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

Project leader

- Sten Johansson (LiU)

Members

- Guocai Chai (SMT/LiU)
- Johan Moverare (LiU)
- Mattias Calmunger (LiU)
- Hugo Wärner (LiU, new PhD student)

Outline

- Background to the project
- Project goals
- Results & Discussion
- Future work

Background to the project

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

Gärdstadverken Linköping.
Photo Åke E. Lindman

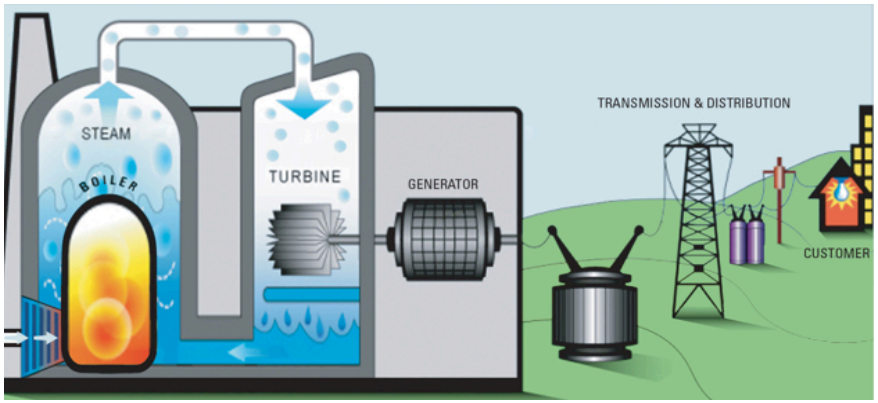


Image from Xcel Energy

Project goals

The main purposes of this project are to evaluate the mechanical behaviours for structure 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. Ongoing

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

- 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. Ongoing

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

Results & Discussion

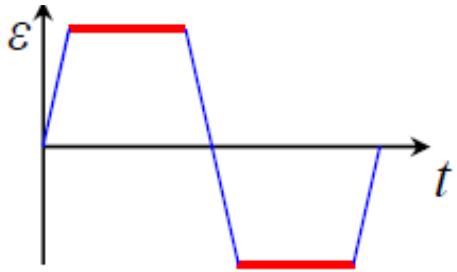
- Creep/LCF interaction of Sandvik Sanicro™ 25
- The influence of long term ageing on deformation and fracture behaviour of Alloy 617
- Cyclic oxidation in humidified air

For better understanding of materials behaviour to be used in material development.

Creep/LCF interaction of Sandvik Sanicro™ 25

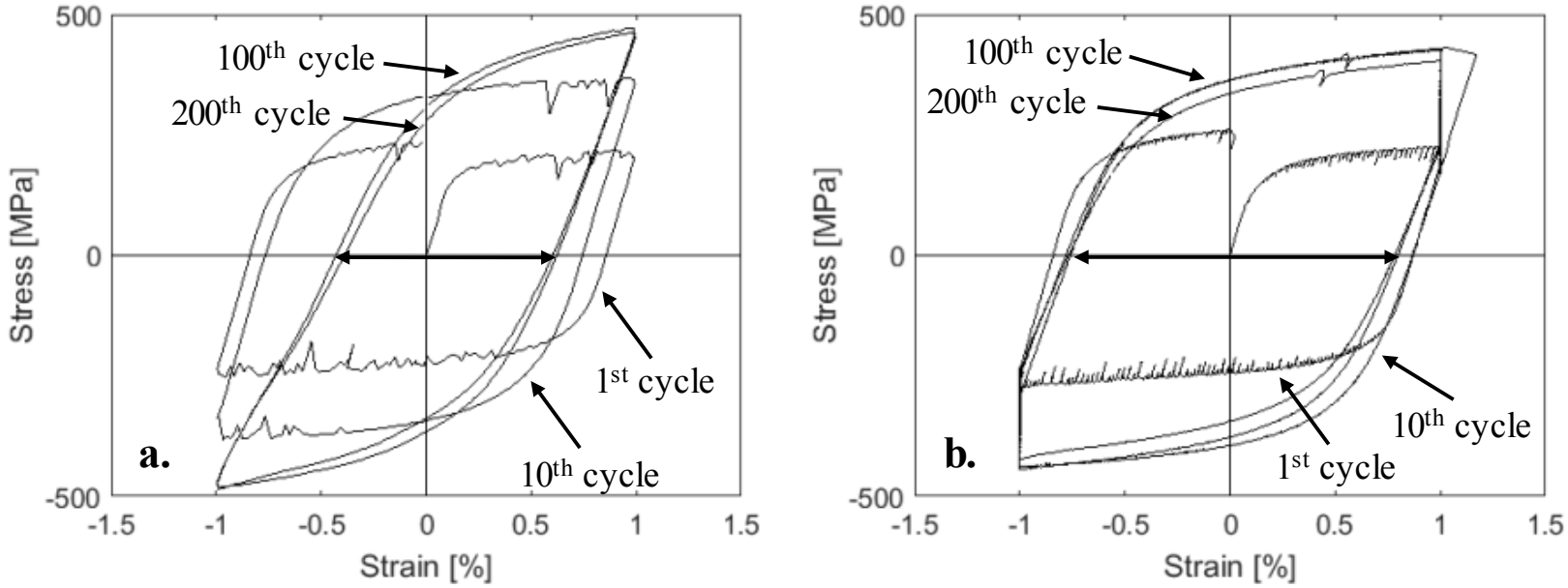
Creep-fatigue interaction testing

- Strain rate: 10^{-3} s^{-1}.
- Temperature: 700 °C.
- Strain range: 1% and 2%.
- Strain controlled testing.
- Dwell times: 0, 10 and 30 minutes.

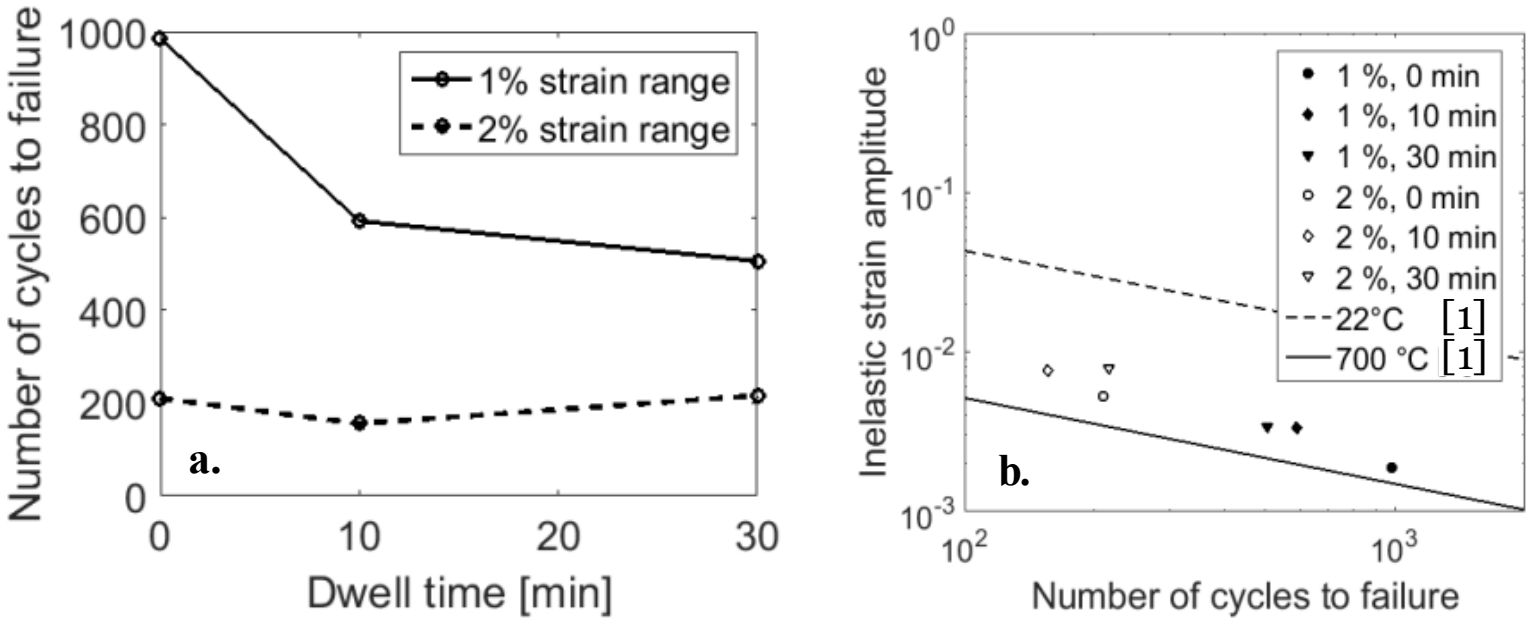


M. Calmunger et al., Trans.Indian.Inst.Met., **69** (2016) 337

2 %

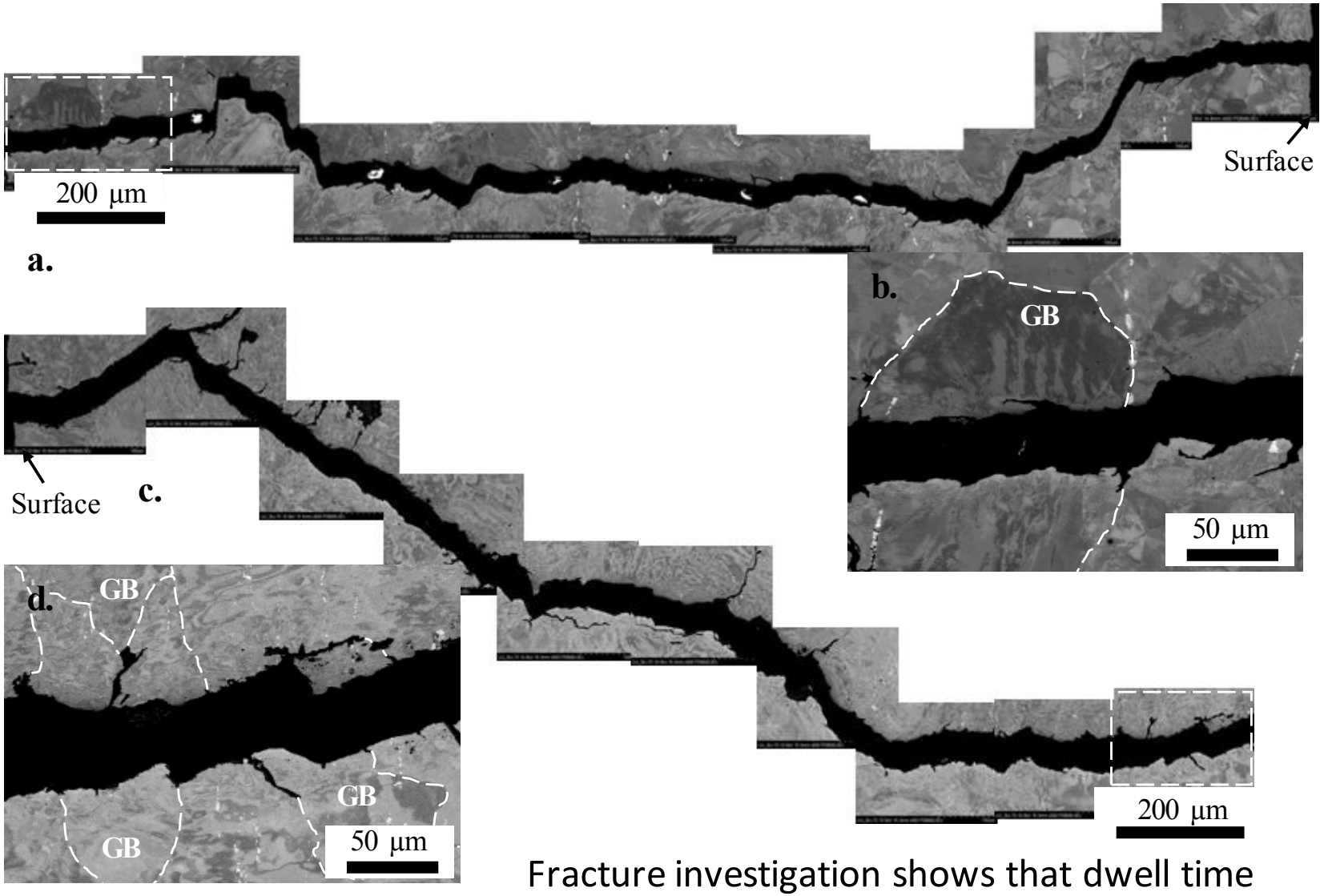


The results show that the introduction of dwell time causes a larger plastic strain range.



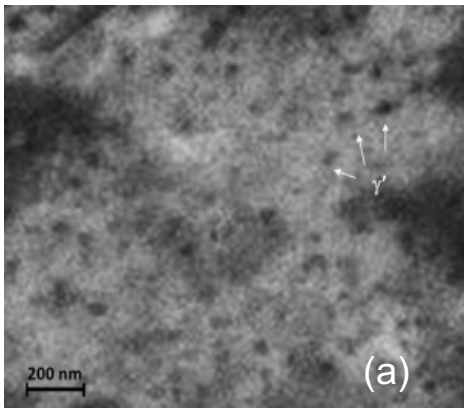
The results also show that dwell time gives a shorter life at a lower strain range, but has no or small effect on the life at a higher strain range.

[1] J. Polák et al., Mat.Sci.Eng.A., **615** (2014) 175.

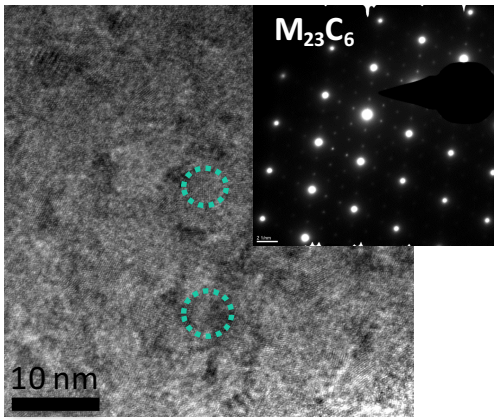


Fracture investigation shows that dwell time results in more intergranular cracking.

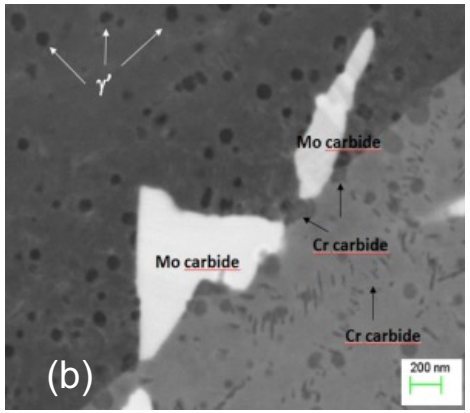
The influence of long term ageing on deformation and fracture behaviour of Alloy 617



700 °C, 3000 h



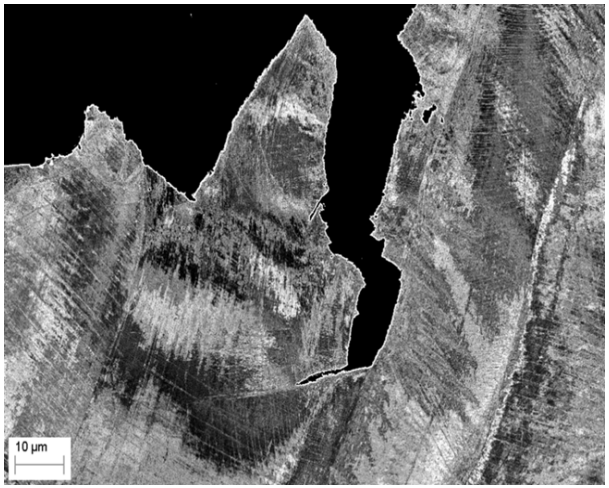
700 °C, 10 000 h

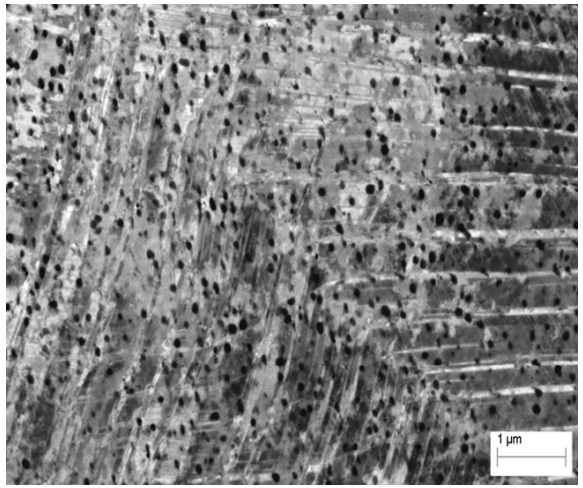


700 °C, 20 000 h

G. Chai et al., accepted for presentation THERMEC2016 (Mater.Sci.Forum)

Time (hours)	Impact toughness (J)
3000	151
10 000	135
20 000	104

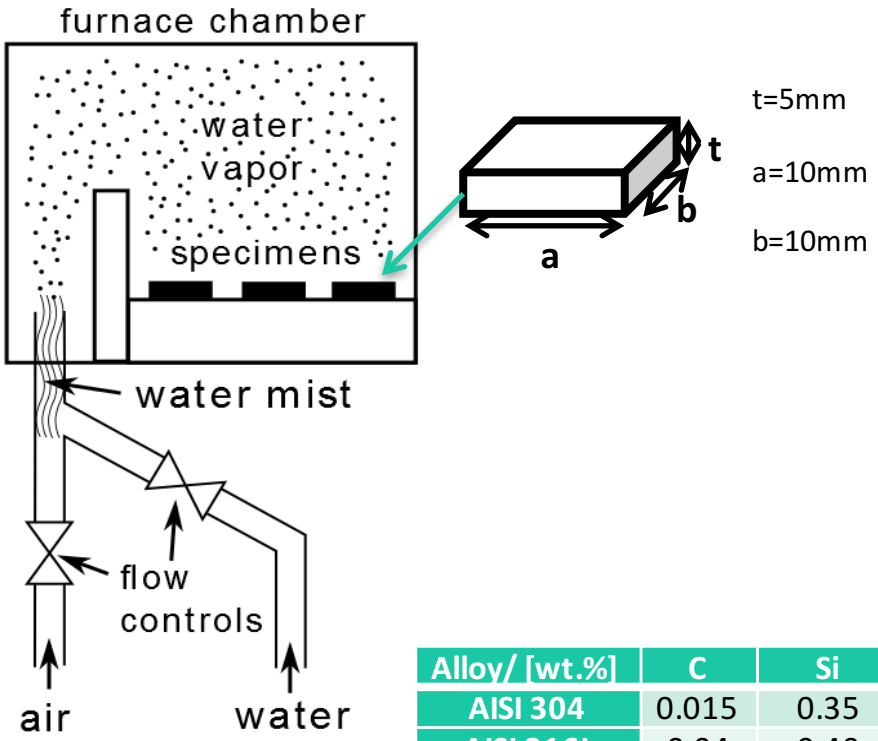




700 °C, 20 000 h

Alloy 617 still have a high toughness even after an ageing at 700°C for 20 000 hours.

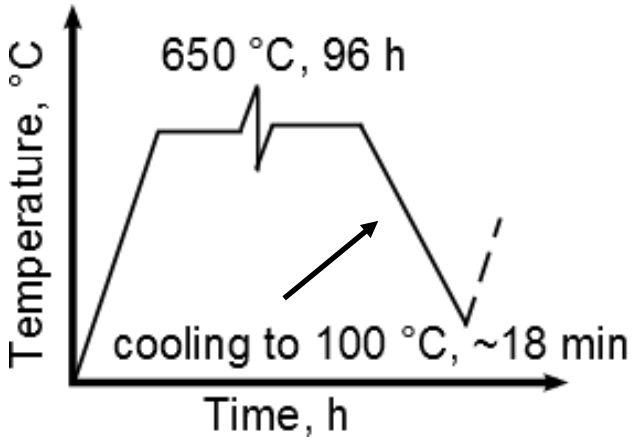
Cyclic oxidation in humidified air



t=5mm

a=10mm

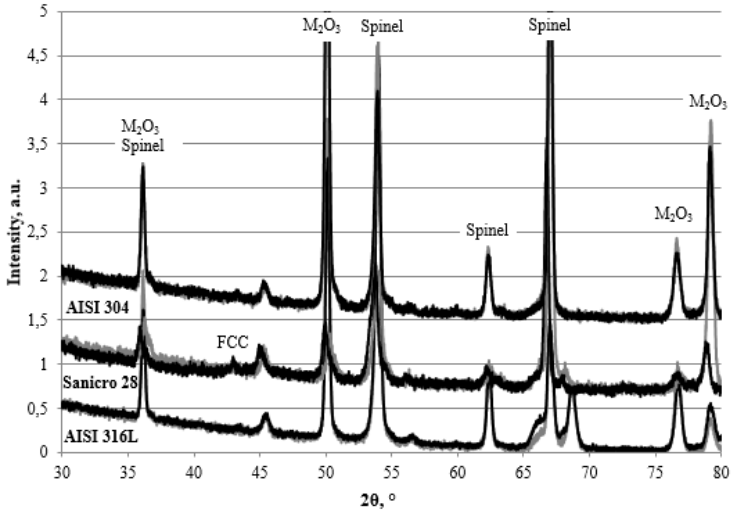
b=10mm



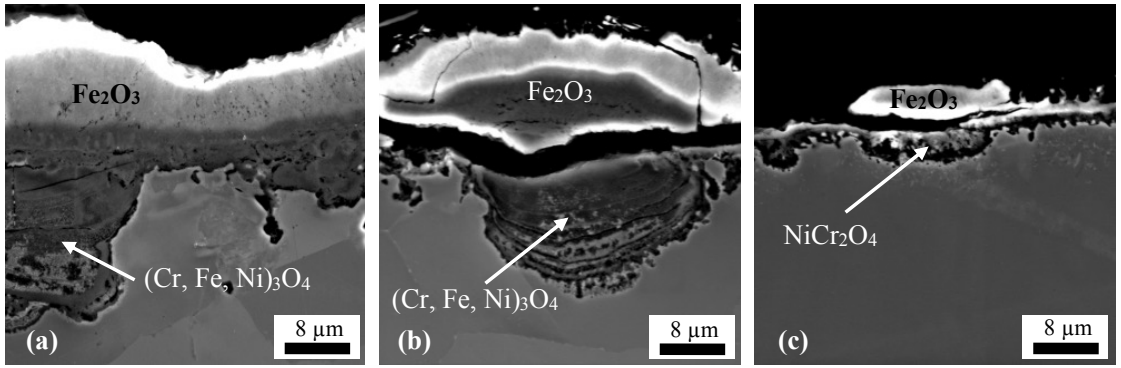
Alloy/ [wt.%]	C	Si	Mn	Cr	Ni	Mo	Cu	Fe	Cr/Fe ratio
AISI 304	0.015	0.35	1.20	18.3	10.3	-	0.3	Balance	0.26
AISI 316L	0.04	0.40	1.70	17.0	12.0	2.6	-	Balance	0.26
Sanicro 28	0.019	0.43	1.83	27.0	30.8	3.4	0.9	Balance	0.76

M. Calmunger et al., accepted for presentation THERMEC2016 (Mater.Sci.Forum)
M. Calmunger et al., Corros.Sci., **100** (2015) 524

20 and 30 cycles



AISI 304 AISI 316L Sanicro 28

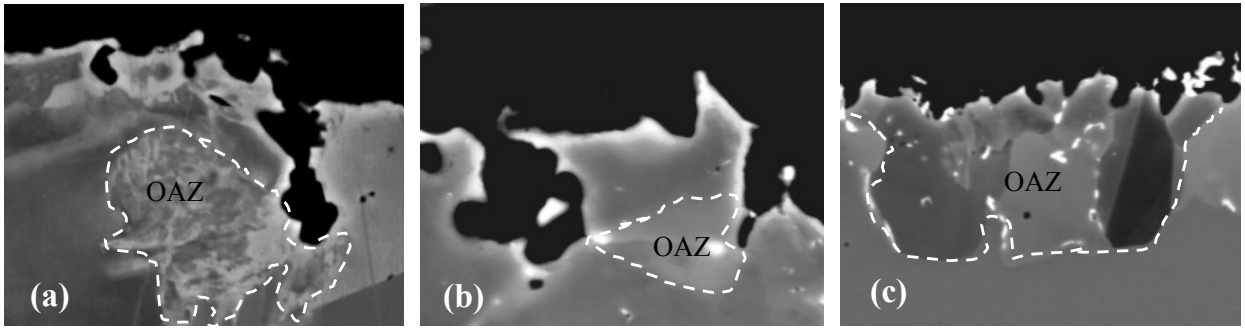


30 cycles

Oxide/[at.%]	O	Si	Cr	Mn	Ni	Fe
Fe_2O_3	52.0	0.09	1.68	0.34	0.08	45.8
Ni-rich spinel	41.30	0.93	18.61	1.95	25.35	11.86
Ni-poor spinel	55.34	0.92	20.03	0.64	8.37	14.69
$NiCr_2O_4$	50.40	0.80	22.12	0.49	24.18	2.02

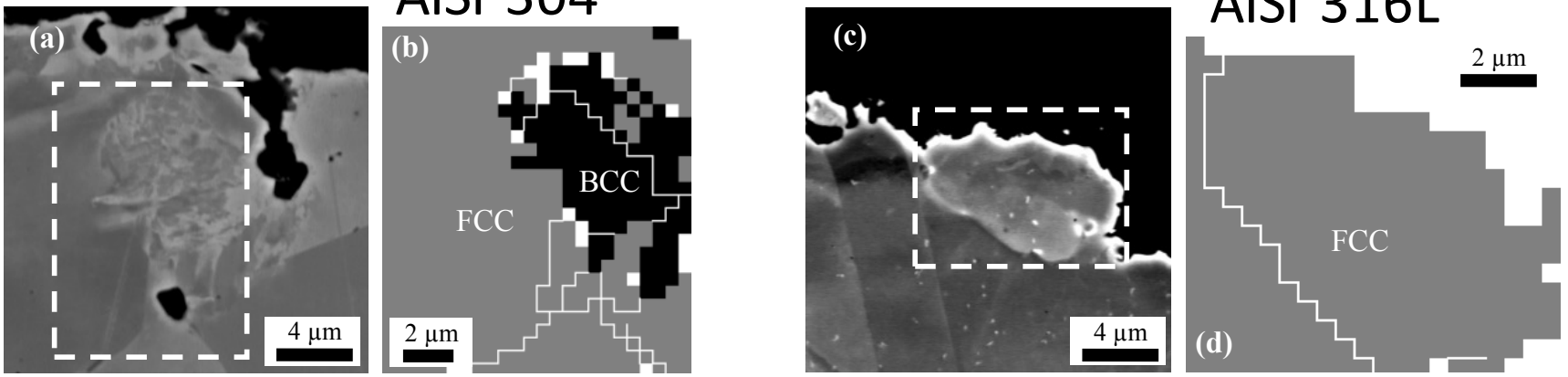
Oxidation affected zones (OAZ)

AISI 304 AISI 316L Sanicro 28

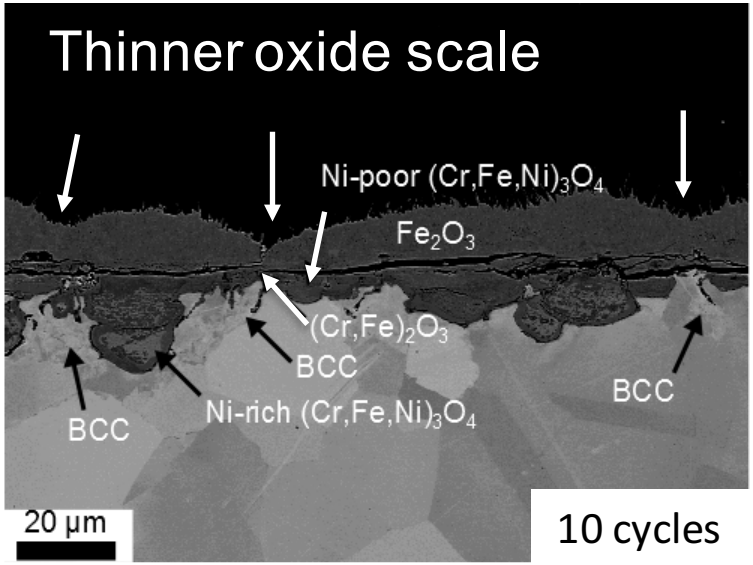


Alloy/[wt.%]	Si	Cr	Mn	Ni	Fe	Cr/Ni-ratio
AISI 304	0.40	11.48	0.38	12.96	74.33	0,89
AISI 316L	0.25	9.65	0.74	20.32	68.75	0.47
Sanicro 28	0.19	17.04	1.05	39.42	41.31	0.43

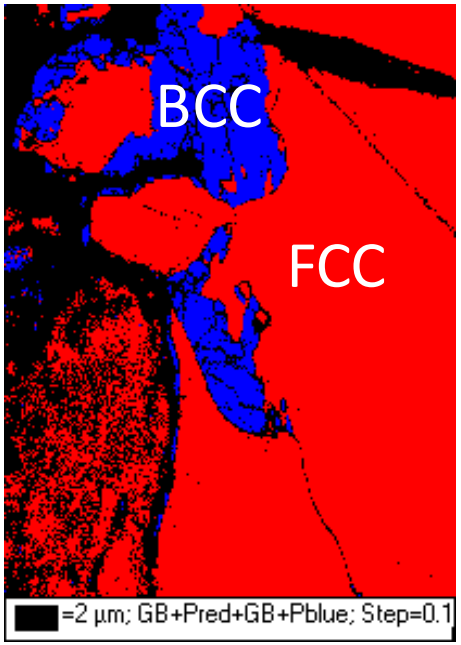
AISI 304 AISI 316L

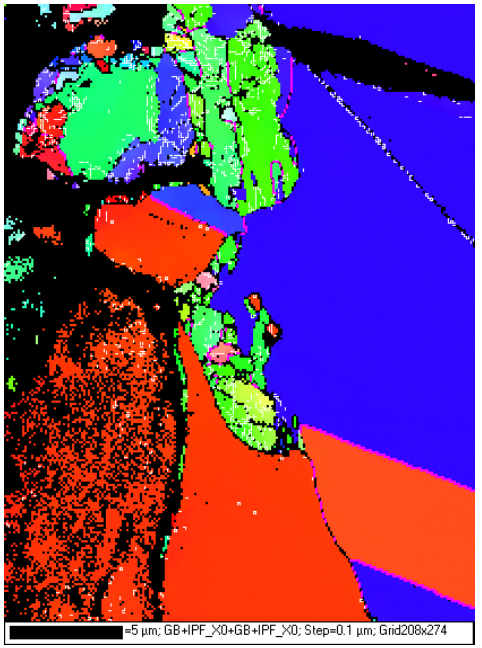


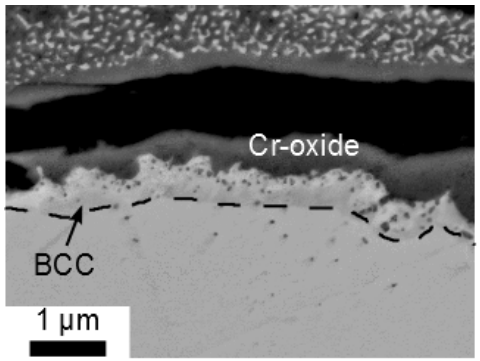
AISI 304

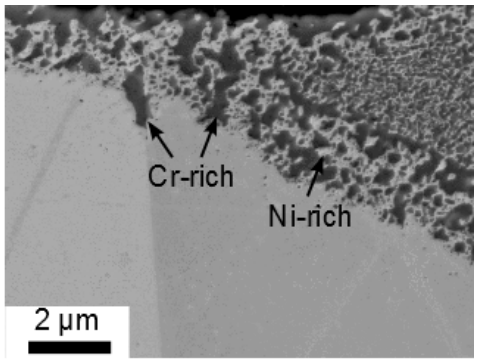


10 cycles



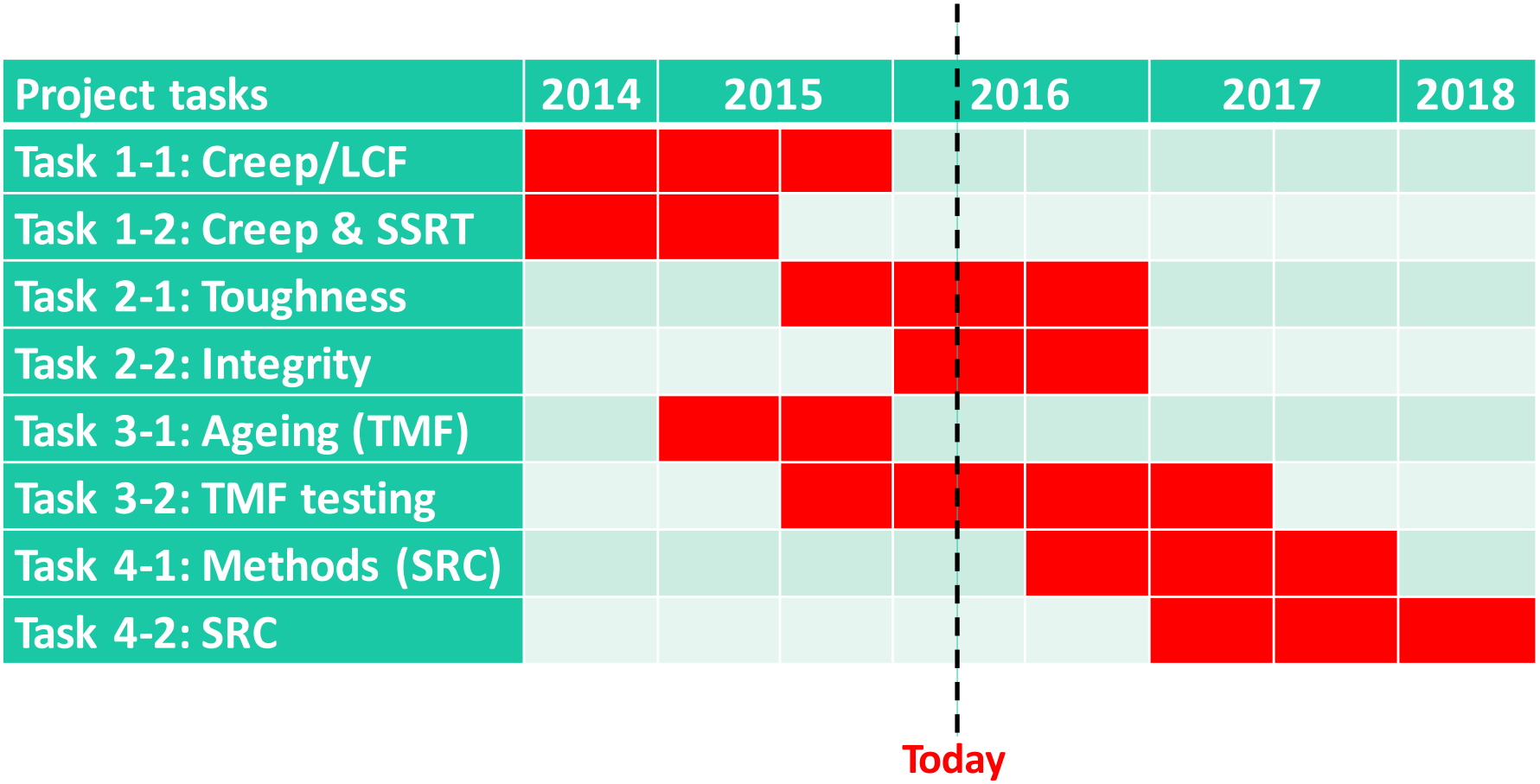






The formation of α' martensite is locally decreasing the in- and outward scale growth due to increased Cr-supply from an increased number of grain boundaries.

Future work


Project tasks
2014
2015
2016
2017
2018
Task 1-1: Creep/LCF
Task 1-2: Creep & SSRT
Task 2-1: Toughness
Task 2-2: Integrity
Task 3-1: Ageing (TMF)
Task 3-2: TMF testing
Task 4-1: Methods (SRC)
Task 4-2: SRC
Today

Thank you for your attention!

Questions?

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