

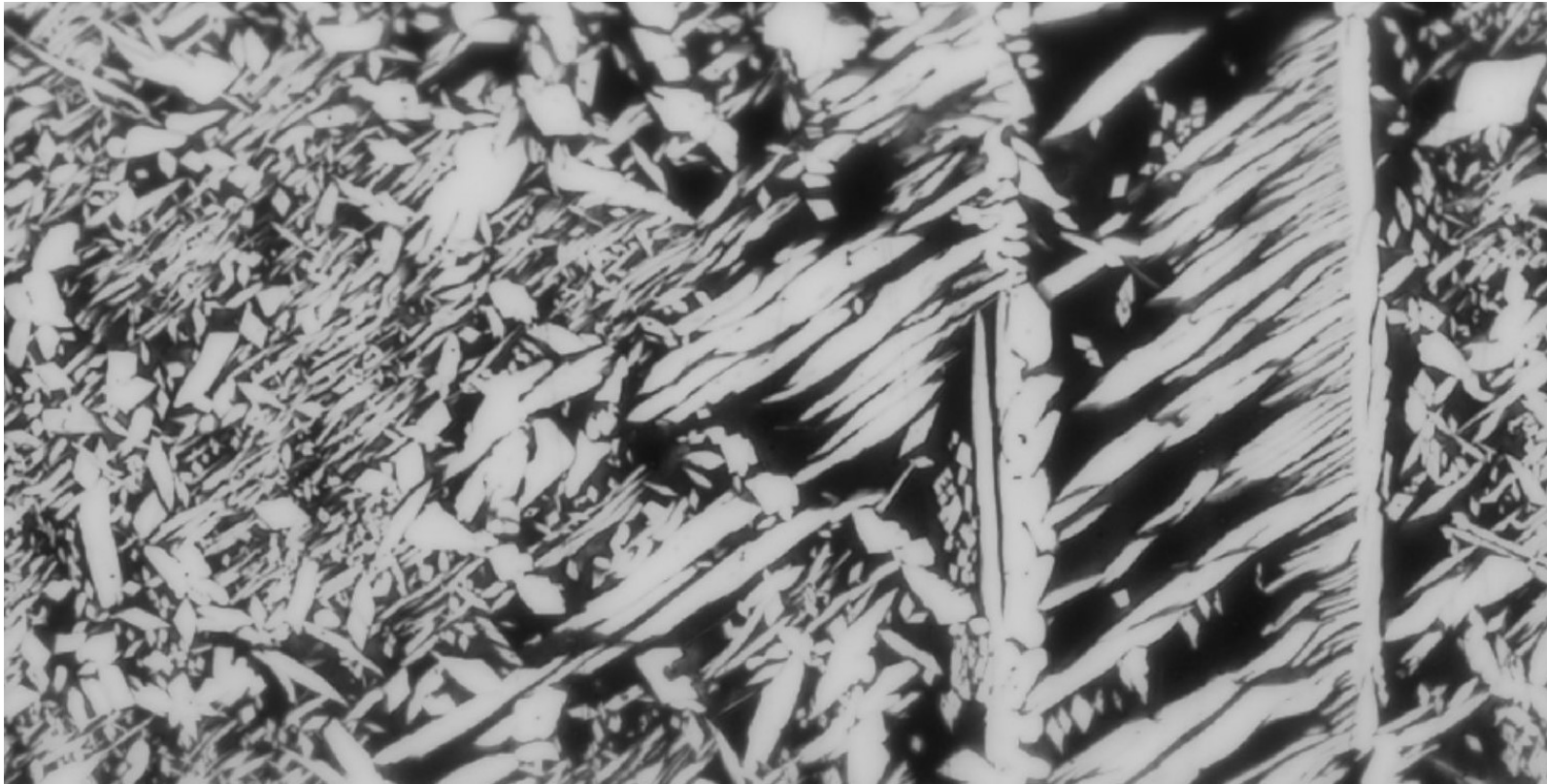
Welding of duplex stainless steels

– amazing but challenging!

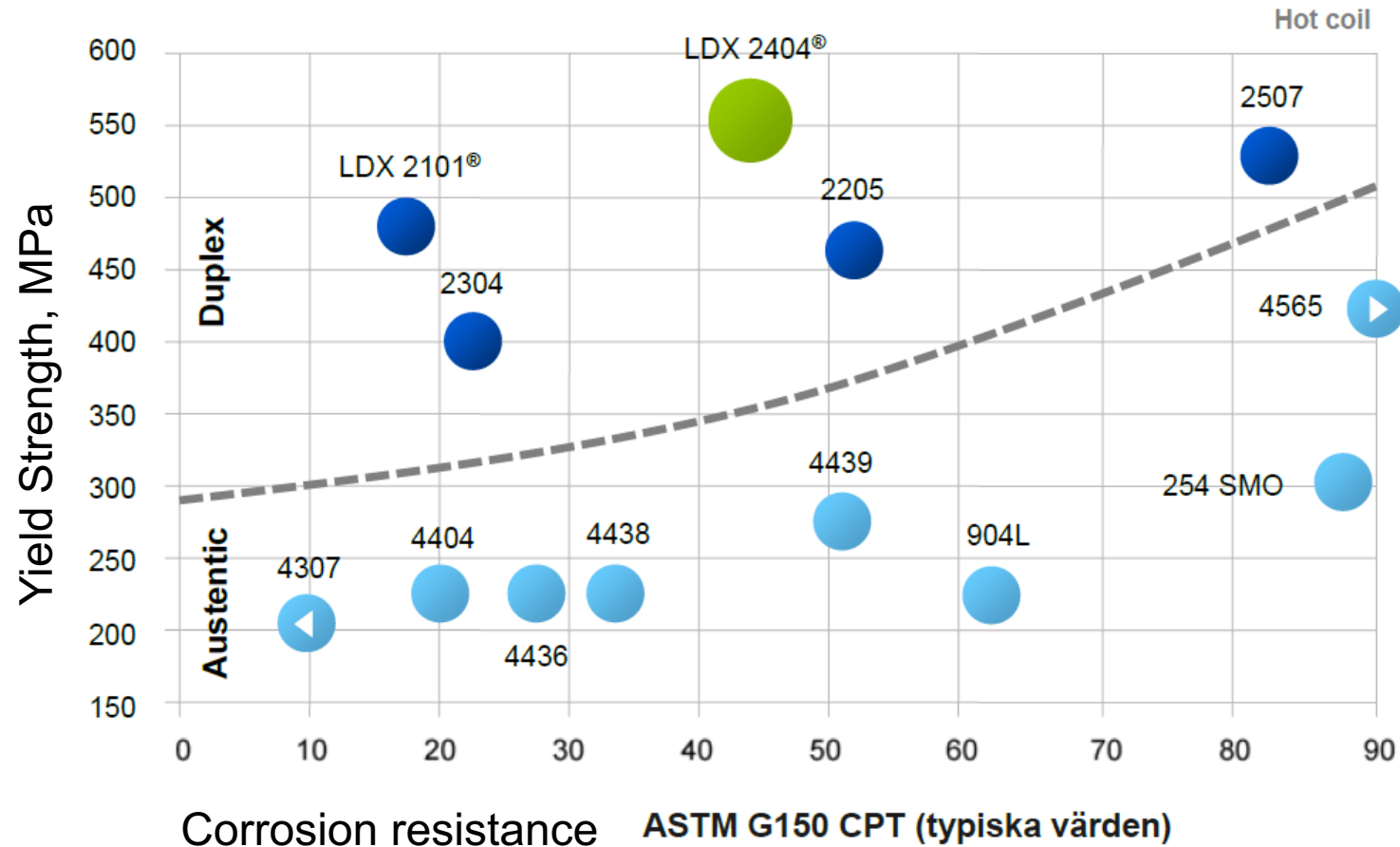
Asun Valiente

Workshop 20th February 2020, Jernkontoret, Stockholm

Why amazing?

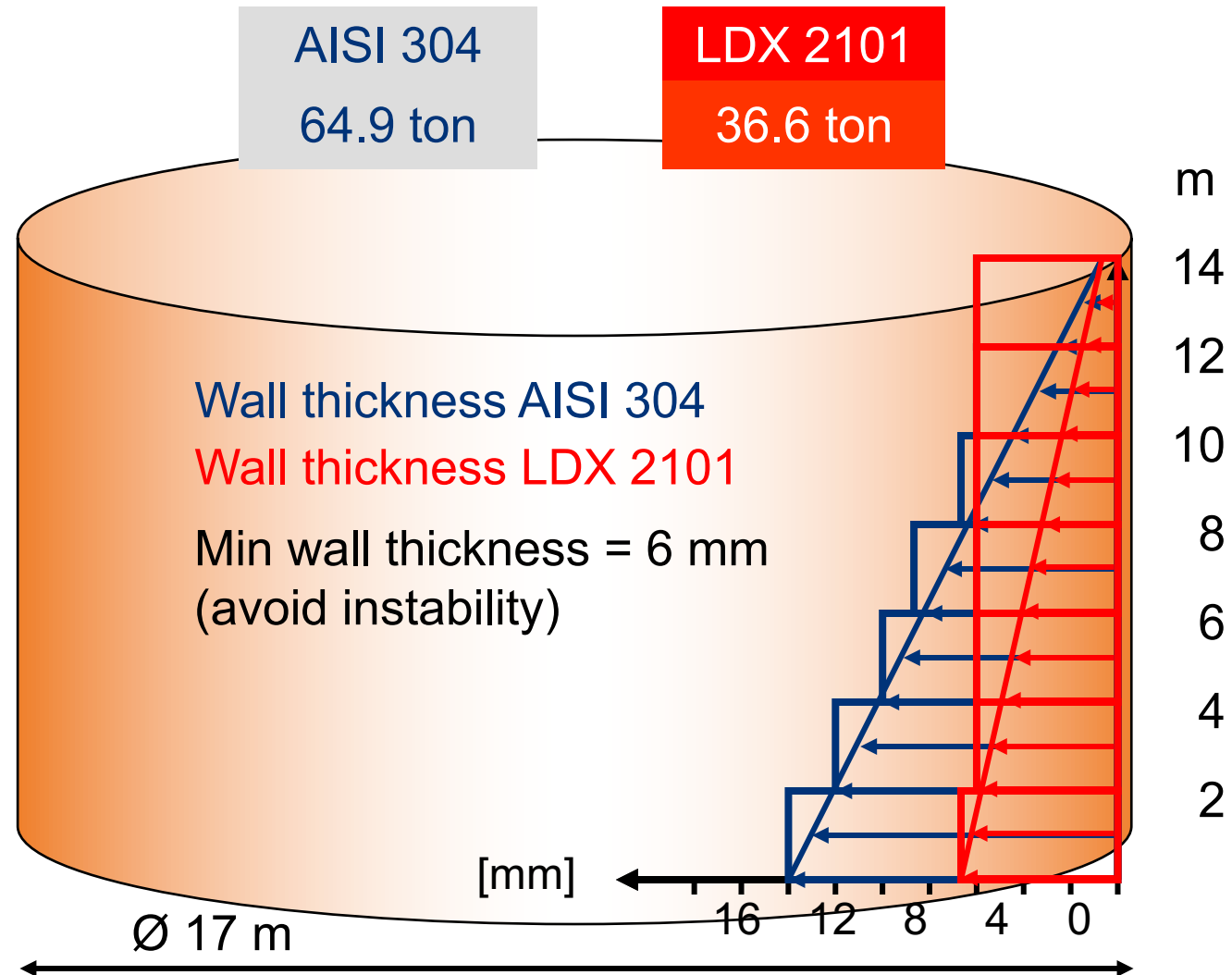


Properties– Corrosion vs Strength



CPT: Critical Pitting corrosion Temperature

This means....



Subsea applications: Umbilicals, Noth Sea, Hyperduplex



Sweden, storage tank 2304 grade

Pulp & Paper industry - Digesters



Sweden, 2101 grade

Why challenging?

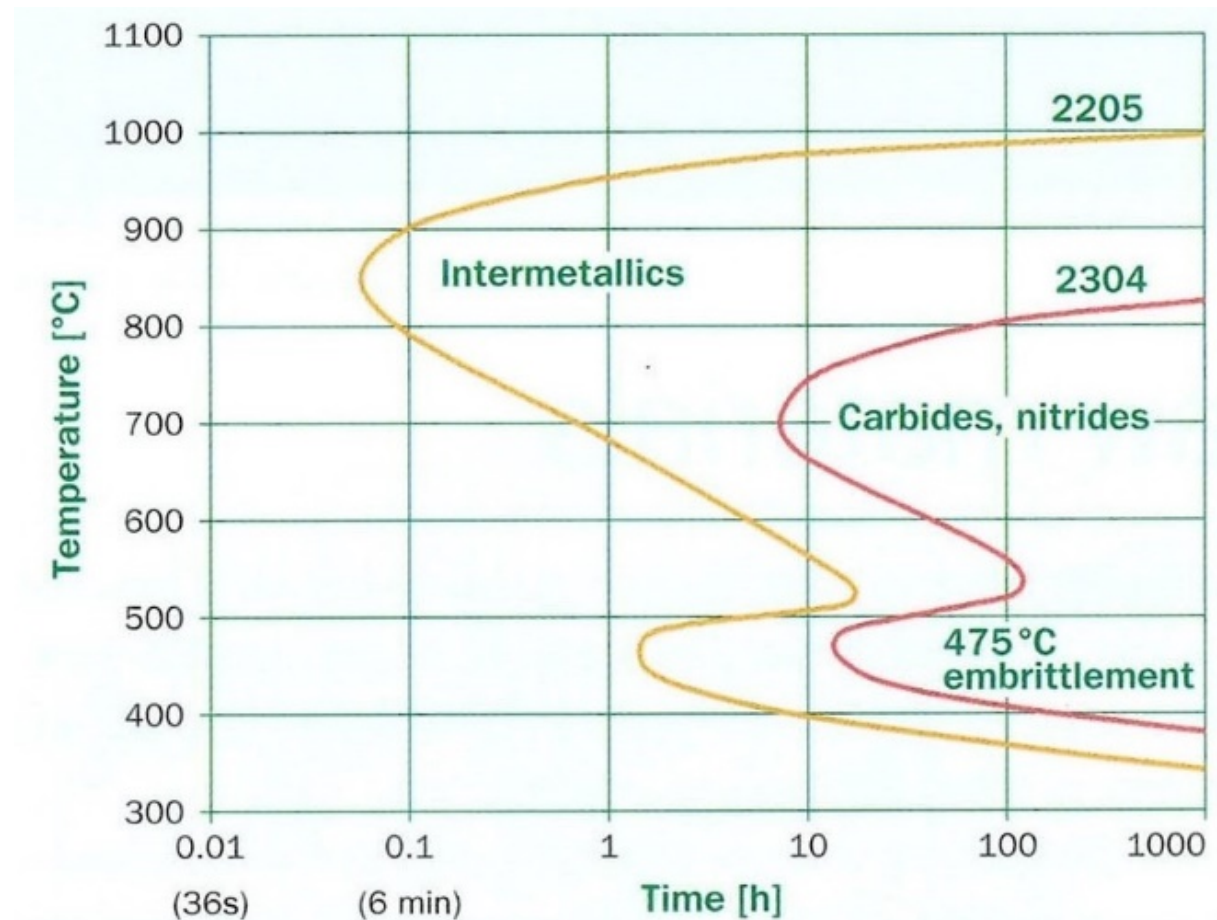


Multi-pass welding

AM

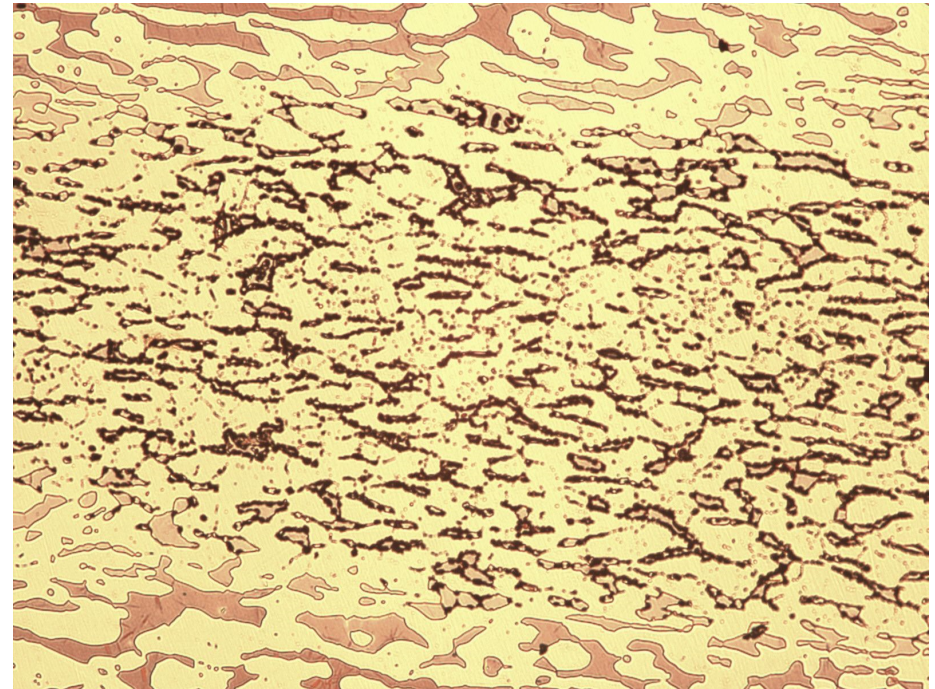
Intermetallics, carbides, nitrides, 475°C embrittlement, secondary austenite

TTT diagram for conditions causing a 50% reduction in impact toughness



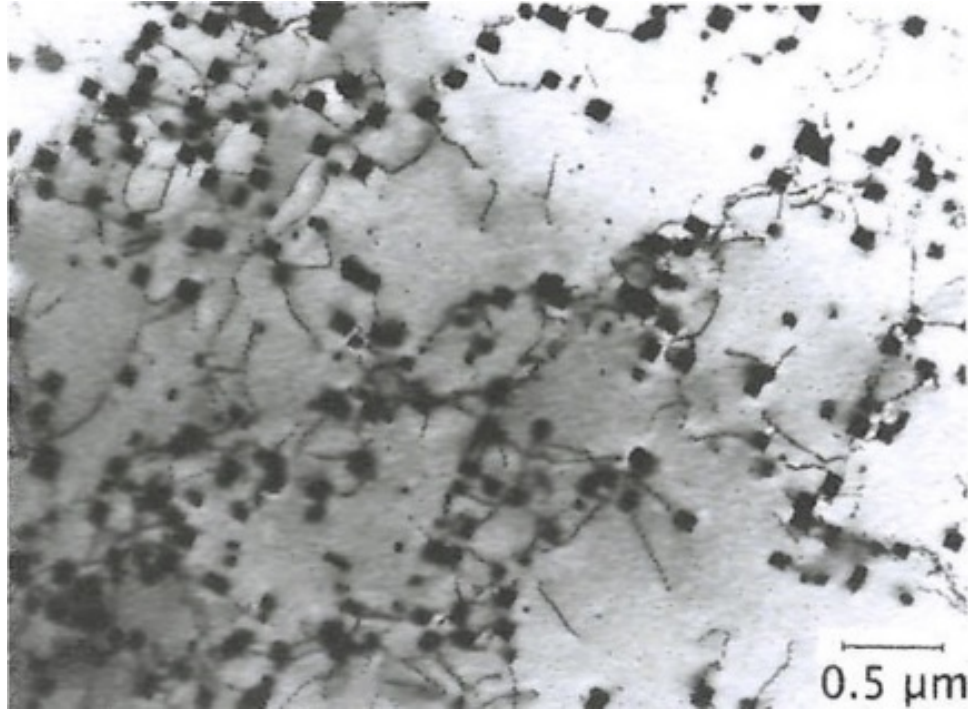
Intermetallic phases

- Range 600-1000C intermetallic phases can form (sigma phase Fe-Cr-Mo, Chi phase $\text{Fe}_{36}\text{Cr}_{12}\text{Mo}_{10}\dots$)
- Very brittle! Reduce ductility! & corrosion resistance!
- Highly alloyed, more susceptible



Sigma-phase in duplex stainless steel

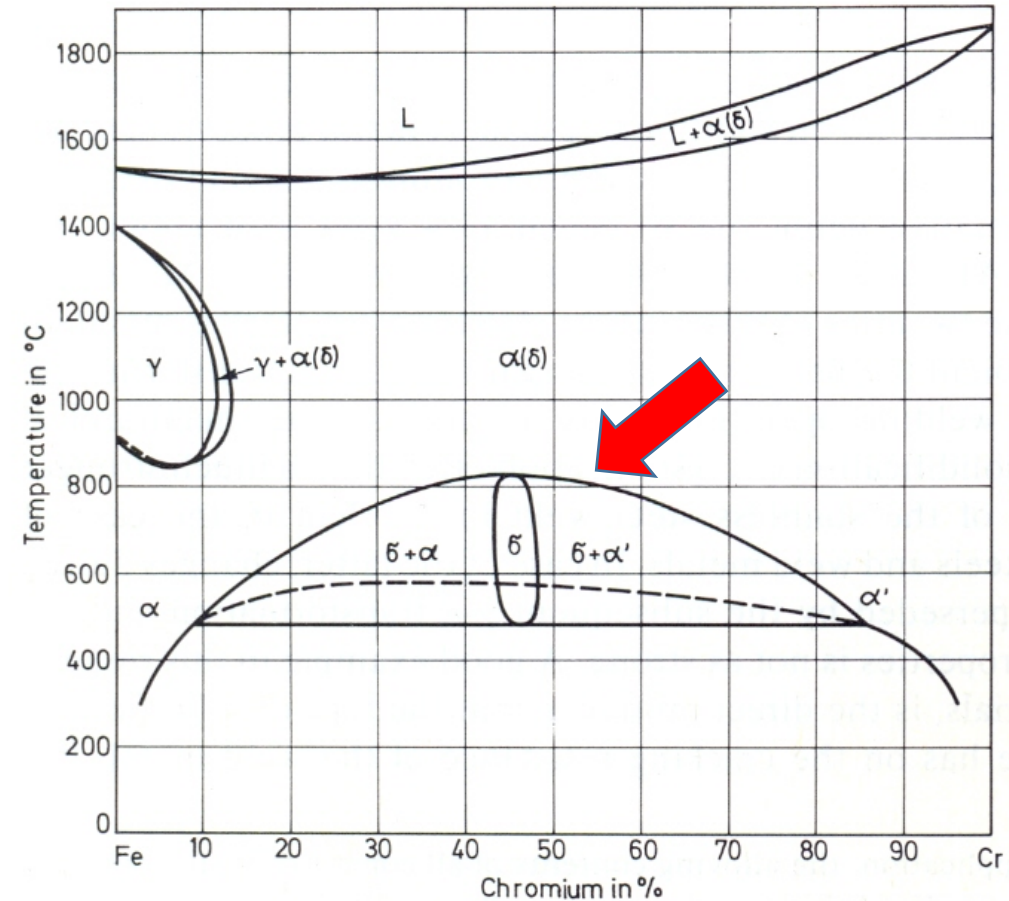
Carbide and nitride precipitation



- 550-800C
- Carbides formed in the grain boundaries
- Cause intergranular corrosion
- And might also decrease toughness
- Nitrides formed in the primary ferritic grains

475°C embrittlement

- Temperature range 300-500C
- Decrease in toughness!!!!
Embrittlement!!



- Ferrite $\rightarrow \alpha$ (rich in Fe) + α' (rich in Cr) : spinodal decomposition



How to control the microstructure of the weldments?

1- Controlling the cooling rate (interpass temperature and arc energy)

Arc energy (0.5 – 2.5 kJ/mm and interpass temperature (100°C-200°C)
depending on the specific grade and welding process

The more highly-alloyed grades, the lower maximum arc energy and interpass temperature

2- Controlling the chemical composition of the weld metal (choice of filler material, shielding gas and dilution)



How to control the microstructure of the weldments?

2- Controlling the chemical composition of the weld metal (choice of filler material, shielding gas and dilution)

Welding consumable: Important to match BM strength, toughness and corrosion properties

Rule: "Matching filler material", matching elements critical for corrosion resistance (Cr, Mo, W, N, Cu)
Ni is always higher in the filler than in the BM

Shielding gases: 2 trends

- Ar + addition of Nitrogen (TIG, plasma, but in MIG some claim that create porosity)
- Multicomponent shielding gases (with He to improve weld pool fluidity and faster welding speed)

Root shielding: better corrosion resistance if it includes Nitrogen

Some practical tips for Joint design and joint preparation:

Not extremely good fluidity, therefore to achieve good penetration, a wider root gap and a joint angle preparation about 10° larger than for standard steels should be used

Keep the root gap!!

Good tacking is essential!!

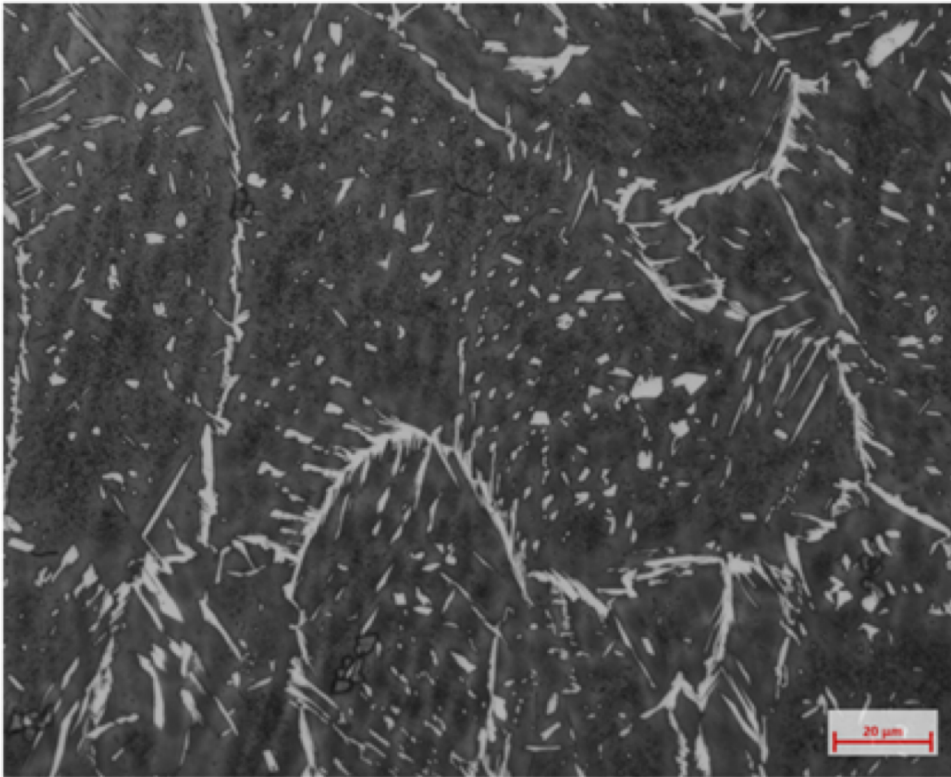
- Tacking using suitable duplex filler metal.
- All tacks outside the joint must be removed by removed properly
- Misalignment should be avoided



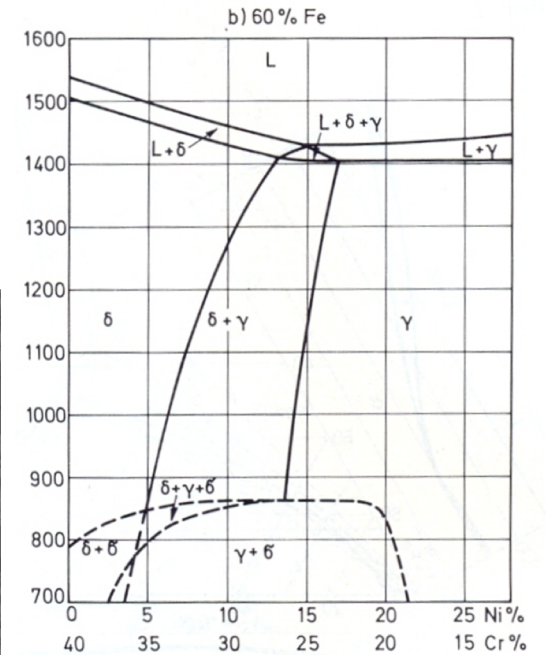


Too rapid cooling?/Low energy input?

2209 Laser Beam Welding



2209 MIG welding



Excessive amount of ferrite and nitride formation- problem in corrosion resistance!



Too slow cooling? Or repeatedly heated (600-1000°C)

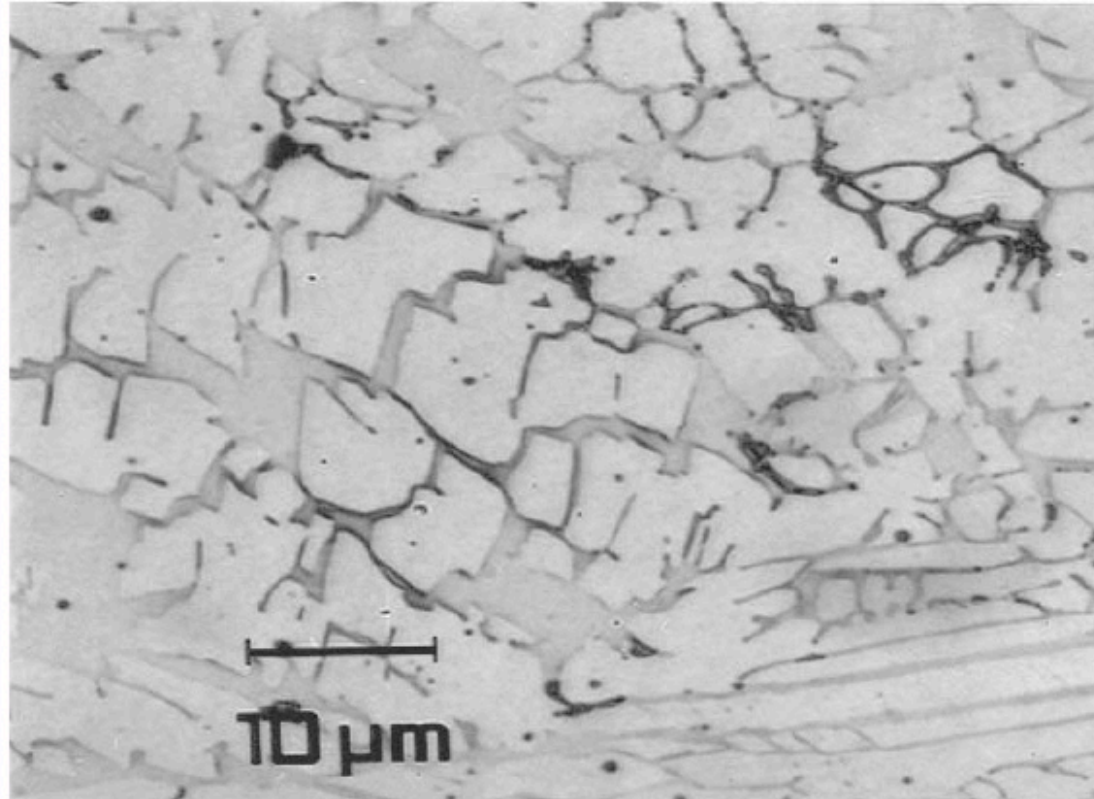
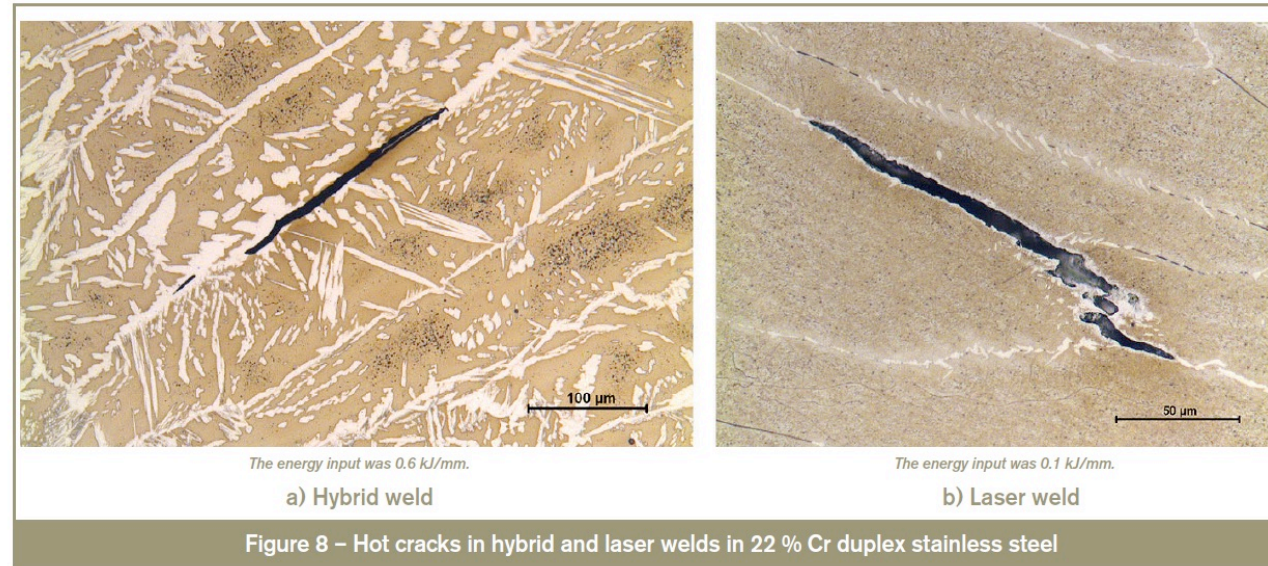


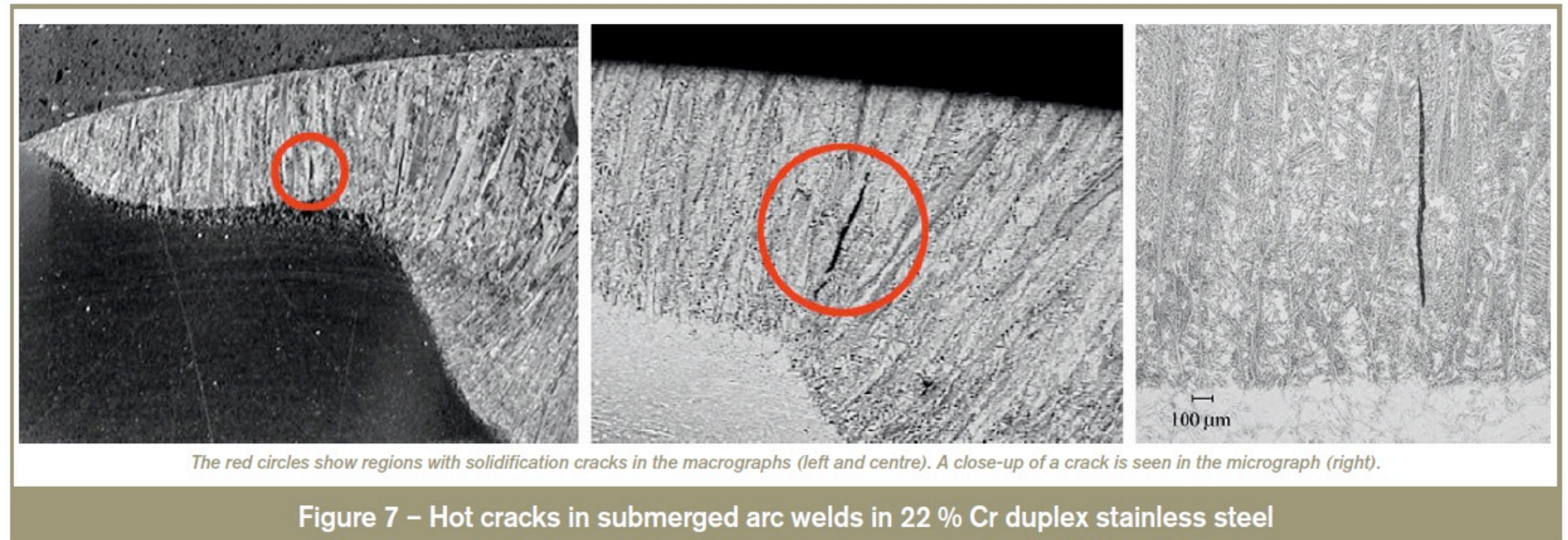
Figure 6 – Intermetallic phase (dark etching) formation in a repeatedly reheated region of a superduplex weld

Decrease in toughness
and corrosion resistance!

Solidification cracking: minor problem in duplex...but in high dilution with low energy input...



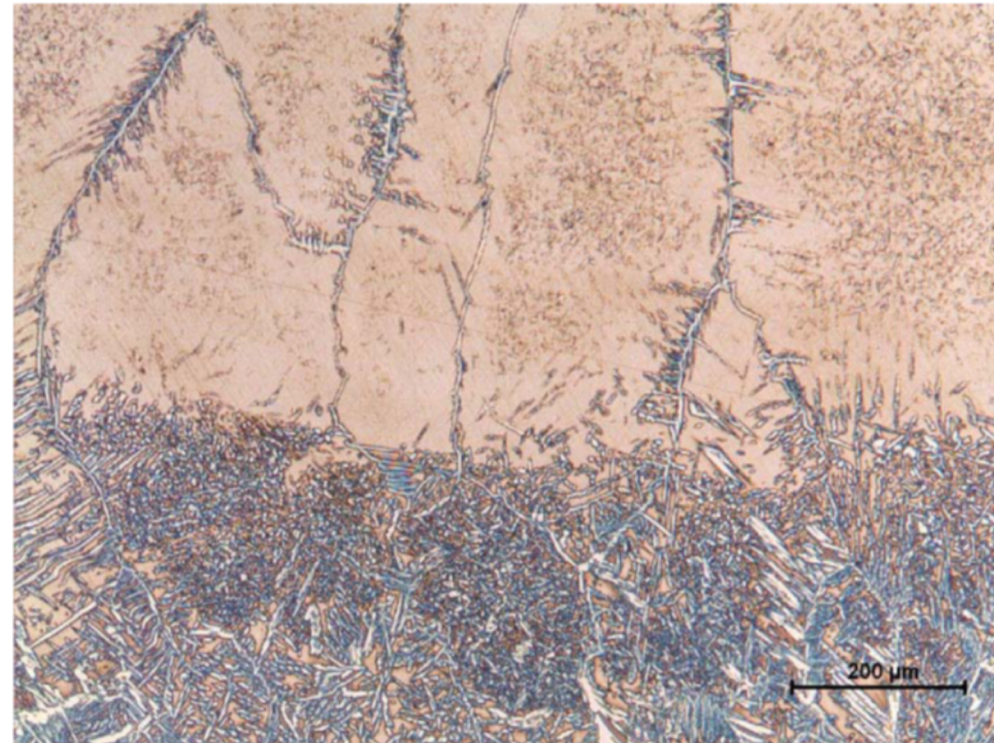
Or in deep and narrow beads highly restrained...



Corrosion resistance: impaired by nitrogen loss and secondary austenite

Too fast cooling rate: ferrite and nitrogen loss

TIG 2209 duplex, not passing G48 test



84 FN

Non-reheated
weld metal

Reheated
weld metal

57 FN

Secondary austenite!

Corrosion resistance: impaired by nitrogen loss and secondary austenite

Secondary austenite, lower
N content than primary austenite
Formed from ferrite,

Lower corrosion resistance!

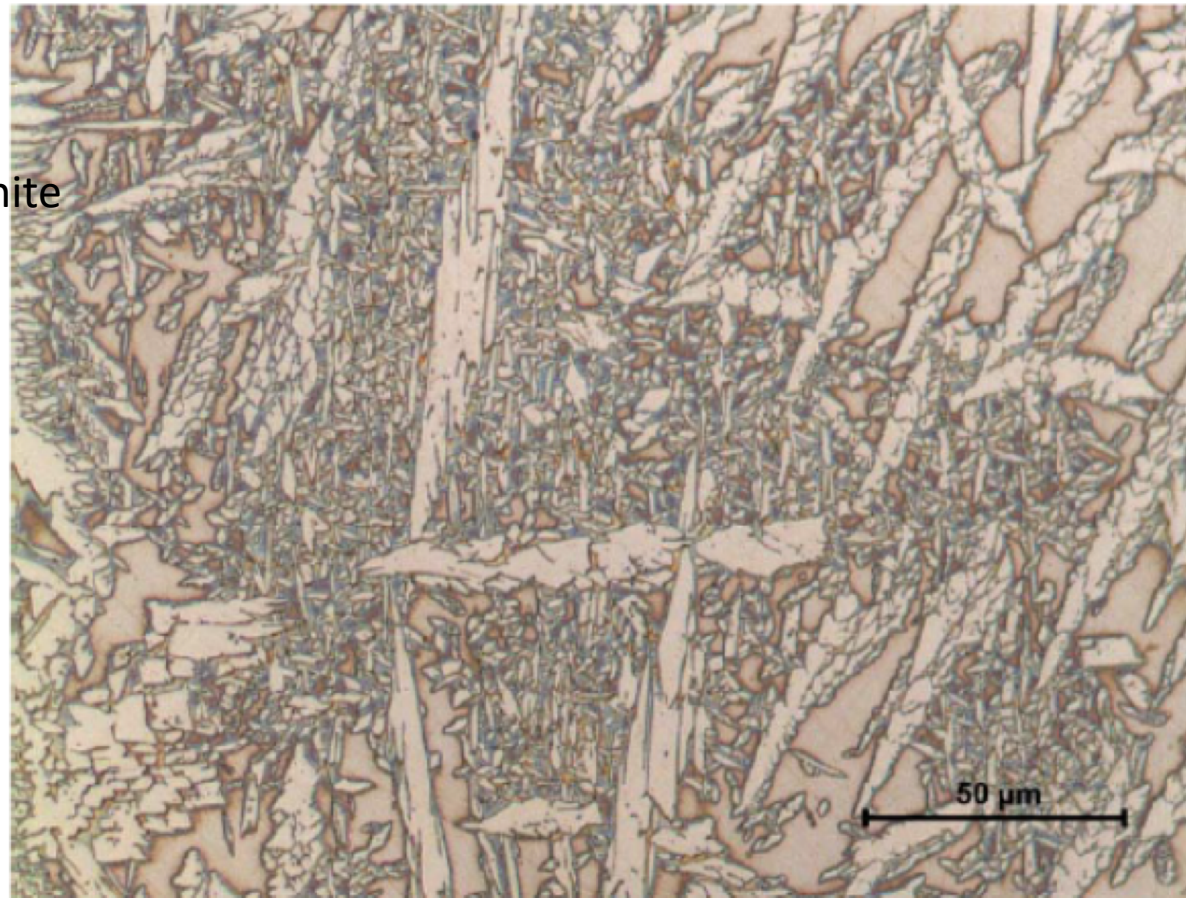


Figure 5. Detail from figure 4 showing an area with rich formation of secondary austenite (small needles). Large needles are primary austenite, beige matrix is ferrite.

References

HV projects

Outokumpu's Handbook of Stainless Steels

ESAB AB & Lincoln Electric

**WELDING DUPLEX STAINLESS STEELS –
A REVIEW OF CURRENT RECOMMENDATIONS**

L. Karlsson

Tack för idag!



Resolution: 1280x1024 px
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