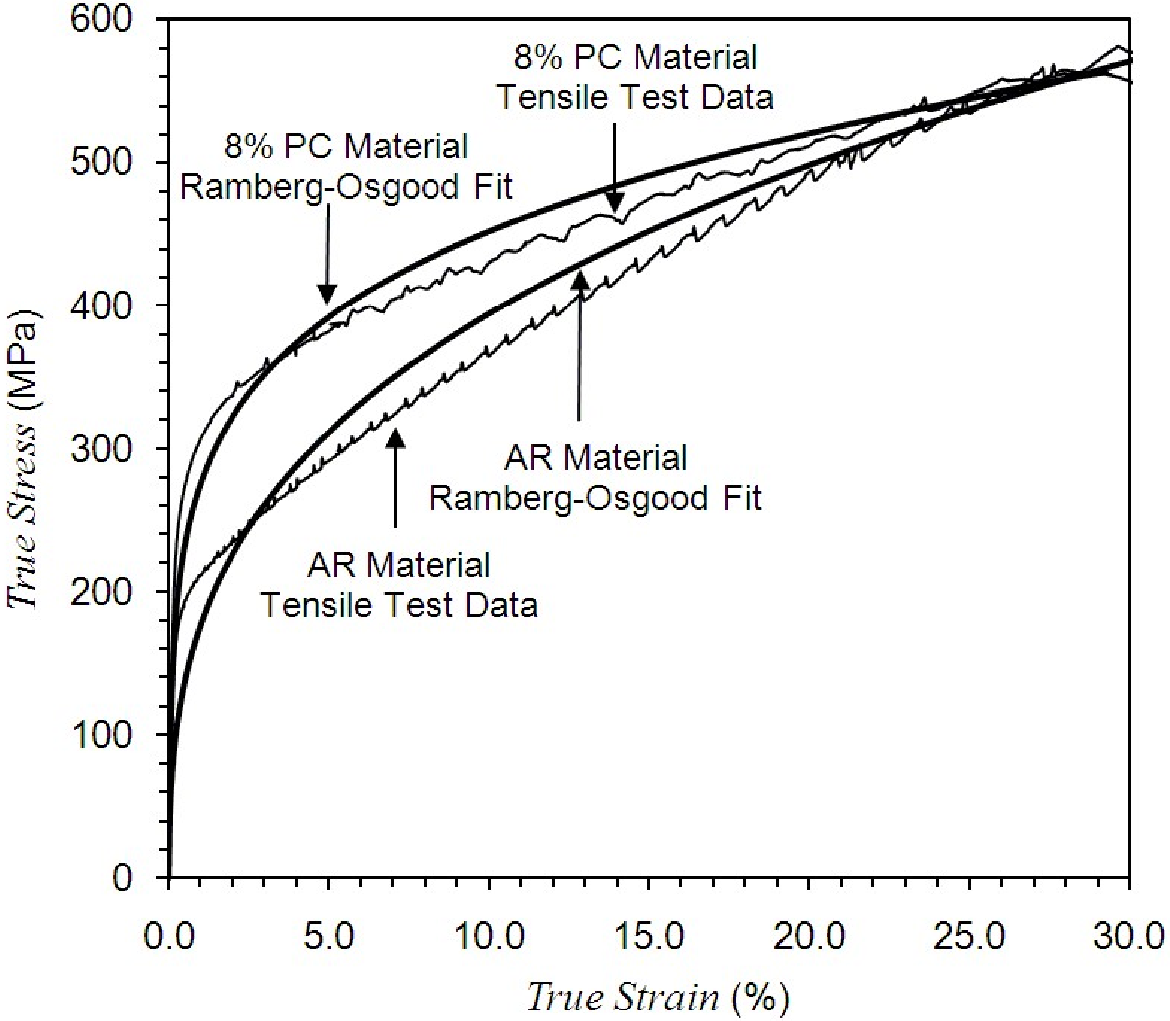
Ramberg-Osgood Material Model

- The normalising stress, σ_{p0}, in Ramberg-Osgood model is often taken as 0.2% proof stress of the material, $\sigma_{0.2}$.

$$\frac{\varepsilon}{\varepsilon_{p0}} = \frac{\sigma}{\sigma_{p0}} + \alpha\left(\frac{\sigma}{\sigma_{p0}}\right)^N$$

- **Non-linearity** is defined to exist from the beginning of the tensile response.
- Thus, **no absolute yield point** is considered in this material model.
- Under **small stresses** the non-linear term is almost negligible (hence linear relationship between stress and strain).
- As the **stress increases**, the linear component becomes negligible and the power law term is magnified.

Ramberg-Osgood Material Model



HRR Stress and Strain Distribution Fields

- For a **non-linear power law hardening** material, the stress and strain distribution fields near the crack tip can be defined in terms of *J*-integral by HRR (Hutchinson, Rosengren&Rice) equations as:

r is the radial distance from the crack tip

α, σ_{p0} and ε_{p0} are Ramberg-Osgood material model constants

$$\frac{\sigma_{ij}}{\sigma_{p0}} = \left[\frac{J}{\alpha\varepsilon_{p0}\sigma_{p0}I_N r}\right]^{\frac{1}{N+1}} \underbrace{\tilde{\sigma}_{ij}(\theta, N)}$$

$$\frac{\varepsilon_{ij}}{\varepsilon_{p0}} = \alpha\left[\frac{J}{\alpha\varepsilon_{p0}\sigma_{p0}I_N r}\right]^{\frac{N}{N+1}} \underbrace{\tilde{\varepsilon}_{ij}(\theta, N)}$$

Solutions for different values of θ and N are provided in a table by Shih

$$I_N = 7.2\sqrt{0.12 + \frac{1}{N}} - \frac{2.9}{N} \quad \text{Plane stress}$$

$$I_N = 10.3\sqrt{0.13 + \frac{1}{N}} - \frac{4.6}{N} \quad \text{Plane strain}$$