Influence of carbide feedstock on properties of protective laser claddings on grey cast iron brake rotors

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Outline

- Cladding process characteristics
- Cladding design
- Influence of reinforcing phases
  Spherical fused tungsten carbide
  NbC / TiC based powders
Cladding process characteristics

- 6-stream powder nozzle
tailored particle density distribution
tailored speed of powder components
- Up to 22 kW laser power
- Up to 300 g/min powder feed rate
- Deposition efficiency 87 - 92%
- Up to 400 m/min cladding speed
- Overlap > 85%
- 80 - 500 µm layer thickness
- Stainless steel + TiC, NbC or W₂C/WC
Cladding process characteristics
Cladding design

- **Multilayer claddings**
  buffer layer and graded hard phase contents reduce residual stresses
  production time, powder consumption and distortion increase with cladding thickness

- **Monolayer claddings**
  stricter hard phase content limitations to avoid crack formation
  reduced crack propagation resistance
  reduced wear resistance
Cladding microstructure

- **Directional solidification**
  stainless steel crystals cover full layer thickness for remelting of previous beads surfaces carbide reinforcement causes grain refinement and prevents grain growth due to thermo-mechanical load

- **Crystal structure**
  non-equilibrium phase composition due to high cooling rates; even Schaeffler diagram not applicable; e.g. AISI 318LN fully ferritic
W₂C/WC reinforcement

- **Carbide content**
  Crack free 30 vol.-% W₂C/WC - stainless steel layers only possible without pre-heating for use of buffer layers as well as limitation of friction ring surface area and cladding thickness

- **Microhardness**
  Inhomogeneous microhardness distribution; individual values of 400-2,500 HV0.3 with average of 900-1,400 HV0.3 for ten measurements
W$_2$C/WC reinforcement

- Flattening degree and degree of dissolution in stainless steel melts depend on heat transfer to inflight carbide particles.
- Heat transfer to carbide particles on their way into the melt pool can be tailored by particle speed / dwell time inside the laser beam.
NbC cube powder

- Route: Leaching
- Good feed rate stability
- Small specific surface area
- Low dilution in stainless steel matrix
- Availability: 2 t/a
- Crater formation due to Al₂O₃ contamination arising from powder production process
TiC / NbC, sintered & crushed

- Acceptable feed rate stability only for sufficiently coarse particle size
- Large specific surface area
- Strong dilution in stainless steel matrix
- Precipitation of dendritic carbides, embrittlement of matrix material
- Long cracks in as clad state due to lack of penetration of cracks originating from crushing process or crack formation during grinding procedure
TiC/FeCr / NbC/FeCr, aggl. & sintered

- Excellent feed rate stability
- Small specific surface area
- Low dilution in stainless steel matrix
- Formation of microcraters during grinding procedure or braking events possible, if porous composite particles are not fully penetrated by matrix material
TiC/FeCr / NbC/FeCr, sintered & crushed

- Good feed rate stability for use of sufficiently coarse particle size
- Large specific surface area
- Limited dilution in stainless steel matrix
- High cohesion even within large composite particles that are not fully penetrated by stainless steel melt
TiC, plasma spheroidized

- Only < 35 µm particles got fully melted
- Excellent feed rate stability
- Small specific surface area
- Low dilution in stainless steel matrix
- Actually limited availability and low production rate of plasma spheroidizers
## Carbide feedstock evaluation

<table>
<thead>
<tr>
<th>production route</th>
<th>feed stability</th>
<th>dilution in matrix</th>
<th>carbide crack resistance</th>
<th>cladding strength</th>
<th>availability</th>
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<td>leached</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>sintered and crushed</td>
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<tr>
<td>sintered and crushed composite</td>
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<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
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</tbody>
</table>
TiC/FeCr / NbC/FeCr reinforcement

• Carbide content
  Crack free 30 vol.-% TiC/FeCr / NbC/FeCr - stainless steel layers possible without pre-heating for use of buffer layers

• Microhardness
  homogeneous microhardness distribution;
  depending on matrix material average microhardness 450-700 HV0.3 with standard deviation < 100 HV0,3 for ten measurements

• Carbide band formation only for TiC observed
Effect of particle density distribution

- Control of local particle density permits influence on local laser interaction with substrate / previous cladding layer surface

<table>
<thead>
<tr>
<th>Rate</th>
<th>Material</th>
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<tbody>
<tr>
<td>28/29/27/27 g/min</td>
<td>AISI 430L steel</td>
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<tr>
<td>17/17 g/min</td>
<td>TiC/FeCr 70/30</td>
</tr>
<tr>
<td>32/32/24/23 g/min</td>
<td>AISI 430L steel</td>
</tr>
<tr>
<td>21/13 g/min</td>
<td>TiC/FeCr 70/30</td>
</tr>
</tbody>
</table>
Conclusions / Key takeaways

- High reproducibility brake disk cladding processes at 22 kW laser power available.
- Choice of reinforcing carbide powder takes influence on process stability, coating properties, availability and costs.
- Cheap machinery solutions might be costly due to lack of process control.
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