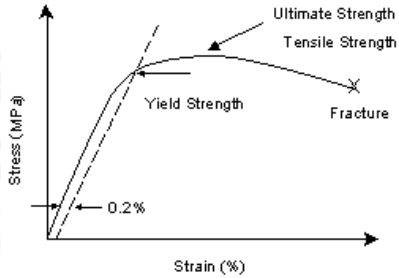
Fatigue life prediction

Fatigue: process of progressive, localized, permanent, structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains, at some point or points, that may culminate in cracks or complete fracture after a sufficient number of fluctuations (ASTM E 1150-1987, Standard Definitions of Fatigue, *1995 Annual Book of Standards*, ASTM, 1995, p 753 – 762)

Fatigue failure process can be divided into 5 stages:

1. **Cyclic plastic deformation prior to fatigue crack initiation** — **Elasto-plastic theory**
2. **Initiation of one or more micro-cracks**
3. **Propagation of one or more micro-cracks to form one or more macro-cracks** — **Continuum damage mechanics**
4. **Propagation of one or more macro-cracks**
5. **Final failure** — **Fracture mechanics**



For practical applications**, fatigue process is separated in two families:**

1. **Low Cycle Fatigue** (LCF): stress and strain above yielding point (plastic domain), number of cycle to failure < 10^4
2. **High Cycle Fatigue** (HCF): stress and strain in the elastic region, number of cycle to failure > 10^5

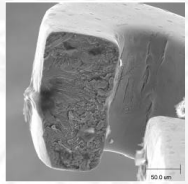
Most common **experimental procedures** for fatigue life characterization are:

1. **"Stress-Life Approach**
2. **"Strain-Life" Approach**

Fatigue life prediction

Stent Total Life Characterization:

- **Dangerous Area Localization**
- **Safety Criteria Formulation**
- **Design Optimization**



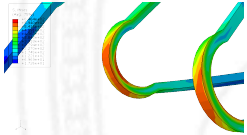
Method for Life Prediction:

Post-Processing Structural Analysis Result: to give evidence of Dangerous Area Localization by quantifying the amount of stress and strain.

Continuum Damage Mechanics Computation: starting from the Structural Analysis Computation Result, it allows to evaluate the number of cycle to Macroscopic crack initiation, the crack initial size and orientation.

Fracture Mechanics Analysis for Fatigue Life Evaluation: to obtain initial crack size and orientation values from Continuum Damage Analysis and allows to evaluate device final failure.

Performing FEM Structural Analysis with Abaqus/ Ansys:



Continuum Damage Mechanics Computation:

- J. Lemaitre Damage evolution law

$$\dot{D} = \left(\frac{Y}{S}\right)^{s} \dot{p} \quad \text{if} \quad \max w_s > w_D \text{ or } p > p_D$$
$$\dot{D} = 0 \quad \text{if not}$$
$$D = D_c \quad \rightarrow \quad \text{crack initiation}$$

D: damage
D_c: damage threshold for crack initiation
ω_D: energy density for microcrack initiation
p_D: plastic strain for microcrack initiation

Goal:

- Low-Cycle Fatigue procedure standardization
- High-Cycle Fatigue procedure standardization

Fracture Mechanics FEM Analysis with Abaqus:

***Contour integral analysis** → **Interaction Module**

- Crack definition : crack front, crack line and crack extension direction
- Mesh the model
  - wedge elements for the crack front
  - hexahedral elements for the other part of the structure

*** *contour:*** ring of elements completely surrounding the crack tip or the nodes along the crack line from one crack face to the opposite one