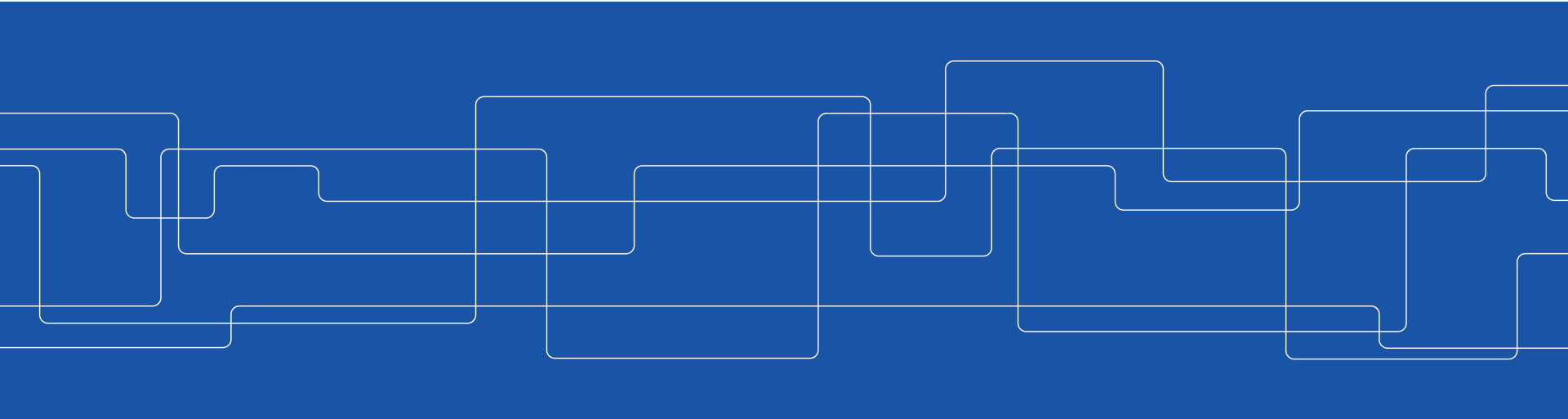
Simulation of nitride precipitation during welding

Lars Höglund, Niklas Holländer Pettersson and Annika Borgenstam

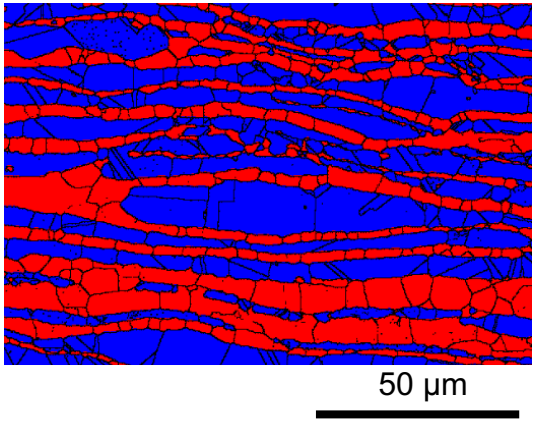


Outline

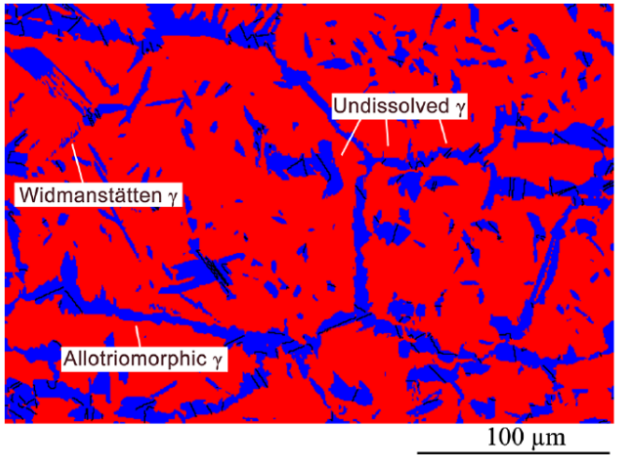
- Background
- Simulation model
- Results
- Comparision with experiments
- Summary

HAZ microstructure duplex stainless steels

Ferrite red
Austenite blue



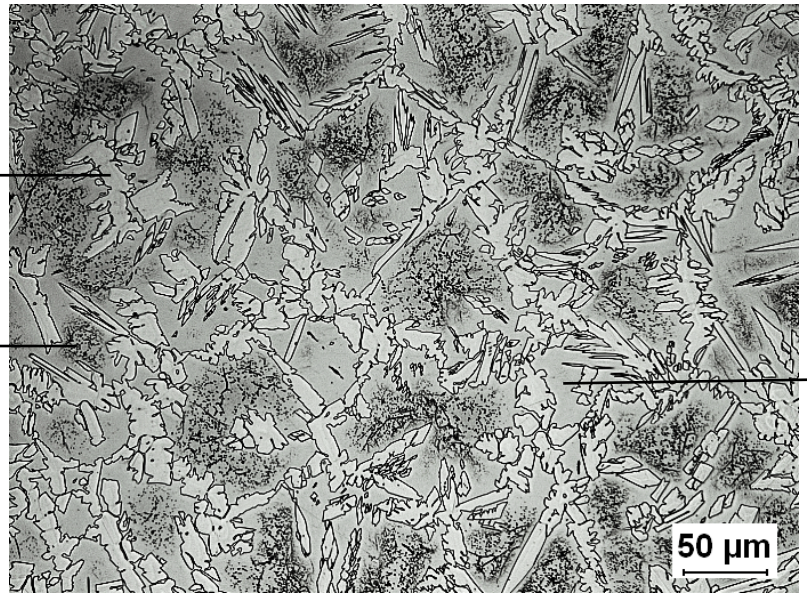
Starting microstructure base metal



Microstructure in high-temperature HAZ
(dilatometer simulation “1 pass”)

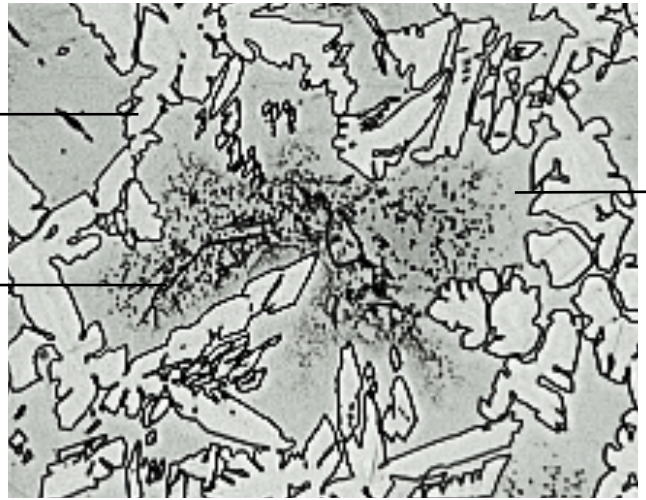
(2507)

Influence of fast cooling from high temperature



Microstructure of 2507 after cooling 150 K/s from 1350 °C (OM image).

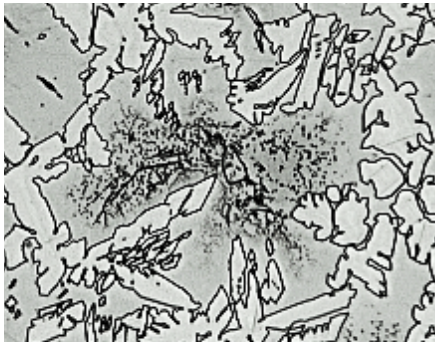
Influence of fast cooling from high temperature



Microstructure of 2507 after cooling 150 K/s from 1350 °C (OM image).

“Wish list” simulations

- Simulation should include
  - Formation of austenite and chromium nitride
  - Influence of grain size, cooling rate, chemistry
  - Nitride-free zone? Nitride free grain?
- A combination of Dictra models applied to capture the behavior during cooling



Can we reproduce nitride-free zone?

Dictra

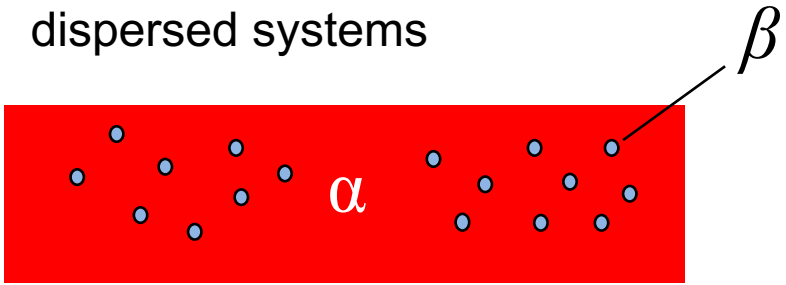
- Simulation of diffusion controlled reactions in multi-component alloys
- Simulation on geometries, which may be reduced to one spatial coordinate (planar, cylindrical or spherical)
- Linked to Thermo-Calc, which provides all necessary thermodynamic properties, and separate database for mobilities
- Homogenization simulation model with a combination of moving boundary and dispersed phase (planar geometry)

Examples of Dictra models

Moving boundary multiphase system with planar geometry

Local equilibrium holds at phase boundary

Diffusion in dispersed systems

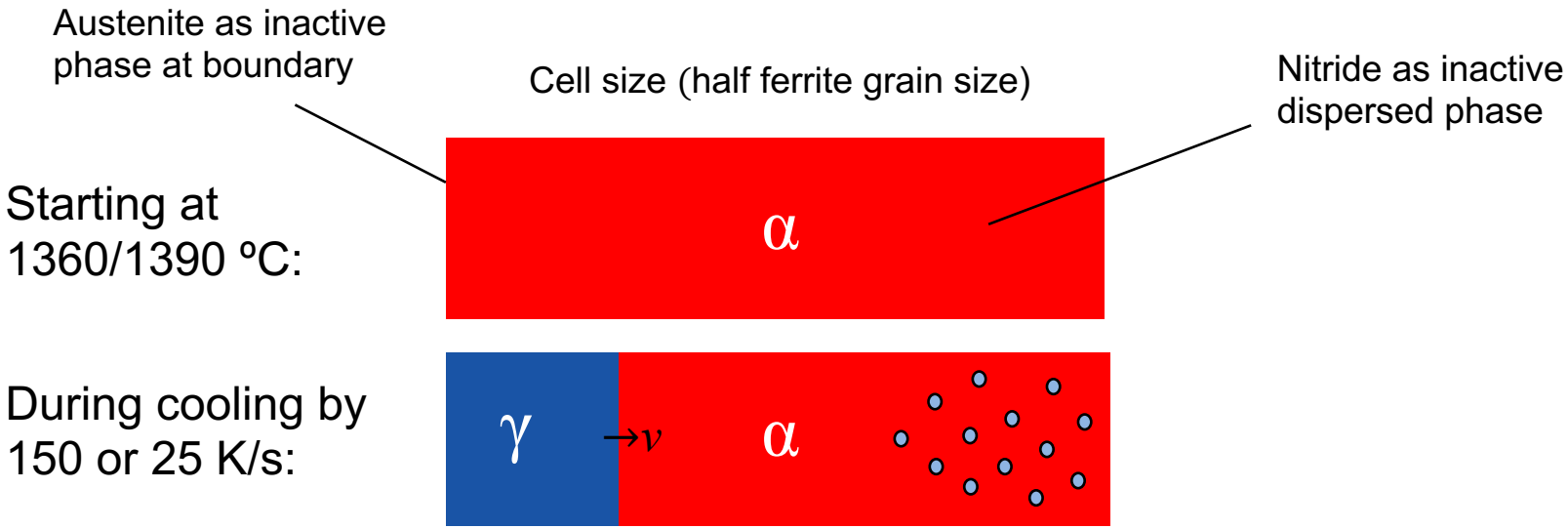


Equilibrium holds locally in each volume element (homogenization model[1])

[1]H. Larsson, Calphad, 47 (2014), 1-8.

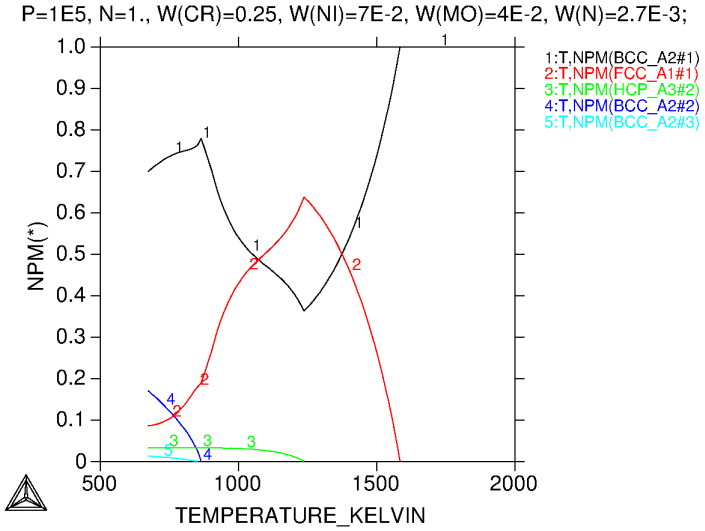
Model setup in SuperAvon

Simulations of 1D moving boundary and dispersed phase reaction using the homogenization simulation model

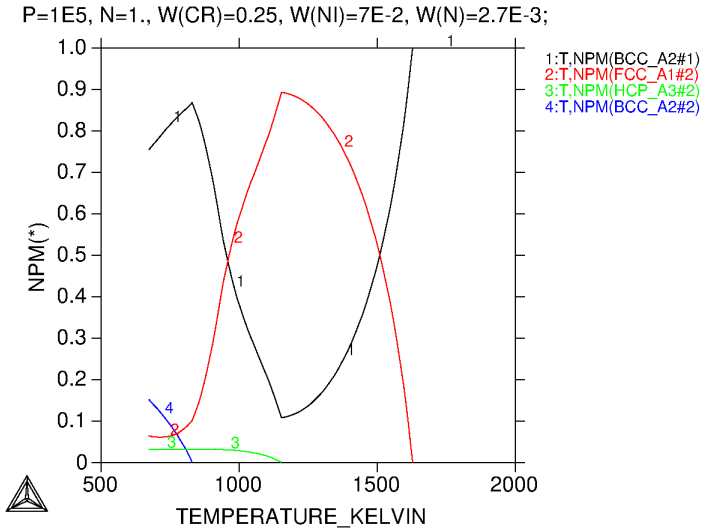


Reduced system FROST database

2507



Fe-Cr-Ni-Mo-N



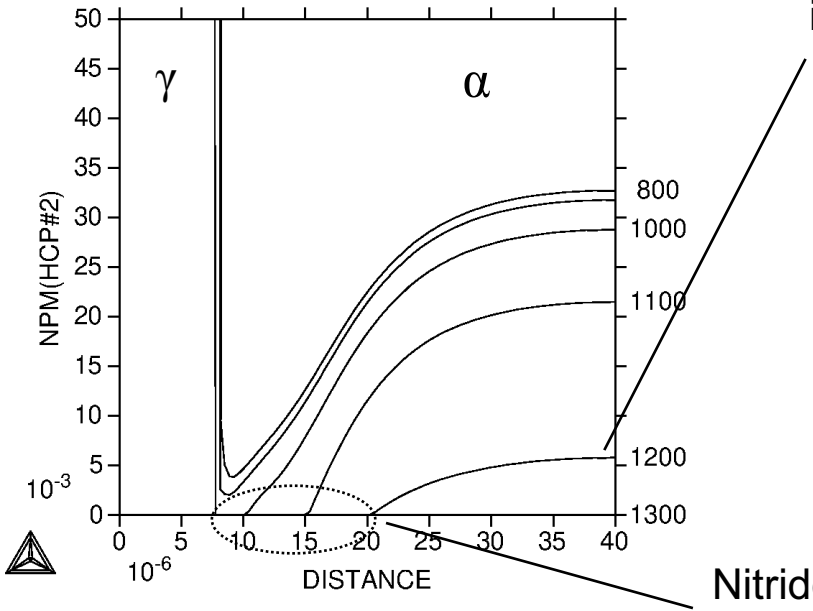
Fe-Cr-Ni-N

Simulations performed

	Mn	Cr	Ni	Mo	N	T start	Cooling rate
2507	0.0	25.12	6.85	3.78	0.288	1390 °C	25, 150 K/s
2101	4.24	21.32	1.56	0.32	0.226	1360 °C	25, 150 K/s
2205	0.0	22.2	5.7	3.1	0.171	1360 °C	25, 150 K/s

In total >50 simulations, each simulation takes from 2 days up to 2 weeks

Simulated microstructure evolution

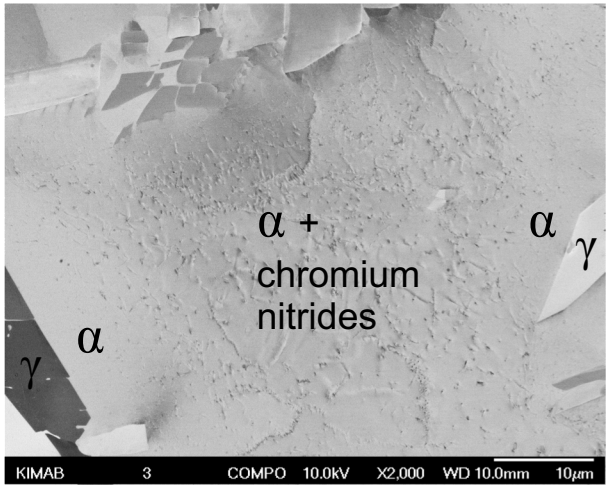


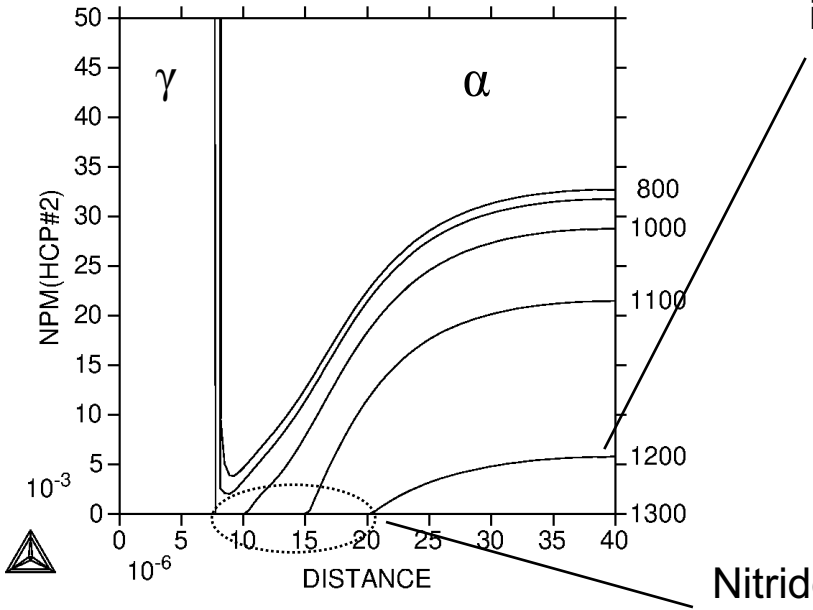
Nitrides formed first in ferrite grain centre

Nitride-free zone to adjacent austenite

2507, 150 K/s

Simulated microstructure evolution



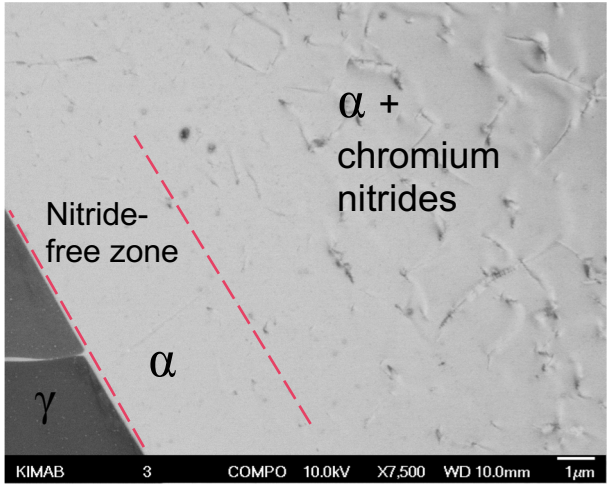


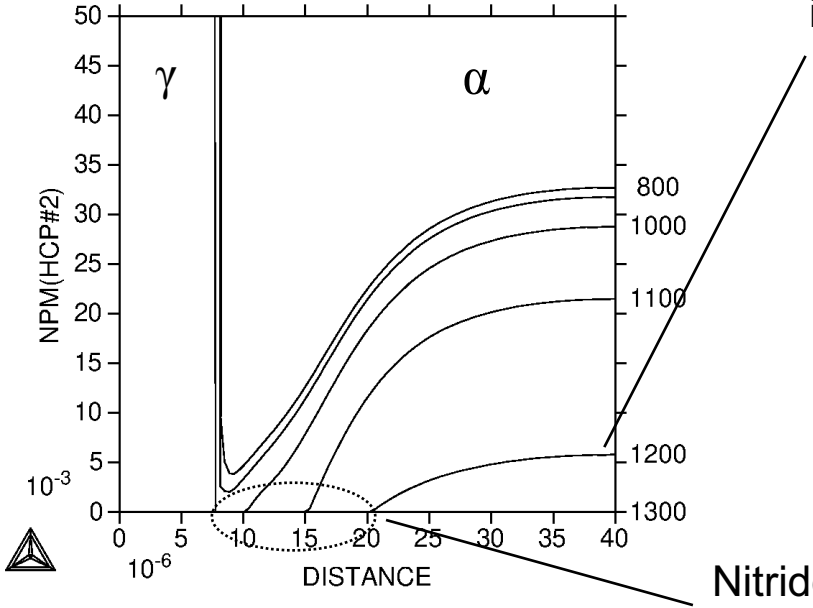
Nitrides formed first in ferrite grain centre

Nitride-free zone to adjacent austenite

2507, 150 K/s

Simulated microstructure evolution

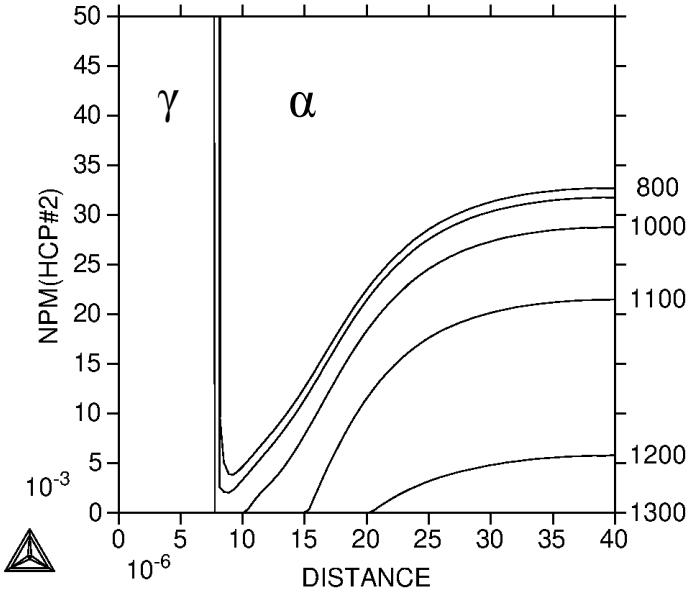




Nitrides formed first in ferrite grain centre

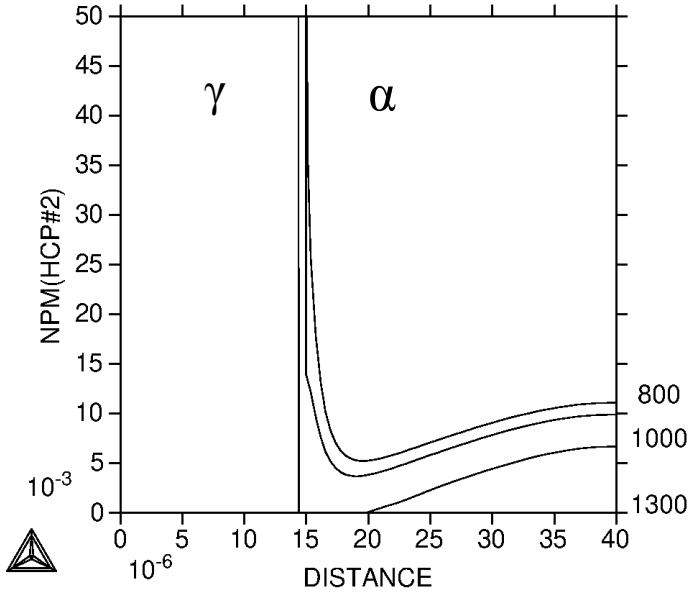
Nitride-free zone to adjacent austenite

Influence of cooling rate



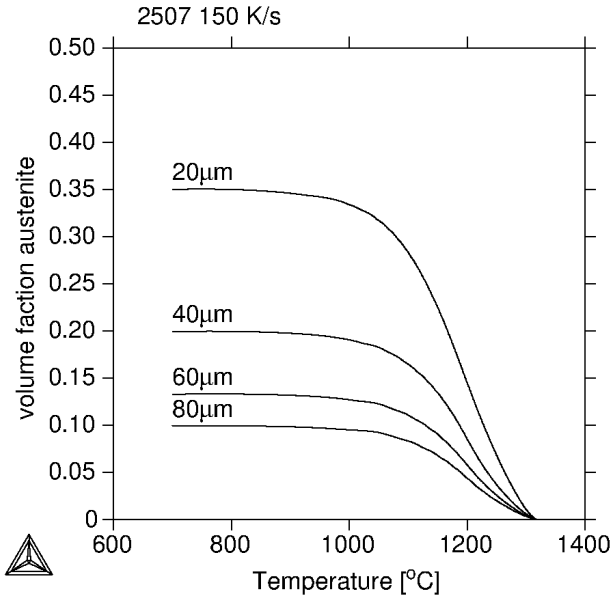
150 K/s

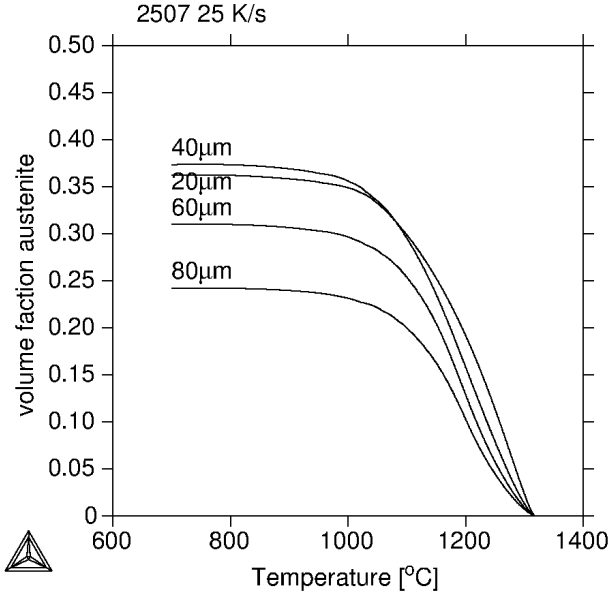
2507



25 K/s

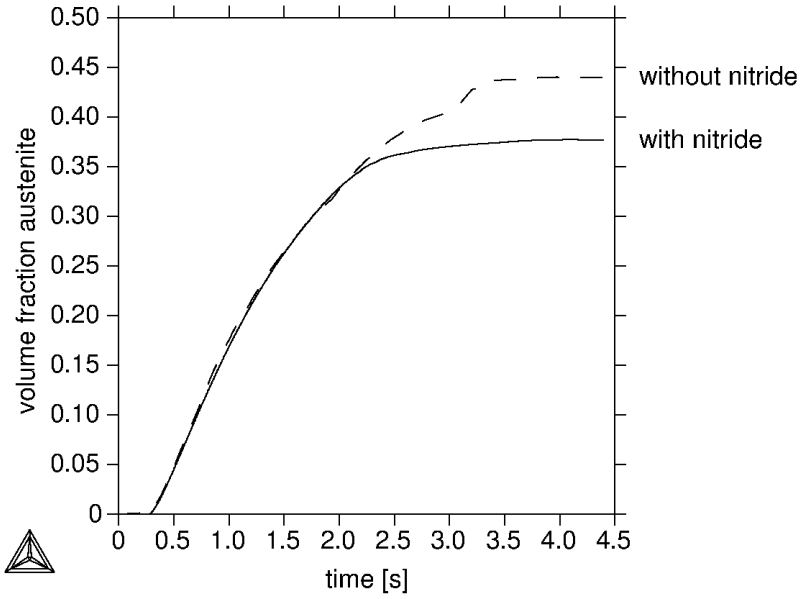
Austenite formation depending on cooling rate and grain size



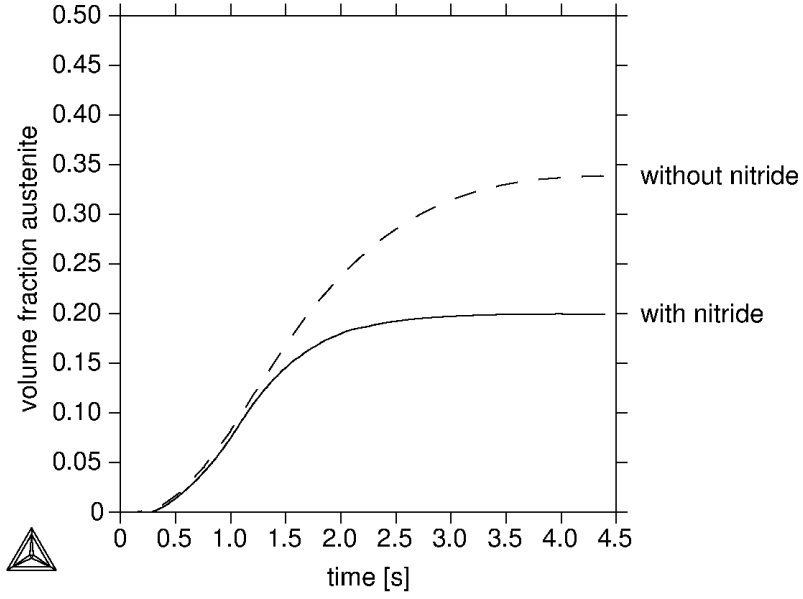


150 K/s 2507 25 K/s

Influence of nitride on austenite formation



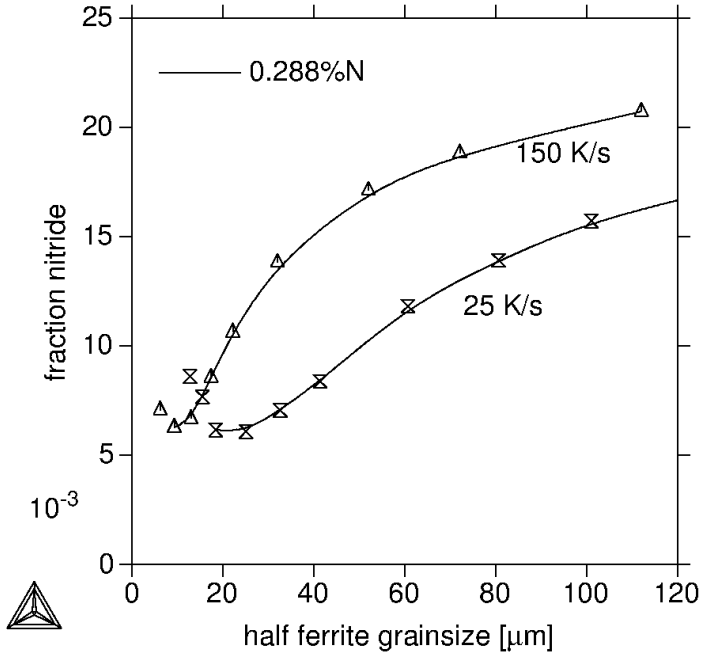
2507, 10 µm cell, 150 K/s



2507, 40 µm cell, 150 K/s

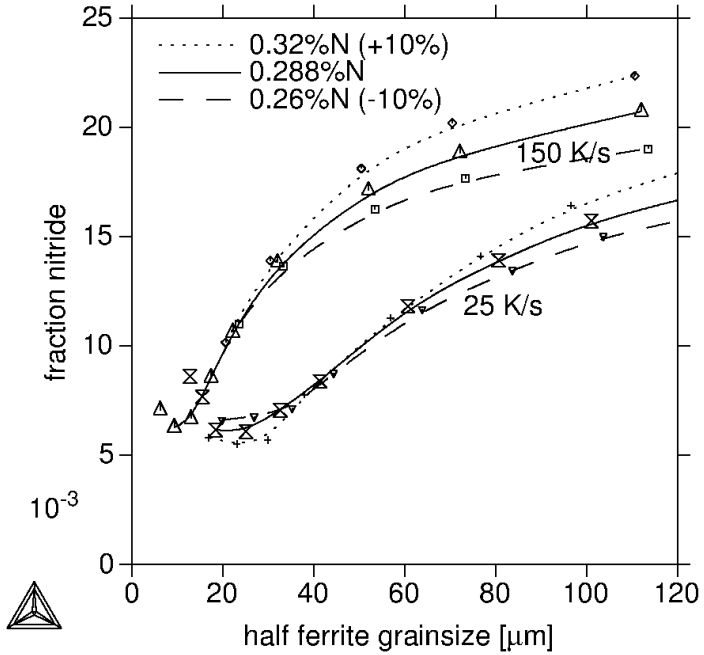
Influence of grain size and cooling rate on fraction of nitride formed

2507



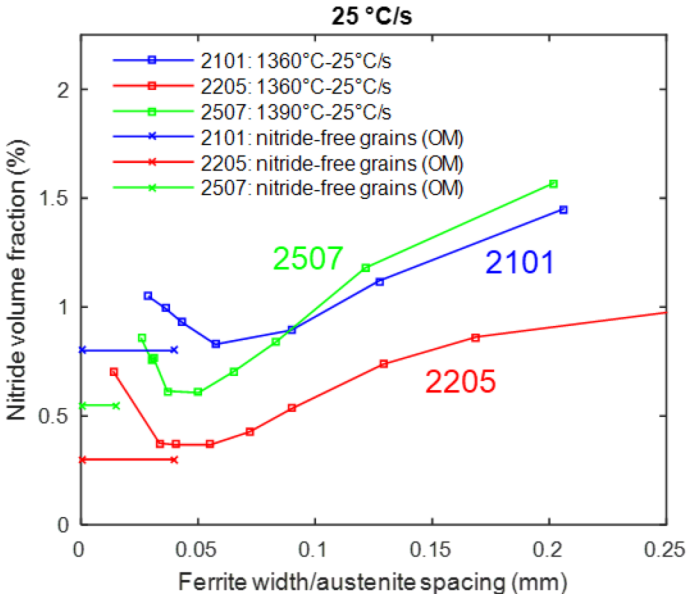
Influence of grain size and cooling rate on fraction of nitride formed

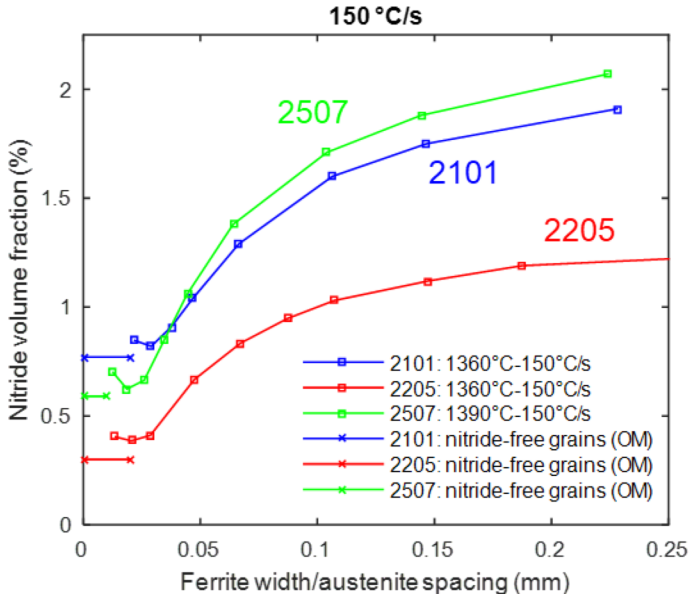
2507



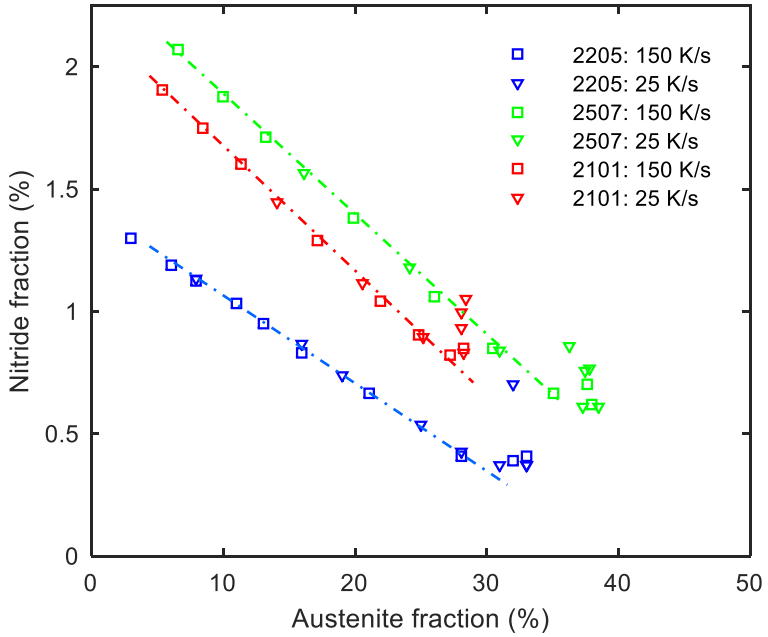
Influence of nitrogen level

Comparison with experiments





Balance between fraction of austenite and nitride formed



Difference between grades?

Summary

- In Dictra the homogenization model makes it possible to simulate combined moving boundary and dispersed phase reactions (however, at a certain cost)
- This model combination have been applied to simulate microstructure evolution in high-temperature HAZ
- Despite simplifications the simulations captures details of the microstructure evolution (e.g. nitride-free zone) and compares reasonably well with experiments

Thank you!