Oerlikon Balzers Coating –
global leader in advanced
surface technology

Wim Geurts
Sales Engineer Nederland

How to fail or to perform with coatings?

20-04-2010 Petten
Company Overview – Six core competencies

1 Discontinued operations
Key data for Business Unit Oerlikon Balzers

- Unique company with global network for coating service
- Nearly 90 coating centres in more than 30 countries
- CHF 509 million sales in 2008
- About 2900 employees worldwide
- About 30% global market share (job coating)
- Approximately 3.5 times bigger than the No. 2
- More than 550 coating systems in operation
Close to you – anywhere in the world

22 Centres

America
Argentina
Brazil
Canada
Mexico
USA

40 Centres

Europe
Liechtenstein
Austria
Benelux
Czech Rep.
Finland
France
Germany
Great Britain
Hungary

Italy
Poland
Portugal
Romania
Spain
Sweden
Switzerland
Turkey

24 Centres

Asia
China
India
Indonesia
Japan
Korea
Singapore
Thailand

As of June 2009
Oerlikon Balzers Coating Benelux

Management:
David Franz

Marketing:
Willy Boghe

Sales:
Mathieu Desmet (B)
Wim Geurts (NL)

Product Management:
John Bexkens
Renaud Cuisinier

Quality & ISO system:
Tim Dètre

Customer Service:
Sylvia Pieraerts
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Pick-up service available on request
Leading companies rely on us

- Tool manufacturers
- Automotive industry
- Aircraft industry
- Metalworking industry
- Plastics processing industry
- Mechanical engineering and plant construction
Manufacturing flow for tool coating

Pick up

Job ordering

Cleaning

Batch loading

Coating

Packaging / dispatch
BALINIT® - one brand for many applications / History of 30 years

<table>
<thead>
<tr>
<th>Year</th>
<th>TiN</th>
<th>TiCN</th>
<th>TiAlN</th>
<th>WC/C</th>
<th>AlTiN</th>
<th>AlCr</th>
<th>P3e™</th>
</tr>
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<tbody>
<tr>
<td>1980</td>
<td></td>
<td></td>
<td></td>
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</table>
## Characteristics of BALINIT® Coatings for tools

### Multifunctional coatings

<table>
<thead>
<tr>
<th>Composition</th>
<th>Microhardness (HV 0.05)</th>
<th>Coefficient of friction against steel (dry)</th>
<th>Internal Stress (GPa)</th>
<th>Max. temperature of use (°C)</th>
<th>Colour</th>
<th>Coating temp. (°C)</th>
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</thead>
<tbody>
<tr>
<td>BALINIT® A</td>
<td>TiN</td>
<td>2380</td>
<td>0.4</td>
<td>-2.5</td>
<td>gold-yellow</td>
<td>480*</td>
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<tr>
<td>BALINIT® ALCRONA</td>
<td>AlCrN</td>
<td>3220</td>
<td>0.35</td>
<td>-3</td>
<td>blue-grey</td>
<td>480</td>
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<tr>
<td>BALINIT® R</td>
<td>TiCN</td>
<td>3090</td>
<td>0.4</td>
<td>-4</td>
<td>blue-grey</td>
<td>480</td>
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<tr>
<td>BALINIT® FUTURA NANO</td>
<td>TiAlN</td>
<td>3330</td>
<td>0.3 - 0.35</td>
<td>-1.3 / -1.5</td>
<td>violet-grey</td>
<td>480*</td>
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<tr>
<td>BALINIT® HELICA</td>
<td>AlCr-based</td>
<td>3090</td>
<td>0.25</td>
<td>-3</td>
<td>copper</td>
<td>480</td>
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</table>

### Coatings for optimal performance

<table>
<thead>
<tr>
<th>Composition</th>
<th>Microhardness (HV 0.05)</th>
<th>Coefficient of friction against steel (dry)</th>
<th>Internal Stress (GPa)</th>
<th>Max. temperature of use (°C)</th>
<th>Colour</th>
<th>Coating temp. (°C)</th>
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</thead>
<tbody>
<tr>
<td>BALINIT® C</td>
<td>WC/C</td>
<td>1500</td>
<td>0.1 - 0.2</td>
<td>-1</td>
<td>black-grey</td>
<td>&lt;250</td>
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<tr>
<td>BALINIT® CROVEGA</td>
<td>CrN</td>
<td>1750</td>
<td>0.5</td>
<td>-1.5 / -2</td>
<td>silver-grey</td>
<td>&lt;250</td>
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<tr>
<td>BALINIT® DIAMOND</td>
<td>Polycrystalline Diamond</td>
<td>&gt; 8000</td>
<td>0.15 - 0.20</td>
<td>-600</td>
<td>grey</td>
<td>800</td>
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<tr>
<td>BALINIT® HARDLUBE</td>
<td>TiAlN - WC/C</td>
<td>3000</td>
<td>0.15 - 0.20</td>
<td>-1.7 / -2</td>
<td>dark-grey</td>
<td>480</td>
</tr>
<tr>
<td>BALINIT® X.CEED</td>
<td>AlTiN</td>
<td>3300</td>
<td>0.4</td>
<td>-3 / -3.5</td>
<td>blue-grey</td>
<td>&gt;480</td>
</tr>
</tbody>
</table>
Comparison on scale of hardness
Wear resistant BALINIT® coatings for tools

- Cutting
  - Tool life
  - Productivity
- Punching/forming
  - Tool life
  - Dry running
- Plastics processing
  - Mould protection
  - Shorter cycle times
- Die casting
  - Wear resistance
BALINIT® coatings for precision components

Gears

Engine components

Hydraulic Compressor parts
Wear protection coatings for precision components

Rocker arm

Injection system
Wat zijn PVD coatings?

Physical Vapour Deposition

- Are attached at temperatures between 200 and 480 °C
- Thickness of the coating 1-16 µm
  - Standard: 3±1 µm
  - Thin (reamerproces): ±1 µm
  - Special: ±16 µm
- Strong adhesion of the coatings
- High hardness and low coëfficiënt of friction.
Thickness of the coating in comparison

Human hair
0.05 mm

BALINIT® hard coating
0.003 mm
Thickness of the coating

1 µm = \frac{1}{1000} \text{ mm}

hair: 50 - 100 µm

coating: 3 à 4µm
PVD - coating BALINIT®

- Only 0,003 mm thickness.
- Harder than steel.
- Ceramic properties
- Follows surface structure exactly.
IBAD (Ion Beam Assisted Deposition)
Ionplating-process

- Argon
- Substrates<br>  < 500°C
- Reactive gas
- Coating material
- Crucible (Anode)
- Low voltage arc discharge
- Vacuum pump
- Hot filament cathode
- Substrates
AIP (Arc Ion-Plating)
Arc evaporation-process

Argon  \rightarrow \text{Arc sources} \rightarrow \text{Substrates} \rightarrow \text{Reactive gas} \rightarrow \text{Vacuum pump}

< 500°C
Sputter process

BAI830C
Enhanced Sputter-process

- Argon
- Planar Magnetron-Sputtering source (coating material)
- Substrates
- Vacuum pump
- Hot filament cathode
- Reactive gas
- Auxiliary anode
- Low voltage arc discharge
- < 250°C
What are CVD coatings?

*Chemical Vapour Deposition*

- Are attached in vacuum at temperatures >800 °C
Cross section of PVD- and CVD- coating (TiN) on cemented carbide
### Difference PVD <> CVD

<table>
<thead>
<tr>
<th></th>
<th>PVD</th>
<th>CVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procestemperatuur</td>
<td>&lt;500°C</td>
<td>850 -1100°C</td>
</tr>
<tr>
<td>Hechting van de coating</td>
<td>Etsen, metallische binding</td>
<td>Diffusie</td>
</tr>
<tr>
<td>Microstructuur van de coating</td>
<td>Fijnkorrelig</td>
<td>Grofkorrelig</td>
</tr>
<tr>
<td>Invloed op het substraat</td>
<td>Onbeduidend</td>
<td>Tot 30% vermindering van de buigweerstand</td>
</tr>
<tr>
<td>Interne spanningen van de coating</td>
<td>Hoge drukbelasting</td>
<td>Spanningsbelasting</td>
</tr>
<tr>
<td>Snijkant hardmetaal</td>
<td>Zoals het substraat</td>
<td>Verzwakt (η− fase)</td>
</tr>
<tr>
<td>Coatbaarheid scherpe sneden</td>
<td>Ja</td>
<td>Neen</td>
</tr>
<tr>
<td>Dikte</td>
<td>1 - 4 µm</td>
<td>5 - 10 µm</td>
</tr>
<tr>
<td>Ruwheid van de coating</td>
<td>Zoals het substraat</td>
<td>$R_z&gt;2\mu$m</td>
</tr>
<tr>
<td>Coatbaarheid cermets</td>
<td>Ja</td>
<td>Neen</td>
</tr>
<tr>
<td>Milieuvervuiling</td>
<td>Onbestaande</td>
<td>Verwijdering metaalchloriden</td>
</tr>
</tbody>
</table>
Leap into a new Dimension
Innovative new technologies

P3e™ Technology
(Pulse enhanced electron emission)

- Metal oxide coatings of corundum type structure
- Opens a new field of applications for PVD
- Thick coatings possible
- Large degree of freedom in designing coating structures and coating properties

New coating system INNOVA

- With P3e™ technology or with standard technology
- New etching process
- High flexibility
INNOVA. The future of tool coating

**P3e™-Technology**  
**Pulsed Enhanced Electron Emission**

- $\text{Al}_2\text{O}_3$ layers deposited in PVD process below 600°C
- New pulsed technology
- New etching technology
- High pressures processes
- NADJA upgrade arc sources

Equipment available in Tiel since 12/2008
Thick layers are possible

- Multilayer oxide coating
- TiAlN base
Thermal stability

Inserts heated at 1000°C, 30 minutes, on air

- uncoated Carbide substrate (WC, Co) completely oxidized (blue colour due to Co-oxide)
- TiCN coating oxidizes, no protection of carbide substrate
- P3e™ (Al, Cr)₂O₃ protects carbide substrate at high temperatures from oxidation
Comparison P3e™ to standard PVD and CVD

<table>
<thead>
<tr>
<th>Properties</th>
<th>PVD</th>
<th>CVD</th>
<th>P3e™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deposition temperature</td>
<td>500°C</td>
<td>1000°C</td>
<td>500 - 600°C</td>
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<tr>
<td>Residual stress of coating</td>
<td>compressive</td>
<td>tensile</td>
<td>adjustable</td>
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<tr>
<td>Toughness</td>
<td>high</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Thermal cracks</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Maximum coating thickness</td>
<td>6 µm</td>
<td>&gt; 20 µm</td>
<td>&gt; 10 µm</td>
</tr>
<tr>
<td>α-Al₂O₃</td>
<td>no</td>
<td>yes</td>
<td>(Al,Cr)₂O₃ Corundum</td>
</tr>
</tbody>
</table>

P3e™ combines beneficial properties of PVD and CVD
First P3e™ aluminium oxide coating

X3turn
Coating structure of X3turn

*(Al,Cr)*₂*O*₃ corundum structure
Chemical and thermal wear resistance

TiAlN
Mechanical wear resistance

Cemented carbide substrate
Turning: equivalent to existing benchmarks

**Tool**
Insert, CNMG120408
Coating thickness 13 µm

**Workpiece**
Steel DIN 1.1221 (~AISI 1060)

**Cutting data**
\( f = 0.25 \text{ mm/rev} \)
\( a_p = 2 \text{ mm} \)
\( V_B_{max} = 0.3 \text{ mm} \)
dry

Source: Tool manufacturer

![Graph showing tool life comparison at different cutting speeds](chart.png)
BALINIT® DIAMOND
Properties of BALINIT® DIAMOND

<table>
<thead>
<tr>
<th>BALINIT® DIAMOND</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Composition</td>
</tr>
<tr>
<td>8-10000</td>
<td>Microhardness (HV 0.05)</td>
</tr>
<tr>
<td>0.1</td>
<td>Coefficient of friction against aluminium (dry)</td>
</tr>
<tr>
<td>6 - 20</td>
<td>Thickness (µm)*</td>
</tr>
<tr>
<td>≈ 600</td>
<td>Max. temperature of use (°C)</td>
</tr>
<tr>
<td>grey</td>
<td>Colour</td>
</tr>
<tr>
<td>800</td>
<td>Coating temp. (°C)</td>
</tr>
</tbody>
</table>
BALINIT® DIAMOND
1. Organic compounds:
   - Graphite
   - Composites (carbon fibers+epoxy, glass fibers+polyesters, …)
   - Reinforced plastics, honeycomb, foam, …

2. Semi-organic compounds:
   - Sandwich (Glare®, carbon-epoxy + Al alloys and/or Ti, …)
   - MMC (Al bases, Duralcan®)

3. Metallic compounds
   - Al-Si alloys (with or without Cu)
   - Al series 2000 and 7000 (under dry conditions)
   - in general non-ferrous alloys (platinum, palladium, …)
PPD - Pulse Plasma Diffusion Machine
With the integrated PPD technology, Balzers VST has set a new industry standard for the life long protection of cast iron tooling. Not only the maximum dimensions (largest vessel in the US), but new milestones have been set in quality of treatment, diffusion depth, surface finish and process control.

Advanced PVD - Physical Vapour Deposition Chamber
A new generation of PVD coatings increases the production up time on high strength structural parts that has only been seen possible with high temperature CVD coatings. The Advanced PVD coatings reduce the need for additional lubrication saving cost and the environment.

PA-CVD- Plasma Activated Chemical Vapour Deposition Chamber
Specially designed and developed coatings for the trimming and forming of Aluminium parts. Aluminium parts used to reduce the weight of the vehicle and improve fuel efficiency bring there own varied set of production problems which can be eliminated with Balzers VST's a-C:H coatings.

Metallurgic Laboratory
Extensive testing of coatings and metals, with 100% quality control of all treatments and processes.
BALINIT ARCTIC coating series
Wear protection coatings for tools

Low tempered steels are used
Coating temperature of 200°C is requested
What does ARCTIC mean?

ARCTIC coating series
- BALINIT® A ARCTIC
- BALINIT® D ARCTIC
- BALINIT® FUTURA NANO ARCTIC

Deposited at 200°C
Balinit® Arctic coating series

Coating temperature at 200°C has the benefits of:

- no loss of hardness for low tempered steel grades
- no effect on corrosion resistance
- prevention of distortion

Balinit® properties and performance are unaltered

Excellent coating adhesion
No loss of hardness for low tempered steel grades

Tempering diagram for steel: K107 (1.2436)

- Standard coating temperature
- ARCTIC coating temperature
No effect on corrosion resistance

Tempering diagram for steel:
M310
(1.2083)

Corrosion resistance [%]

Tempering temperature [°C]

Standard coating temperature

ARCTIC coating temperature
Prevention of distortion

Tempering diagram for steel: M310 (1.2083)

- Standard coating temperature
- ARCTIC coating temperature
ARCTIC coating series - properties

<table>
<thead>
<tr>
<th>Coating Series</th>
<th>Hardness</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>BALINIT® A ARCTIC (TiN)</td>
<td>2300 HV</td>
<td>- abrasive wear resistance - adhesive wear resistance</td>
</tr>
<tr>
<td>BALINIT® D ARCTIC (CrN)</td>
<td>1750 HV</td>
<td>- adhesive wear resistance - corrosion resistance - oxidation resistance</td>
</tr>
<tr>
<td>BALINIT® FUTURA NANO ARCTIC (TiAIN)</td>
<td>3300 HV</td>
<td>- abrasive wear resistance - high thermal stability - high oxidation resistance - high chemical stability</td>
</tr>
</tbody>
</table>

Deposition temperature 200°C

Max. coating thickness 5-6 μm (depending on tool size)
What are we able to coat?

- **Substrate size/weight:**
  - Max. dimensions: 700 x 1000 mm (external SPC L1500)
  - Max. weight: 600 kg

- **Coatable material:**
  - Metals like high speed steel, cold and hot working steel, stainless steel, carbide, cermet.
  - Requirements for hardened steels: **tempering temperature > coating temperature**
  - Copper and Aluminium type: please contact us

- **Surface finish and hardness:**
  - Blank material: no oxide layer, not chromed, ....
  - Clean, free of residues: no silicone, no glue, no paint, no plastic, no burrs, ....
  - Roughness: Ra ≤ 0,3 µm and Rz ≤ 3 µm
  - Hardness to be 55 HRc or more to avoid eggshell effect.
  - Demagnetised if possible.

- **Coating zone:**
  - Always a zone without coating, due to fixation of the tool
  - Coating inside holes is limited to 1D
# Coatable materials

<table>
<thead>
<tr>
<th>Hotwork-steel</th>
<th>Coldwork steel</th>
<th>Pre-hardened steel</th>
<th>Stainless steel</th>
<th>High Speed Steel</th>
<th>Bronze</th>
<th>Miscelanous</th>
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<tbody>
<tr>
<td>1.2323</td>
<td>1.2083</td>
<td>1.1151</td>
<td>1.4002</td>
<td>1.3202</td>
<td>Ampco 8</td>
<td>Ferro Titanit</td>
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<tr>
<td>1.2343</td>
<td>1.2316</td>
<td>1.1181</td>
<td>1.4006</td>
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<td>Ampco 18</td>
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<tr>
<td>1.2344</td>
<td>1.2362</td>
<td>1.1191</td>
<td>1.4021</td>
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<td>1.2360</td>
<td>1.2363</td>
<td>1.1221</td>
<td>1.4028</td>
<td>1.3245</td>
<td>Ampco 83 (300°C)</td>
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<td>1.2365</td>
<td>1.2369</td>
<td>1.2307</td>
<td>1.4034</td>
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<td>Ampco 88 (450°C)</td>
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<td>1.2367</td>
<td>1.2376</td>
<td>1.2311</td>
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<td>1.2567</td>
<td>1.2378</td>
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<td>1.4110</td>
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<td>1.2581</td>
<td>1.2379</td>
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<td>Ampco 940 (420°C)</td>
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<td>1.2603</td>
<td>1.2380</td>
<td>1.6582</td>
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<td>1.2678</td>
<td>1.2609</td>
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<td>1.4125</td>
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<td>Hovadur K220 (420°C)</td>
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<td>Hovadur K265 (450°C)</td>
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<td>1.2851</td>
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<td>1.4542</td>
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<td>Hovadur K350 (300°C)</td>
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<td>1.2777</td>
<td>1.3551</td>
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<td>CPM Rex M4</td>
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<tr>
<td>1.2799</td>
<td>CPM 9V</td>
<td>Elmax</td>
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<td>CPM Rex T15</td>
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<tr>
<td>1.2885</td>
<td>CPM 10V</td>
<td>M 390 PM</td>
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<td>ASP 23/ 30/ 60</td>
<td>Moldmax LH (375°C)</td>
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<td>1.2889</td>
<td>T440V</td>
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<td>S 390 PM</td>
<td>Moldmax HH (315°C)</td>
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<td>1.6358</td>
<td>Vanadis 4</td>
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<td>K190 PM</td>
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<td>SMV 5</td>
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</tr>
</tbody>
</table>
Some examples....
Considerably higher service life with BALINIT®

**Hobbing of gears**

- **Tool:** PM-HSS hob
- **Workpiece:** Steel, DIN 1.7131 (~ AISI 5115)
- **Cutting parameters:**
  - $v_c = 200$ m/min
  - $V_B \sim 0.3$ mm
  - Dry
- **Source:** Automotive manufacturer

![Graph showing manufactured parts comparison](image)

- 4,100 pc. BALINIT® ALCRONA
- 2,300 pc. AlTiN / Competitor

+ 80 %
Finishing carbon steel (C45E)

Parameters
- End milling
- Finishing
- Coated carbide
- Wet
- \( VB_{\text{max}} = 0.12 \text{ mm} \)

![Graph showing tool life vs. cutting speed for different coatings and resistance properties.](image-url)
ALCRONA in punching & forming

**Explanation:**
Wear comparison TiN with Alcrona after 970,000 strokes

**tool:**
Contour punch
ASP23 (1.3344 HRC 64)

**workpiece:**
steel sheet C22
thickness 1.25 mm

**Process parameter**
Frequency: 125 spm
Punch
displacement/stroke: 4mm
**Ophangbeugel Ford Ka**

**Materiaal**: HLE (High Level Elasticity Steel) 4mm

**Gereedschap**: 1.2379

**Machine**: 1600 T - 14 Slag / min

**Smering**: Pure olie

**Bron**: Benteler Spanje

<table>
<thead>
<tr>
<th>Zonder coating</th>
<th>Balint X-Cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koudlas van de stempels na 300 000</td>
<td>Na 1 200 000 slagen nog geen slijtage</td>
</tr>
<tr>
<td></td>
<td>Nog Steeds in gebruik</td>
</tr>
</tbody>
</table>
BALINIT® reduces production costs by 46 %

Production of hinges for Volvo tailgates

<table>
<thead>
<tr>
<th></th>
<th>Uncoated</th>
<th>BALINIT® C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool costs (EUR)</td>
<td>3'445</td>
<td>4'065</td>
</tr>
<tr>
<td>Tool life (parts)</td>
<td>50'000</td>
<td>89'600</td>
</tr>
<tr>
<td><strong>Tool costs per part (EUR)</strong></td>
<td>0.07</td>
<td>0.05</td>
</tr>
<tr>
<td>Yield per min. (parts)</td>
<td>28</td>
<td>38</td>
</tr>
<tr>
<td>Production costs per min. (EUR)</td>
<td>3.84</td>
<td>3.84</td>
</tr>
<tr>
<td><strong>Production costs per part (EUR)</strong></td>
<td>0.14</td>
<td>0.10</td>
</tr>
<tr>
<td>Machine downtime (EUR)</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>Subsequent machining (EUR)</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td><strong>Additional costs per part (EUR)</strong></td>
<td>0.07</td>
<td>0.00</td>
</tr>
<tr>
<td>Total production costs per part (EUR)</td>
<td>0.28</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Savings</strong></td>
<td></td>
<td>46 %</td>
</tr>
</tbody>
</table>
BALINIT A / nitriding

number of parts (mean values)

<table>
<thead>
<tr>
<th>TIN</th>
<th>TIN / Nitriding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000,000</td>
<td>5,000,000</td>
</tr>
</tbody>
</table>

**tool:**
Knife (dividing)
mat. 1.3344 (62 – 64 HRC) / Nitriding polished

**workpiece:**
1,00 mm sheet - thickness
Mat. KBB S320GD+Z

**application:**
profiles cutting

**source:** BFL
BALINIT® boosts productivity by 20%
Threaded cores for bottle caps

Description
Production process: injection moulding
Particularity: lubricants and mould release agents cannot be used for pharmaceutical or food packaging.

Threaded cores uncoated
Production downtime: 1 day per week

Threaded cores BALINIT®-coated
✓ Trouble-free production during several months
✓ 10% shorter cycle times
✓ Yield productivity gains of up to 20%
Performance increase by BALINIT®
Diesel injector with piezo technology

Components of the injector out of a Common-Rail diesel injection system are coated with performance increasing carbon coatings in mass-production.

BALINIT® DLC-coated injection needles are dimensionally stable even in long-term usage, thus ensuring the leak tightness of the system. The good sliding properties guarantee a precise flow of the diesel fuel.

BALINIT® C-coated valve pistons virtually show no wear even at extreme pressures.
Cylindrical roller thrust bearing

- Life time [hours]: > 250
- Temperature: 30 °C
- Coefficient of friction: 0.004
- Roller wear: 5 mg

**Rings and rollers**
- BALINIT® C coated

**Bearing 81206**
- Load: 33 kN
- Cage material: PA 66
- Speed: 15 rpm
- Dry running
BALINIT® coatings for highly demanding components
Being part of all successful formula 1 racing cars

Cam follower
(rocker arm and shaft, tappets)

Camshafts

Valves

Gear wheels

Suspension parts

Wrist pins

Con rods

Pistons

Crank shaft
Summary of advantages of BALINIT® coatings

- Longer lifetime of parts / tools
- Reduced friction
- Better (product) release
- Less corrosion
- Less maintenance
- Lower weight due to smaller components
- Less oil/fuel consumption
- Reduced emission
- Possibility of replacing inexpensive and/or tough materials again.
How to fail or to perform with coatings?
Most important forms of damage.

Abasive wear
Adhesive wear
Breaking out
Plastic deformation
Breakage
# Causes of different forms of wear

<table>
<thead>
<tr>
<th>Type of wear</th>
<th>Needed property</th>
<th>Location</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic deformation</td>
<td>Resistance against deformation</td>
<td>Mass</td>
<td>Type of steel + Heat treatment</td>
</tr>
<tr>
<td>Brittle crack</td>
<td>Resistance against breakage</td>
<td>Mass</td>
<td>Type of steel + Heat treatment</td>
</tr>
<tr>
<td>Breaking out</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chipping</td>
<td></td>
<td>Surface</td>
<td>Type of steel + Heat treatment + <strong>coating</strong></td>
</tr>
<tr>
<td>Abrasive wear (Coldwelding)</td>
<td>Resistance against wear</td>
<td>Surface</td>
<td>Surface properties + <strong>coating</strong></td>
</tr>
<tr>
<td>Adhesive wear</td>
<td>Lowering friction + surface tension</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Wear

## Types of wear

<table>
<thead>
<tr>
<th>Type of wear</th>
<th>Appearance</th>
<th>Cause and phenomena</th>
</tr>
</thead>
</table>
| Adhesive wear      | ![Image](adhesive_wear.png) | **Cause** Cold welding with material transfer  
**Phenomena** Cavities, material build-up |
| Abrasive wear      | ![Image](abrasive_wear.png) | **Cause** Hard particles score the surface  
**Phenomena** Scores, scratches |
| Tribo-oxidation    | ![Image](tribo-oxidation.png) | **Cause** Formation of chemical oxidation react or products by oscillating sliding movement  
**Phenomena** Riffing, corrosion |
| Surface fatigue (pitting) | ![Image](surface_fatigue.png) | **Cause** Material fatigue with crack formation under dynamic loads  
**Phenomena** Cracks, pitting |

## Sliding wear test

**Test method**
- **Clamped ball** 3 mm
  - DIN 1.3055 (~ AISI 52100), 60 HRC
- **Test ring**
  - DIN 1.3055 (~ AISI 52100), 60 HRC
  - Blasted or ground, N4 Coated
- **Test conditions**
  - **F** = 32 N  
  - **v** = 0.3 m/s  
  - Dry sliding

## Coefficient of friction

![Graph](coefficient_of_friction.png)

- **DIN 1.3055 (~ AISI 52100) uncoated**
- **DIN 1.7325 (~ AISI 4140) nitrided**
- **Chromium-coated**

**Note:** Test stopped due to severe abrasive wear

**BALINIT® C (WC/C)** Virtually no wear
How do we prepare a surface?

- Geometry (e.g. cutting tool edge, topography)
- Substrate (Strength, ductility, roughness)

Influence of pretreatment to adhesion of PVD layer

<table>
<thead>
<tr>
<th>Pretreatment</th>
<th>Good</th>
<th>Pretreatment Necessary</th>
<th>Not Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>grinded</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Turned/milled</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>blasted</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>polished</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>eroded</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Steam temper</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>nitrided</td>
<td></td>
<td>plasmanitrided</td>
<td>gasnitrided bathnitrided</td>
</tr>
<tr>
<td>Hartchrom plated</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Chem. Nickel</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>photoetched</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
Grinding / Polishing: tribological behaviour

Friction Coefficient

Coating Topography

Ra [µm]

Rz (µm )

20 µm
Influence of the direction of surface roughness on critical load (coating fracture) in scratch testing of TiN on HSS.
<table>
<thead>
<tr>
<th>SIZE OF GRAIN</th>
<th>MEDIUM DIAMETER APPROX. IN MICRONS</th>
<th>Ra OBTAINED</th>
<th>Rt OBTAINED</th>
<th>CORRESPONDANCE CONDITIONS OF SURFACE OBTAINED</th>
</tr>
</thead>
<tbody>
<tr>
<td>P 80</td>
<td>185</td>
<td>1.27</td>
<td>12.30</td>
<td>abrasive paper</td>
</tr>
<tr>
<td>P 100</td>
<td>129</td>
<td>0.65</td>
<td>6.00</td>
<td>grinding stone</td>
</tr>
<tr>
<td>P 120</td>
<td>109</td>
<td>0.70</td>
<td>7.10</td>
<td>abrasive paper</td>
</tr>
<tr>
<td>P 180</td>
<td>69</td>
<td>0.43</td>
<td>4.40</td>
<td>abrasive paper</td>
</tr>
<tr>
<td>P 220</td>
<td>58</td>
<td>0.46</td>
<td>4.30</td>
<td>abrasive paper</td>
</tr>
<tr>
<td>P 220</td>
<td>58</td>
<td>0.71</td>
<td>6.00</td>
<td>grinding stone</td>
</tr>
<tr>
<td>P 320</td>
<td>29</td>
<td>0.39</td>
<td>2.89</td>
<td>Blasting</td>
</tr>
<tr>
<td>P 320</td>
<td>29</td>
<td>0.27</td>
<td>2.50</td>
<td>abrasive paper</td>
</tr>
<tr>
<td>P 320</td>
<td>29</td>
<td>0.51</td>
<td>5.30</td>
<td>grinding stone</td>
</tr>
<tr>
<td>P 400</td>
<td>17</td>
<td>0.28</td>
<td>2.05</td>
<td>Blasting</td>
</tr>
<tr>
<td>P 400</td>
<td>17</td>
<td>0.23</td>
<td>2.20</td>
<td>abrasive paper</td>
</tr>
<tr>
<td>P 400</td>
<td>17</td>
<td>0.32</td>
<td>3.00</td>
<td>grinding stone</td>
</tr>
<tr>
<td>P 500</td>
<td>12</td>
<td>0.14</td>
<td>1.40</td>
<td>Blasting</td>
</tr>
<tr>
<td>P 500</td>
<td>12</td>
<td>0.17</td>
<td>1.70</td>
<td>abrasive paper</td>
</tr>
<tr>
<td>P 600</td>
<td>9.3</td>
<td>0.13</td>
<td>1.40</td>
<td>start diamond paste / abrasive paper</td>
</tr>
<tr>
<td>P 600</td>
<td>9.3</td>
<td>0.20</td>
<td>1.90</td>
<td>start diamond paste / grinding stone</td>
</tr>
<tr>
<td>P 800</td>
<td>6.5</td>
<td>0.13</td>
<td>1.00</td>
<td>abrasive paper</td>
</tr>
<tr>
<td>P 800</td>
<td>6.5</td>
<td>0.14</td>
<td>1.40</td>
<td>grinding stone</td>
</tr>
<tr>
<td>P 1000</td>
<td>4.5</td>
<td>0.12</td>
<td>0.90</td>
<td>abrasive paper</td>
</tr>
<tr>
<td>15μ</td>
<td>Lapping</td>
<td>0.10</td>
<td>1.30</td>
<td>water based diamond paste</td>
</tr>
<tr>
<td>10μ</td>
<td>Lapping</td>
<td>0.07</td>
<td>0.90</td>
<td>water based diamond paste</td>
</tr>
<tr>
<td>7μ</td>
<td>polishing</td>
<td>0.03</td>
<td>0.20</td>
<td>water based diamond paste</td>
</tr>
<tr>
<td>3μ</td>
<td>polishing</td>
<td>0.02</td>
<td>0.20</td>
<td>water based diamond paste</td>
</tr>
<tr>
<td>1μ</td>
<td>clean room</td>
<td>0.01</td>
<td>0.04</td>
<td>hardened steel / 52-54HRc / 1.2767</td>
</tr>
</tbody>
</table>
## Roughness table of different methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Ra (μm)</th>
<th>Rz (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro Blasting</td>
<td>0.2 0.19 0.18 0.17 0.16 0.15 0.14 0.13 0.12 0.11 0.1 0.09 0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01</td>
<td></td>
</tr>
<tr>
<td>Wet Blasting</td>
<td>0.15 0.14 0.13 0.12 0.11 0.1 0.09 0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01</td>
<td></td>
</tr>
<tr>
<td>Brushing</td>
<td>0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01</td>
<td></td>
</tr>
<tr>
<td>Aero lap</td>
<td>0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01</td>
<td></td>
</tr>
<tr>
<td>Grinding</td>
<td>0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01</td>
<td></td>
</tr>
<tr>
<td>Lapping</td>
<td>0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01</td>
<td></td>
</tr>
<tr>
<td>Polishing</td>
<td>0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01</td>
<td></td>
</tr>
<tr>
<td>Magnet finishing</td>
<td>0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01</td>
<td></td>
</tr>
<tr>
<td>Drag grinding/vibrating devices</td>
<td>0.08 0.07 0.06 0.05 0.04 0.03 0.02 0.01</td>
<td></td>
</tr>
</tbody>
</table>
EDM surfaces

- EDM surfaces can only be coated when they have had the right pretreatment (blasting or grinding).
  - Total removal of the white layer is crucial for tools / parts that are suffering under high loads.
White layer: microblasting reduces the white layer thickness
Nitriding surfaces: compound layer defines topography

ű Three common processes are usable for steel treatment (salt, gas, plasma).
ű Plasma nitriding gives the best result to increase hardness.
ű It’s a stable process which produces clean surfaces (no compound layer)
ű Meanwhile we are able to combine plasma nitriding and PVD coating in one process; Balinit Alcrona Advanced.
www.coating-guide.balzers.com

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Thank you for your attention!