Heavy section austenitic stainless steel for the future header and piping material in high-efficient biomass fired power plants

- Microstructural evolution during high temperature dwell-fatigue

KME-801

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CONSORTIUM MATERIALS TECHNOLOGY

for development and demonstration of thermal energy processes

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Sumitomo SHI FW

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CONSORTIUM MATERIALS TECHNOLOGY
for development and demonstration
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Outline

- Background
- Method
- Results
- Summary

Background

- Future power generation needs to be more efficient and flexible.
- Increasing demands on mechanical properties of the materials in critical components.
- Influence of cyclic high temperature deformation, creep, creep-fatigue interaction (CF) and long term service.

Gärdstadverken Linköping.
Photo Åke E. Lindman

Fuel

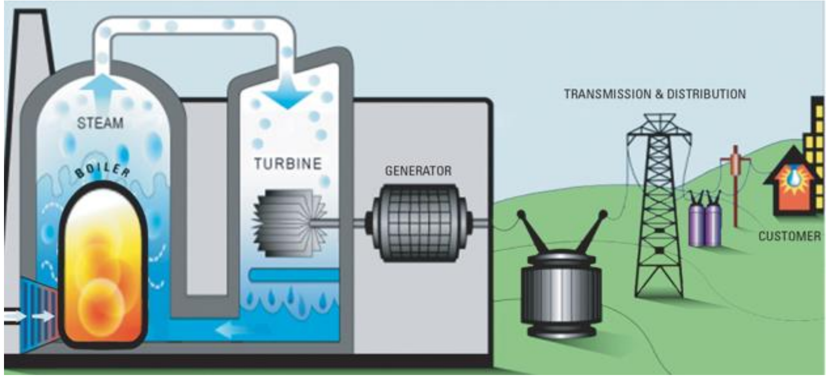
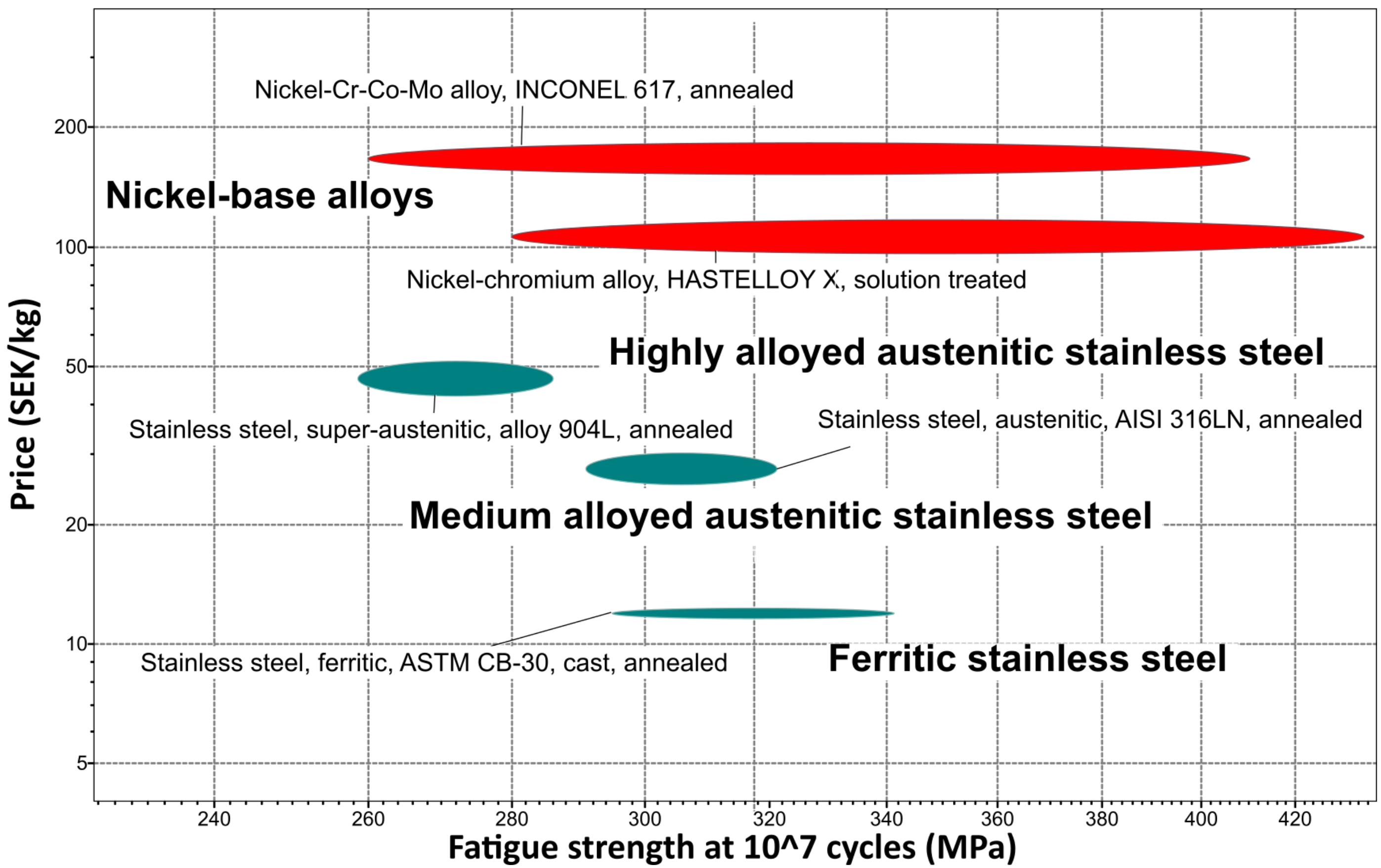
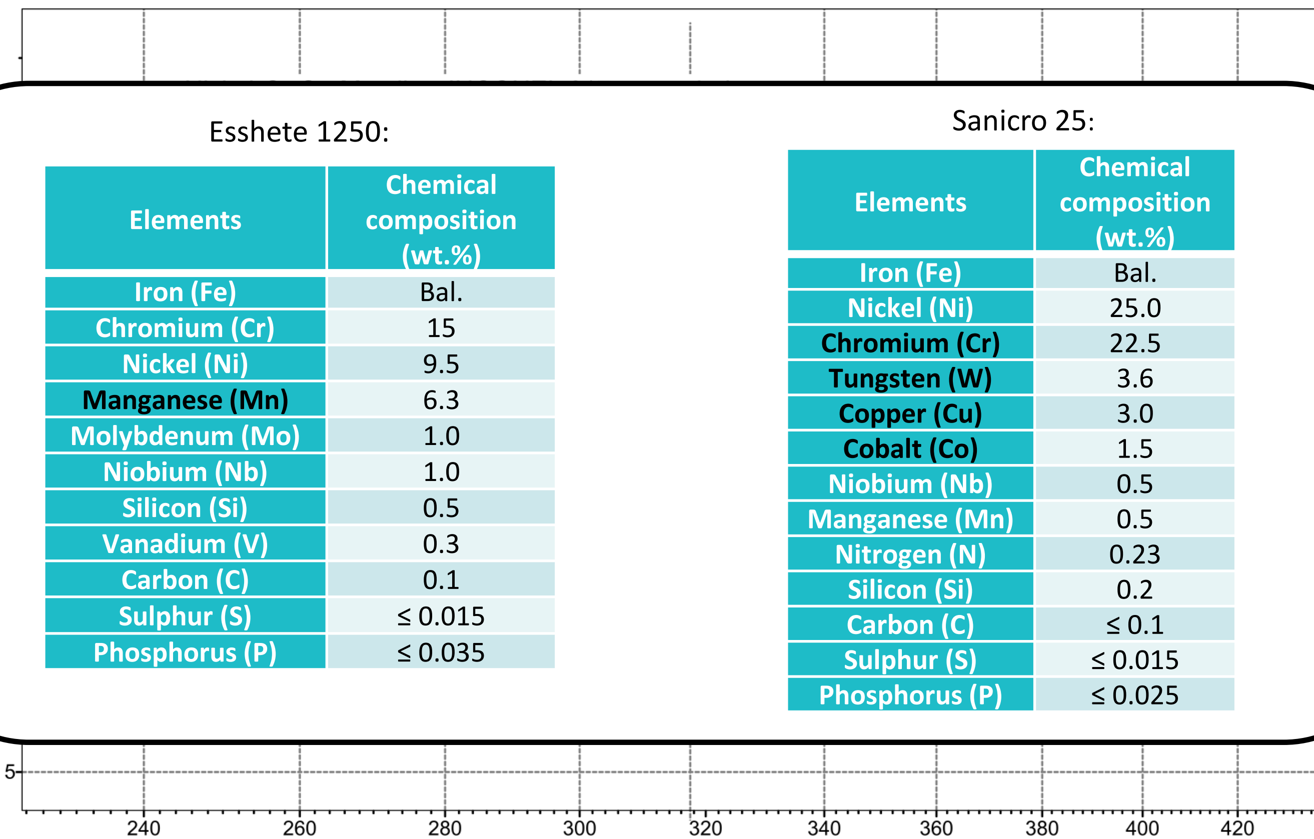


Image from Xcel Energy



Difference in price [SEK/kg] vs. fatigue strength (max stress to survive 10^7 cycles, RT , R=-1), for power plant materials (From CES EduPack 2018).



Esshete 1250:

Elements	Chemical composition (wt.%)
Iron (Fe)	Bal.
Chromium (Cr)	15
Nickel (Ni)	9.5
Manganese (Mn)	6.3
Molybdenum (Mo)	1.0
Niobium (Nb)	1.0
Silicon (Si)	0.5
Vanadium (V)	0.3
Carbon (C)	0.1
Sulphur (S)	≤ 0.015
Phosphorus (P)	≤ 0.035

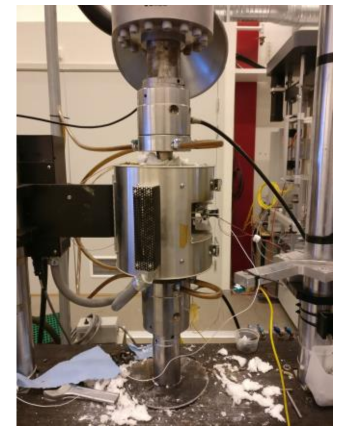
Sanicro 25:

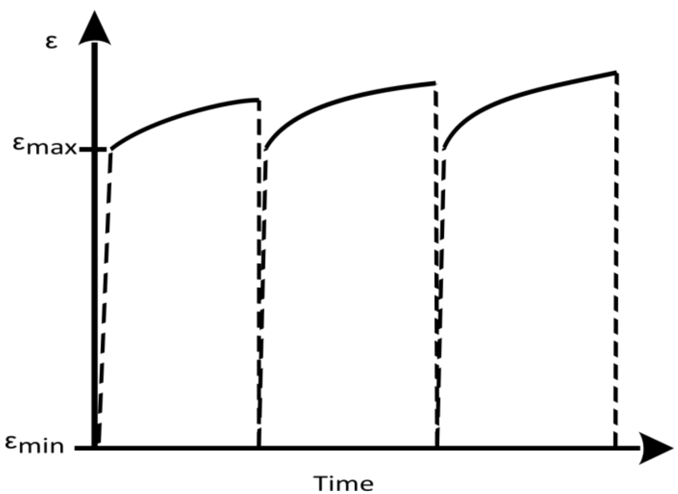
Elements	Chemical composition (wt.%)
Iron (Fe)	Bal.
Nickel (Ni)	25.0
Chromium (Cr)	22.5
Tungsten (W)	3.6
Copper (Cu)	3.0
Cobalt (Co)	1.5
Niobium (Nb)	0.5
Manganese (Mn)	0.5
Nitrogen (N)	0.23
Silicon (Si)	0.2
Carbon (C)	≤ 0.1
Sulphur (S)	≤ 0.015
Phosphorus (P)	≤ 0.025

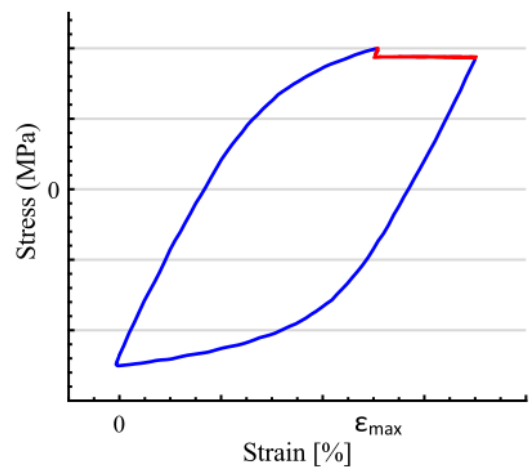
Difference in price [SEK/kg] vs. fatigue strength (max stress to survive 10^7 cycles, RT , R=-1), for power plant materials (From CES EduPack 2018).

Creep and low cycle fatigue (LCF) testing

- Strain controlled fatigue part
- Load controlled dwell time
- Temperature: 700°C
- Dwell time: 0, 100, 300, 600 and 1800 seconds
- Strain amplitudes: 0.25%-0.5%

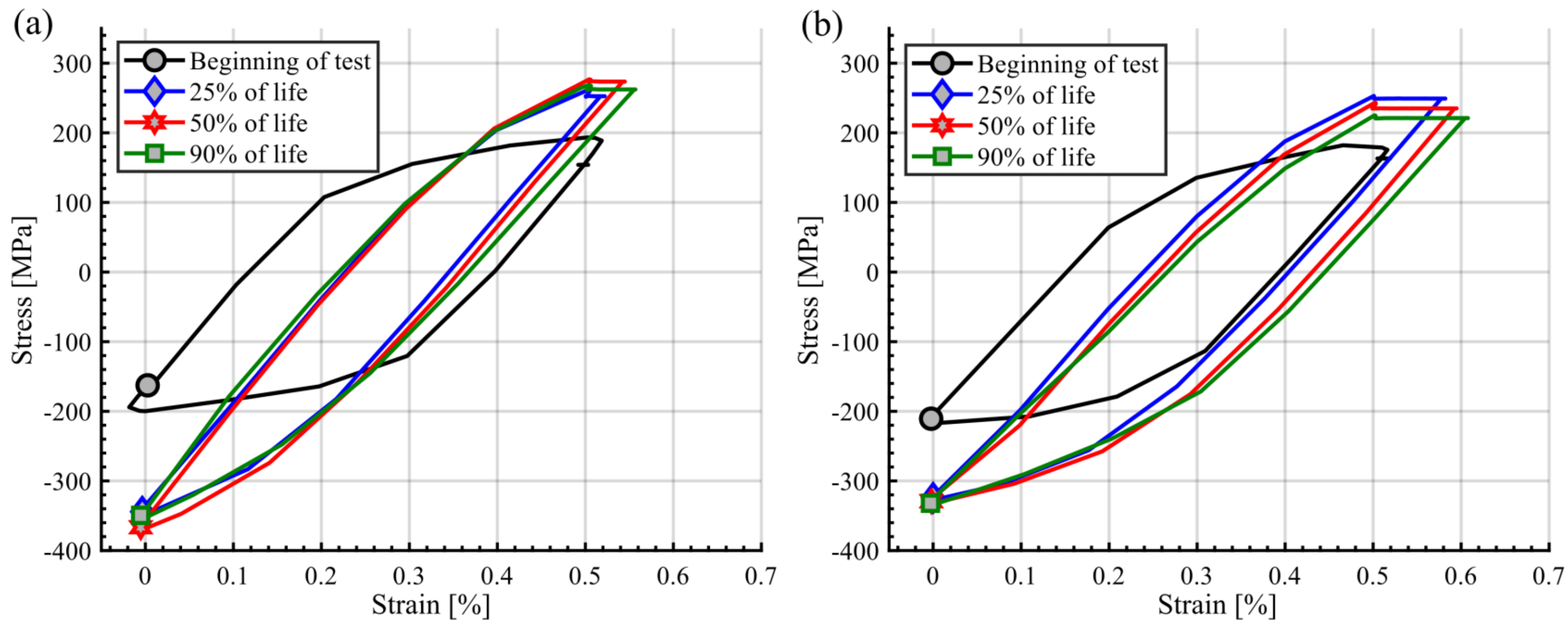






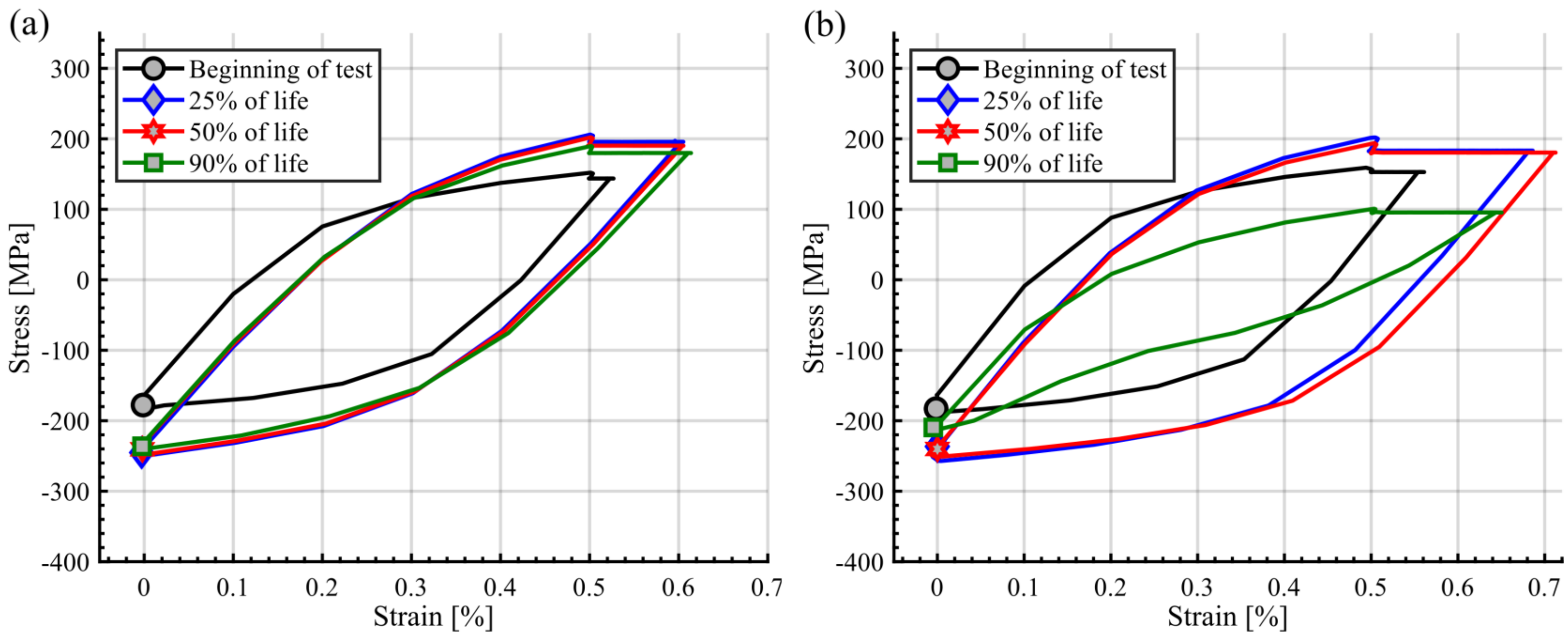
Results – Mechanical testing

- Sanicro 25

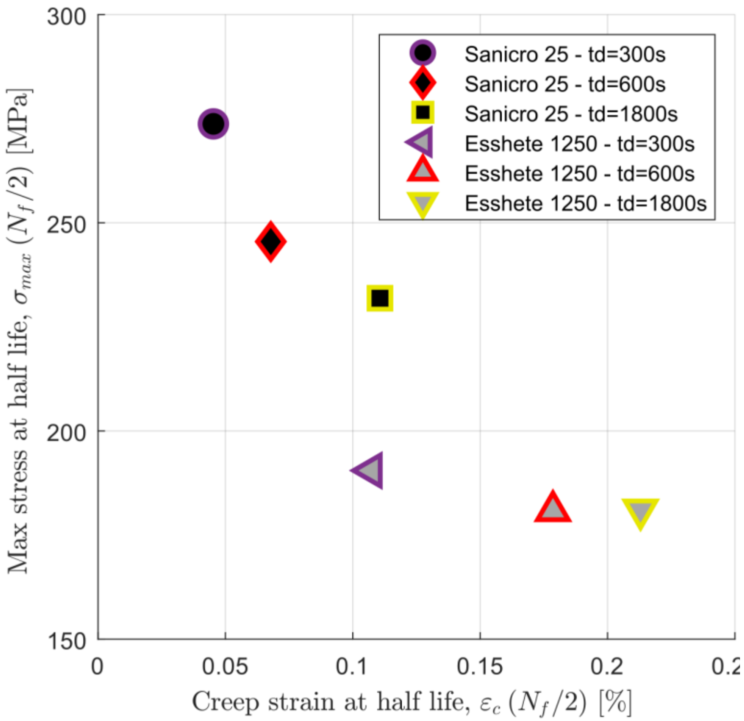


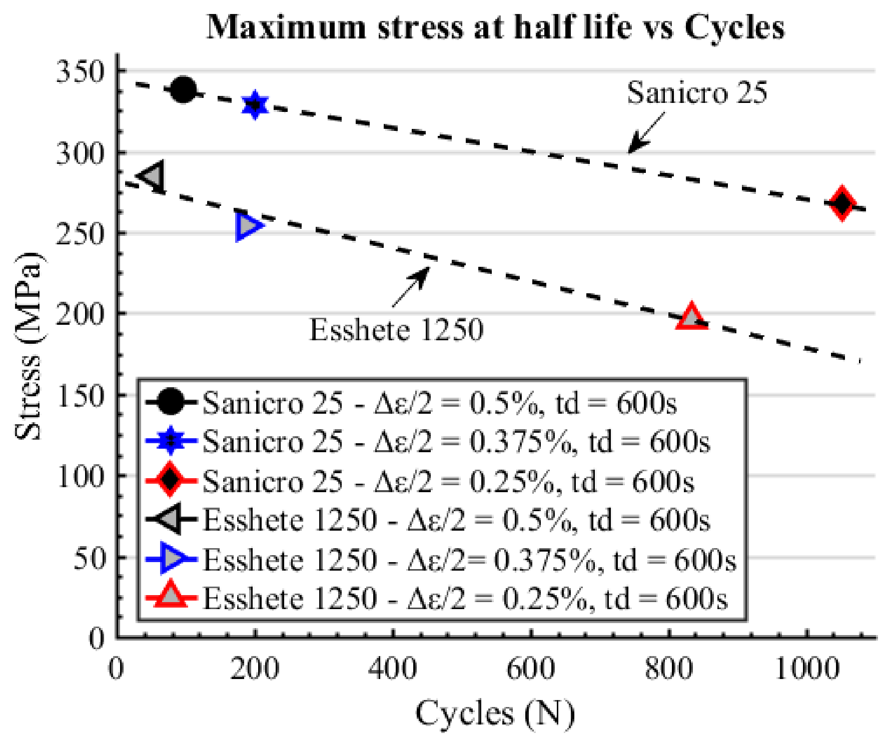
ε_a = 0.25%, (a) td=300 s, (b) td=1800s.

- Esshete 1250



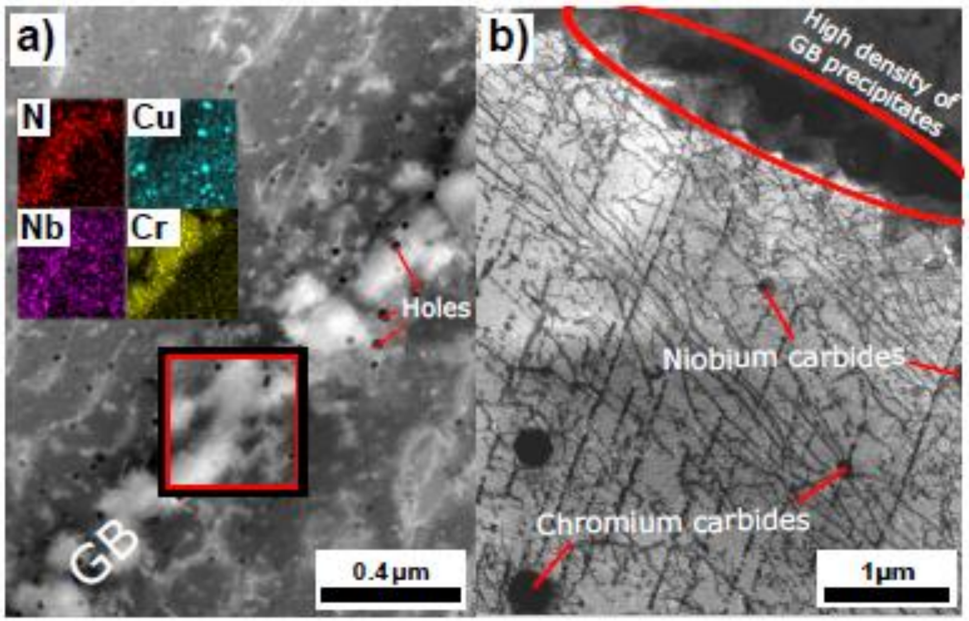
ε_a = 0.25%, (a) td=300 s, (b) td=1800s.

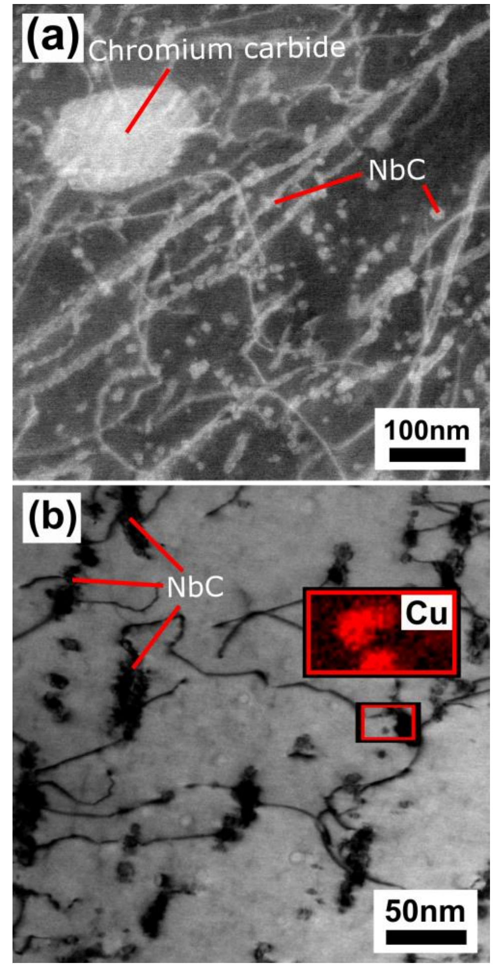

Sanicro 25 - td=300s
Sanicro 25 - td=600s
Sanicro 25 - td=1800s
Esshete 1250 - td=300s
Esshete 1250 - td=600s
Esshete 1250 - td=1800s
Max stress at half life, σ_{max} ($N_f/2$) [MPa]
Creep strain at half life, ε_c ($N_f/2$) [%]


Maximum stress at half life vs Cycles
Sanicro 25
Esshete 1250
Stress (MPa)
Cycles (N)
Sanicro 25 - Δε/2 = 0.5%, td = 600s
Sanicro 25 - Δε/2 = 0.375%, td = 600s
Sanicro 25 - Δε/2 = 0.25%, td = 600s
Esshete 1250 - Δε/2 = 0.5%, td = 600s
Esshete 1250 - Δε/2= 0.375%, td = 600s
Esshete 1250 - Δε/2 = 0.25%, td = 600s

Results – Microstructural evolution

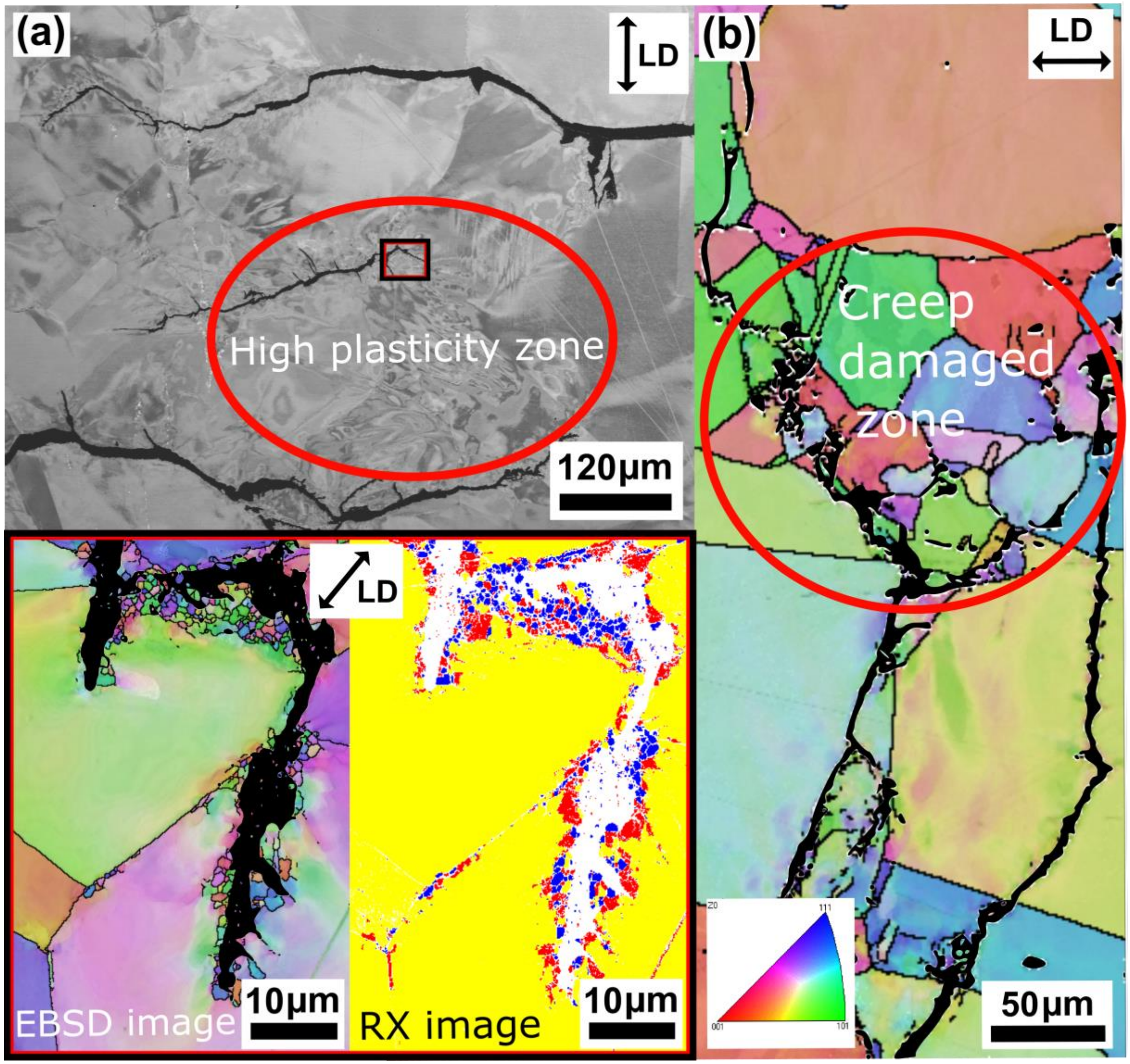
- Sanicro 25





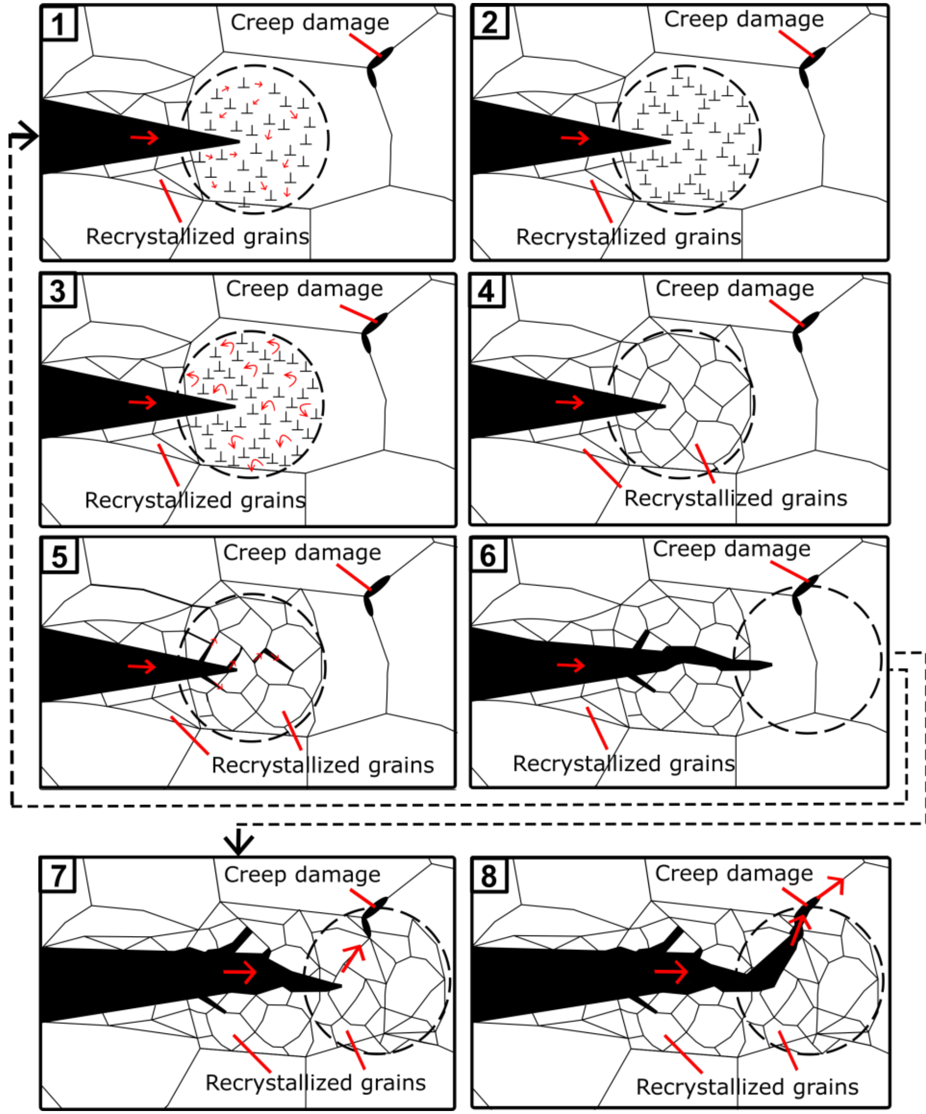
Cu-rich precipitates and Nb-carbides, act as dislocation obstacles. Z-phase particles and large Cr-carbides located at the grain boundaries.

$\varepsilon_a = 0.25\%$, td=600 s

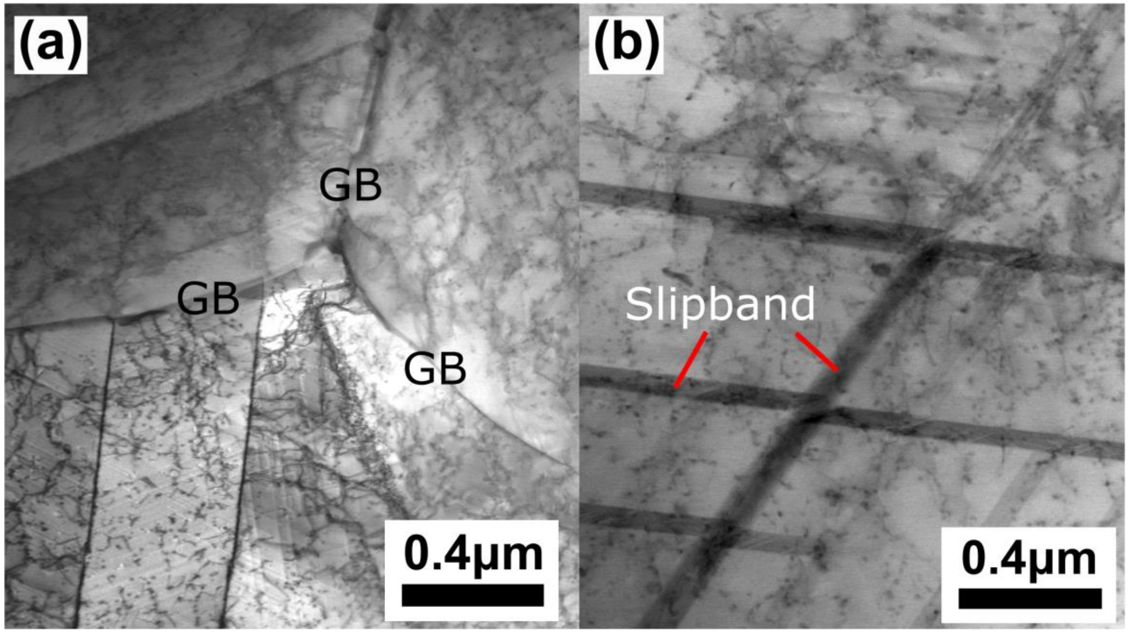


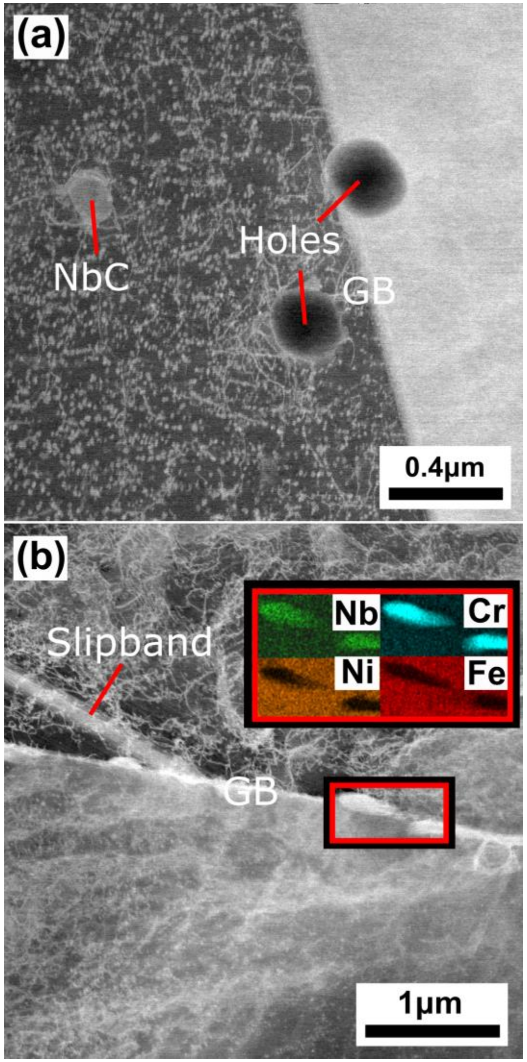
ε_a = 0.25%, td=600 s, (a) BSE and RX- Image (b) EBSD.

-> The propagation and interaction sketch of Sanicro 25 during high temperature CF loadings



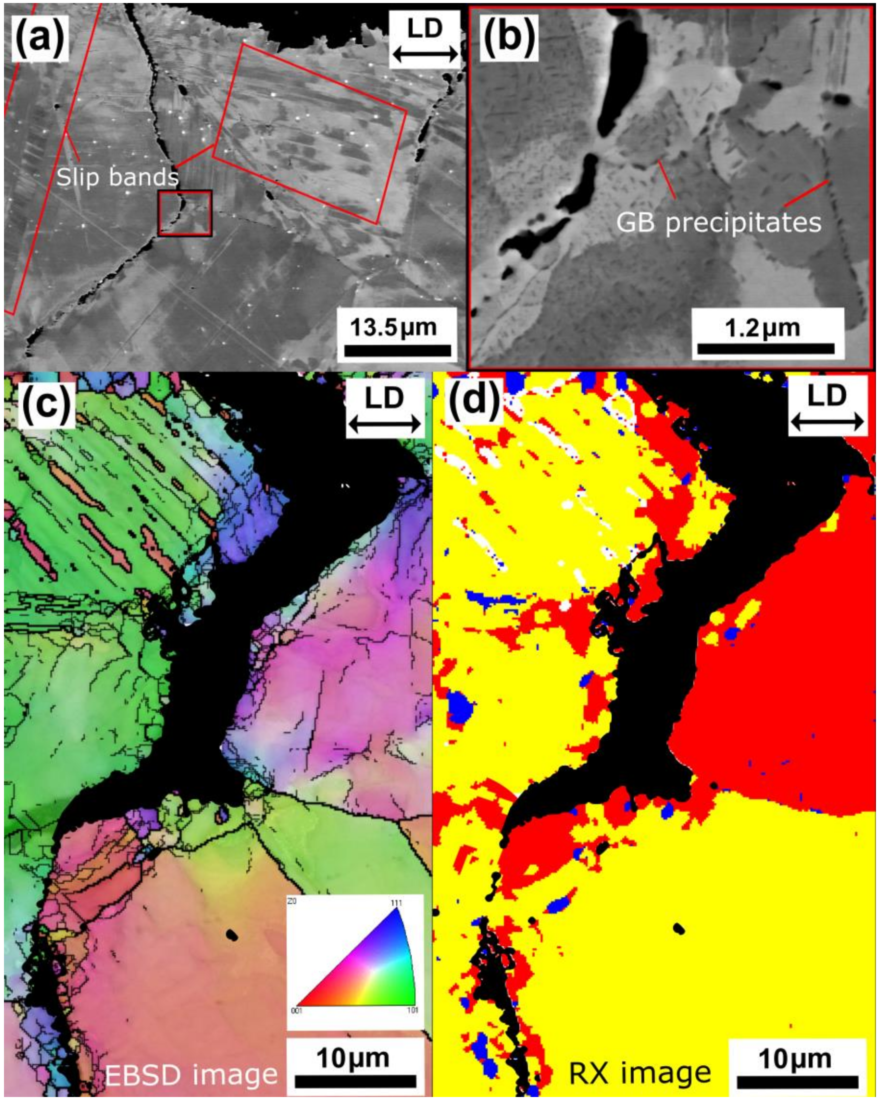
- Esshete 1250





Sparsely located Cr and Nb-carbides at the grain boundaries. Interaction of slip bands with grain boundary precipitates.

ε_a = 0.25%, td=600 s



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ε_a = 0.25%, td=600 s, (a) and (b) BSE, (c) EBSD and (d) RX- Image.

Summary

- Coherent Cu-precipitates and incoherent Nb-carbides were found to impede dislocation motion, increase hardening and improving the high temperature properties of Sanicro 25.
- Dynamic recrystallization of the plastic zone at the crack tip appeared to affect crack propagation of Sanicro 25 by providing an energetically privileged path.
- Sparsely placed intergranular Cr- and Nb-carbides made Esshete 1250 susceptible to creep damage and intergranular crack propagation, mainly from interaction of the carbides and fatigue induced slip bands.

Thank you for your attention!

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