Joining of additive and conventional components of HSLA steel

IIW Annual Assembly

Commission IX-L

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Outline

1. Motivation and Introduction

2. Experimental
   - 2.1 Investigation of the AM samples
   - 2.2 Materials and processes
   - 2.3 Metallography
   - 2.4 Mechanical Properties

3. Summary and Outlook

Motivation and Introduction

Coamweld

Advanced metal components through optimal combination of Additive Manufacturing and welding techniques

Motivation / Objectives

Development of joining concepts for joining metal printed parts to each other and to conventionally manufactured components

1. Which processes can be used to connect metal-printed parts to conventionally manufactured pieces?
2. Guidelines for the optimal combination of conventional techniques and AM techniques.
3. What are the consequences of the applied welding process for the properties of the parts?

Research Partners

Belgian Welding Institute

VIVES University of Applied Sciences

SLV Munich
SLV Berlin-Brandenburg

Chair of Materials Engineering of Additive Manufacturing

Motivation and Introduction

Additive Manufacturing Processes

Wire Arc Additive Manufacturing (DED-Arc)

Laser Metal Deposition (DED-LB)

3D Plasma Metal Deposition (DED-(Plasma)-Arc)

Laser Powder Bed Fusion (PBF-LB)

Welding Processes

Arc welding (GMAW, TIG, PAW)

Laser welding

Resistance welding

Rotary friction / Friction stir welding

AM sample geometries

Selected benchmarking geometries (DIN EN ISO 15614)

Minimum Dimensions:	100x150x3 mm (a x b x t)	100x40x3 mm (a x D x t)

Combinations

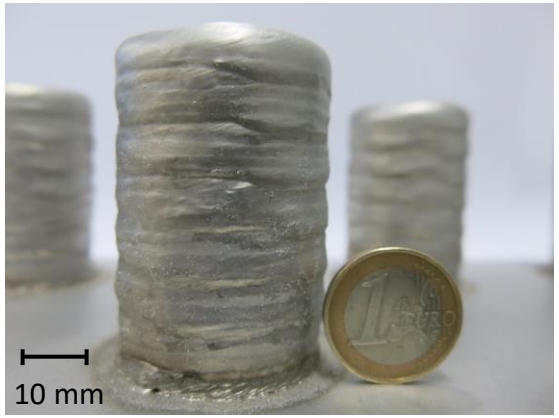
Conventional + Conventional	AM + Conventional	AM + AM

Motivation and Introduction

AM Materials

Aluminum alloys

- AlSi5 (3.2245)
- AlSi10Mg (3.2382)
- **AlMg4,5Mn (3.3548)**



Stainless steels

- 304 L (1.4307)
- 308 LSi (1.4316)
- **316 LSi (1.4430)**

Low alloy steel

- **HC 380 LA (1.0550)**

Investigation of the AM samples

DIN EN ISO 17296-3: Main properties and corresponding test methods

1. Testing category

- H – Highly developed components (safety-relevant)
- M – Functional components (not safety-relevant)
- **L – Sample components and prototypes**

2. Scope of testing

- Geometrical requirements:
  - Form, position and dimensional tolerances
- Mechanical requirements:
  - Hardness and tensile strength
- Material requirements:
  - Density and *chemical composition*

Chemical composition

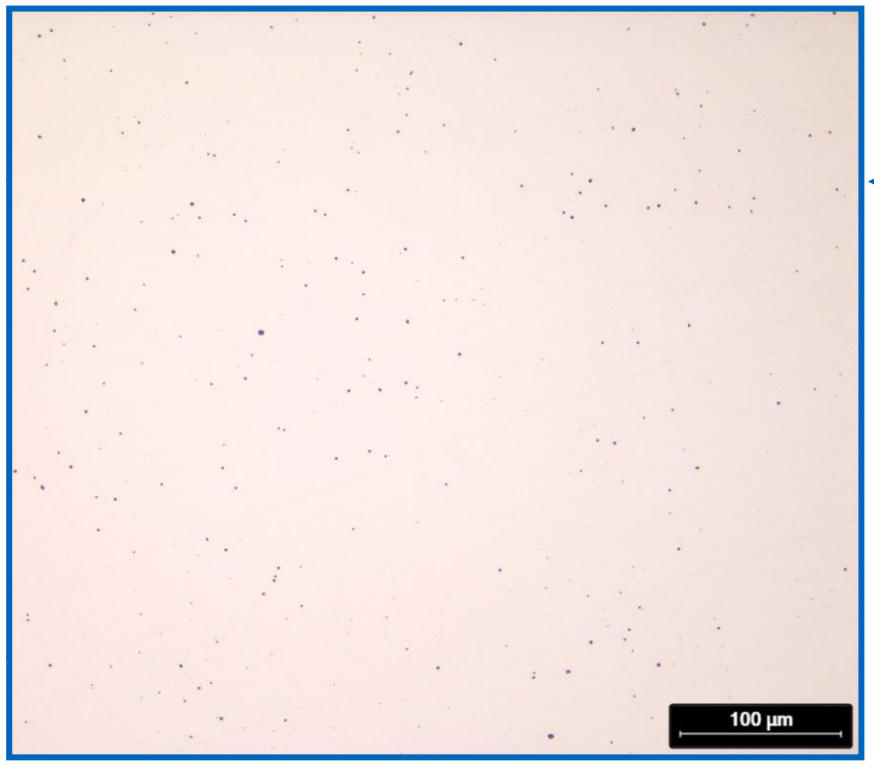
Precipitation strengthening

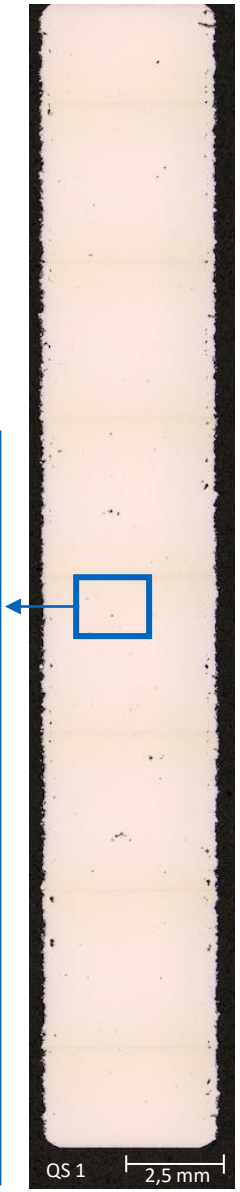
	C	Si	Mn	P	S	Al	Ti	Nb	Cr	Mo	Ni	Fe
AM	0.011	0.451	0.930	0.015	0.0073	0.018	< 0.001	0.041	0.115	0.0159	0.0800	98.2
CONV	0.055	0.419	1.10	0.016	0.0068	0.032	0.0204	0.046	0.048	0.0012	0.0359	98.1
DIN EN 10268	< 0.12	< 0.5	< 1.6	< 0.03	< 0.025	> 0.015	< 0.15	< 0.09	–	–	–	–

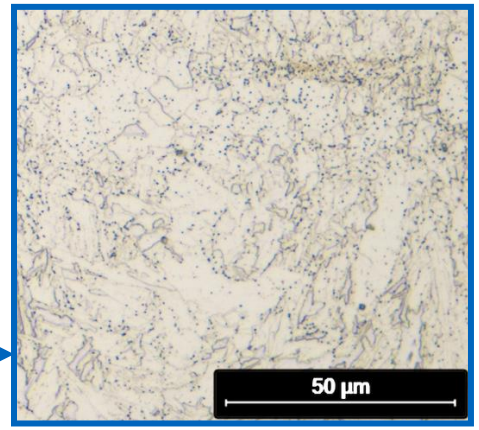
Investigation of the AM samples

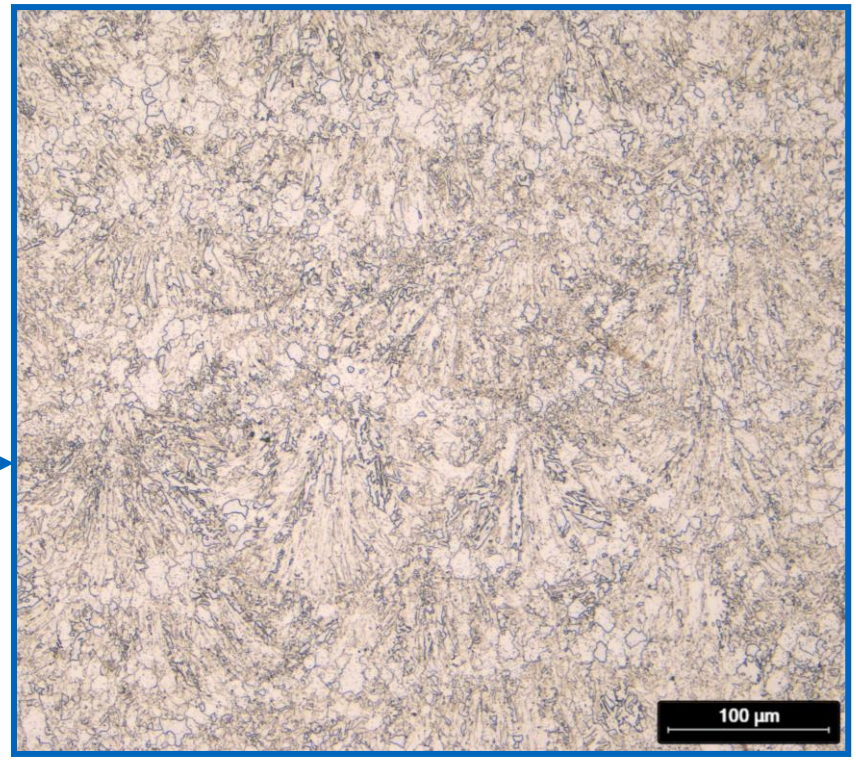
Metallographic examination

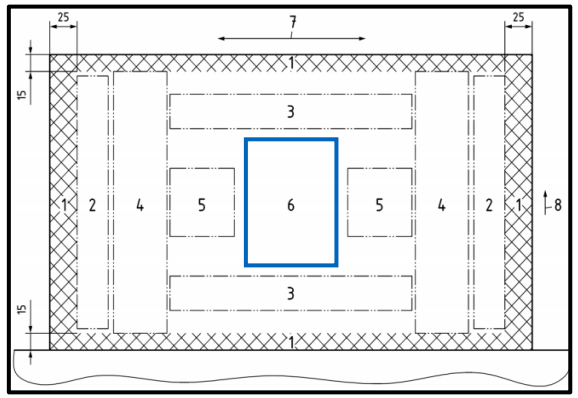
- 4 cross-sections along the build-up direction of the wall structure





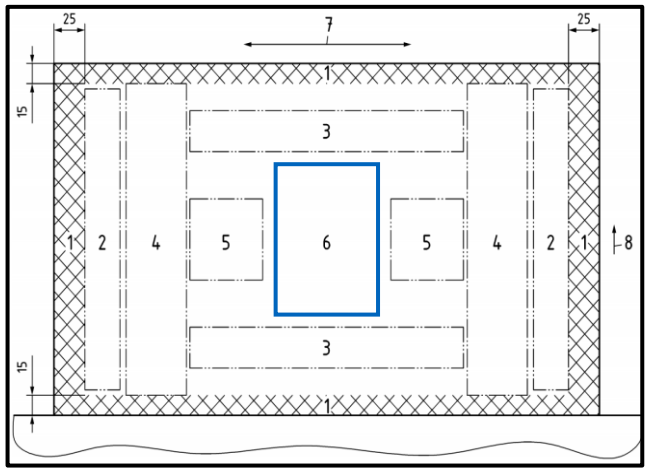


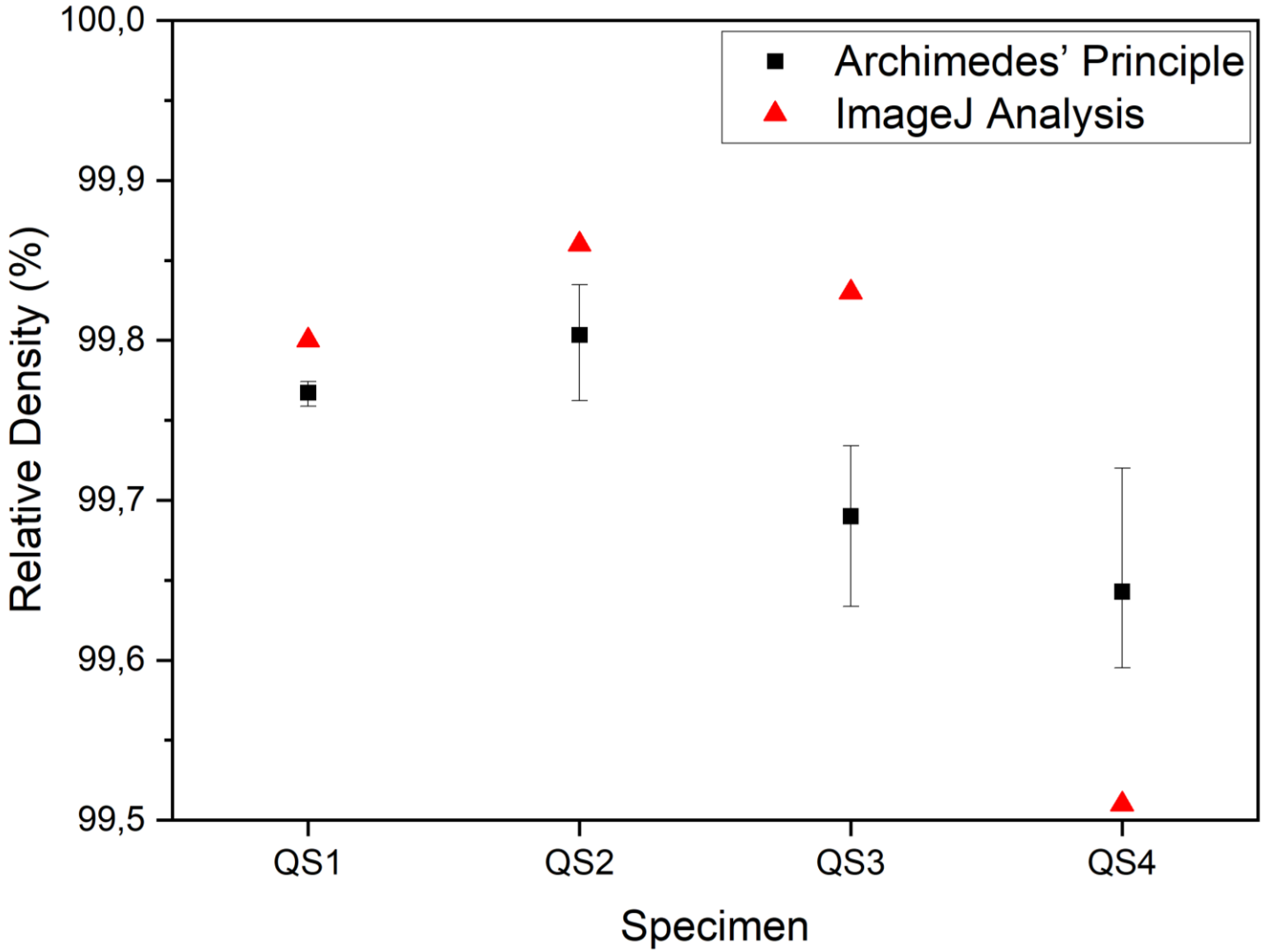




Investigation of the AM samples

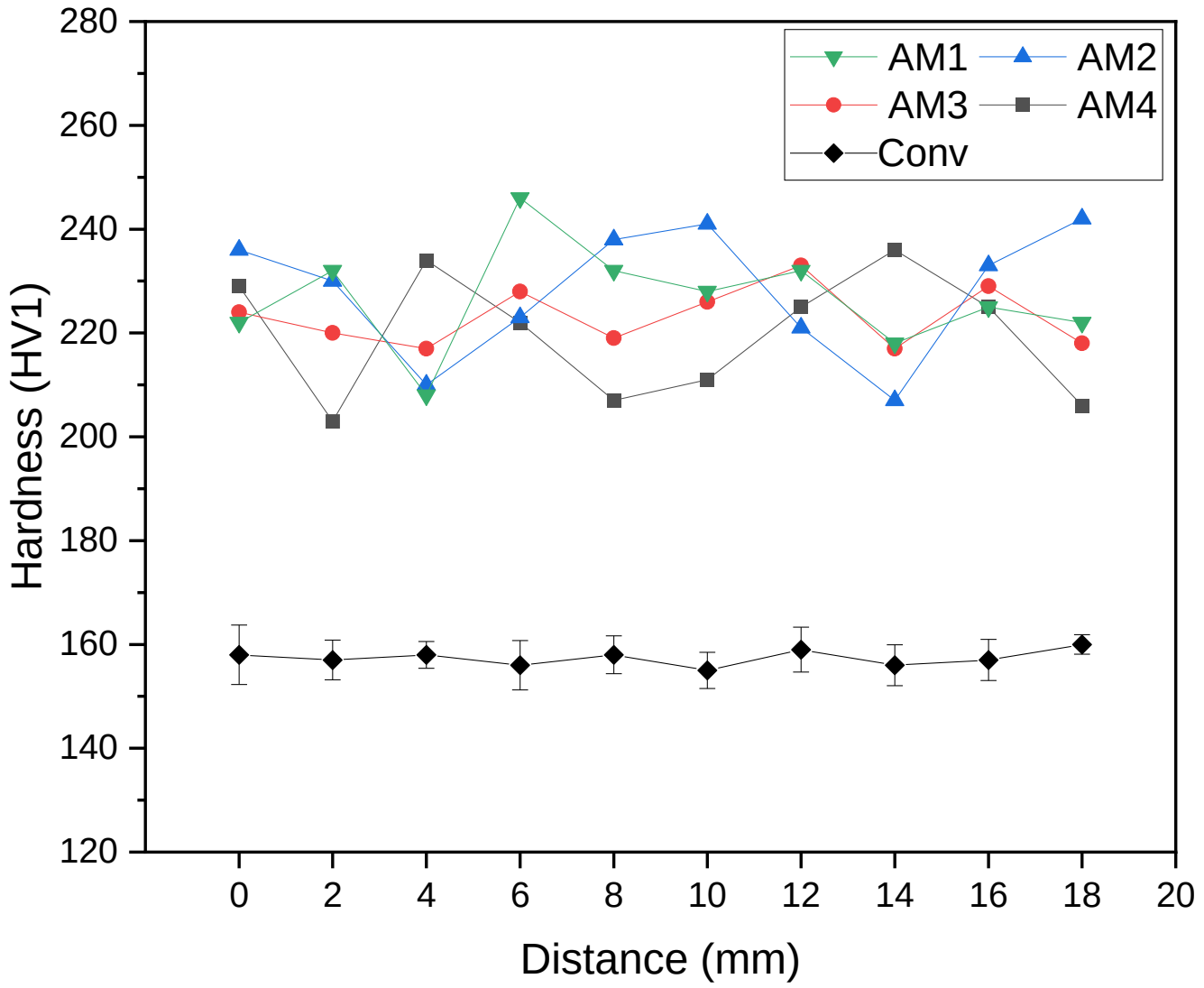
Metallographic examination – Density determination

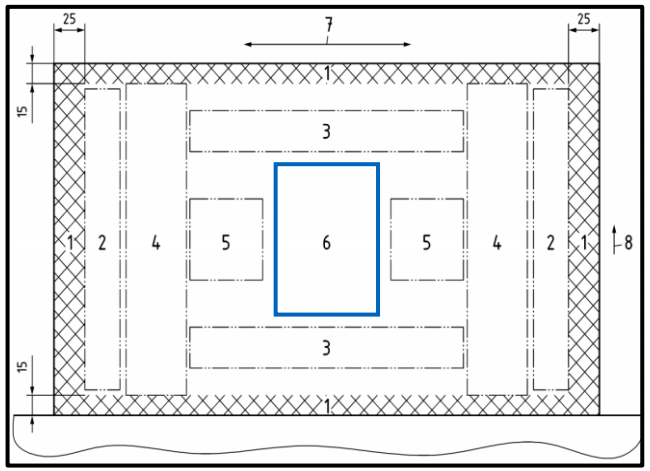




Investigation of the AM samples

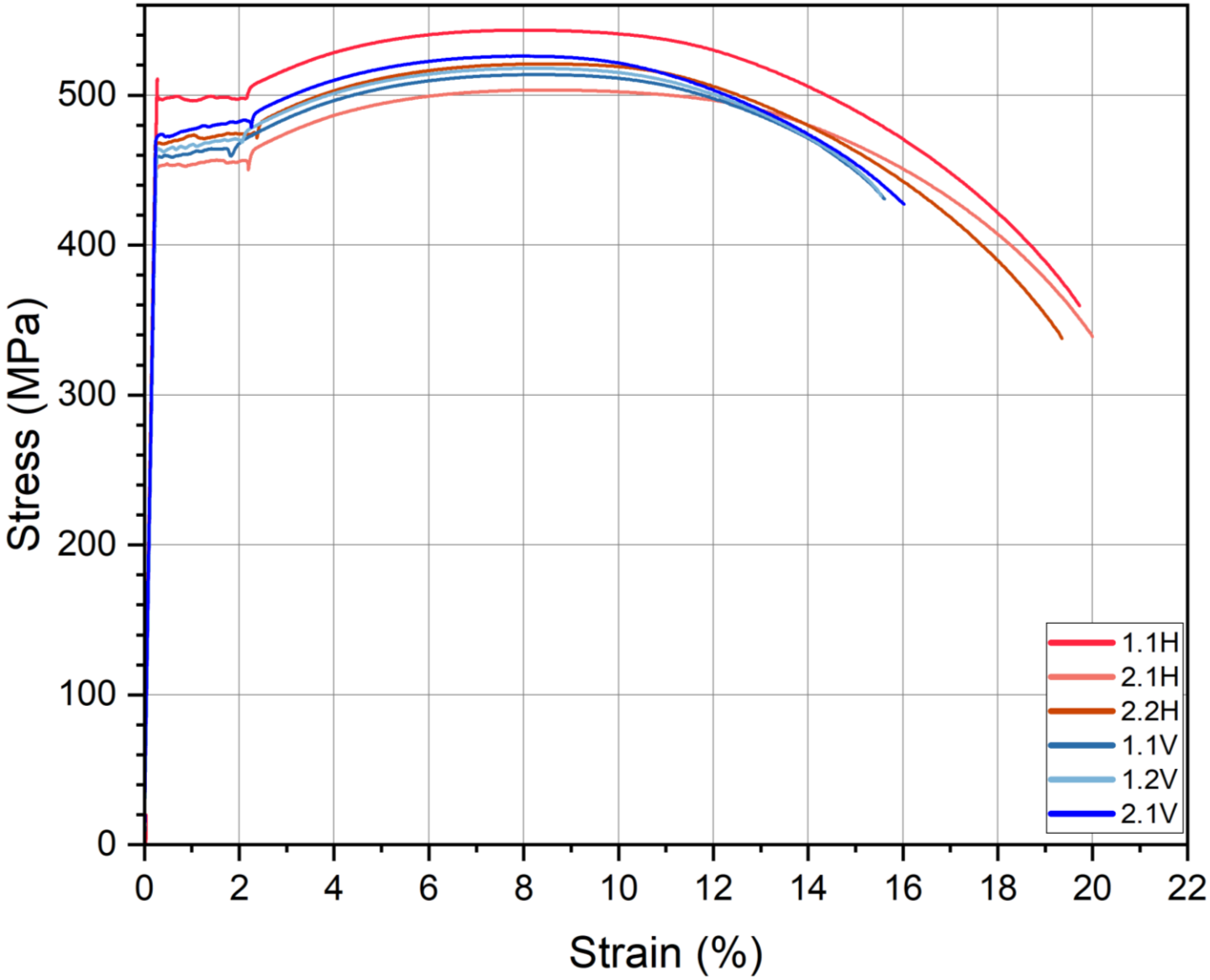
Hardness testing

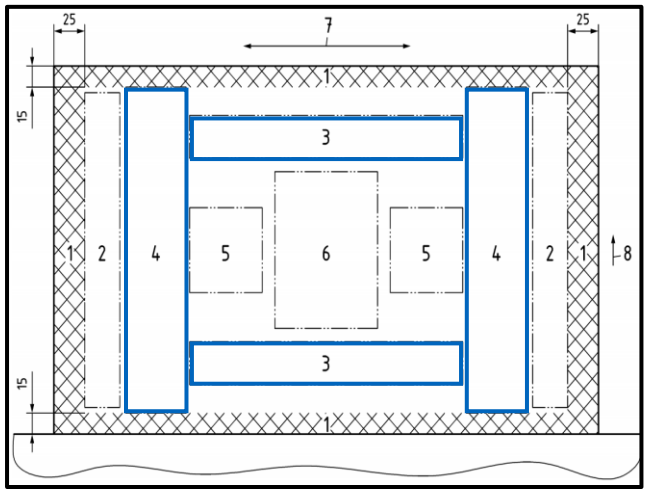




Investigation of the AM samples

Tensile testing





X.X**H** → **H**orizontal (3)

X.X**V** → **V**ertical (4)

Materials and Processes

Conv. material

- Alloy: HC 380LA (1.0550) / A 1008 HSLAS Grade 380
- Supplier: ESB-Group
- Dimensions: 190 x 80 x 3 mm

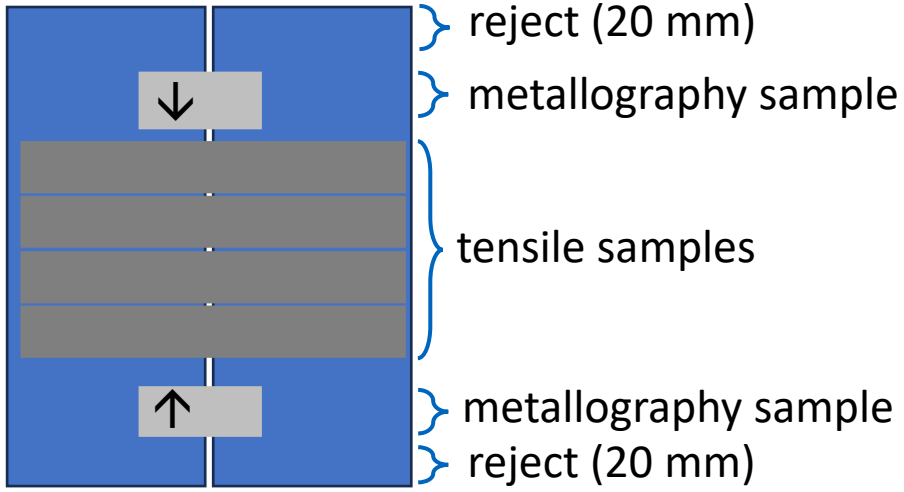
Filler metal

- Alloy: G3Si1 / ER70S-6 (Carbon manganese steel (Mn/Si alloyed)
- Manufacturer: ESAB (OK Aristorod 12.50)
- Diameter: 1.2 mm

Processes

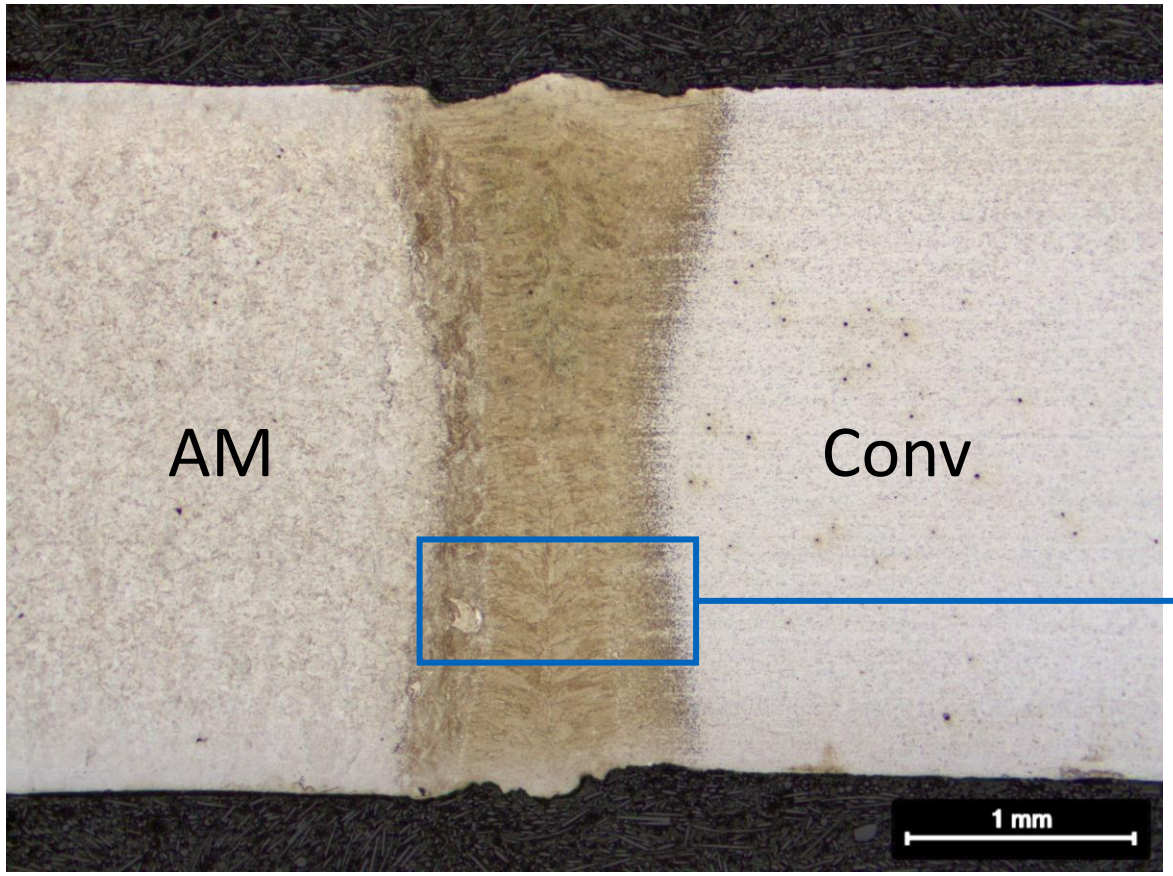
- Laser welding → CO_2-Laser 6kW Rofin/WB (cw)
- GMAW → Fronius VR 7000 CMT
- Plasma → SBI PMI 350 AC/DC

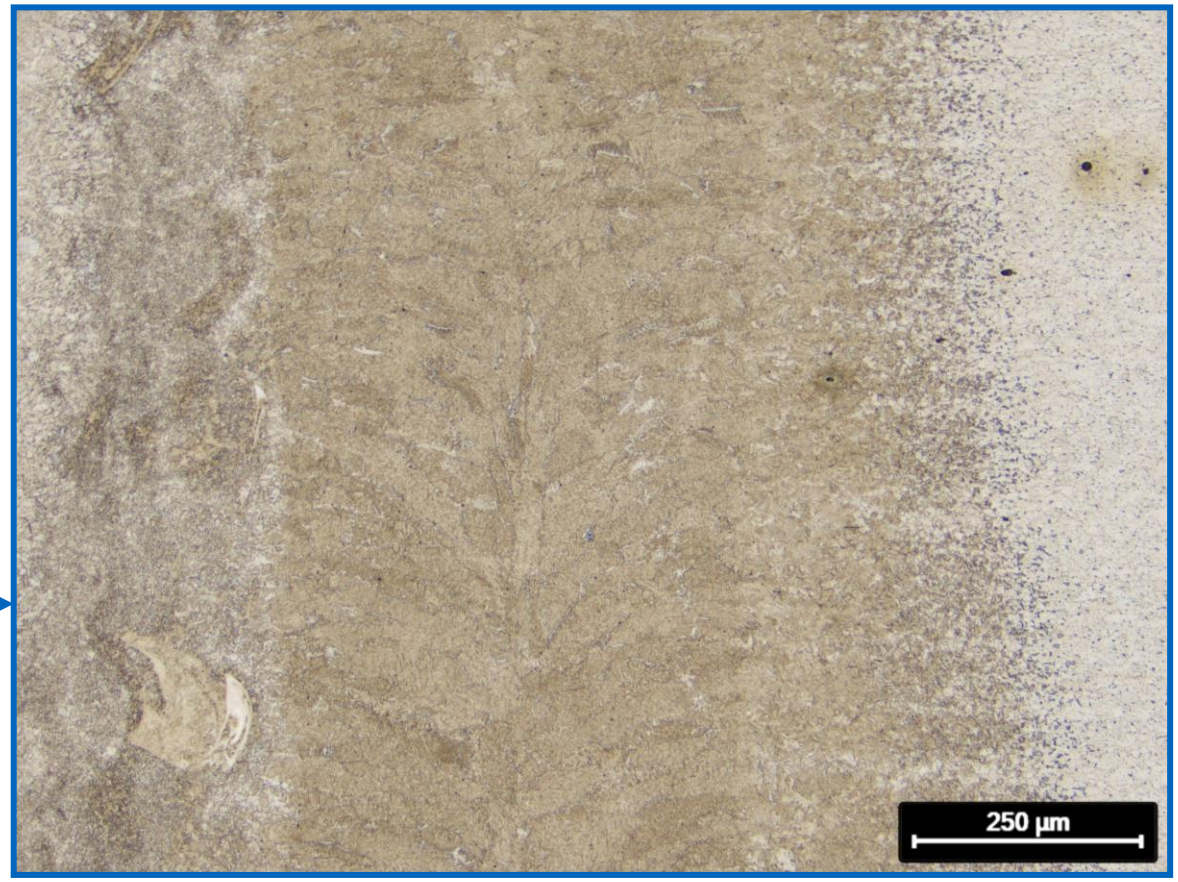
Welding configuration and Sample extraction



Metallography

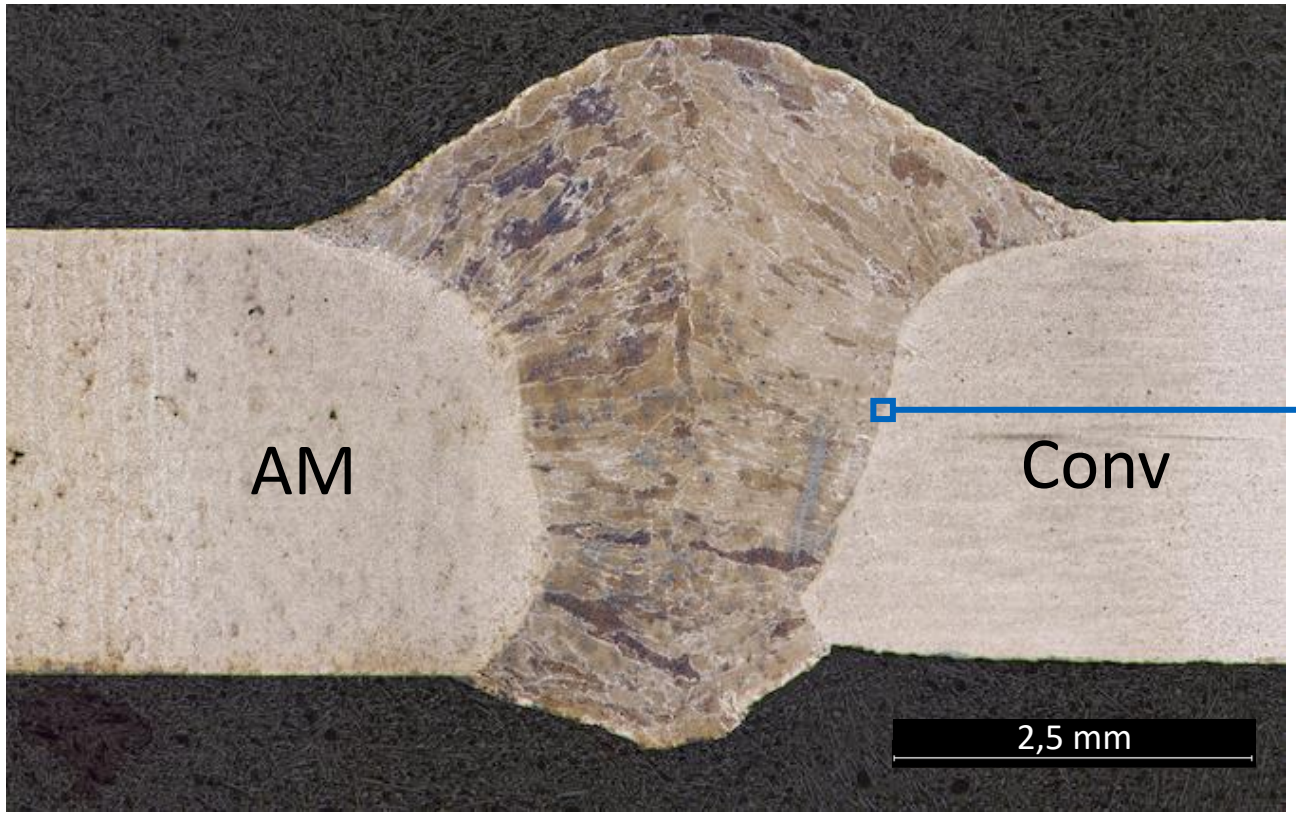
Laser welded joint

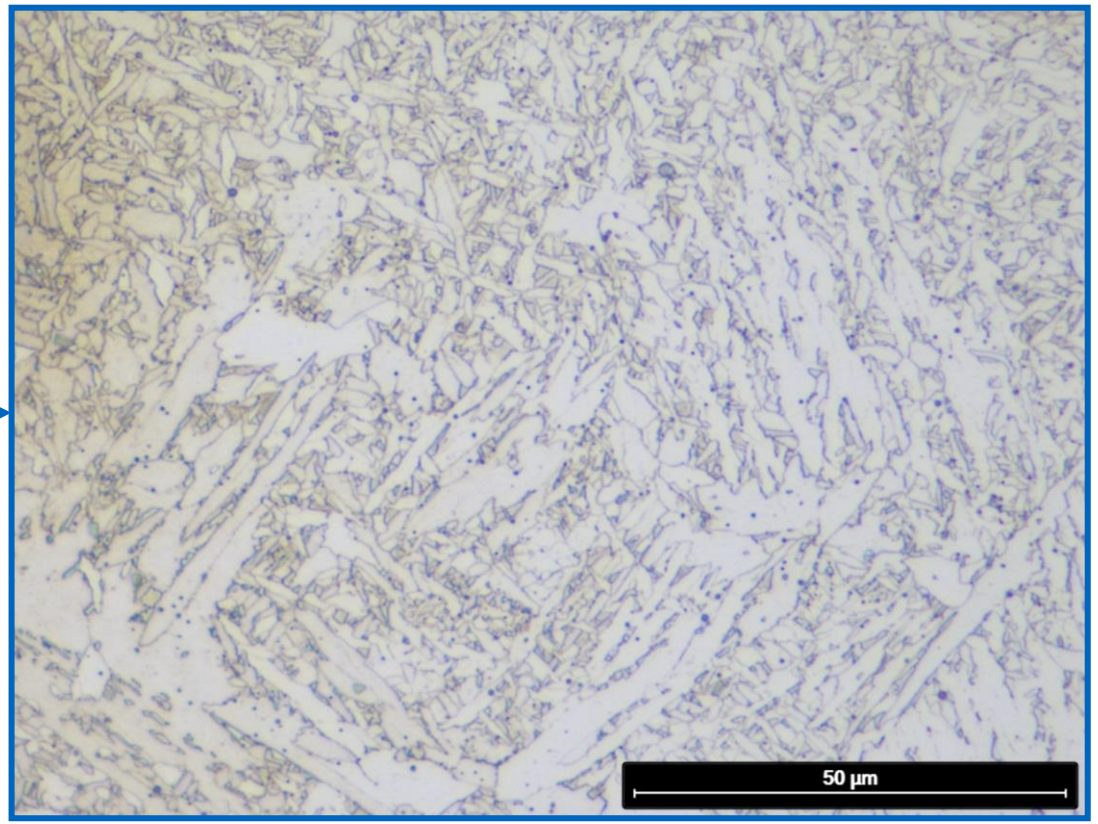




Metallography

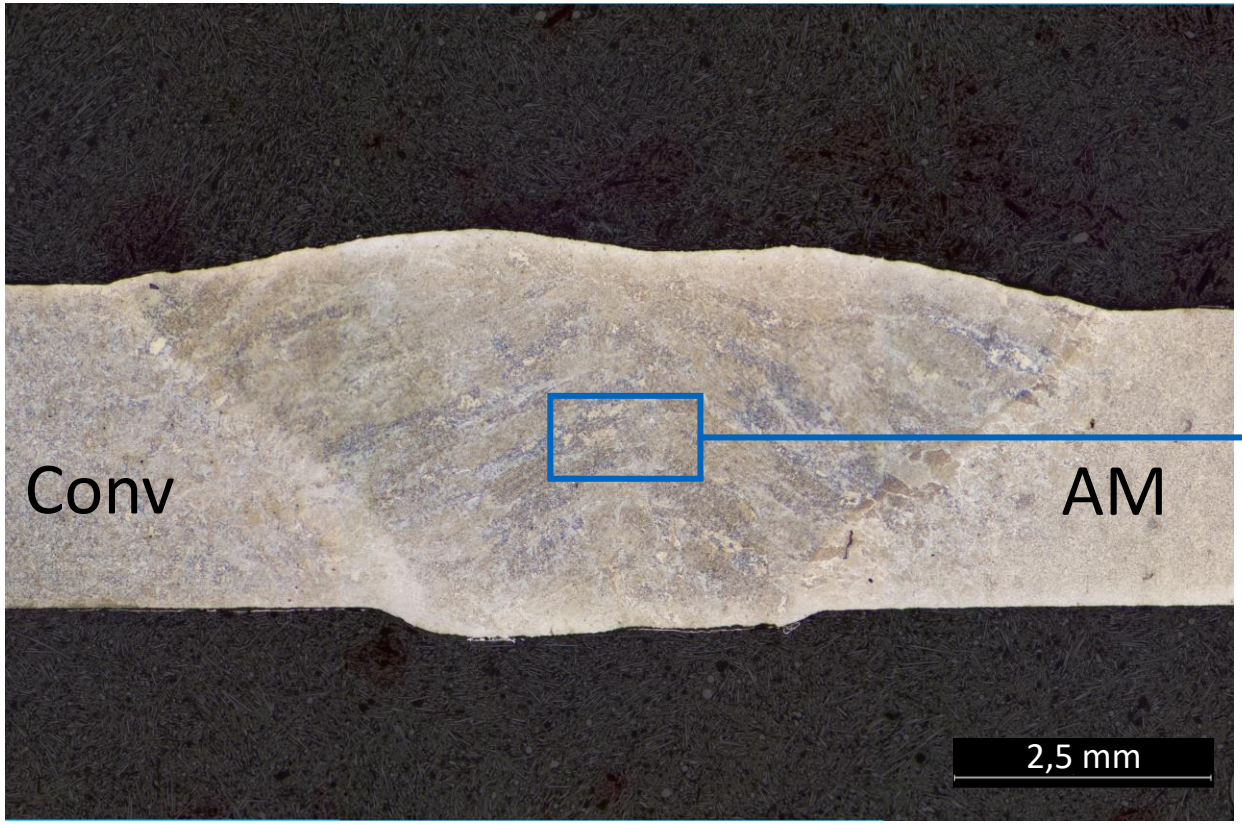
GMAW welded joint

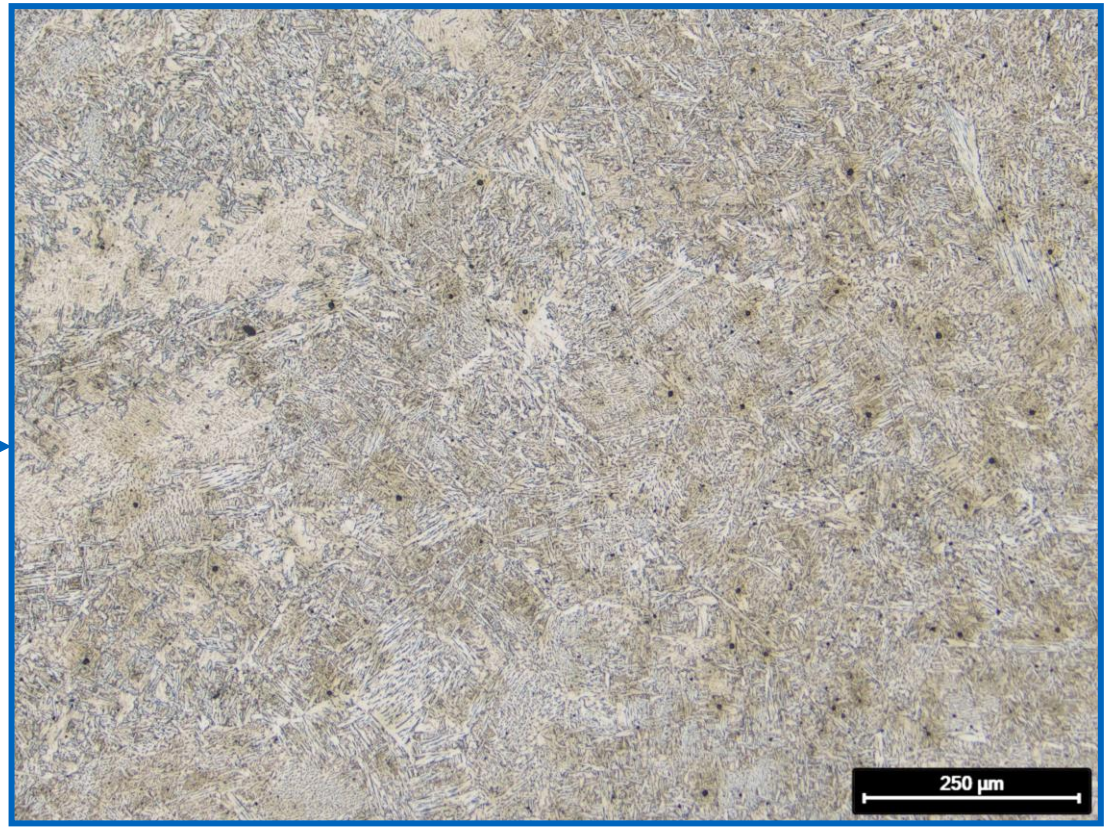




Metallography

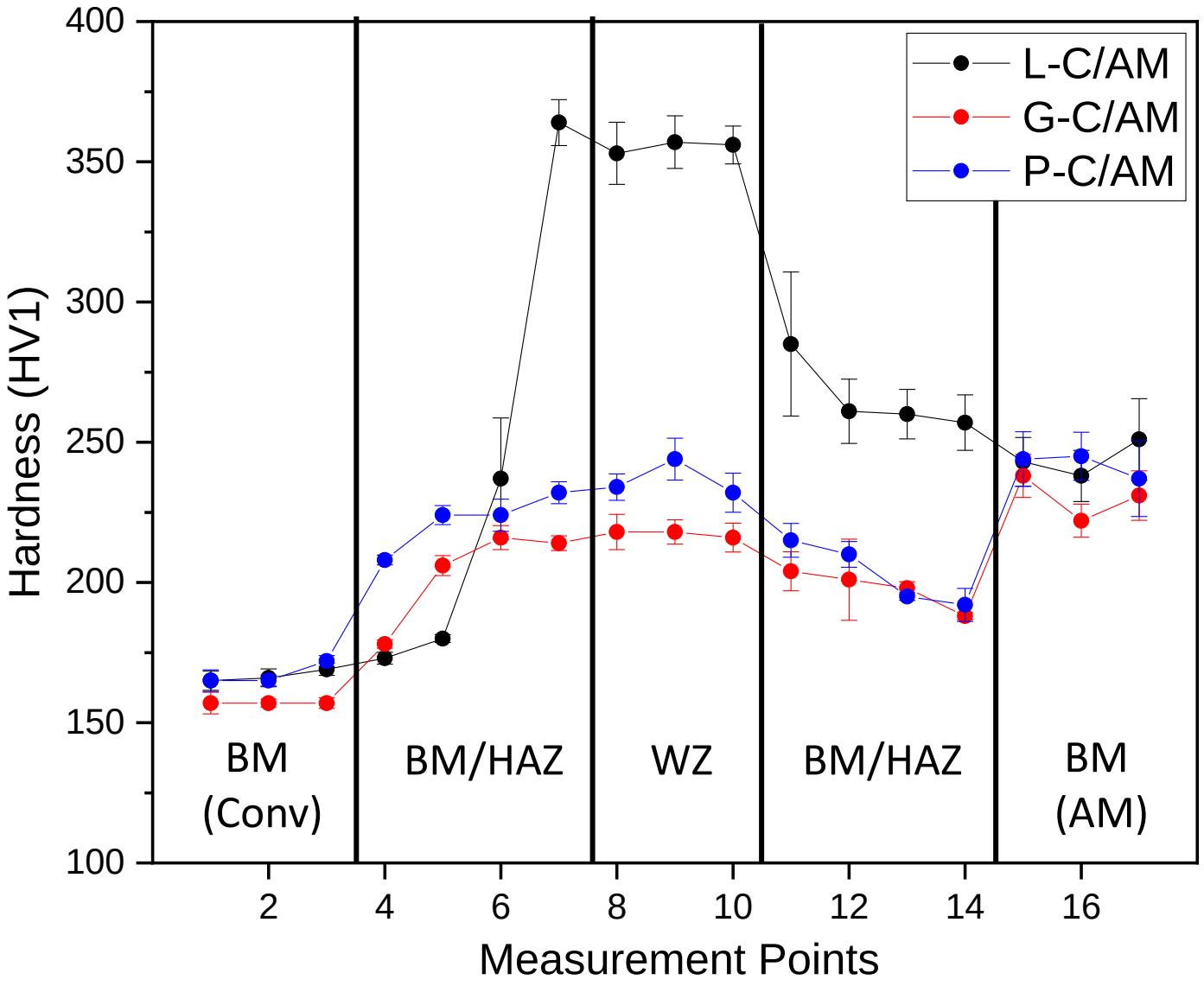
Plasma welded joint





Mechanical Properties

Hardness testing

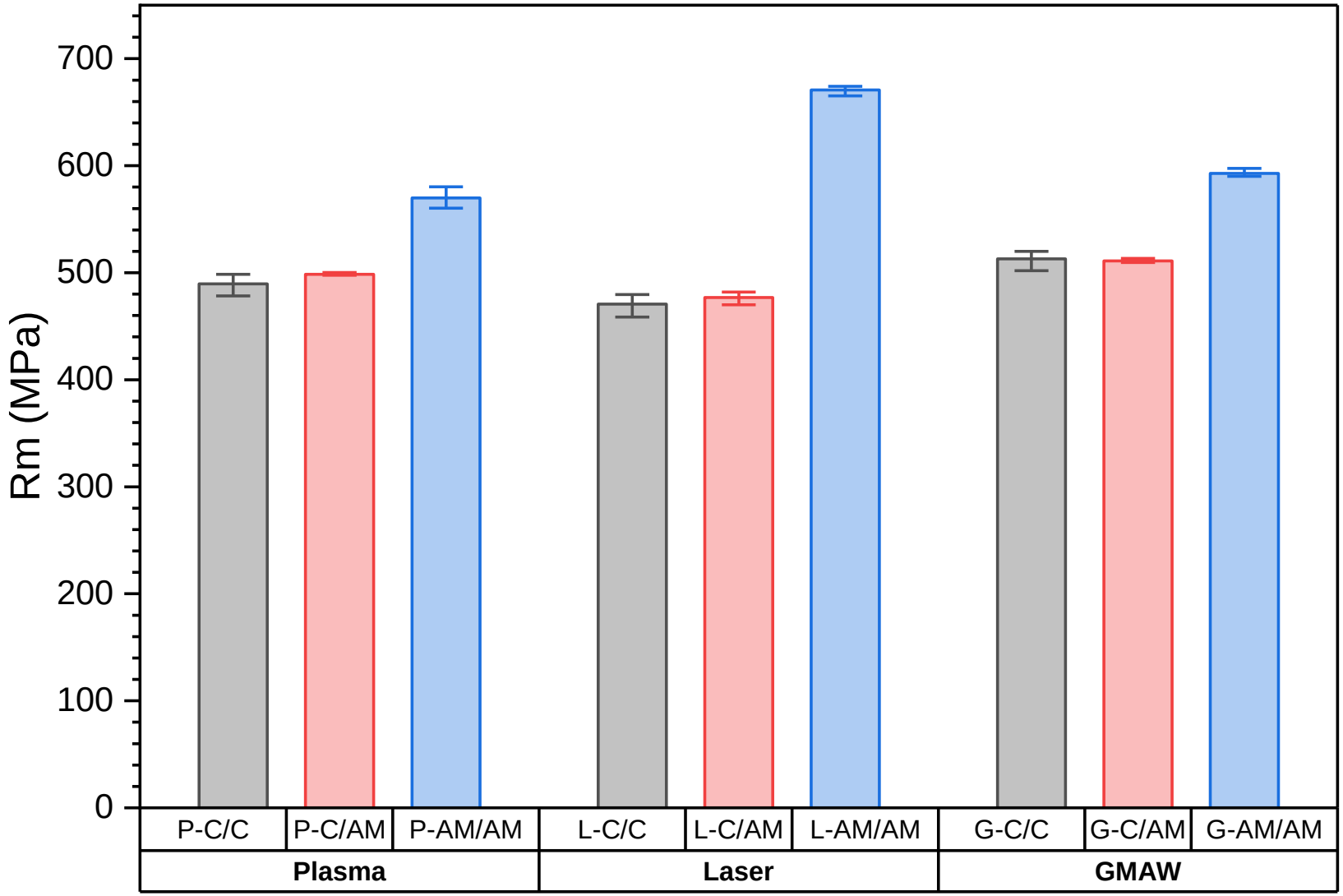


L-C/AM
→ **L**aser-**C**onventional/**AM**
G-C/AM
→ **G**MAW-**C**onventional/**AM**
P-C/AM
→ **P**lasma-**C**onventional/**AM**

Conventional/AM refers to manufacturing method of the joint sheets

Mechanical Properties

Tensile testing



L-C/AM
→ **L**aser-**C**onventional/**AM**
G-C/AM
→ **G**MAW-**C**onventional/**AM**
P-C/AM
→ **P**lasma-**C**onventional/**AM**

Conventional/AM refers to manufacturing method of the joined sheets

Summary and Outlook

Summary

- All investigated processes are suitable for joining the HC380 LA sheets using the three different material combinations (Conv/Conv, Conv/AM, AM/AM)
- Hardness testing revealed the expected trends
  → LW joint shows the highest hardness values in the WZ due to higher cooling rates
- Joints between AM/AM combinations show the highest UTS for all three processes

Outlook

- SEM investigation to identify the type of potential carbides which are mainly located at the grain boundaries
- Hardness Mapping in the HAZ to investigate the different formation of the HAZ related to the sheet manufacturing process (Conv (rolled) /AM)

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