

DUWELTOOL

Ferrite measurements & general methodology

Vahid A Hosseini, Kjell Hurtig, Leif Karlsson, Sten Wessman

Department of Engineering Science, University West, SE-461 86 Trollhättan, Sweden

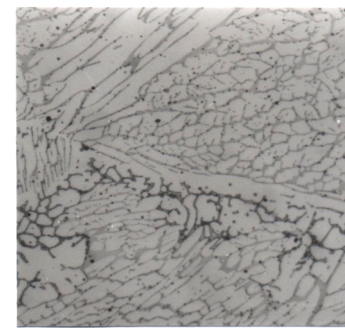
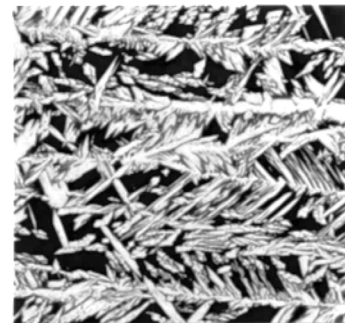
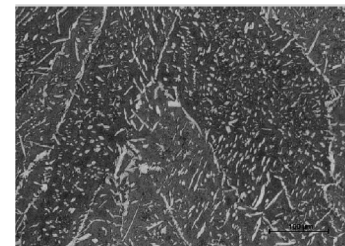
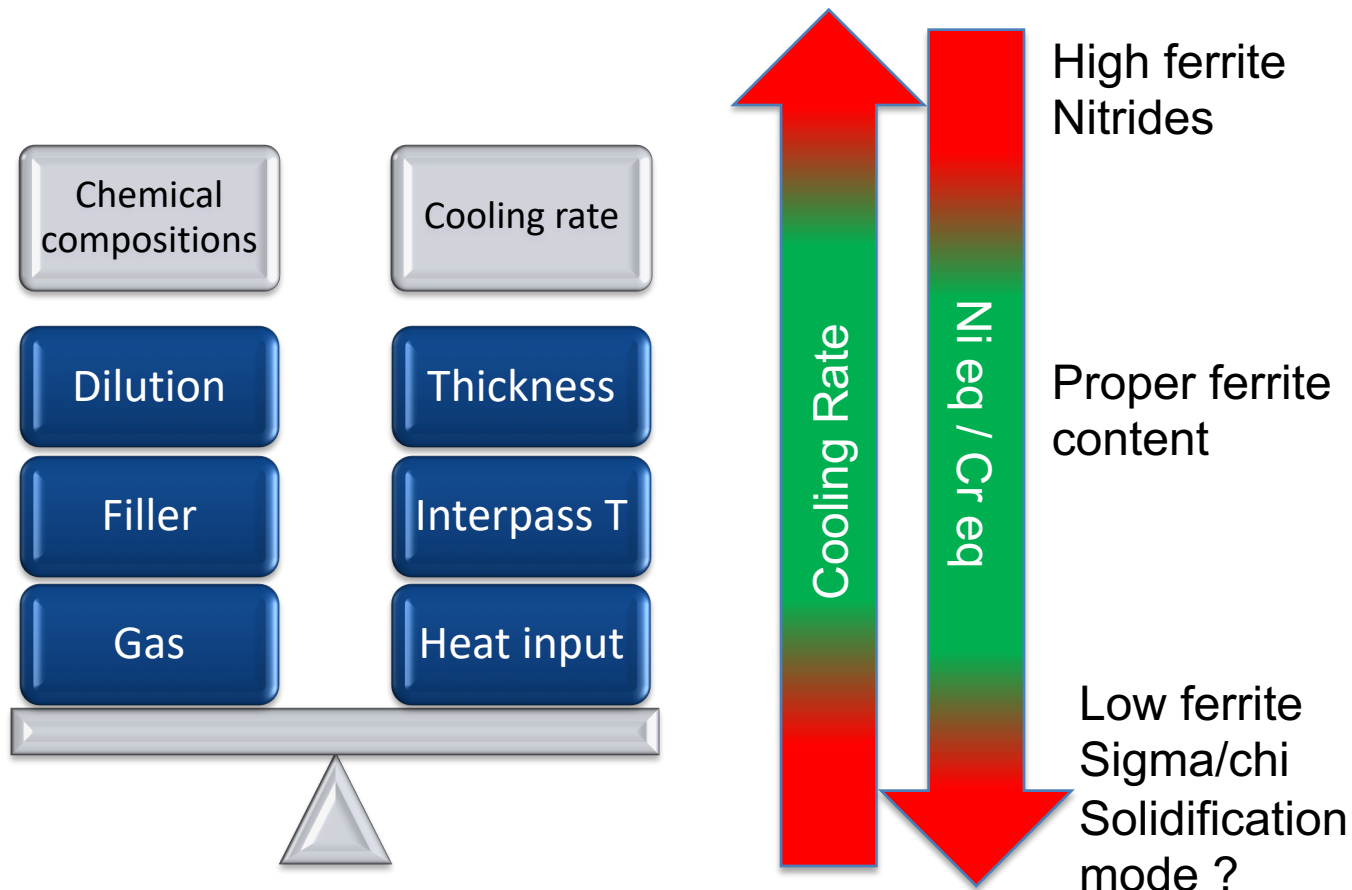
Last bead microstructure

Background

Ferrite
Measurement

Methodology

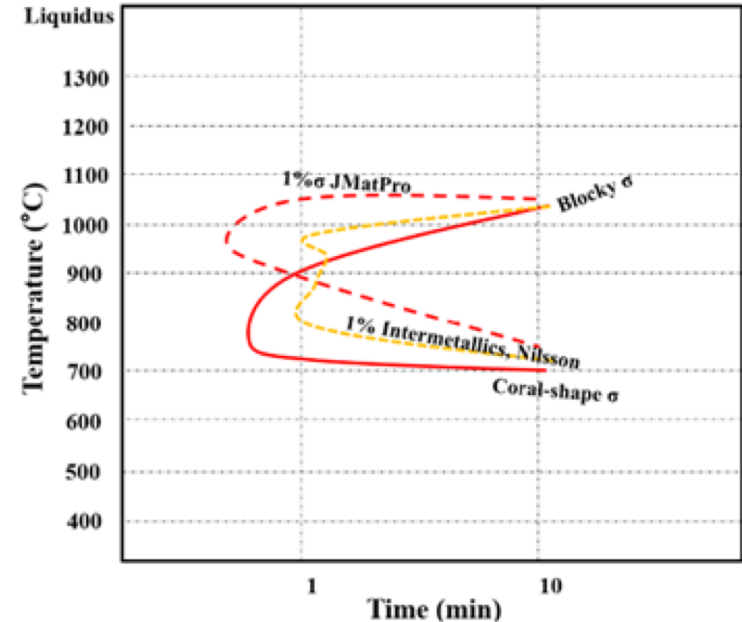
Conclusion



Multipass welding

- Multiple reheating
 - Formation of secondary austenite
 - Precipitation of secondary phases
 - Local variation in microstructure and ferrite fraction (some knowledge gap)

Sigma phase- all weld metal



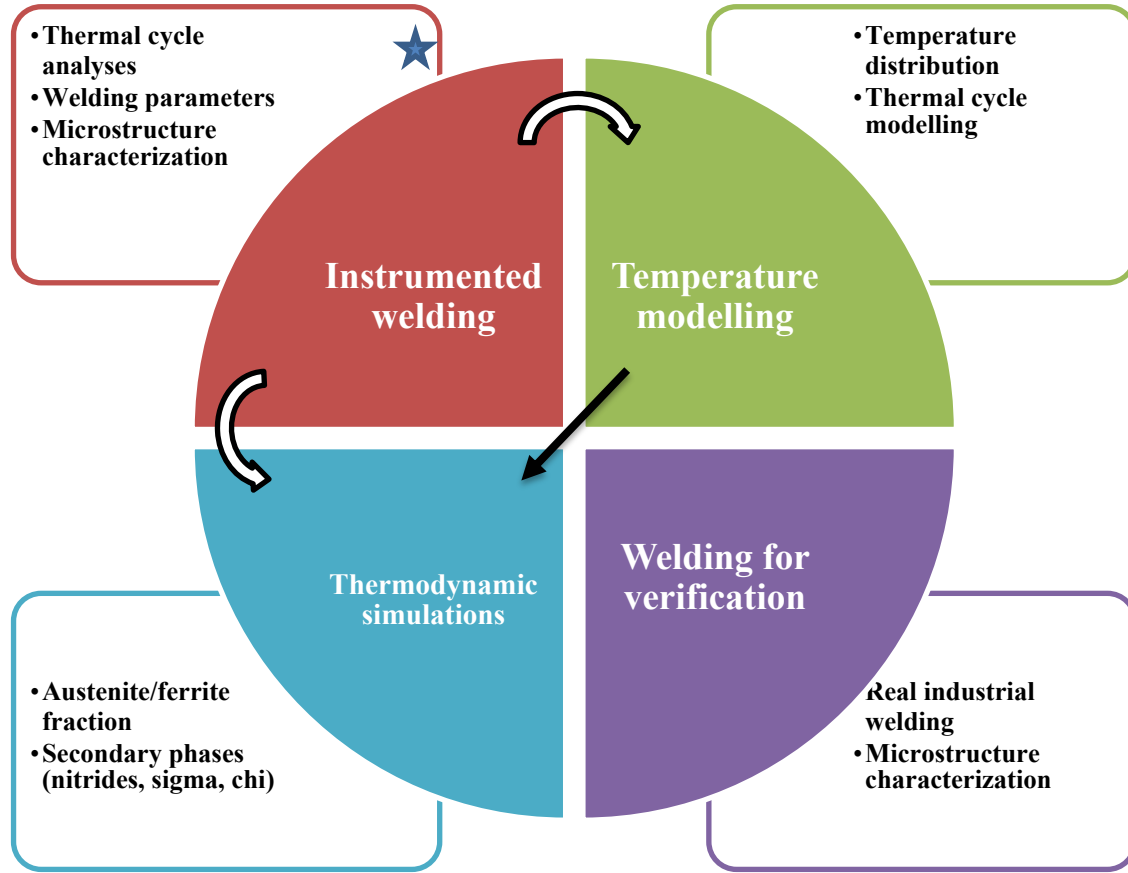
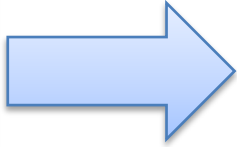


swerea | KIMAB



SVETS
KOMMISSIONEN

★
Round robin test to measure ferrite fraction



Standards for ferrite fraction

Ferrite measurements

Ferrite content measurements

Experimental methods

- Metallography and point counting (%)
- Metallography and image analysis (%)
- EBSD (%)
- FERITSCOPE and ferrite number (FN)
- FERITSCOPE and ferrite fraction (%)
- Magne-Gage
- XRD (%)

Calculations

- Shaeffler diagram
- WRC1992
- Equilibrium phase fraction
- Kinetics of phase transformation
- Phase field modelling

Ferrite content measurements

Background

Ferrite
Measurement

Methodology

Conclusion

Experimental methods

- Metallography and point counting (%)
- Metallography and image analysis (%)
- EBSD (%)
- FERITSCOPE and ferrite number (FN)
- FERITSCOPE magnetic factor (%)
- Magne-Gage
- XRD (%)

Calculations

- Shaeffler diagram
- WRC1992
- Equilibrium phase fraction
- Kinetics of phase transformation
- Phase field modelling

Aims

- 1. Round Robin for ferrite fraction (percentage) measurement**
- 2. Ferrite fraction (percentage) vs Ferrite number**

Round Robin for ferrite fraction (percentage) measurement

Bead-on-plate
GTAW of 6-
mm-thick plate

Selection of
etching
technique

Selection of
analyzing
method

Round Robin
test to verify
the
repeatability

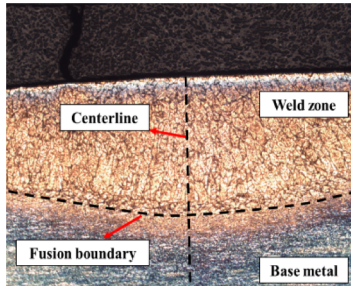
Comparison of
microscopes

- 10% Oxalic Acid
- Two-step-etching
- 20% NaOH
- Modified Beraha

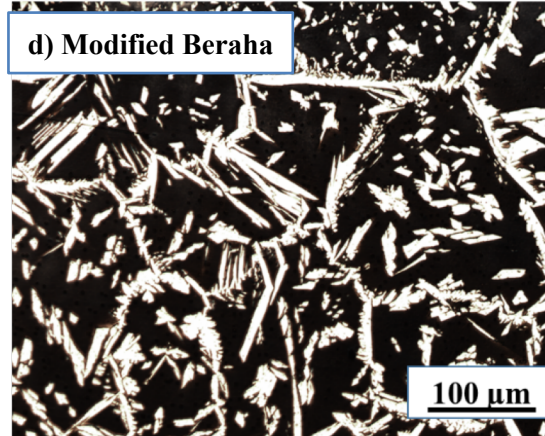
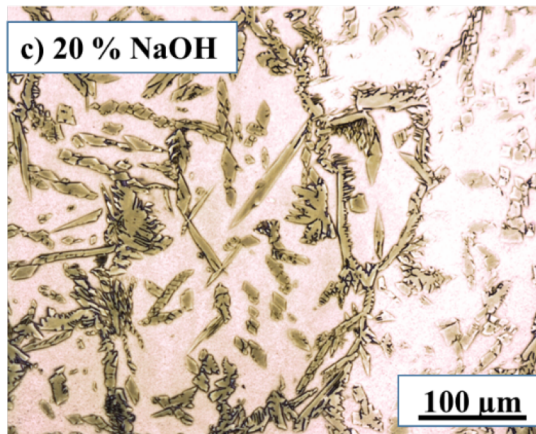
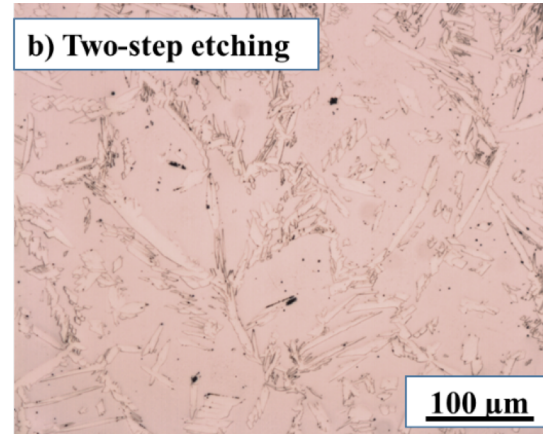
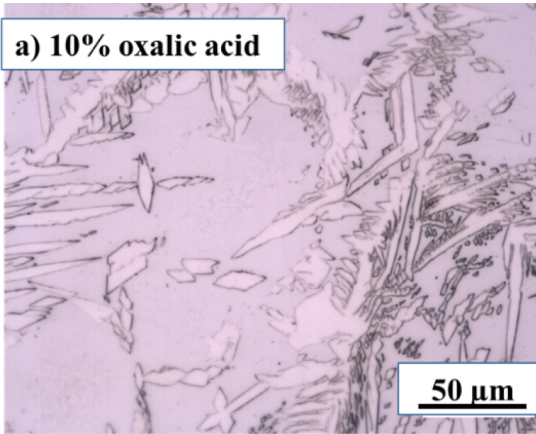
- Point counting
- Image analysis
- EBSD

- University West
- Sandvik Materials Technology
- Outokumpu Stainless AB
- Swerea KIMAB

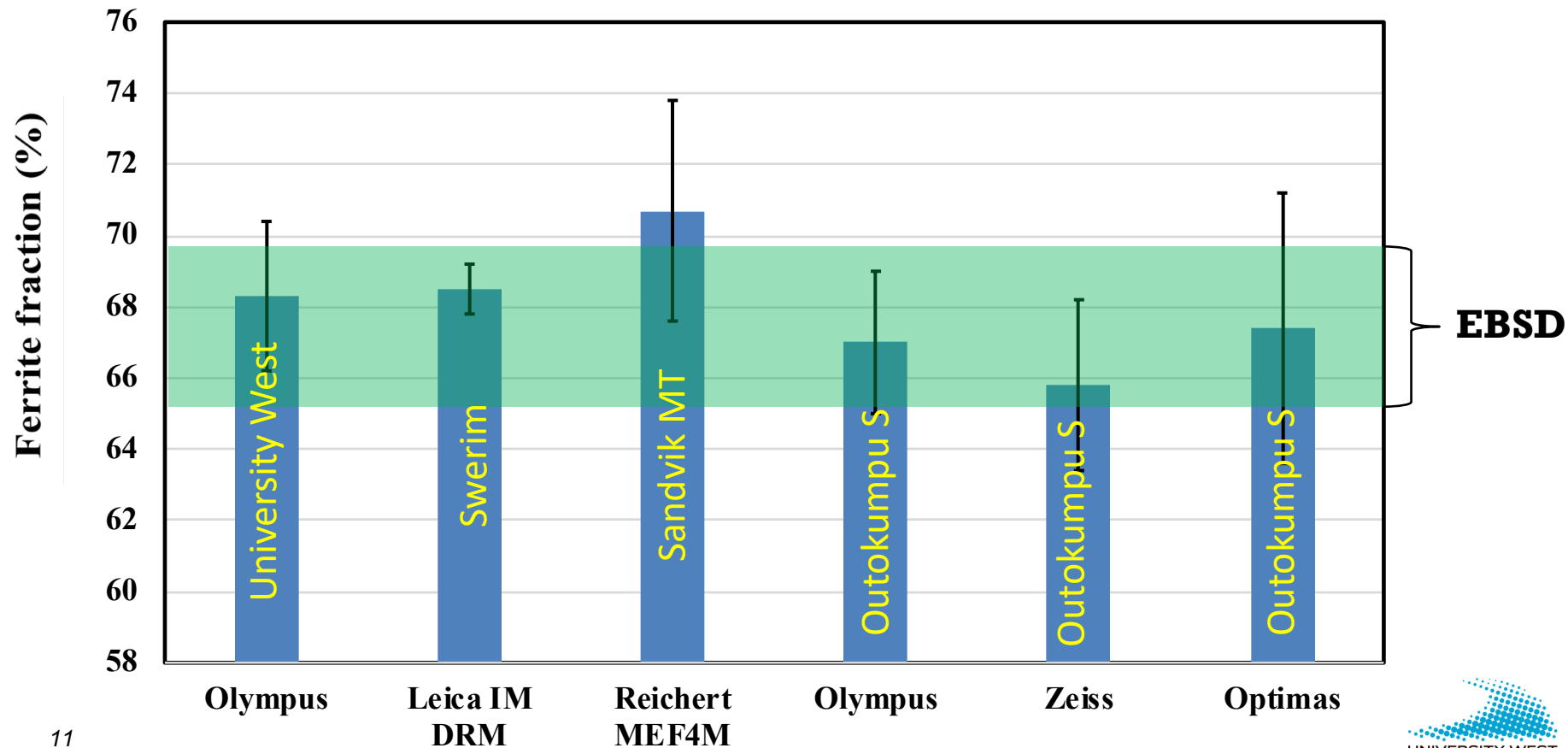
- Outokumpu



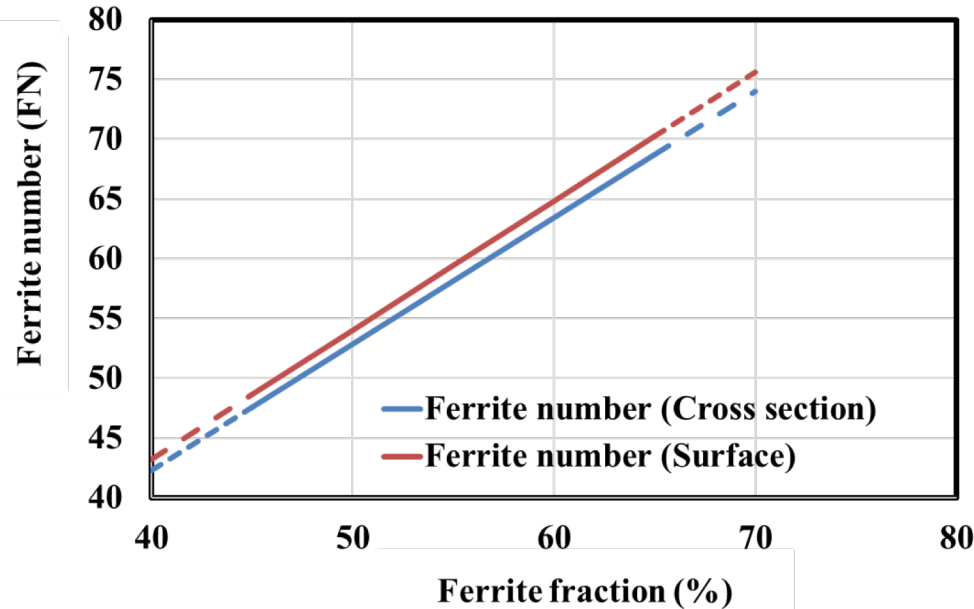
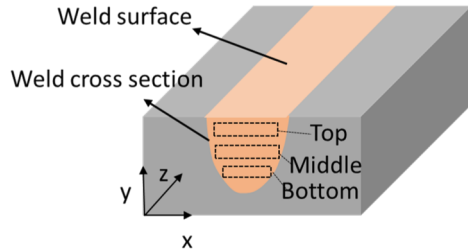
Selection of etchant



Round robin



Ferrite fraction vs Ferrite Number in SDSS single pass welds

[Background](#)[Ferrite Measurement](#)[Methodology](#)[Conclusion](#)

$$\text{Ferrite Number (FN)} = 1.1 \text{ Ferrite fraction (\%)}$$

Comparison of different studies

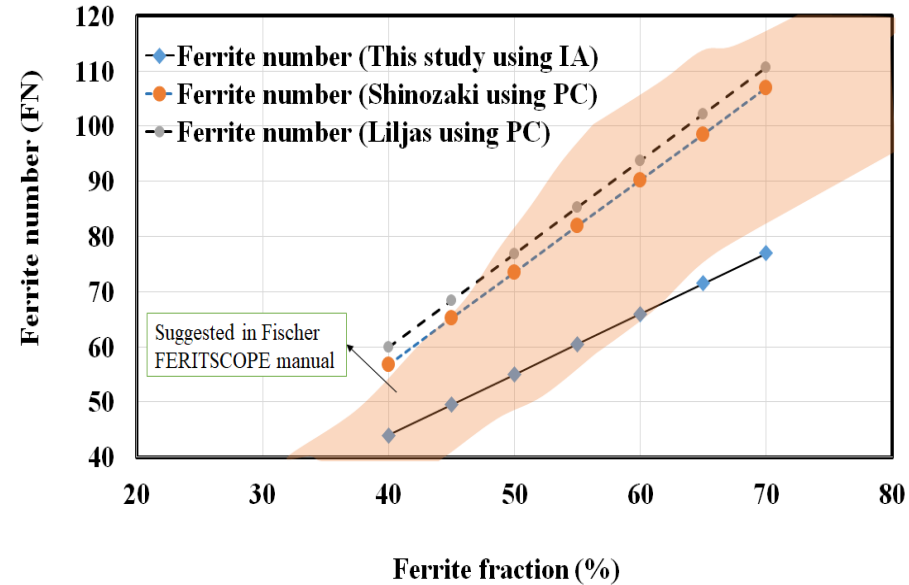
Background

Ferrite
Measurement

Methodology

Conclusion

Does ferrite fraction (%) measurement with Feritscope give the right %?

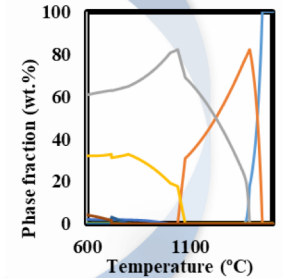
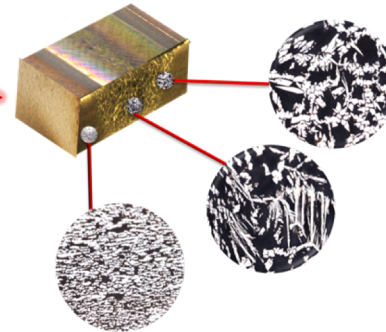
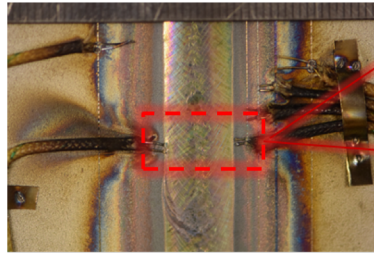
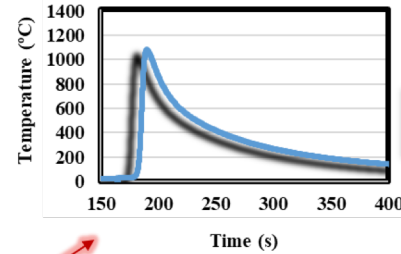
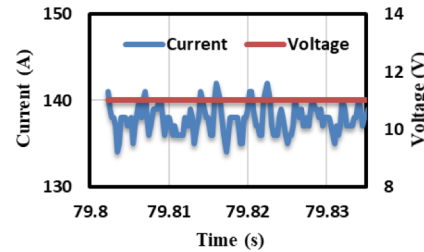


Methodology

Single pass welds

Instrumented welding

- Single pass welds
- Multipass welds



Single pass welds

Background

Ferrite
Measurement

Methodology

Conclusion

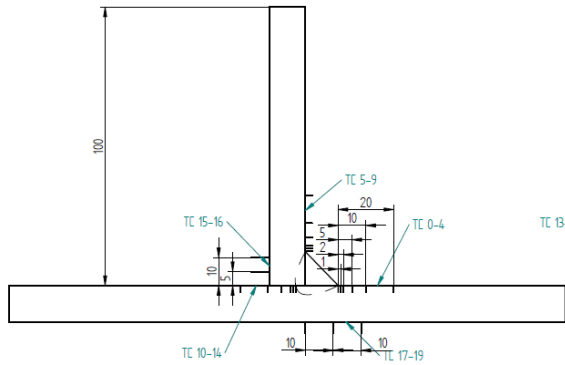
	Thickness and type	
T joint*	13 mm 2507	GMAW
L joint*	13 mm 2507	GMAW, SAW
Butt weld without groove	3 mm 2507	GTAW
Bead on plate V-grooved	13 mm 2507, 13 mm 2304	SAW, GMAW, GTAW, SMAW
V groove butt weld	10 mm, 21 mm 2507	GTAW, GMAW
X grooved butt weld	25 mm 2507	GTAW

* High and low HI

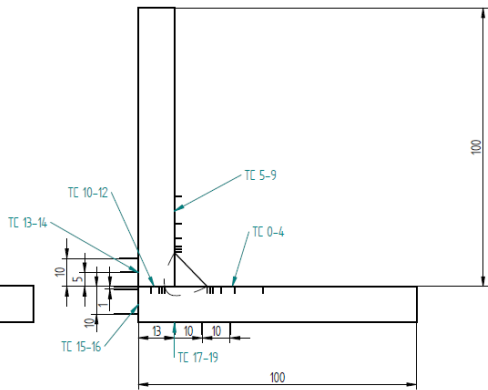
+ 2101, 2205, and 2304 welding without instrumentation

Thermocouple attachments

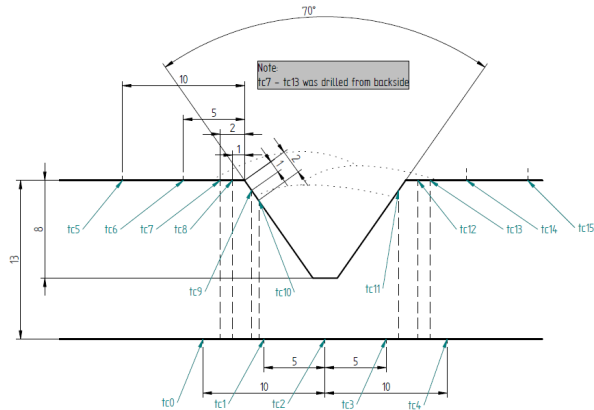
13 mm T joint



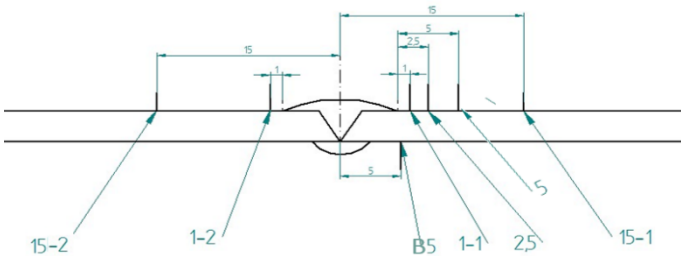
13 mm L joint



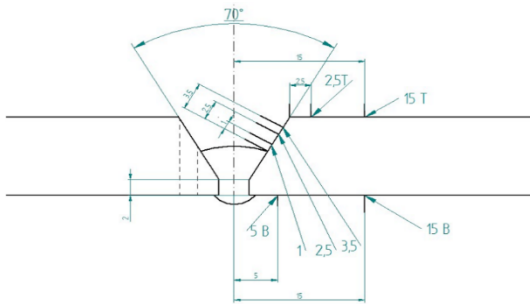
Bead on plate V-grooved



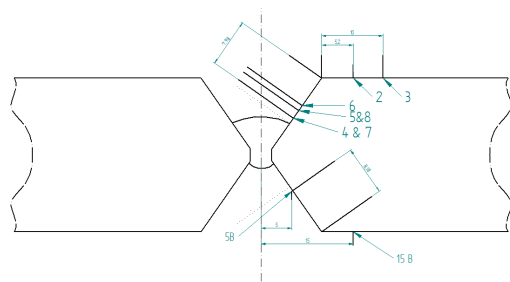
3 mm



10 mm , 21 mm



25 mm



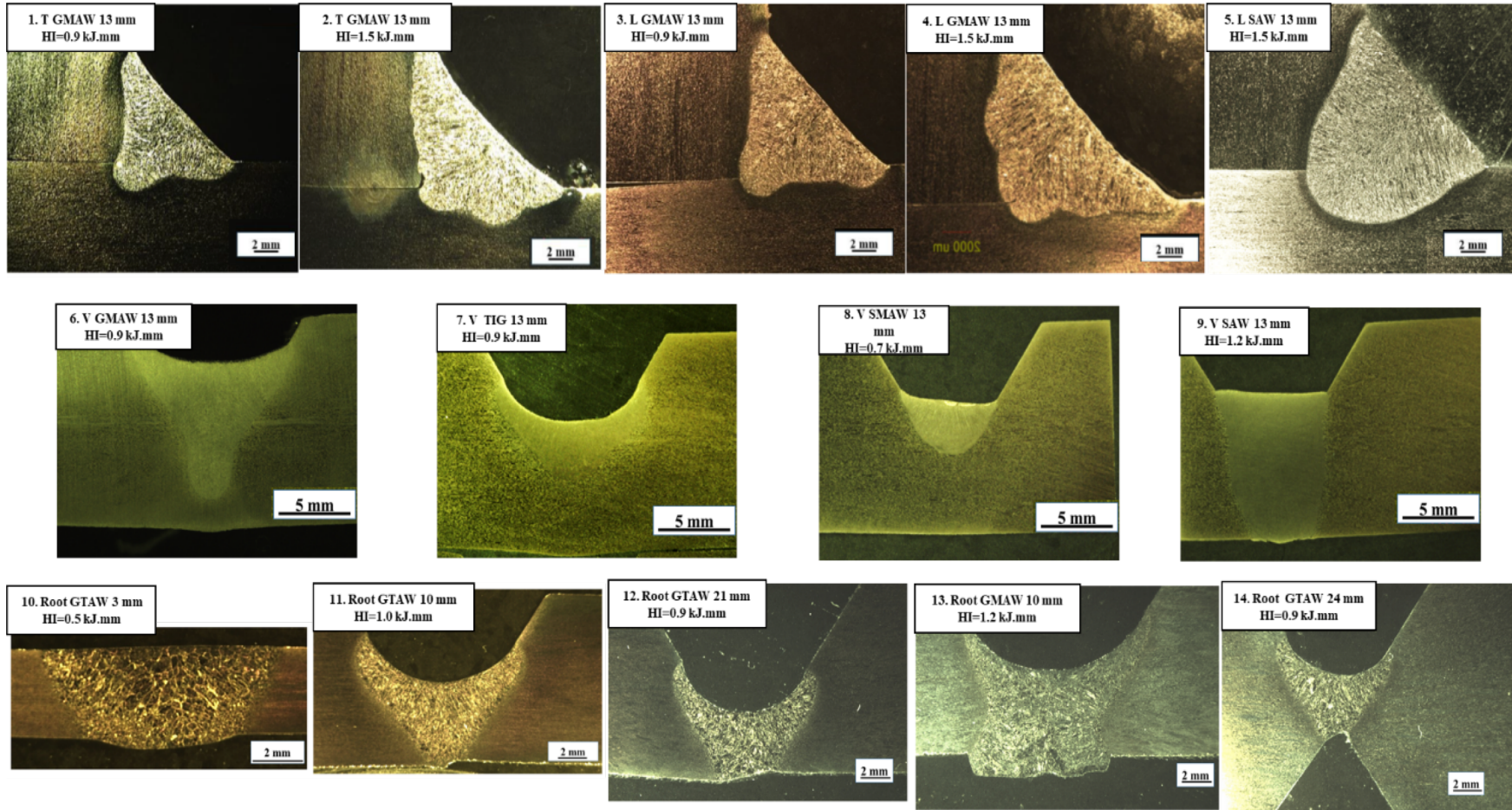
Cross section

Background

Ferrite
Measurement

Methodology

Conclusion



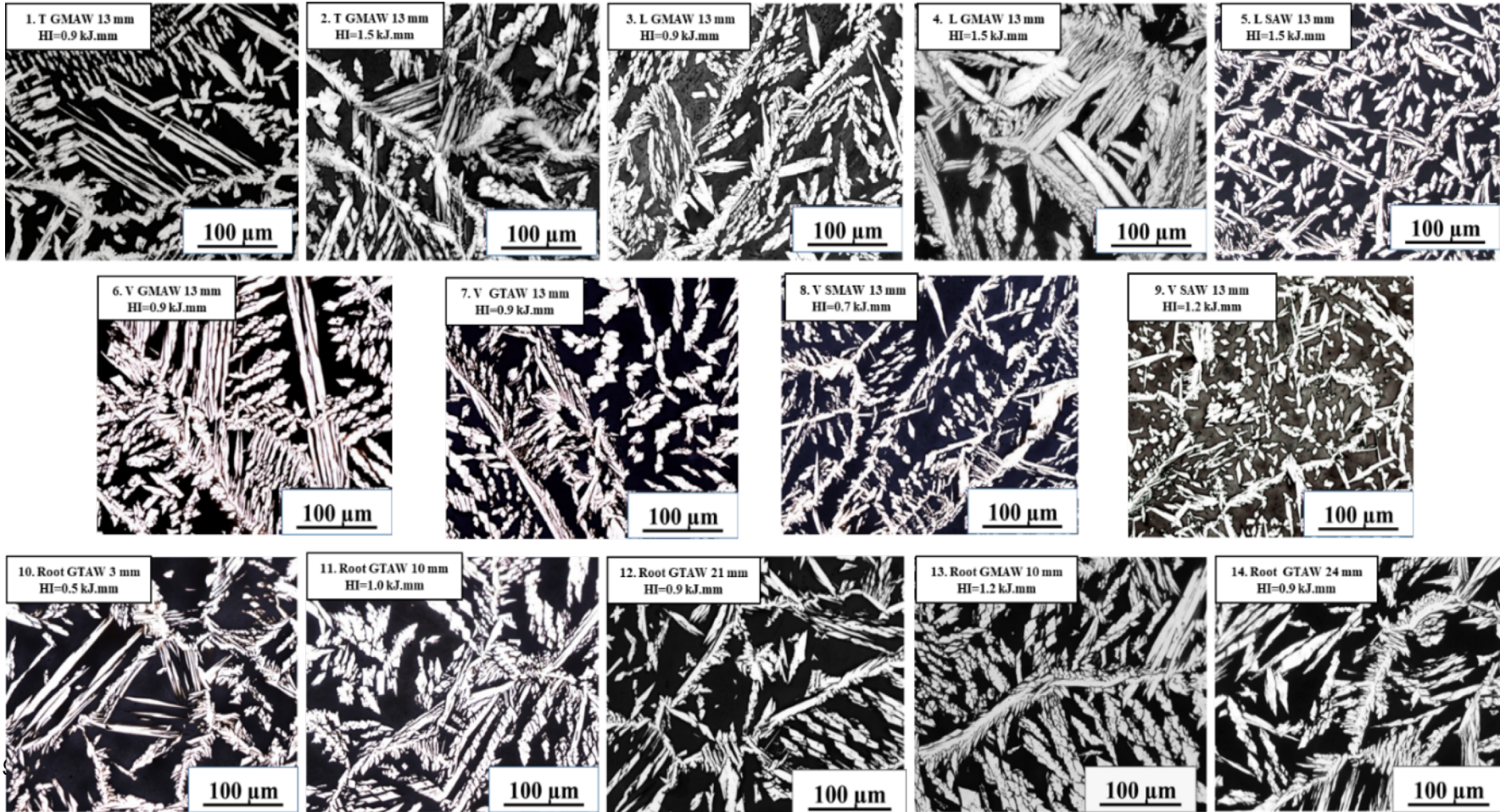
Weld metal microstructure

Background

Ferrite
Measurement

Methodology

Conclusion



Single pass weld metal

- Heat input is not the only variable in welding of DSS
 - welding process, voltage, current, speed, mode of transfer, joint types, etc, can have separate effects if we keep heat input constant.
- With the same ferrite fraction, we may have different microstructure.

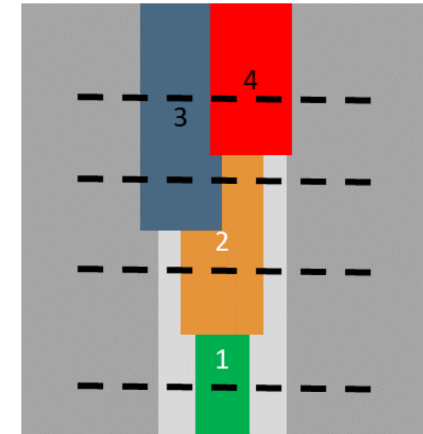
Methodology

Multipass welds

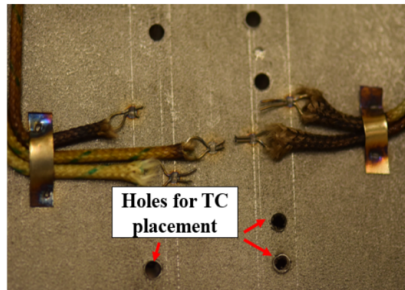
Bead by bead study of a multipass shielded metal arc welded super duplex stainless steel

Pass	Current	Voltage	Current	v (mm/s)	Arc energy (kJ/mm)
1	120	23	DC	3.2	0.8
2	145	23	DC	3.6	0.9
3	145	23	DC	4.0	0.8
4	145	23	DC	3.2	1.1

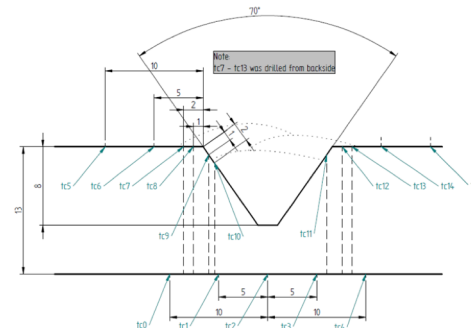
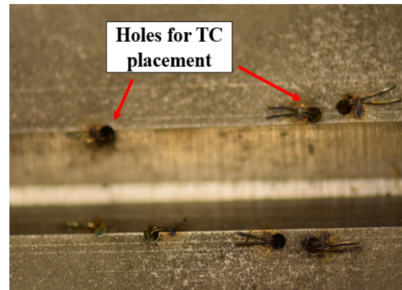
2D top side



Backside



Topside



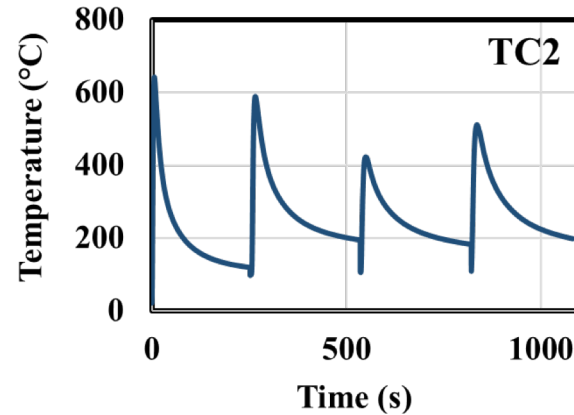
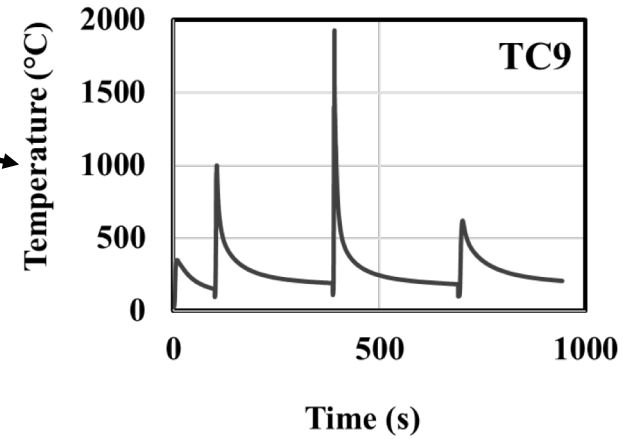
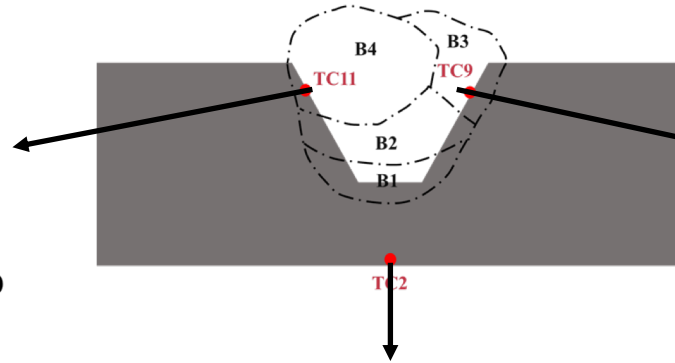
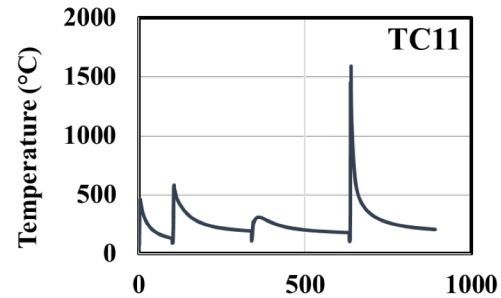
Thermal cycles

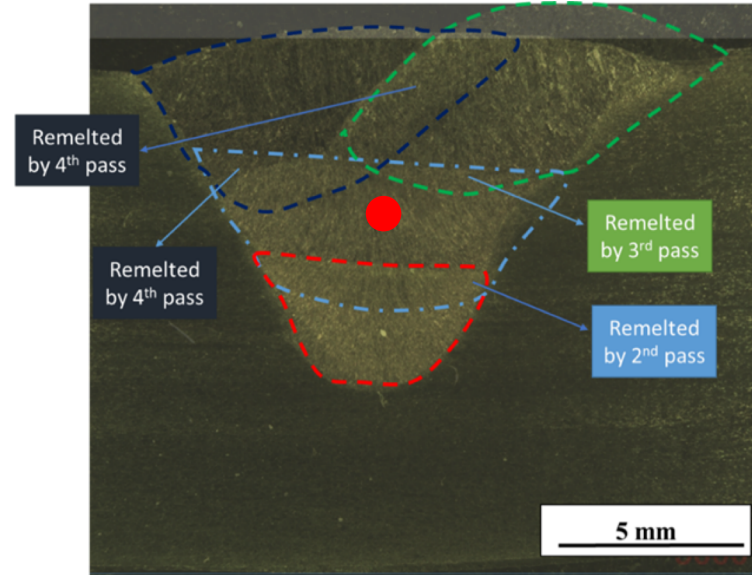
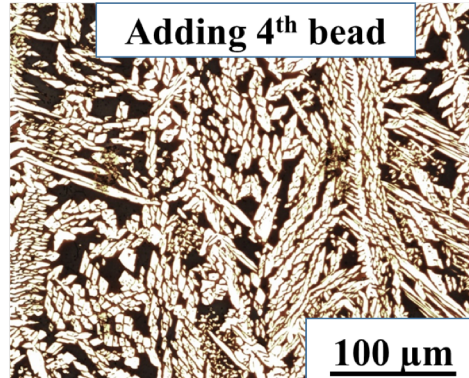
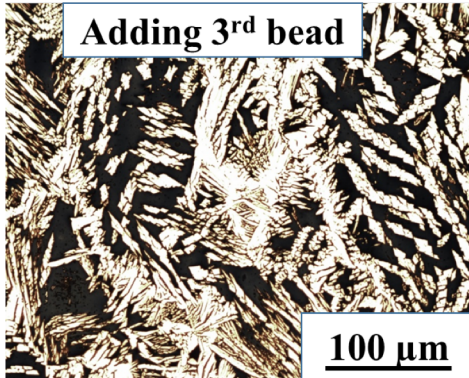
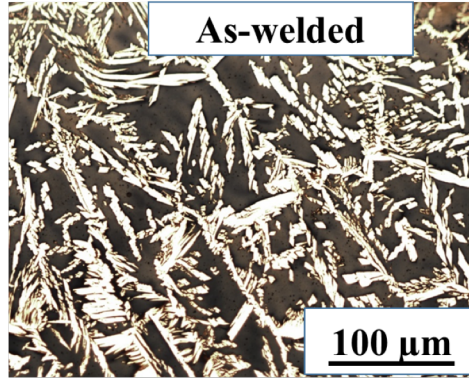
Background

Ferrite
Measurement

Methodology

Conclusion





Complex microstructure in different locations

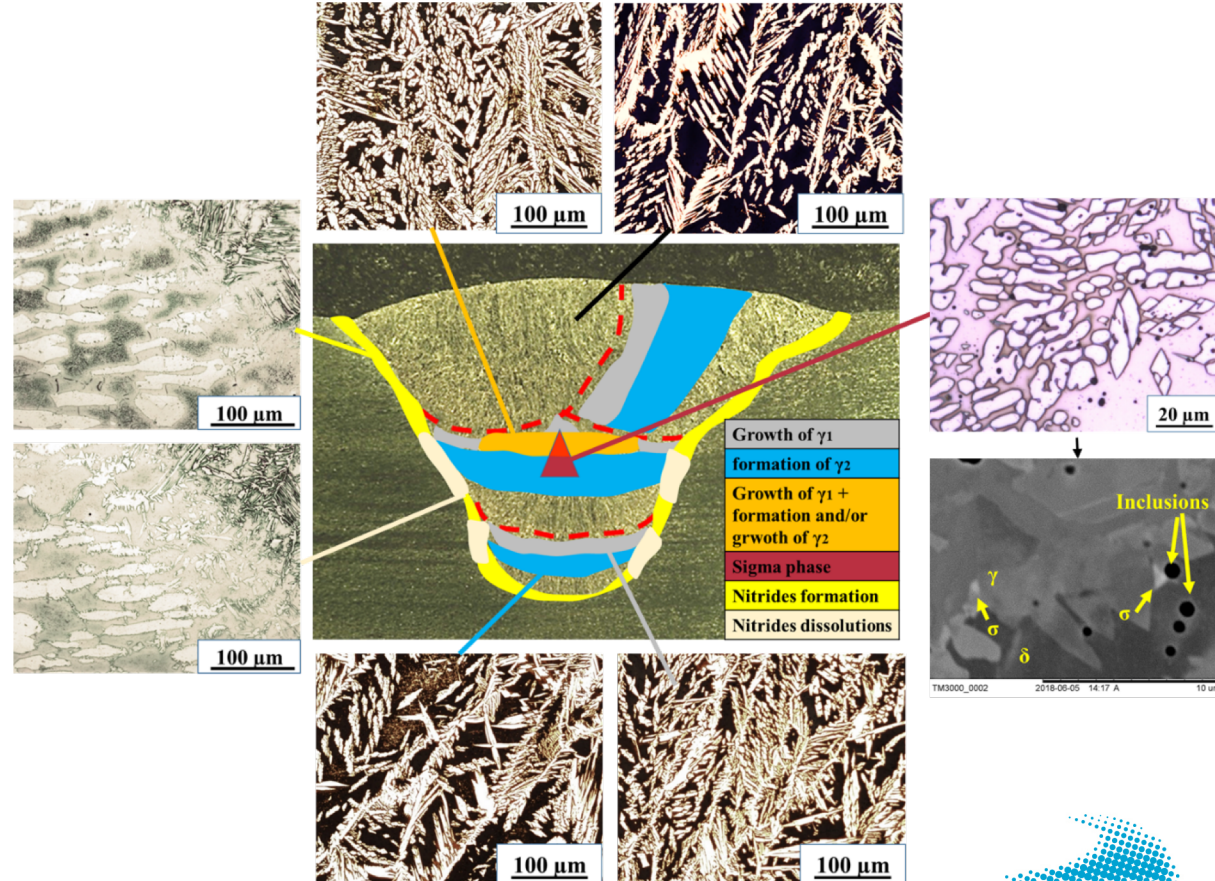
Background

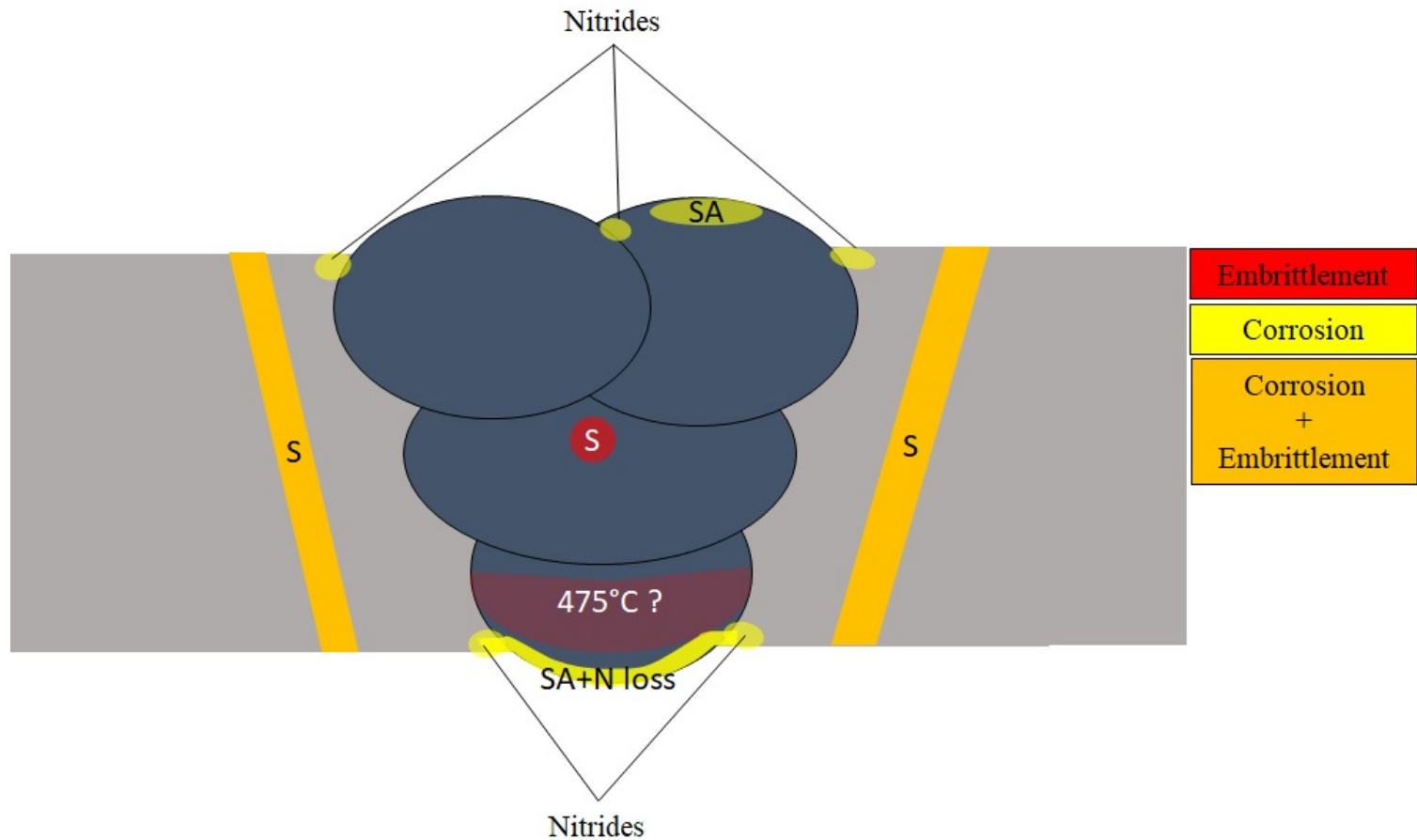
Ferrite
Measurement

Methodology

Conclusion

- Weld metal
 - Different behavior for austenite precipitation and/or growth
 - Precipitation of intermetallics
- HTHAZ
 - Precipitation-dissolution of
 - Nitrides
 - Austenite





Dilution classification

Type 1: Its only neighbor is base metal.

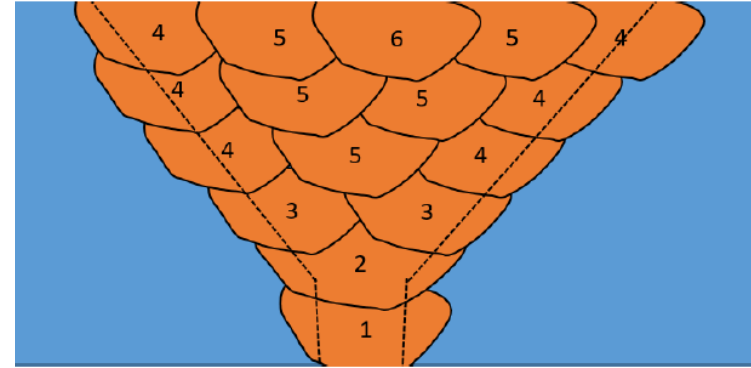
Type 2: Touches the BM on both sides.

Type 3: touches the BM from one side and is connected to other beads which touch base metal.

Type 4: is quite similar to Type 3, but one of its neighboring bead is less diluted

Type 5: This type does not have any contact with BM, but has neighbors which have direct contact with BM.

Type 6: Neither this bead nor its neighbors touch BM.



Conclusion

- Ferrite measurement using Beraha + Image analysis → Repeatable results
- A formula was found to convert FP (%) to FN (FN) in SDSS welds
- Thermal cycle and dilution govern ferrite fraction in SDSS single pass welds
 - Special focus on nitrogen behavior must be considered
- Multipass welding creates complex graded microstructure
 - Intermetallics → multiple reheated zone (700-1000°)
 - Secondary austenite forms by reheating
 - Nitrides forms in HTHAZ, but can be dissolved by reheating to intermediate temperatures
 - Dilution is different in different beads

References

- V. A. Hosseini, K Hurtig L. Karlsson, *Bead by bead study of shield metal arc welding of a super duplex stainless steel plate*, Welding in the world, 2020
- V.A. Hosseini , S. Wessman, K. Hurtig, L. Karlsson, *Predicting ferrite fractions in single pass super duplex stainless steel welds – thermal cycle analysis and phase transformation modeling*, Duplex 2019, Vienna.
- V.A. Hosseini, *Embrittlement and sensitization to corrosion in super duplex stainless steels welds*, Stainless Steel World, 2019
- V. A. Hosseini, M. Högstöm, K. Hurtig, M. A. V. Bermejo, L.-E. Stridh, and L. Karlsson, *Wire-arc additive manufacturing of a duplex stainless steel: thermal cycle analysis and microstructure characterization*, Welding in the World, vol. 63, no. 4, pp. 975-987, 2019.
- V. A. Hosseini, L. Karlsson, *Physical and kinetic simulation of nitrogen loss in high temperature heat affected zone of duplex stainless steels*, Materialia, p. 100325, 2019.
- V.A. Hosseini, K. Hurtig, D. Eyzop, A. Östberg, P. Janiak, L. Karlsson *Ferrite Content Measurement in Super Duplex Stainless Steel Welds*, Welding in the World, 2019

Questions?