Failures in stainless steel welds – examples and causes

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Content

- Overview of a few real-life examples

1. Intermetallic precipitation – Sigma phase
2. HAZ Liquation cracking
3. Solidification cracking
4. Stress corrosion cracking (SCC)
5. Heat tint

1. Sigma phase

Case Study A Loss of corrosion resistance

Case Study B Embrittlement

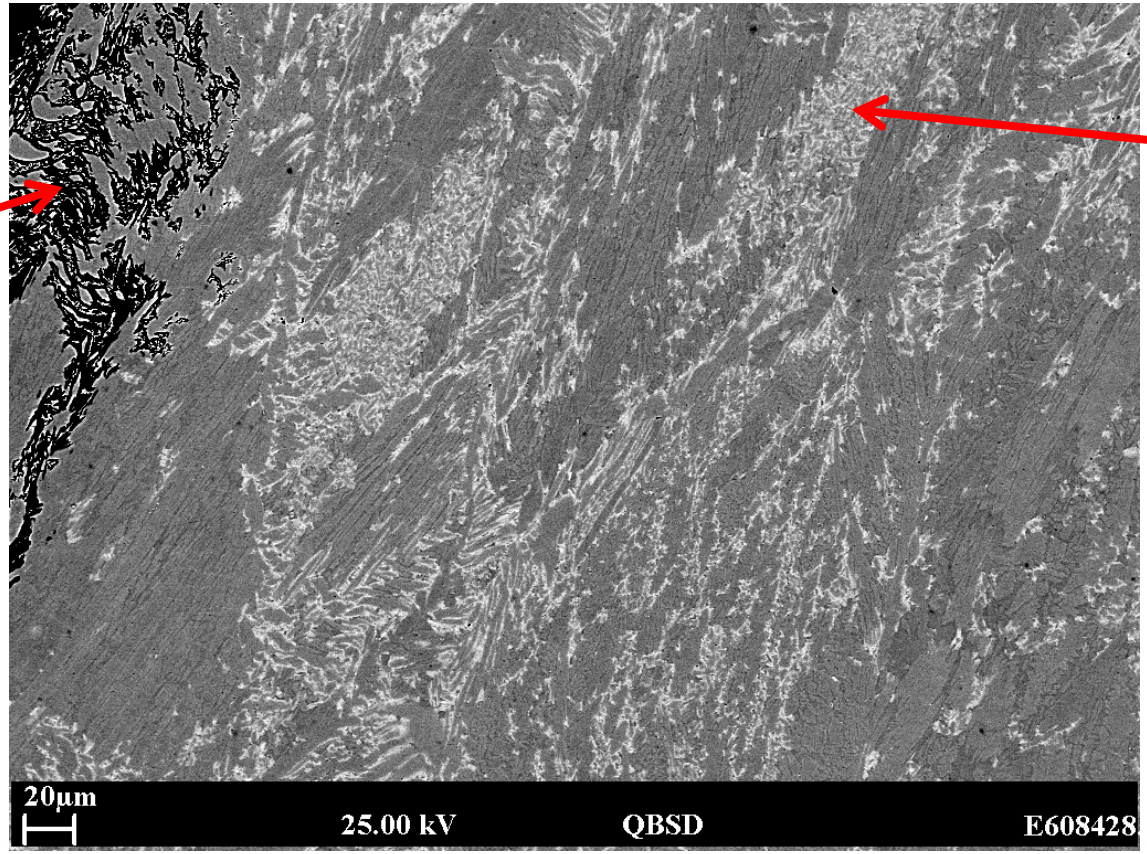
Case Study A

Superduplex stainless steel

- Subsea spoolpiece
- Weld metal/HAZ crack
- Hydrogen embrittlement

Sigma phase

- Pitting corrosion and preferential phase corrosion due to sigma phase



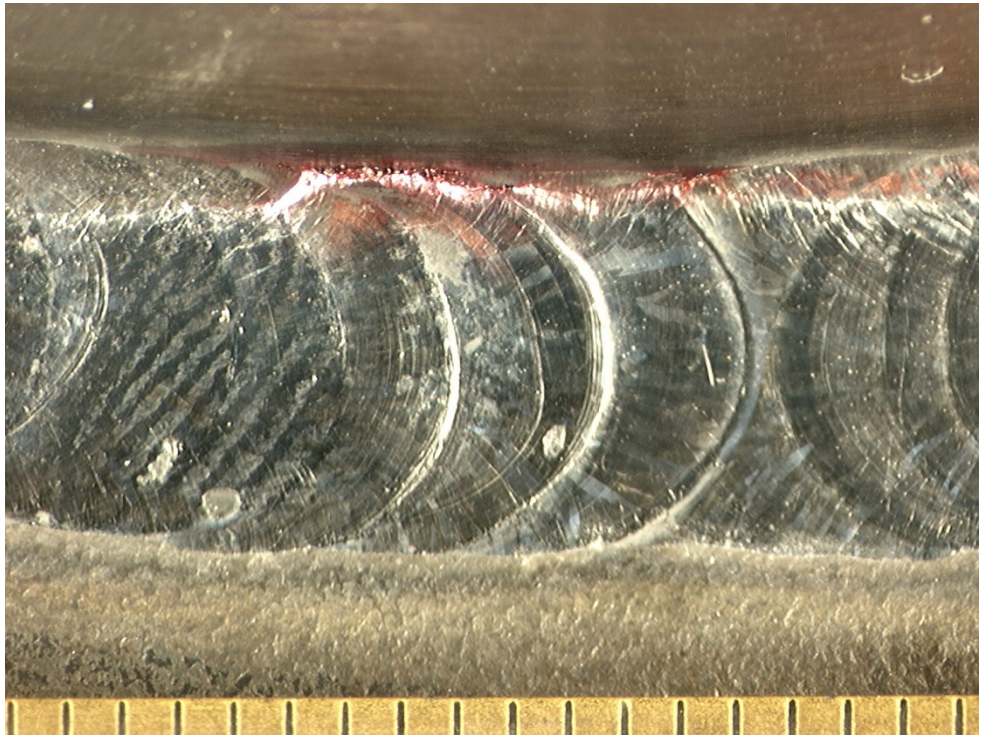
Causes of Failure

- Superduplex stainless steel
- Girth weld repair
  - High heat input
- Sigma phase precipitation
- Pitting corrosion
- Hydrogen embrittlement crack
  - Hydrogen from corrosion
  - Tensile stress

Case Study B

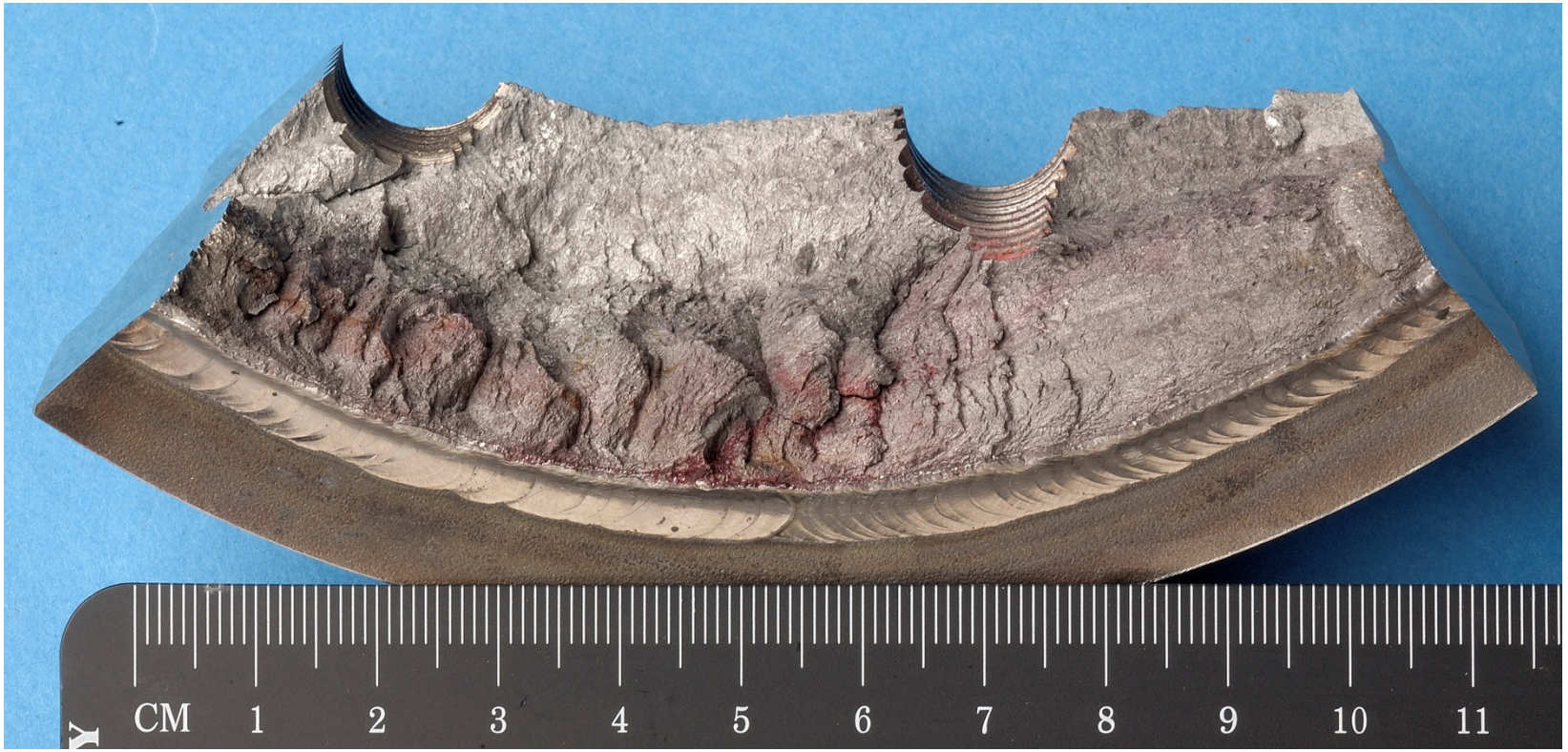
Duplex stainless steel

- Dye penetrant showing weld metal/HAZ crack

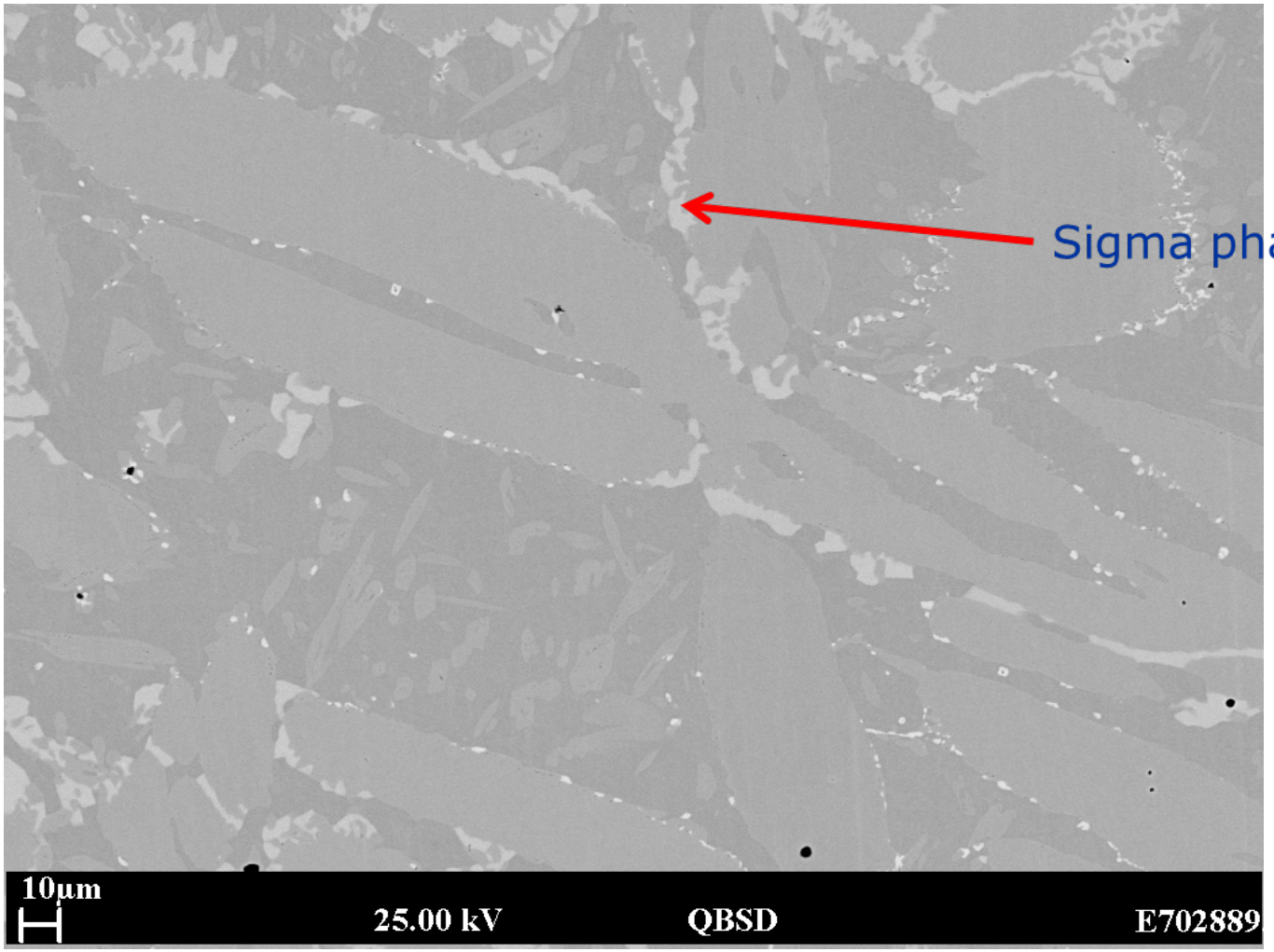


Fracture face

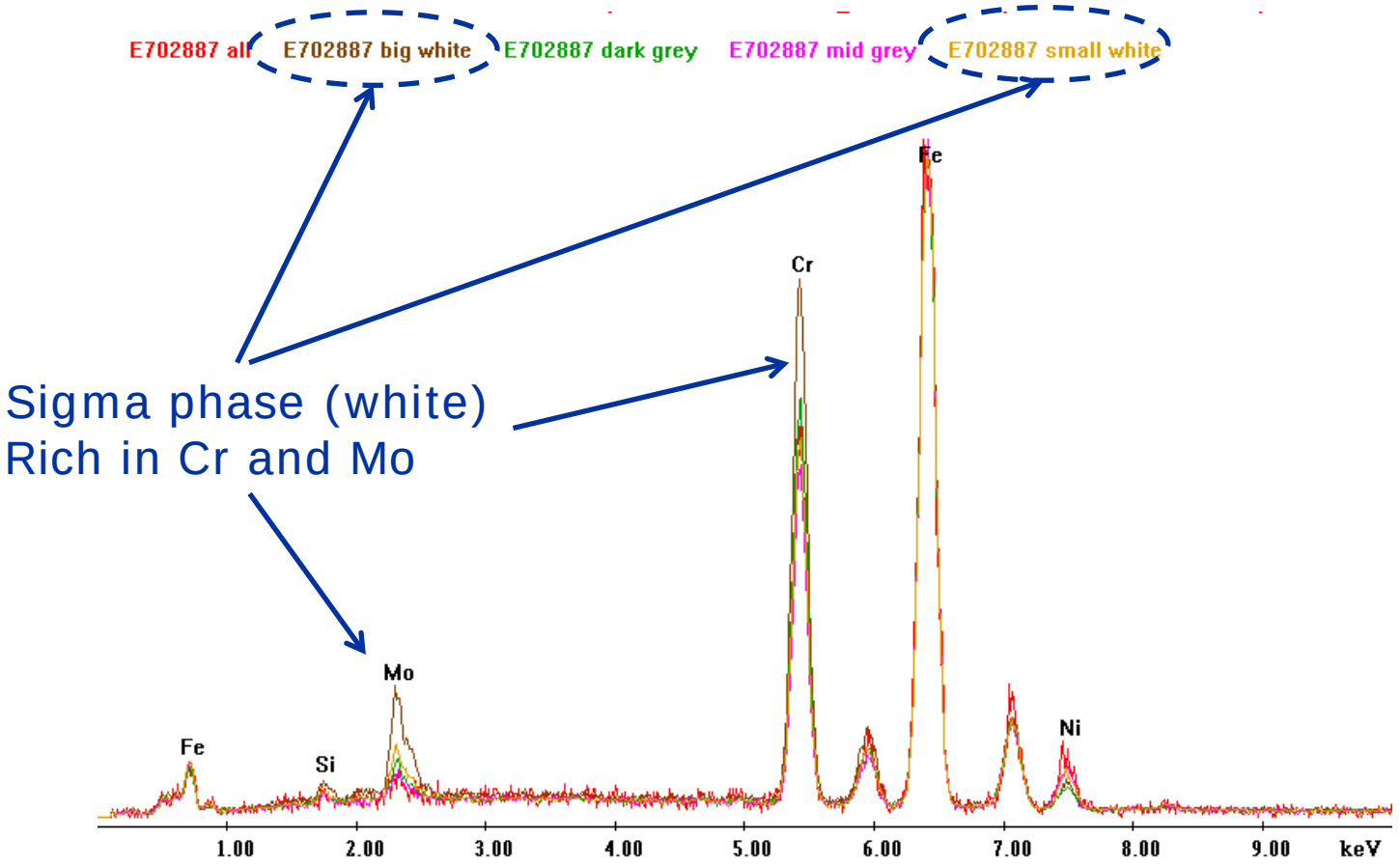
- Brittle fracture due to sigma phase



Duplex stainless steel Microstructure



Composition of phases EDX spectrum



Causes of failure

- Duplex stainless steel
- Sigma phase precipitation
- Incorrect heat treatment of forging
- Tensile stress
  - Residual stress
  - Applied stress during hydrotest

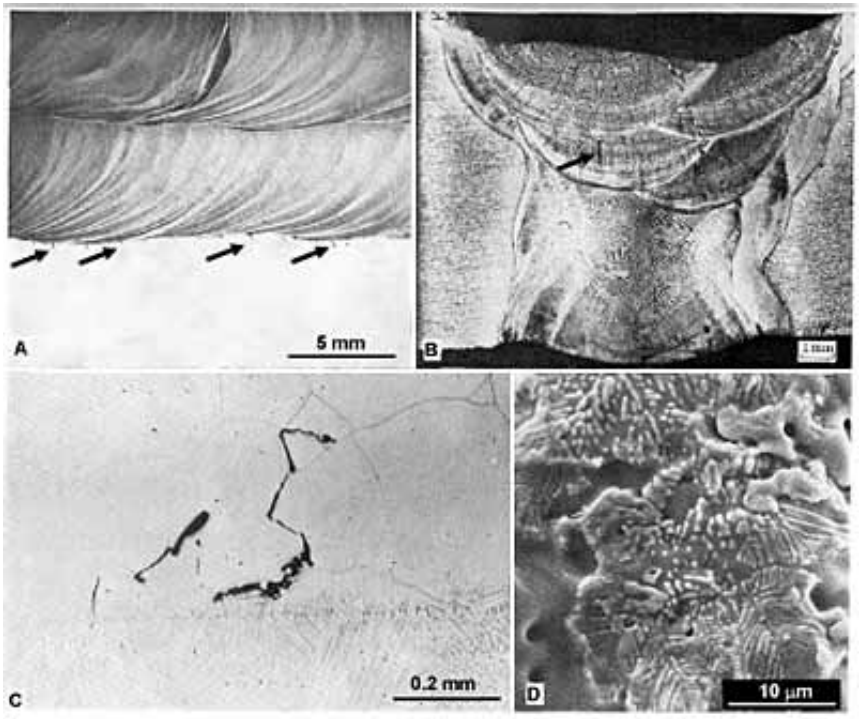
2. HAZ Liquation cracking

HAZ Liquation Cracking

- Short intergranular cracks:
  - In high-temperature zone of the HAZ, or
  - In previously deposited weld metal, during a subsequent run
- Due to formation of grain boundary liquid films at temperatures below the alloy melting temperature
- On cooling this liquid is unable to accommodate tensile strains, caused by contraction, and cracks may form

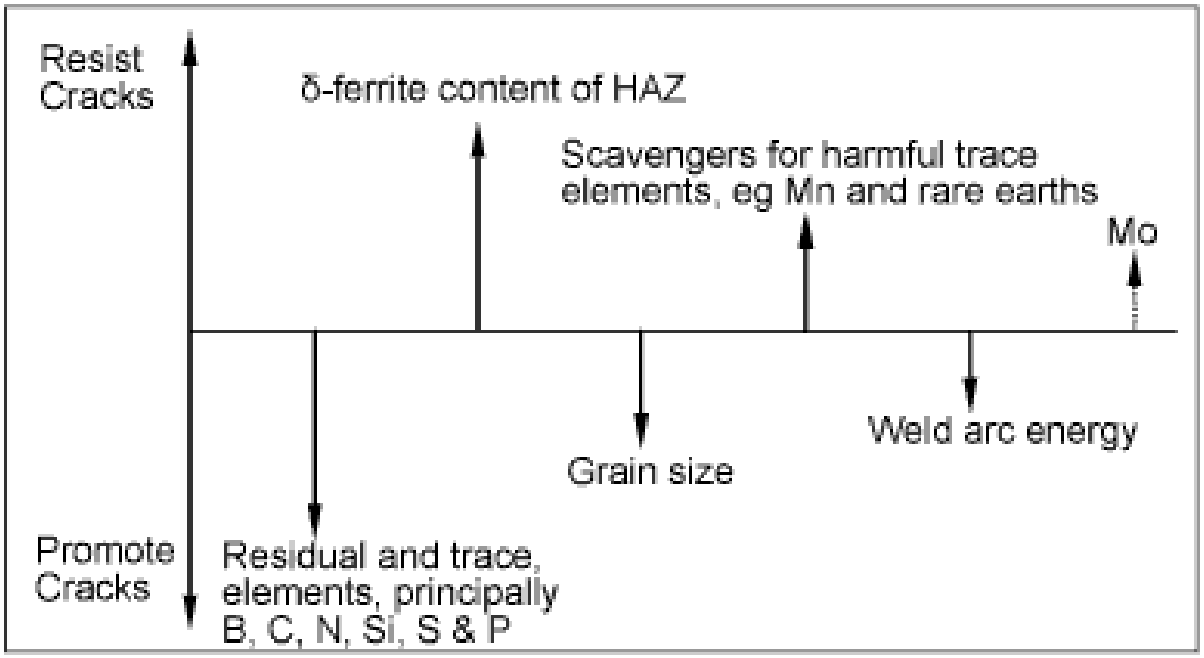
http://www.twi.co.uk/technical-knowledge/knowledge-summaries/liquation-cracking/

HAZ Liquation Cracking



1a) Photomacrograph of HAZ liquation cracking in austenitic stainless steel cladded with a nickel alloy weld metal. Location of liquation cracking indicated by arrows;
1b) Liquation cracking in AISI 316 austenitic stainless steel weld metal, reheated by subsequent weld bead. Location of liquation cracking indicated by arrows;
1c) HAZ liquation cracking in AISI 310 austenitic stainless steel (Magn. x 114);
1d) Scanning electron micrograph of liquated film on liquation crack surface in an AISI 316 austenitic stainless steel weld metal (Magn. x 1800)

Factors affecting liquation cracking



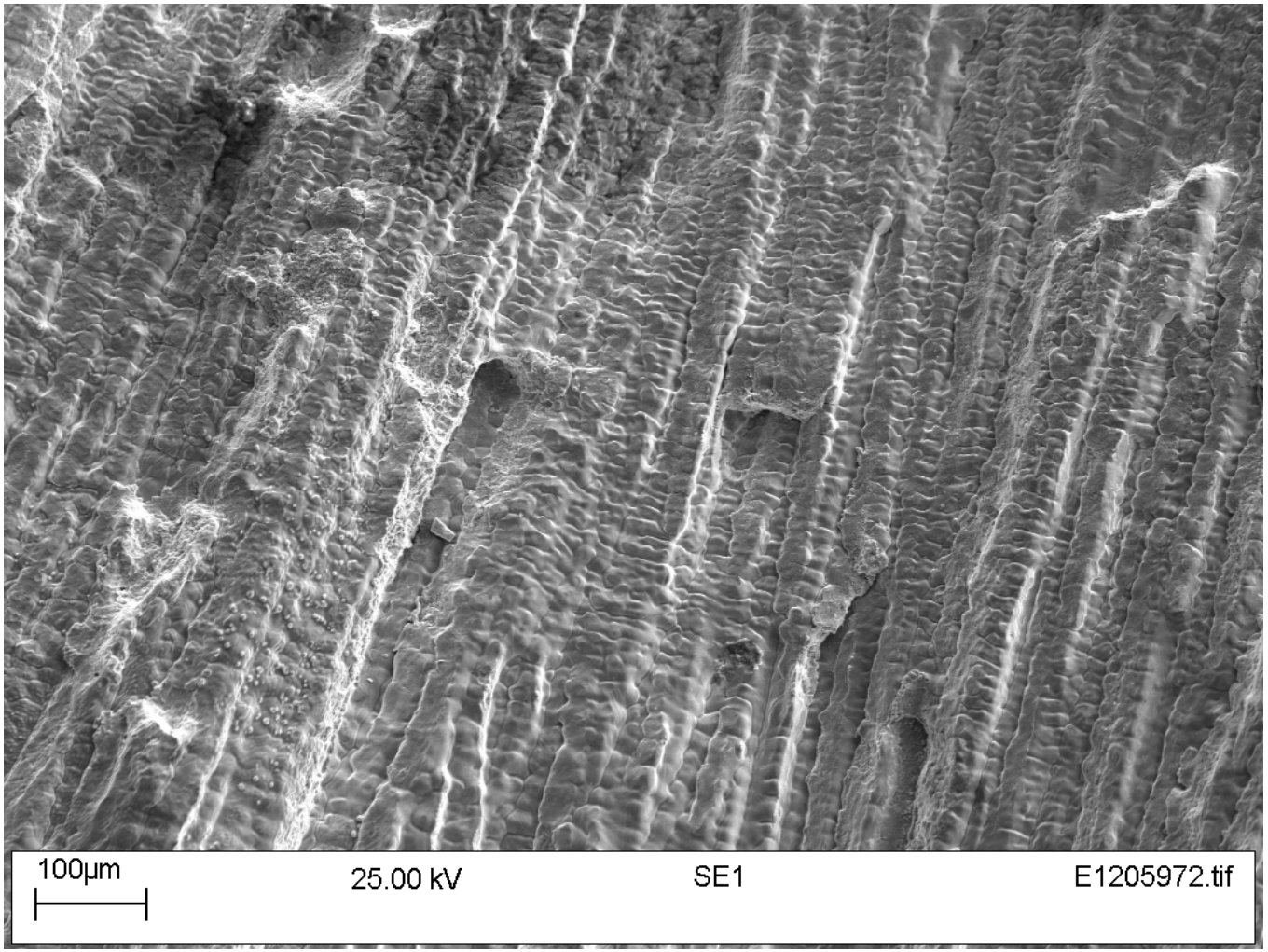
3. Solidification Cracking

Solidification crack

- Butt weld
- Repair weld

- Solidification crack arrowed

Solidification crack fracture face



Causes of failure

- Duplex stainless steel
  - Less common than austenitic

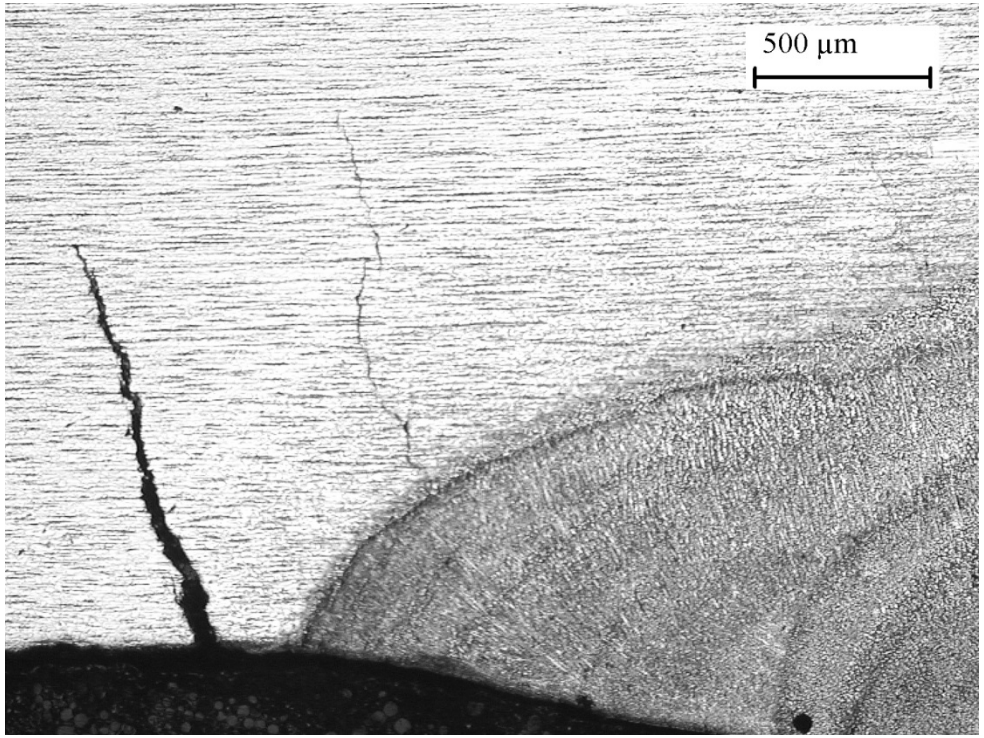
- Bend test failure
- Factors involved in solidification cracking
  - Tensile stress
  - Delta ferrite content
  - Sulphur

- Cause - Unusually wide weld bead due to weaving?

4. Stress corrosion cracking (SCC)

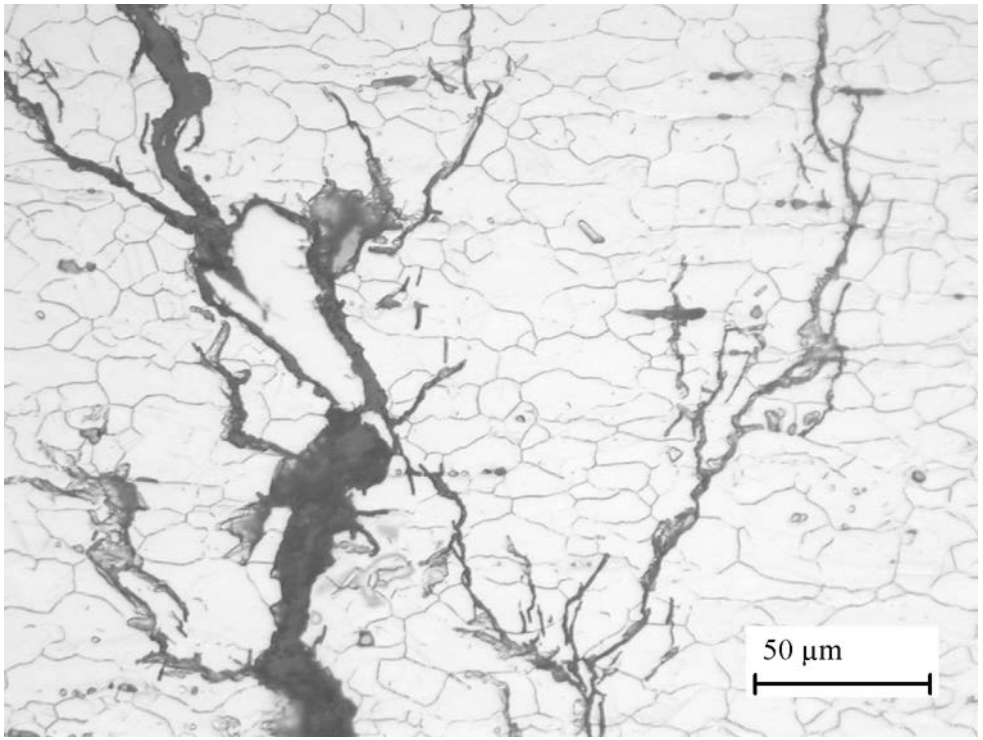
Stress corrosion cracking

- Austenitic stainless steel, pipe girth weld



Stress corrosion cracking

- Austenitic stainless steel
- Branched, transgranular cracks



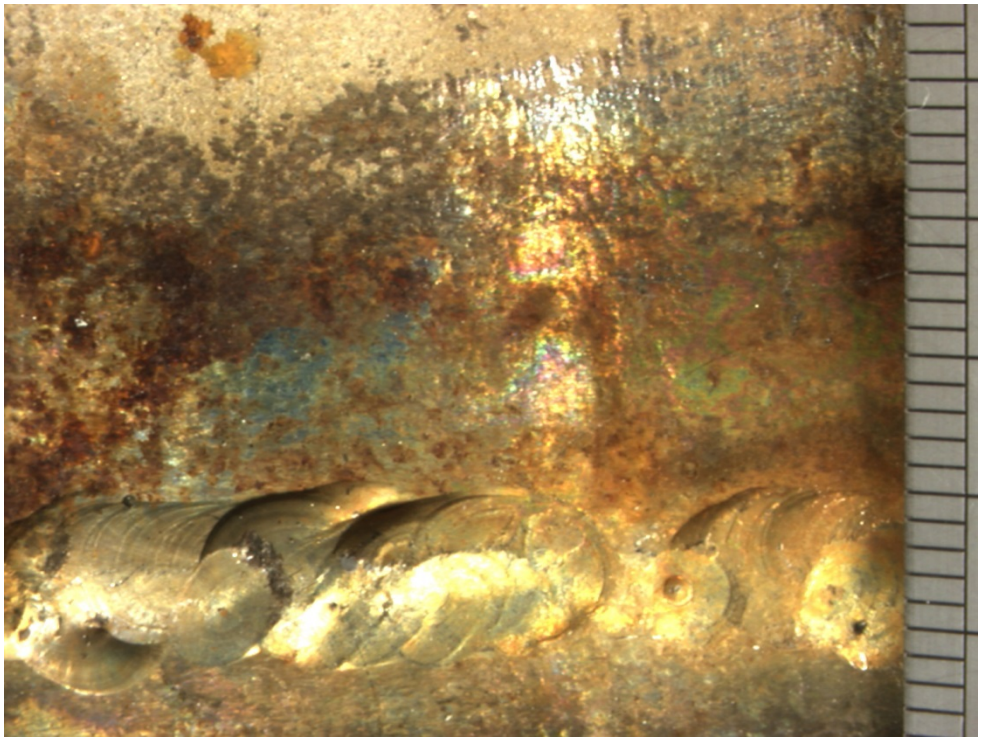
Causes of Failure

- Chloride-containing environment
- Residual tensile stresses from welding
- Weld profile
  - Difficult to drain – liquid collection
  - Concentration of chlorides
- Elevated temperature (55-60°C)

5. Heat tint

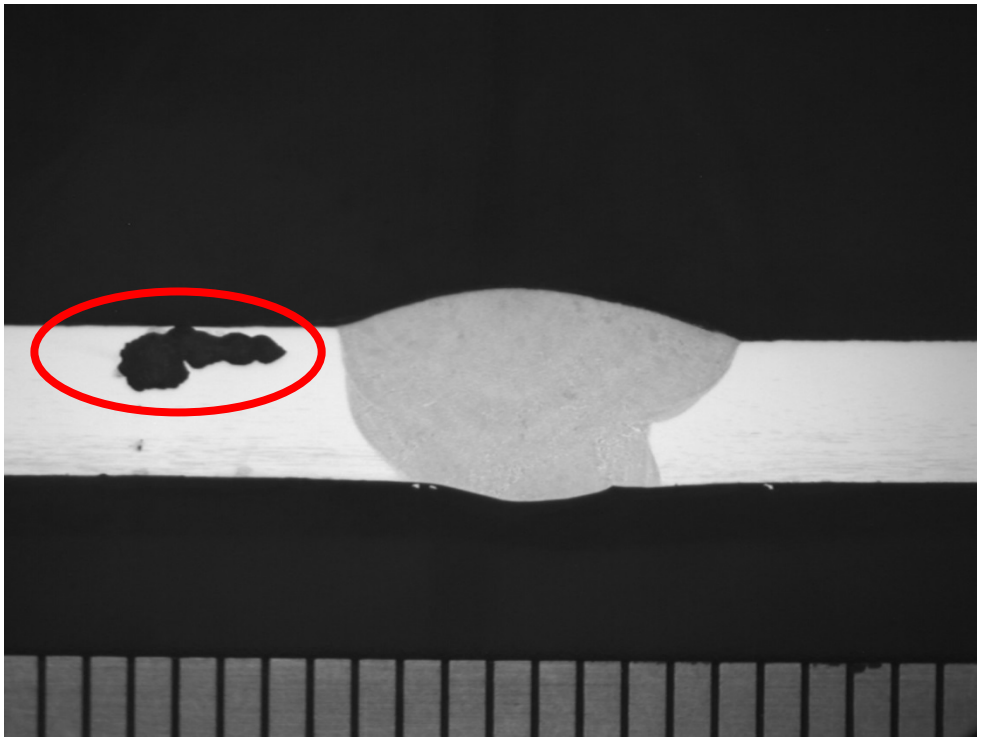
Heat tint
Pitting and crevice corrosion

- Lowered corrosion resistance
- Corrosion pits in heat tint



Heat tint

- 304L stainless steel welded pipe
- Pitting corrosion much larger under the surface than visible on the surface



Causes of failure

- Oxidation of the root bead + adjacent HAZ during welding of SS.
- Cr-rich scale is formed, the surface becomes Cr-depleted which impairs corrosion resistance.

- Avoid heat tint:
- Need good shielding and backing (purging) gas.
  - Shield: Ar, Ar/He, Ar/N mixtures.
  - Purge: Ar or N_2.
- Use several volumes of purge gas before welding.
- Maintain purge for 3 or 4 weld passes in multi-pass weld.
- May also pickle and passivate

Summary

- Welding can introduce or promote various failure mechanisms
- Best practice for welding should be followed
- For further guidance:

http://www.twi-global.com/technical-knowledge/

Contact

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