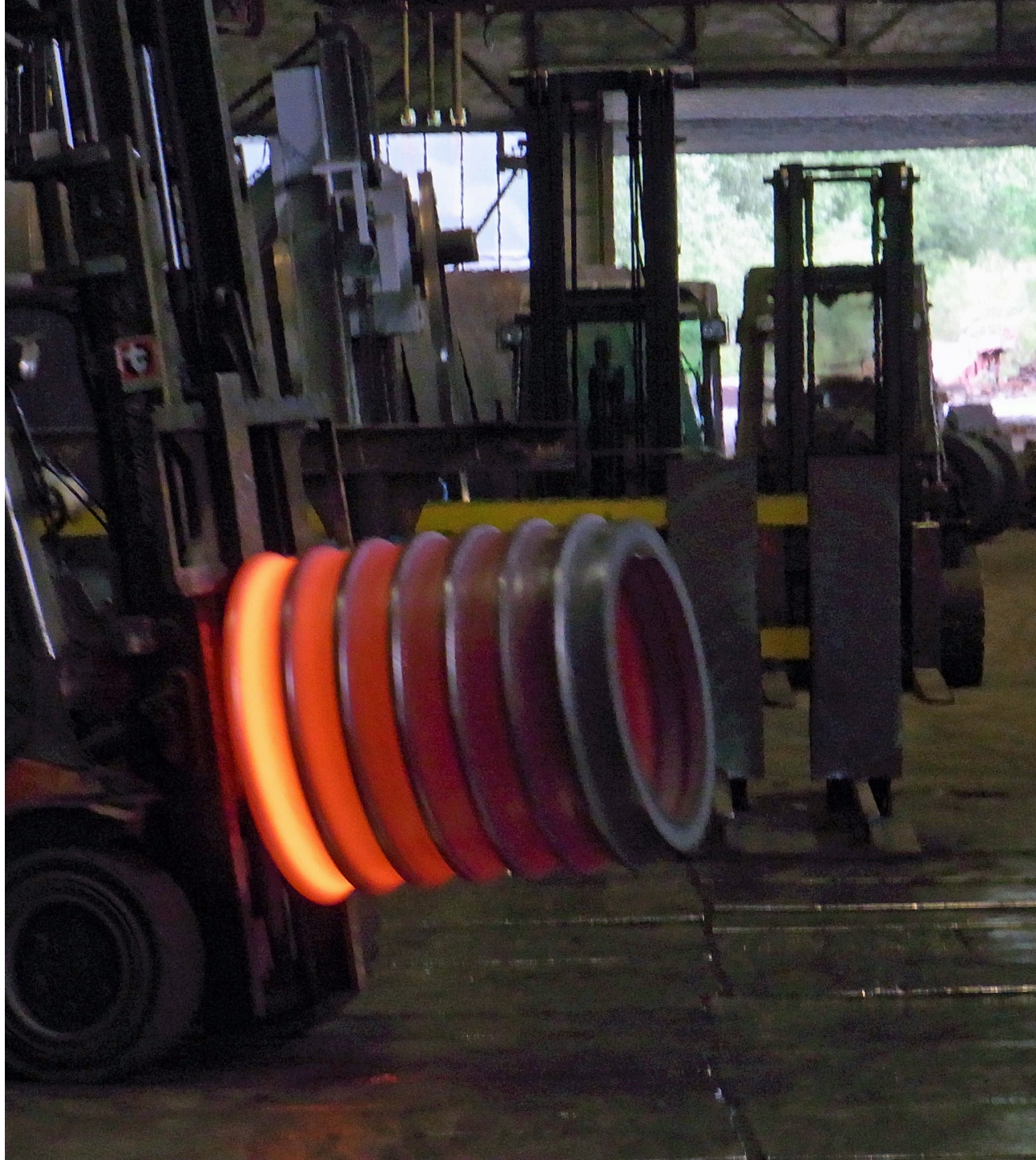
Lectures on Materials Science - Fatigue and wear

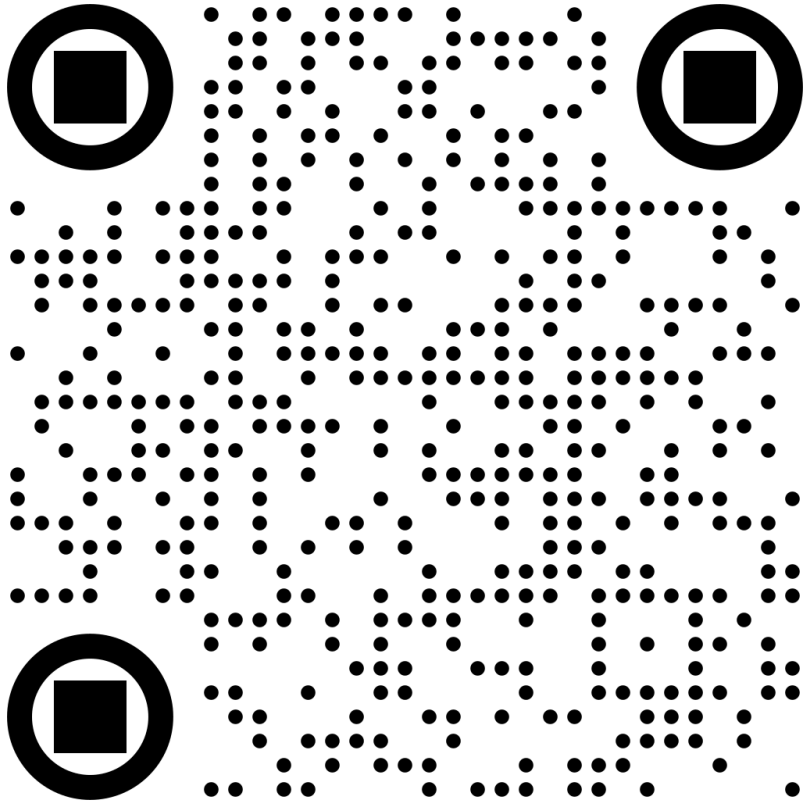
Prof. Dr.-Ing. Christian Willberg
Magdeburg-Stendal University of Applied Sciences

Contact: christian.willberg@h2.de

Parts of the script are adopted from
Prof. Dr.-Ing. Jürgen Häberle



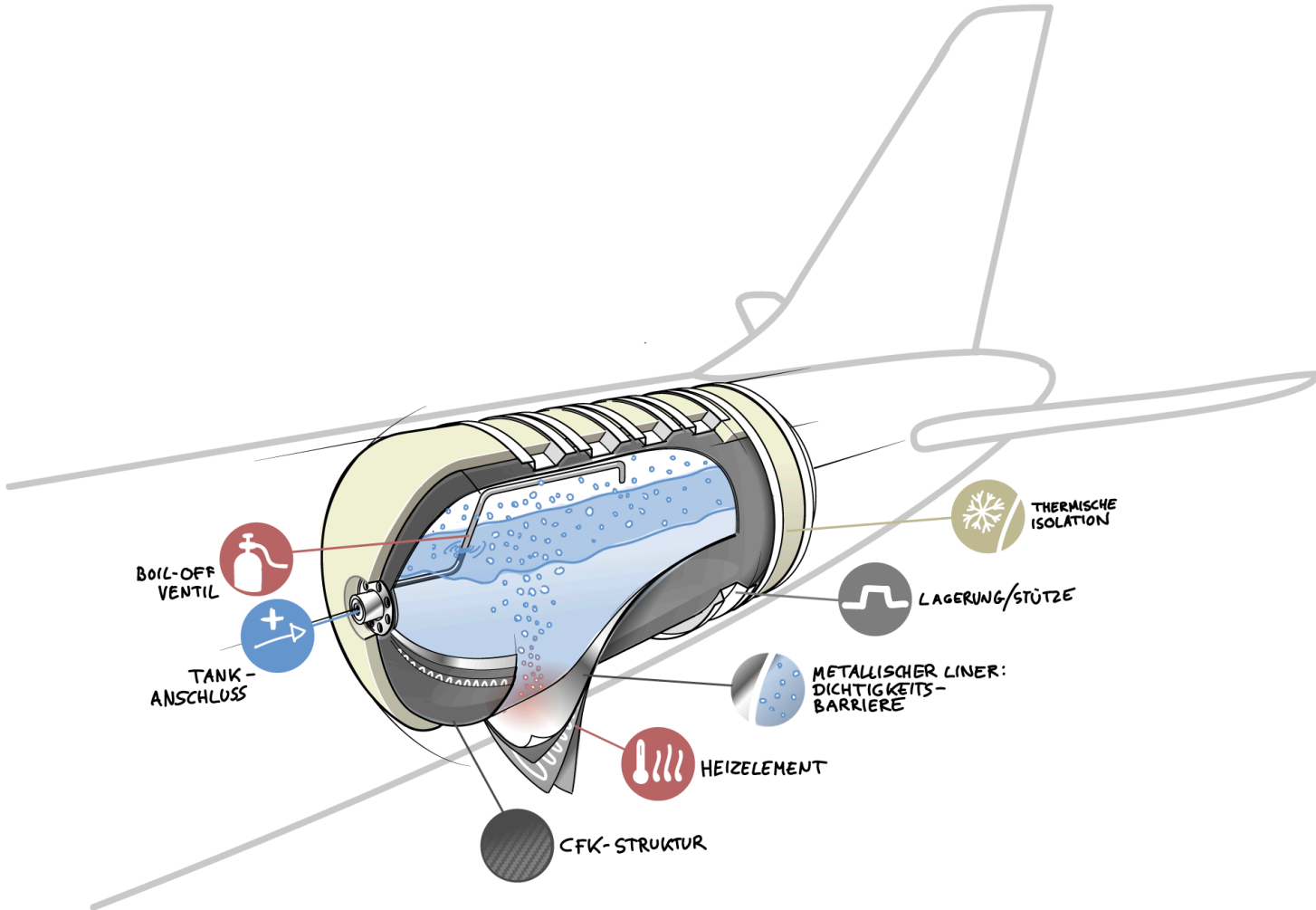
Topics



Fatigue

- What is Fatigue?

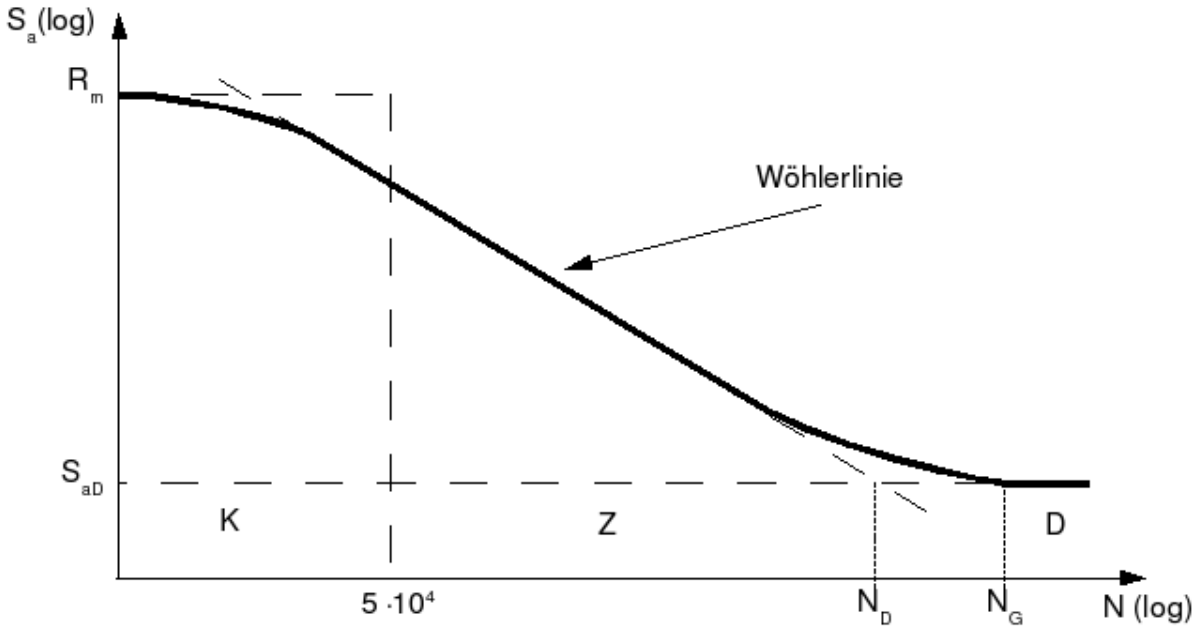
- Typically occurs with cyclic loading
  - Isothermal mechanical fatigue
    - Oscillating load
    - Aircraft fuselage (pressure build-up and release)
  - Thermal fatigue
    - Ovens, heating elements
  - Thermo-mechanical fatigue
    - High-pressure tanks
  - Electro-thermal fatigue
    - Electrical conductors (filaments)

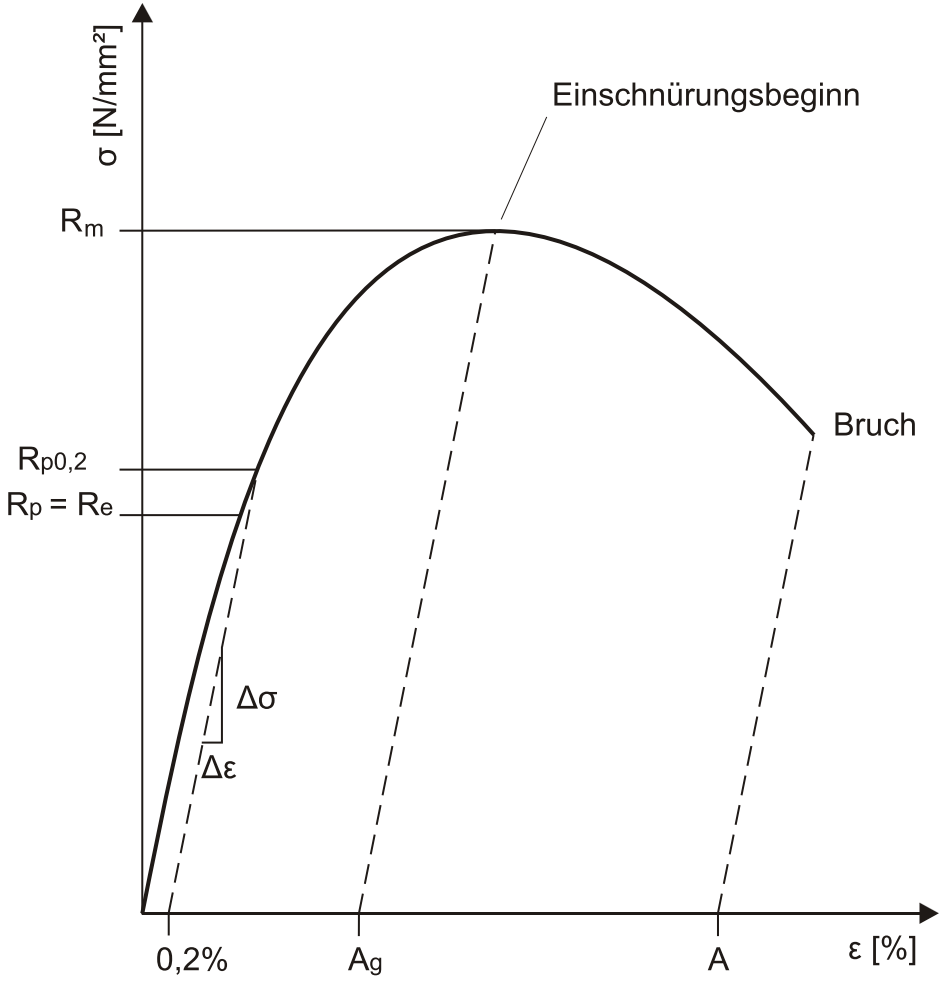

BOIL-OFF VENTIL
TANK-ANSCHLUSS
THERMISCHE ISOLATION
LAGERUNG/STÜTZE
METALLISCHER LINER: DICHTIGKEITS-BARRIERE
HEIZELEMENT
CFK-STRUKTUR

Fatigue

- The load is below the yield strength $R_{p0,2}$
  - > *Reminder: What does $R_{p0,2}$ indicate?*
- Stress concentrations occur in material defects (pores, microcracks, etc.) or in the crystal (dislocations, vacancies, etc.)
- Initially, randomly distributed regions of local plastic deformation develop under alternating loads
- These points represent stress concentration areas, which enlarge over time and can lead to fracture

Explanation video


S_a(log)
R_m
Wöhlerlinie
S_aD
K
Z
D
5 ·10⁴
N_D
N_G
N (log)


σ [N/mm²]
Einschnürungsbeginn
R_m
Bruch
R_p0,2
R_p = R_e
Δσ
Δε
0,2%
A_g
A
ε [%]

Terms

- Lifespan
- Fatigue crack
- Fatigue fracture
- Short-term strength (K)
- Operational strength (Time strength Z)
- Endurance limit (D)

Countermeasures

- Reduce notch effect
- Material adaptation
- Design adjustments to prevent local stress from exceeding allowable limits
- Regular inspections

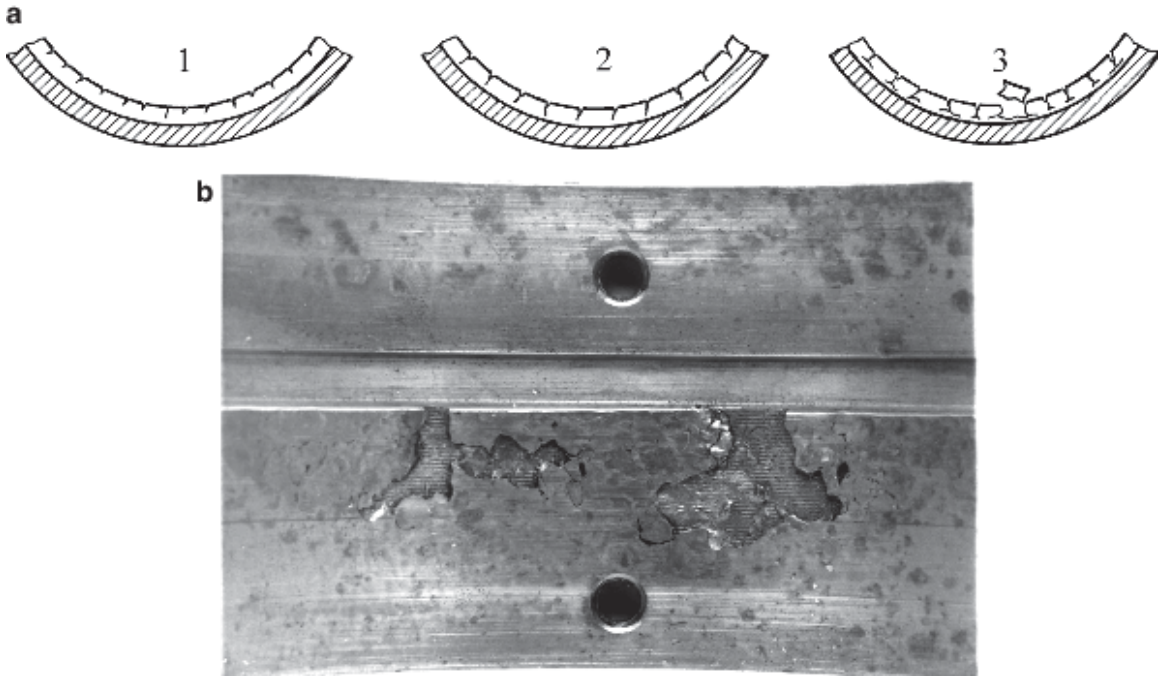
Wear

- Permanent deformation and material loss on the surface of solids due to friction
- Technologically unintended and can lead to functional failure
- Influenced by:
  - Frictional pairing
  - Surface layer and intermediate substance properties
  - Type of motion
  - Load intensity

Wear Type	Appearance	Primary Occurrence
Sliding wear	Grooves or furrows from abrasion, material transfer, or local melting	Unlubricated bearings, clutches, brakes
Rolling wear	Flaking due to fatigue cracks	Rail/wheel, rolling bearings
Pitting	Pitting formation: pitting	Rolling elements, especially gears
Abrasive wear	Plastic deformation, erosion	Excavating equipment, bulk material transport, particle impingement
Cavitation	Pitted surface with fatigue	Water turbines, pumps

Sliding Wear

- Influenced by
  - The average roughness depth R_z
  - Contact pressure
  - Wear path ratio $W = k\frac{F_N}{A}10^6$
  - k in $\left[\frac{mm^3}{Nm}\right]$ specific wear rate (independent of load)



Rolling Wear

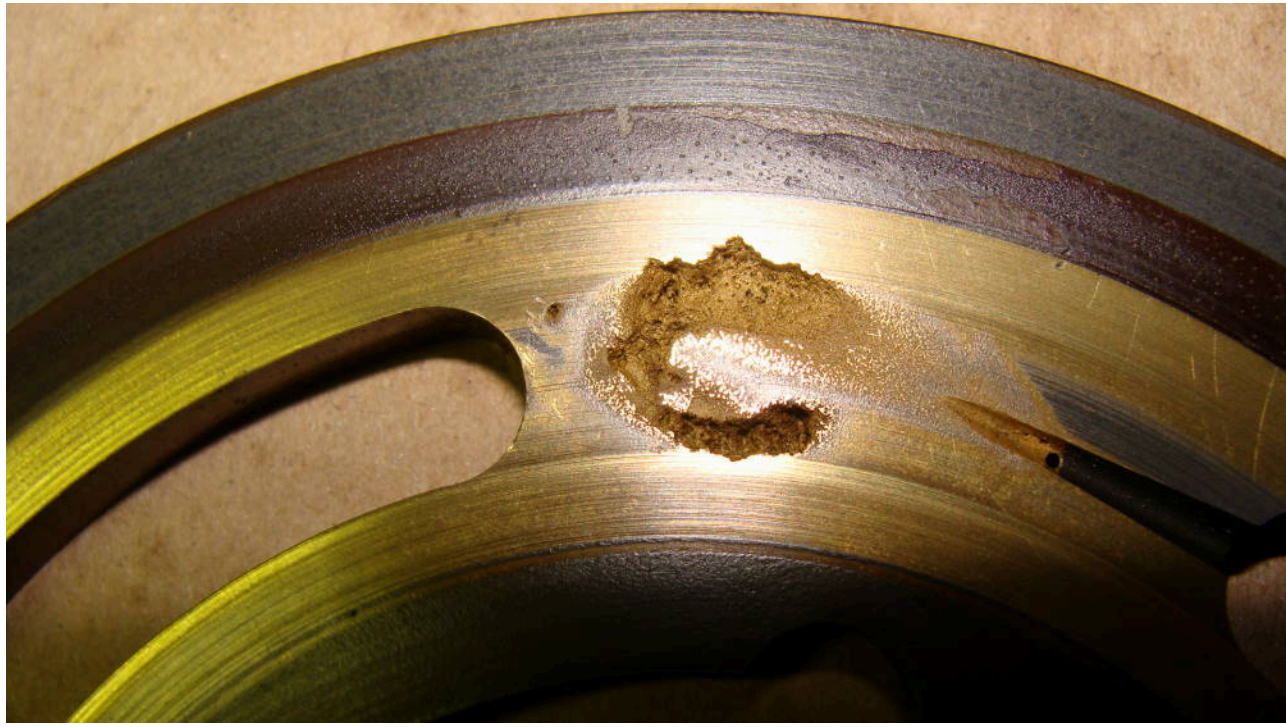
- Rolling involves slip components superimposed on the rolling process
- Small contact area; high surface pressure
- Surface degradation (plastic deformation, microstructure changes, etc.)
- Can be significantly reduced by lubrication $\rightarrow$ specific lubricant film thickness λ

Cavitation

Video

- Physical cause?

- Localized stress on the surface
- These regions weaken and flake off
- Surface is affected by:
  - Efficiency reduction
  - Corrosion
  - Areas where cracks can initiate



Fretting Corrosion

- Sliding motions between two highly loaded components
- Typically occurs with insufficient interference fit $\rightarrow$ Fits