Adhesion measurement of microforged Al6061 cold sprayed coatings with modified pin pull test

Cold Spray Club- Fall 2023

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HSU Hamburg

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HELMUT SCHMIDT UNIVERSITÄT
Universität der Bundeswehr Hamburg

Content and motivation

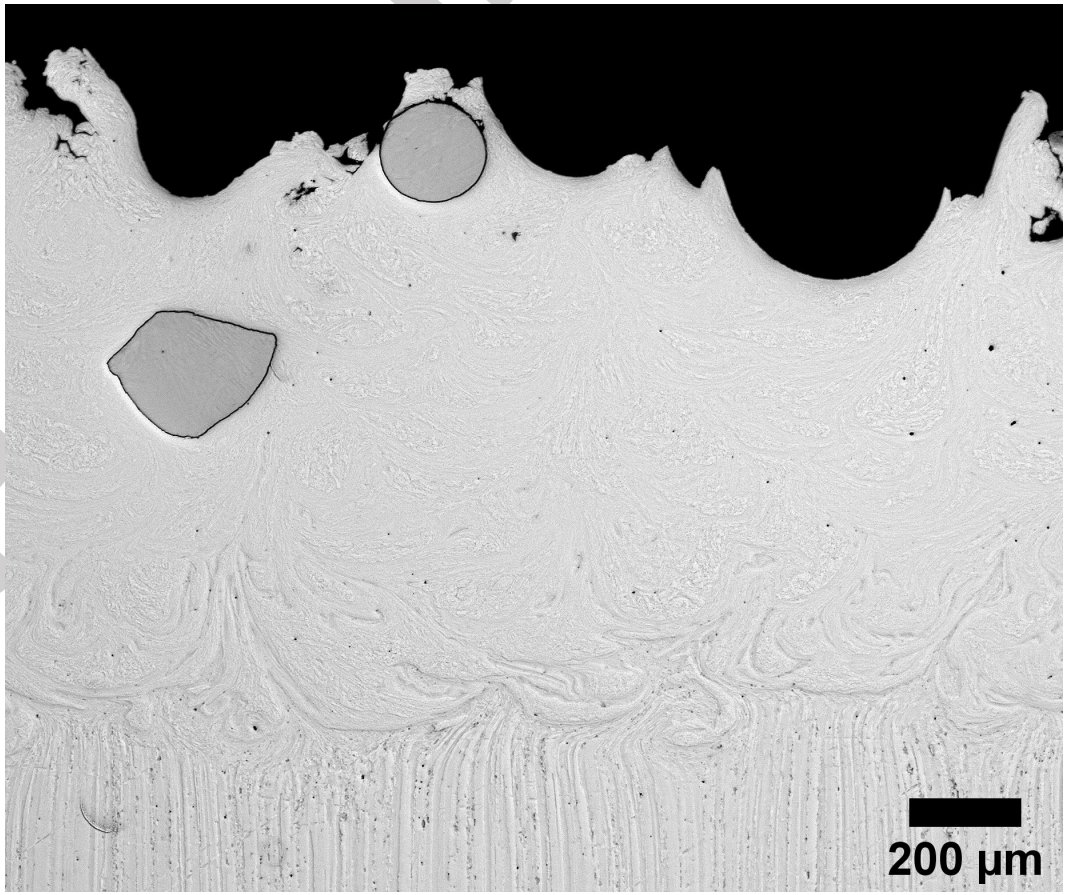
Introduction & Methods

- Microforging with cold spray system impact 5/11
- Powder and shot sizes
- Adhesion testing with pin pull test

Results

- Adhesion measurements of microforged Al6061 coatings
- Limitations of the pin pull test

Summary



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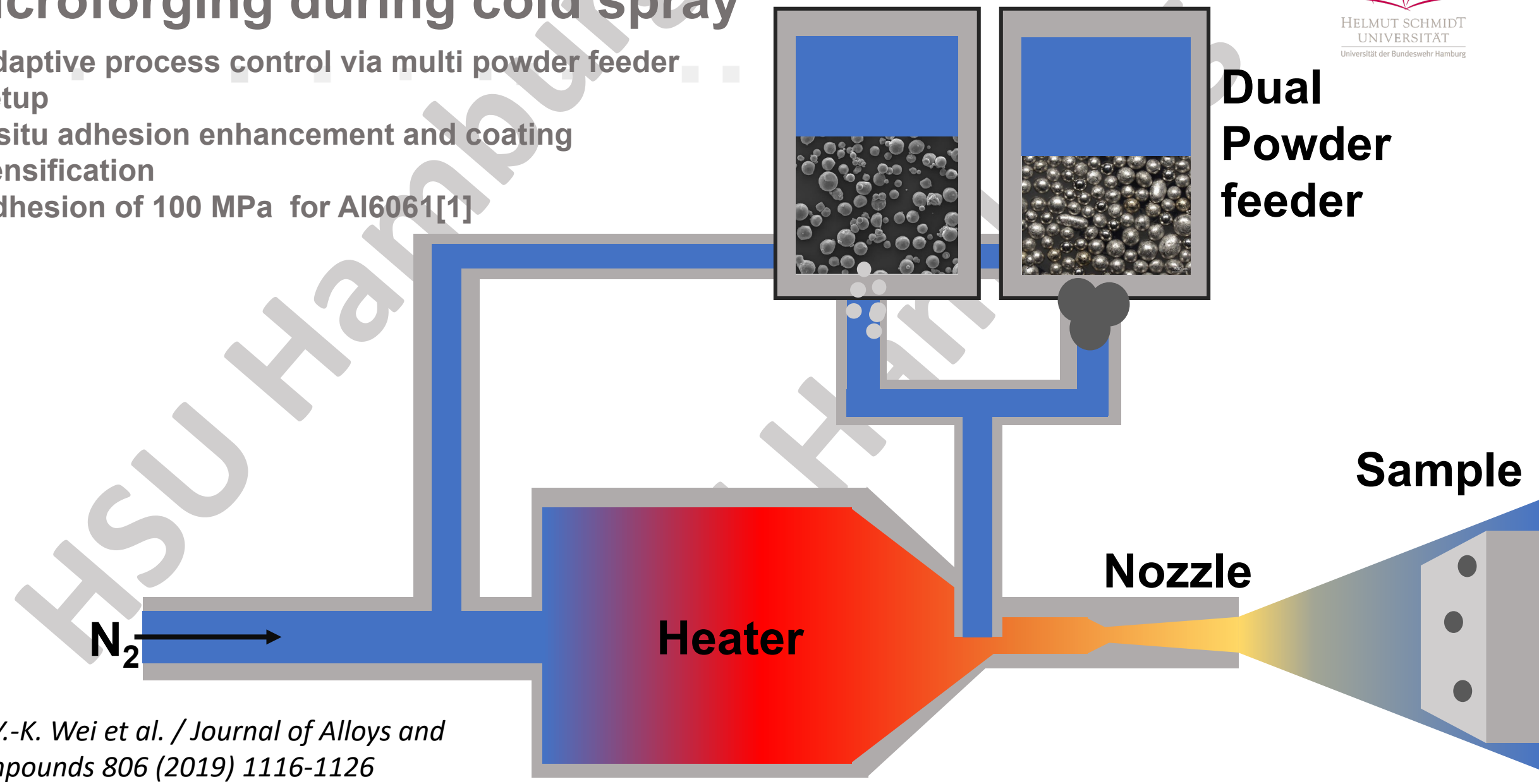
Microforging during cold spray

- Adaptive process control via multi powder feeder setup
- Insitu adhesion enhancement and coating densification
- Adhesion of 100 MPa for Al6061[1]



[1] Y.-K. Wei et al. / Journal of Alloys and Compounds 806 (2019) 1116-1126

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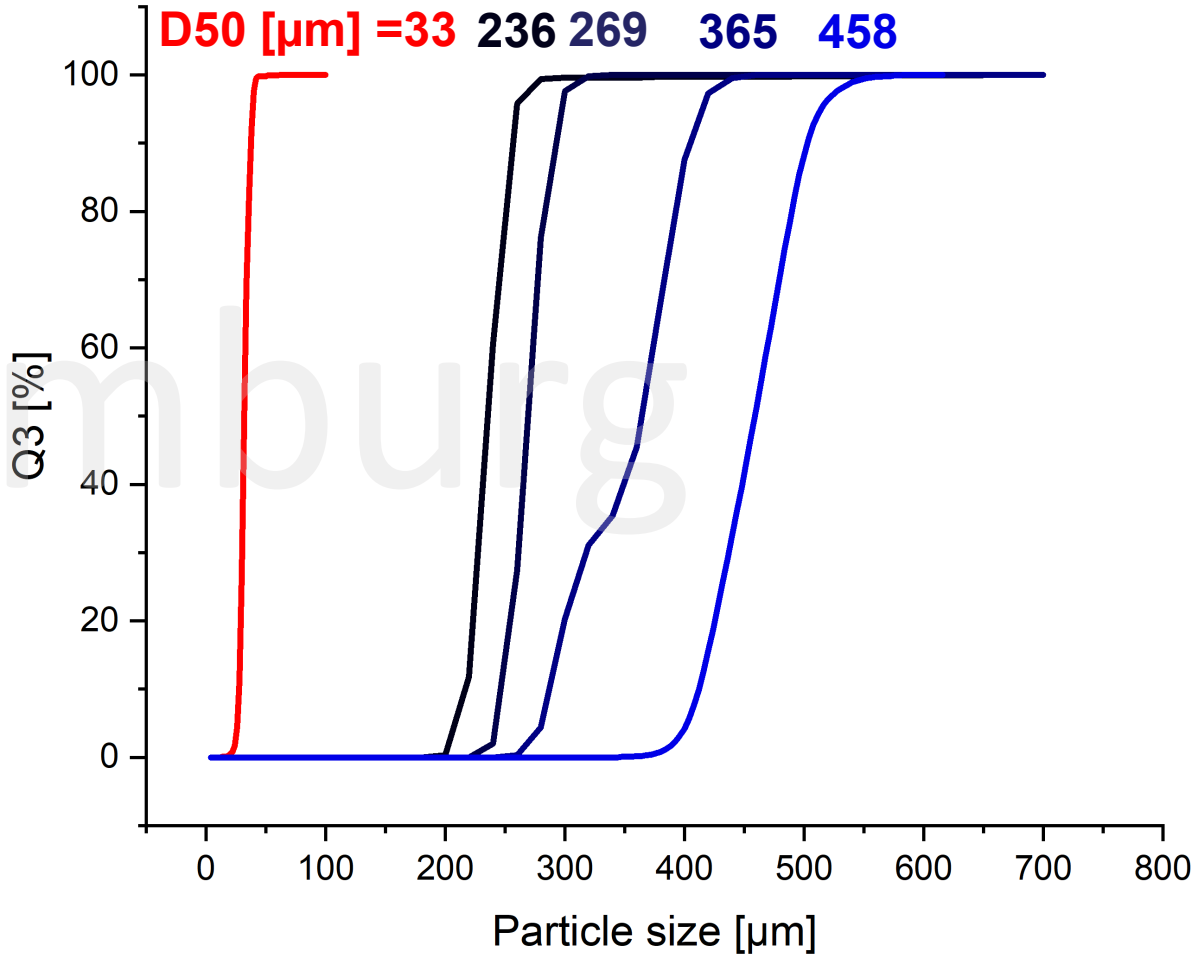
Powder and steel shot size distribution



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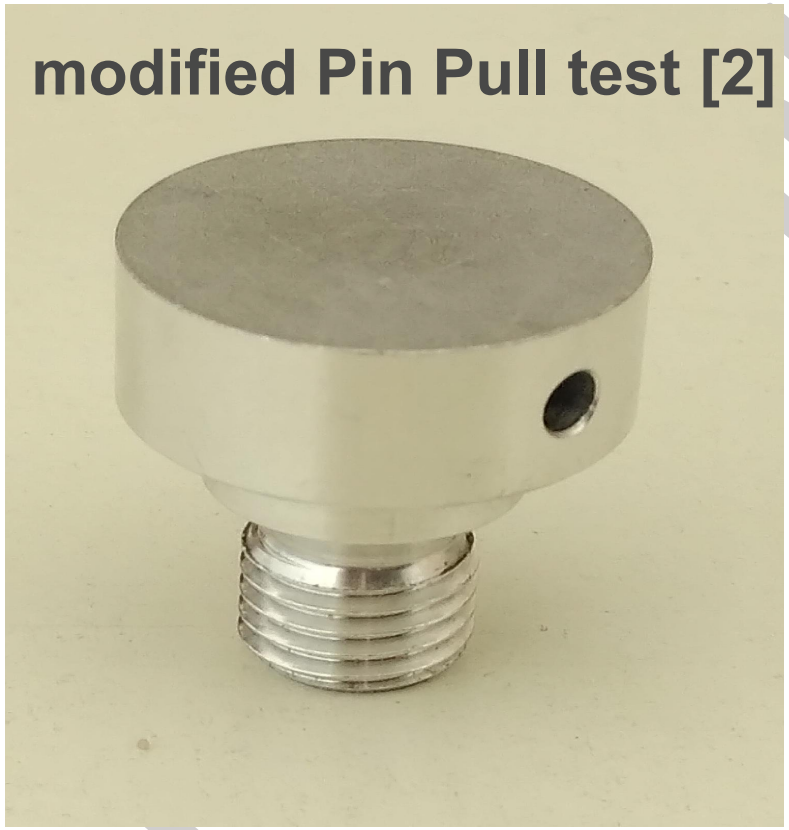
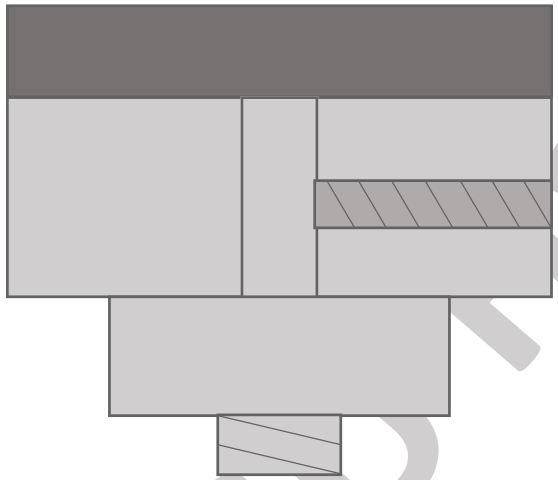
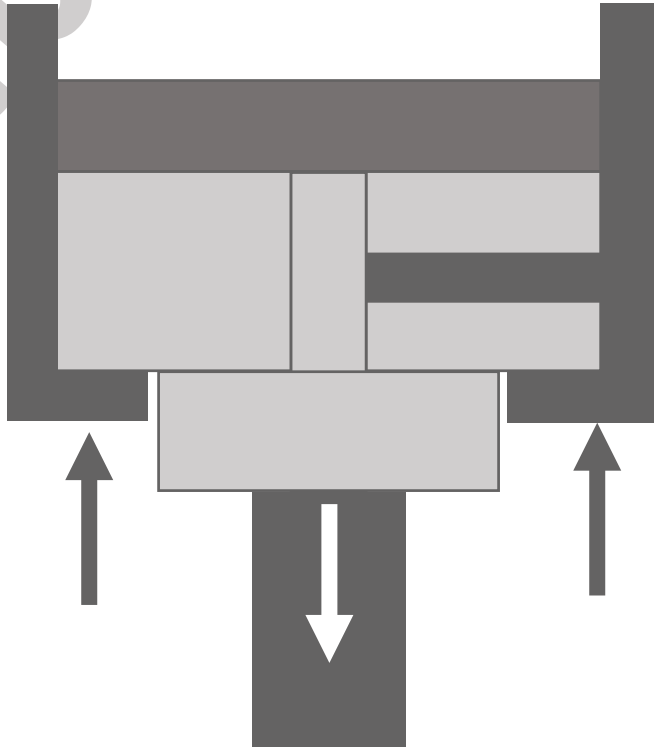
Principle of novel adhesion testing







[2] D.Boruah et al. Surface & Coatings Technology 381 (2020) 125130

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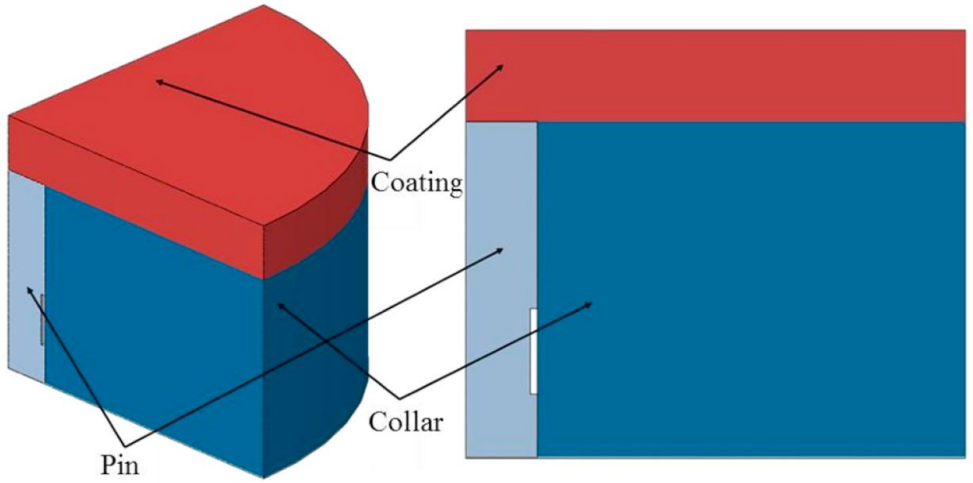
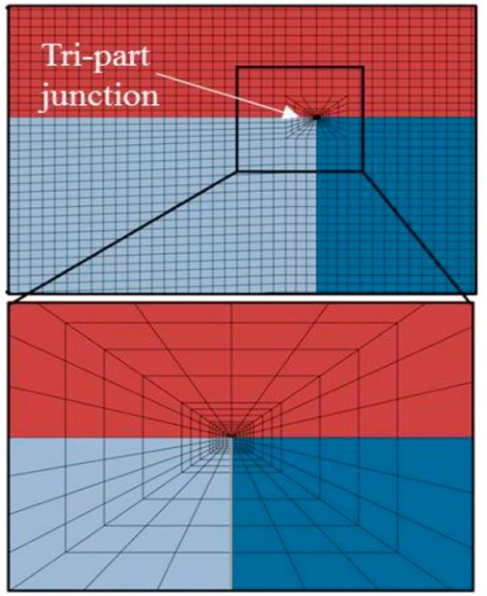
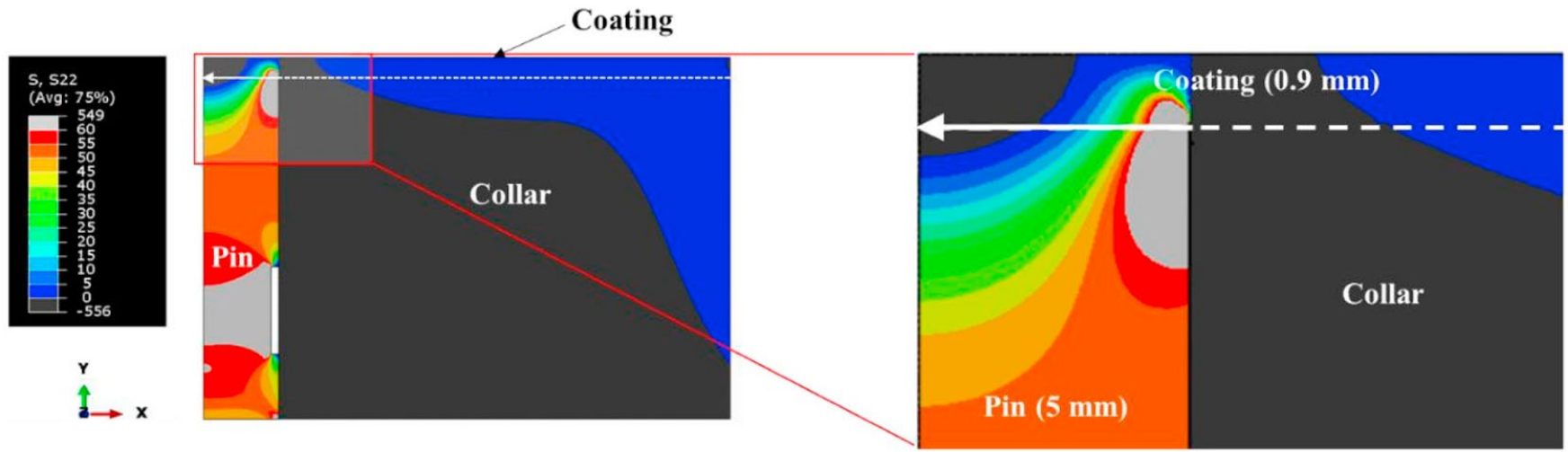
Modelling of Pin Pull test

- **Boruah modelled Tri-part junction already in his paper**
- **As a result of stress concentration potential for underestimation of adhesion**







[2] D.Boruah et al. Surface & Coatings Technology 381 (2020) 125130

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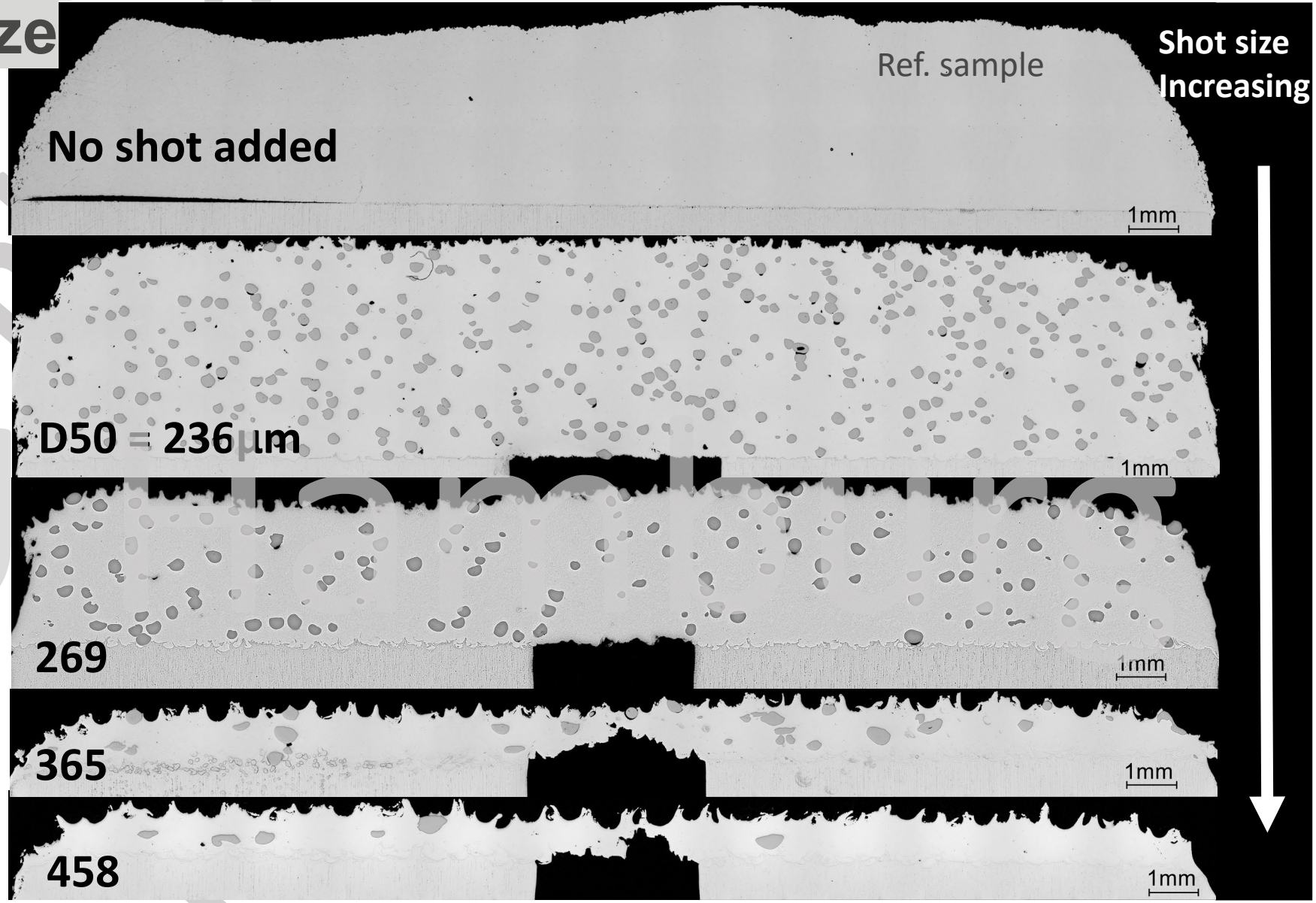
Variation of shot size

Mixing ratio:
20 % powder – 80% steel shot

Process gas	N_2
Temperature	500 °C
Pressure	50 bar
Stand off distance	45 mm
Powder	EN AW - 6061 20-38µm
Substrate	EN AW - 2007
Layers	40
FR Powder (fine disk)	2 RPM
FR Steel shot (coarse disk)	4 RPM



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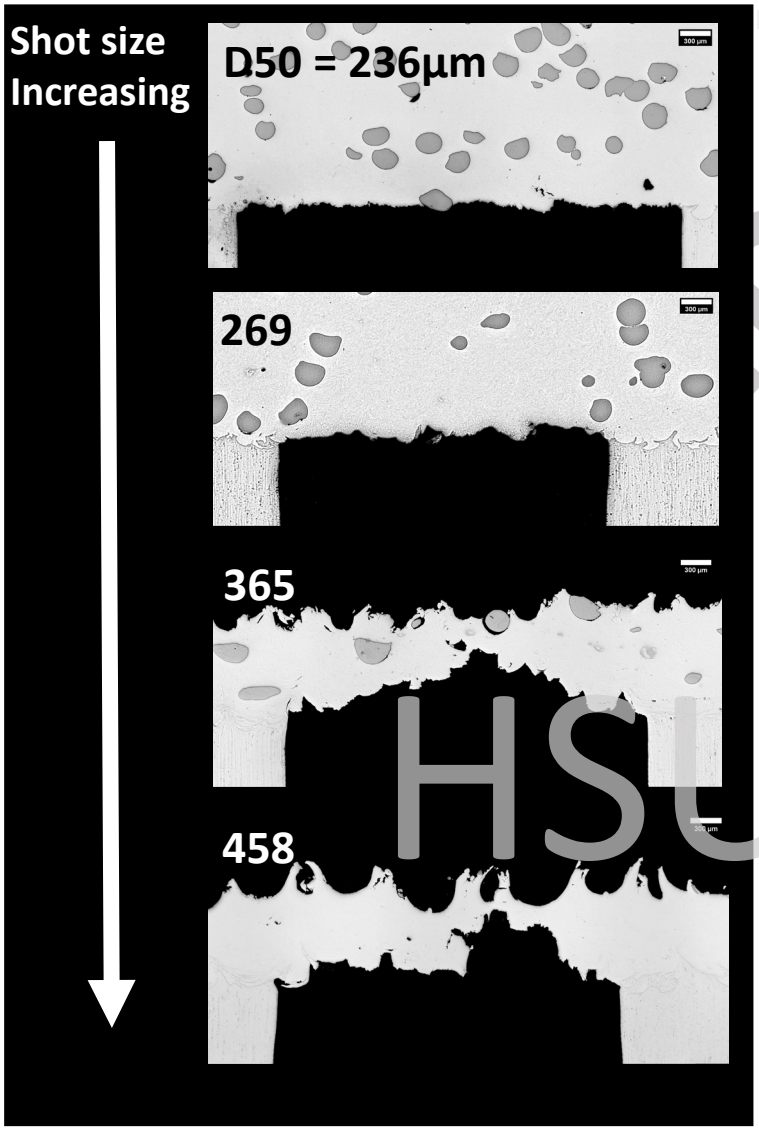
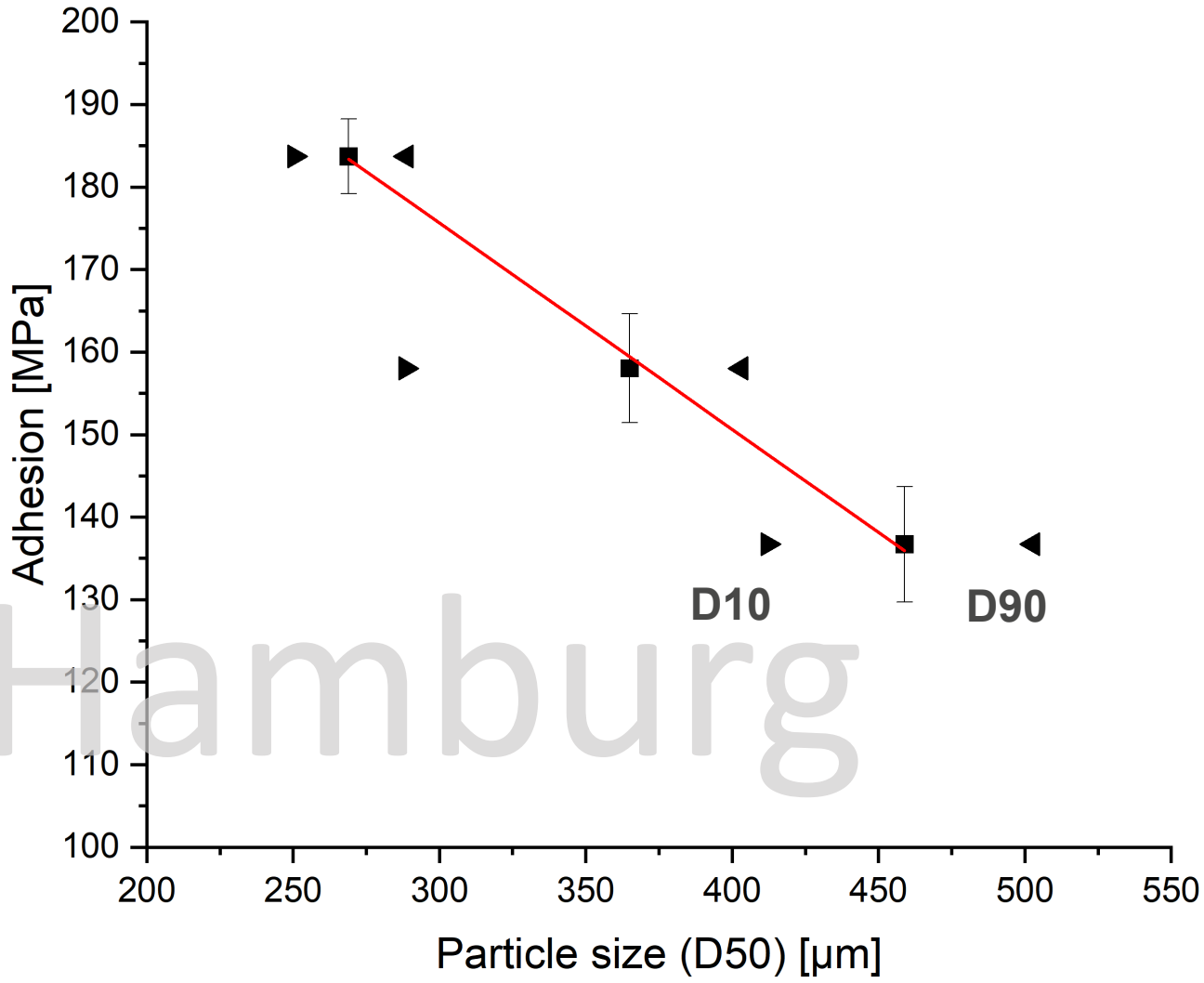
Dependency of adhesion on shot size





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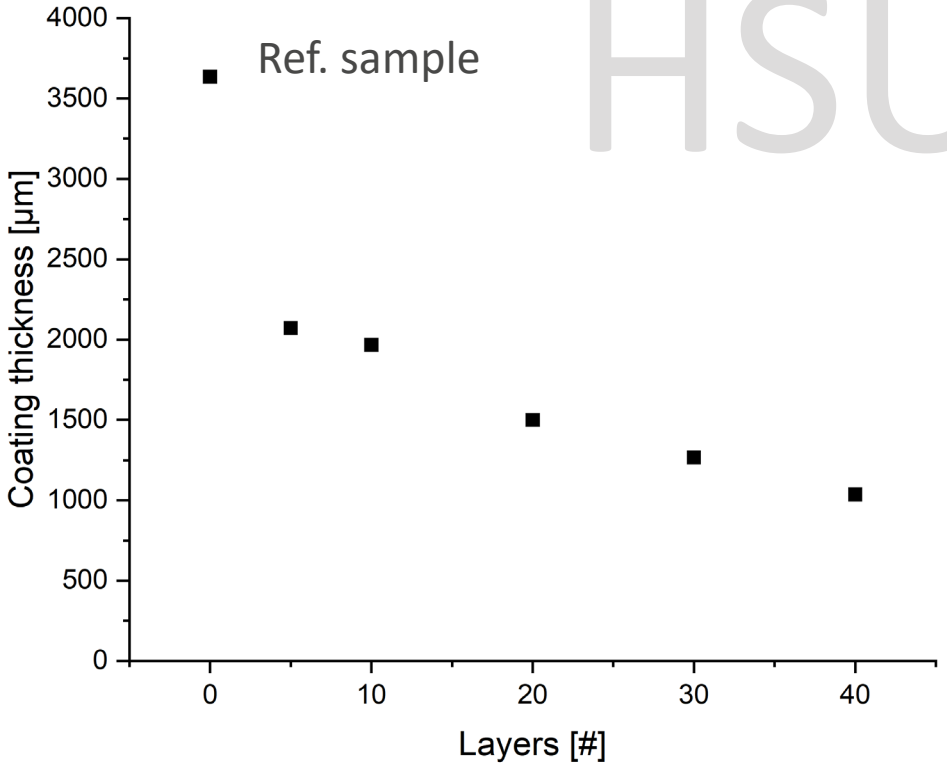
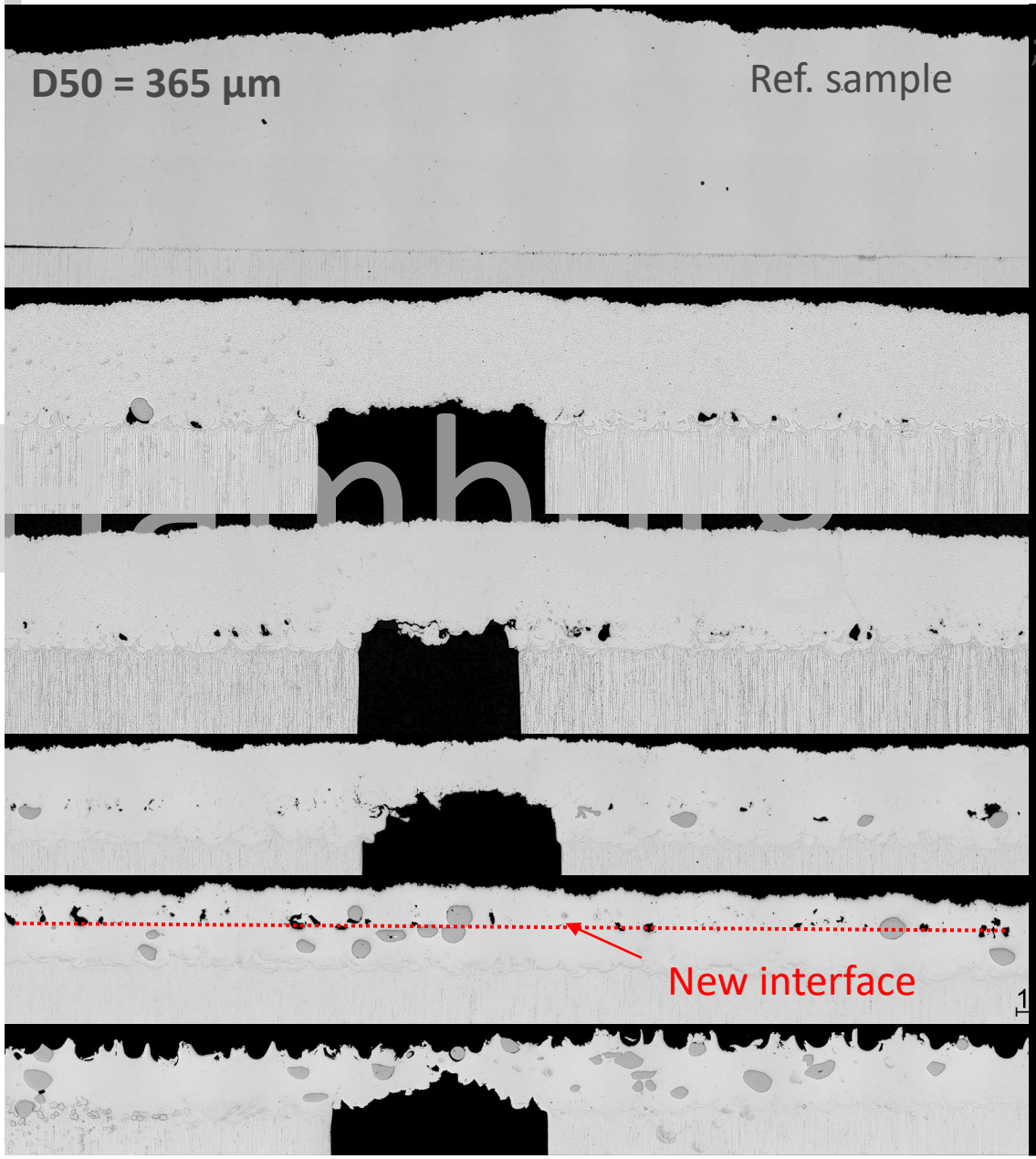
Microforging a bondlayer

Variation of microforged layers





#MF	#CS
0	40
5	35
10	30
20	20
30	10
40	0

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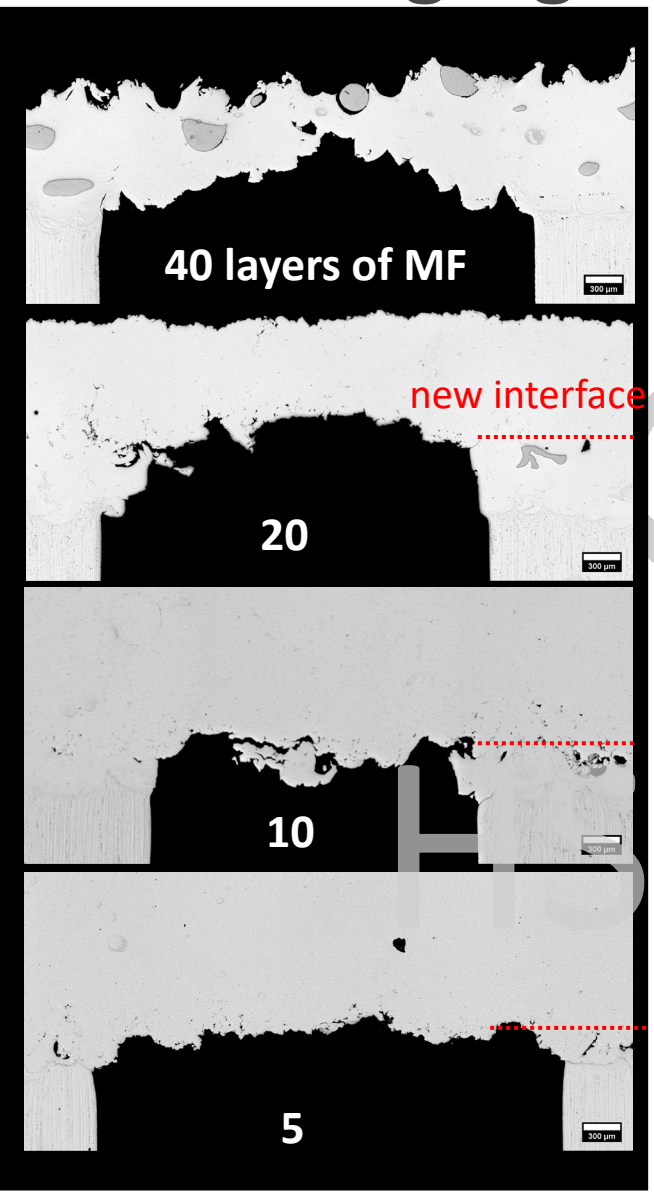
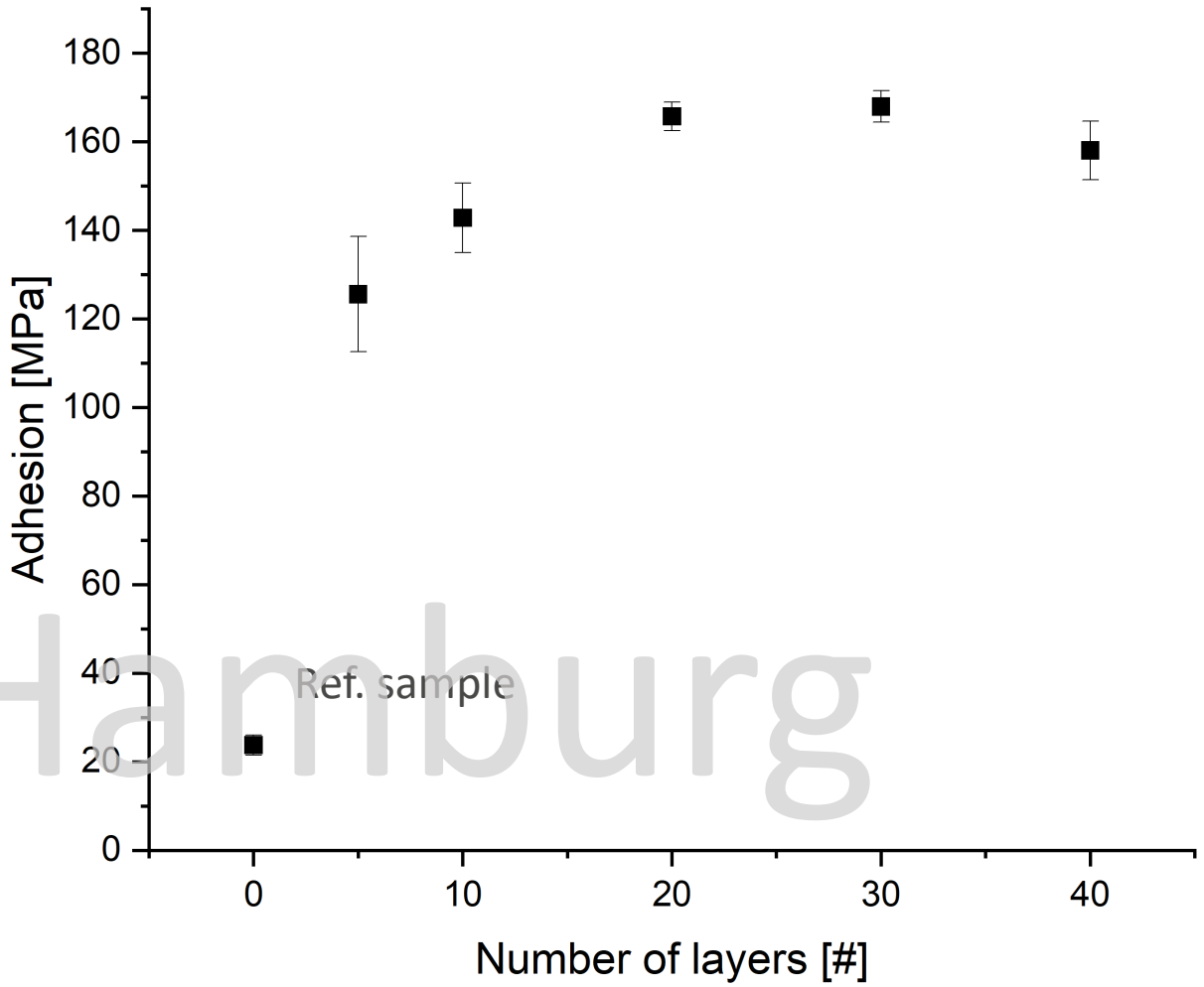
Microforging for as adhesion bond layer



D50 = 365 µm



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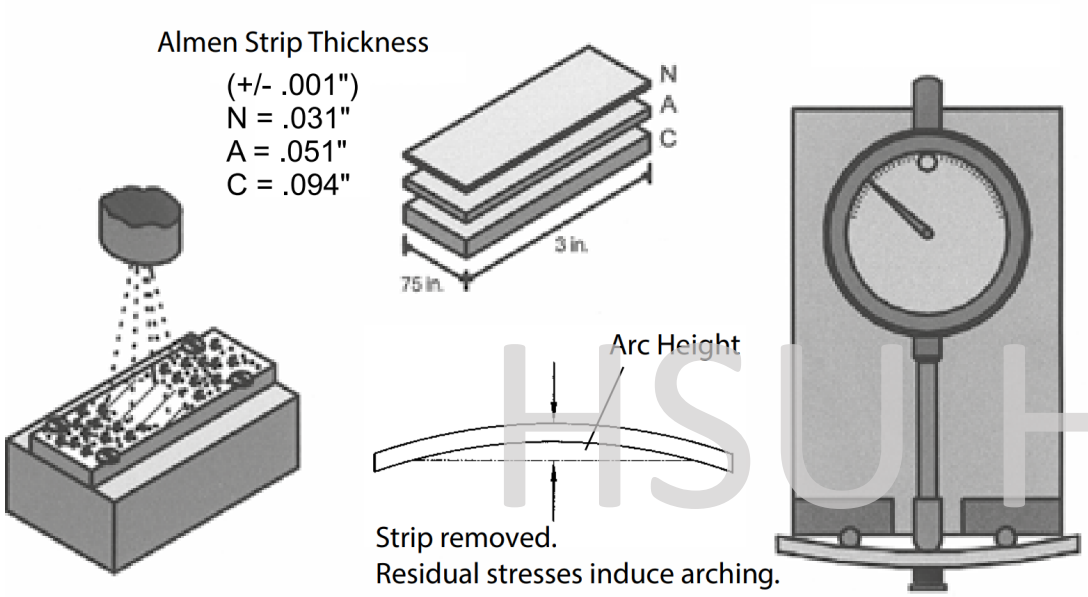
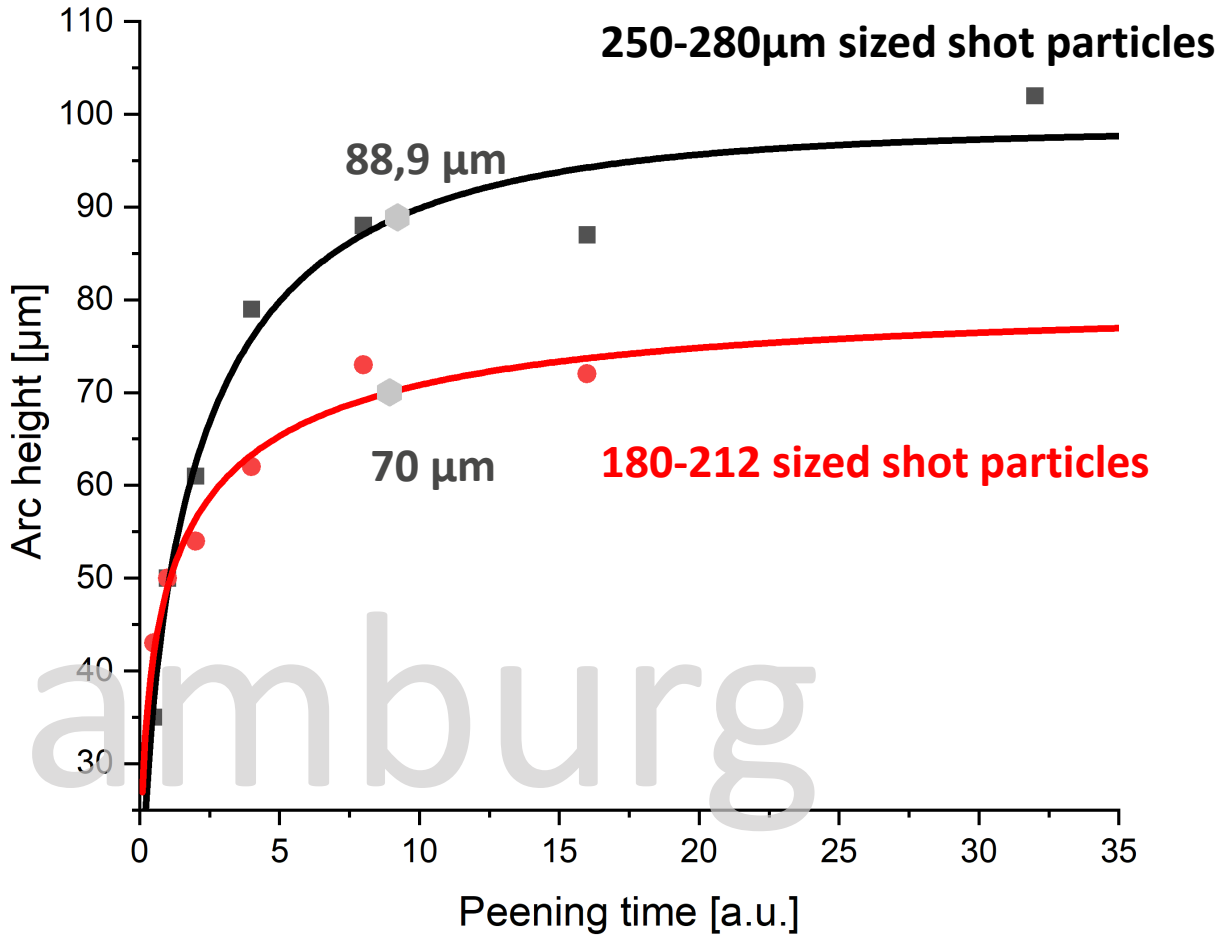
Intensity measurements of steel shot

Temperature	**500 °C**
Pressure	**50 bar**
Stand off distance	**45 mm**
Almen strip	**C-typ**





[3] Shot peening applications, Surface Technologies, Curtis Wright, p.45

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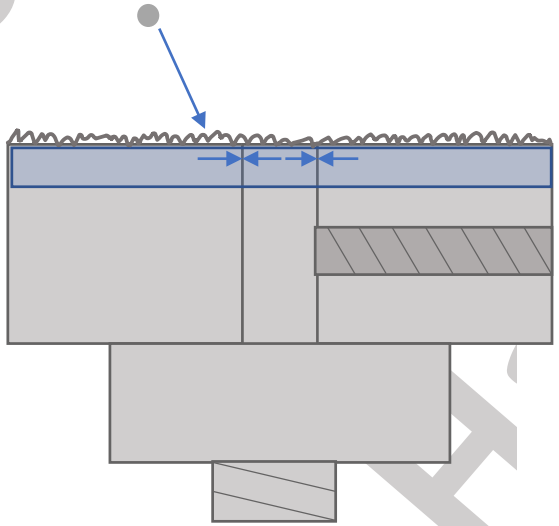
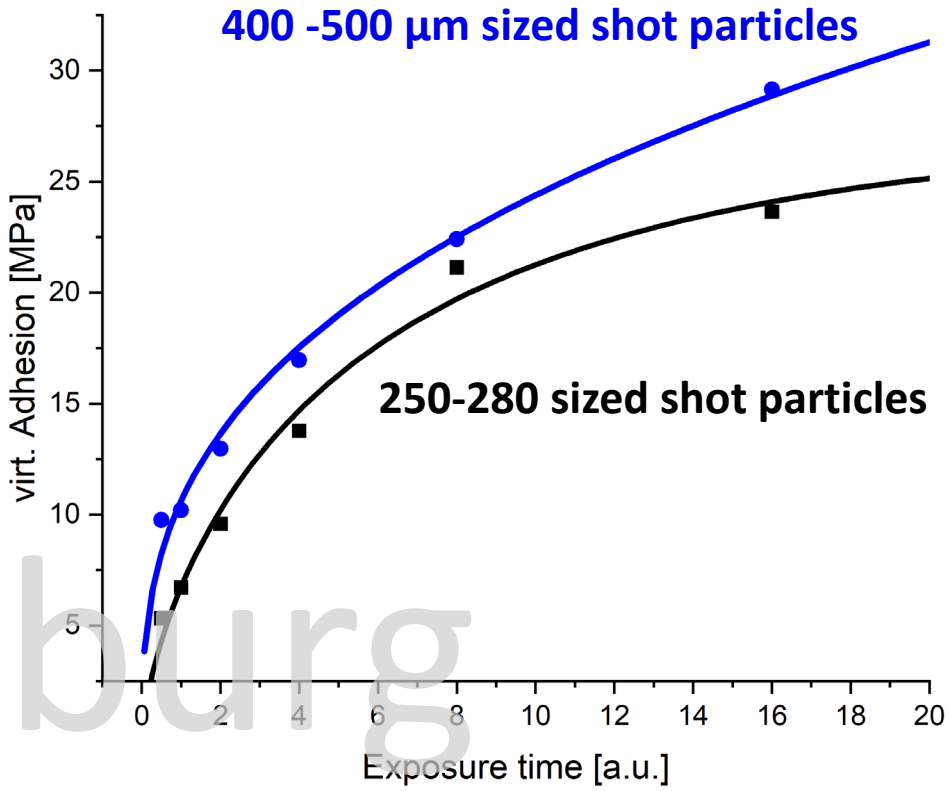
„Virtual“ adhesion as a result of shot peening





30 MPa „virtual“ adhesion as possible systematic error

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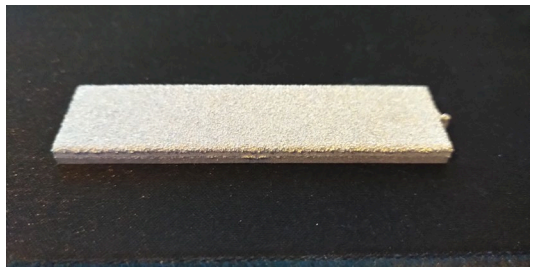
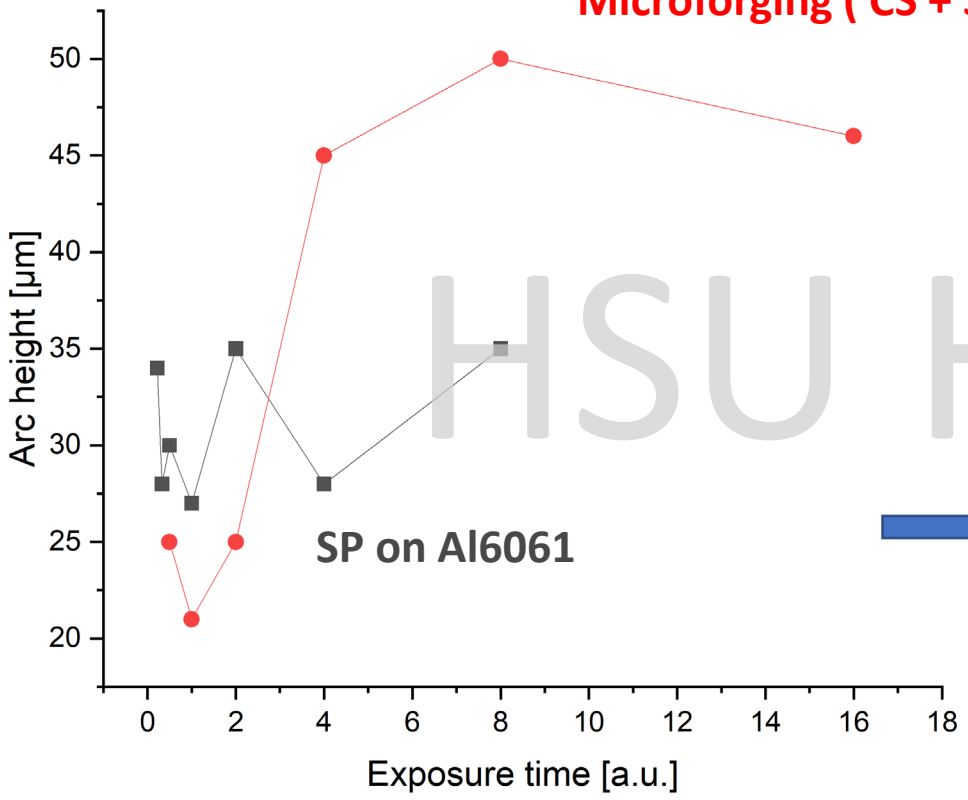
Arc height on Al6061 strips

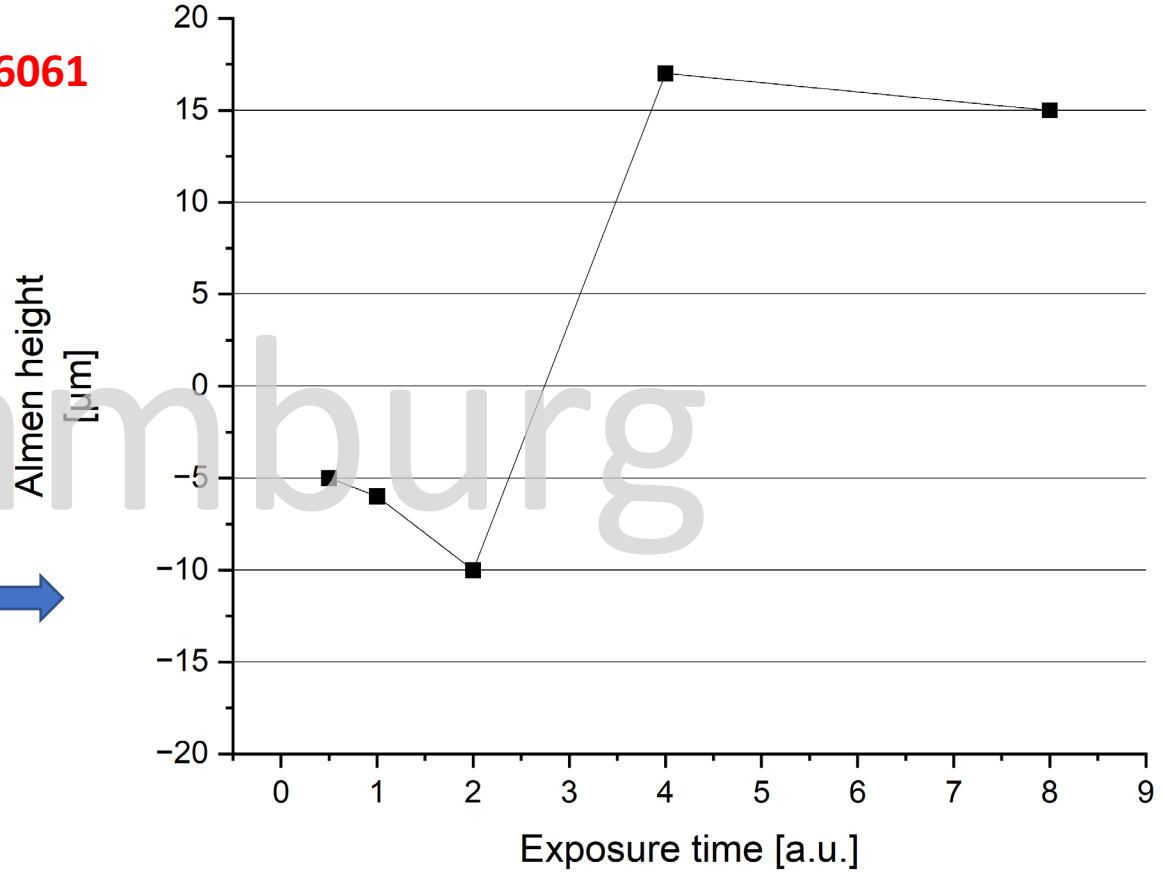


Control the systematic error via reference sample?

Microforging (CS + SP) on Al6061



MF – SP = CS



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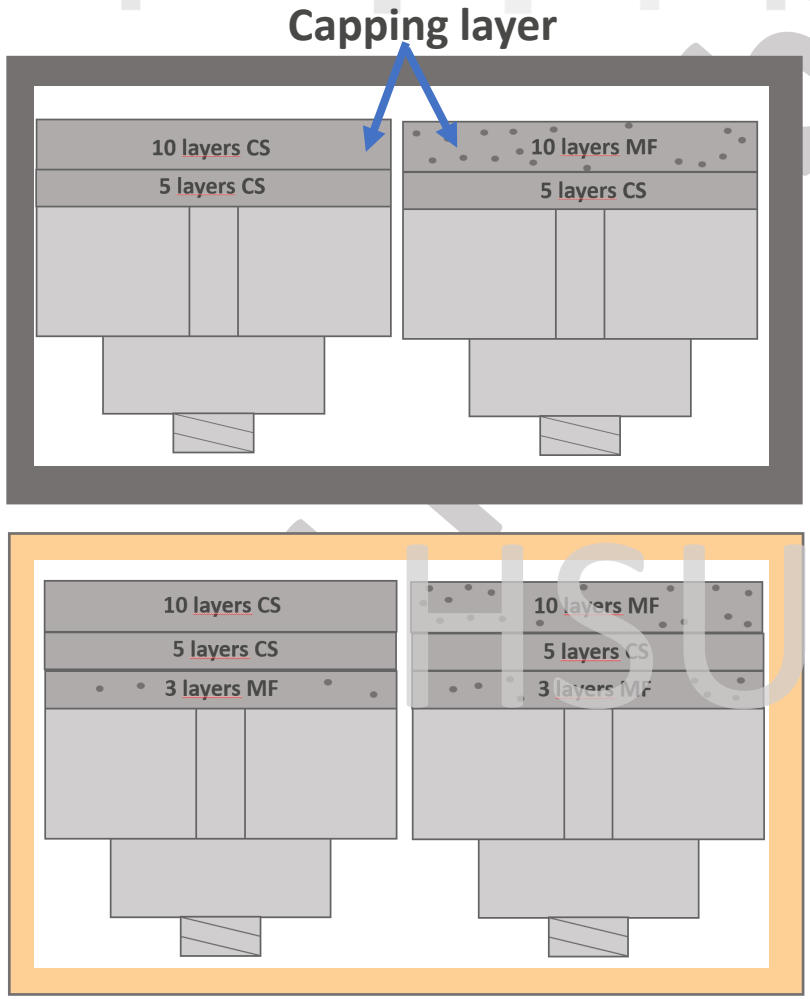
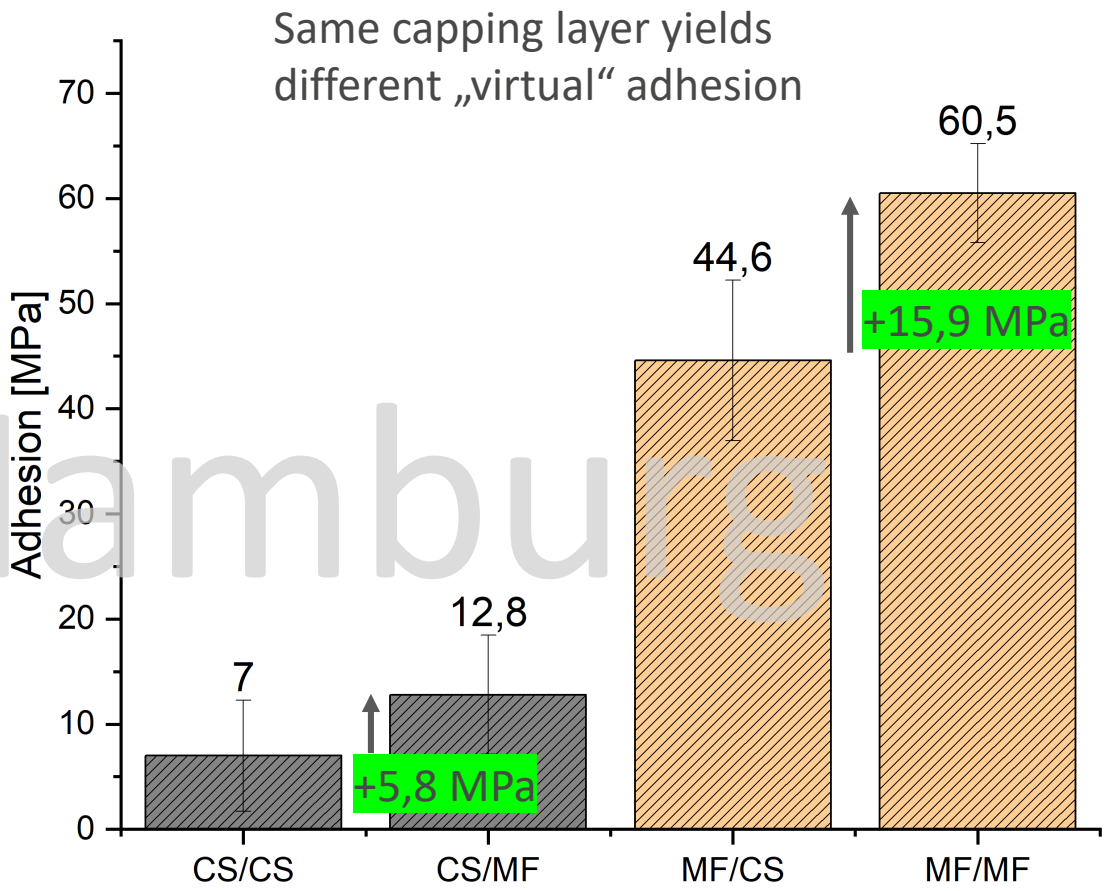
Virtual adhesion as a result of layering





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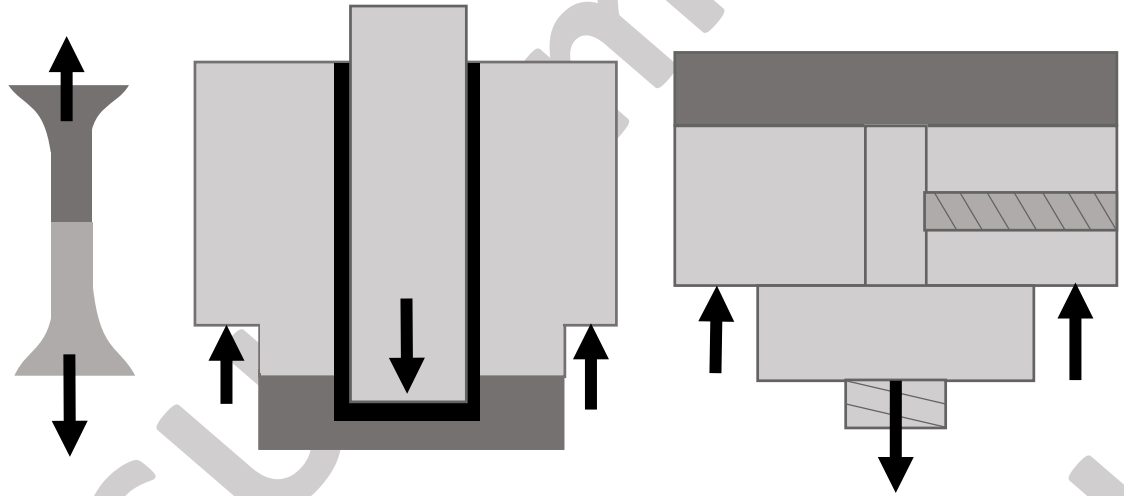
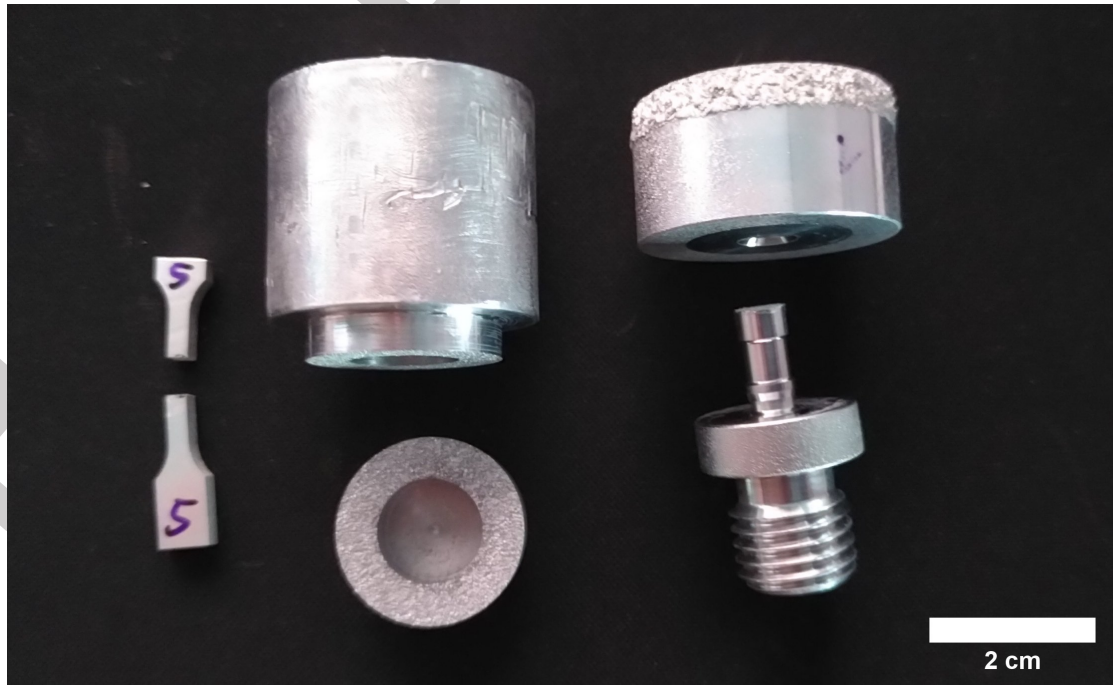
Comparison of adhesive free adhesion tests





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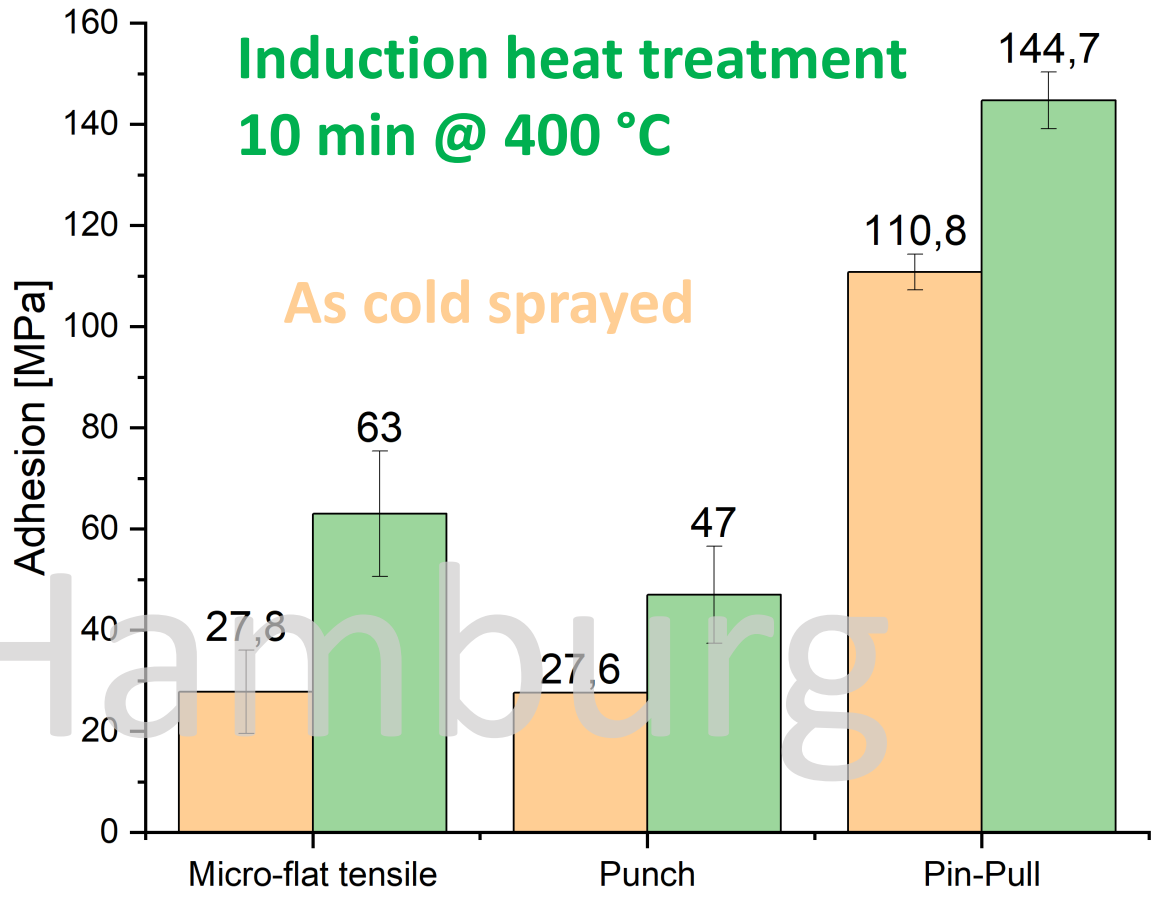
Comparison of adhesive free adhesion tests

Process gas	N_2
Temperature	550 °C
Pressure	20 bar
Stand off distance	60 mm
Powder	EN AW - 6061 20-38µm
Substrate	EN AW - 6061
Layers	60
FR Powder (fine disk)	2 RPM
FR Steel shot (coarse disk)	4 RPM



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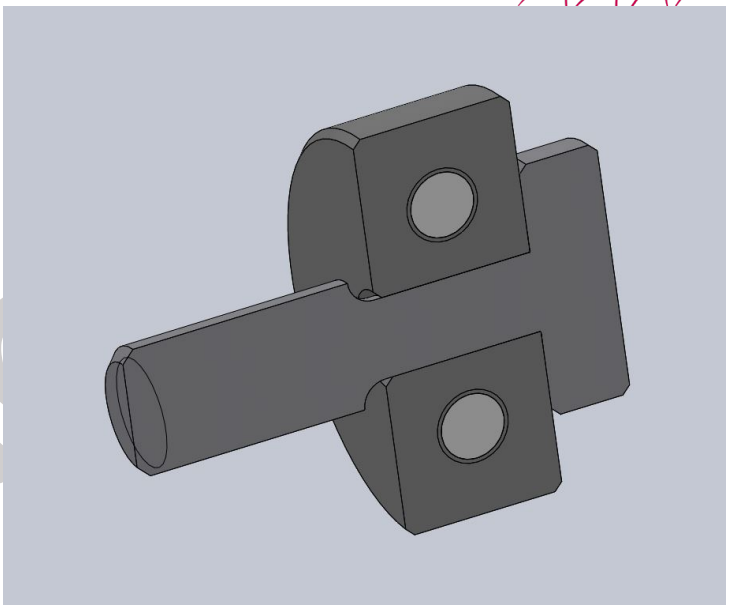
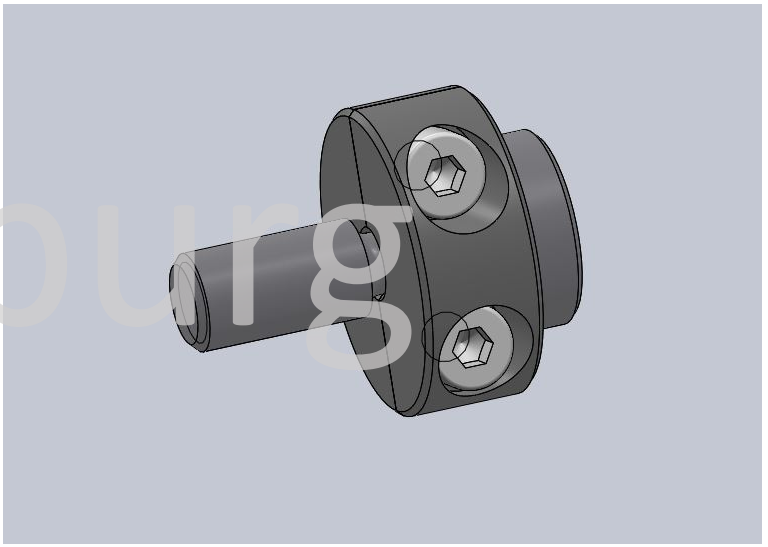
Pin pull geometrie for bulk tests





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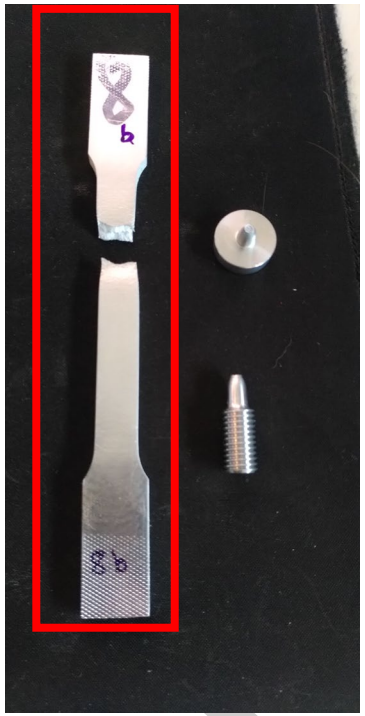
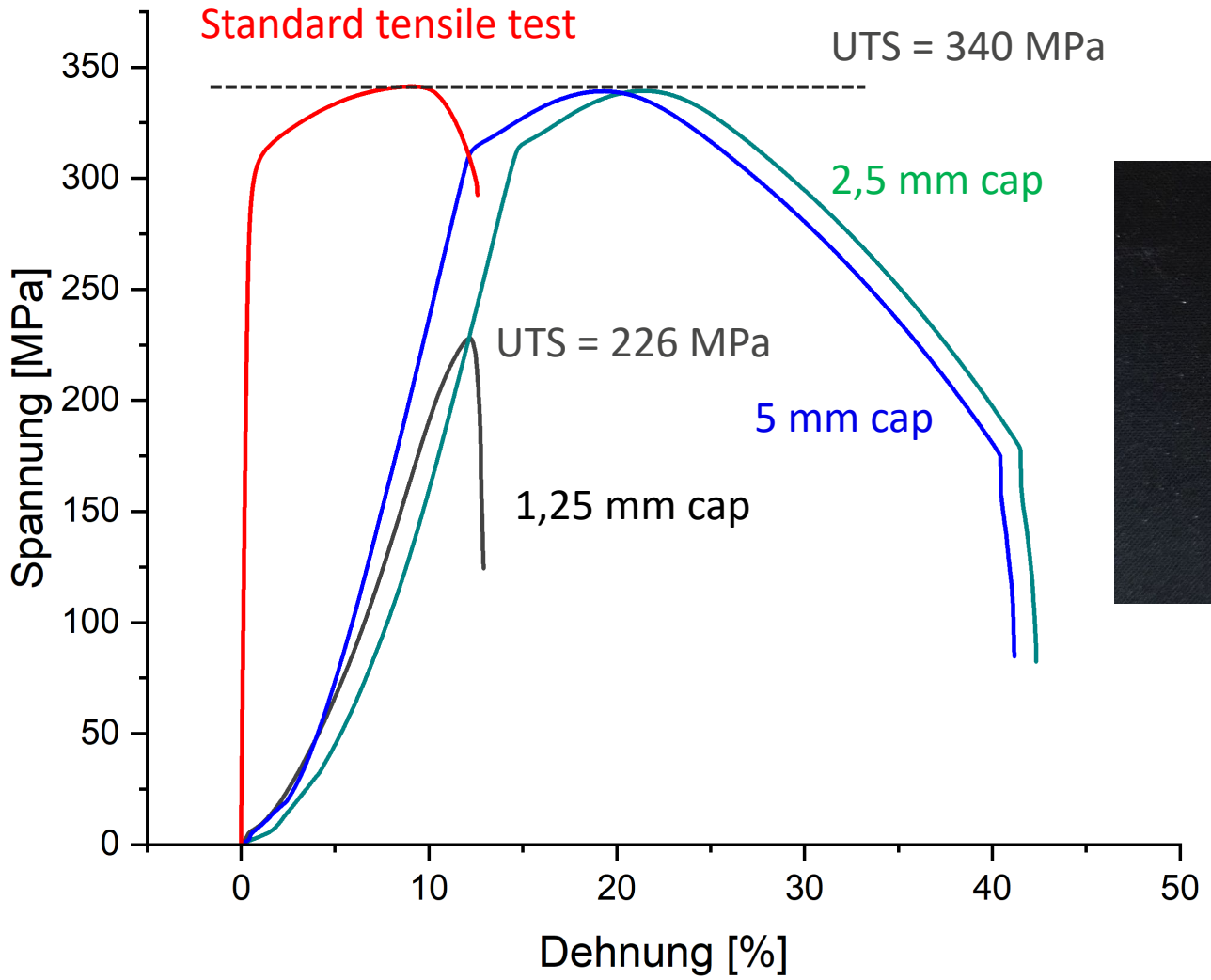
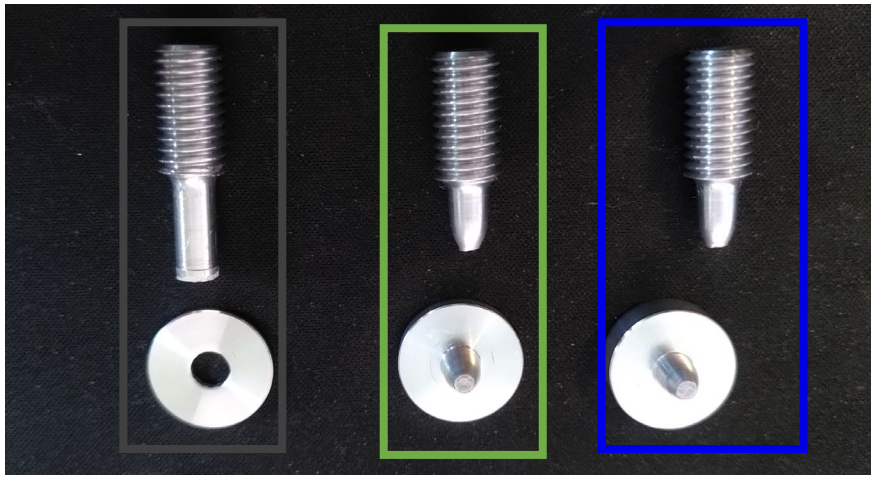
Pin Pull geometrie for bulk tests







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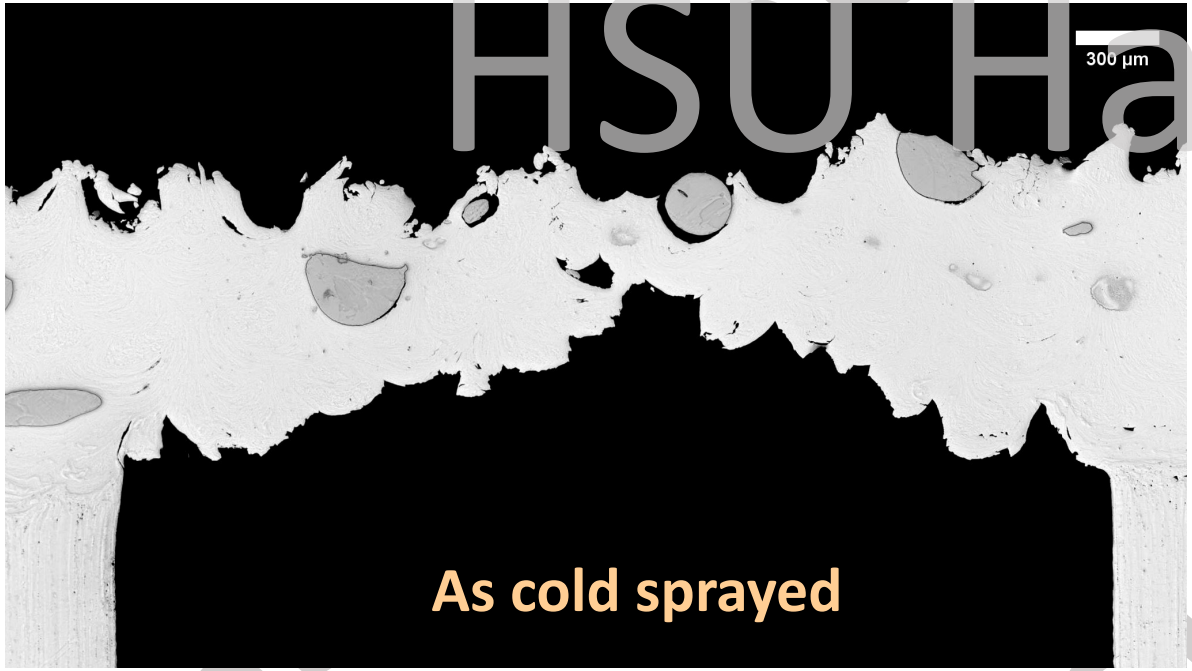
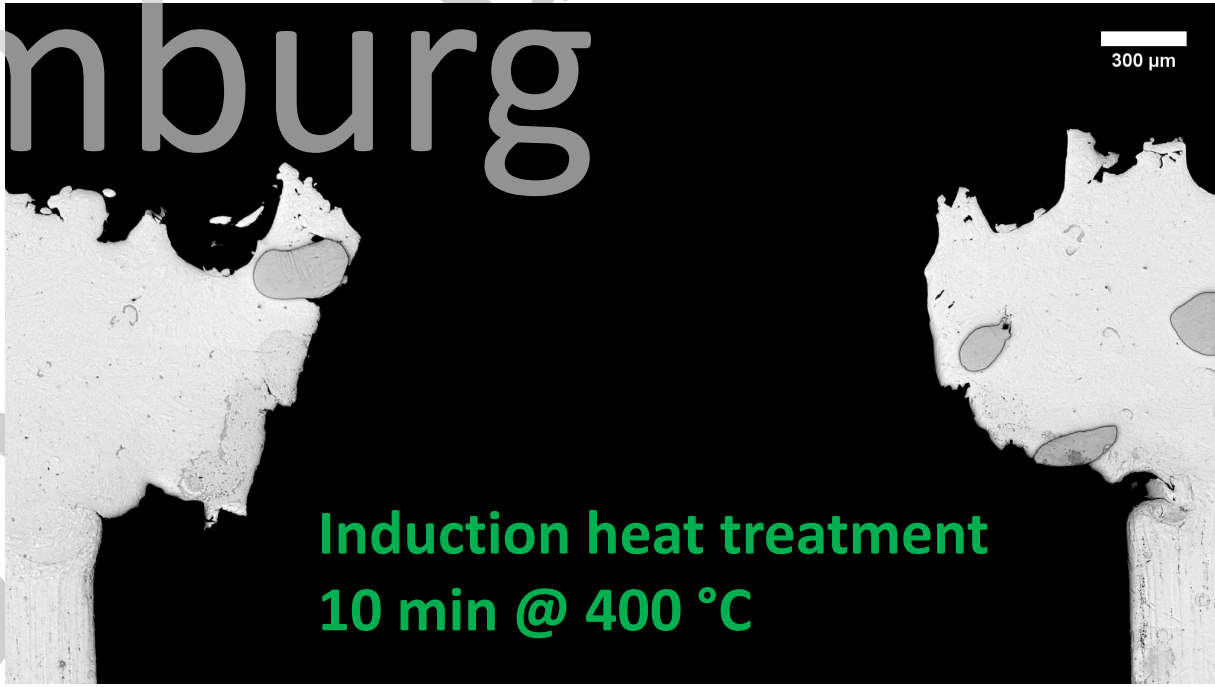
Insufficient coating thickness





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Learnings

- Application of the Pin Pull test is problematic in combination with microforging
  - Introduction of systematic error because of residual compressive stress, plastic deformation
  - Systematic error hard to quantify for individual spray parameters
- Micro-flat tensile and punch adhesion test yield similar results for MF samples in contrast to Pin Pull test
- Pin Pull test unreliable for thin coatings

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