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Thermit® Welding of Bainitic Rails

Dr. Jörg Keichel

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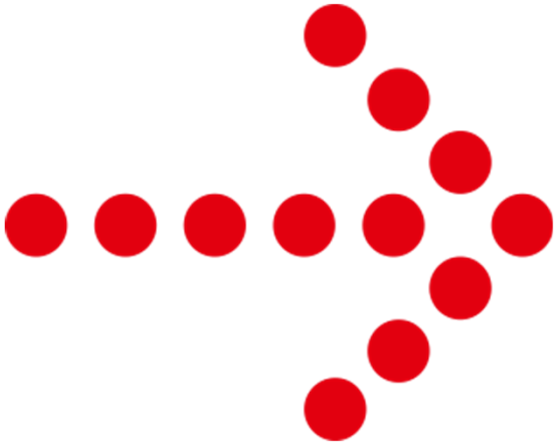
100+ years of Thermit® welding

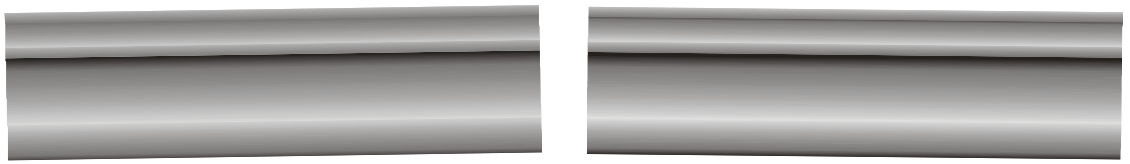
- We create the continues welded track…..
- Steelmaking and welding in the track



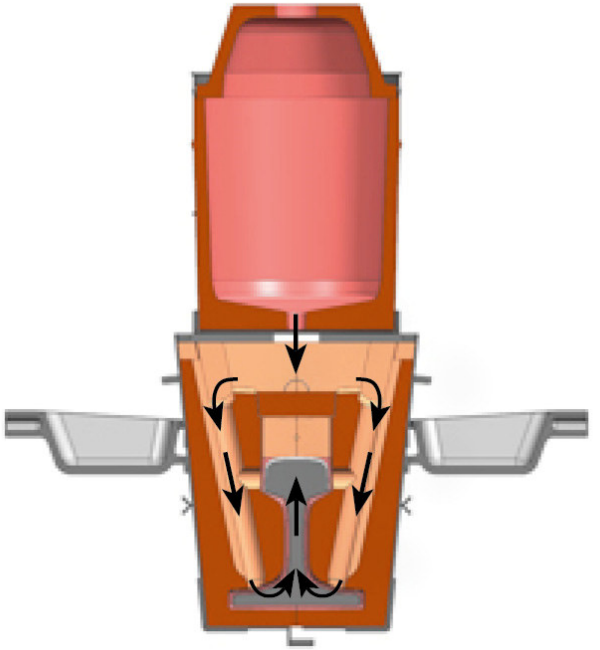
BAINITIC THERMIT® WELDING

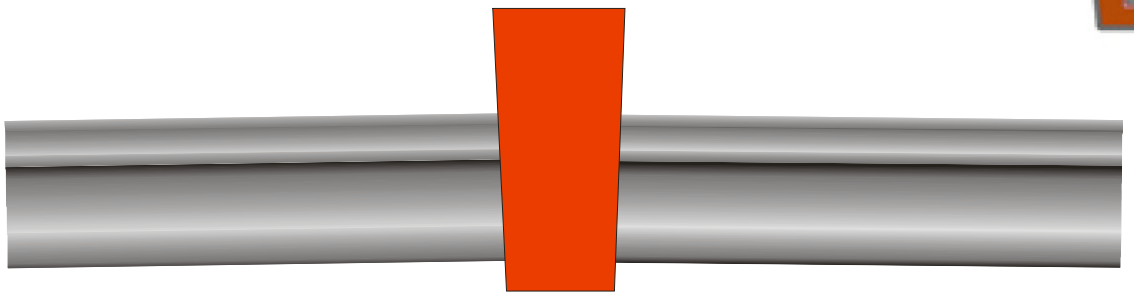
The principle welding of perlitic and bainitic rails is the same!

Gap

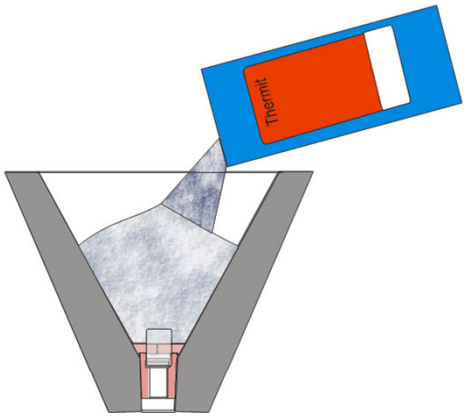


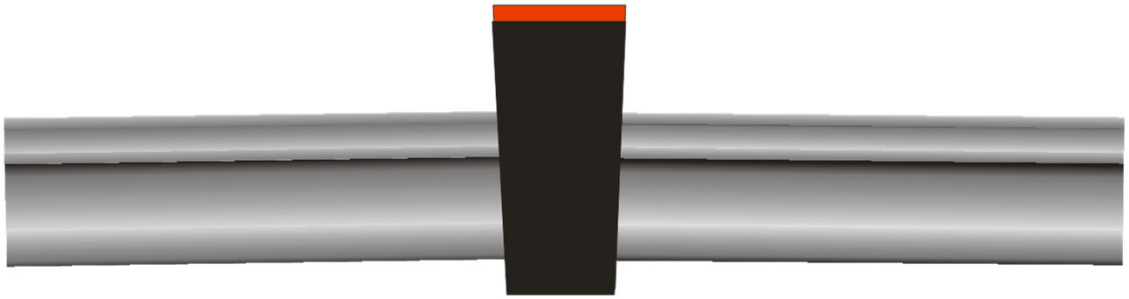
Mould





Portion in crucible





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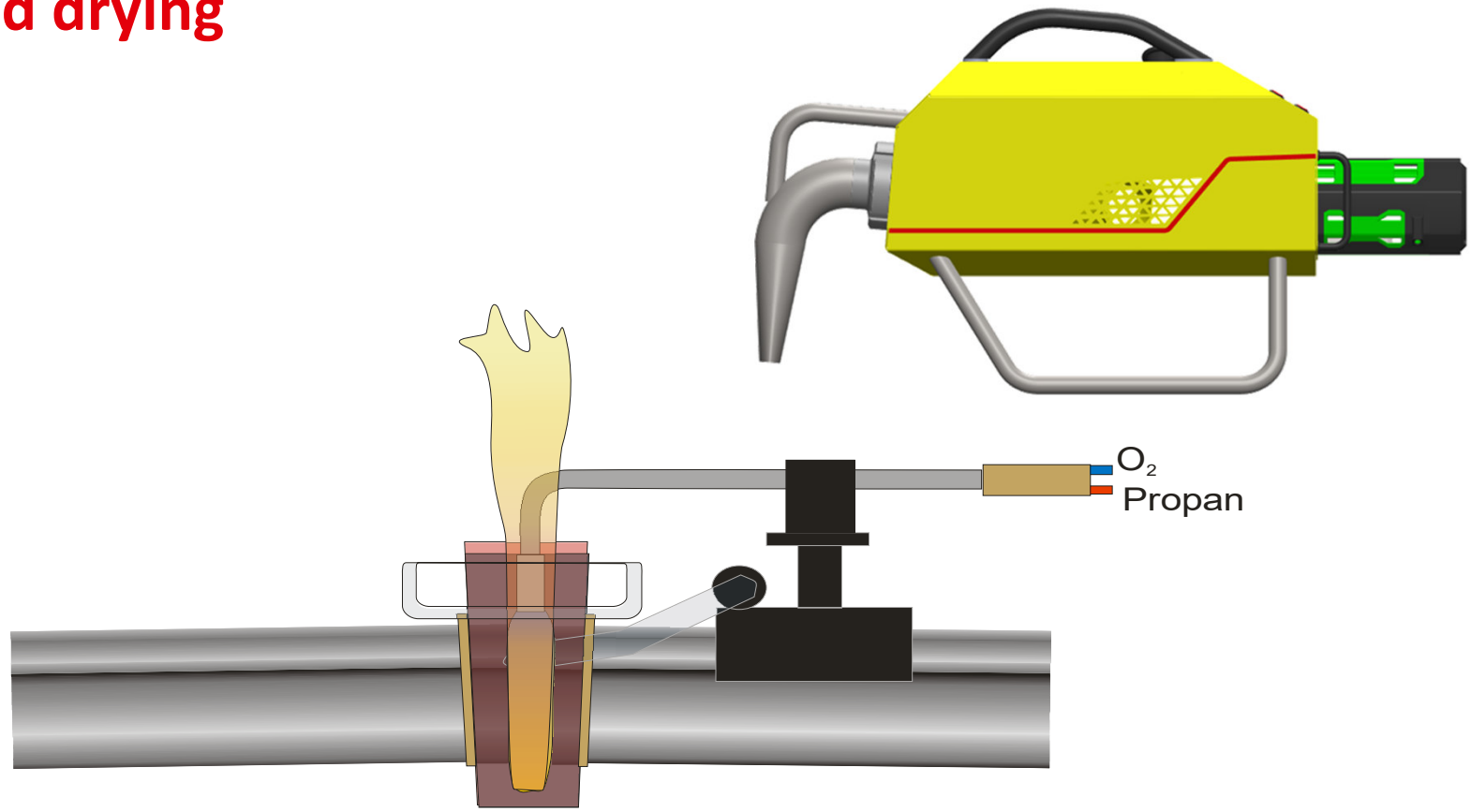
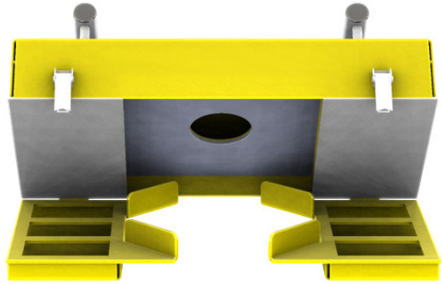
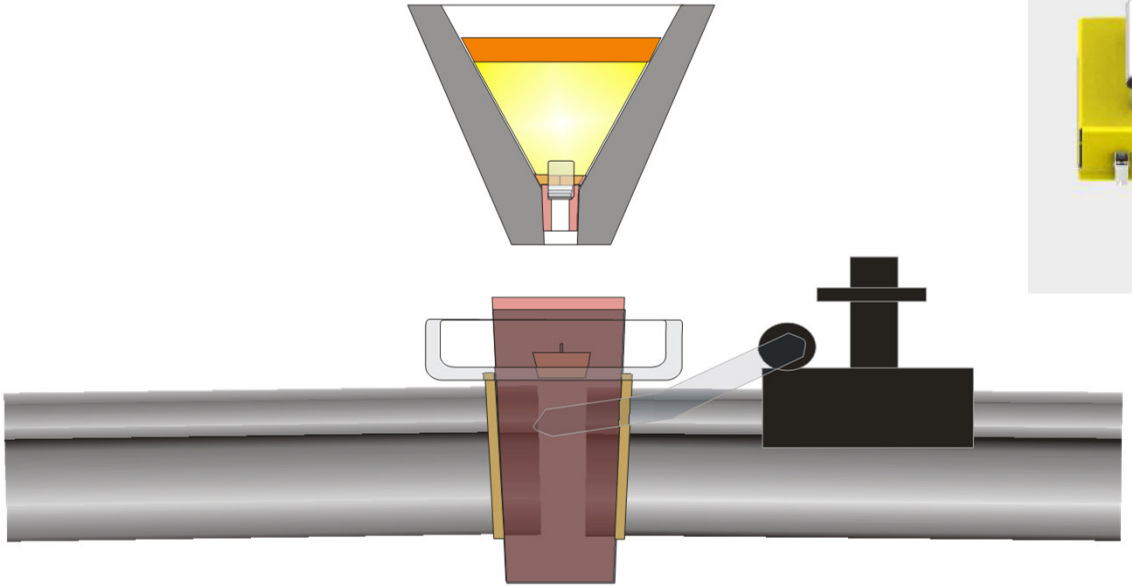
Pre-heating and drying

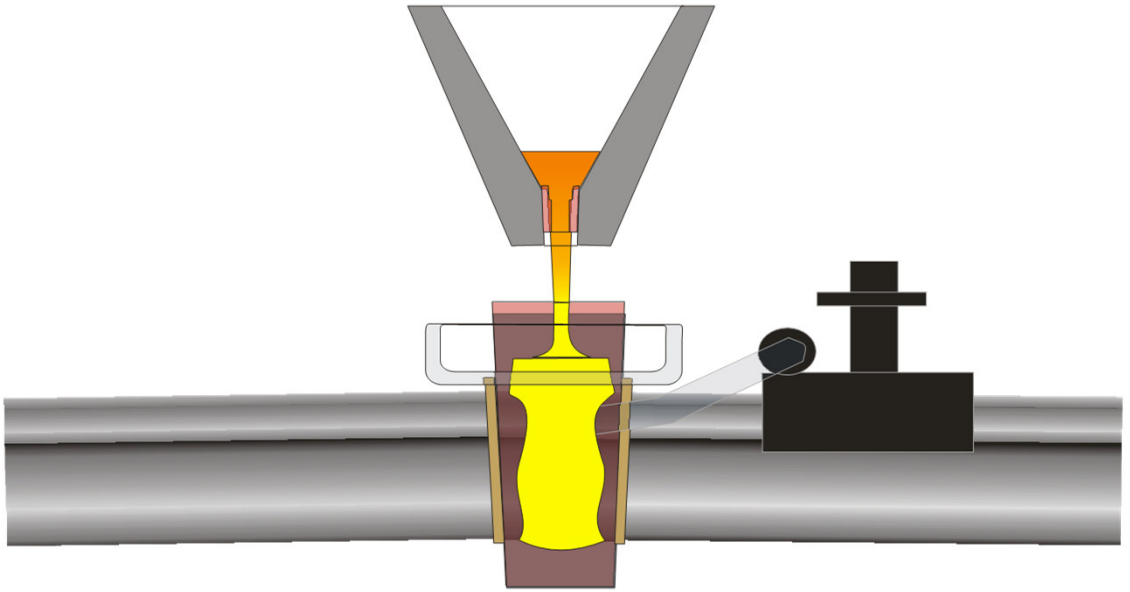


Thermit reaction – steel making

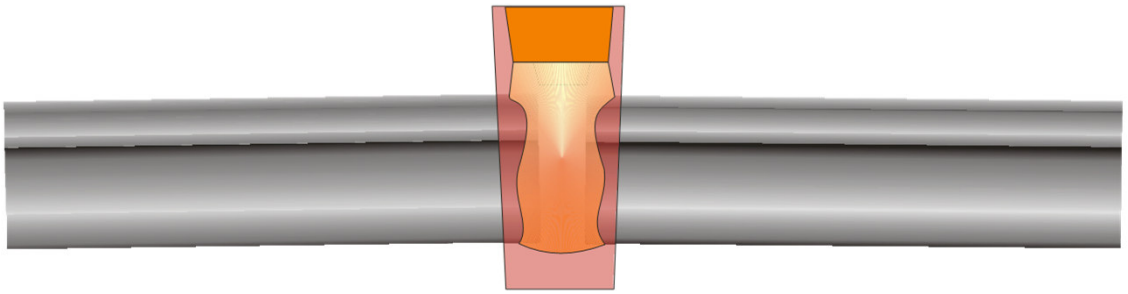




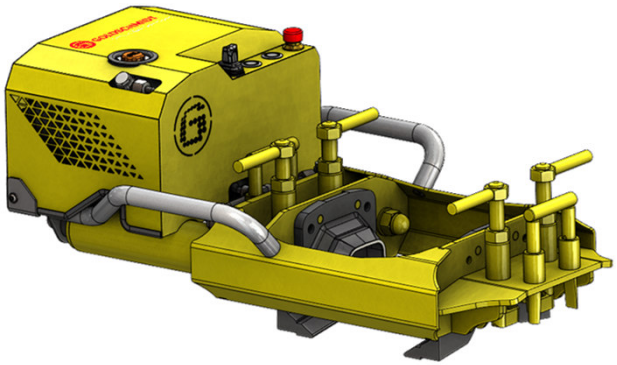
Casting

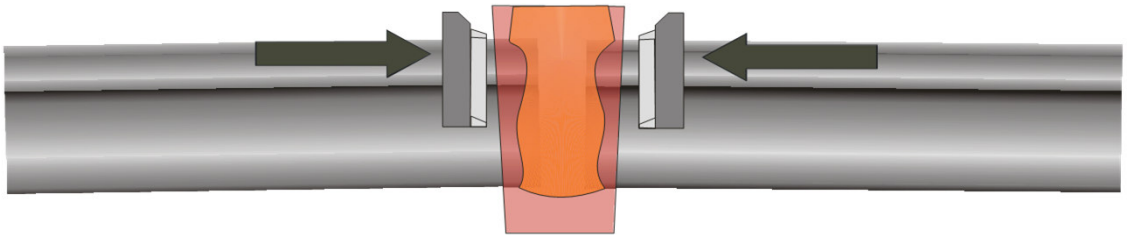


Solidification

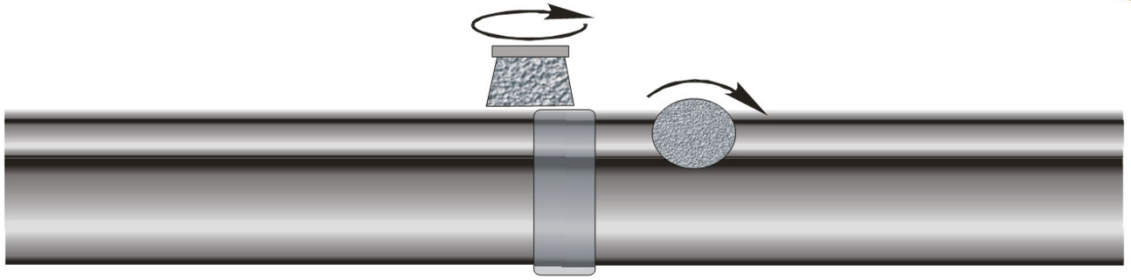


Shearing / trimming

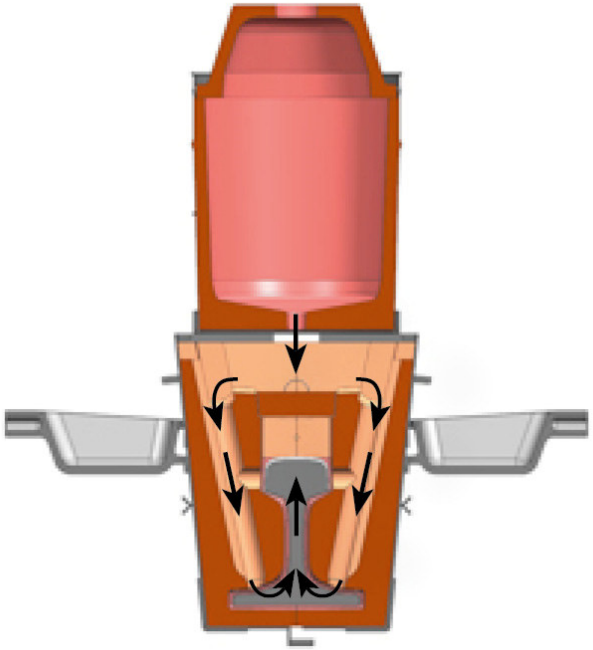




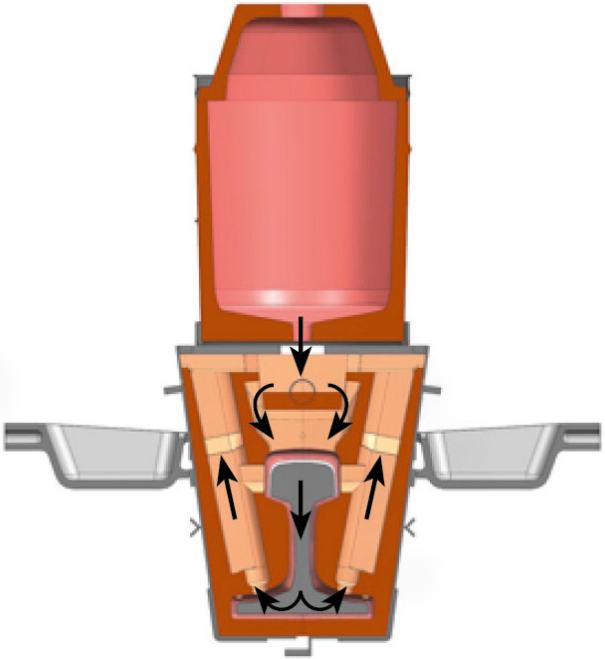
Grinding



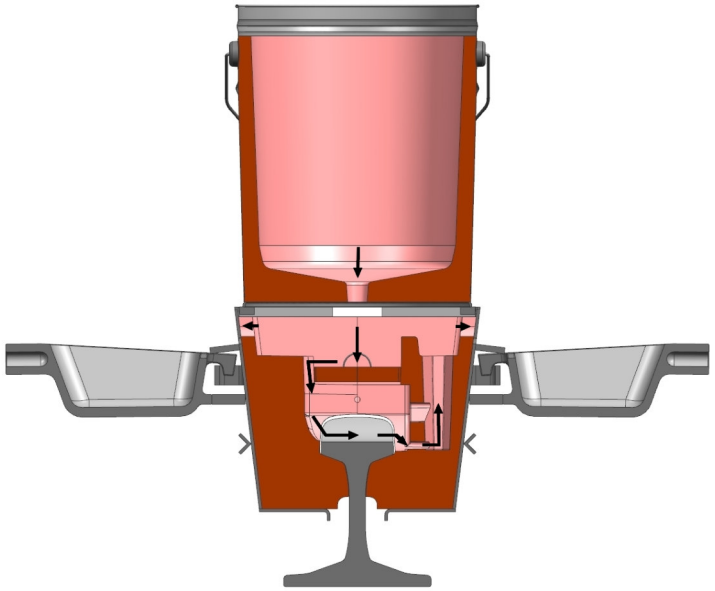
Execution // Principle of existing processes



SoW-5: Central pouring,
rising casting system

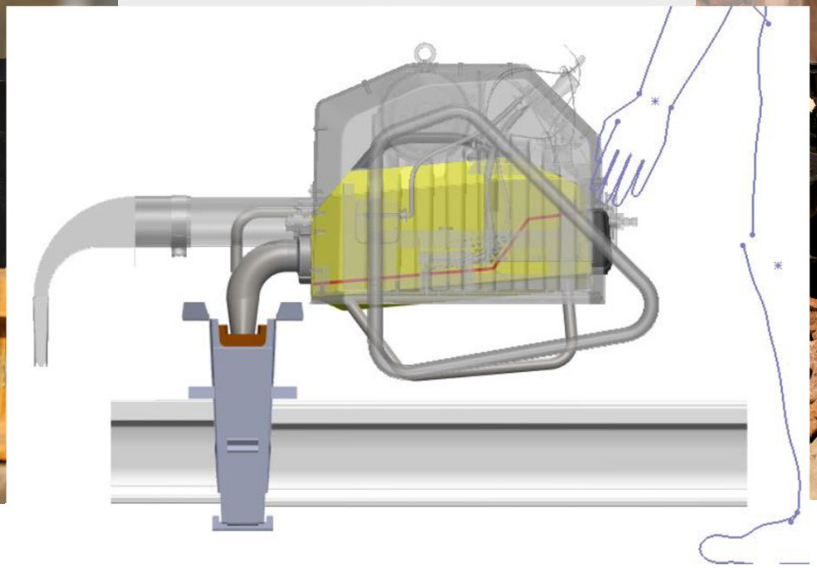


SkV xxx: Central pouring,
down-hill casting system



THR: Central pouring,
side casting system

BAINITIC THERMIT® WELDING



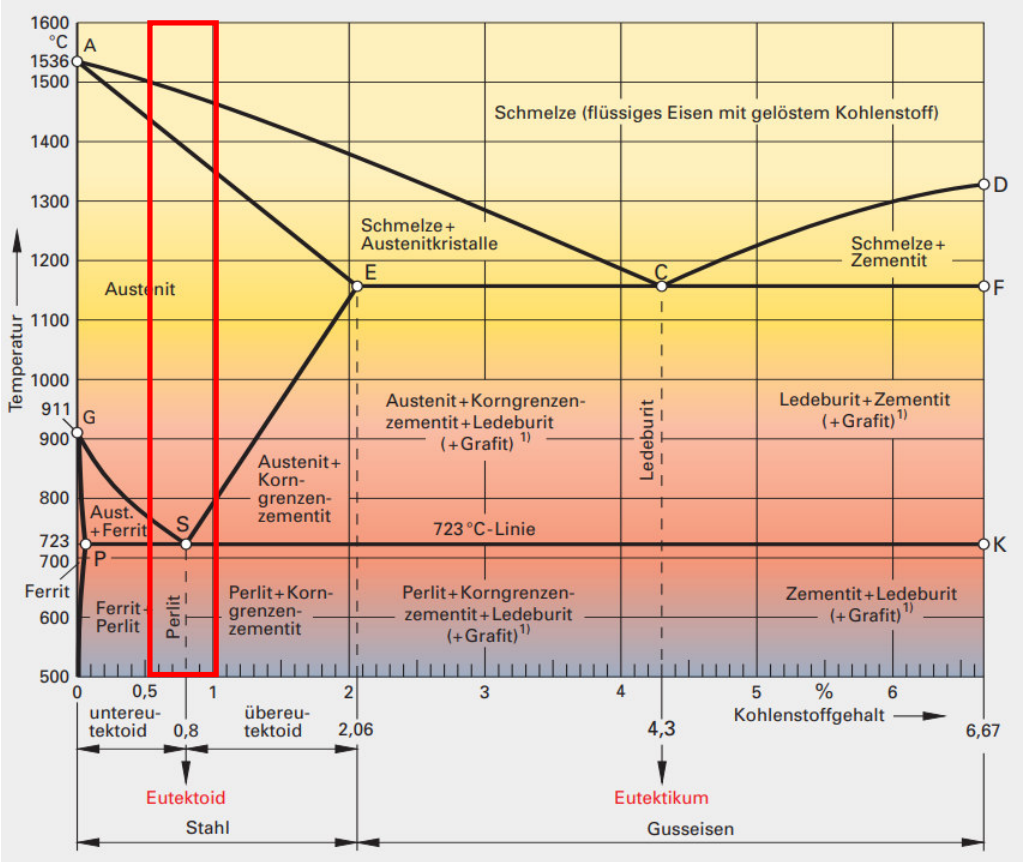
Motivation

- Rail steels
- Perlitic microstructure
- Rolling contact fatigue

Perlitic rails

Phase diagram Iron / Carbon

- Structures in phase diagram are in equilibrium
- Depending on Carbon content and cooling rate
- different microstructures develop



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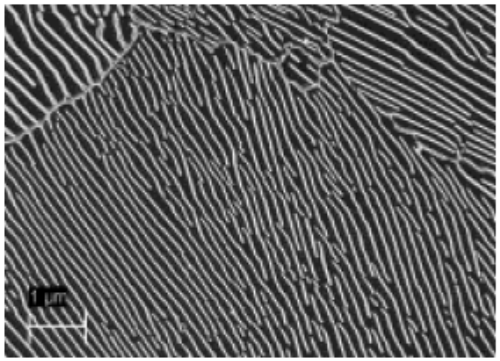
Microstructure in perlitic rail steels

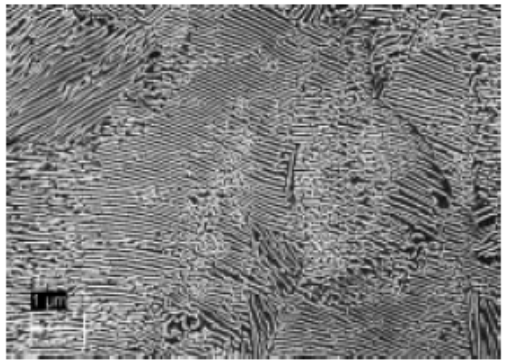
R260

naturally hard



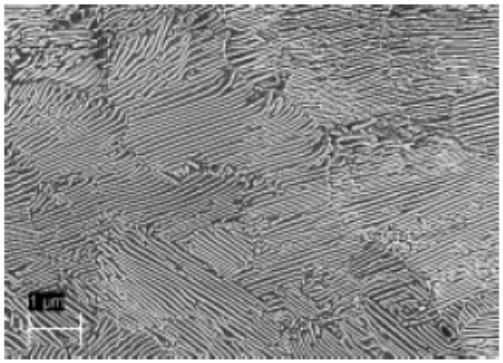
R350HT

heat treated



R400HT

heat treated
+ hyper-eutectoid



Pictures taken from: Zukunft der Schienenwerkstoffe, voestalpine, Sören Röhrig

(Perlitic) Rail defects / rolling contact fatigue

wear

corrugation

head checks

squats

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Bainitic rail and Thermit weld

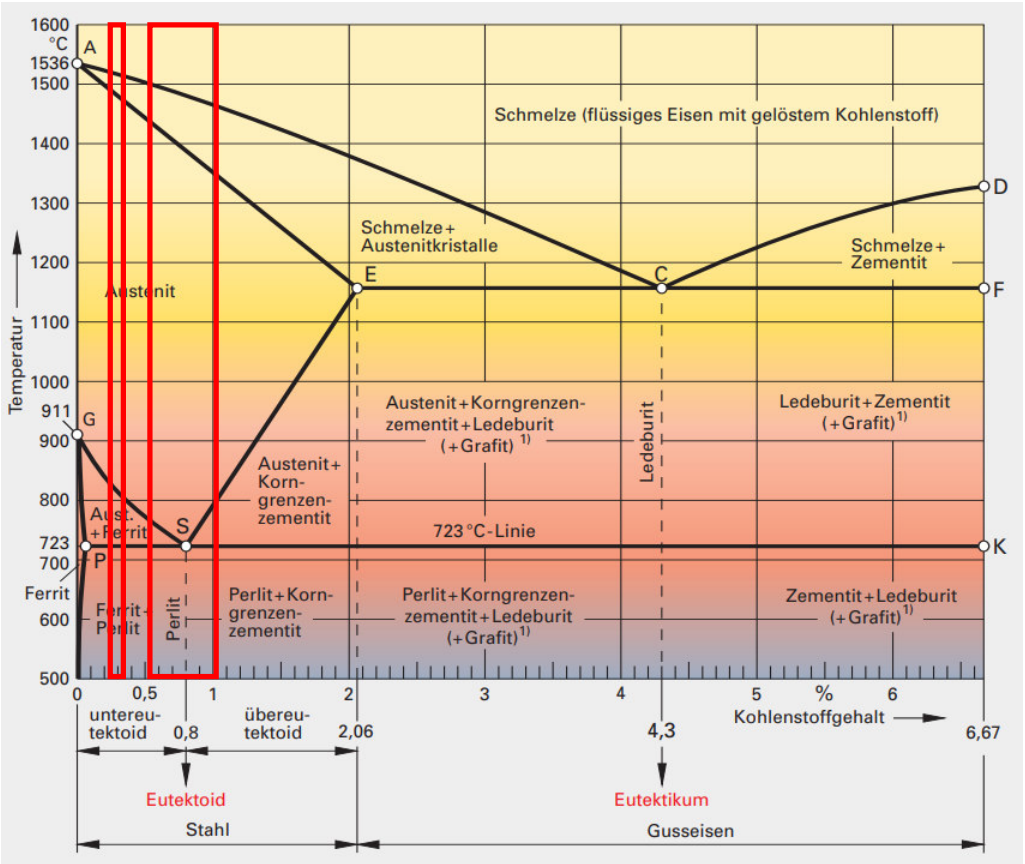
- Bainitic rail steels / microstructure
- From portion mix to a bainitic weld

What`s Bainite?

Phase diagram Iron / Carbon shows the equilibrium …

Bainitic rails:

- Less carbon
- with alloying of Si, Mn, Cr, Mo …
- Depending on cooling rate / mode different bainitic microstructures develop



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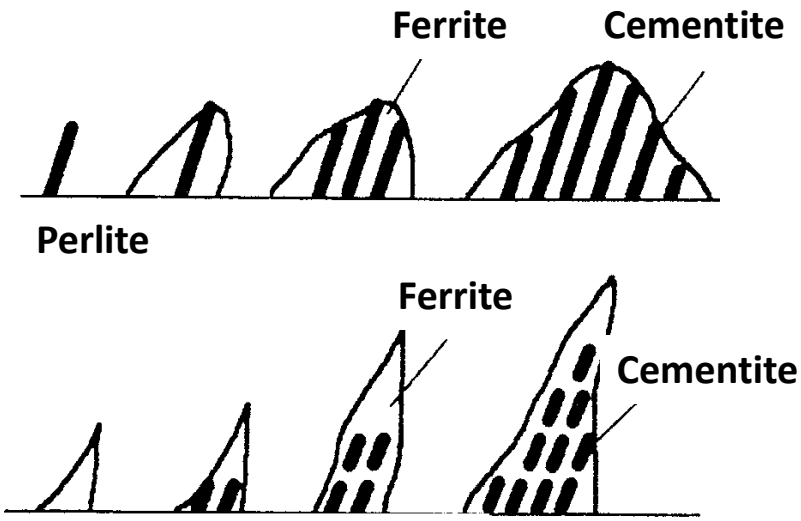
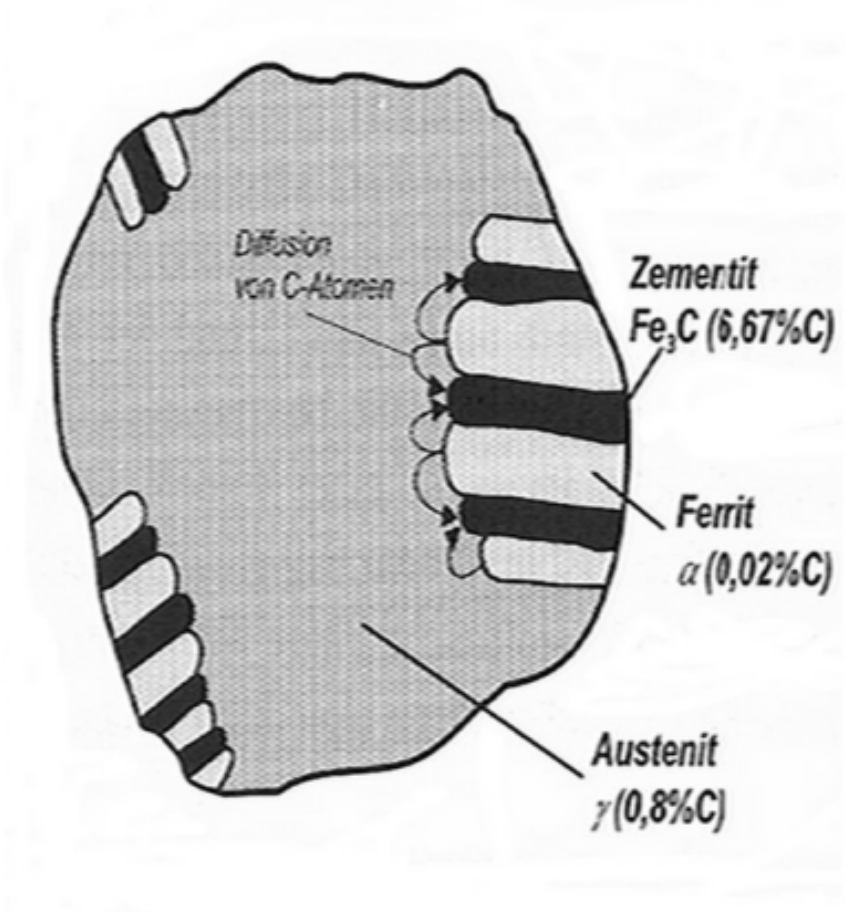
What`s Bainite?



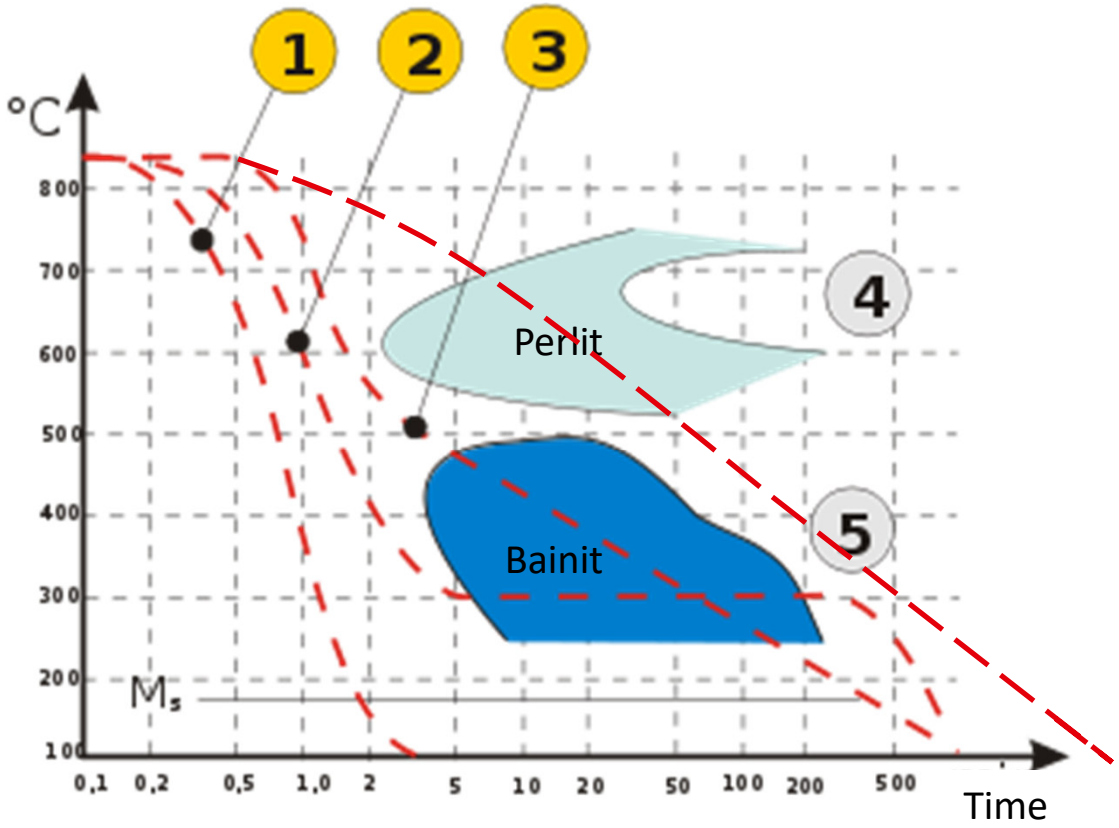
Bainite: Cementite needles are shown greatly enlarged



What`s Bainite?

TTT Diagram shows phase development for one alloy but with cooling (not the equilibrium)

- **Perlite:** C, Fe and alloying elements had time to diffuse and arrange (minimisation of energetic state)
- **Martensite:** no time for C diffusion at all, folding down / flipping into new grit with high tension
- **Bainite:** Is also Ferrite and Cementite, but no time for longer diffusion distances



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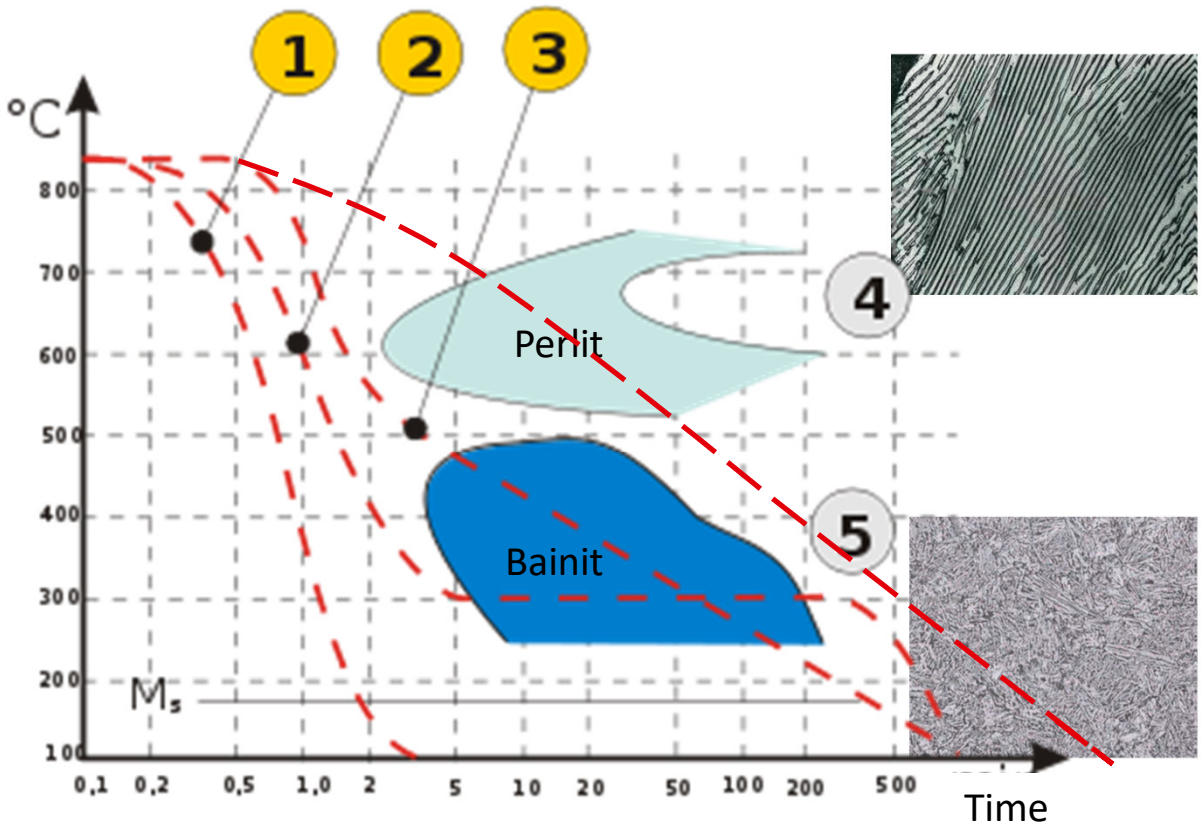
What`s Bainite?

Time Temperature Transformation diagram

- (1) Quenching into Martensite
- (2) Cooling mode to Bainite
- (3) Cooling into Bainite (residual Austenite)
- (4) Perlite phase area
- (5) Bainite phase area



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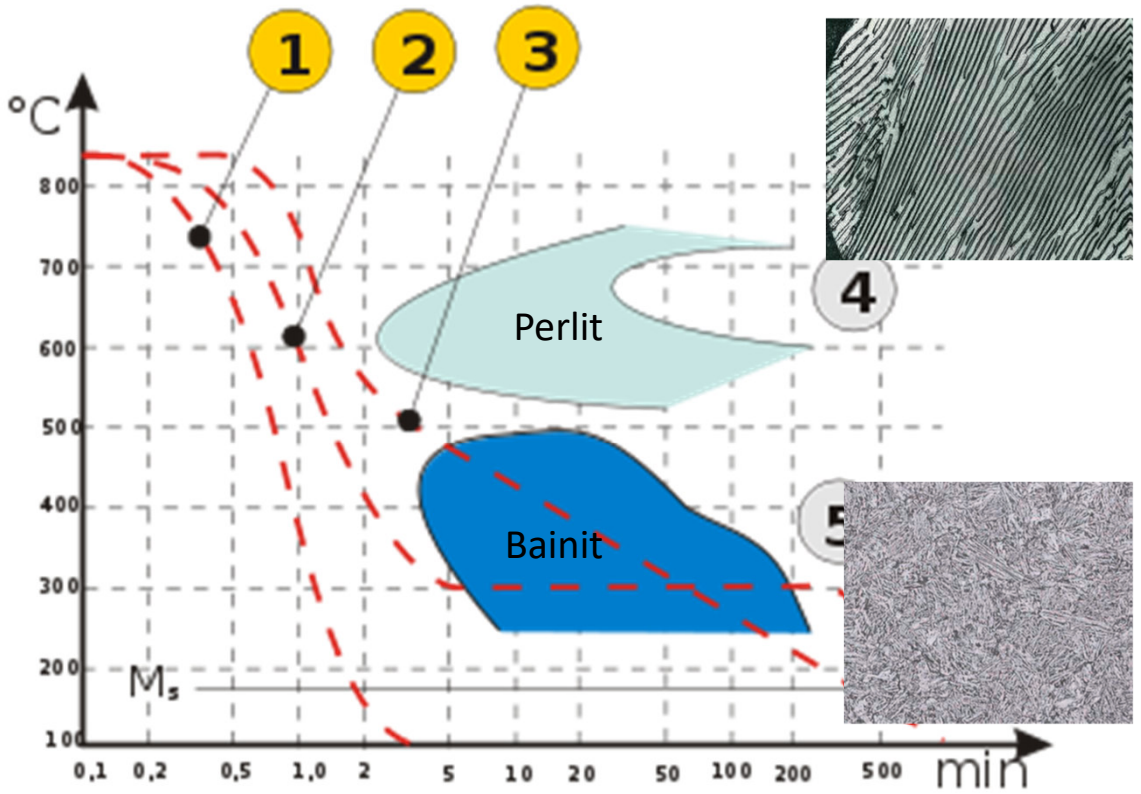
Bainitic rails

Rail steel can be made bainitic by

- Alloying in the steelworks - elements enlarge, minimize or shift the phase noses
- Mechanical treatment/deformation in the rolling mill changes the Austenite grain size (means diffusion distances) and shifts the phase noses (left, right)
- and temperature control during rolling and cooling bed



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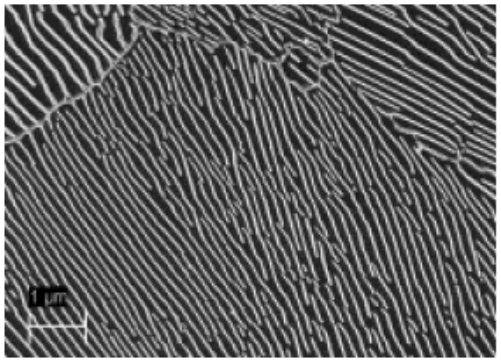
Microstructure Perlite and Bainite

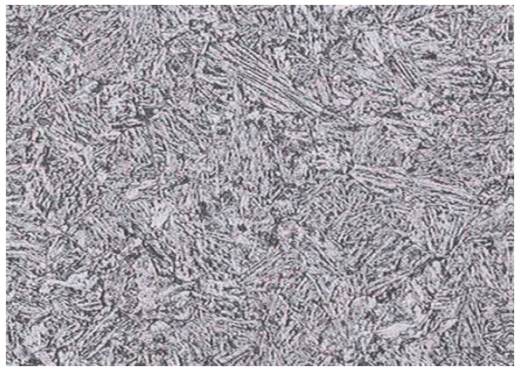
R260

naturally hard

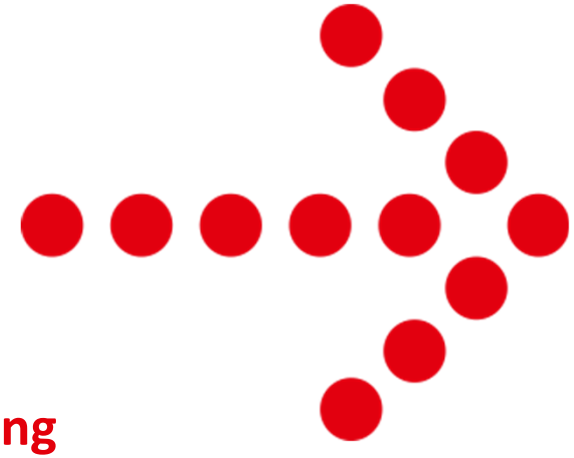


R300CrMoHT

heat treated



What to consider for Thermit® welds?



A bainitic weld material is created by

1. **adjusting the right chemical composition (alloy), by alloying elements in portion // Thermit® steel (after reaction) + rail steel dissolved.**
2. **and the “natural” cooling in track, which is the cooling treatment.**

What`s Bainite?

Main influential factors on phase formation in rail manufacturing:

- Hypothermia of Austenite / cooling rate
- Austenite grain size due to rolling / diffusion distances
- Alloying elements / spaces in iron grit /diffusion speed
- Carbon content
- Cooling mode

Possibilities of influential factors in Thermit welding:

- Just natural cooling in track
- Austenite grain size only created by solidification
- Alloying in portion
- Carbon content, addition in portion
- Just natural cooling in track

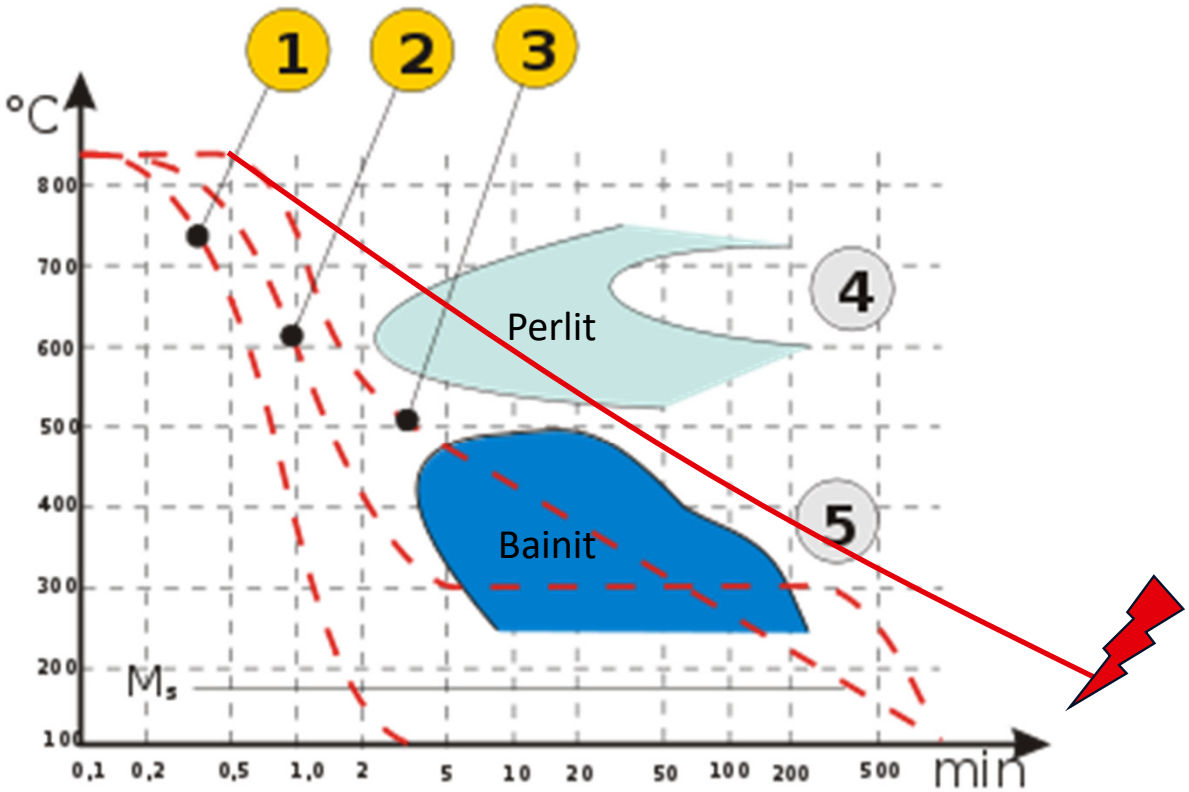
Bainitic weld

- Adjusting the chemical composition similar to the rail
- **Respecting different cooling rate.**
- Respecting casting structure

➢ Hardness has to be correct

➢ and not allowing un-wanted shares of microstructure

⇢ **A „Thermit“- alloying concept is needed.**



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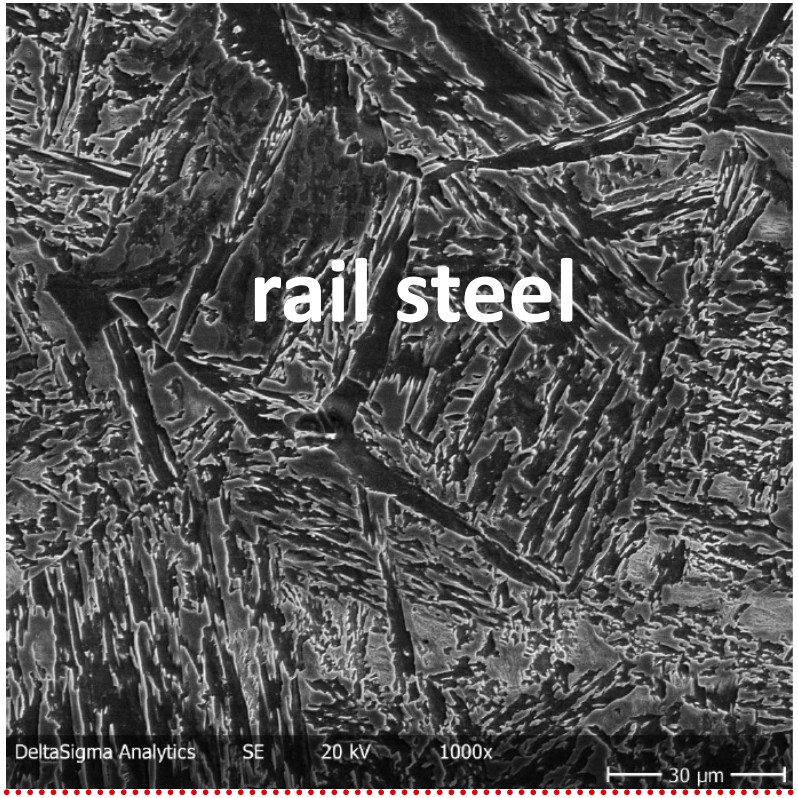
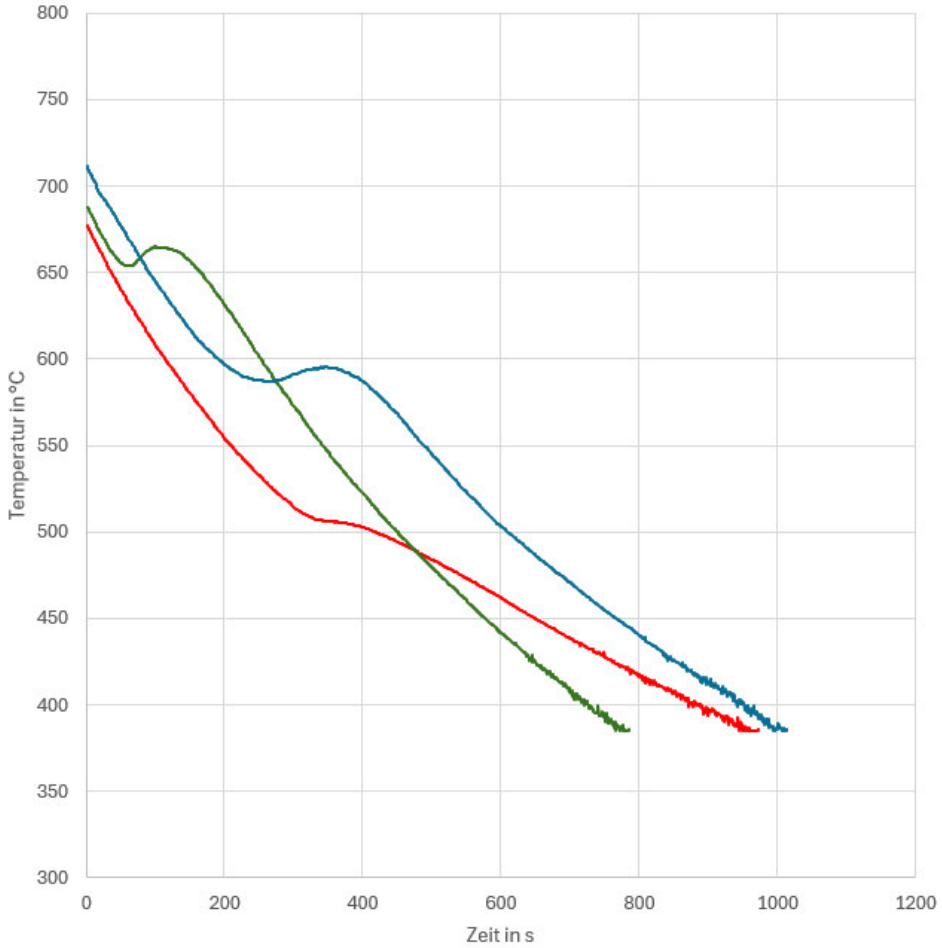
Microstructure comparison / differences but similar behaviour …



Measurable microstructure transformation

Phase formation with same cooling rate at different temperatures due to

- Carbon content
- and other alloying differences



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Additional aspect due of solidification sequence in the weld

Running surface

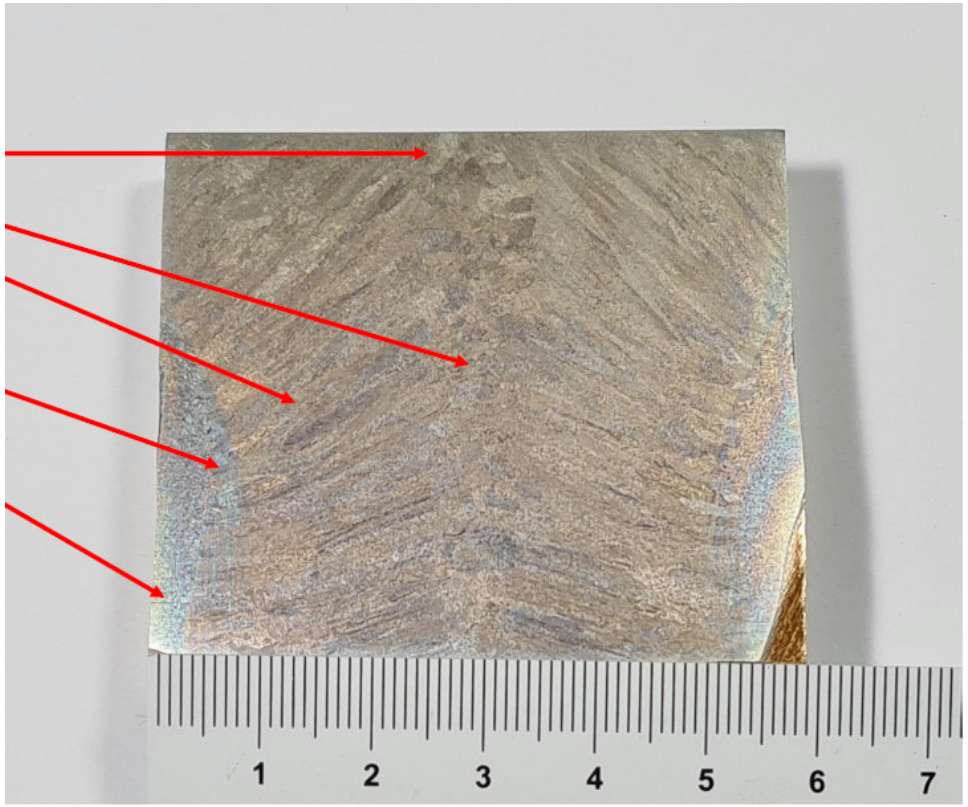
Centre of weld

Dendritic area

Fusion line

Heat effected zone
rail steel

- heat treated
- with new cooling treatment
- means new microstructure



KLEINE SCHRITTE SIND DER FORTSCHRITT!

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