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Fatigue process in materials

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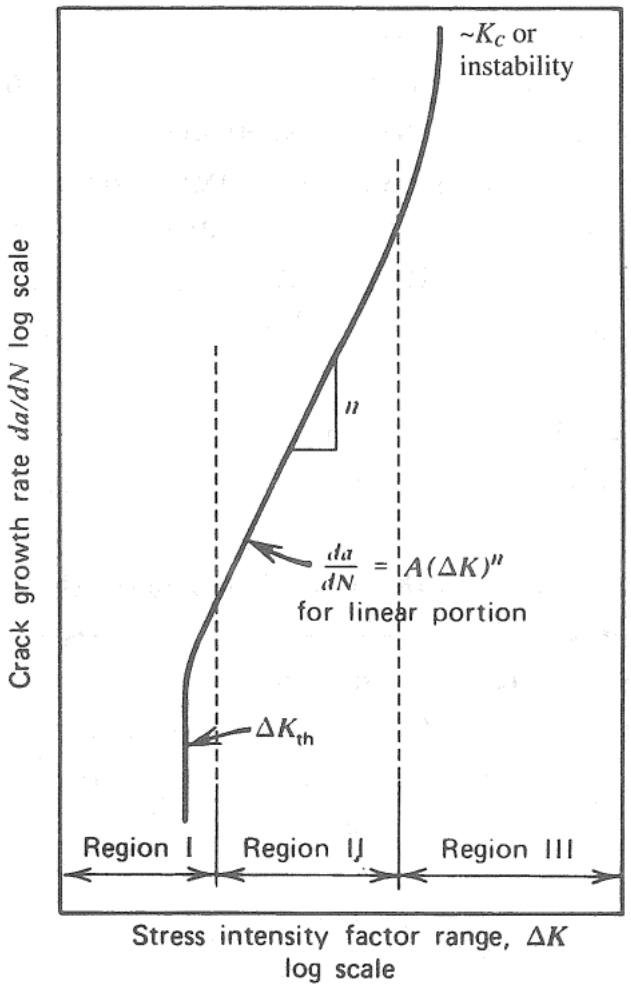
Fatigue and fracture mechanics

- The fatigue process can be considered as a sequence of small fracture processes.
- The crack growth depends on the stress intensity factor.
- The crack growth also depends on some material parameters.
- The final breakdown is a fracture problem. The structure will break when the fatigue crack become unstable.

Fatigue process

- Crack initiation
- Crack growth (Paris law)
- Final breakdown



Fatigue process

- The number of cycles in the crack initiation phase will in general be hard to predict.
  - Depend on imperfections in material.
  - Formations of micro-cracks.
- The number of cycles in the crack growth phase can be predicted quite good.
  - Growth of a macro crack.
- The number of cycles in the final stage is hard to predict.
  - Very few
  - The maximum crack size can be predicted quite well.

Fatigue process

- Minimum stress required to initiate fatigue cracks (K_threshold)
- Constant growth rate of fatigue cracks (A)
- Constant exponential growth rate depending on stress level (n)

- All the parameters are material values depending also on temperature.

Test results

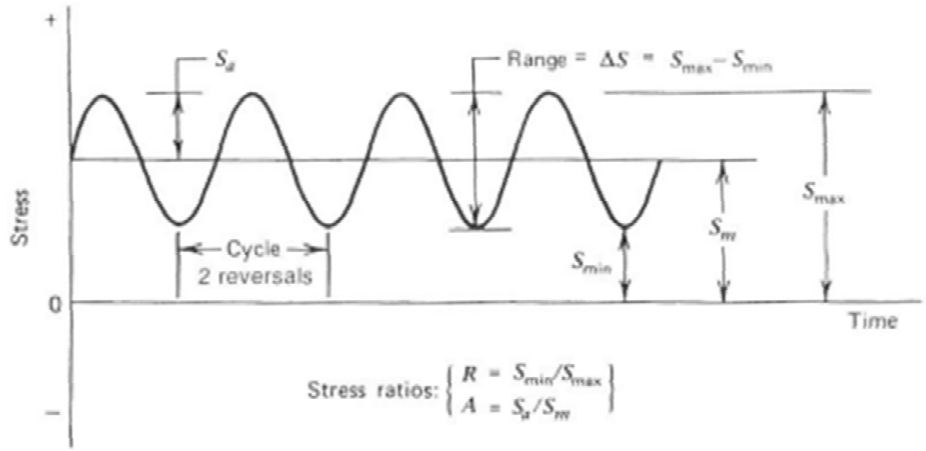


Figure 4.2 Nomenclature for constant amplitude cyclic loading.

- Test are typical done with sinusoidal stress variations.
- Som test on stochastic variations of stresses.
- Stress amplitude and average stress.

Experimental results

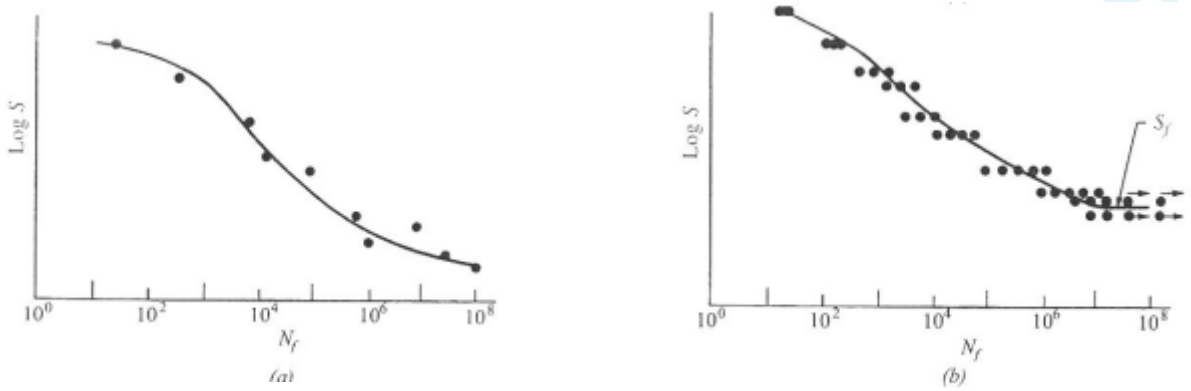


Figure 4.6 Typical S–N diagrams.

- Large variations (crack initiation phase)
- Tests not finished

Fatigue process – stress dependency

- Stress variations are the central element.
  - Principal stresses, tension or shearing components.

- For some materials the average stress has very little influence.
  - Pretensioned steel bolts
  - Welded steel

Fatigue problems

- High cycle-fatigue.
  - Large number of cycles (> 10^5)
  - Typical in windturbine towers and (most) other components.
- Low cycle-fatigue
  - Relative small number of components
  - Typical in components used in a very limited period.

Corrosion and fatigue

- Corrosion may considerably speed up the fatigue growth process.
- Threshold values for minimum stress values for fatigue crack growth are very small (or 0).
- Standards may require increased inspection and lower values of the Palmgren-Miner sum.

Time-dependent materials

- Time-dependent materials are timber and other polymeric based materials.
- Visco-elasticity – continued deformation under time.
- Time under load is of major importance.
- Interesting for windturbine blades.

Wind-turbine foundations - reinforced concrete

- Concrete is in general believed to be very resistant to fatigue.
  - True?
  - Concrete is mostly in compression
  - Shear gives both compression and tension.
- Grouted connections.
  - Transition piece.
  - Crack-formations.
- Soil fatigue
  - Monopiles and cyclic deformations.

Stress or strain driven

- Normally the fatigue process is dictated by load-variations which are transferred into stress variations.
  - Bolts in pretensioned connections.
- In other situations the variations are induced by strain variations.
  - Structure is deformed between two outer limits. (e.g. component in a device).
  - Less severe than stress driven as the load decreases.
- In statically indeterminate structures fatigue will have a component of strain driven.
- Fatigue cracks in circumferential welded connections?