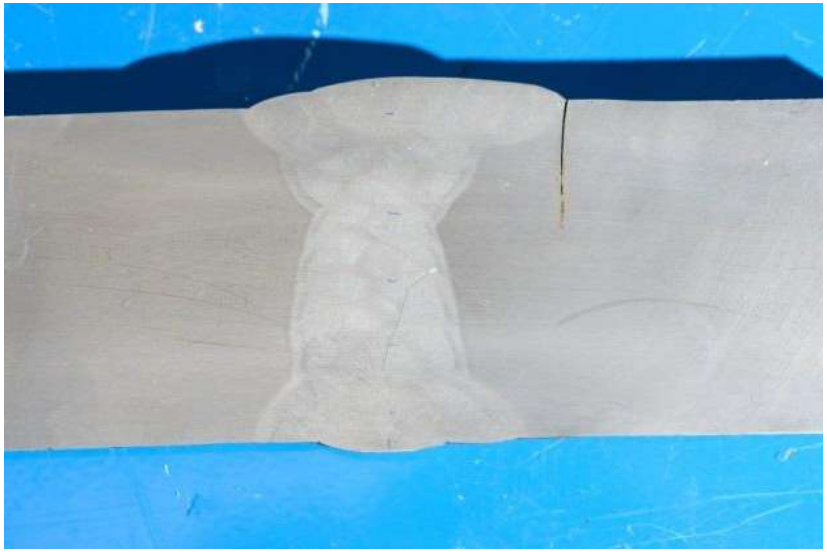
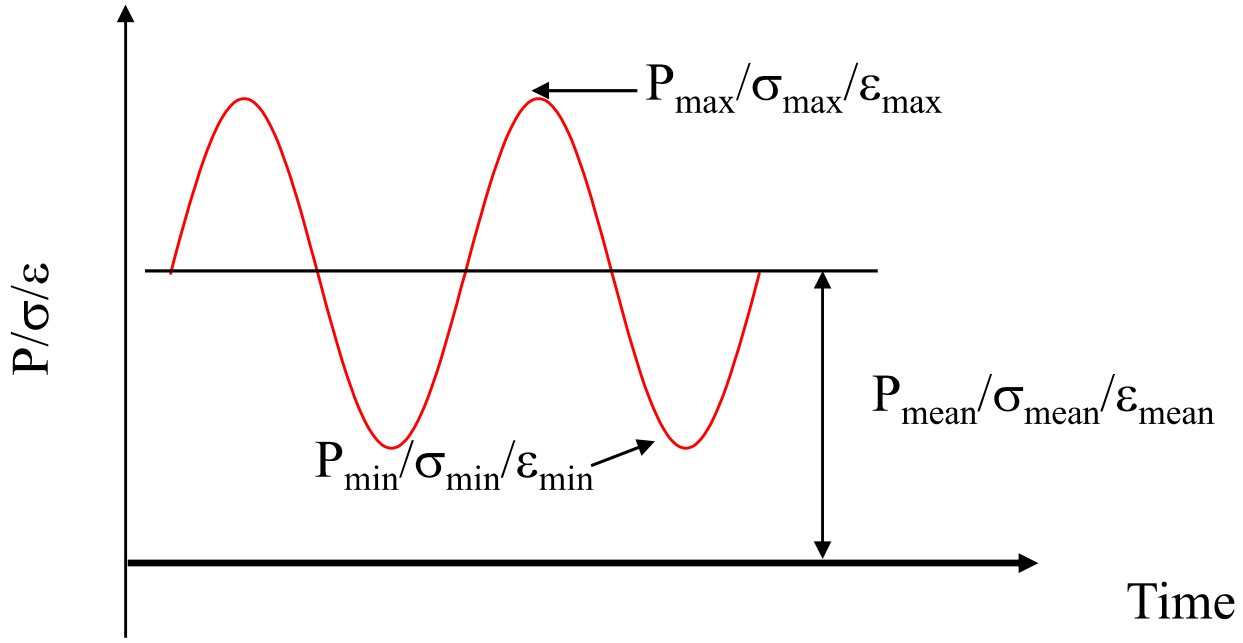
Fatigue Loading in Offshore Wind Turbines

- Offshore wind turbines are subjected to current, wave and wind forces causing both **fatigue** and **corrosion** damage
- It is vital to characterise the fatigue crack initiation and growth behaviour of monopile foundations
- This will help to develop a suitable and cost effective **inspection plan**



Fatigue

Failure of a material under repeated or otherwise varying load which never reaches a level sufficient to cause failure in a single application



$$\Delta P = P_{max} - P_{min}$$

$$R = \frac{P_{min}}{P_{max}}$$

$$\sigma_{mean} = \frac{\sigma_{max} + \sigma_{min}}{2}$$

Stages in Fatigue

- **Stage I** **Fatigue Crack Initiation**
  Micro Crack Growth under the action of Shear Stresses

- **Stage II** **Fatigue Crack Propagation**
  Macro Crack Growth on a plane perpendicular to the maximum Principal Stress

- **Stage III** **Catastrophic Failure**

Fatigue Crack Initiation

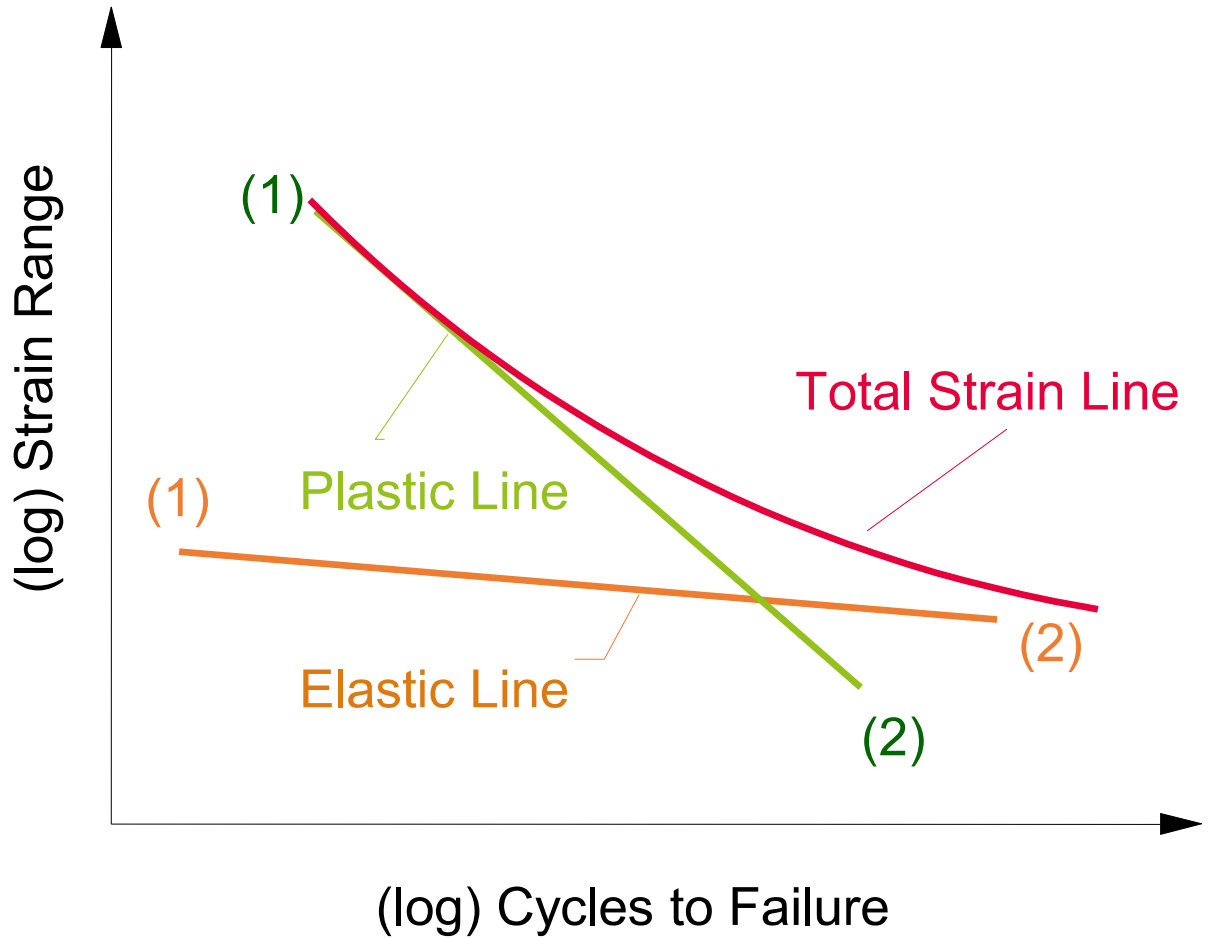
- Low Cycle Fatigue (Strain-Life) - **LCF**

  Strain Driven, relatively independent of surface condition and environment.

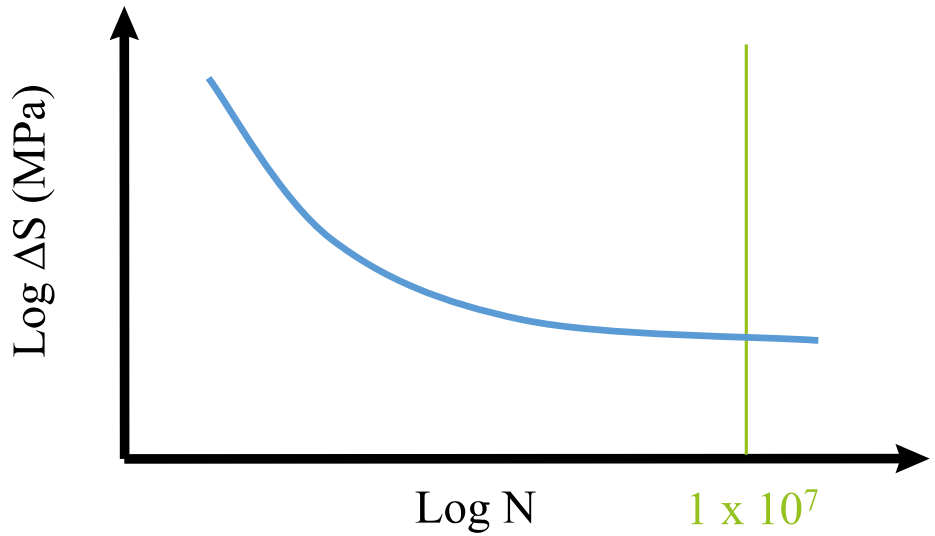
- High Cycle Fatigue (Stress-Life) - **HCF**

  Stress Driven, Very sensitive to surface condition, mean/residual stresses and environment

Low Cycle Fatigue

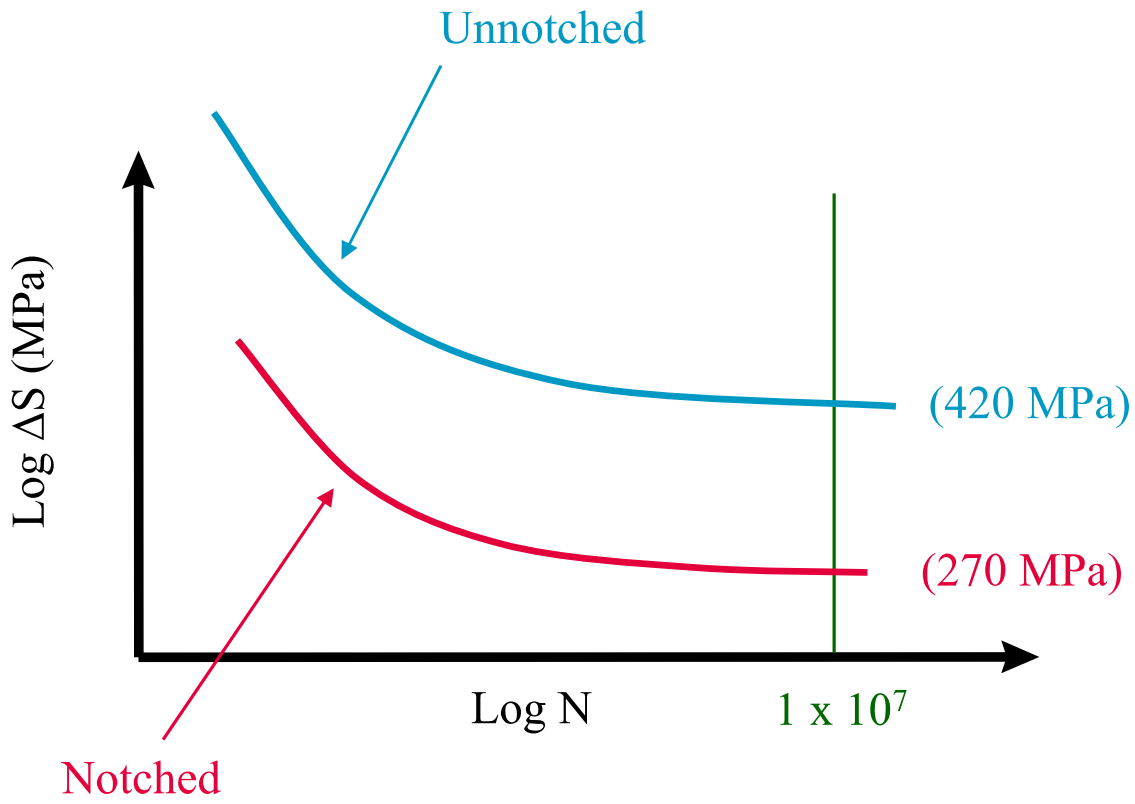


High Cycle Fatigue: S-N Curve



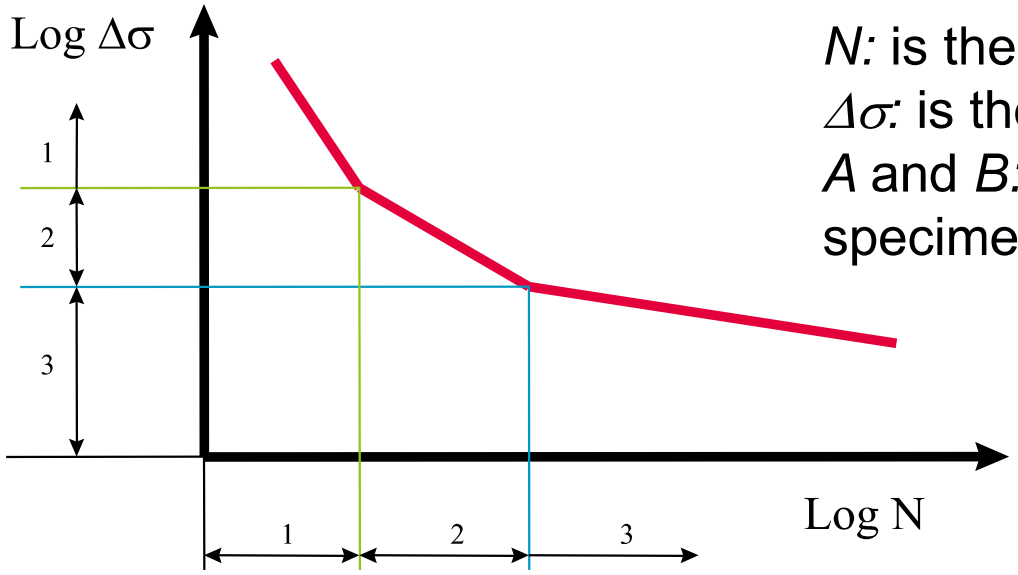
$N = a(\Delta\sigma)^B$ …Basquin Relationship

High Cycle Fatigue: Notch Sensitivity



High Cycle Fatigue: Stress-Life

$$Log_{10}N = A + BLog_{10}\Delta\sigma$$



N: is the number of cycles to failure
Δσ: is the stress range *(MPa)*
A and *B:* are constants specific to that specimen and test environment

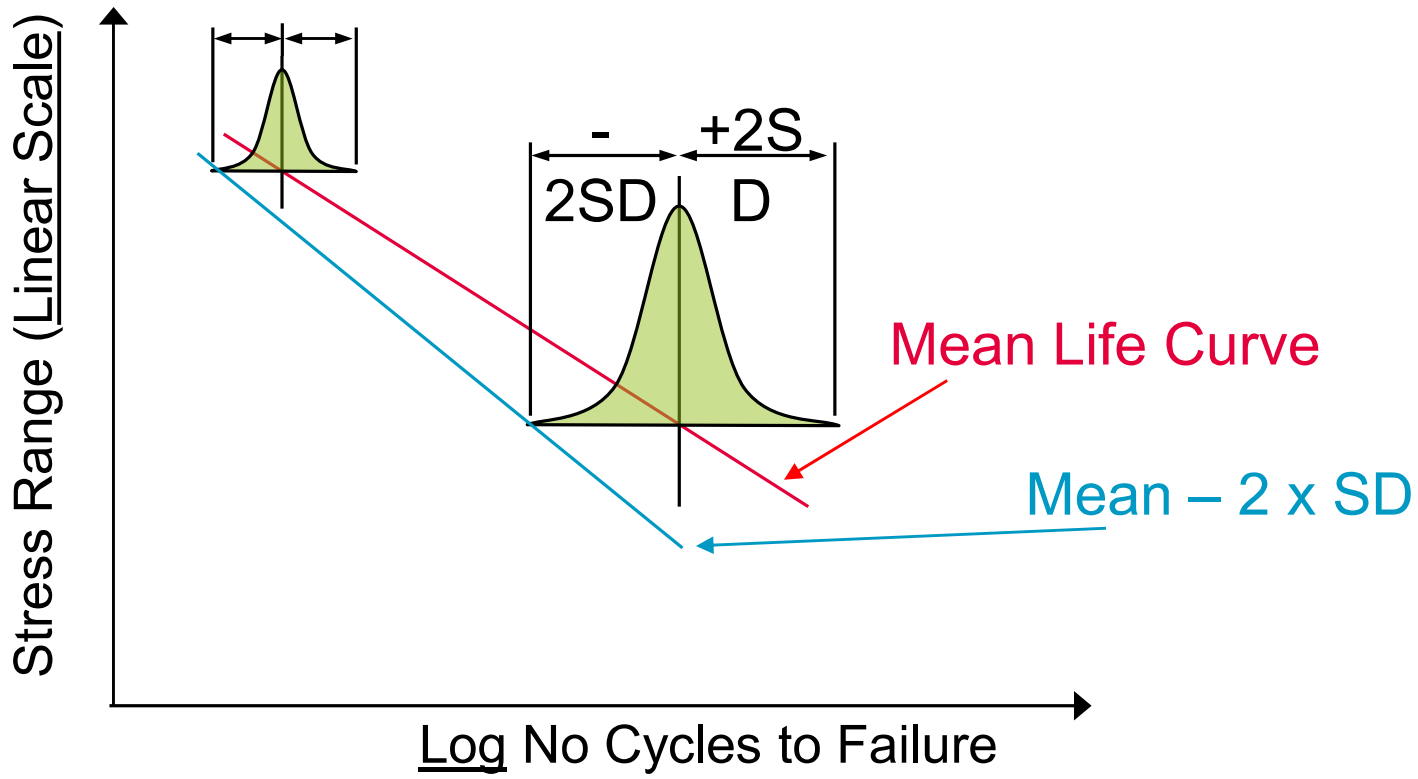
$$Log_{10}N = 12.182 - 3Log_{10}\Delta\sigma \quad (for\ N < 10^7)$$

$$Log_{10}N = 15.637 - 5Log_{10}\Delta\sigma \quad (for\ N > 10^7)$$

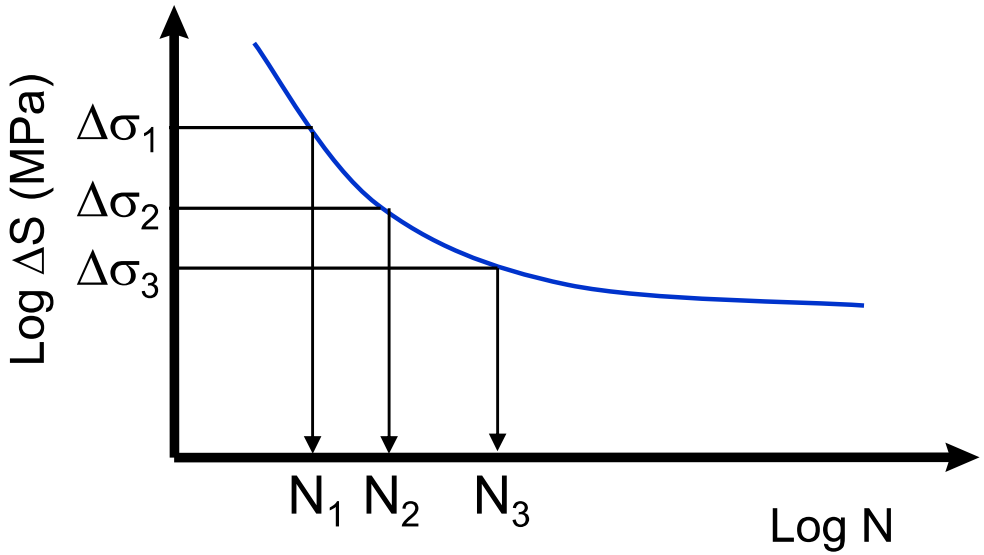
High Cycle Fatigue: Scatter

Inherent scatter in experimental data

Bigger scatter at lower stress ranges



High Cycle Fatigue: Cumulative Damage



No of Stress Ranges

$$D = \sum_{i=1}^{m} \left(\frac{n_i}{N_i} \right)$$

Damage

No of cycles at Stress Range ‘i’

…….Miner

No of cycles to failure at stress range ‘i’