Influence of high-temperature environments on the mechanical behaviours of high-temperature austenitic stainless steels

KME-701

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Acknowledgment

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

Swedish Energy Agency

SANDVIK

Project group and reference committee

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Members:

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- Jan Högberg/Magnus Olaison (SMT)
- Johan Moverare (LiU)
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Reference committee:

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- Bo Jönsson (Kanthal/Sandvik)
- Rikard Norling (Swerea KIMAB)

Outline

- Background to the project
- Project goals
- Selected project results
- Summary

Background to the project

- Future need of more efficient energy production.
- Increasing demand on materials high-temperature performance.

Gärdstadverken Linköping.
Photo Åke E. Lindman

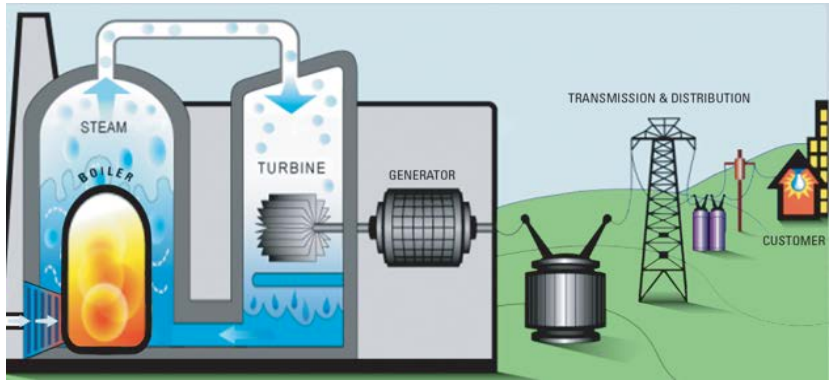


Image from Xcel Energy

Continuation of KME-501 and 521.

Project goals

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

- To evaluate the creep and LCF interaction diagram and integrity analysis since the boiler materials can undertake both creep and low cycle fatigue during the service.

- To evaluate the structure stability and the toughness after long term service at a elevated temperature for safety analysis.

- To evaluate thermo-mechanical fatigue properties of the boiler materials for safety and life evaluation since the power plants can start/shutdown quite often during service for energy saving and flexibility purposes in the future.

- To evaluate the stress relaxation cracking behaviour of the boiler material. It is critical problem for some boiler materials.

Selected project results - Materials

7 austenitic stainless steels

3 nickel-based alloys

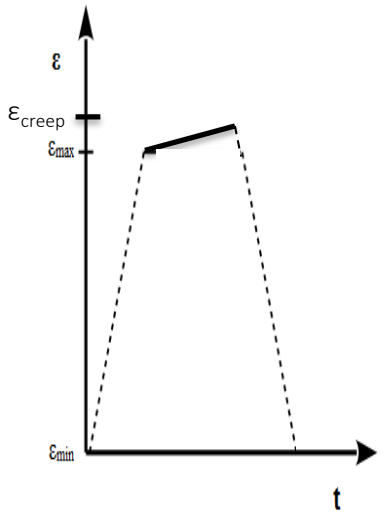
Alloy	C	Mn	Cr	Ni	Mo	Cu	Co	Nb	Fe
Esshete1250	0,1	6,3	15	9,5	1,0	-	-	1,0	B
AISI 304	0,02	1,2	18,3	10,3	-	0,3	-	0,01	B
AISI 310	0,05	0,84	25,43	19,21	0,11	0,08	-	-	B
AISI 316L	0,04	1,7	17,0	12,0	2,6	-	-	-	B
AISI 347H	0,06	1,7	17,5	11	-	-	-	>0,6	B
Sanicro 25	0,07	0,47	22,33	24,91	0,24	2,95	1,44	0,52	B
Sanicro 28	0,02	1,83	27,02	30,76	3,39	0,9	0,09	-	B
Alloy 617	0,06	0,02	22,53	B	9,0	Ti 0,46	12,0	Al 0,94	1,1
Sanicro 31HT	0,06	0,5	20,32	30,06	-	Ti 0,52	0,03	Al 0,47	B
Haynes 282	0,06	-	19,6	B	8,7	Ti 2,2	10,3	Al 1,5	0,5

B = balance

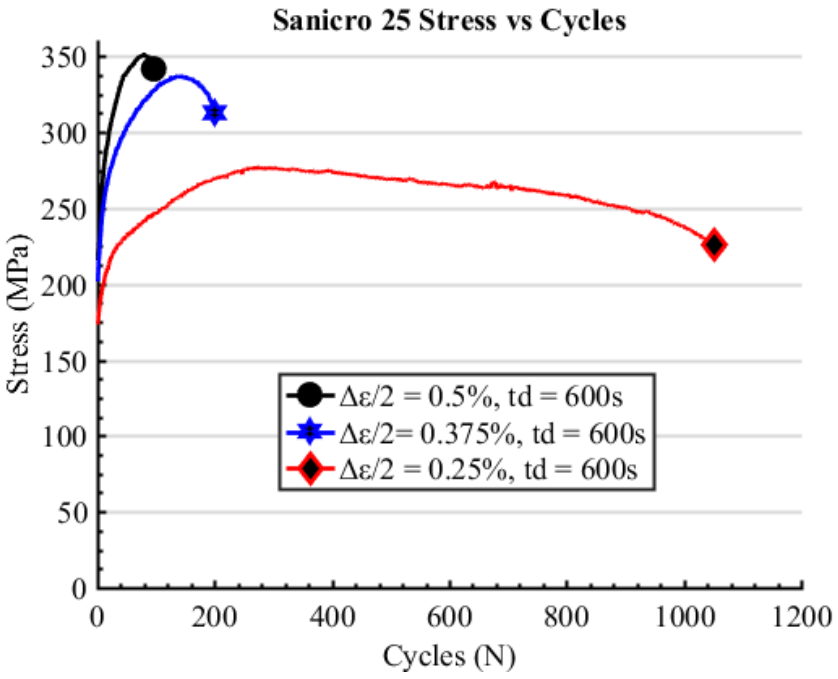
Selected project results

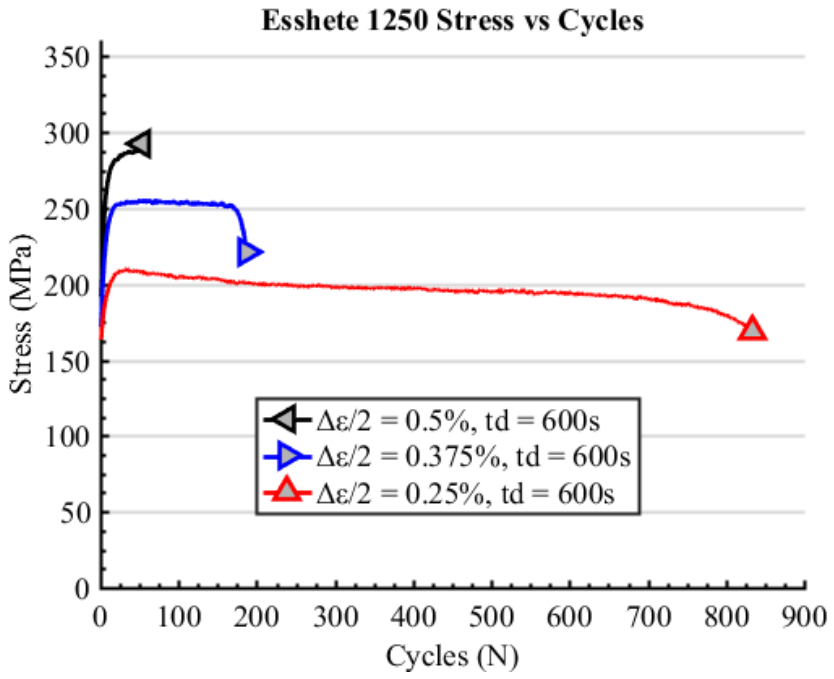
Creep-fatigue interaction behavior at 700 °C

Strain controlled fatigue part (dotted lines)
Load controlled creep part (solid lines)



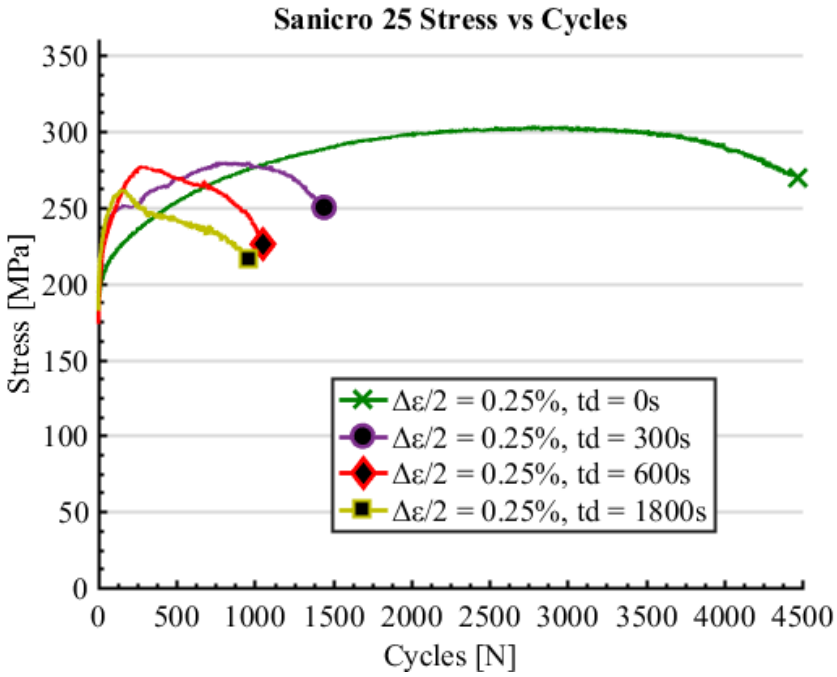
Varied fatigue part and constant creep part

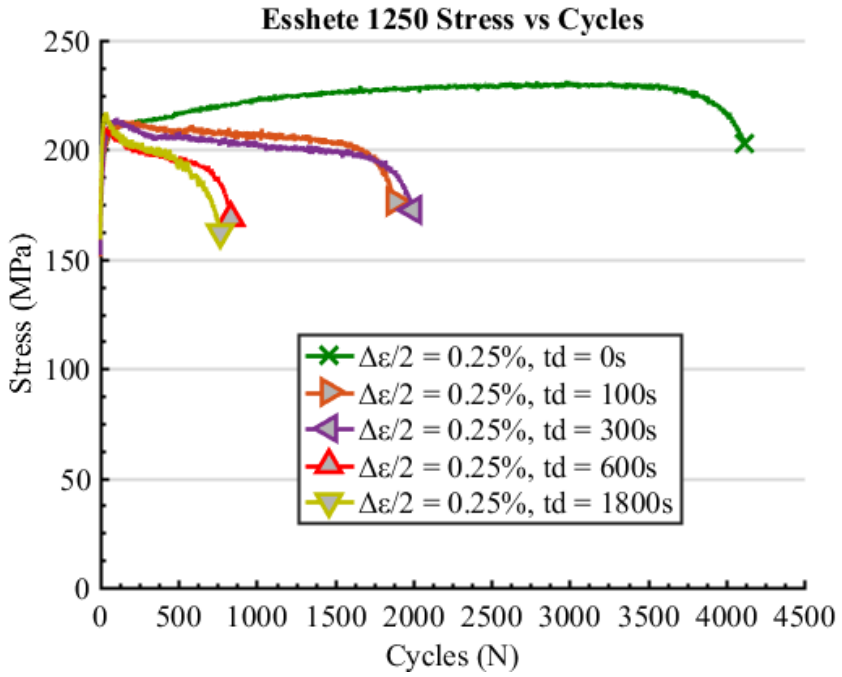




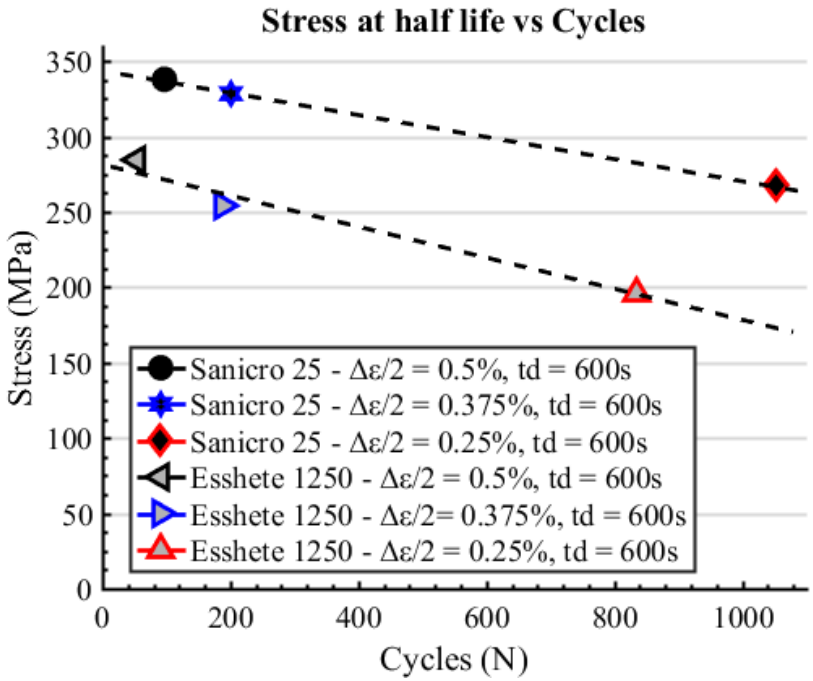
- Increased strain amplitude (fatigue part) results in reduction of creep-fatigue life

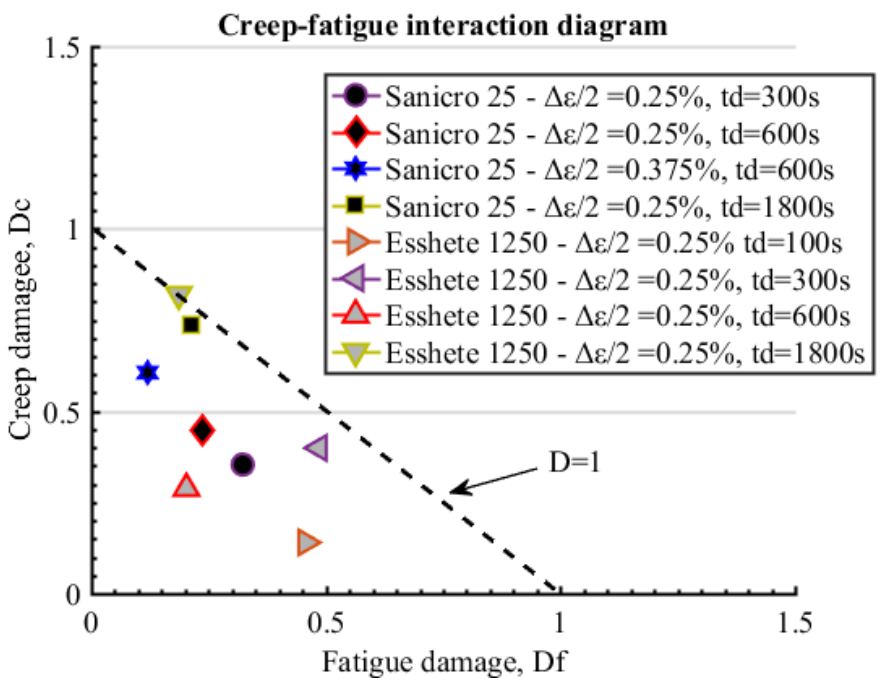
Constant fatigue part and varied creep part





- Increased dwell time (creep part) results in reduction of creep-fatigue life



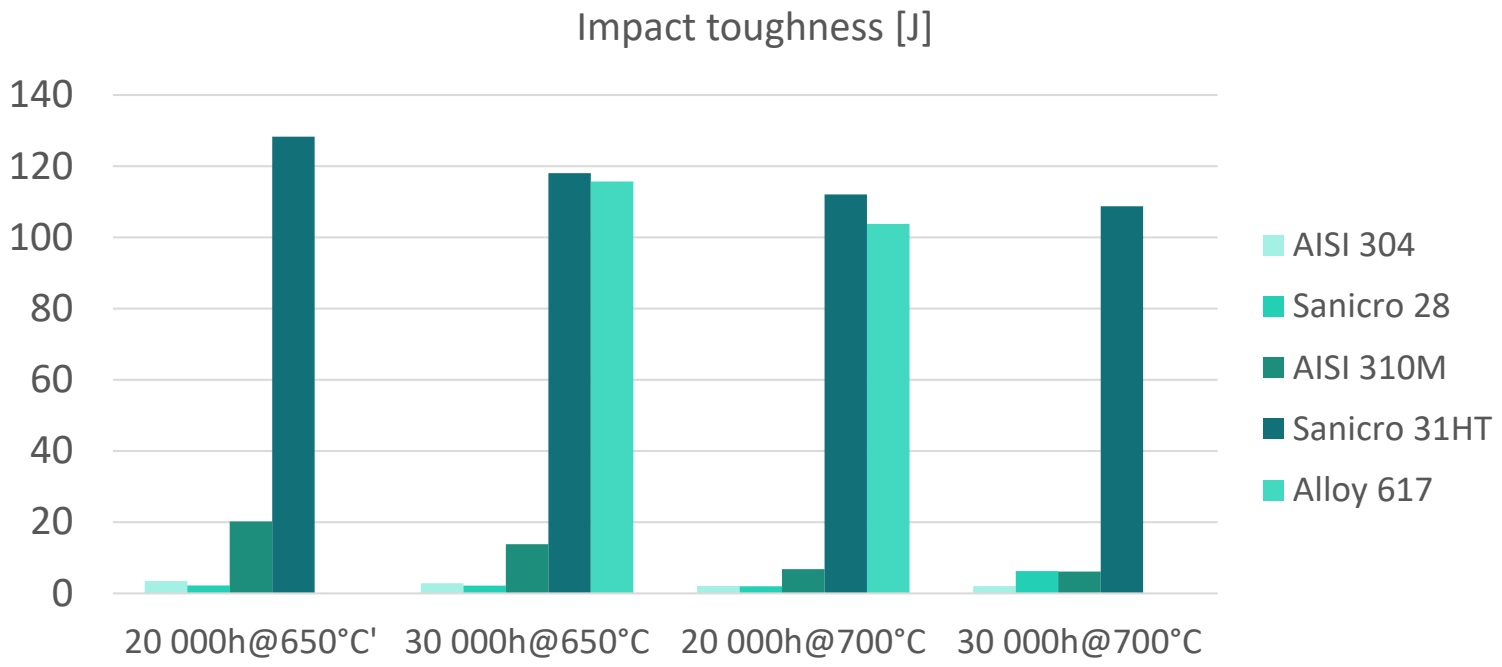


- Sanicro 25 showed superior Creep-fatigue life compared to Esshete 1250 due to greater high-temperature strength and creep resistance.
- Both alloys showed creep fatigue interaction damage for specific test configurations.

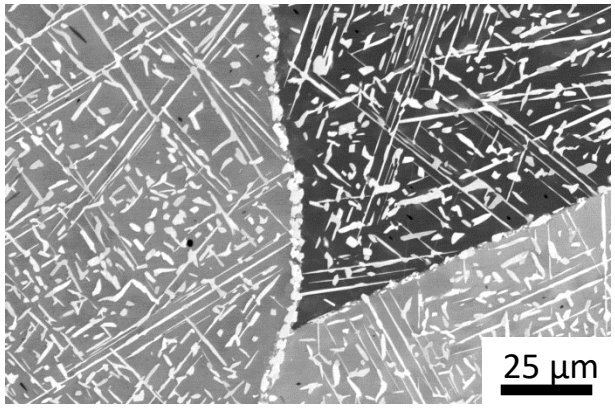
H. Wärner et al., accepted for presentation at Fatigue 2018 (MATEC Web of Conferences (open access))

Selected project results

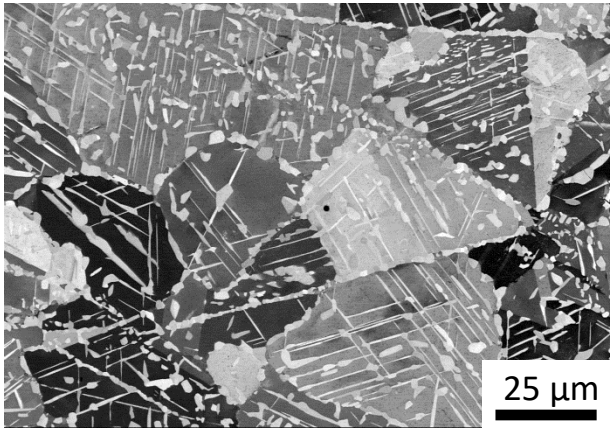
Impact toughness test after long-term ageing at 650 ° C and 700 °C



Long-term aged austenitic stainless steel and nickel-based alloy

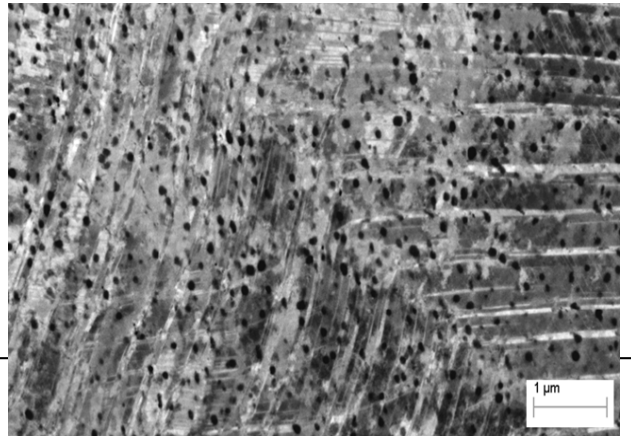


Sanicro 28



AISI 304

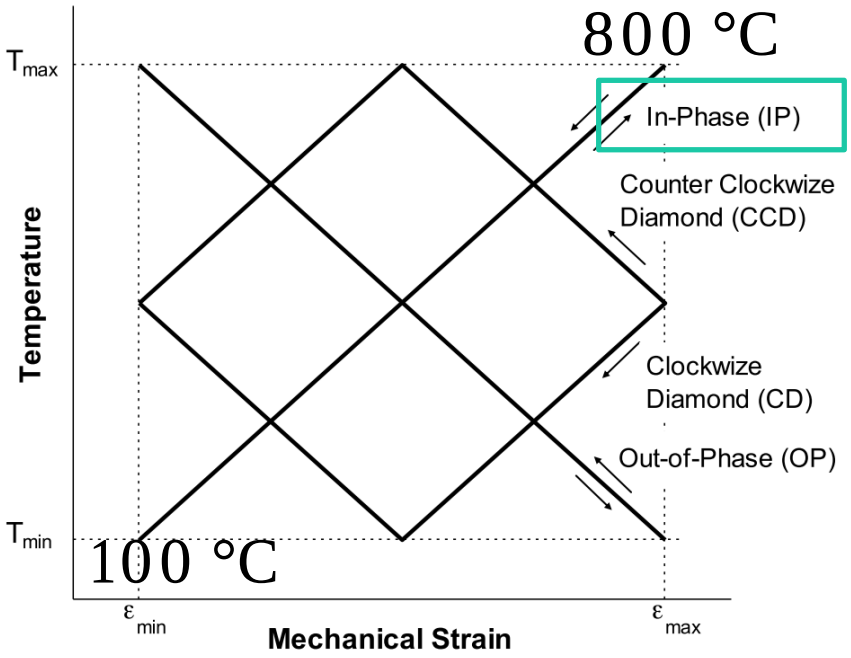
- Austenitic stainless steels suffer of embrittlement from intermetallic precipitates

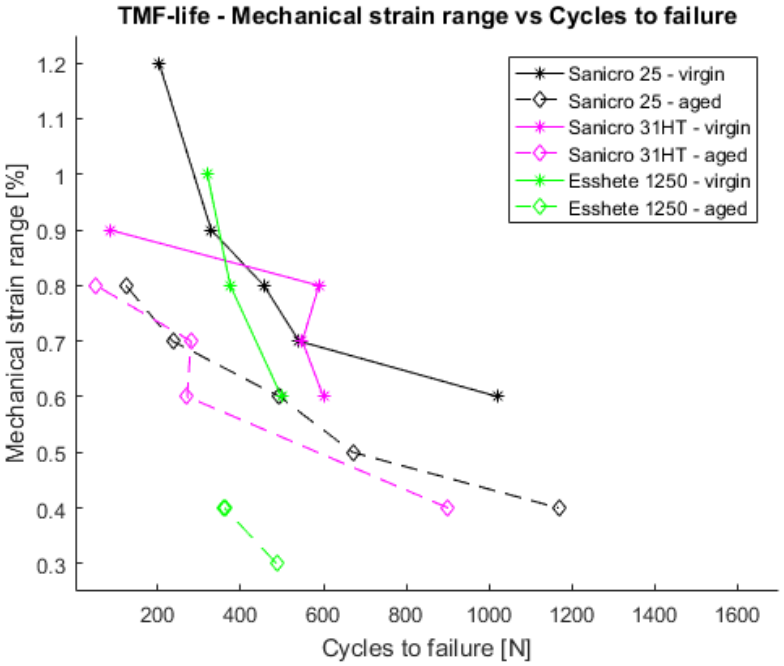


Alloy 617

Selected project results

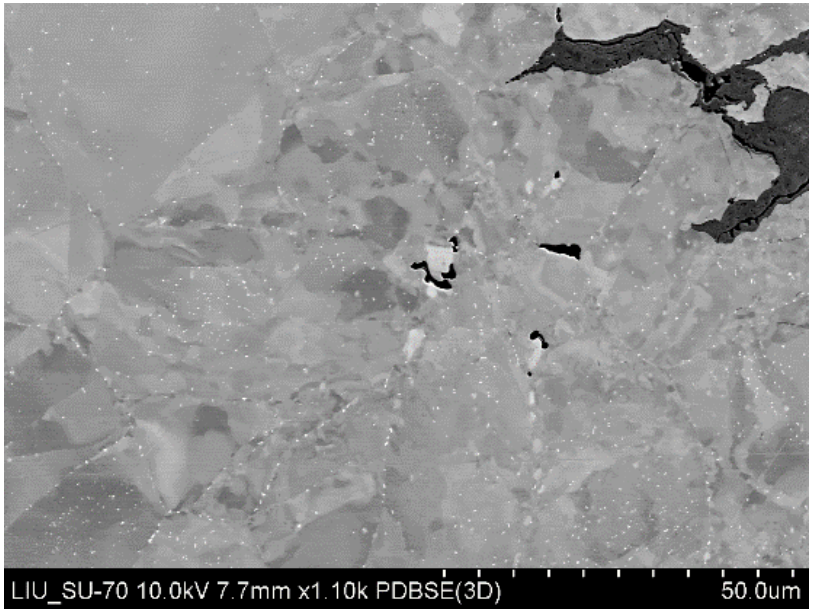
Thermo-mechnical fatigue on aged materials (2000h@800 °C)



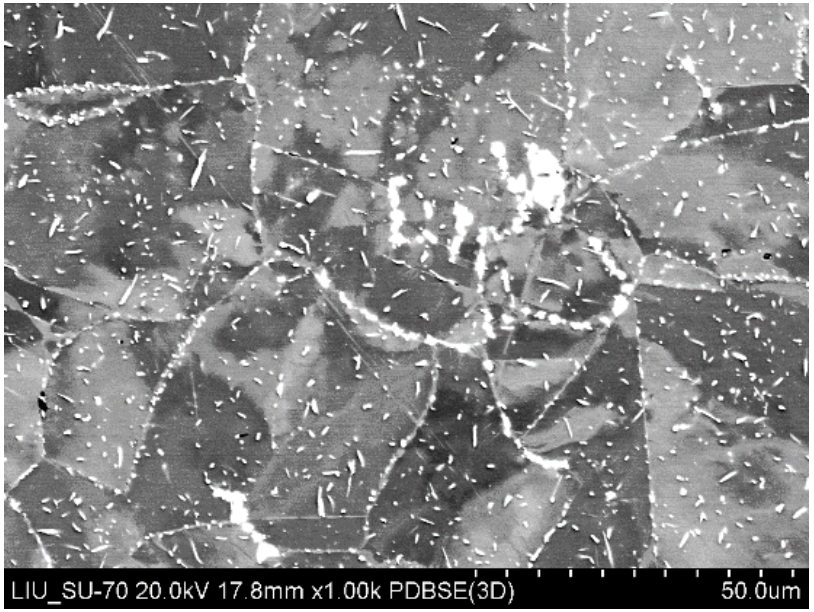


- The pre-aged samples showed a shorter TMF-life compared to non-aged samples.

Sanicro 25 virgin



Sanicro 25 pre-aged



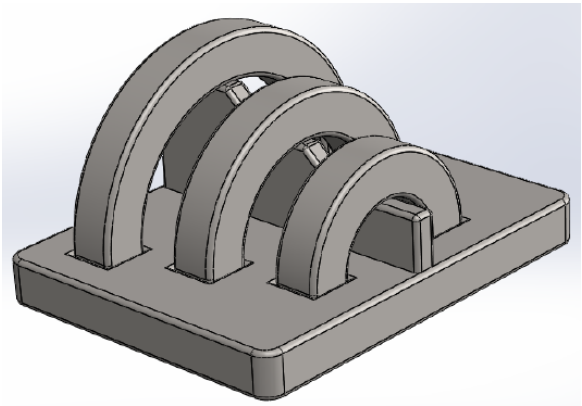
- The shorter TMF life for the pre-aged samples were attributed to an embrittling effect from precipitation

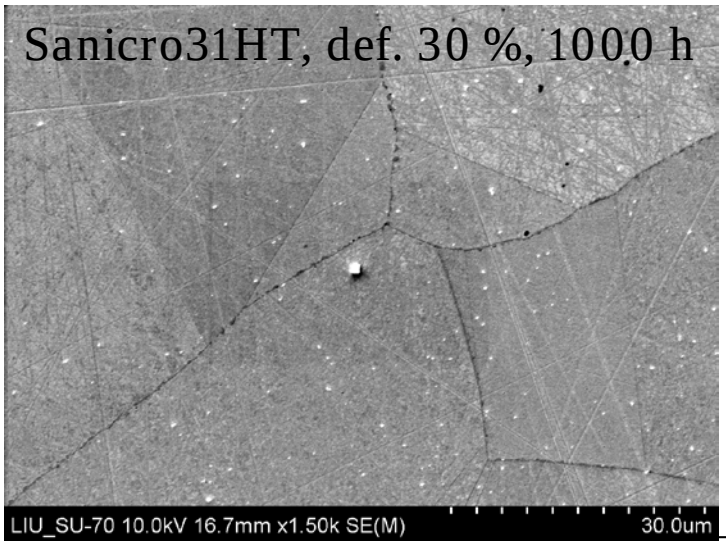
Selected project results

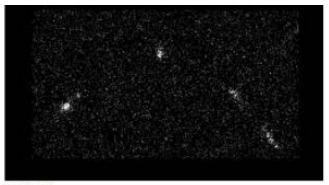
Stress relaxation cracking – screening method

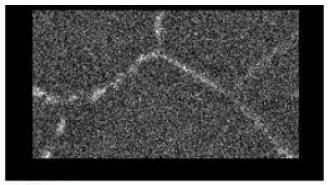
Deformation degrees: 16 %, 21 % and 30 %.

Heated for 500 and 1000 hours at 700 °C.









- No cracks observed (only precipitates)

Summary

- Creep-fatigue life is improved by increased high-temperature strength and creep resistance.
- Austenitic stainless steels suffer of embrittlement from intermetallic precipitates after long-term ageing at 650 °C and 700 °C that reduces the toughness.
- Pre-ageing decreases the TMF-life compared to virgin material.
- The stress relaxation cracking screening method showed no cracking. More understanding and further development of the method is needed.

Thank you for your attention!

Questions?

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