Thermal spray technology

- Applications -

Applications of thermal spray coatings

Applications

- HVOF coatings -

Applications of HVOF coatings
Typical spray materials
- Cermets: WC/Co(Cr), WC/Ni(Cr7C2), Cr7C2/NiCr
  Hard alloys: NiCrBSi, CoCrWC, CoCrMoSi, FeCrC

Aim
- Wear protection for surfaces of components build of cheap base materials or base materials that fulfill structural demands (strength, formability) in an optimal way; especially for dynamically loaded components (ceramics are not applicable due to not sufficient damage tolerance)
- Partially in combination with corrosion protection
- Abrasion resistant rough surfaces for secure fixation of components without damage of their surfaces (e.g. for Forming processes) or for transportation of piece goods (e.g. grippers, carrier rollers)

Hydro power plants
- Pelton-, Francis- and Kaplan turbine blades
- Especially for water with high content of abrasive particles (e.g. Huang He) HVOF WC/Co coatings are much superior to polyurethane
Doctor blades

- Improvement of edge stability and thereby also of lifetime compared to uncoated spring steel as well as APS Al₂O₃/TiO₂ or Cr₂O₃ coated blades
- Coating material: WC/Co 88/12

Wear protection

Doctor blades

- Continuous coating of band steel (thickness: 0.25 mm - 3 mm) on coiler
- Grit blasting on separate machine
- Optimized handling, component cooling and burner technology

Wear protection
Wear protection

Aeroplane landing gear
- Financially very attractive, but aviation approval is required; very time demanding

![Bombardier-de Havilland Dash 8 Main Landing Gear - Menasco](image1)

![F-18 Nose Landing Gear Messier-Dowty](image2)

**Wear protection**

Aeroplane landing gear
- Hard chromium replacement for military and civil aeroplanes
- WC/Co(Cr), because of high wear (and corrosion) resistance and improvement of fatigue properties of coated high strength steels due to high compressive residual stresses in coatings
- Overheating of components has to be securely avoided!
Titanium compressor blades

- Particle laden air causes severe wear especially of titanium alloy compressor blades
- HVOF WC/Co(Cr) coatings effectively protect blades; only partial coating (bands) is required

Demountable automotive drawing bars

- Duplex HVOF Ni20Cr + Cr2C3/Ni20Cr 75/25 coatings saves extensive wear protection measures
- Low dynamic bending strength of corrosion resistant aluminium alloys prevents broad application of this solution
Big diesel engines
- Repair coating of worn cylinder bores of diesel trains
- WC/Co due to high wear resistance and warm hardness
- Application of a special burner for internal coating production

Rollers in paper industries
- Drying and transport rollers
- WC/CoCr due to combined high wear and corrosion resistance as well as high thermal conductivity
- Addition of PTFE to reduce tendency of paper to stick
Rollers in paper industries
- Anvil rollers for production of corrugated paper
- WC/Co 88/12, 5 µm < d < 25 µm, for high wear resistance and low roughness already in as sprayed state (Ra = 2 µm)
- For suitable strategy of gun movement even coating thickness distribution on teeth of roller surface possible

Wear protection

Additional applications - WC/Co(Cr)
- Large piston rings (e.g. ship diesel engines, mining)
- Hydraulic cylinder
- Pump housings
- Protective bushings
- Vanes and slides
- Ventilator for fumes
- Worm gears for extrusion (alternative to PTA, rare)
- (Calender rollers) Problem: Roughness in superfinished state
- (Forming tools) Problems: Accessibility of surfaces, sharp edges
- Grippers
- Carrier rollers

Wear protection
### Further applications - Cr$_3$C$_2$/Ni20Cr
- Wear plates for wood machining
- Worm gears for transportation of slags
- Hydraulic cylinders
- Calender rollers
- Finned walls in fossil fuel power plants

### Further applications - NiCrBSi, FeCrC
- Rollers for printing machines (Hard chromium replacement)
- Worm gears for extrusion (rare)

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#### Wear protection

#### Demands
- Prevent material transfer between roller and steel band
- High wear resistance; long-term avoidance of surface defects that will be transferred to the steel band surface
- Cope with temperatures in operation without significant loss of surface properties by oxidation or loss of hardness
- Prevent slip between steel band and roller, because this would have detrimental effect on the appearance of the band steel surface

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**Tension pulleys for band steel production**
Tension pulleys for band steel production

**Solution**
- HVOF WC/Co(Cr), commonly applied: GTV 80.71.1
- WC/Co 88/12, 20 µm < d < 45 µm
- Porosity: 1% (depending on evaluation technique)
- Microhardness: > 1200 HV0.3
- Bond strength: > 70 MPa
- Coating thickness: 200 µm (common)
- Roughness: $R_a = 2\text{-}5 \mu m$
  (only removal of roughness peaks)
- Temperature in use:
  < 550 °C

Tension pulleys for band steel production

**Solution**
- Relatively high surface roughness ascertains prevention of slip between band steel and roller
- After removal of roughness peaks high abrasion resistance of the surface. Therefore friction conditions between roller and steel band remain constant even for long process time
- Low adhesion tendency between roller and steel band
Carrier rollers in heat treatment processes

Demands

- High oxidation and wear resistance
- High bond strength in the complete relevant temperature range, even under thermal cycling conditions
- High warm hardness
- Avoid material transfer between steel band and rollers
- Avoid slip between steel band and rollers

Solution

- HVOF Cr₃C₂/Ni20Cr 75/25 (GTV 80.81.1)
  - 20 µm < d < 45 µm
- Porosity: 1% (depending on evaluation technique)
- Microhardness: 1100 HV0.3
- Bond strength: > 70 MPa
- Coating thickness: 200 µm - 300 µm (common)
- Temperature in use: < 850 °C
  - (WC not applicable due to formation of volatile oxides for T > 550 °C)
Sink rollers for galvanizing lines

Demands
- High resistance against zinc (alloy) melt taking into account the applied flux also
- Low tendency to be wet by the zinc (alloy) melt
- Low tendency to take up zinc dross

Solution
- HVOF WC/Co(Cr), commonly applied: GTV 80.76.1
  WC/CoCr 86/10-4, 20 µm < d < 45 µm
- Porosity: 1% (depending on evaluation technique)
- Microhardness: 1400 HV0.3
- Bond strength: > 70 MPa
- Coating thickness: 200 µm
  (common)
- Application in combination with an adapted sealer!

Sink rollers for galvanizing lines
Sink rollers for galvanizing lines

Solution
- Up to now there is no really completely satisfying solution; HVOF WC/Co(Cr) coatings permit significantly improved lifetime compared to alternative approaches
- In laboratory dip tests CoCr- matrices showed improved lifetime compared to pure Co matrix
- Nickel matrices are not suitable due to fast dissolution in zinc melt
- Alternative (thermal spray) approaches: Cr, Cr₂O₃, MoBₓ/CoCr
- MoBₓ/CoCr is claimed to be superior to WC/CoCr (laboratory dip tests), but are much more expensive; material approach is not clear, because the Co(Cr) metallic matrix limits the lifetime - and not the embedded hard phase

Solution
- Sealers take a decisive influence on the lifetime of the rollers in use. Typical sealers that have proven to be suitable in industrial practice are:
  - Graphite in a thermal resistant binder
  - Hexagonal boron nitride in a thermal resistant binder
  - Porcelain
  - Molybdenum disulfide MoS₂
  - Hydrated chromium oxide
Copper moulds for continuous casting

Demands
- High resistance against wear by the cast steel
- No significant detrimental effect on heat transfer
- High bond strength in the complete relevant temperature range, even under thermal cycling conditions

Solution
- HVOF WC/Co(Cr), commonly applied: GTV 80.71.1
  WC/Co 88/12, 20 µm < d < 45 µm
- Porosity: 1% (depending on evaluation technique)
- Microhardness: > 1200 HV0.3
- Bond strength: > 70 MPa
- Coating thickness: 200 µm (common)
- Temperature in use: < 550 °C

Copper moulds for continuous casting
**Solution**

- WC/Co shows significantly higher thermal conductivity than Cr$_3$C$_2$/Ni20Cr
- WC/Co shows significantly higher difference in thermal expansion behavior to copper alloys compared to Cr$_3$C$_2$/Ni20Cr
- Bond strength of WC/Co coatings on copper is less than on mild steel; for evaluation of coatings suitability not only (shear) bond strength at room temperature but in the complete temperature range in use is relevant
- Up to now there is no detailed knowledge concerning optimal process parameters depending on mechanical and thermal load in use

> Suitable criteria for coating evaluation have to be considered!!!

**Copper moulds for continuous casting**

**Demands**

- High temperature oxidation resistance
- Low tendency to dissolve in or to react with steel melt
- High bond strength, even under thermal cycling conditions

**Copper moulds for continuous casting**
Copper moulds for continuous casting

Solution
- HVOF Hastaloy C (GTV 80.931.1)
  - $20 \mu m < d < 53 \mu m$
- Porosity: 1% (depending on evaluation technique)
- Coating thickness: 200 $\mu m$ - 500 $\mu m$ (common)
- Microhardness: 500 HV0.3

Fixation tools for forming processes (spin extrusion)
- WC/Co 88/12 coatings with 5 $\mu m$ average carbide size
- Clamping of cylindrical semi-finished parts of aluminum alloys or steels without surface damage
- One-step production of hollow (internal profiled) shafts

Coatings for friction enhancement
Coatings for friction enhancement

Fixation tools for forming processes (spin extrusion)
- Earlier applied toothed wedges damage the semi-finished parts surface (clamped section will be lost)
- Hard metal coatings permit fixation without damage

Additional applications - Ni20Cr, 316L
- Corrosion protection for rollers with low wear load
- Hydraulic cylinders
- Calender rollers
- Finned walls in fossil fuel power plants

Additional applications - nickel based super alloys
- Corrosion protection for components in chemical and petrochemical industries (Inconel 625, Hastaloy C)
- Rapid Prototyping of complex shaped combustion chambers build of Inconel 718 for aeroplanes
Hot gas corrosion protection

- MCrAlY coatings (M: Ni, Co), bond coats for YPSZ TBC’s
- Combustion chambers with up to 4.5 m diameter and up to 3.5 t weight
- For aero engines aviation approval required
- K2 permits particularly low oxygen content
- Replacement of VPS for cost reduction

Thank you for your attention!