FAMSE – Exercise 2

Creep Fundamentals/ Ni-base Superalloy Single Crystals/ Martensitic Transformation & Shape Memory Alloys (SMA)/ SMA Fracture Mechanics & Basics of Structural Fatigue

(1) Creep Fundamentals

1.1 What is creep?

1.2 What is a stress rupture plot (text and drawing)?

1.3 What is the Larson Miller Parameter?

1.4 Why is there a need to extrapolate from short term creep data into the long-term regime (text and drawing)?

1.5 How does a generic creep curve look like (plots: strain vs. time, log strain rate vs. strain)?

1.6 Explain the dependence of creep-curves on stress/temperature changes (text and drawing)

1.7 How does the secondary creep rate depend on stress and temperature (equation)?

1.8 How can the stress exponent *n and activation energy* Q_{app} be determined?

1.9 What role plays dislocation climb in creep?

1.10 Schematically draw an Ashby map and explain the principle behind it.

(2) Ni-base Superalloy Single Crystals

2.1 Name five alloy elements which are typically contained in superalloy single crystals except for Ni.

2.2 How does the Bridgman process work (drawing)?

2.3 What is the problem with a dislocation entering an ordered crystalline phase?

2.4 Why do γ'-precipitations form cubes?

2.5 What are the γ and γ' phases in Ni-based superalloys? Draw the unit cells and explain the two basic differences.

2.6 Provide drawings which explain the early (decreasing creep rates) and later (from creep rate minimum) stages of single crystal super alloy creep.

2.7 What is rafting?

(3) Martensitic Transformation & Shape Memory Alloys (SMA)

3.1 Why is martensite in steel hard while martensite in NiTi shape memory alloys is soft?

3.2 What does martensitic transformation and twinning have in common? What are the differences?

3.3 Sketch the Bain orientation relationship for a diffusionless martensitic phase transformation from the austenite! Determine the crystallographic directions/planes in the body centered tetragonal unit cell, which are parallel to $(111)_\gamma$, $[-101]_\gamma$, $[1-10]_\gamma$ and $[11-2]_\gamma$!

3.4 Why are accommodation processes required?

3.5 What are the invariants of a martensitic transformation?

3.6 Explain how the one way effect (1WE) and pseudoelasticity (PE) works (drawings).

3.7 Provide the Clausius Clapeyron equation? How does it help to describe the strong temperature dependence of the pseudoelastic plateau stress in the loading part of a loading/unloading experiment?

(4) SMA Fracture Mechanics & Basics of Structural Fatigue

4.1 What is the crack extension force G, how does it relate to the stress intensitiy factor K?

4.2 What information on elementary processes in front of cracks in SMAs can one obtain using in-situ scanning electron microscopy (SEM), a thermocamera and synchrotron radiaton?

4.3 What is the difference between structural and functional fatigue?

4.4 Draw $\sigma(t)$ diagrams for the three possible cases of loading of a fatigue experiment. Highlight the following parameters: σ_{max}, σ_{min}, σ_a. What is the definition of R?

4.5 The performance of fatigue testing under tension and/or compression can be stress or strain controlled. Please draw under the consideration of a)-d) stress-strain diagrams, which describe the curve evolution from the beginning of the first changing in load until saturation, respectively. Additionally draw for each case three single diagrams for σ_a, $\varepsilon_{tot} = \varepsilon_{el} + \varepsilon_{pl}$ and ε_{pl} in dependence of the number of load cycles N. For this holds $\sigma_m=0$.
a) σ_a = const., $\varepsilon_{pl} = 0$,
b) σ_a = const., material softens,
c) ε_{pl} = const., material hardens,
d) ε_{tot} = const., material hardens.

4.6 Why do we observe a stress strain hysteresis during fatigue testing?

4.7 What is a Wöhler curve?

4.8 What is the Paris law?

4.9 What is the Bauschinger effect?

4.10 What is the microstructural origin of functional fatigue?