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

Tjockväggiga austenitiska rostfria stål för framtidens högeffektiva biomasseldade kraftverk

KME-801

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Linköping University

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Acknowledgment

SANDVIK

Sumitomo SHI FW

KME
CONSORTIUM MATERIALS TECHNOLOGY
for development and demonstration of thermal energy processes

Swedish Energy Agency

Energiforsk

Project group

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Outline

- Background to the project
- Project goals
- Results
- Summary

Background to the project

- Increasing demand on materials high-temperature performance. Such as creep and corrosion resistance.
- High thermal expansion of austenitic stainless steel lead to increased thermal stresses in heavy section components.

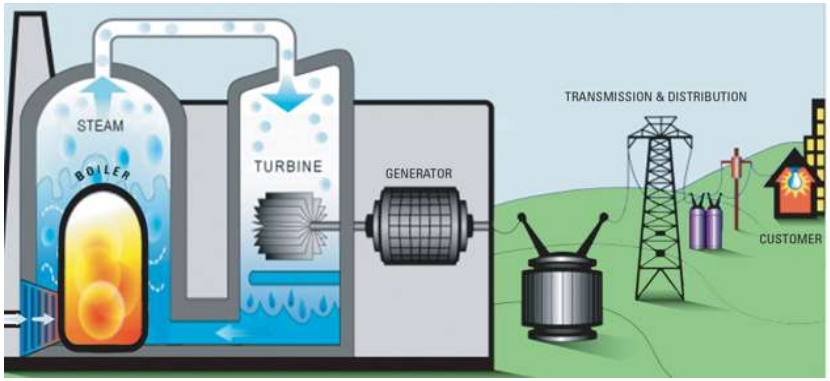
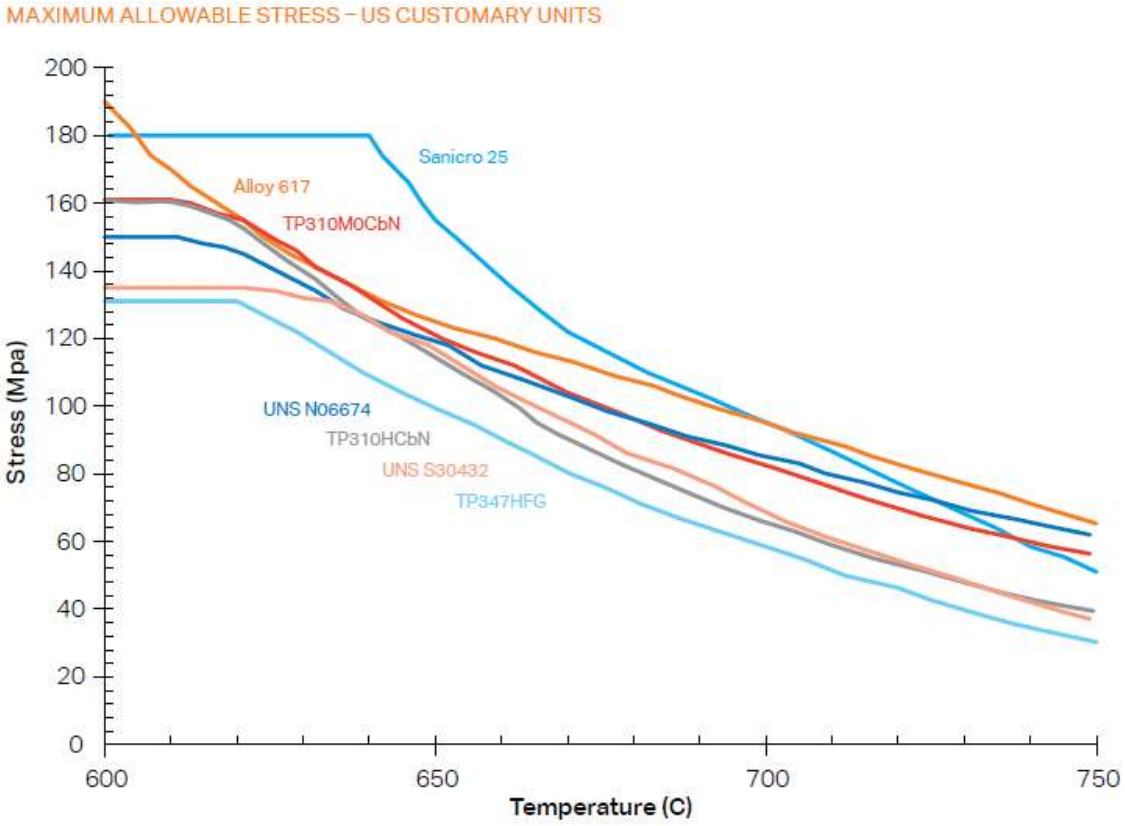


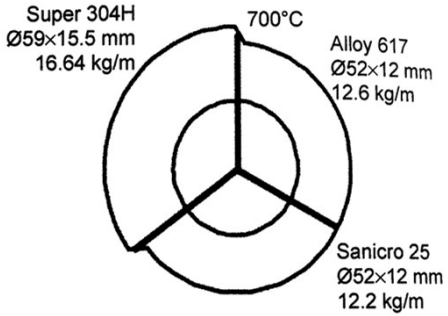
Image from Xcel Energy

Gärdstadverken Linköping.
Photo Åke E. Lindman

Continuation of
KME-501, 521 and 701.

Sanicro 25 show great potential to improve the performance and efficiency of next generation biomass-fired power plants.





Gianfrancesco (2017)

www.sandvik.se

Project goals

The main purposes of this project are to evaluate the mechanical behaviours for structure safety and integrity analysis, namely:

1) To **evaluate thermo-mechanical fatigue properties** of new heavy section materials for safety and life evaluation since the biomass-fired power plants can start/shutdown quite often during service for energy saving and flexibility purposes in the future.

2) To **evaluate the fatigue crack propagation behaviour** of new heavy section materials used in safety and reliability considerations since the material can undertake low cycle fatigue during the service.

3) To **evaluate the creep resistance** of new heavy section materials used in safety and reliability considerations since the material can undertake creep during the service.

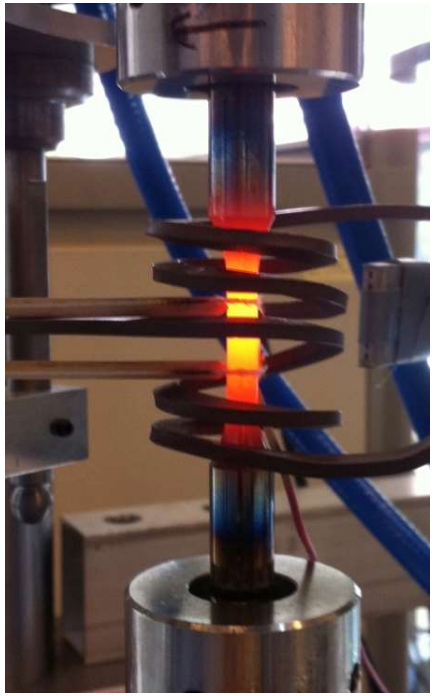
4) To **evaluate the structure stability and the toughness of welded and aged material** after long term service at high temperatures for safety analysis.

5) To **evaluate the new candidate material compared to currently used materials using FE-models** of the applications.

Results – Testing method

Thermo-mechanical fatigue testing

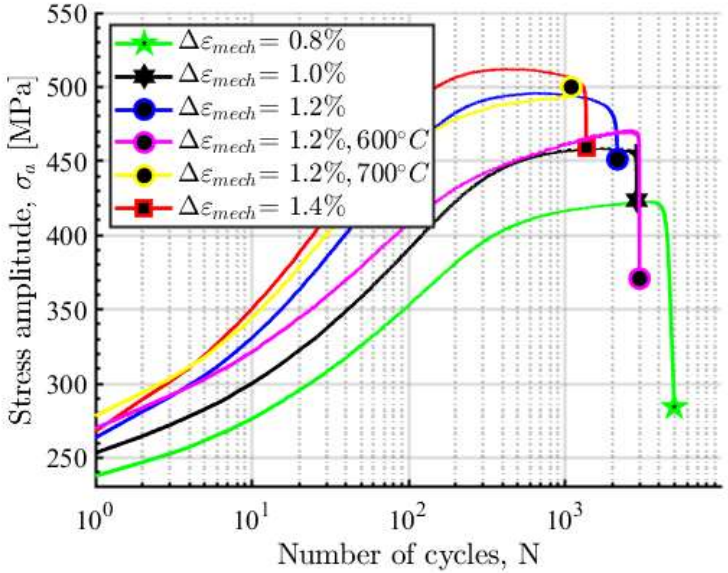
- Cycle type
  - Phase-shift — Out-of-Phase (OP)
  - Heating/Cooling rate — 5°C/s
  - Maximum temperature — 600, **650**, 700°C
  - Minimum temperature — 100°C
- Instron 8801 servo hydraulic test machine
  - Strain controlled



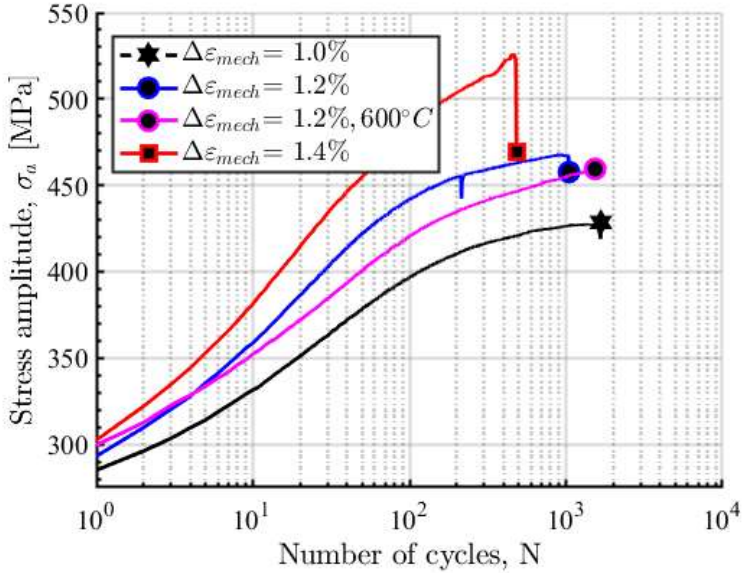
Material	C	Cr	Ni	W	Co	Cu	Mn	Nb	N	Si	Fe
Sanicro 25	0.1	22.5	25.0	3.6	1.5	3.0	0.5	0.5	0.23	0.2	Bal.

Results – Mechanical testing

Virgin

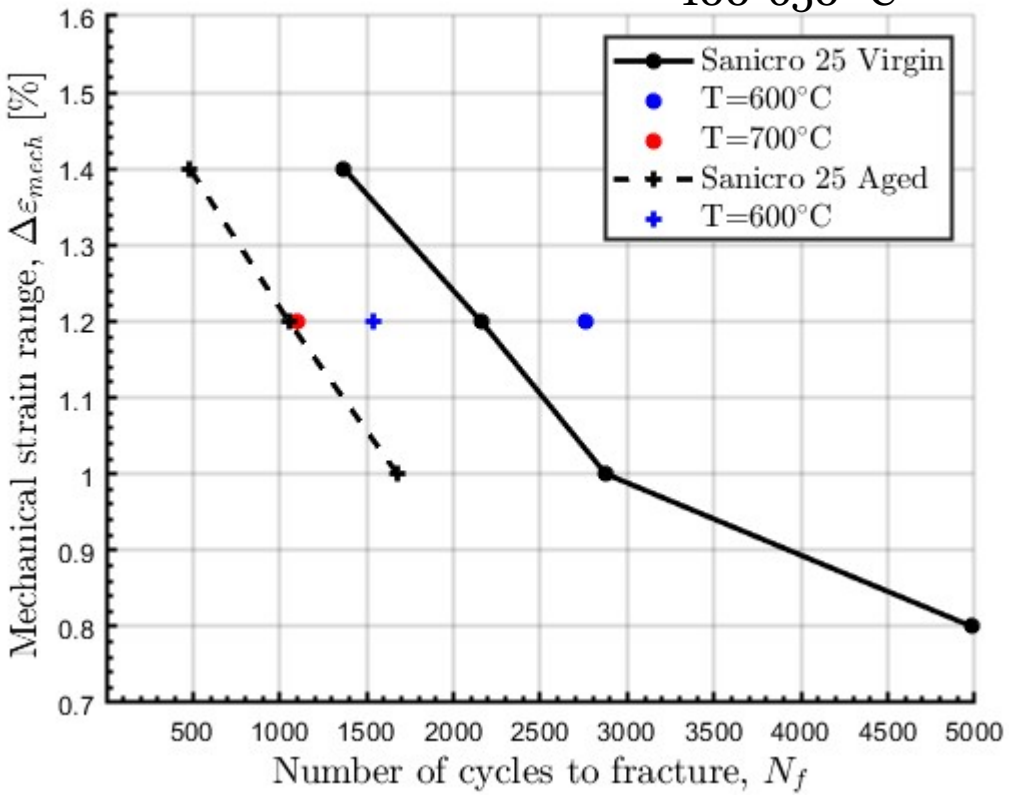


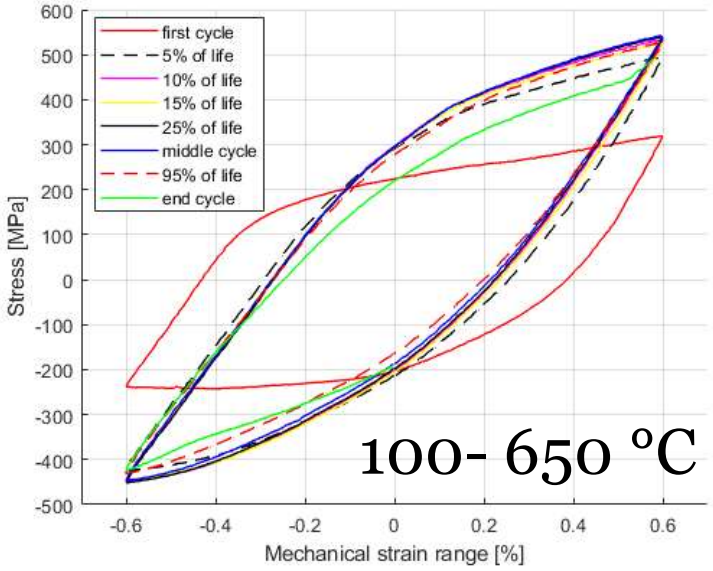
Aged 3000 h @ 650 °C

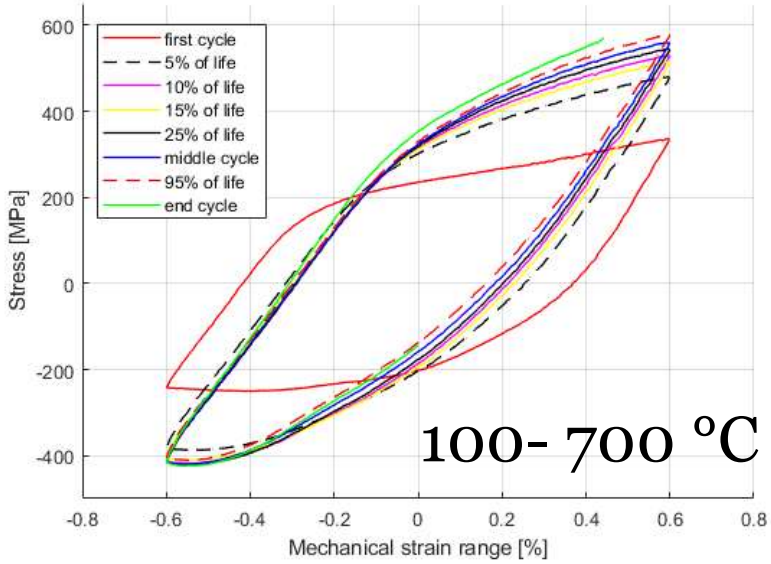


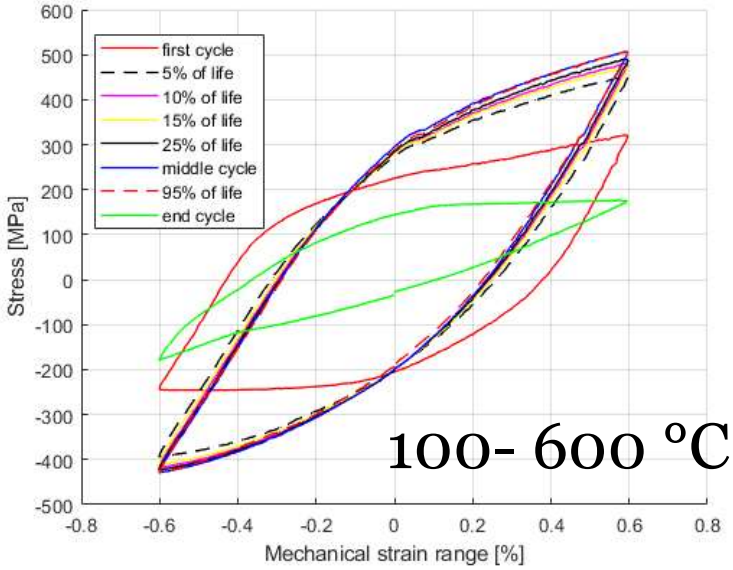
100-650 °C

100-650 °C


Sanicro 25 Virgin
T=600°C
T=700°C
Sanicro 25 Aged
T=600°C
Mechanical strain range, $\Delta\varepsilon_{mech}$ [%]
Number of cycles to fracture, N_f
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

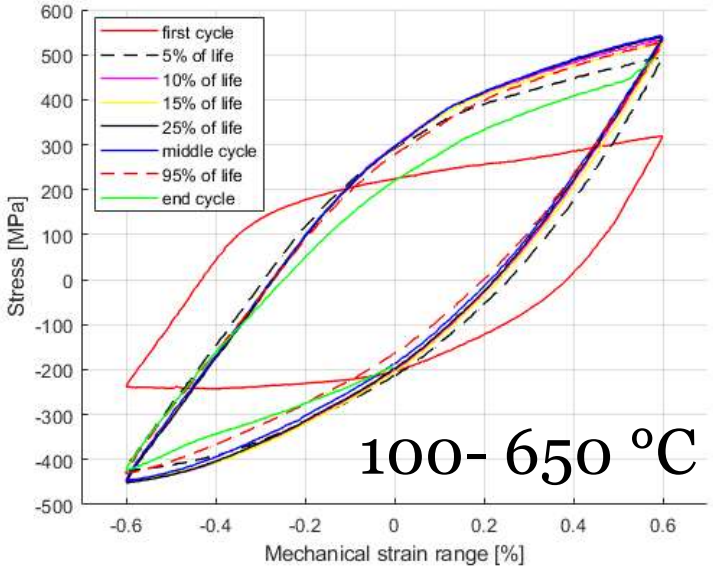




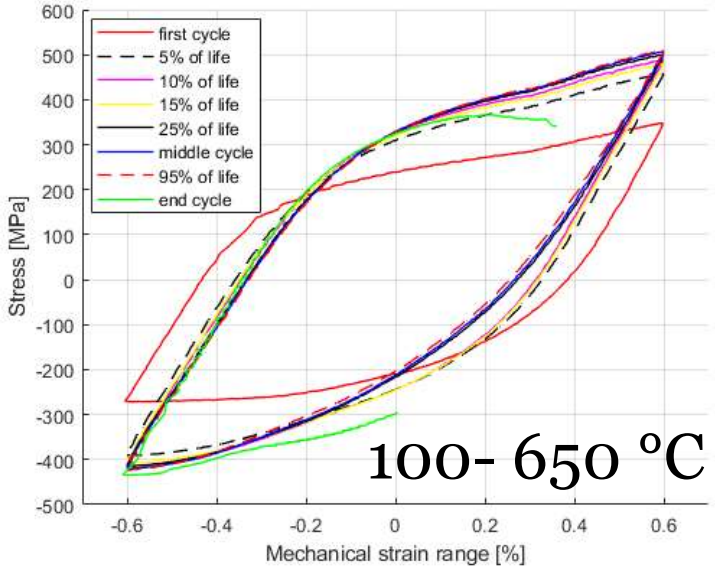


1,2 % strain range

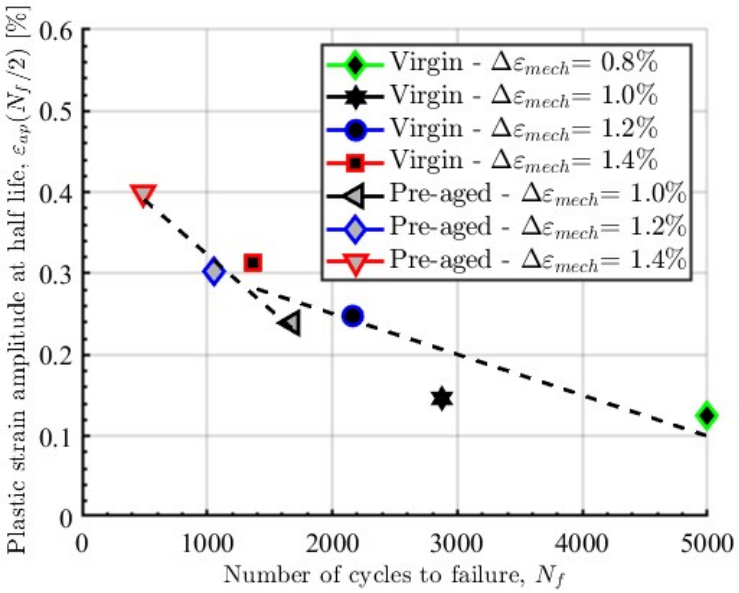
Virgin

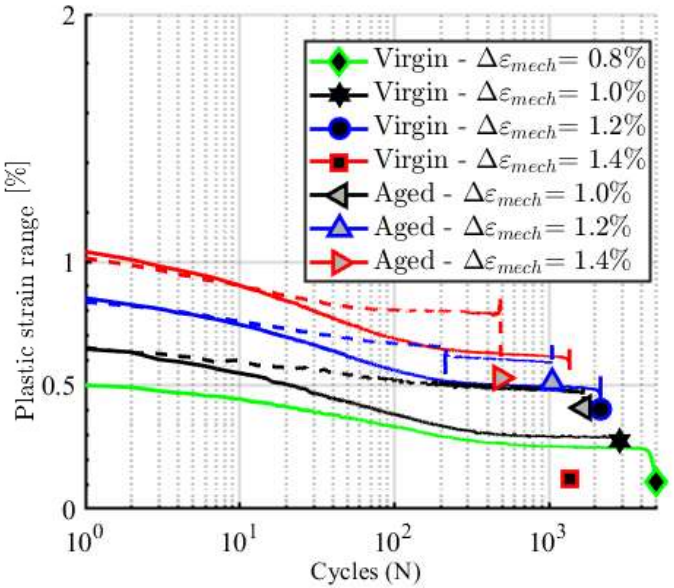


Aged 3000 h @ 650 °C



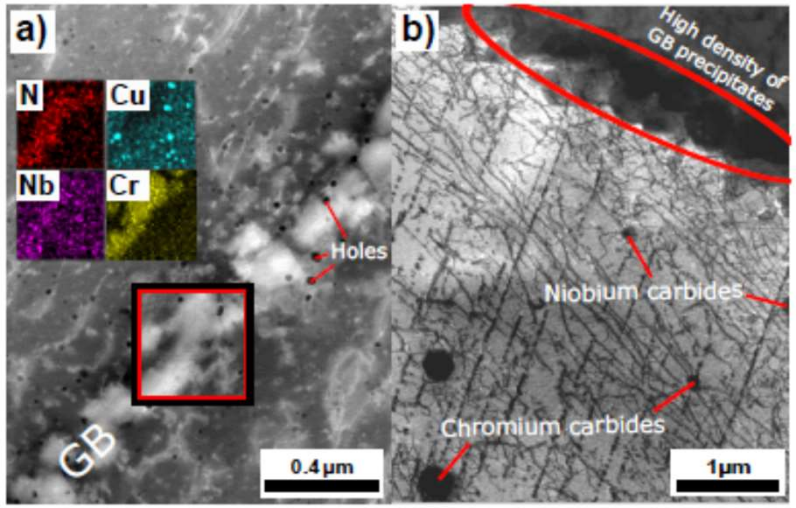
1,2 % strain range

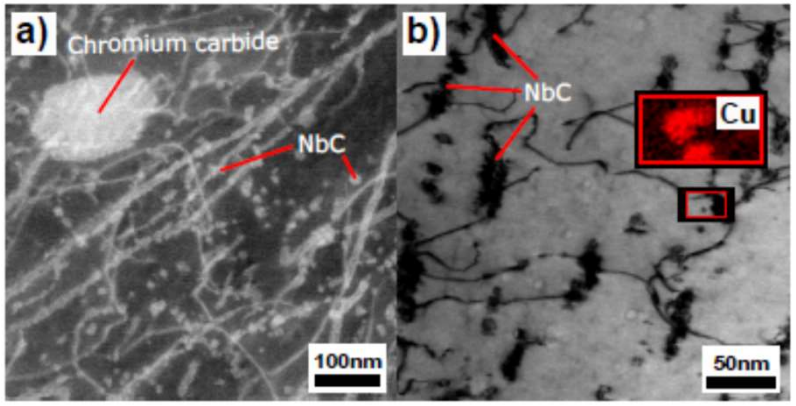

Plastic strain amplitude at half life, $\varepsilon_{ap}(N_f/2)$ [%]
Number of cycles to failure, N_f
Virgin - $\Delta\varepsilon_{mech}$= 0.8%
Virgin - $\Delta\varepsilon_{mech}$= 1.0%
Virgin - $\Delta\varepsilon_{mech}$= 1.2%
Virgin - $\Delta\varepsilon_{mech}$= 1.4%
Pre-aged - $\Delta\varepsilon_{mech}$= 1.0%
Pre-aged - $\Delta\varepsilon_{mech}$= 1.2%
Pre-aged - $\Delta\varepsilon_{mech}$= 1.4%


Plastic strain range [%]
Cycles (N)
Virgin - $\Delta\varepsilon_{mech}$= 0.8%
Virgin - $\Delta\varepsilon_{mech}$= 1.0%
Virgin - $\Delta\varepsilon_{mech}$= 1.2%
Virgin - $\Delta\varepsilon_{mech}$= 1.4%
Aged - $\Delta\varepsilon_{mech}$= 1.0%
Aged - $\Delta\varepsilon_{mech}$= 1.2%
Aged - $\Delta\varepsilon_{mech}$= 1.4%

Results – Microstructural evolution

Virgin Sanicro 25 tested at 700 °C under creep-fatigue conditions

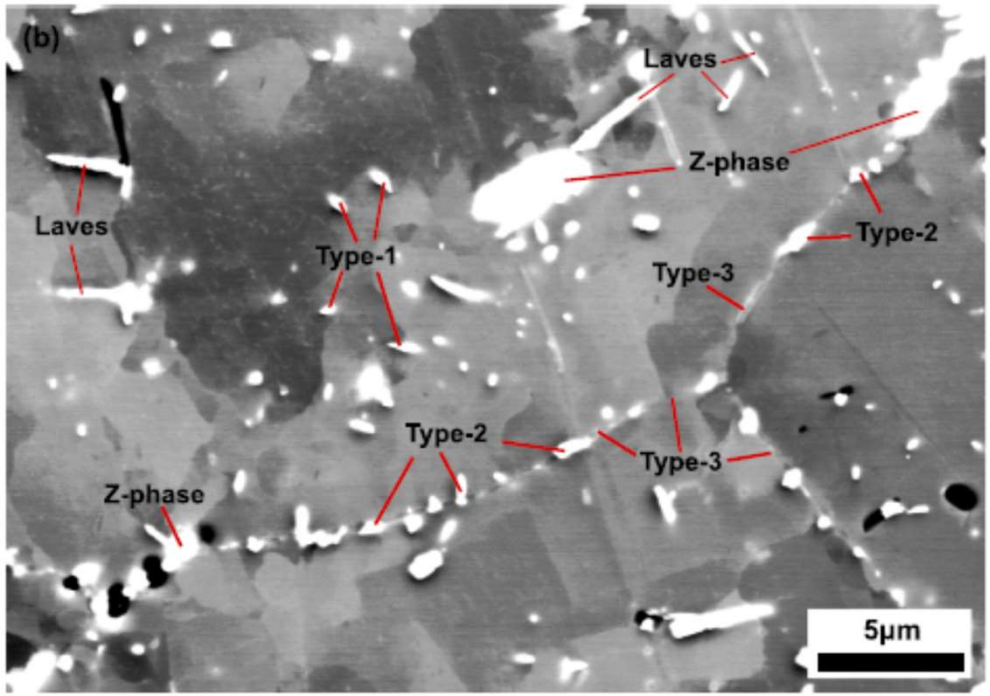




Cu-rich precipitates and Nb-carbides, act as dislocation obstacles adding hardening and high temperature strength. Z-phase particles and large Cr-carbides located at the grain boundaries.

Results – Microstructural evolution

Aged Sanicro 25 at 800 °C 2000 h and tested IP-TMF



Z-phase
Laves phase
Laves phase (1-type sites)
$M_{23}C_6$/Laves phase (2-type sites)
$M_{23}C_6$(3-type sites)

Summary

Sanicro 25 show reduced OP-TMF life after long term ageing at high temperature.

Aged Sanicro 25 show increased plastic strain over number of cycles compared to virgin materials.

Ageing increase the plastic strain accumulation leading to reduction in OP-TMF life.

Thank you for your attention!

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