Innovative welding technologies for the application of 7xxx series aluminium alloys in car body construction

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AUTOMOTIVE CIRCLE

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Modul 2: Thermisches und mechanisches Fügen
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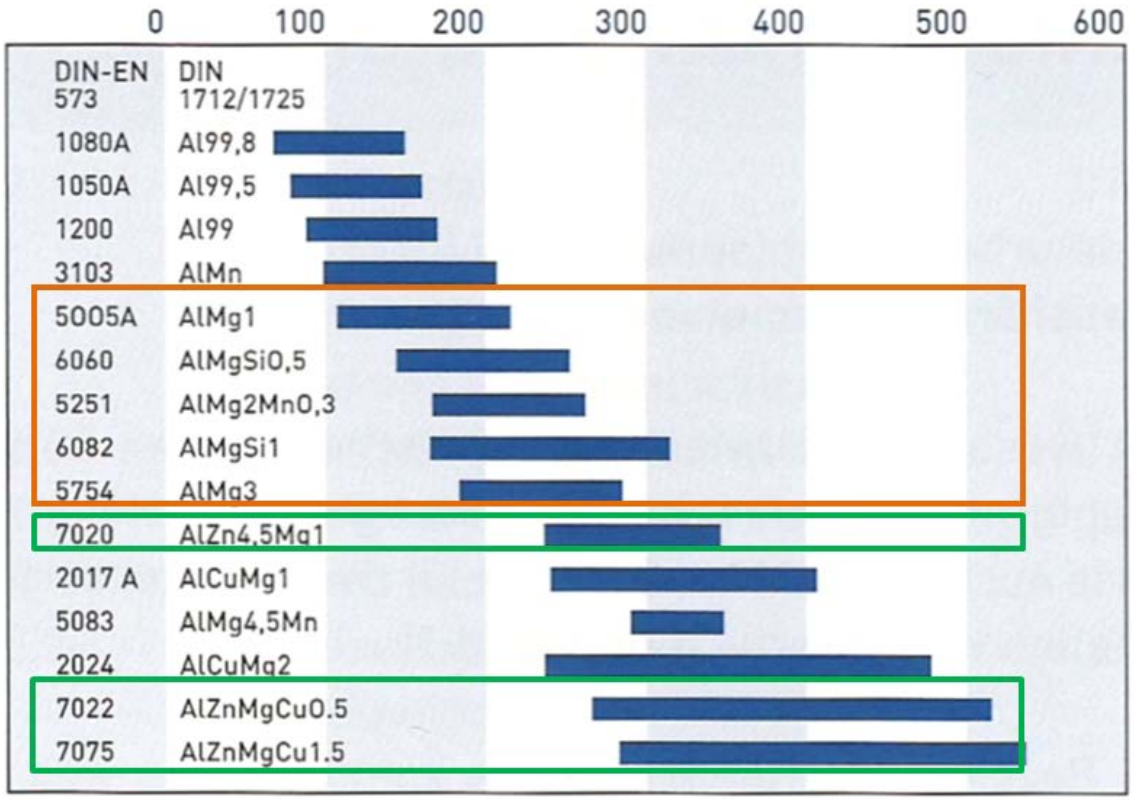
High strength aluminum alloys → a high potential for lightweight construction

- The strength of the 7xxx-aluminium is as **twice as high** as the strength of conventional alloys (**AW 6016: Rm = 240 MPa**; **AW 7075: Rm = 600 MPa**).



Tensile strength of aluminium wrought alloys

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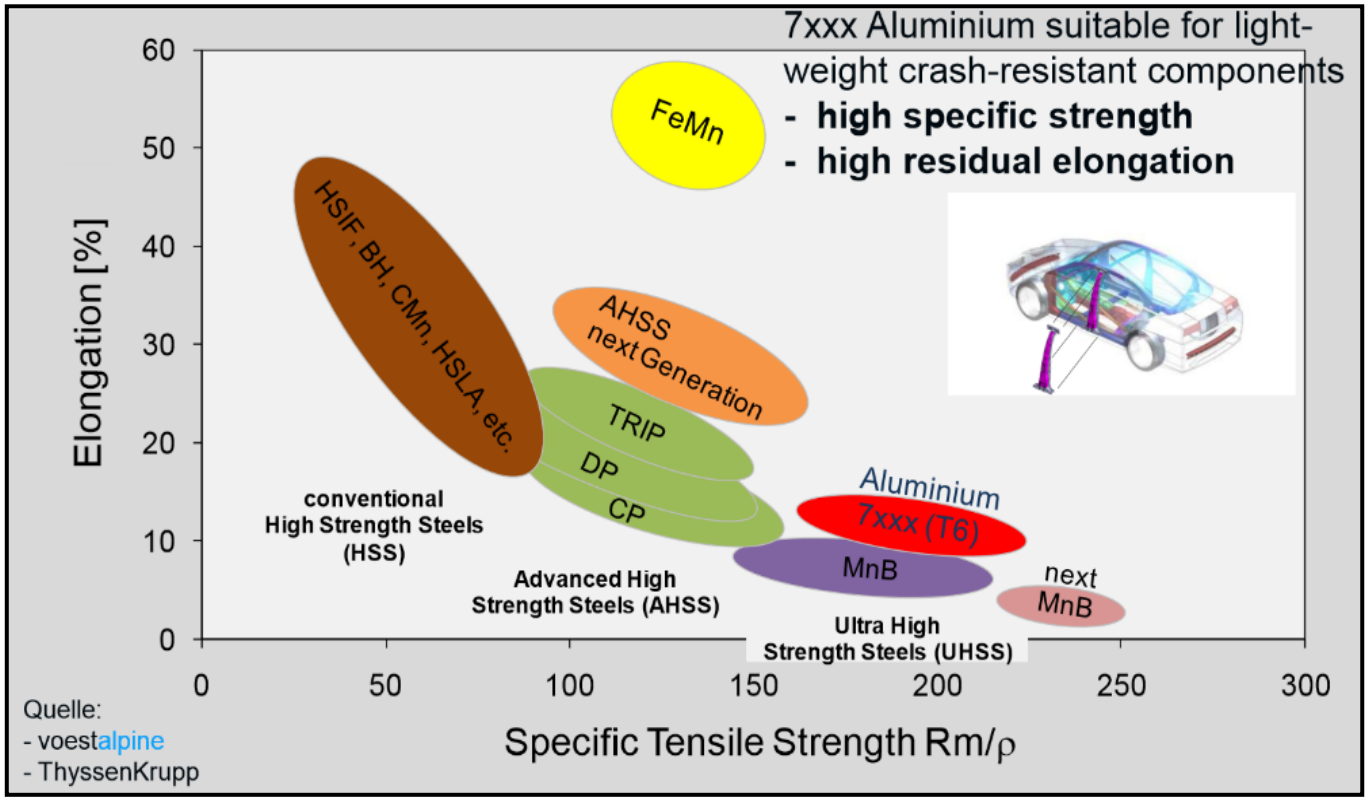
High strength aluminum alloys → a high potential for lightweight construction

- The specific strength (strength / density) is **similar to high strength steels**.

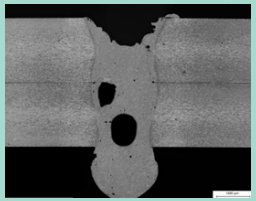


Elongation at fracture over specific tensile strength

Problems

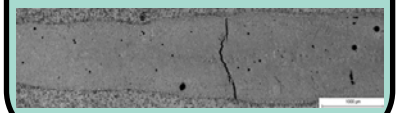
- limited weldability

1. Seam quality



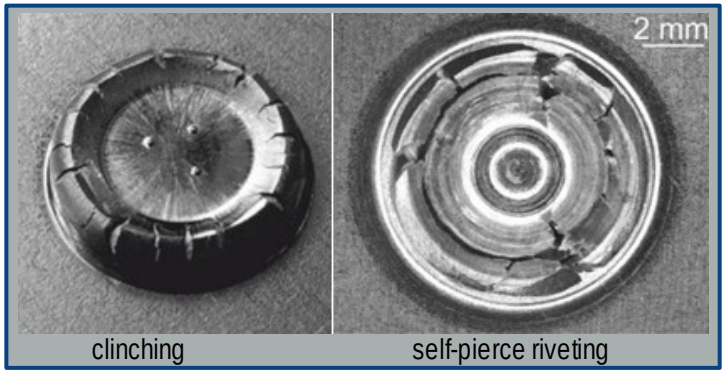
2. Softening

3. Formation of hot cracks



4. stress corrosion cracking

- limited formability



Cracking of high strength aluminium alloys by using mechanical joining technologies

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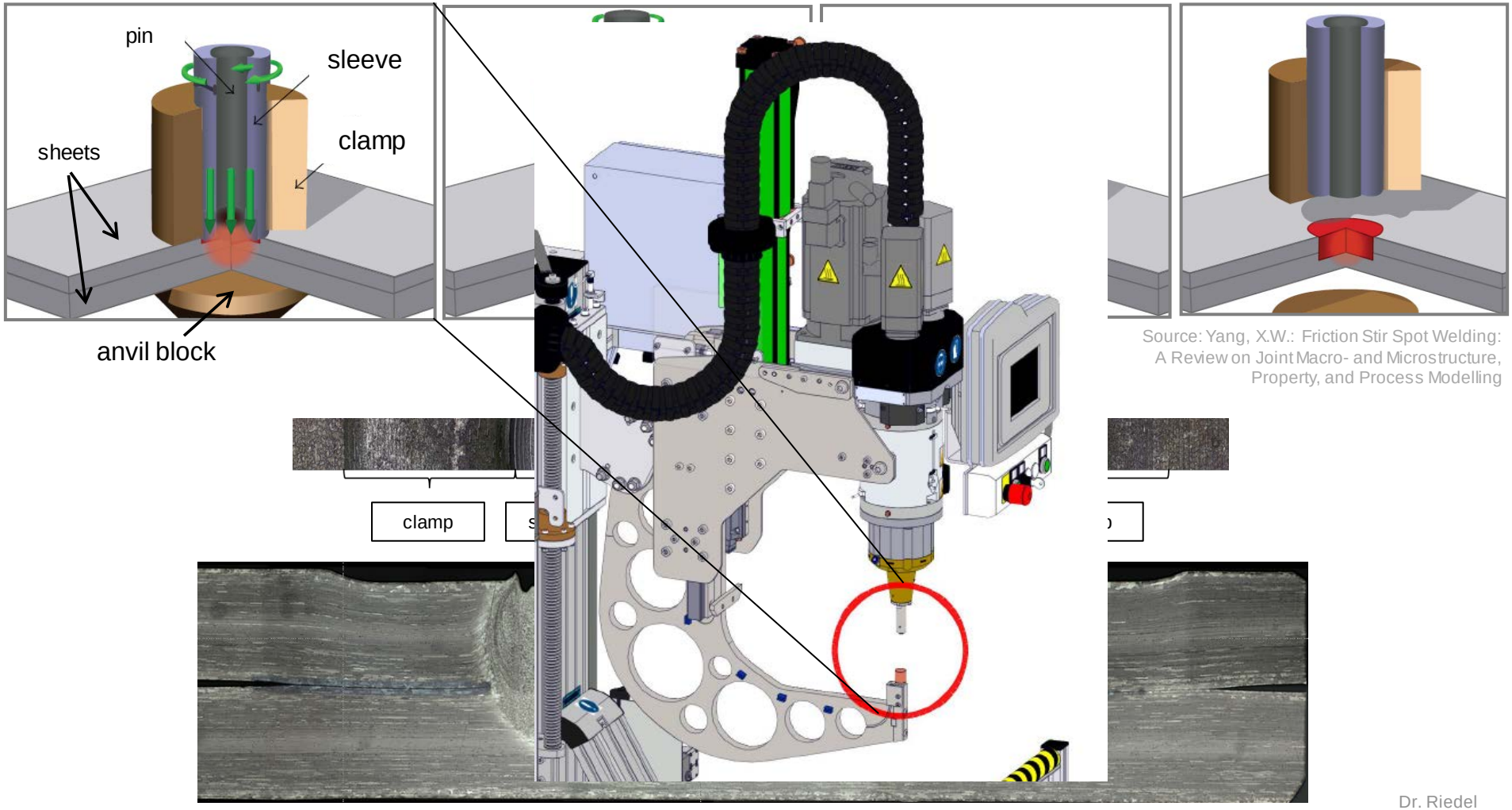
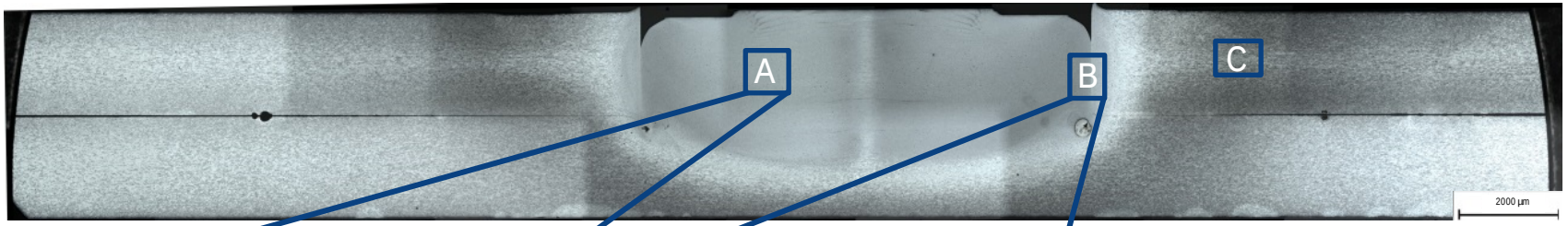
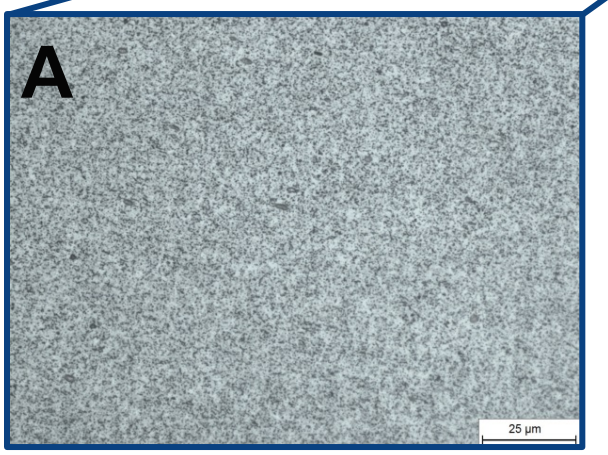
Procedural principle

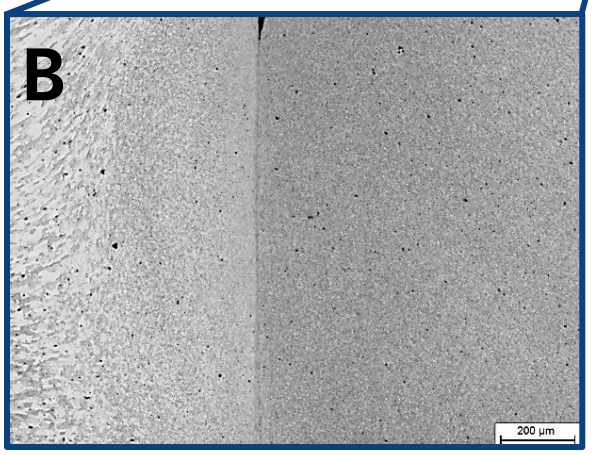


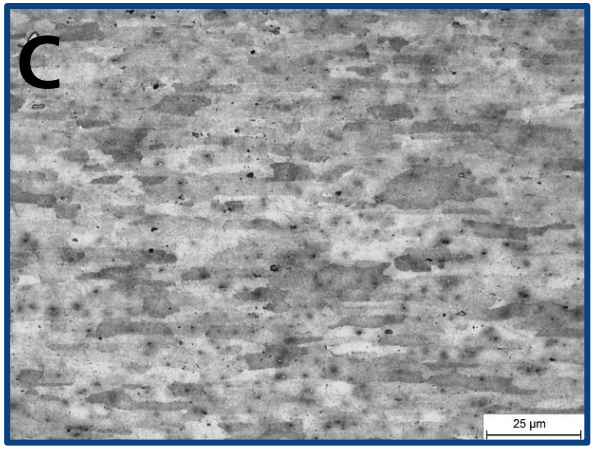
Source: Yang, X.W.: Friction Stir Spot Welding: A Review on Joint Macro- and Microstructure, Property, and Process Modelling

Cross section friction spot welded - EN AW-7075 T6 (t = 2 mm)







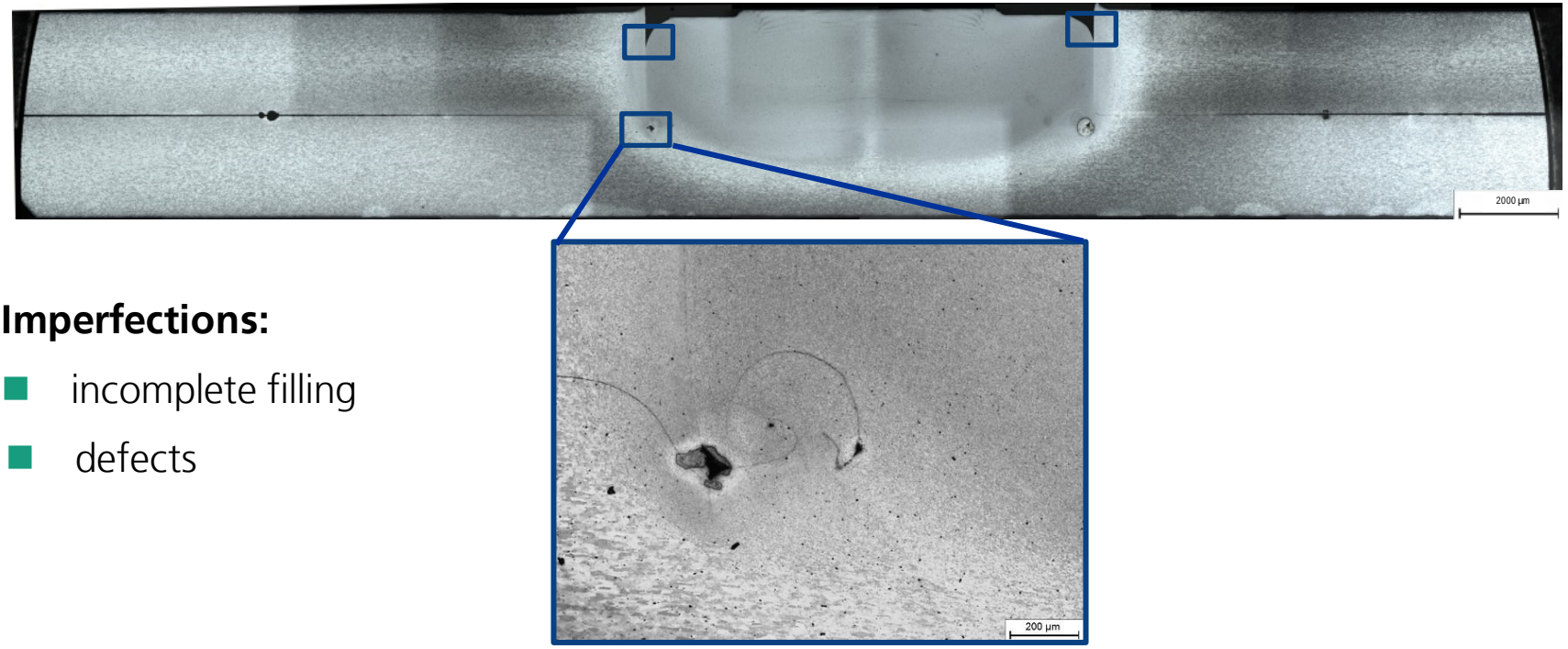


Stir/welding zone → very fine grains

Thermo-mechanically affected zone

Heat affected zone

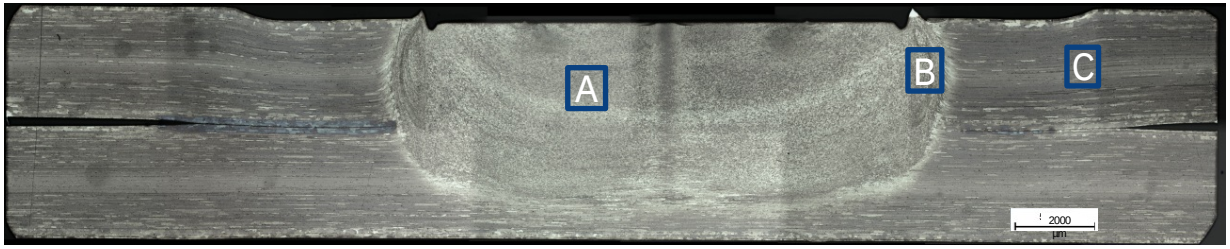
Cross section friction spot welded - EN AW-7075 T6 (t = 2 mm)

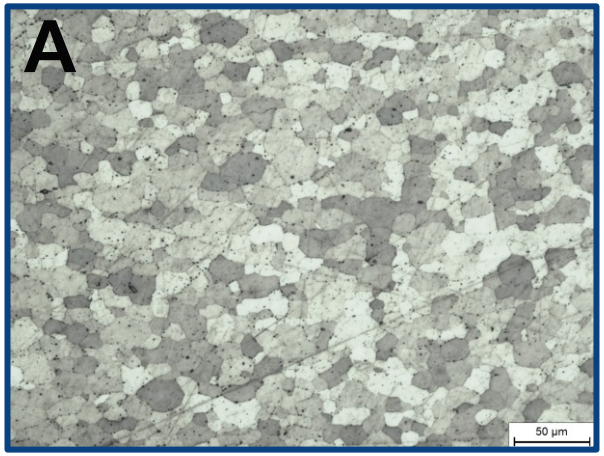


Imperfections:

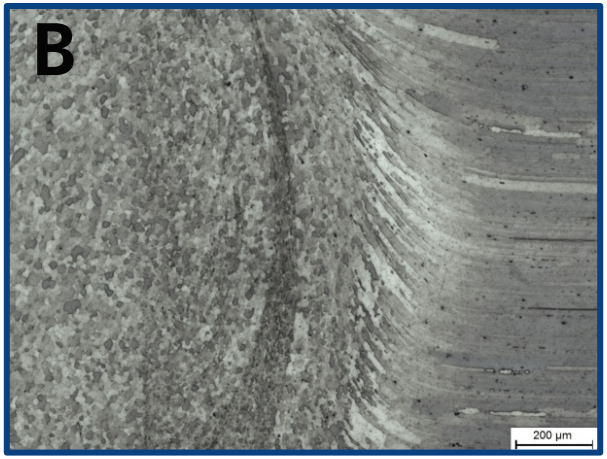
- incomplete filling
- defects

Cross section friction spot welded - EN AW-7021 T4 (t = 2 mm)

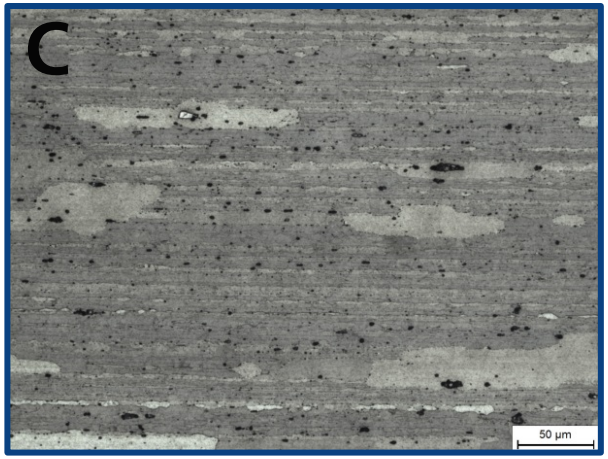




Stir/welding zone → very fine grains



Thermo-mechanically affected zone



Heat affected zone

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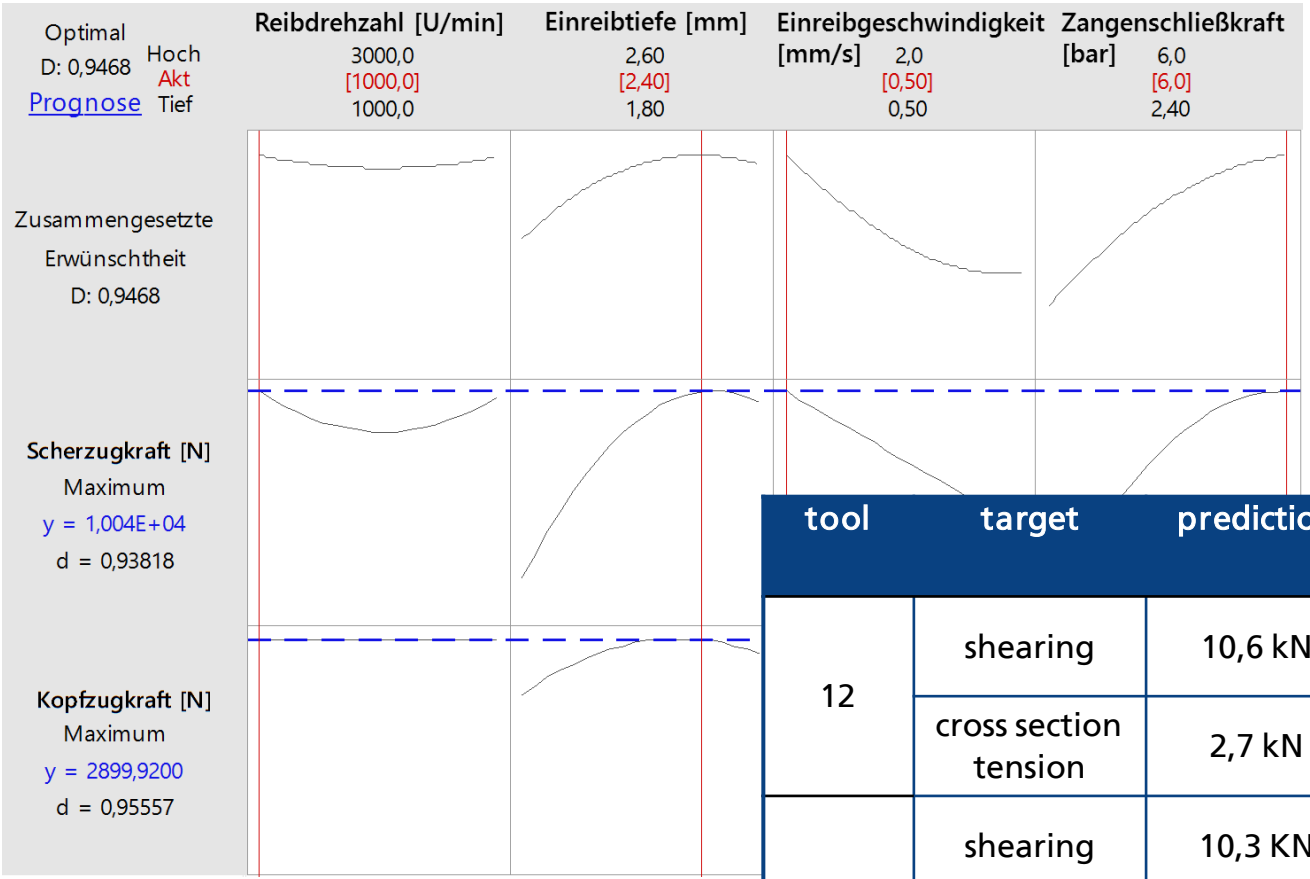
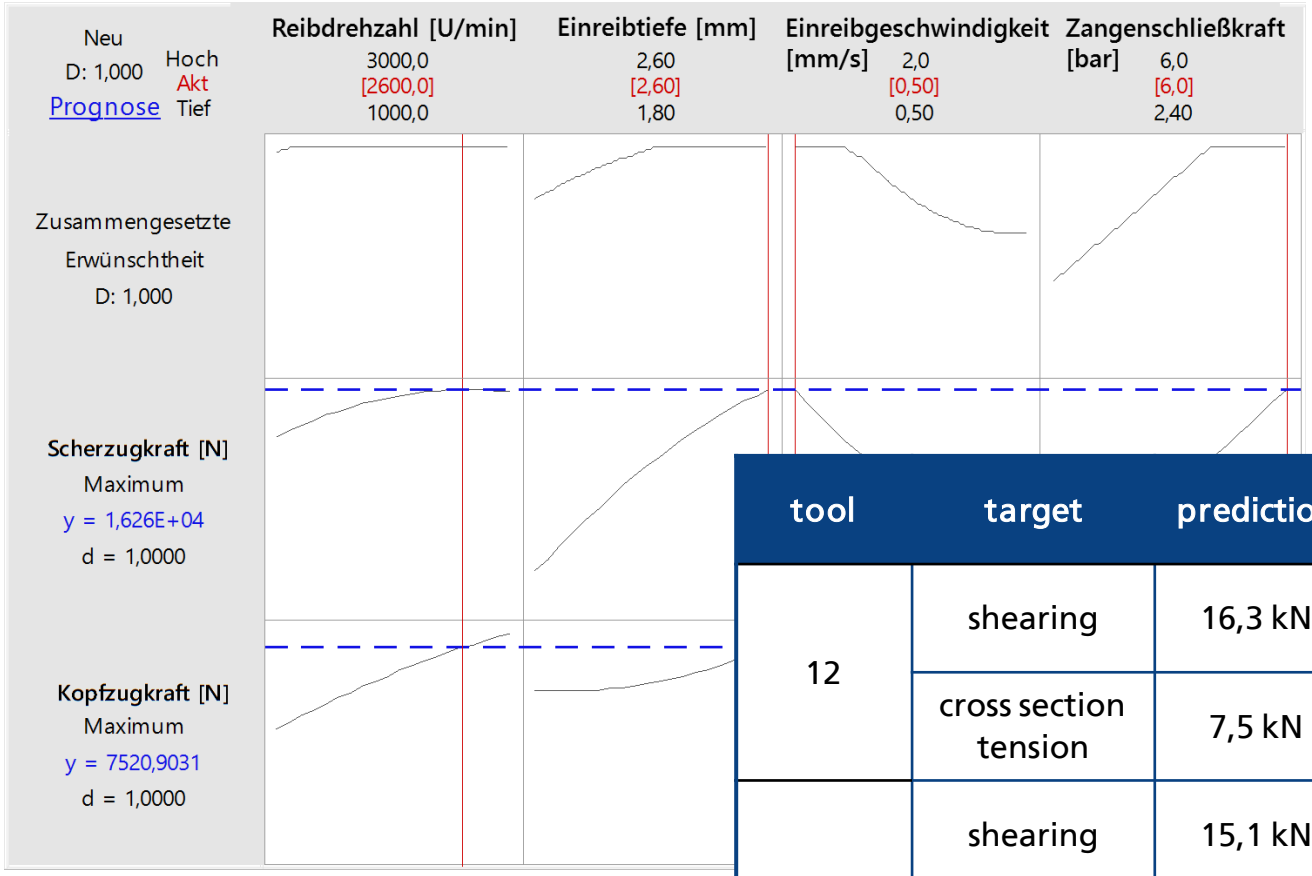
Joint strength optimization - EN AW-7075 T6 (t = 2 mm)



Optimization diagram for FSSW EN AW-7075 T6 with tool Wz17

tool	target	prediction	95 %-PI	validation-tests
12	shearing	10,6 kN	(8,2 - 12,8)	**11,3 kN**
	cross section tension	2,7 kN	(2,2 - 3,6)	**3,7 kN**
17	shearing	10,3 KN	(7,3 – 13,3)	**9,0 KN**
	cross section tension	3,1 kN	(2,1 – 4,2)	**2,1 kN**

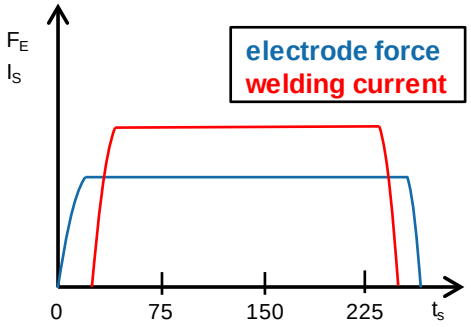
Joint strength optimization - EN AW-7021 T4 (t = 2 mm)



Optimization diagram for FSSW EN AW-7021 T4 with tool Wz17

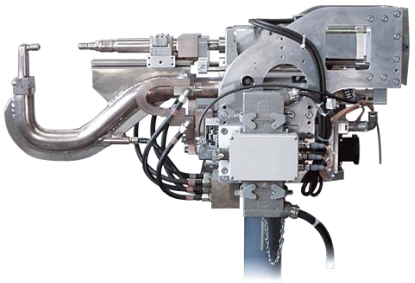
tool	target	prediction	95 %-PI	validation-tests
12	shearing	16,3 kN	(13,7 - 18,9)	**14,1 kN**
	cross section tension	7,5 kN	(6,6 - 8,5)	**5,7 kN**
17	shearing	15,1 kN	(12,9 - 17,4)	**12,7 kN**
	cross section tension	7,0 kN	(5,1 - 8,1)	**5,3 kN**

Resistant spot welding



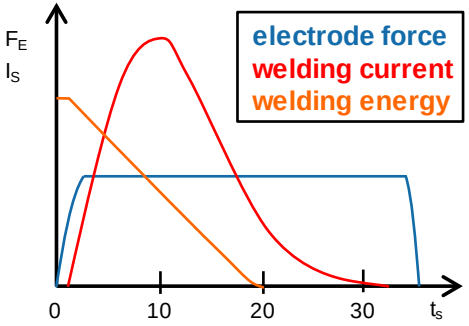
Force-current-relationship

- established process
- high controllability



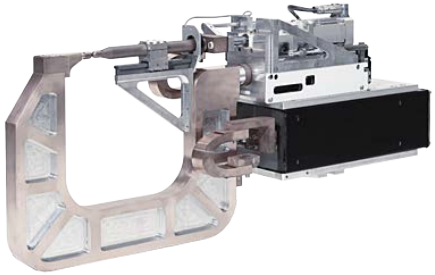
Nimak C 50 (VW)

Capacitor discharge welding



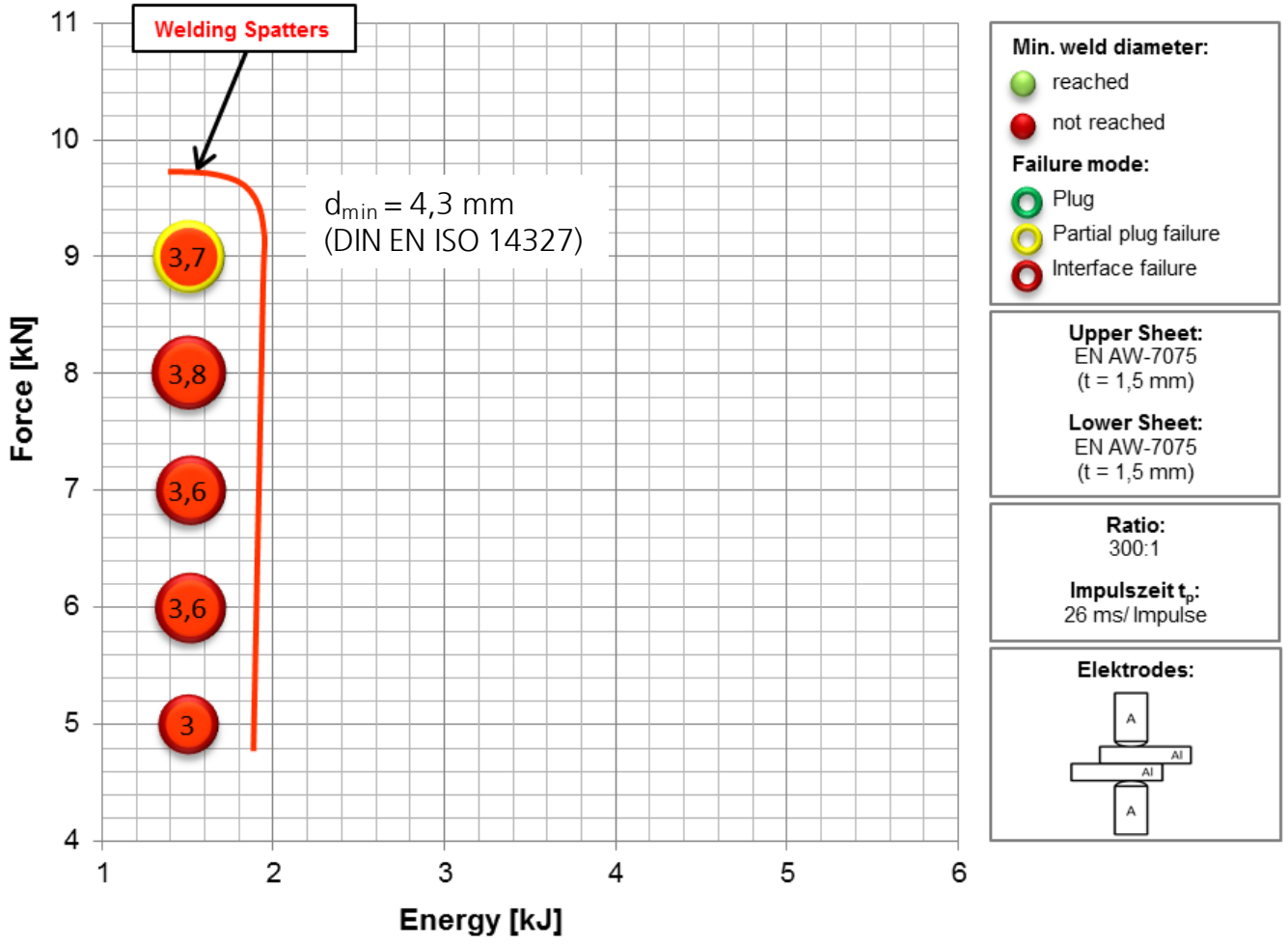
Force-current (energy)-relationship

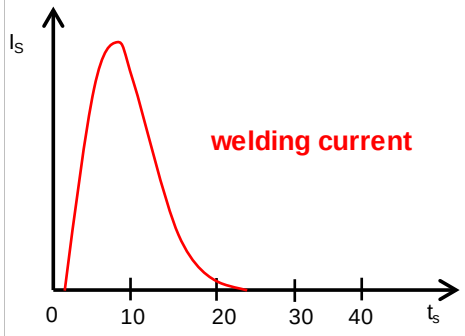
- very short welding time
- fast current slope-up
- extreme low connected load



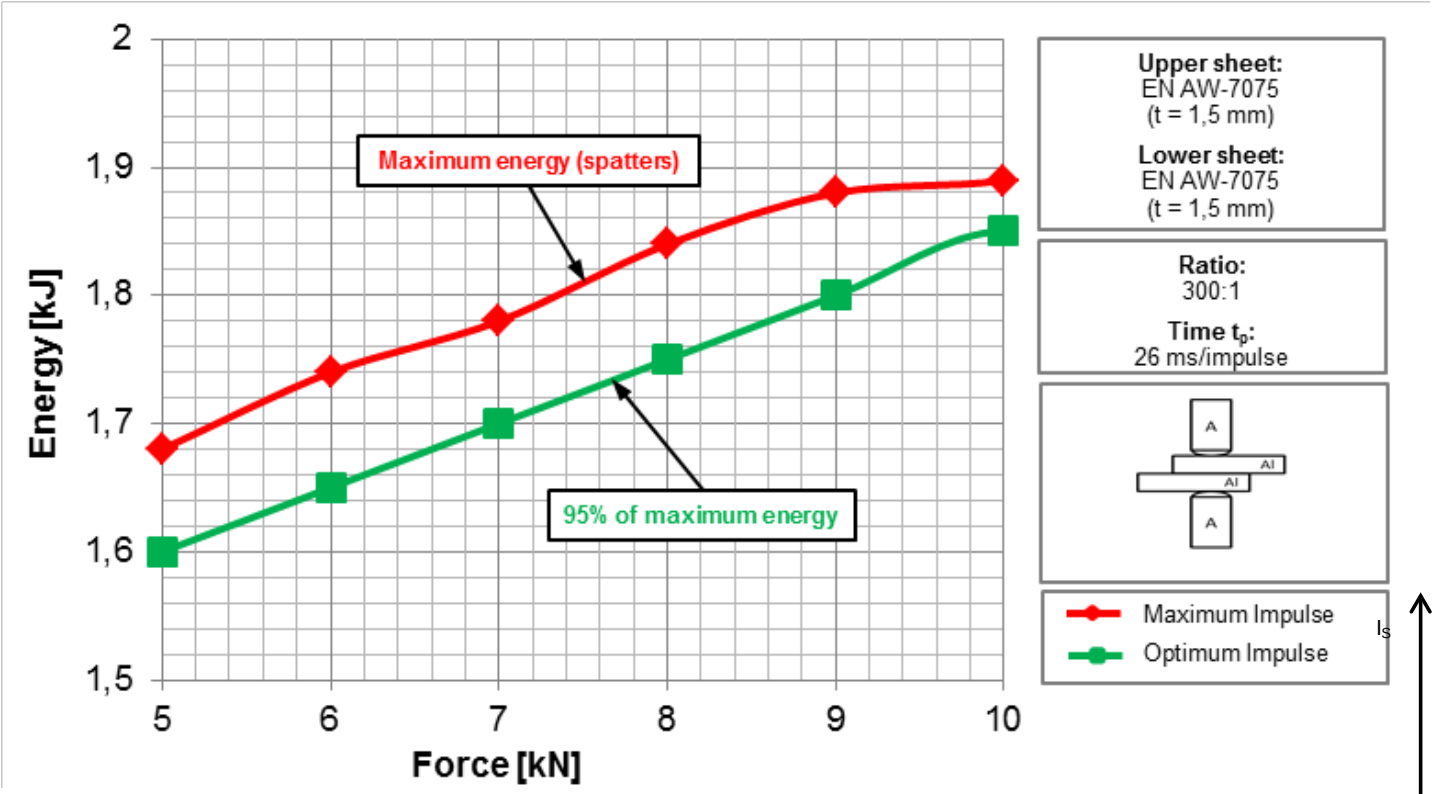
Nimak Robo-KES

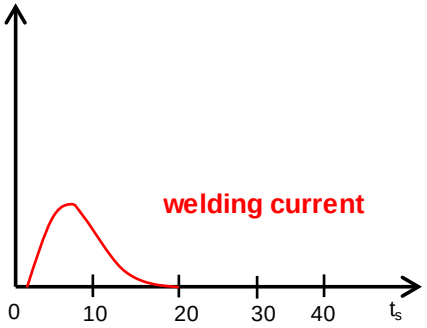
Weldability lobe for one-impulse process



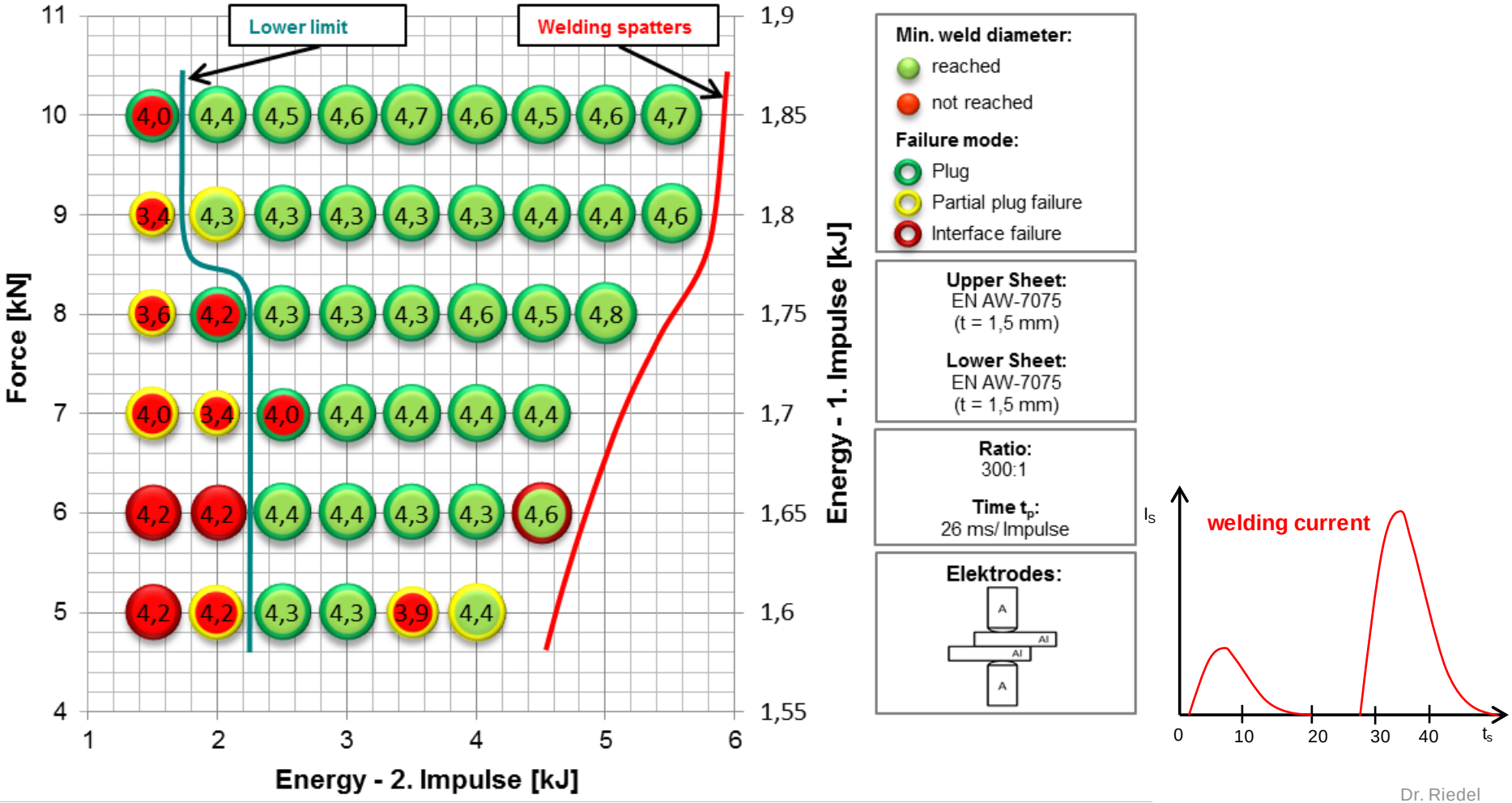


Determination of optimal energy for first impulse

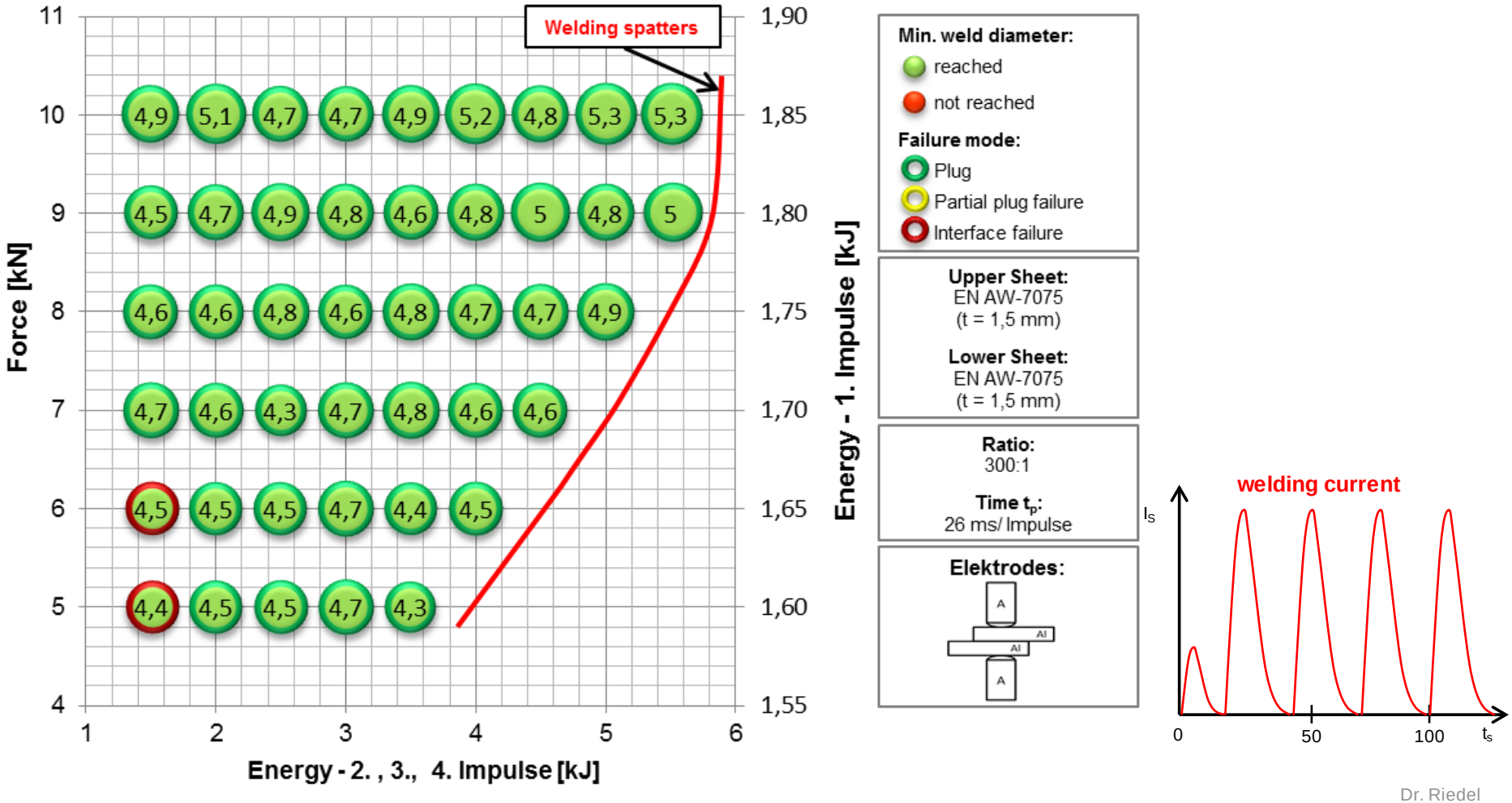




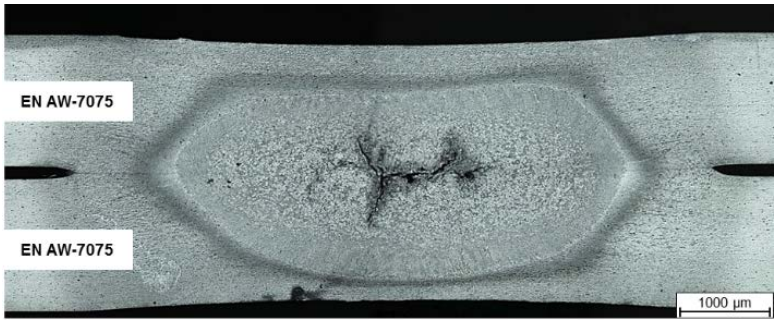
Weldability lobe for two-impulse process



Weldability lobe for four-impulse process



One-impulse process

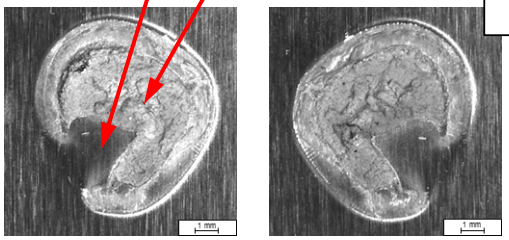


Lack of fusion

Cracks

Lower sheet

Upper sheet



Process parameters:

Energy = 2,0 kJ

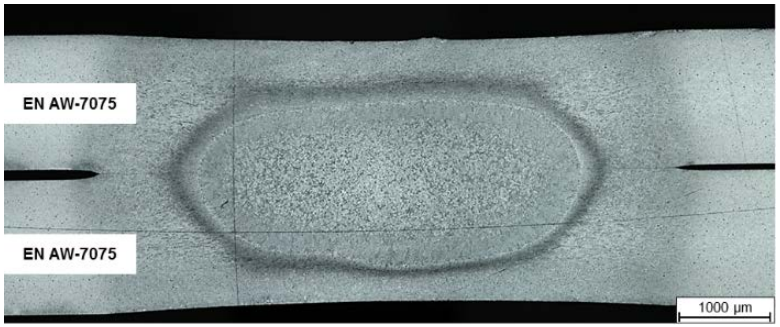
Force = 7,0 kN

Ratio = 300:1

Time t_p = 26 ms

Shear fracture after chisel testing

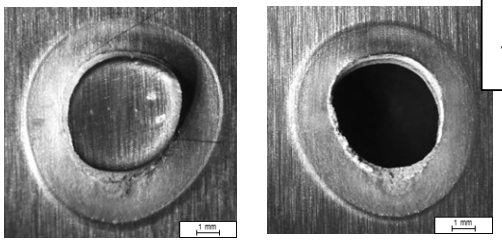
Two-impulse process



No cracks or pores in the welding zone

Lower sheet

Upper sheet



Process parameters:

Energy 1 = 1,7 kJ

Energy 2 = 3,0 kJ

Force = 7,0 kN

Ratio = 300:1

Time t_p = 26 ms/impulse

Plug after chisel testing

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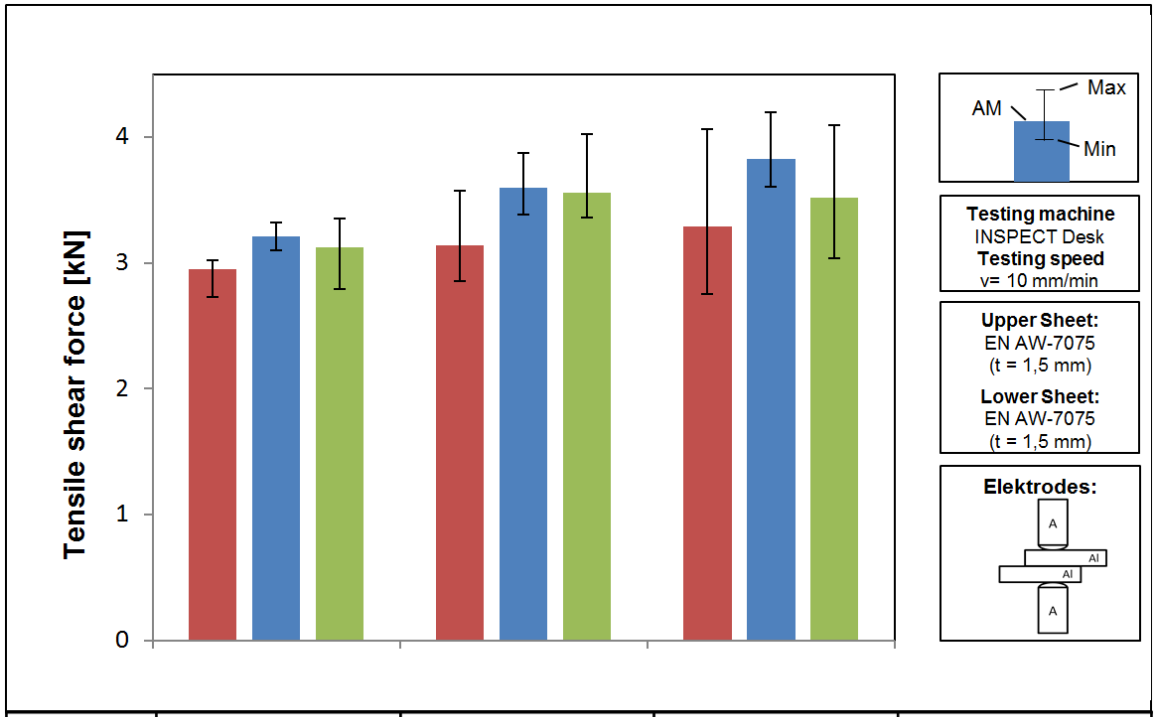


Energy 1 [kJ]	1,5	1,5	1,5	Impulse:
Energy (2), (3), (4) [kJ]	3,0	3,0	3,0	1 Impulse 2 Impulse 4 Impulse
Force [kN]	5,0	7,0	9,0	

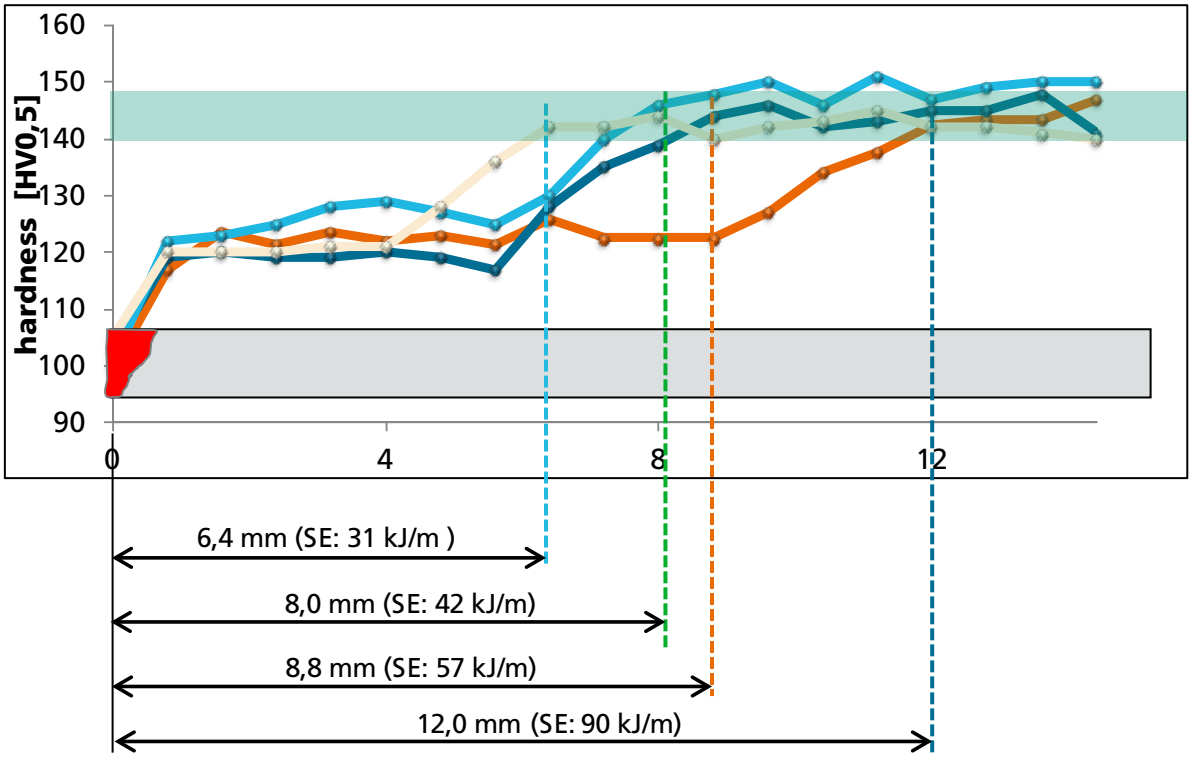
Tensile shear force of CD welded similar EN AW-7075

→ Increasing tensile shear strength by using multi-impulse technique

→ Reducing of welding splatters and alloying of the copper electrode with aluminium

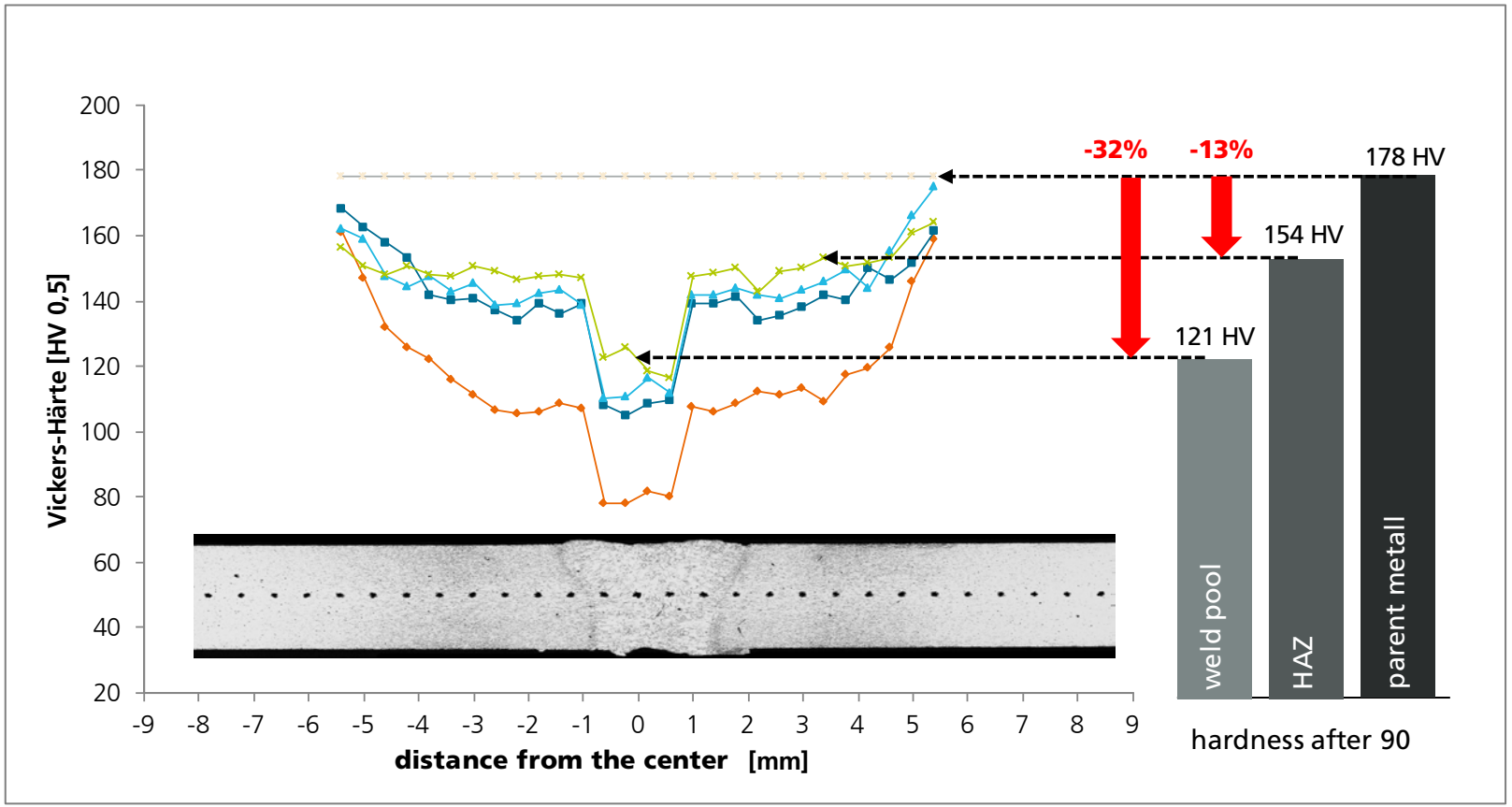
Laser welding - softening after welding

- width of the heat affected zone: 6 - 12 mm
- loss of strength after welding -60% (parent metal) and -38% HAZ



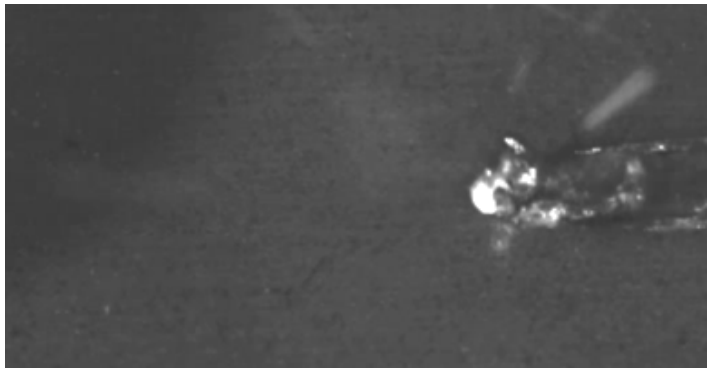
Laser welding - recovery of softening after welding

- Even after 90 days the strength is not completely recovered!



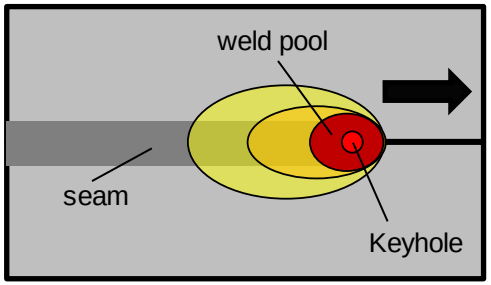
Evolution of the hardness in the weld area after several periods of time for the alloy EN AW-7075

Laser welding without filler material

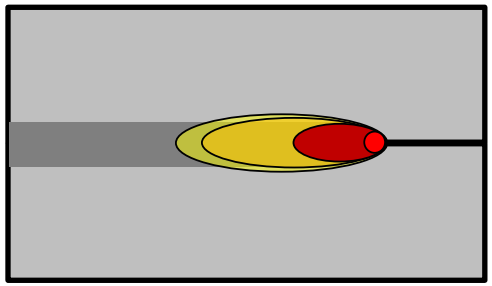


- **Quality depending on the welding speed**

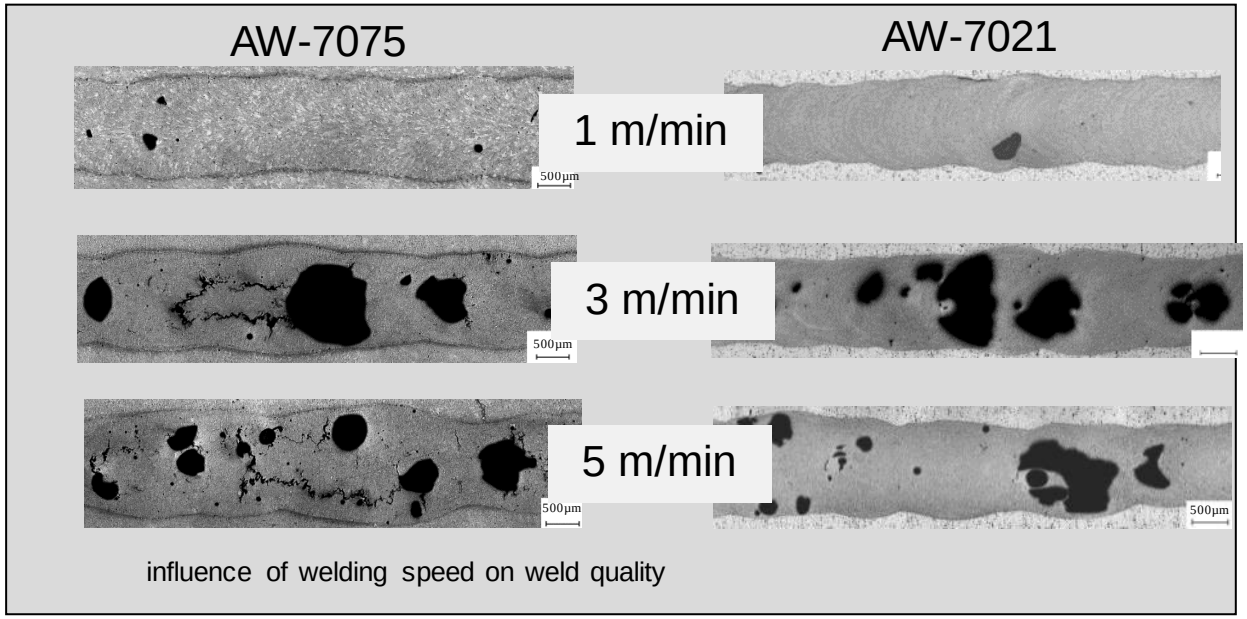
Temperature distribution and position of laser spot welding



low welding speed



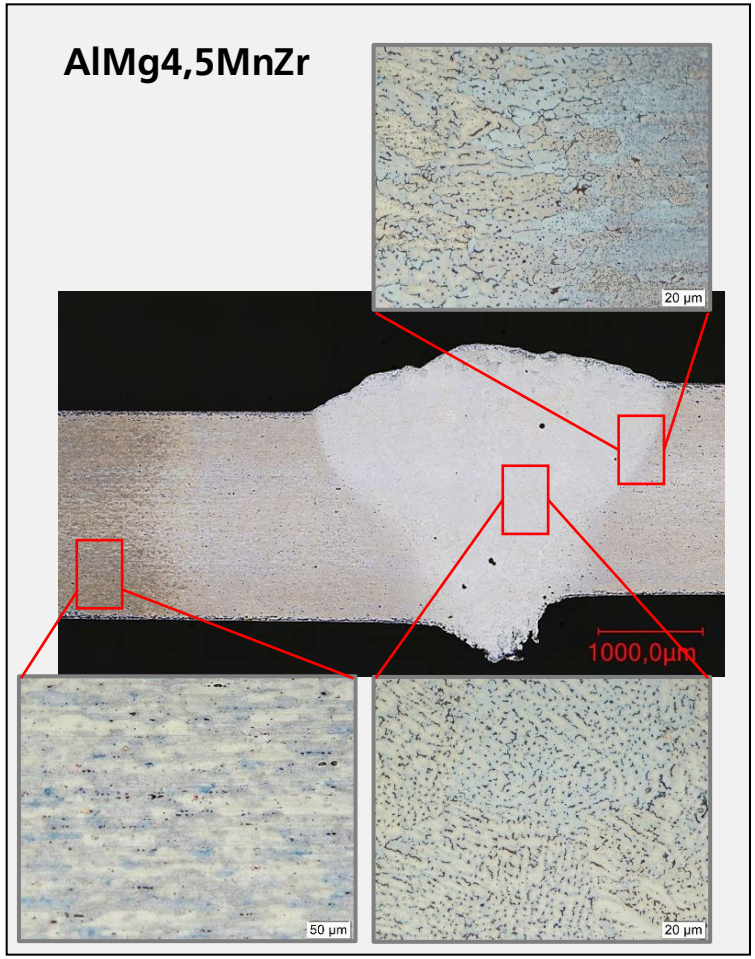
high welding speed

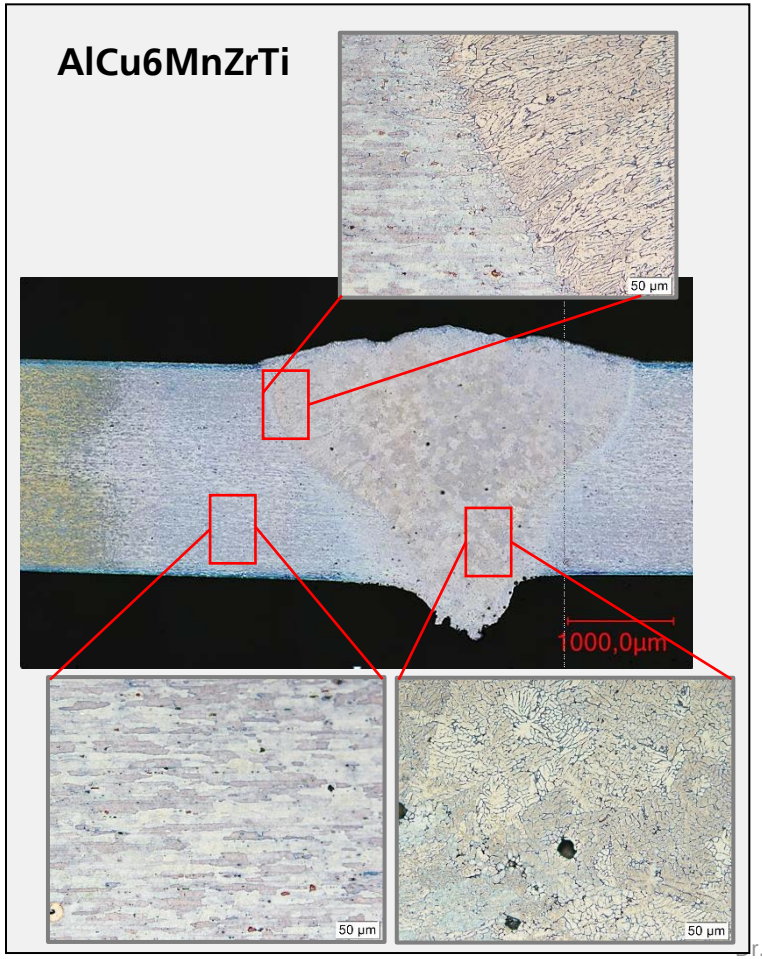


influence of welding speed on weld quality

Laser welding with filler material

- **Quality depending on the filler material**

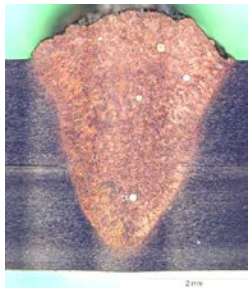




Laser welding with filler material

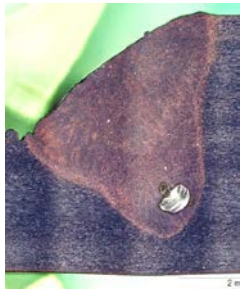
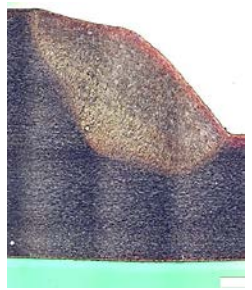
- **Quality depending on the interior seam structure**





Criteria	AlMg4,5MnZr	AlMg4Zn2	AlCu6MnZrTi
Cracks	+	+	--
Pores	-	+	-
Strength (shear)	11-12 kN (seam length = 40 mm)		

Penetration weld at the lap joint

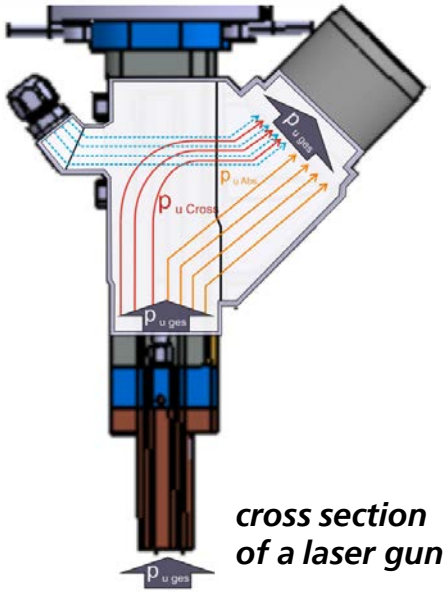




AlMg4,5MnZr	AlMg4Zn2	AlCu6MnZrTi
++	++	++
++	+	++
10-11 kN (seam length = 40 mm)		

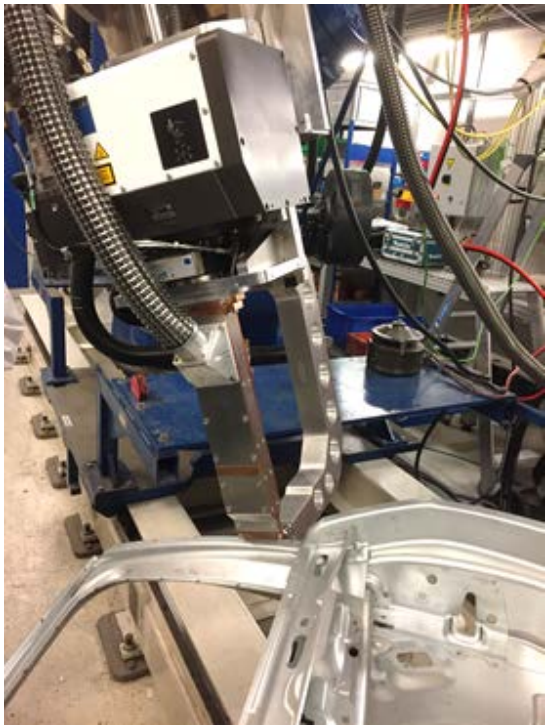
Fillet weld at the lap joint

Potential of robot-guided laser welding guns and pickers

- **more flexibility**
  (without additional protective housing for the laser)
- **clamping system comparable to resistant spot welding**
- **high joint strength**
- **beam modulation by scanner**
- **potential by using an extraction**
- **use of an IDM-system**
  (control for the penetration depth)



cross section of a laser gun



Welding of door components with a laser gun (RayFlex Alpha V2)

Industrial applicability

- **Friction stir spot welding has a high potential for 7xxx series aluminium alloys.**
  - ➢ Boundary conditions have to be set for the transfer from principle suitability to an industrial application.
- **Capacitor discharge welding gun already exists and the evidence for a reproducible application has been provided (stage of principle suitability).**
  - ➢ Multi-impulse technique has a higher performance than one-impulse process.
- **Laser beam welding technology of 7xxx series aluminium alloys is suitable for an industrial application.**
  - ➢ Laser guns have a high potential.

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current project:

„Technologieentwicklung zur Herstellung von Karosseriebaugruppen aus höchstfesten Aluminiumlegierungen„

(funding supported by the Sächsische Aufbaubank)

- **Subproject Joining:**

  Fraunhofer-Institute for Machine Tools and Forming Technology IWU

  (M. Puschmann, Dr. F. Riedel)

- **Subproject Forming:**

  KWD Karosseriewerke Dresden GmbH

  (Dr. J. Ulrich)

Thank you

for your attention.

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