



Development of feedstock material and monitoring tools for laser cladding of brake disks

Andreas Wank

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Outline

- Brief company introduction
- Motivation for laser cladding of brake disks
- Process characteristics
- Cladding properties
- Material concepts and cladding properties
- Cladding process control and monitoring tools



founded in 1983



~ 30 Mio. € turnover



2 locations
D-Luckenbach
CN-Beijing



94 employees
10 in RnD



Owners and CEOs:
Dr.-Ing. Klaus Nassenstein
Dr.-Ing. Konstantin von Niessen

Motivation for coating of brake disks

- Aesthetics
- Corrosion resistant friction ring surface
- Stable friction coefficient despite mostly regenerative braking
- Reduced particle emission
- Non-hazardous wear debris



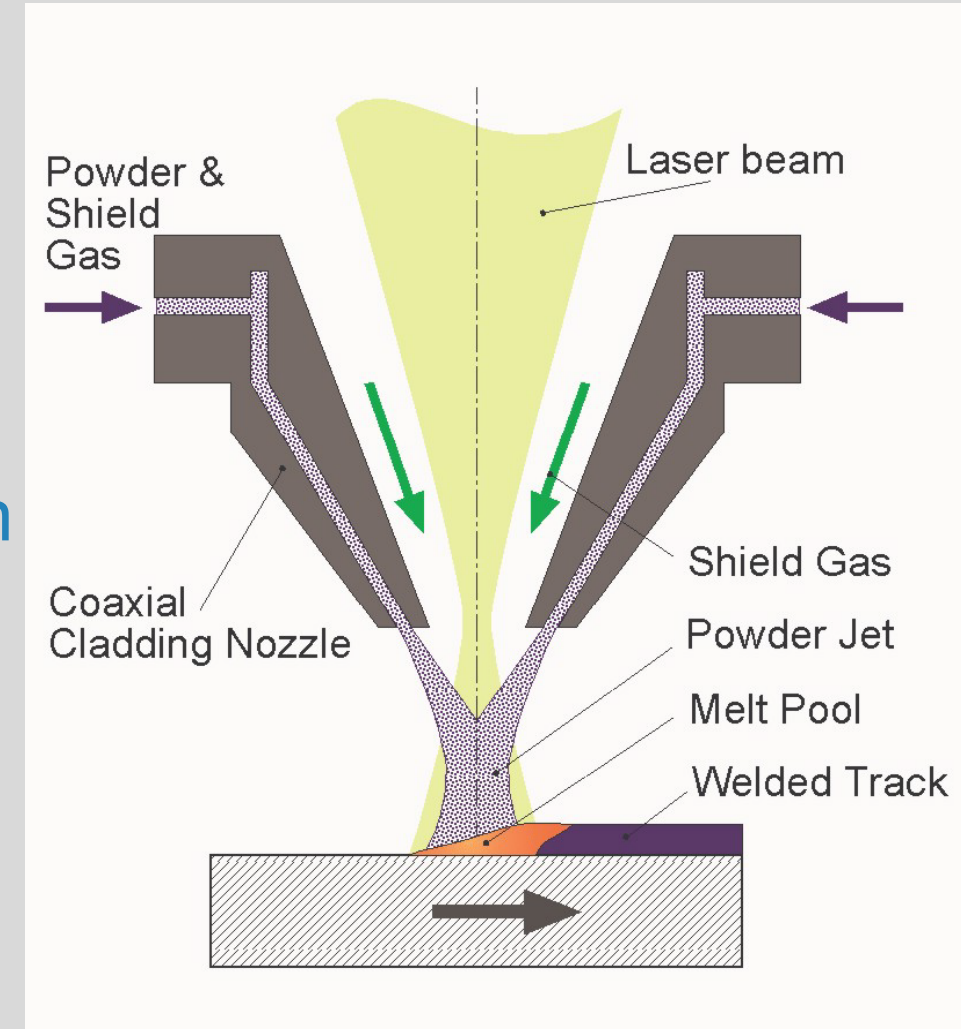
Motivation for laser cladding of brake disks

- Metallurgical bonding between substrate and coating
- Gas tight claddings
- Low heat input
- Low dilution with base material
- Limited distortion
- High deposition efficiency
- High deposition rate possible
- High reproducibility



Process characteristics

- 6-stream powder nozzle
tailored particle density distribution and
tailored speed of powder components
- Up to 22 kW laser power, 300 g/min
powder feed rate at 90% DE, 400 m/min
cladding speed, overlap > 90%
- 80 - 500 μm layer thickness
- Stainless steels + NbC / TiC / W_2C /WC



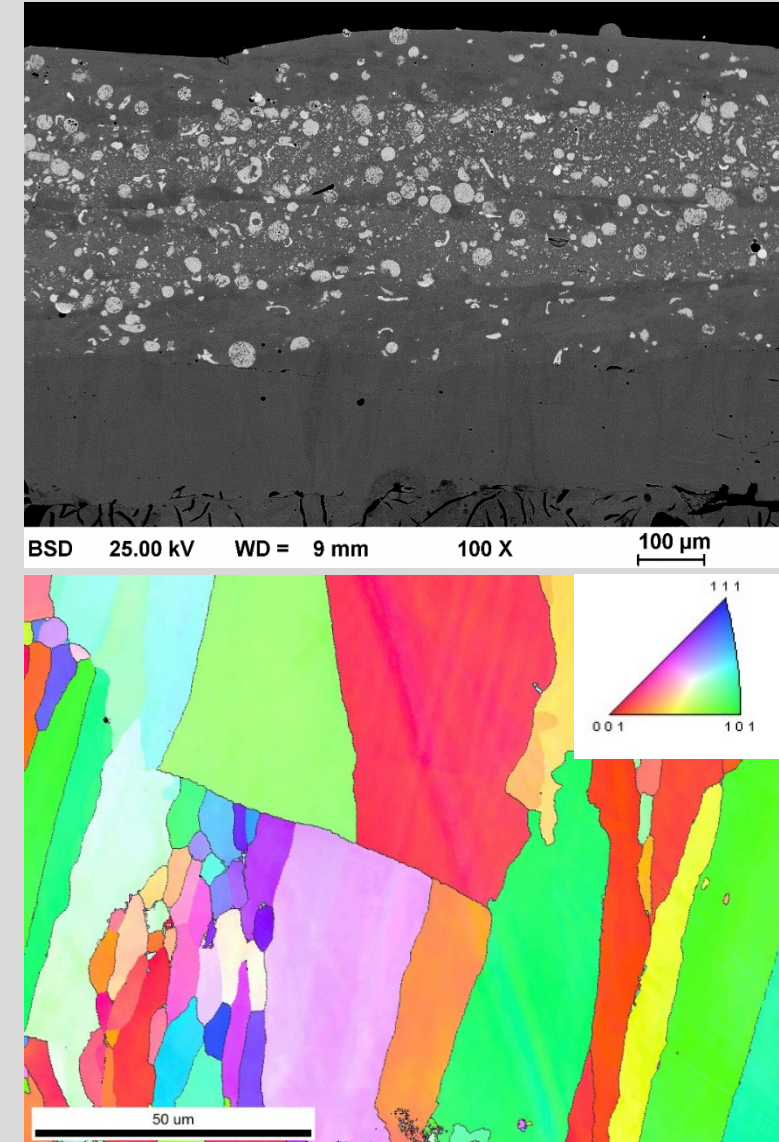


Laser cladding process



Cladding properties - microstructure

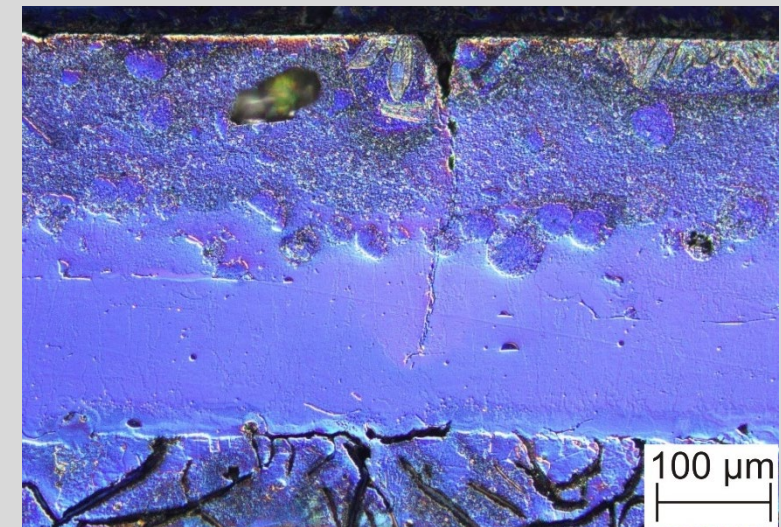
- Directional solidification
- Partially epitaxial crystal growth through bead and layer boundaries
- Multi-layer claddings with graded carbide content possible, advantageous stress state
- Pre-heating permits increased carbide contents without crack formation



Cladding properties - microstructure

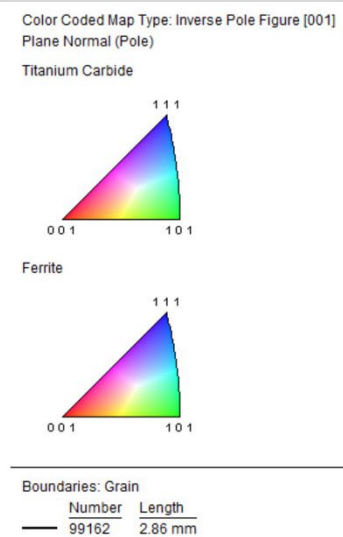
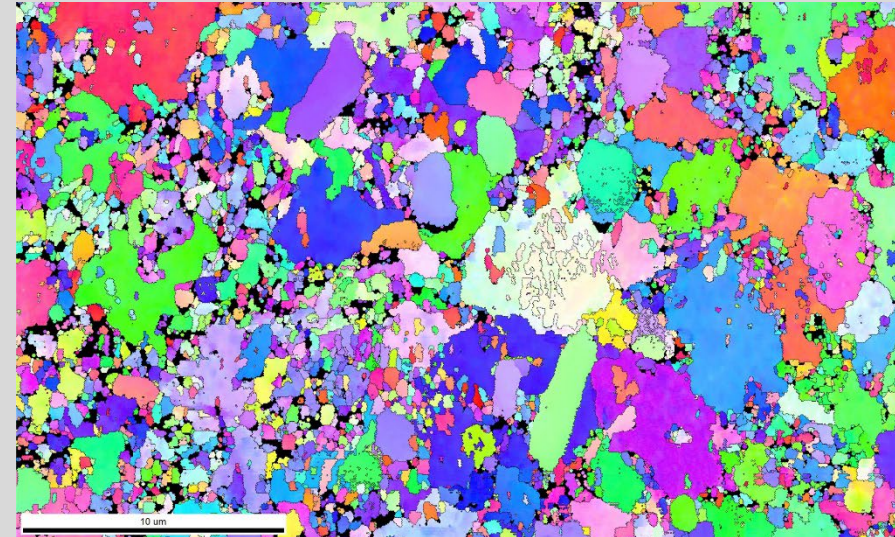
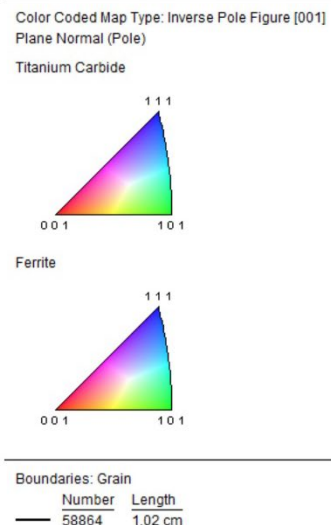
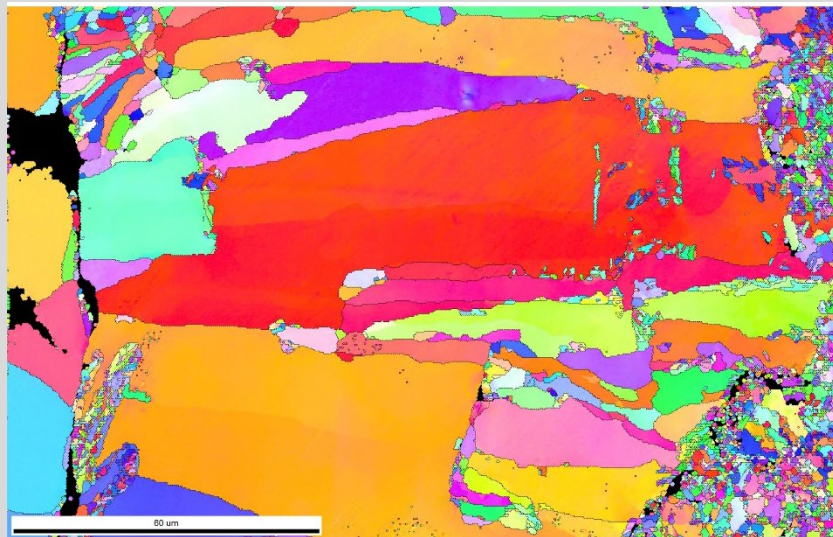
- Non-equilibrium phase composition
AISI318LN solidifies basically 100% ferritic
- Carbide reinforcement results in reduced orientation preference and smaller grain size
- Thermal crack tests cause crack initiation at surface, cracking starts in substrate before cracks propagate through base layer without carbide reinforcement

Phase	Total Fraction	Partition Fraction
Ferrite	0.996	0.997
Austenite	0.003	0.003



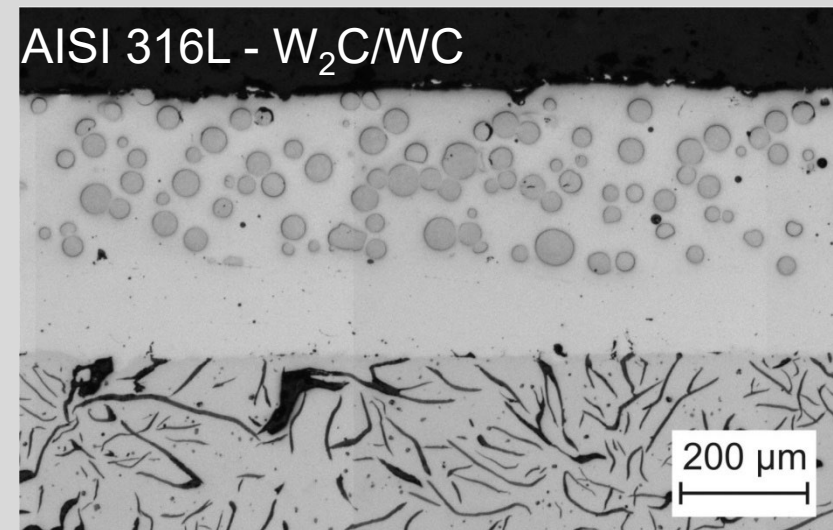
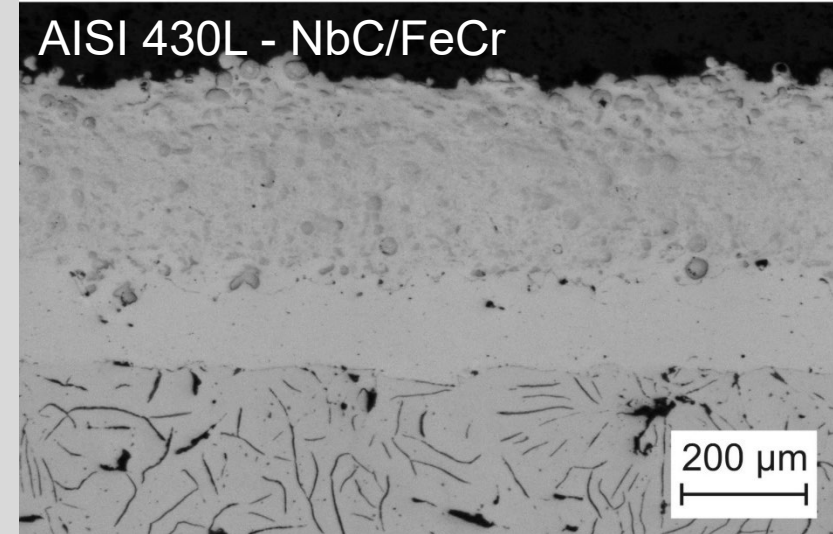
Cladding properties - microstructure

- Tribologically induced heat treatment during thermal crack testing causes grain coarsening only in grey cast iron substrates and stainless steel layers without carbide reinforcement



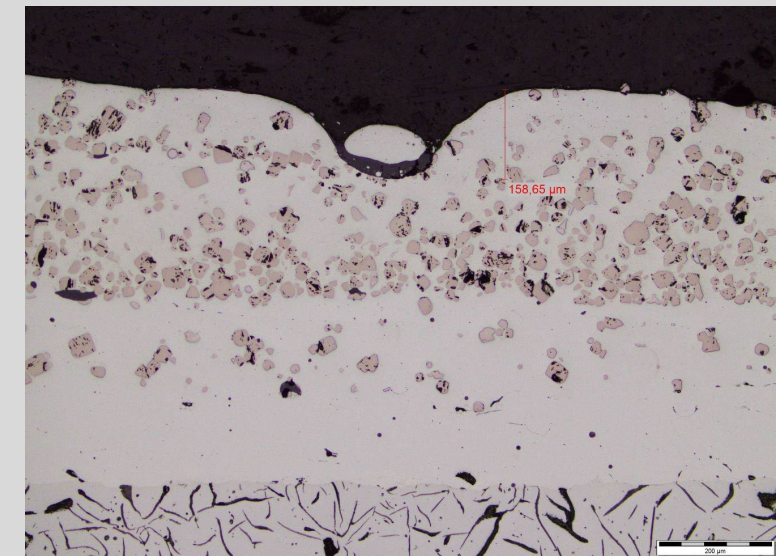
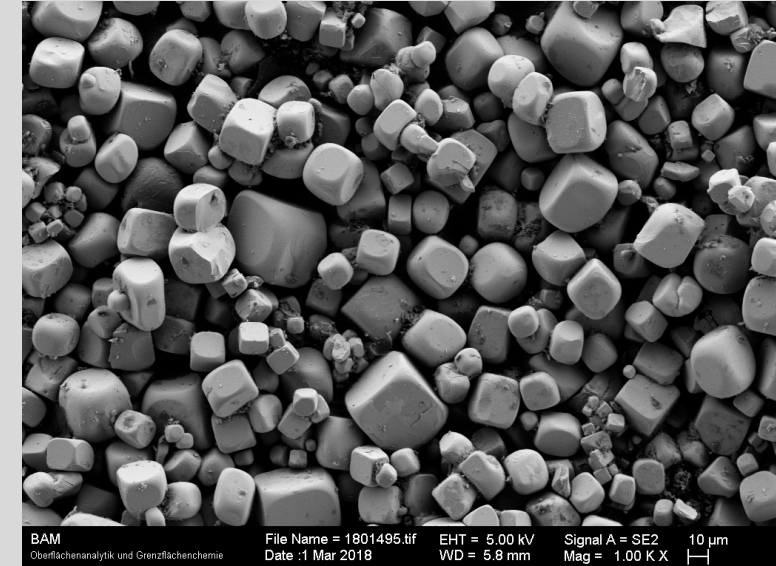
Cladding properties - microhardness

- 30 vol.-% NbC and TiC reinforced stainless steel layers show average microhardness of 450-700 HV0.3 (std. dev. < 100 HV0.3)
- 30 vol.-% W_2C /WC reinforced stainless steel layers show individual microhardness values of 400-2,500 HV0.3 with average of 900-1,400 HV0.3



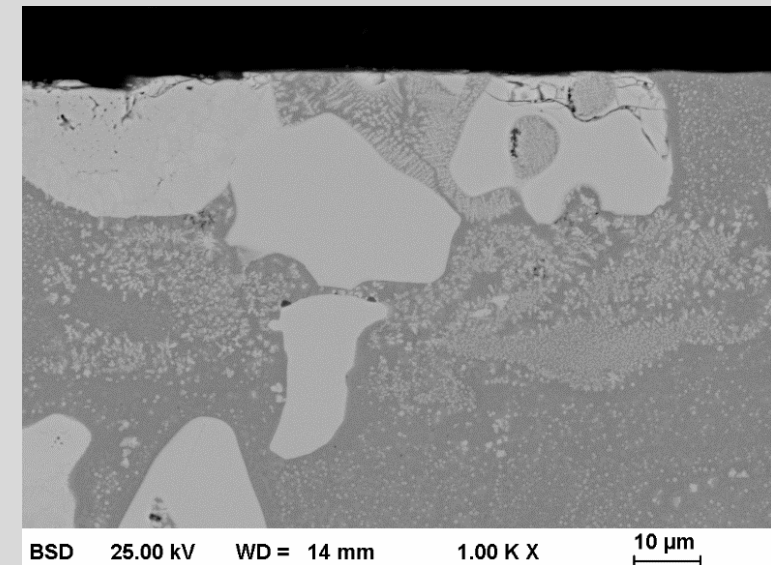
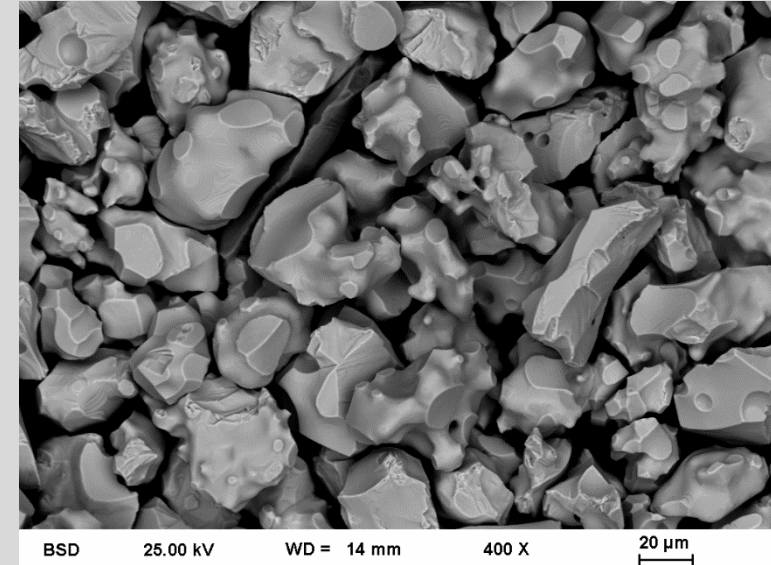
Cladding feedstock development

- NbC cubes, leached
- Avg. diameter $\sim 30 \mu\text{m}$
- Good feed rate stability
- Good wetting by stainless steel matrices
- Small specific surface area, low dilution
- Crater formation due to Al_2O_3 contamination arising from production process
- Limited availability



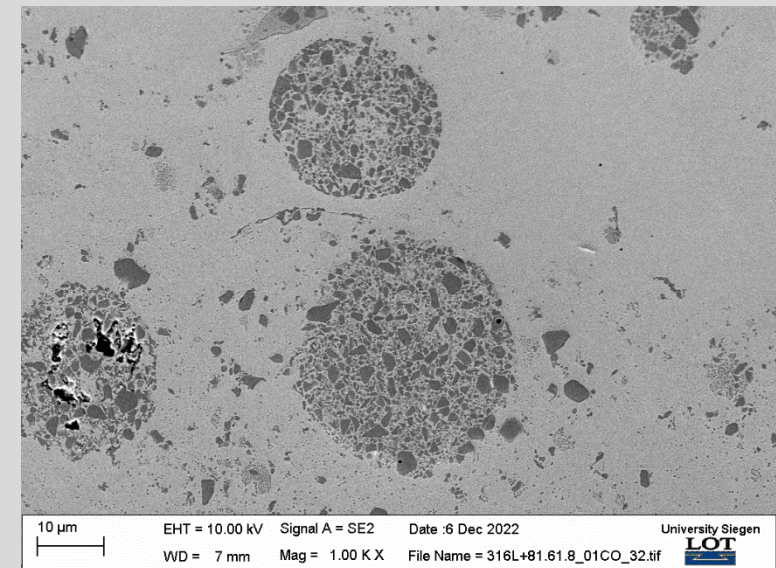
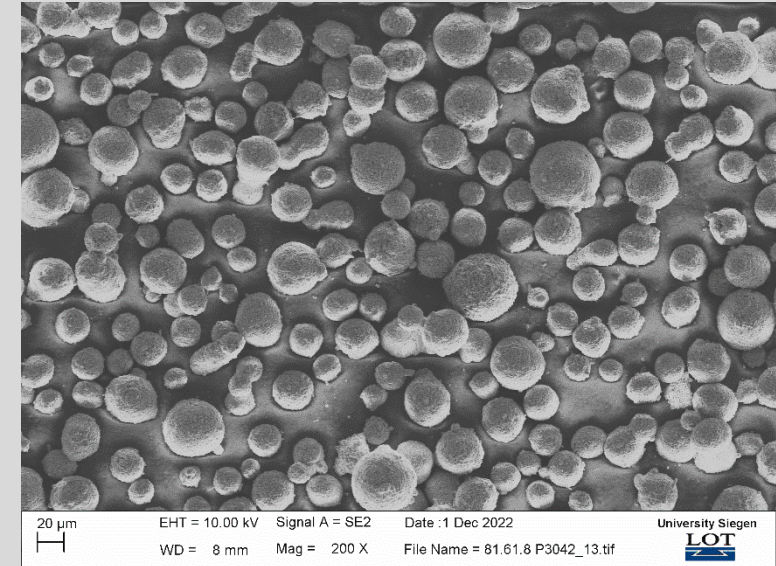
Cladding feedstock development

- NbC (/ TiC), sintered & crushed
- Avg. diameter $\sim 40 \mu\text{m}$
- Limited feed rate stability
- Good wetting by stainless steel matrices
- Large specific surface area, strong dilution
- Dendritic carbide precipitates
- Transfer of cracks caused by crushing procedure into claddings



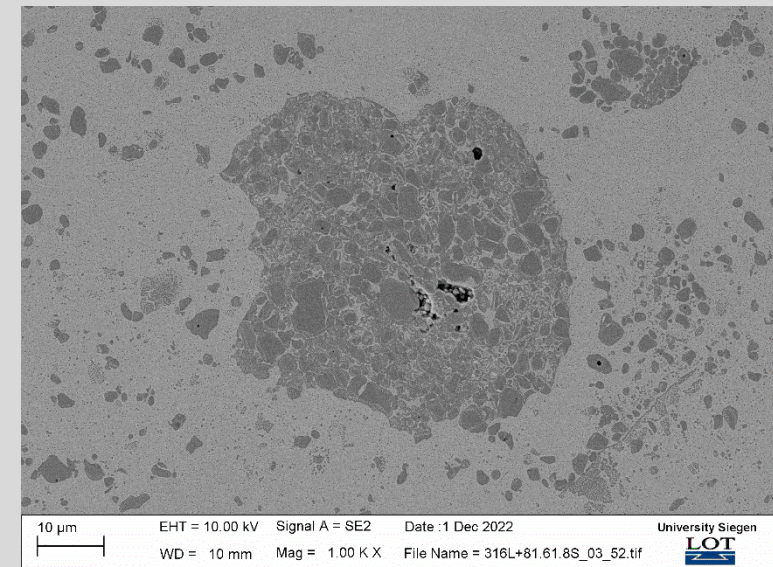
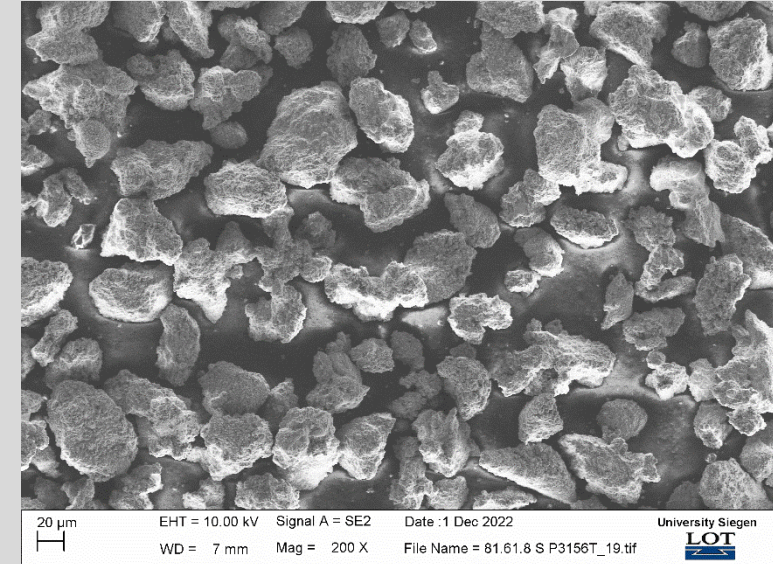
Cladding feedstock development

- TiC/FeCr (/ NbC/FeCr), aggl. & sintered
- Avg. diameter $\sim 25 \mu\text{m}$, FSSS $1 \mu\text{m}$
- Excellent feed rate stability
- Good wetting by stainless steel matrices
- Small specific surface area, low dilution
- Limited cohesion within large composite particles that are not penetrated by stainless steel melt



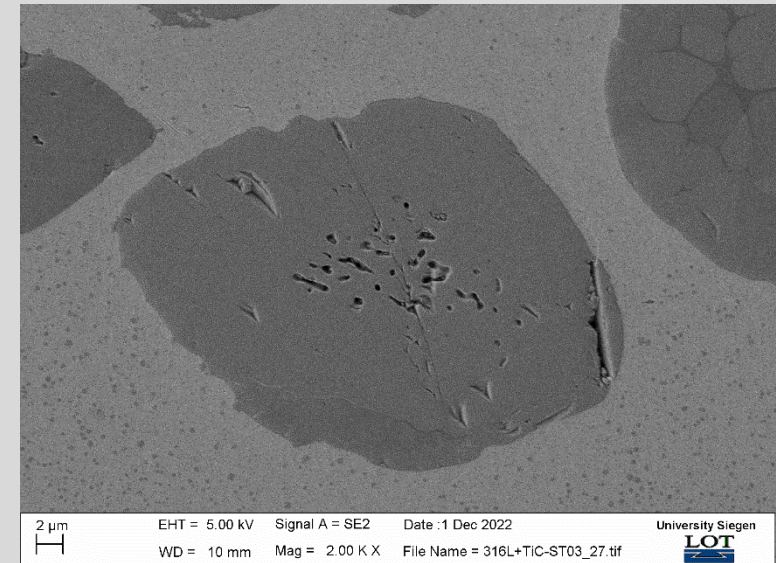
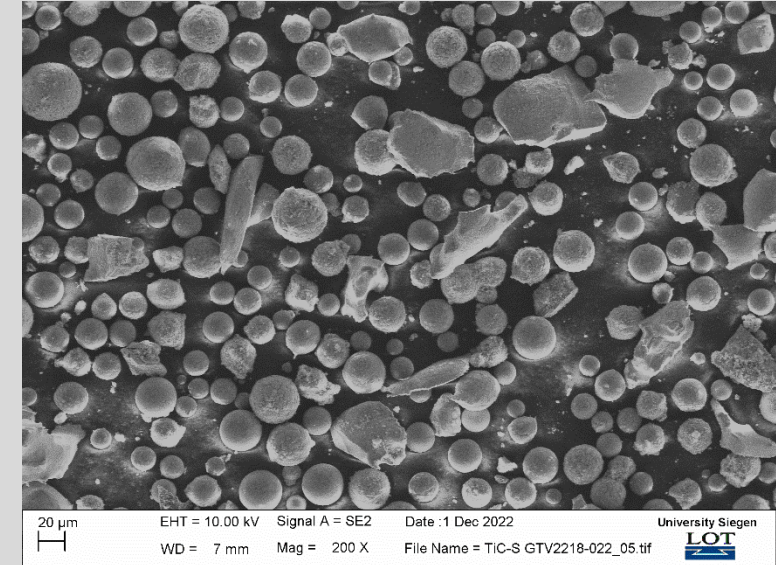
Cladding feedstock development

- TiC/FeCr, sintered & crushed
- Avg. diameter $\sim 40 \mu\text{m}$, FSSS $1 \mu\text{m}$
- Good feed rate stability
- Good wetting by stainless steel matrices
- Large specific surface area, low dilution
- High cohesion even within large composite particles that are not penetrated by stainless steel melt



Cladding feedstock development

- TiC (/ W_2C /WC), plasma spheroidized
- Avg. diameter $\sim 40 \mu m$
- Excellent feed rate stability
- Good wetting by stainless steel matrices
- Small specific surface area, low dilution
- Actually still limited availability

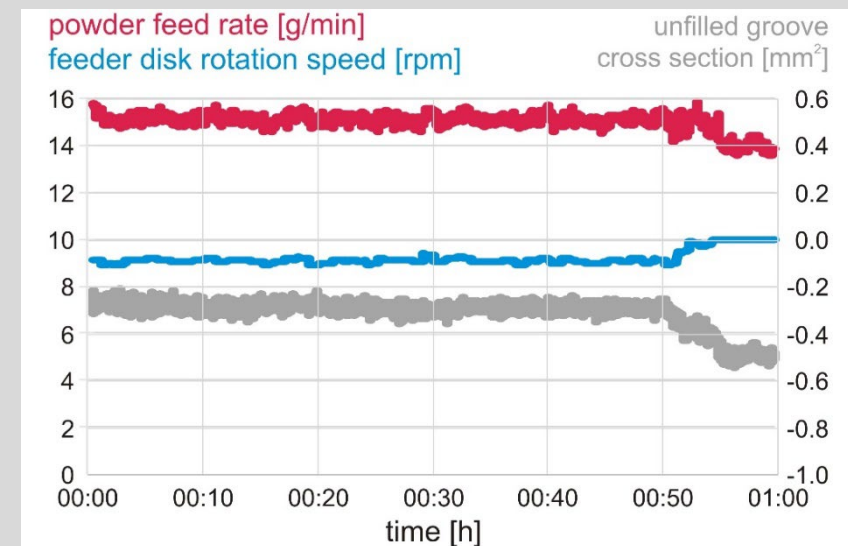
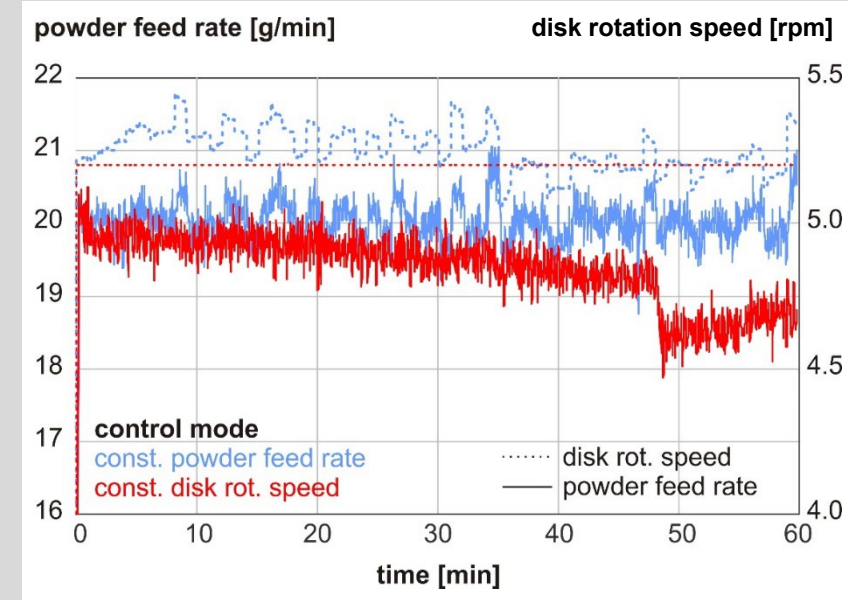


Cladding feedstock development

production route	feed stability	matrix wetting	dilution in matrix	availability	cohesive strength
leached	+	+	+	--	++
sintered and crushed	-	+	-	+(+)	0
agglomerated and sintered composite	++	+	+	+(+)	-
sintered and crushed composite	+	+	+	+(+)	+
plasma spheroidized	++	+	+	-	++

Process monitoring and control tools

- Disk type feeders permit fast change of powder feed rates for individual layers
- Scale powder feeders permit detection and compensation of abrupt and gradual change of powder feed rate
- Monitoring of disk groove filling level based on laser triangulation possible





Process monitoring and control tools

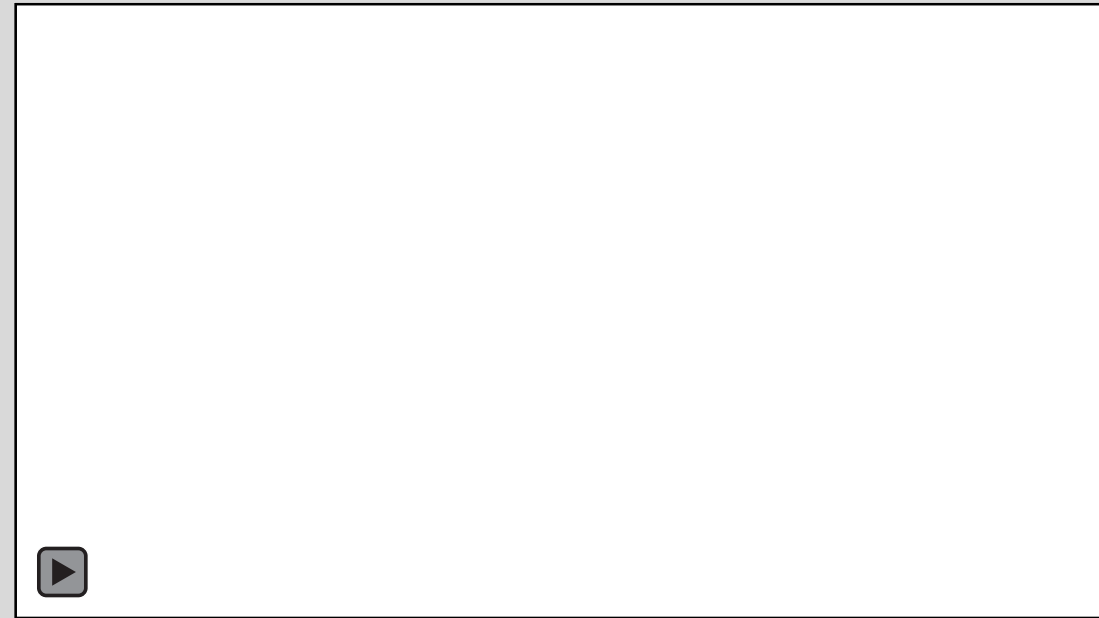
- Offline 3D powder stream analyses based on sheet laser illumination of inflight particles
- Evaluation of powder feed line and nozzle condition
- Automatic determination of characteristic factors





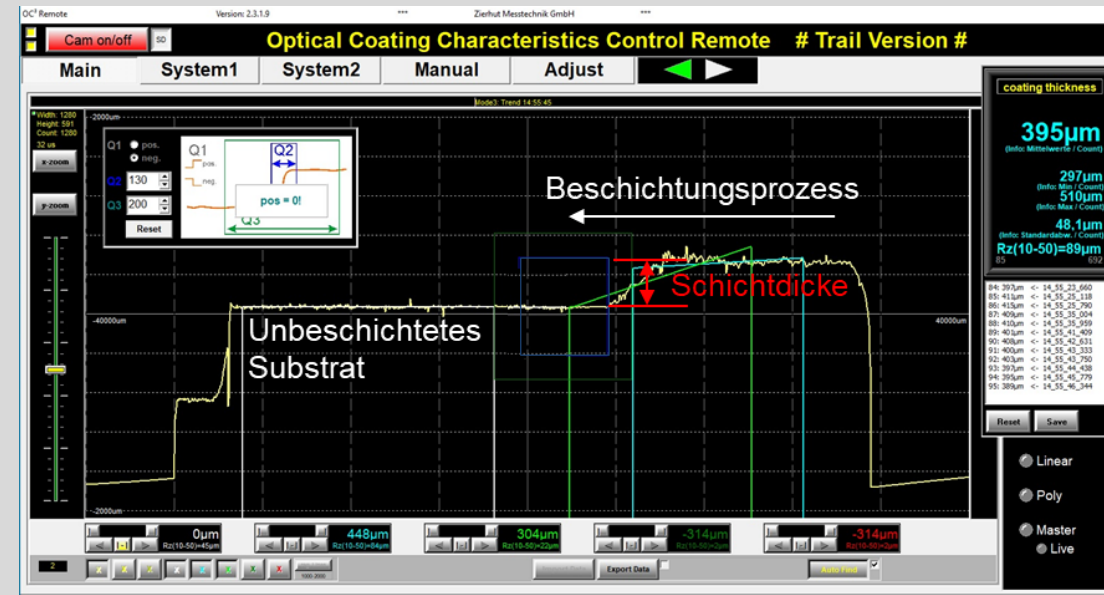
Process monitoring and control tools

- Online powder stream analyses based on sheet laser illumination of inflight particles
- Detection of blocked feed lines, pulsing powder flow and change of powder stream geometry
- Plasma formation over melt pool requires lateral camera images



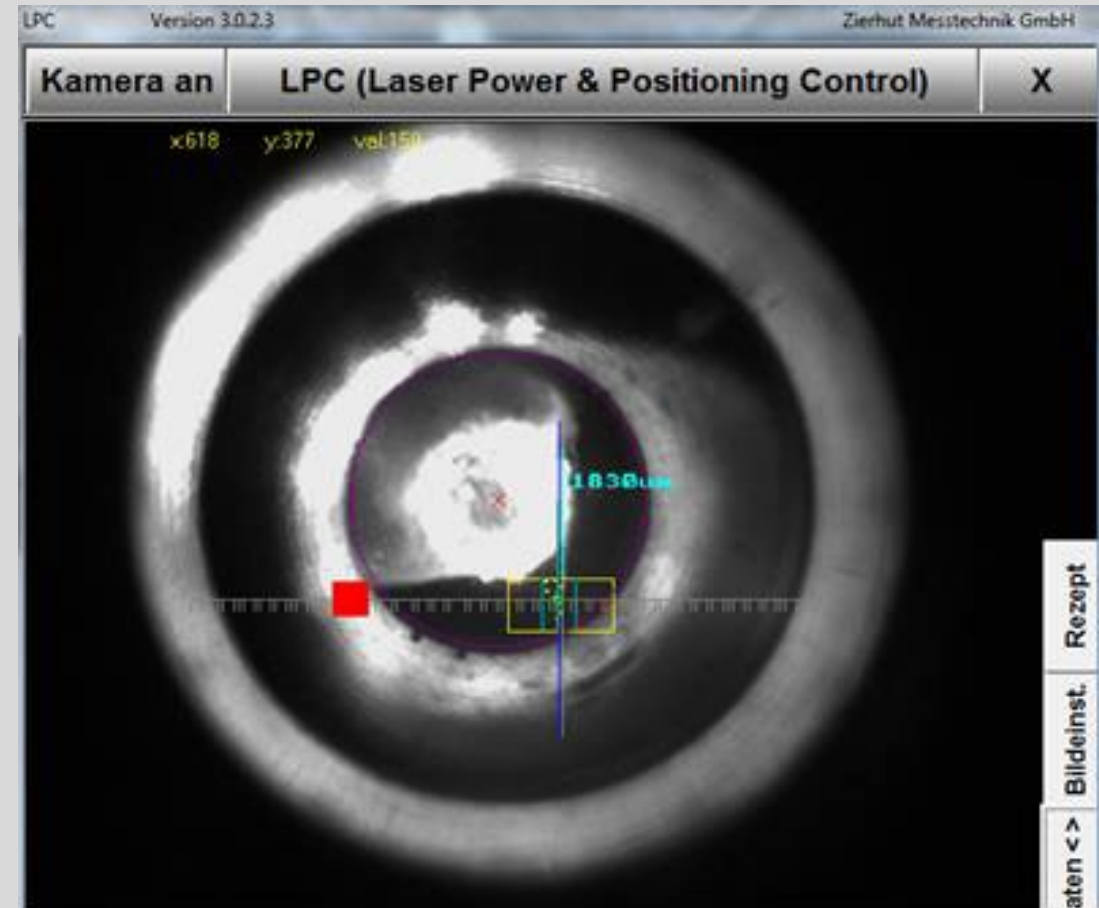
Process monitoring and control tools

- Online layer thickness monitoring based on laser triangulation sensor (7 μm accuracy)
- Difference of plain distances in front of and behind melt pool
- Online detection of crater formation possible



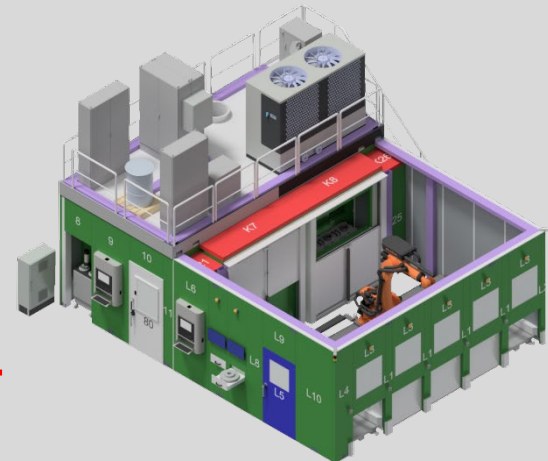
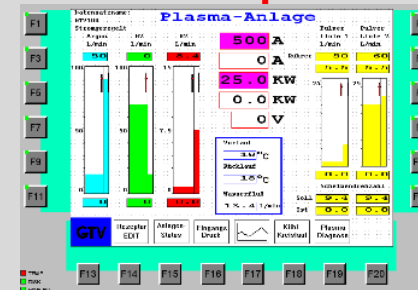
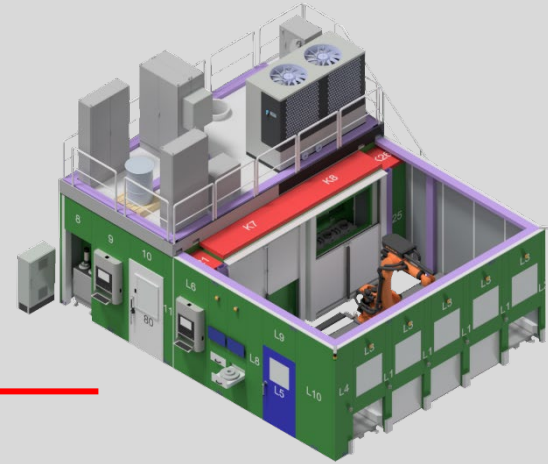
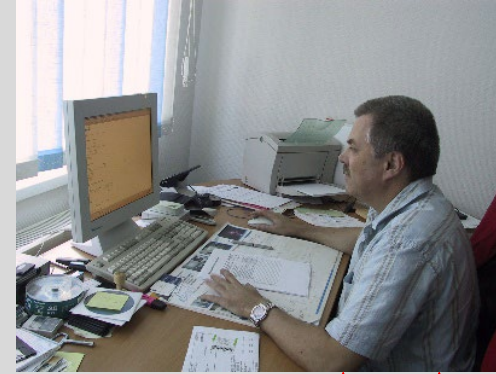
Process monitoring and control tools

- Optimal cladding of friction ring edges based on edge position detection
- Weighing of discs after deposition of individual layers
- Offline determination of laser power by calorimetry



Continuous process improvement

- Workpiece specific process and feedstock data from all processing steps combined with evaluation by (non-)destructive testing permits:
 - fine tuning of process limit values for secure detection of faulty workpieces
 - fine tuning of feedstock specification
 - adaptation of process parameters depending on feedstock properties





Summary

- High productivity laser cladding processes available for coating of grey cast iron brake rotors
- Ongoing development of optimized feedstock for optimal tribological performance and corrosion protective function of claddings
- Several offline and online process monitoring and control tools available for secure detection of impermissible process conditions
- Monitoring and control tool data can contribute to continuous process improvement

Thank you very much for your attention!



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