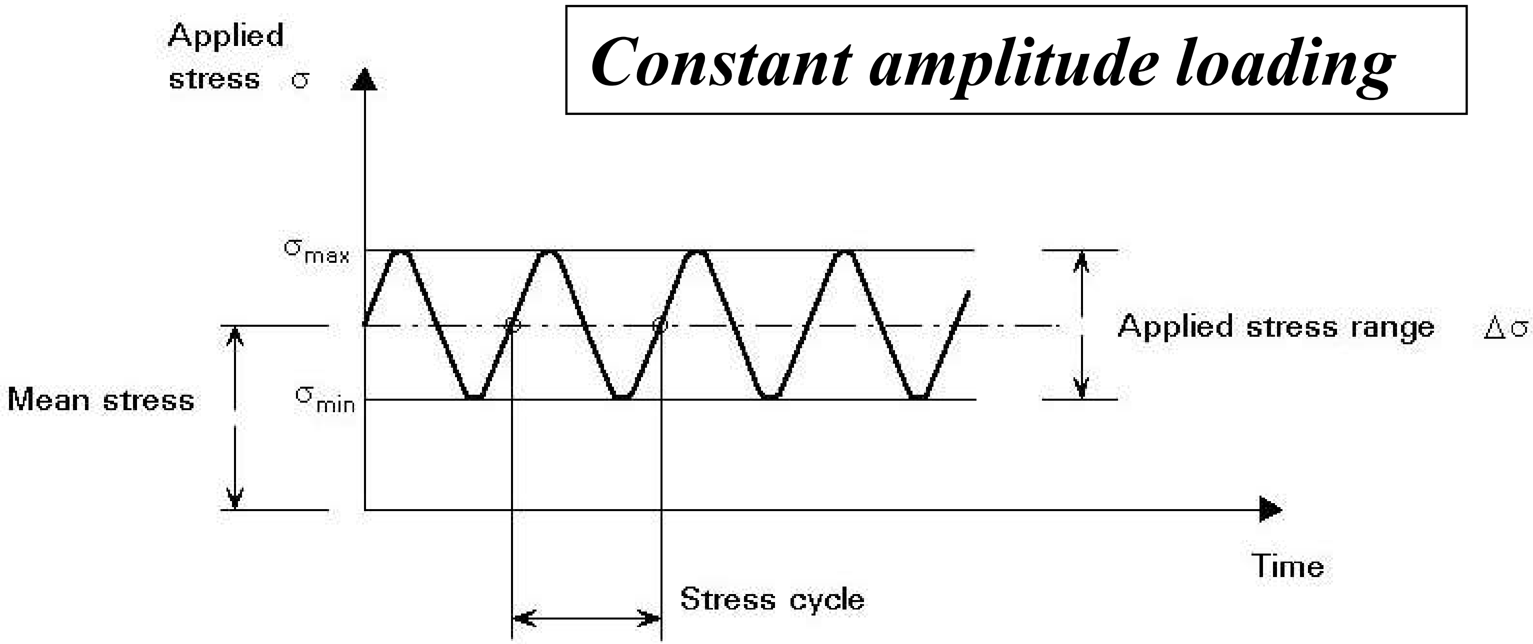
Parameters influencing fatigue life

The main parameters affecting the fatigue life of a bridge detail are:

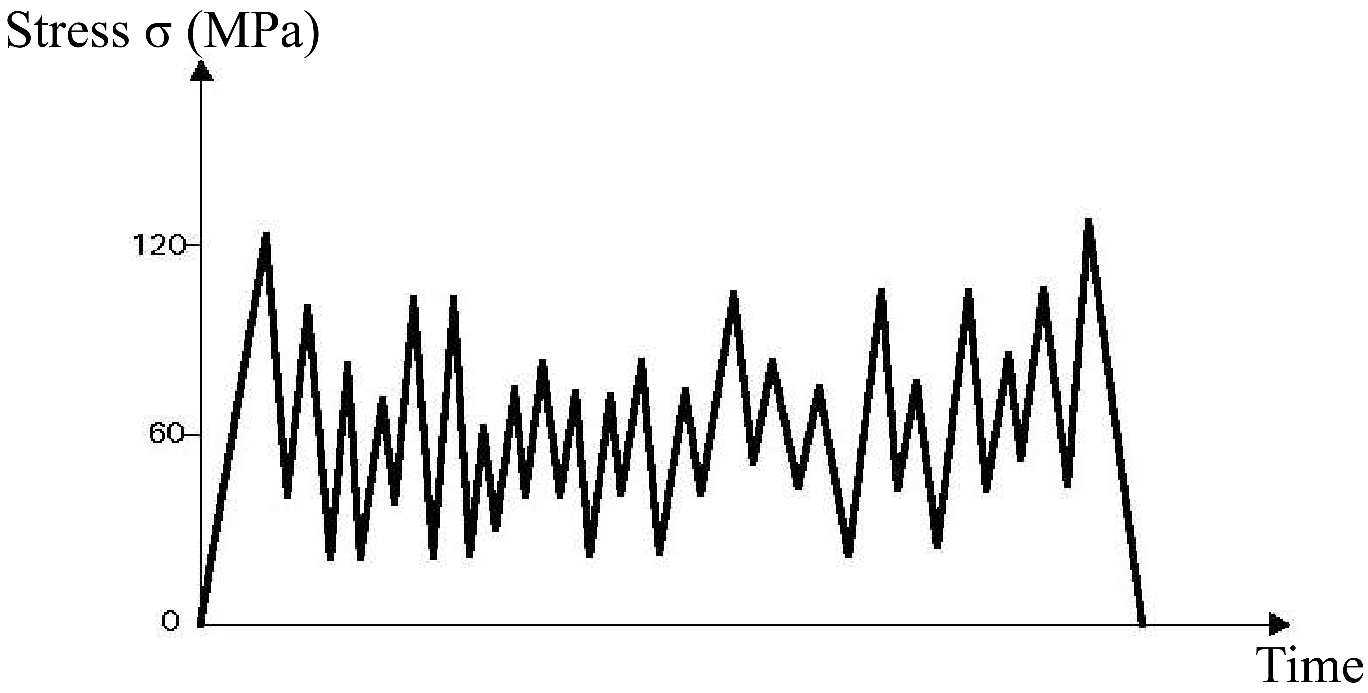
- the applied stress range
- the structural detail geometry
- the material characteristics
- the environment

Fatigue loading



- Stress range $\Delta\sigma = \sigma_{max} - \sigma_{min}$
- Mean stress $\sigma_m = \frac{1}{2}(\sigma_{max} + \sigma_{min})$
- Stress amplitude $\sigma_a = \Delta\sigma / 2$
- Stress ratio $R = \sigma_{min} / \sigma_{max}$

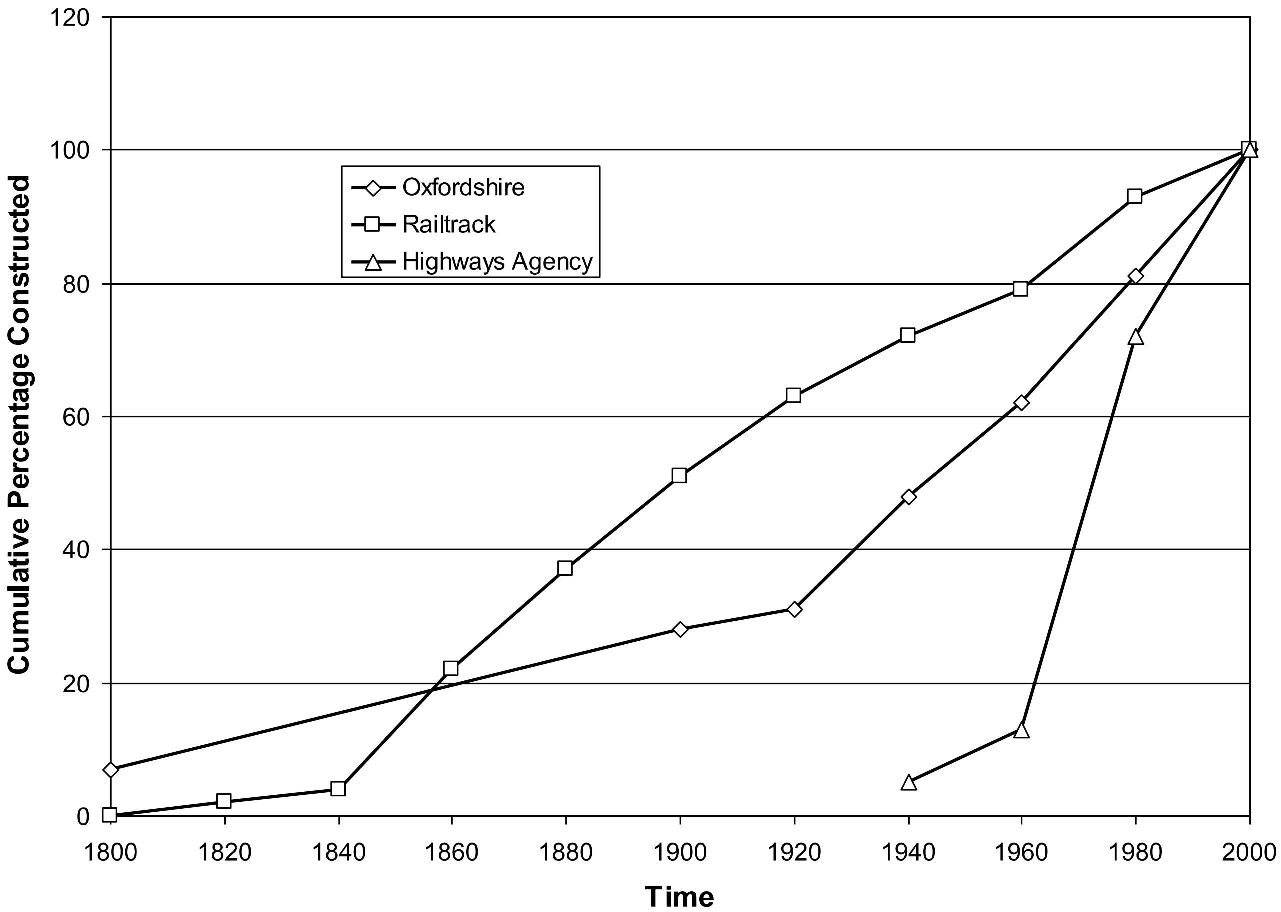
Fatigue loading



Variable amplitude loading

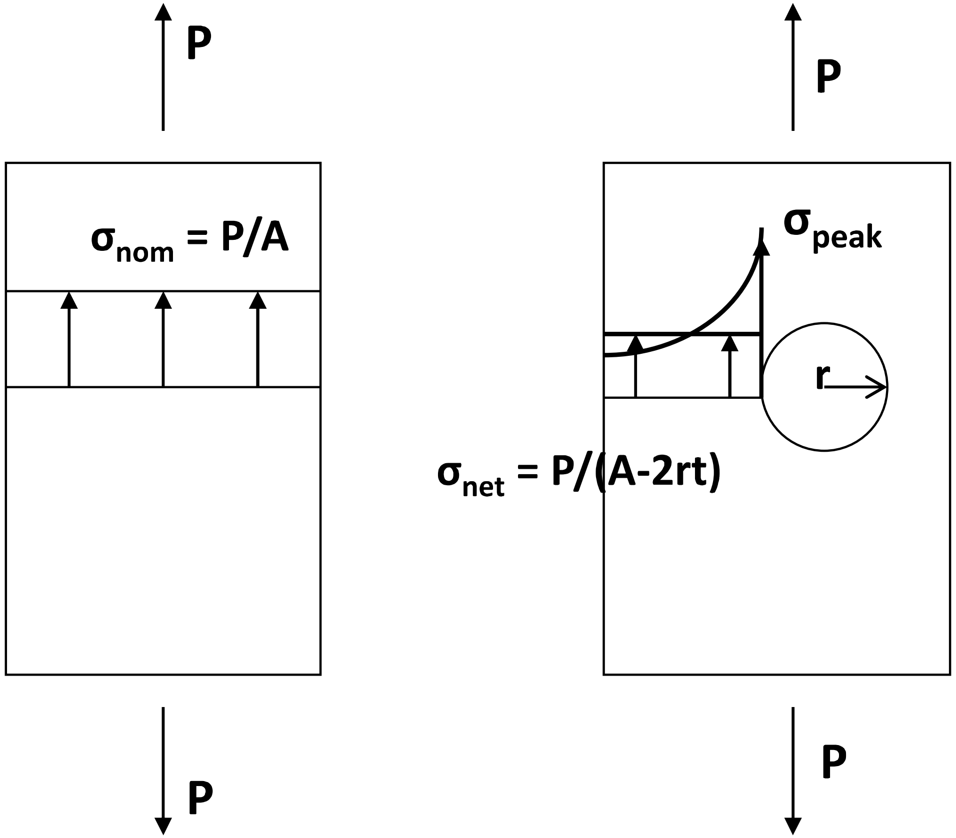
Bridge loading from live loads (e.g. vehicles, cars, trucks, trains)

Need for managing bridge fatigue



- Bridges built over the last 50 years or so are designed to be fatigue-resistant
- BUT there is a large number of steel bridges not designed for fatigue!
- Uncertainty and increase in traffic loads may lead to fatigue cracking
- Inspection and maintenance schemes need to be set on a rational basis

Fatigue & stress concentrations



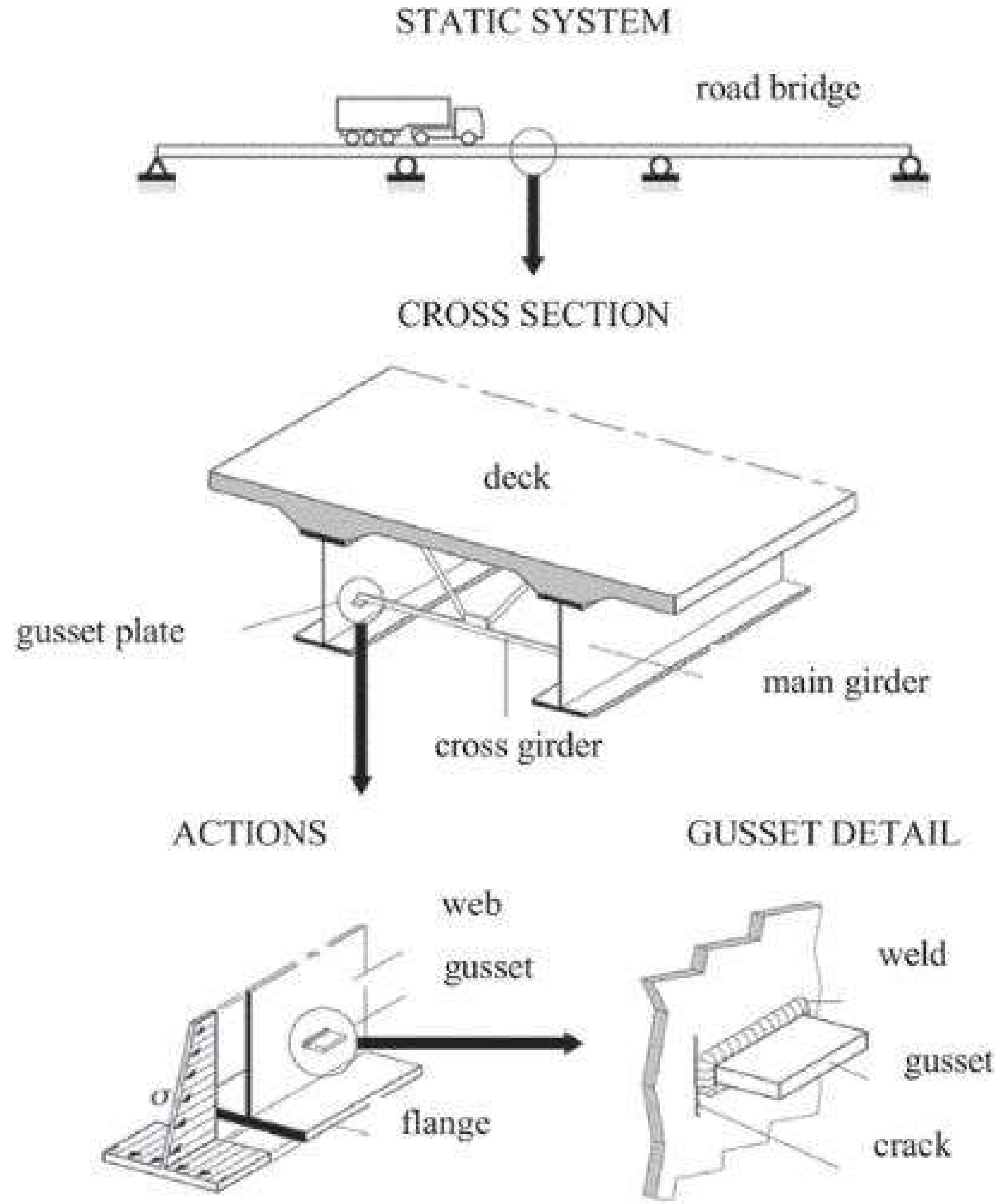
Stress concentration factor

$$K_t = \frac{\sigma_{peak}}{\sigma_{net}}$$

The higher K_t, the lower the fatigue life

- A stress concentration is the elevation of stresses, locally, beyond their nominal values
- Stress concentrations arise from any change in geometry, which disrupts the normal flow of stress
- Holes, notches and the connection of different elements give rise to stress concentrations
- Fatigue cracks are expected to form at the position of these local stress risers

Fatigue & stress concentrations

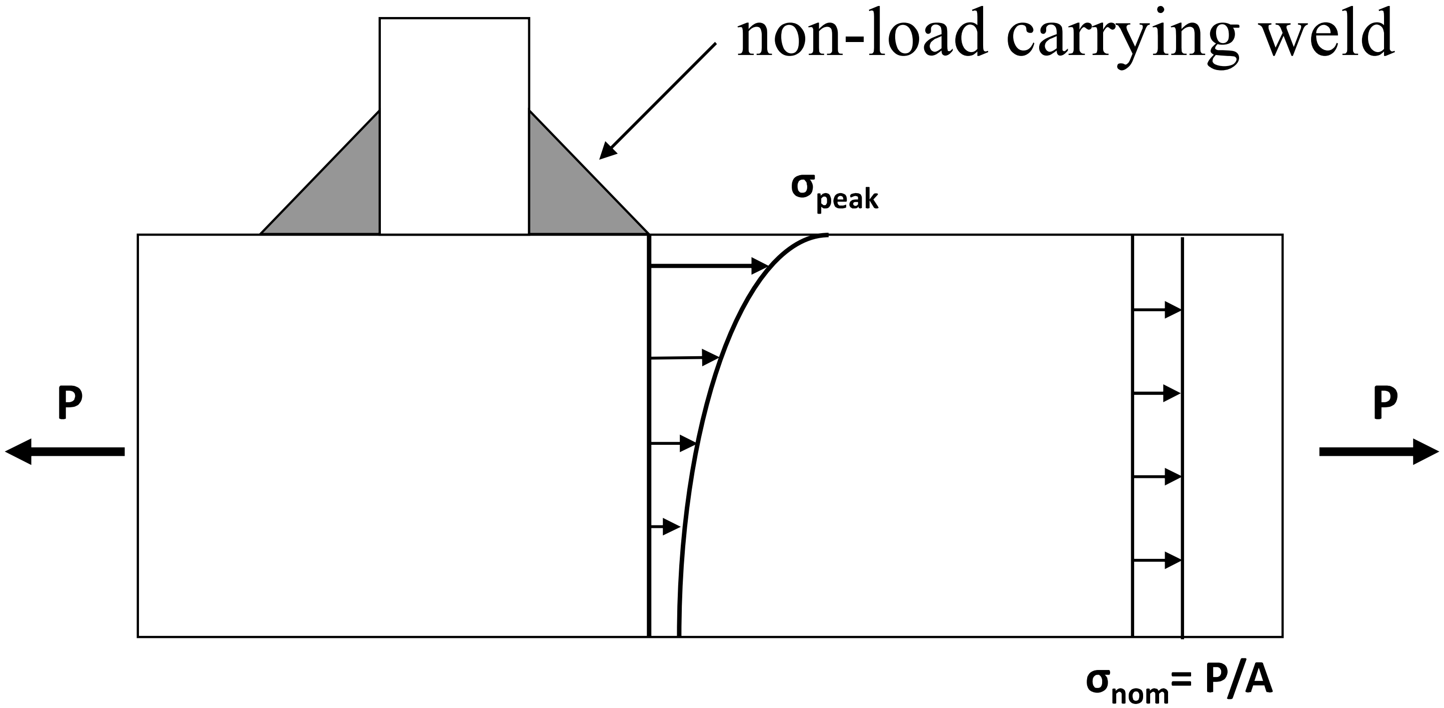


Possible location of a fatigue crack in a road bridge

Fatigue in welded details

Form a considerable part of modern bridge construction. Welded details are particularly prone to fatigue because of :

a) Stress concentrations

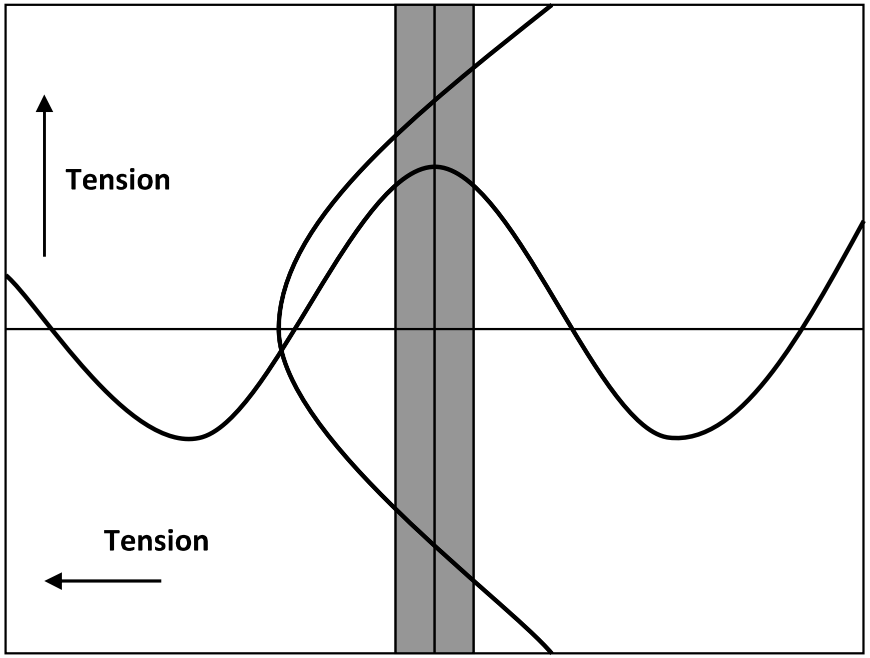


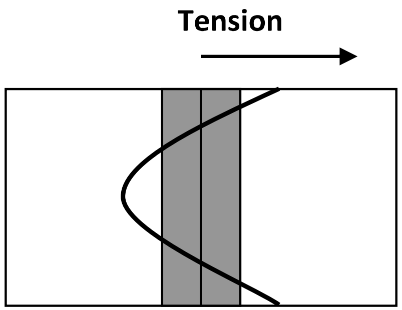
- Since a welded detail connects two different members, stress concentrations are expected at the position of the locally changing geometry
- In the case shown in this figure a crack is expected to grow at the toe of the fillet weld

Fatigue in welded details

Welded details are particularly prone to fatigue because of :

b) High residual stresses





Through-thickness

- Fatigue cracks and failure can occur in welded members which are nominally in compression due to large tensile residual stresses

Fatigue in welded details

Welded details are particularly prone to fatigue because of :

b) High residual stresses

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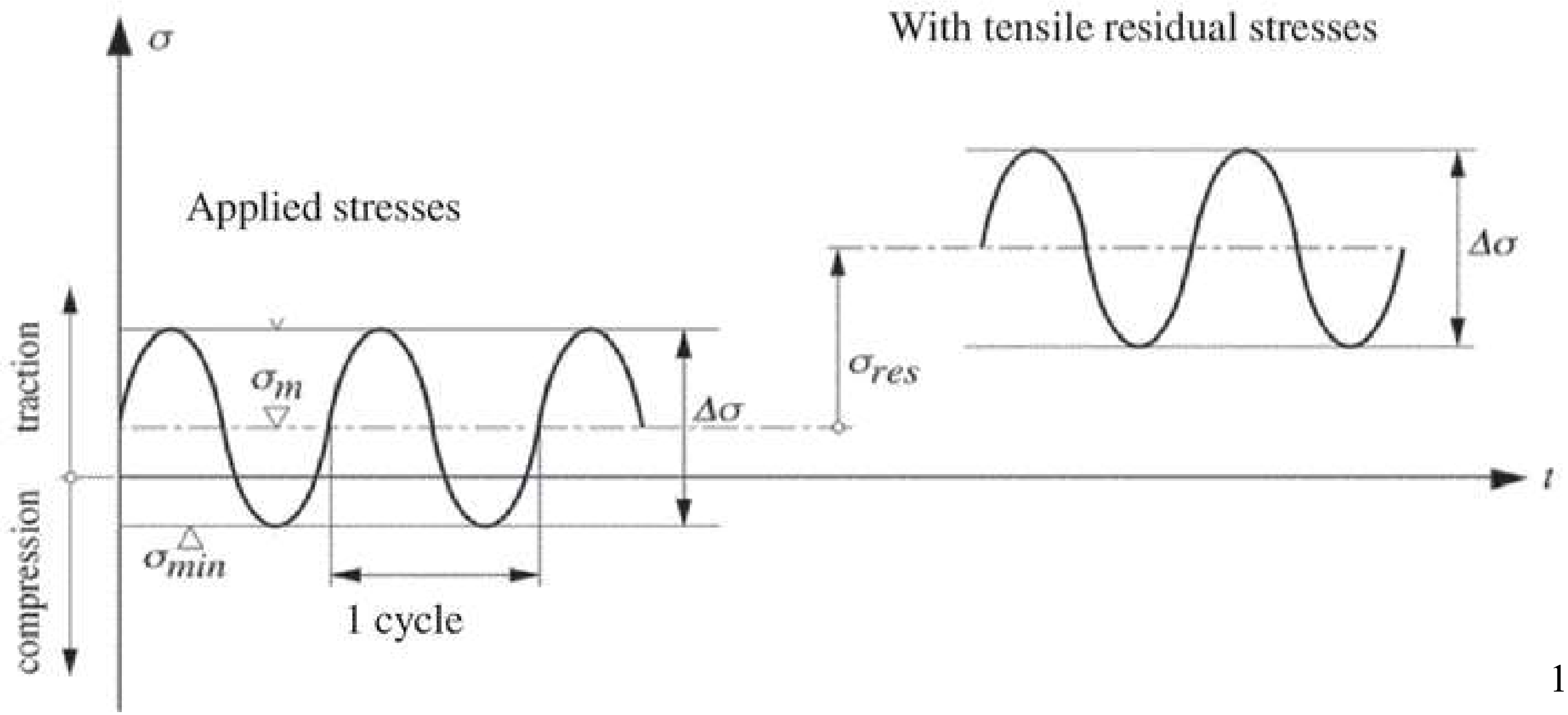
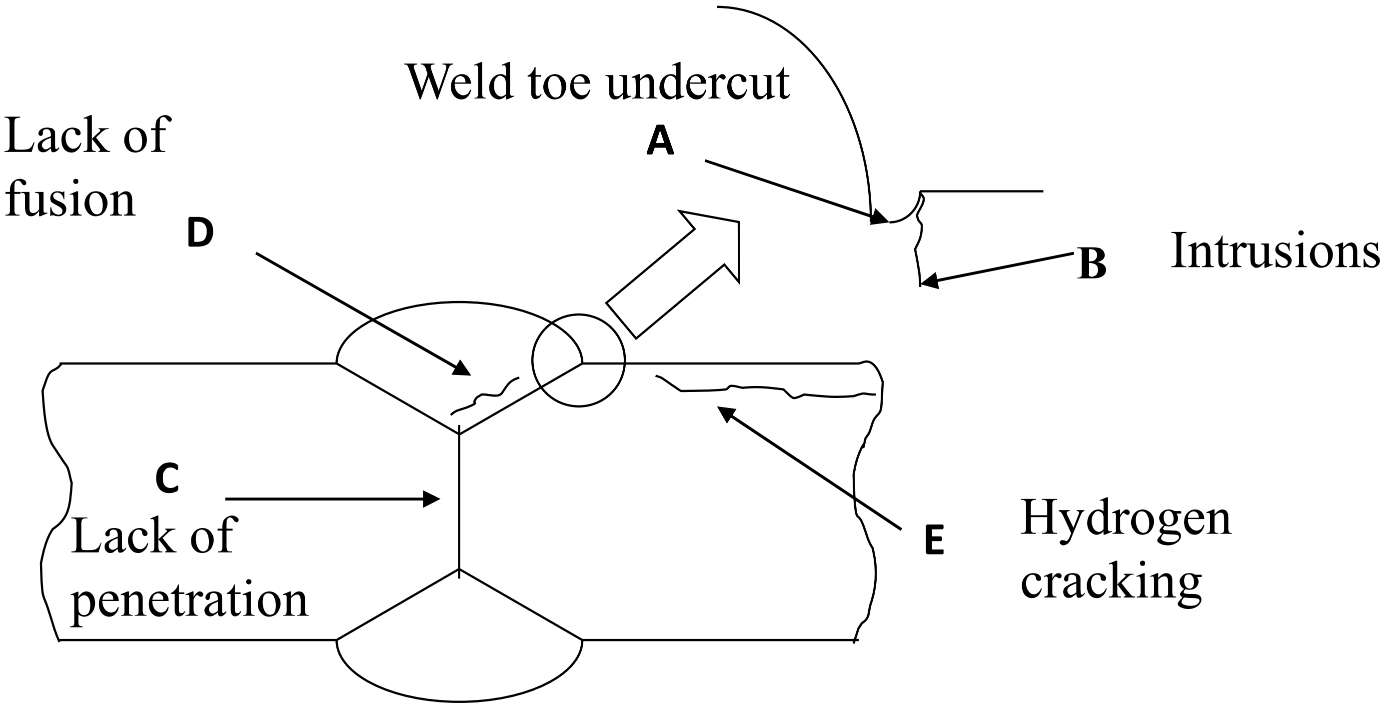


Fatigue in welded details

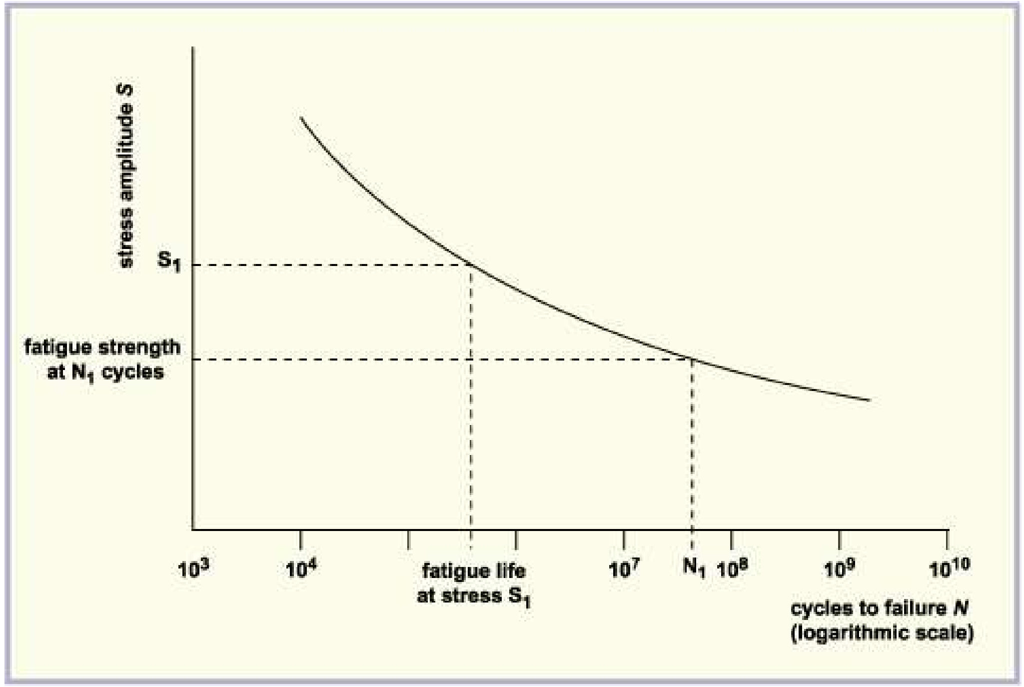
Welded details are particularly prone to fatigue because of :

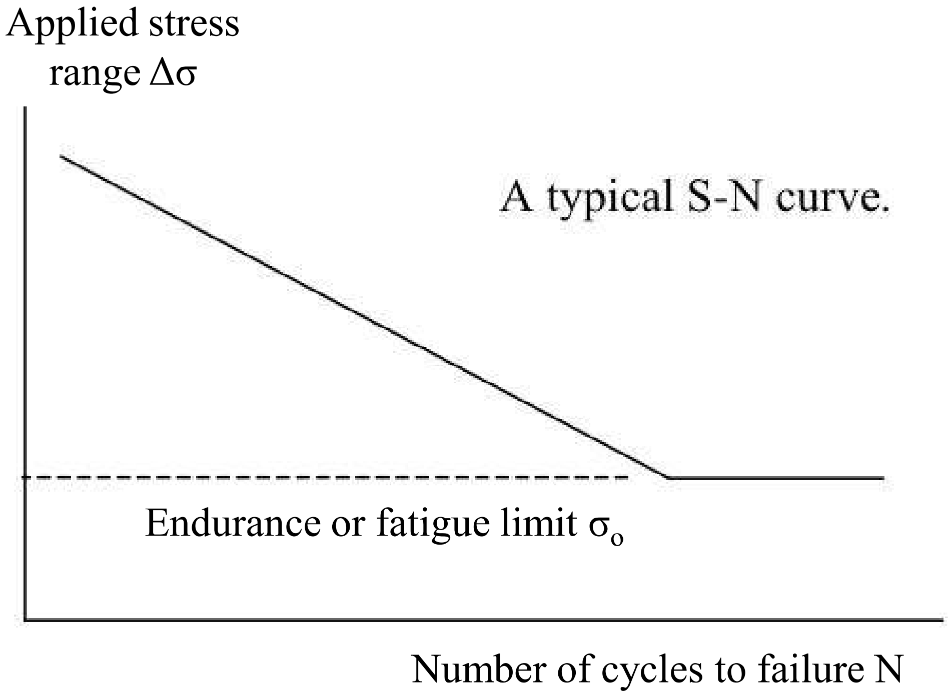
c) Pre-existing flaws (<u>always</u> present)



- All fusion-welding processes invariably result in the formation of defects
- How critical a crack is for the fatigue life of a welded detail depends on
  - i) Its orientation with respect to the applied loading
  - ii) Its size and location

Fatigue strength (S-N curves)

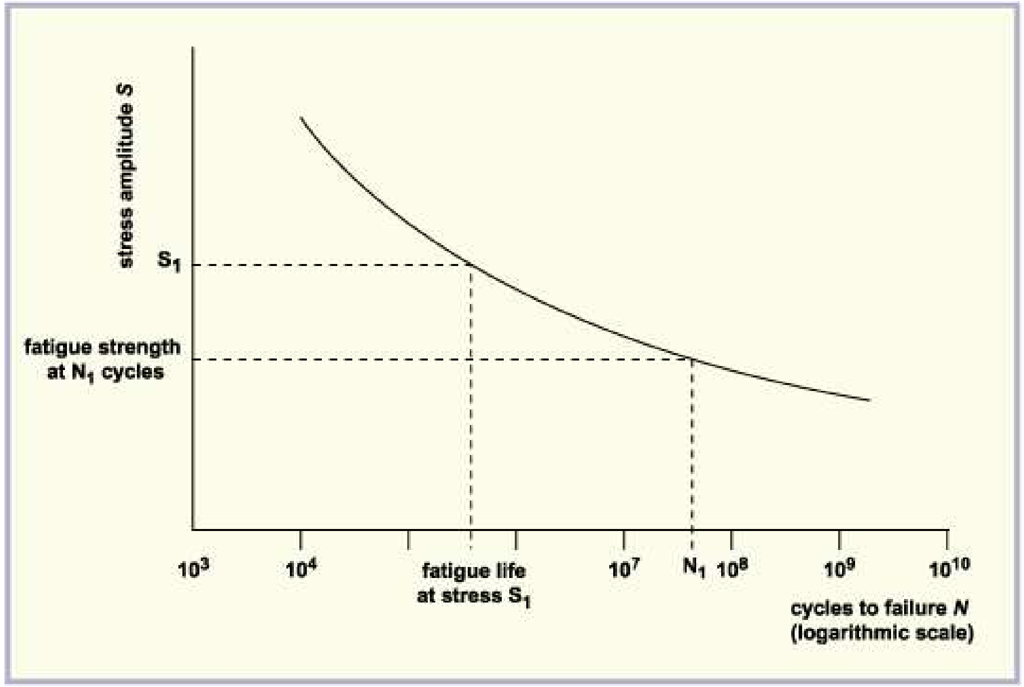


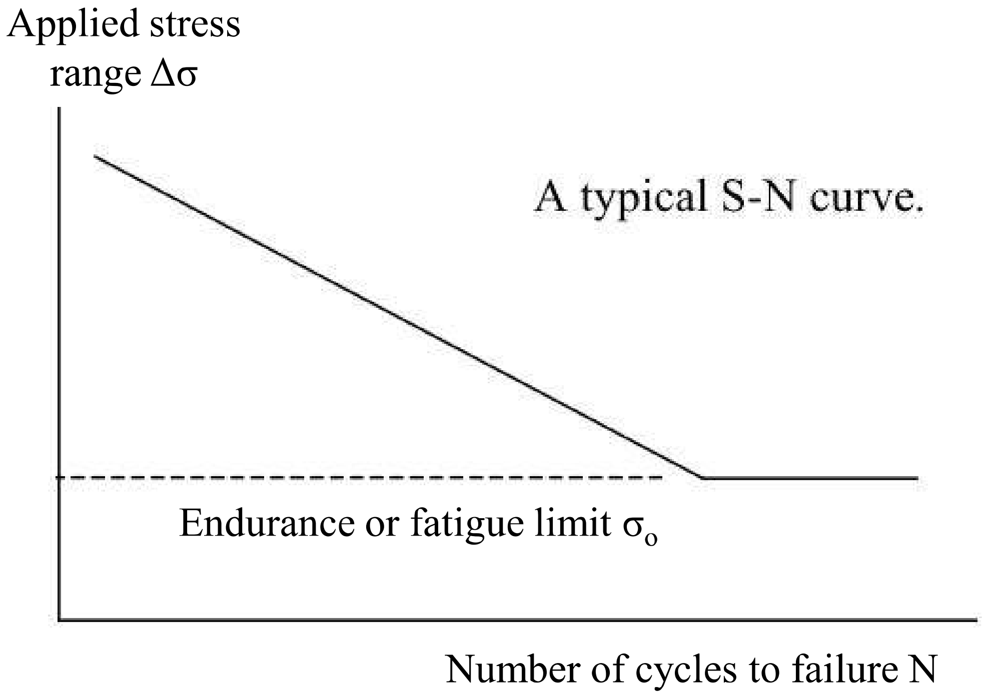


Both Δσ and N in logarithmic scale

- S-N curves plot the fatigue life N of a specimen versus the applied stress range *Δσ*
- Based on experiments of constant amplitude fatigue loading on nominally identical specimens
- An endurance or fatigue limit exists below which no visible cracks form. For this constant amplitude stress range the fatigue life is considered infinite
- For welded specimens, fatigue is typically investigated in the range 10^5-2×10^6 or 10^7
- Forms the basis of the fatigue design rules in bridge design and assessment codes

Fatigue strength (S-N curves)





Both Δσ and N in logarithmic scale

- S-N fatigue experiments result in an approximate relationship

$$N = \frac{A}{\Delta\sigma^m} \qquad \text{or} \qquad \log(N) = \log(A) - m \cdot \log(\Delta\sigma)$$

- Linear regression analysis may be carried out in order to determine *m* and *A*