Superbainite – Laboratory Concept to Commercial Product

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Definition

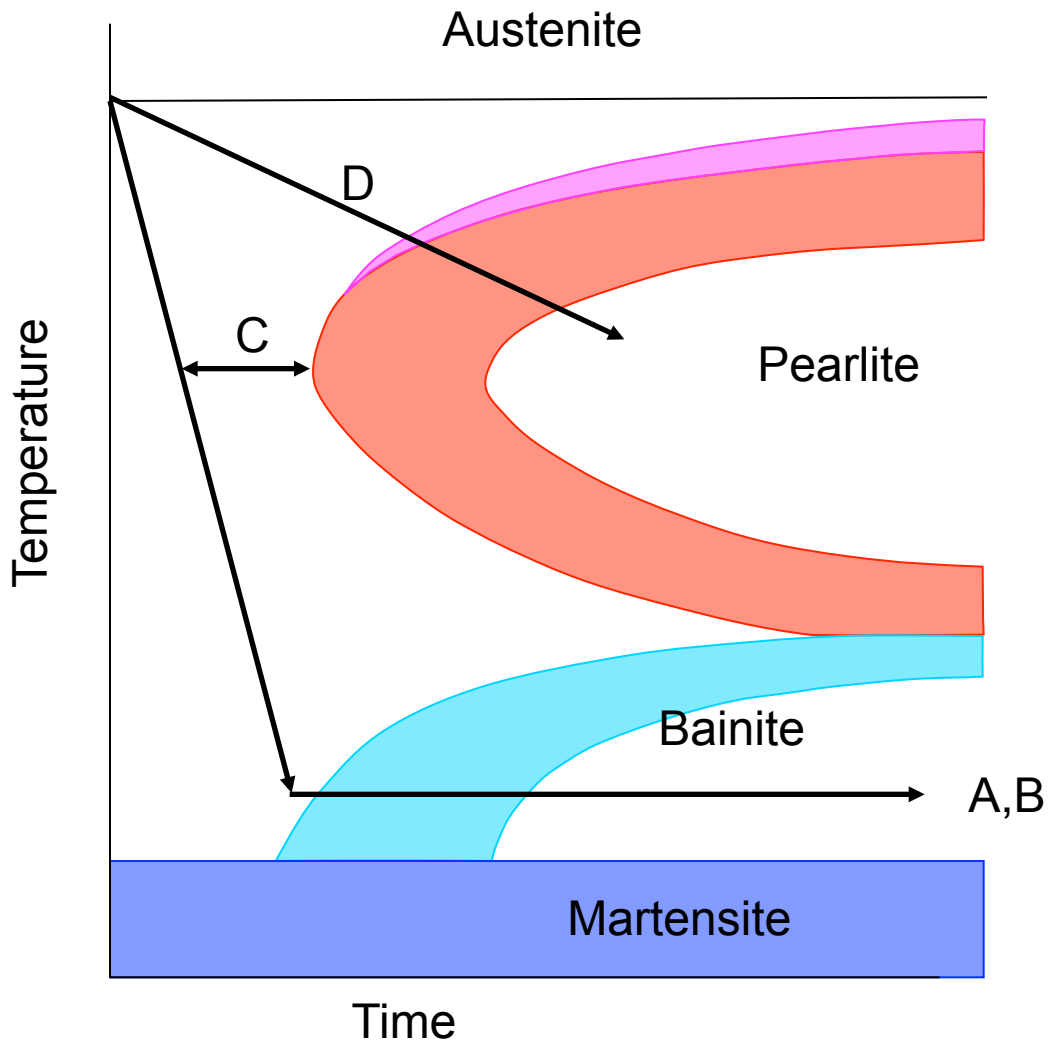
Superbainite is:

- A steel structure which can be developed under certain circumstances, having very high strength and hardness

- A grade of strip steel developed over the last few years, able to be treated to give this structure

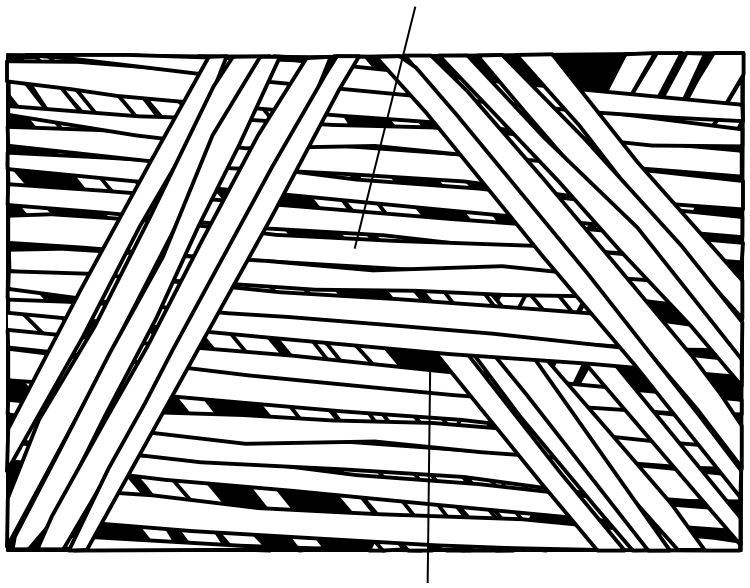
Originally developed at Cambridge University in 1990s

Superbainite

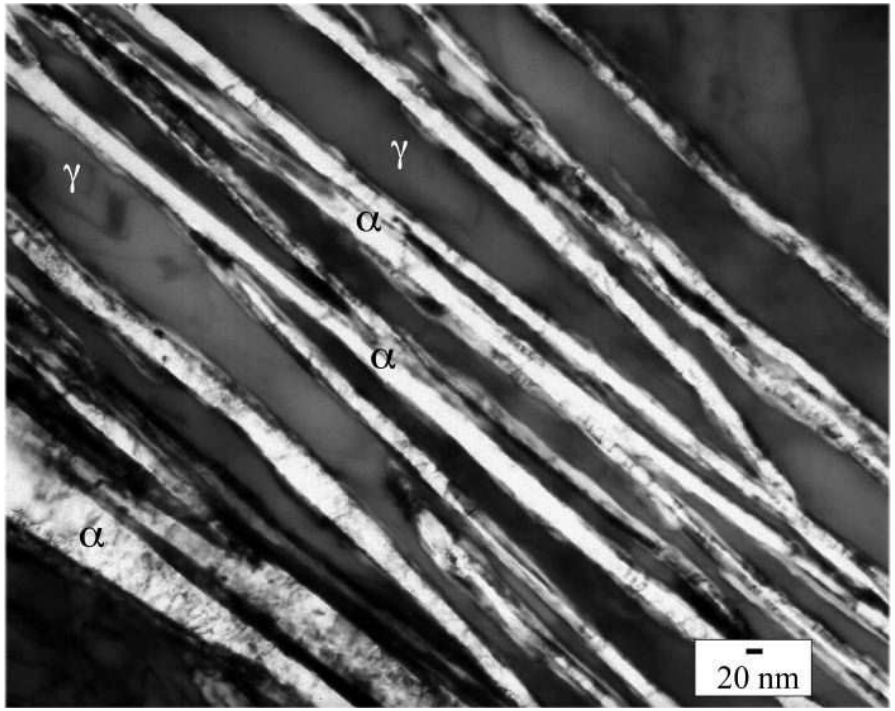


A. Isothermal transformation
B. Si – carbide suppression
C. Hardenability requirement
D. Slow cooling option

Superbainite structure



Schematic



TEM

Properties

Superbainite has:

High carbon content
\+ other alloying elements
\+ very fine structure
= high strength and hardness

Claims:

~ 2.2 GPa UTS
‘3D’ structure

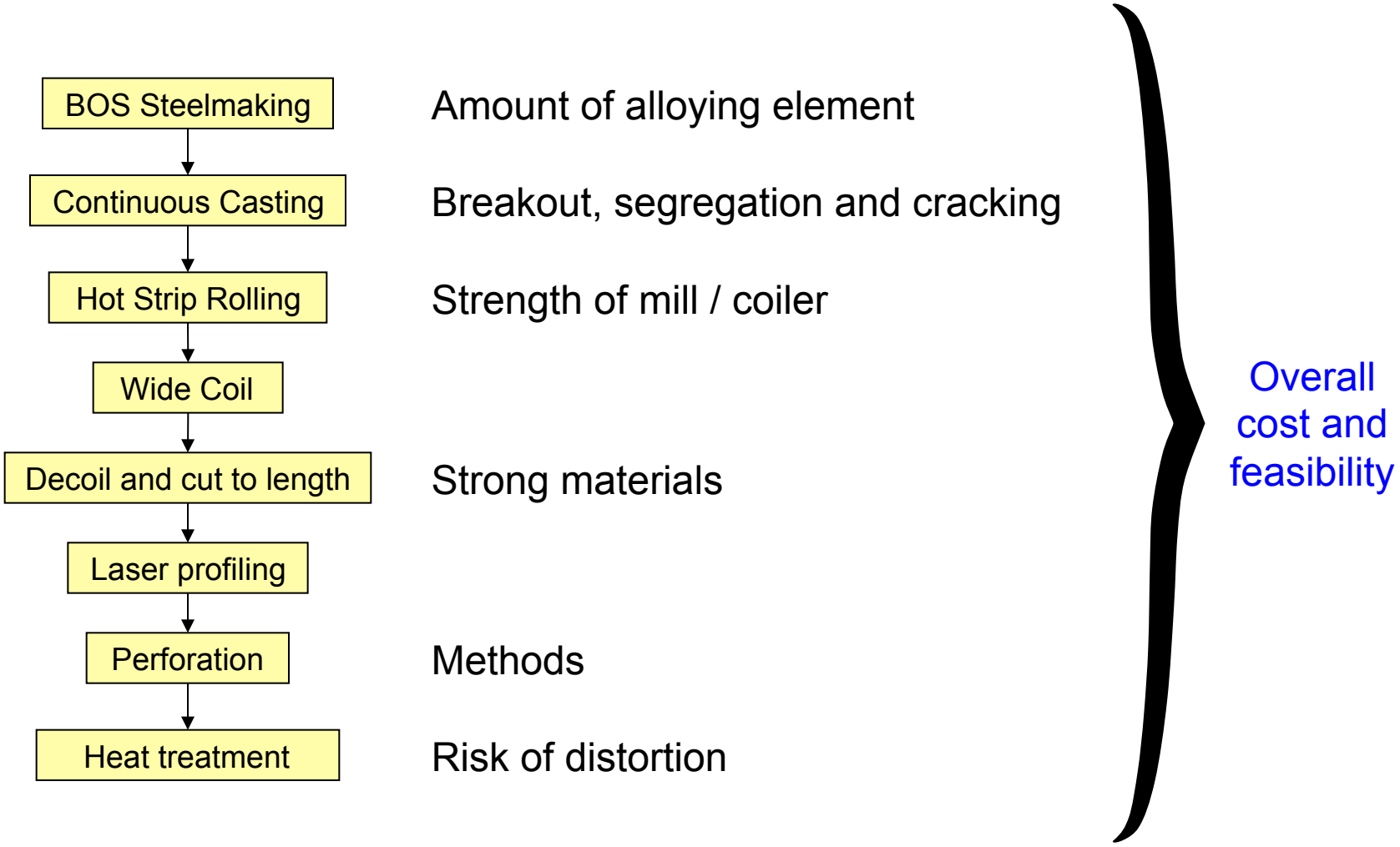
→ suitable for armour plate

“Specialist Armour Steels: The MoD has a requirement for an onshore manufacturing capability.”
Lord Drayson, Defence Technology Strategy, 2006.

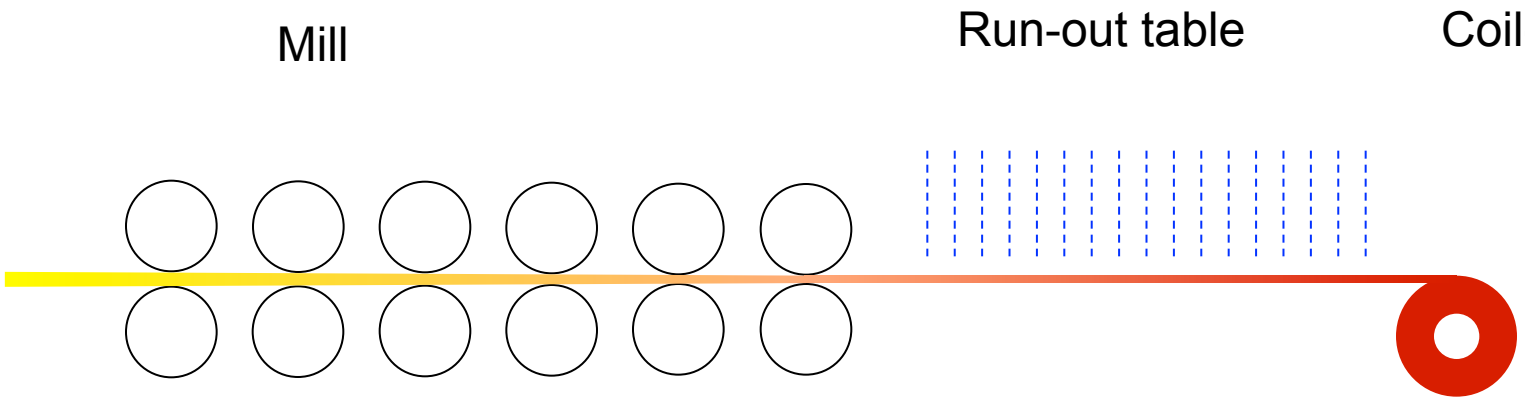
Development activities

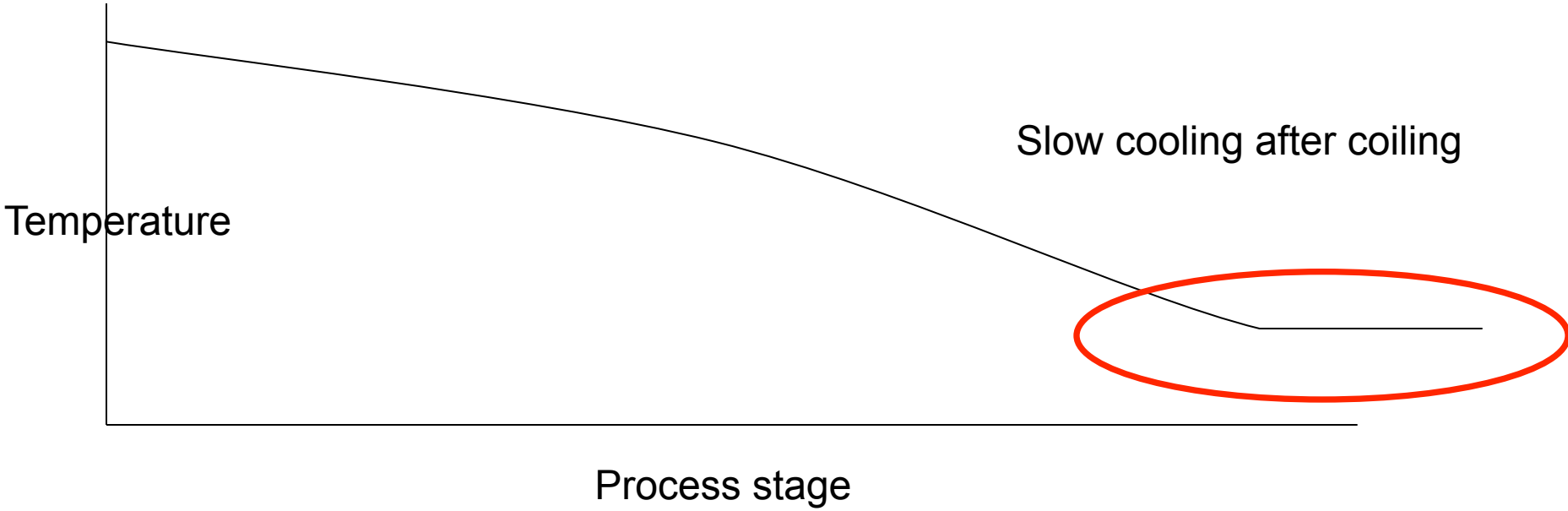
- A pilot-scale cast was made on the Normanton Heavy Pilot Plant at TTC in conjunction with the MoD
  - Large enough for processing through commercial mills
  - Demonstrated that commercial scale production was feasible
- Experimental work at Tata Swinden Technology Centre
  - Effect of variations in composition
  - Characterisation of properties
- Modelling work within Tata R&D

Tata process route

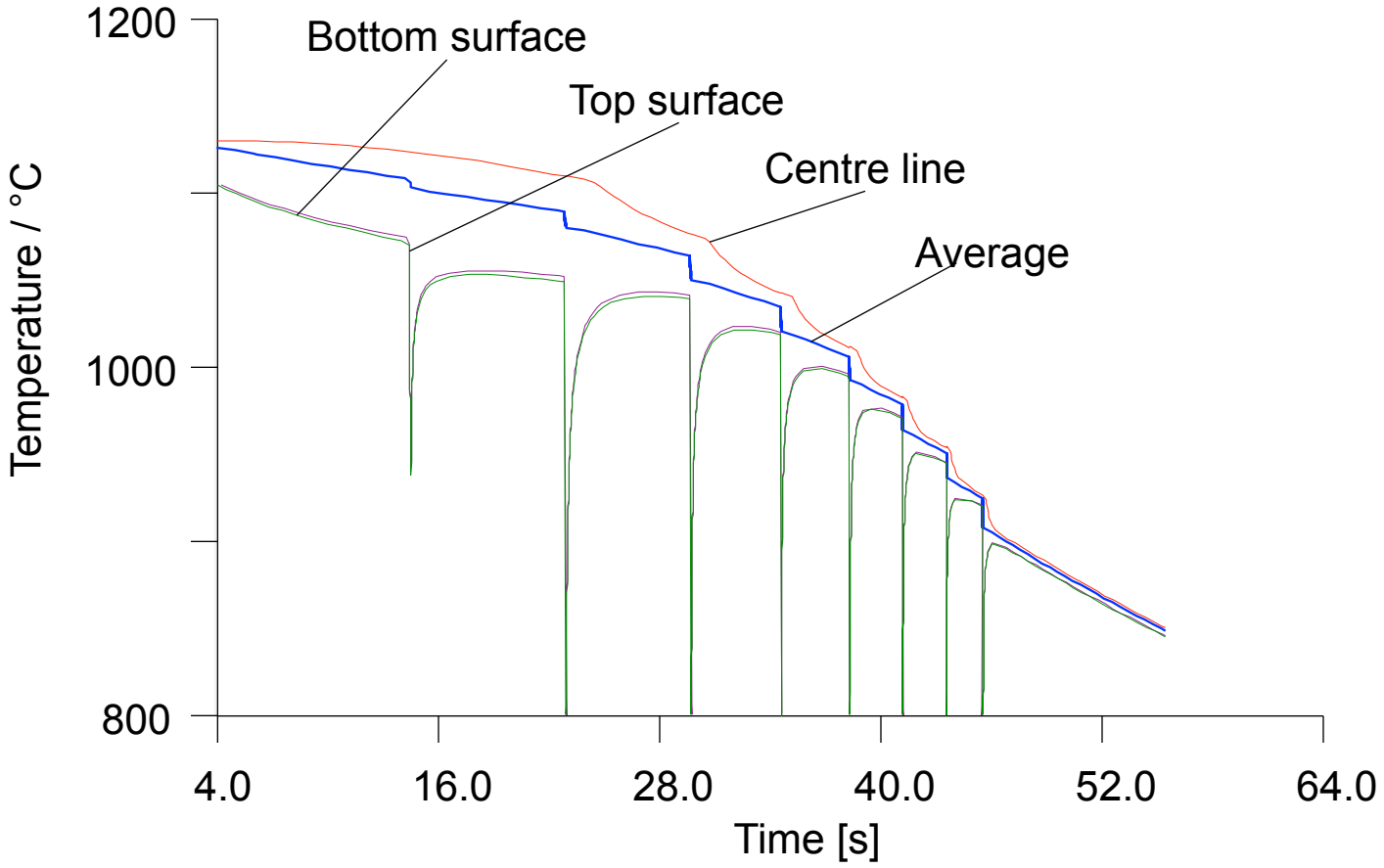


Hot strip route - temperature

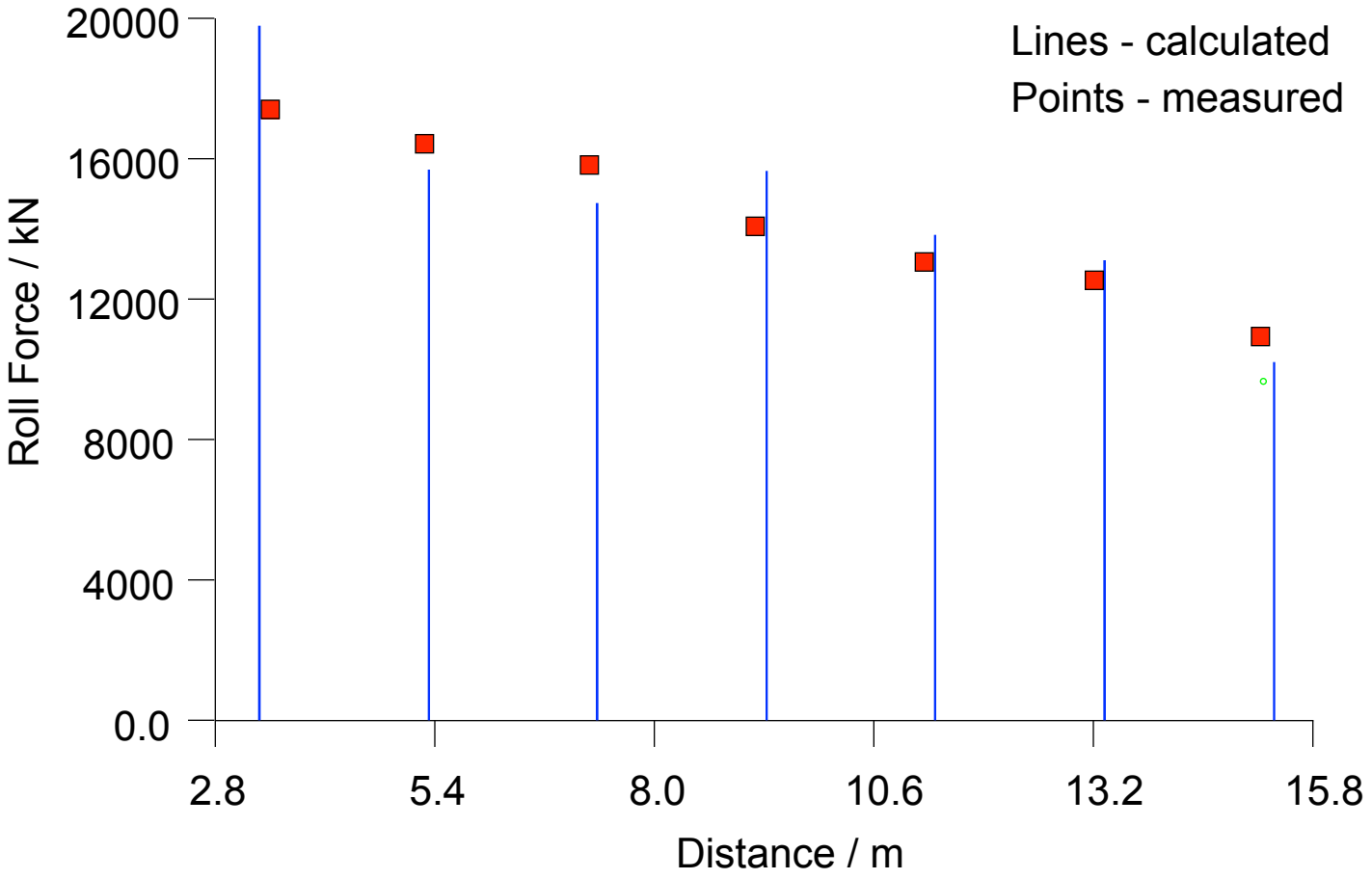




Titan predictions - Temperature



Titan predictions – Roll Force



Commercial compositions

C	Si	Mn	P	S	Cr	Mo
0.85 x	0.75 x	1.4 x	0.015 x	0.01 x	1.0 x	0.3 x

Maxima in all cases

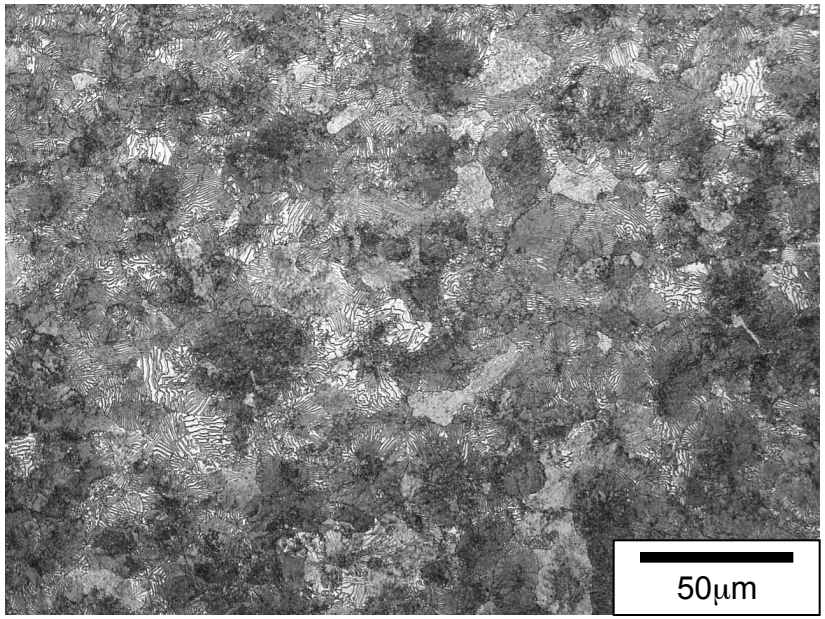
Si - Carbide suppression

P - Promotes segregation – need to keep to minimum

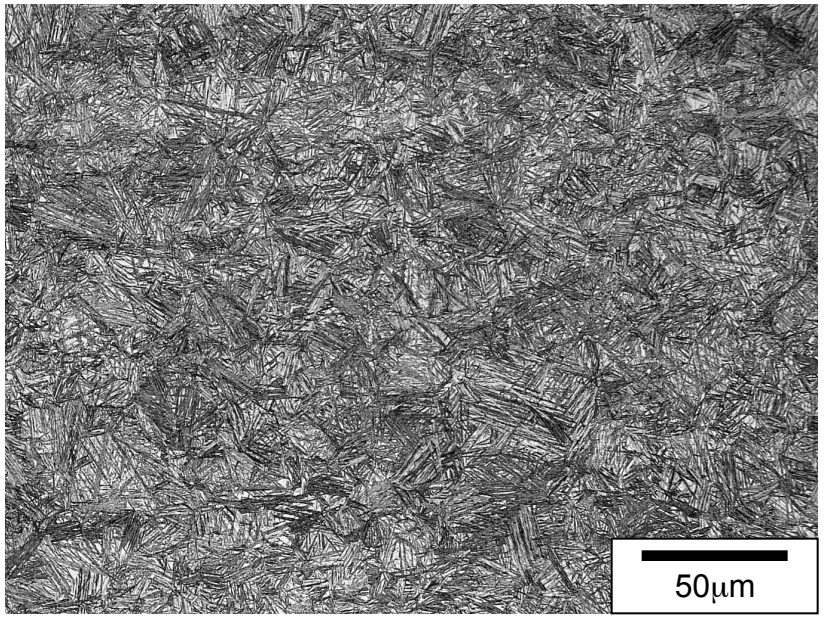
Cr, Mo - Hardenability

Mo - Reduces deleterious effects of P

Microstructures – optical

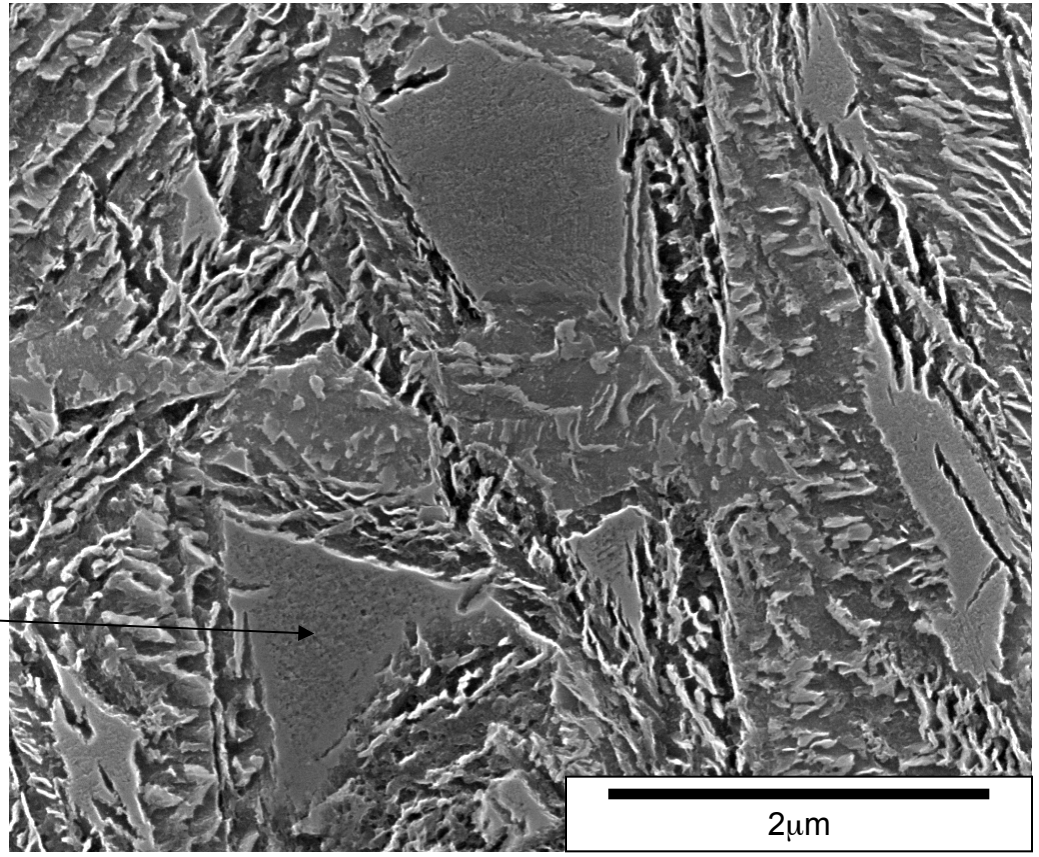


As-hot rolled - pearlite



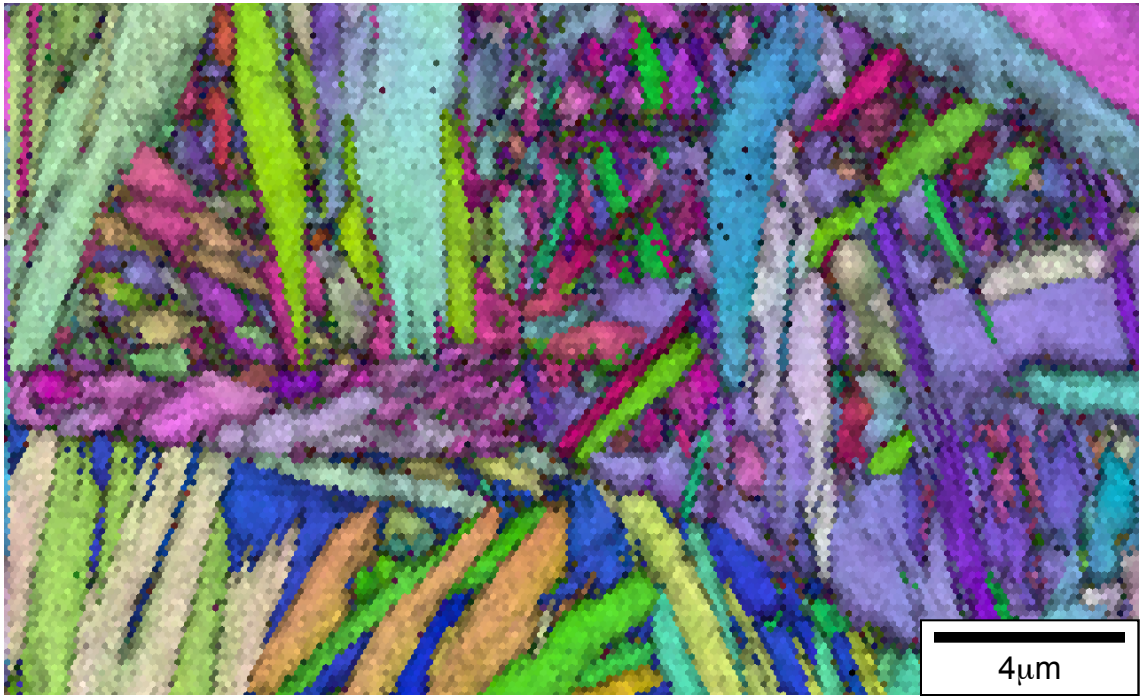
Heat treated - Superbainite

Microstructure – SEM



SEM Micrograph of Superbainite

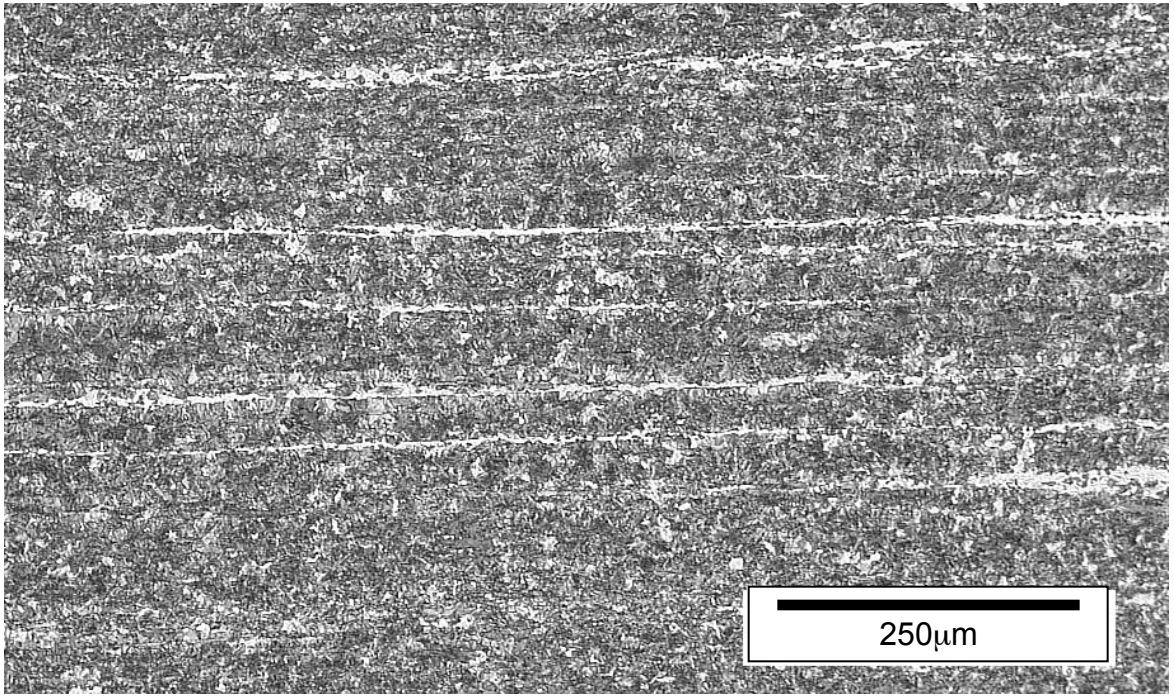
Retained austenite



EBSD - orientation

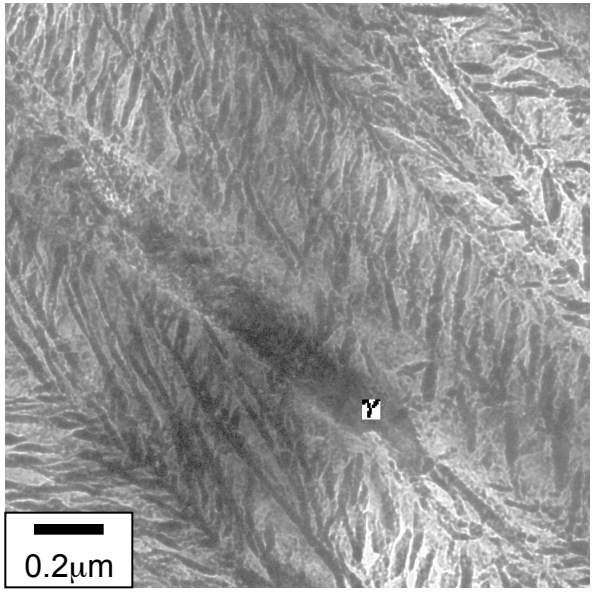
Red : ferrite
Green : austenite.

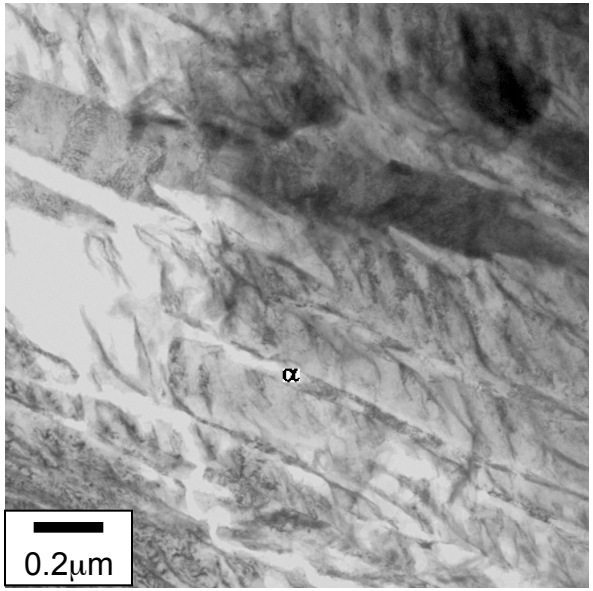
Segregation



Segregation bands in as-rolled Superbainite

TEM examination

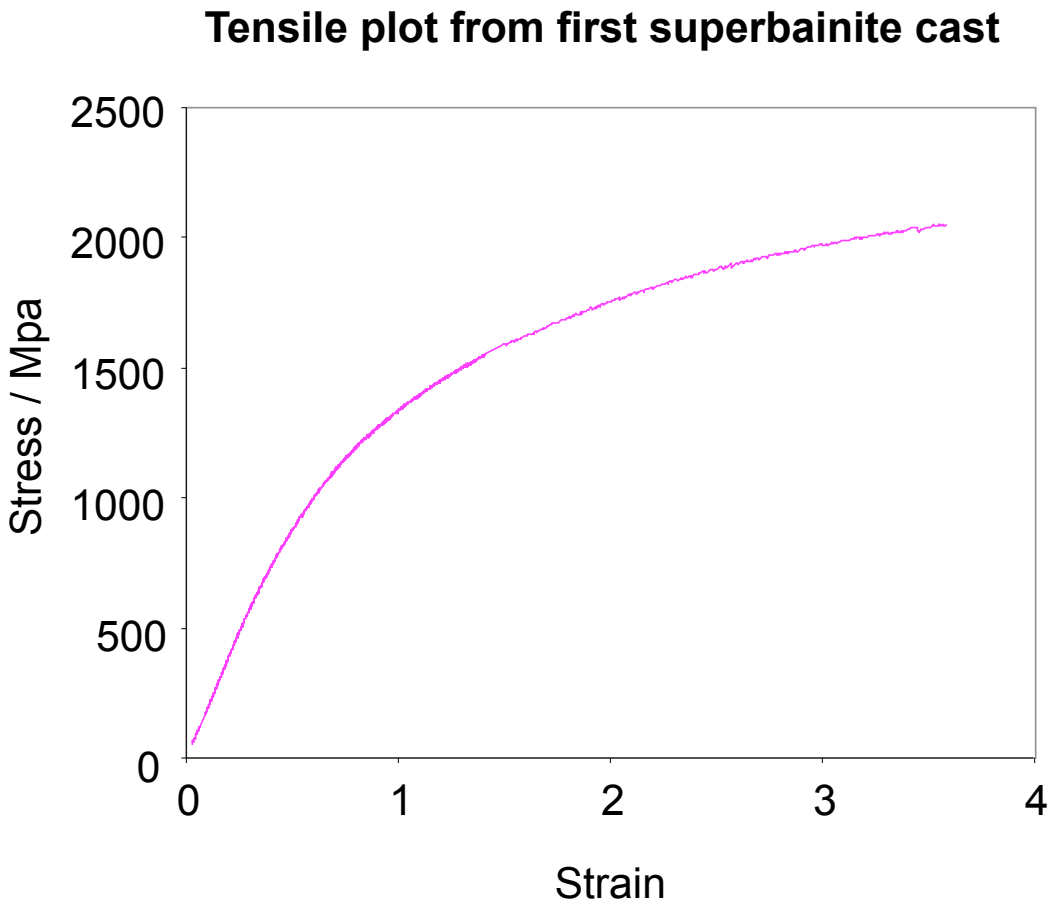




Transmission electron micrographs

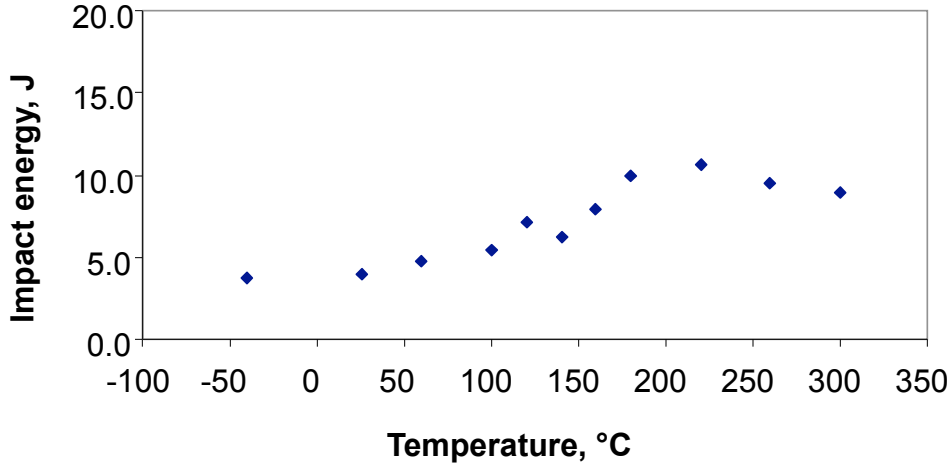
Carbides in commercial casts

Tensile tests

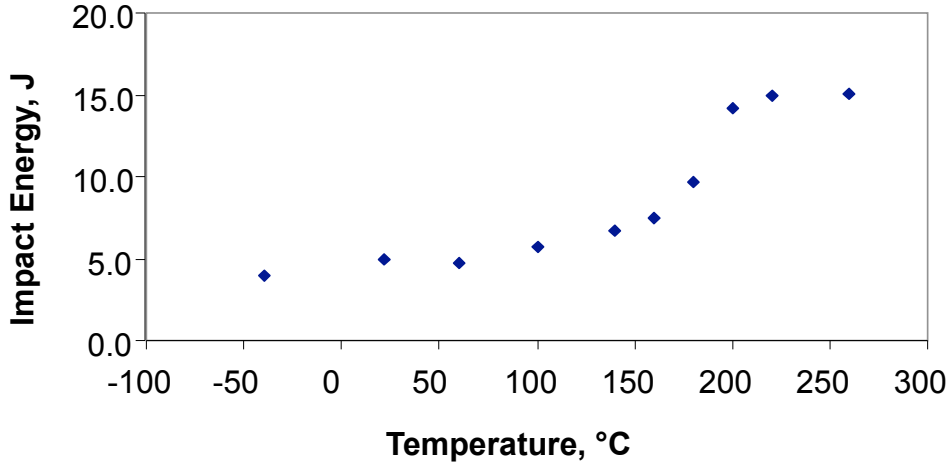


Charpy toughness

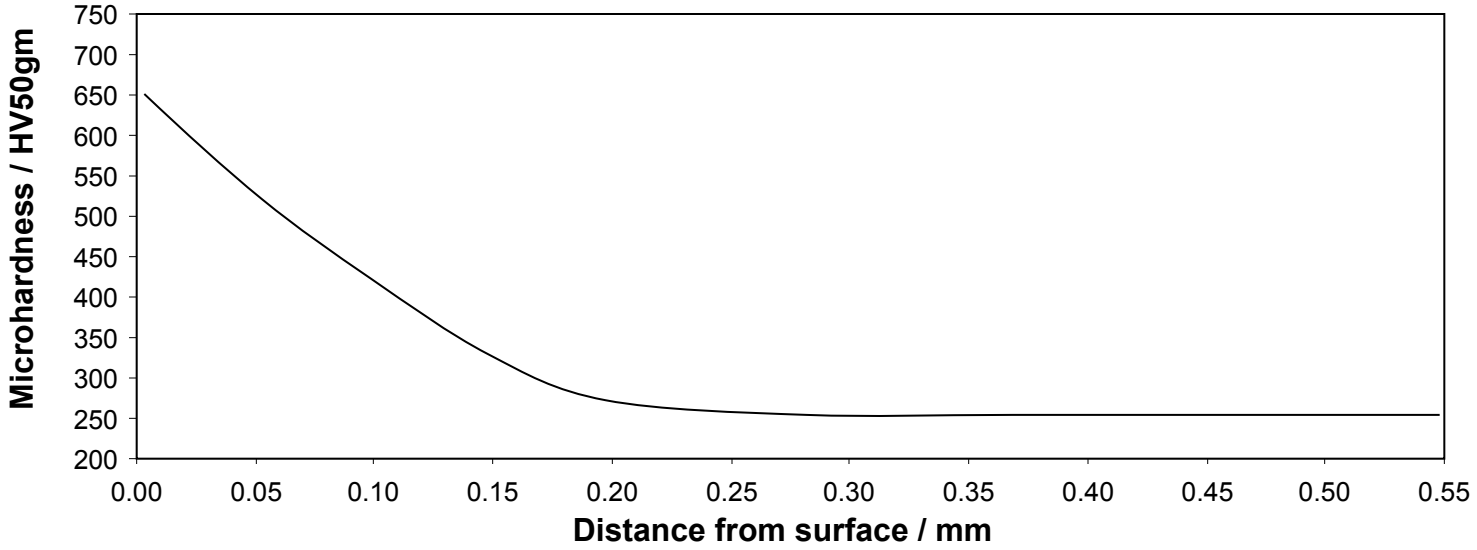
Hot rolled

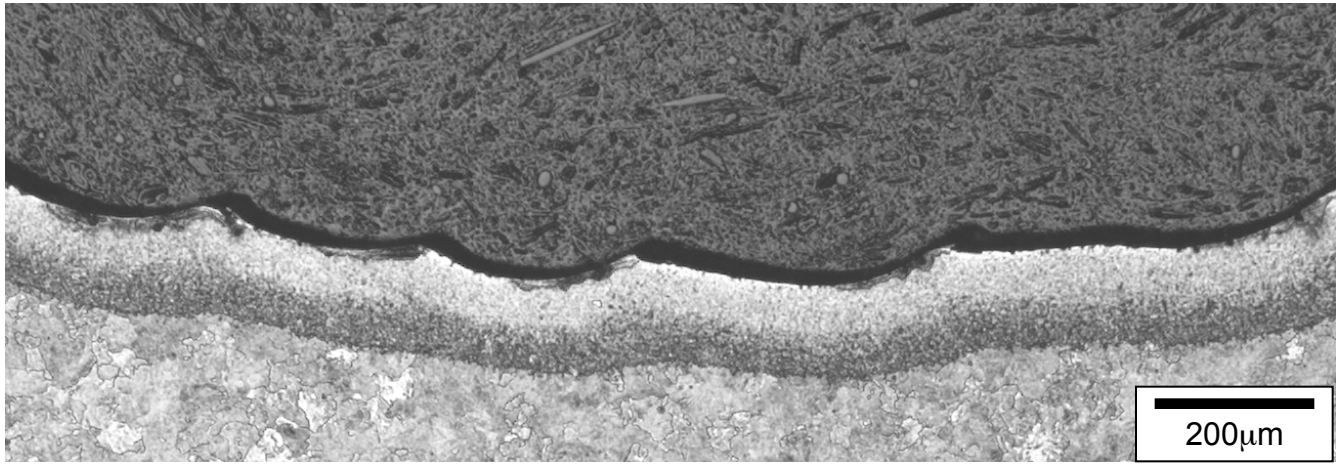


Heat treated



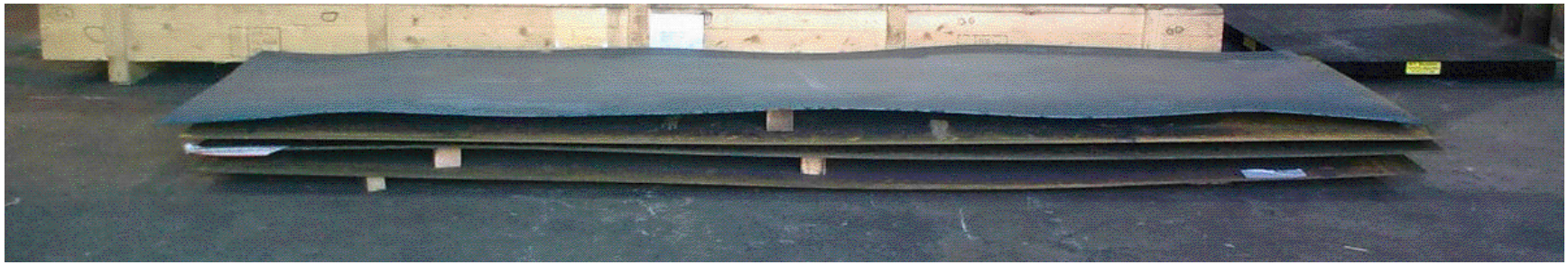
Effect of laser cutting



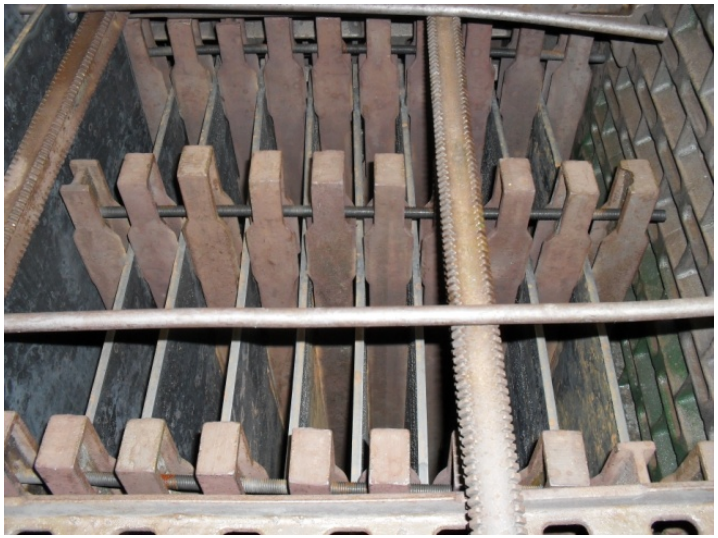


Heat Treatment

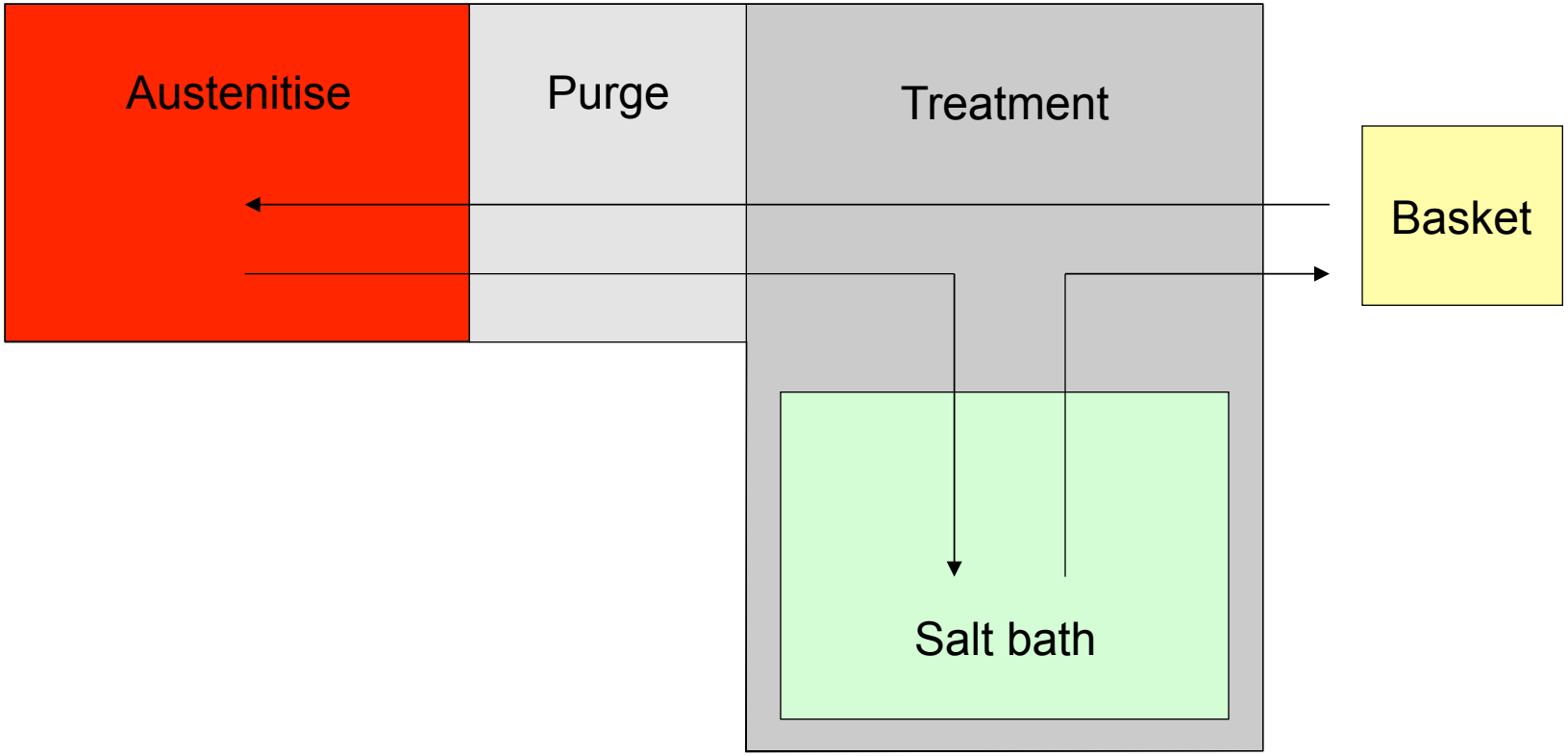
Forced air cooling



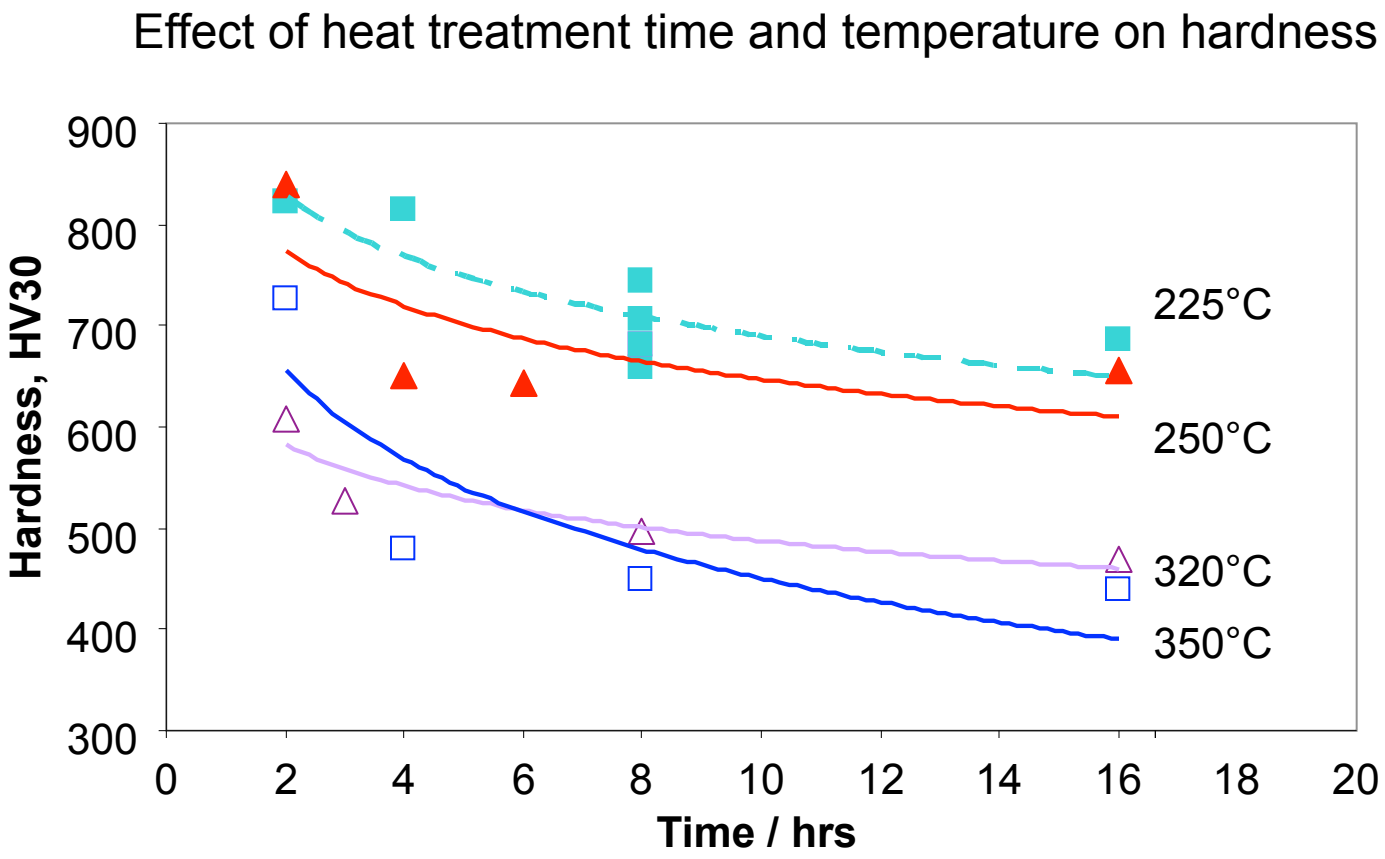
Salt bath treatment



Salt bath treatment



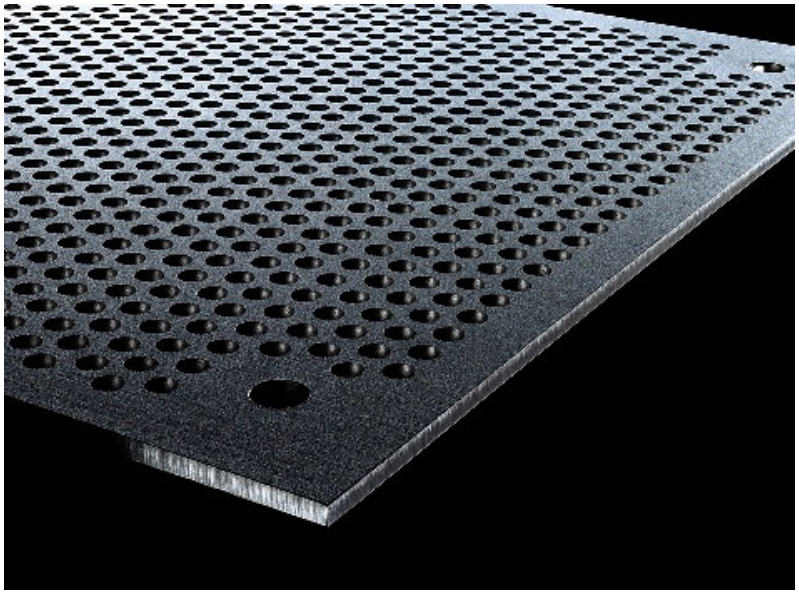
Heat treatment parameters



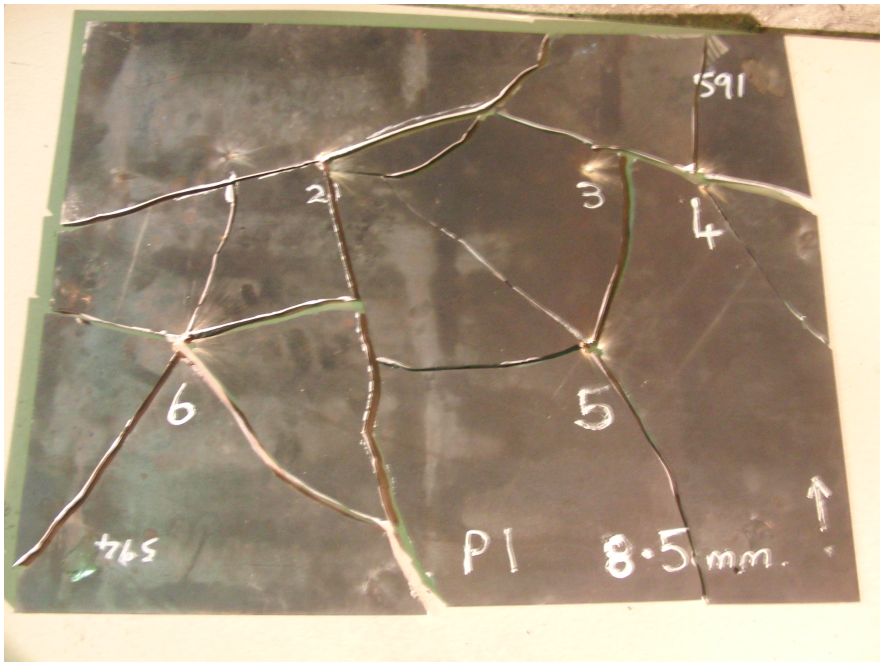
Perforation

Perforation

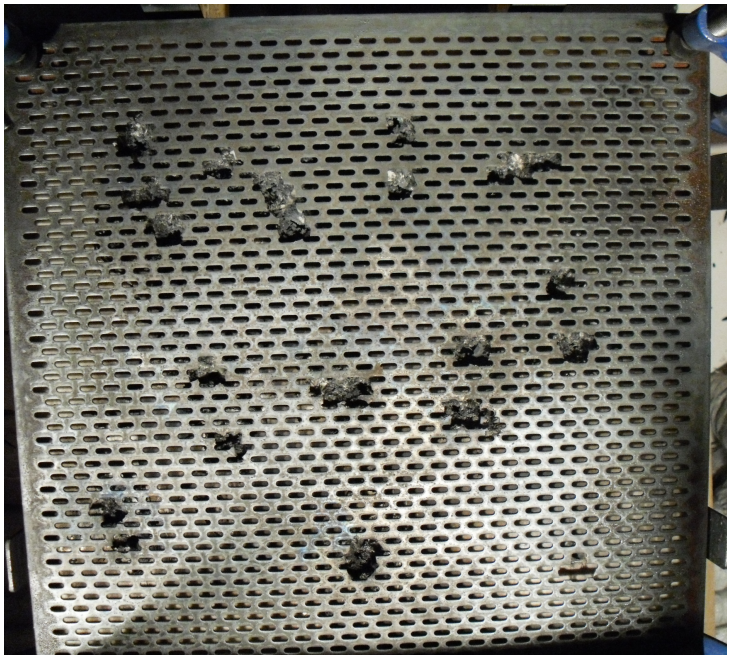
- increases ballistic efficiency
    - deflects bullets
- reduces weight of armour
- acts as crack-stoppers



Ballistic testing



Monolithic



Perforated

Both sheets 500 mm square

Conclusions

Superbainite:

Developed as an academic concept

Investigated in a laboratory / pilot scale testing

Put into commercial production

Bainitic armour steels still under development