Wear Protection with Borocoat-Diffusion Layers
Outline

Brief Introduction to Heat Treatments

Boronizing

• Properties
• Applications
• Boronizing agents
Surface Treatments

Thermal
- Flame hardening
- Induction hardening
- Electron beam hardening

Thermo-chemical
- Carburizing
- Nitriding
- Boronizing

Gas phase
- CVD
- PACVD
- PVD

Galvanic
- Hard Chrome plating
- Nickel plating
- Zinc plating
Heat Treatment Overview

Annealing
- Recrystallization annealing
- Stress relief annealing
- Soft annealing
- Normalizing
- Diffusion annealing

Hardening
- Through hardening
- Surface hardening

Tempering
- <200°C
- >500°C
- Secondary (>480°C)
- Age hardening

Diffusion treatments*
- Nitriding
- Carburizing
- Boronizing
- Oxidizing
Coatings (CVD, PVD, Thermal spray...)

Boundary between coating and steel substrate

Functional layer develops on top of the substrate
- Moderate adhesion
- High stresses on interface
Functional surface is developed within the material

- Superior adhesion
- Low dimensional changes
What is Boronizing?

**Boronizing** is a thermocemical surface treatment in which Boron atoms diffuse into the steel substrate and form a very hard Borocoat-layer.

**Boronizing** easily tops the performance of commonly used methods such as carburizing or nitriding.
Properties of Borocoat Layers

<table>
<thead>
<tr>
<th>Feature</th>
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<tbody>
<tr>
<td>High hardness 1400-2600 HV, even on non-alloyed steels</td>
</tr>
<tr>
<td>Diffusion depth 10-250 μm</td>
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<tr>
<td>High abrasion resistance, resistance against cold welding</td>
</tr>
<tr>
<td>Excellent thermal stability</td>
</tr>
<tr>
<td>Self lubricating effect at high temperatures</td>
</tr>
<tr>
<td>Superior bonding strength, no coating but diffusion layer</td>
</tr>
<tr>
<td>Good resistance against molten metals (Al, Zn)</td>
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Material Selection for Boronizing

- Non alloyed and low alloyed steels.
- Stainless steels
- Cast iron, casted steel
- Cold work, hot work and HSS steel
- Powder metallurgical steels
- Cobald based materials
- Cemented carbides
- Nickel-based alloys (Nimonic®, Inconel®, Hastelloy®, Haynes®)

Boronizing is the most effective wear solution for Nickel-based alloys!
Applications

- Automotive components (turbo charger engineering)
- Oil and gas industry (valves and accessories)
- Power plant engineering
- Toolmaking and metal forming technology
- Plastics processing
- Glass production
- Gear manufacturing
- Components for textile machinery
- Aluminum processing
- Mechanical engineering
Boronizing - Setup -

Metal Box

Ekabor® Boronizing powder

Furnace
Box for Boronizing

Material AISI 314 (1.4841)
Box for Boronizing
Parts Preparation

Sample for quality control

Part

Container

Boronizing powder (Ekabor2)
15mm
Parts Preparation
Batch for Boronizing packed in a Box
Batch for Boronizing packed in a Box
## Properties of Borides

<table>
<thead>
<tr>
<th></th>
<th>FeB</th>
<th>Fe2B</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Bor</td>
<td>16.23</td>
<td>8.83</td>
</tr>
<tr>
<td>Lattice Structure</td>
<td>rhombic</td>
<td>tetragonal</td>
</tr>
<tr>
<td>Stress after cooling down</td>
<td>Tension</td>
<td>Compressive</td>
</tr>
<tr>
<td>Coefficient of Linear Expansion $10^{-6}$/K</td>
<td>23</td>
<td>7.9-9.2</td>
</tr>
<tr>
<td>Hardness [HV0.1]</td>
<td>1900-2100</td>
<td>1650-2000</td>
</tr>
<tr>
<td>Density [g/cm$^3$]</td>
<td>6.75</td>
<td>7.43</td>
</tr>
<tr>
<td>Modulus of Elasticity [GPa]</td>
<td>343</td>
<td>284</td>
</tr>
<tr>
<td>Thermal Conductivity [W/mK]</td>
<td>12</td>
<td>30</td>
</tr>
</tbody>
</table>
Boronizing Layer
(Iron matrix has been etched off, only boronized layer structure is visible)
Microsections of Boronized Steels

- Armco (pure) iron
- AISI 1015 / 1.0401 / C15
- AISI 5115 / 1.7131 / 16MnCr5
Microsections of Boronized Steels

AISI D-6 / 1.2436 / X210CrW12
Cold work steel

AISI 314 / 1.2343
Hot work steel

AISI 4140 / 1.7225 / 42CrMo4
Tempering steel
Microsections of Boronized Nickel-Based Alloy

Hastelloy® C4 / 2.4610
Nickel-Based Alloy

Hardness before boronizing: 425 HK0.1

Hardness boronized: 1715 HK0.1
Wear Comparison of AISI 4131

Ball-disc test ($F_n = 17N, 500m$)
Corrosion of high alloyed Steel in molten Zink

Tsipas et al
Corrosion Resistance of Boronized vs Untreated Steel AISI 1045 (Ck45) at 56°C
Lifetime comparison of boronized and nitrided extruder screws

- 25x
- 20x
- 17x
- 20x
- 41x
- 20x
- 12x

PA 6.6 33% GF
UA A3 25% GF
UA A3 35% GF
PA 6.6 33% GF
DAP 35% GF
PA 6.6 35% GF
PA 6.6 35% GF

Nitrided
Boronized

GF=amount of glass fibres
Boronized Extrusion Screws
Boronized Ball Valves (Stainless Steel)

Material AISI 316

Hardness base material: 315 HV

Hardness boronized 1950 HV
Ball Valves
Boronized Burner Nozzle
Boronized Automotive Parts

Oil pump gears

Only teeth boronized

Hardness 1700 HV

Depth 40µm
Boronized Parts for Glass Bottle Production

Prevention of sticking (glass-metal)
Boronized Parts for Glass Bottle Production
Boronized Filters

Stainless Steel

Hardness before: 285HV

Boronized: 1800HV

Prevention of Abrasion
Boronized Pump Part

Inconel®

Hardness before: 425 HK

Boronized 2880 HK

Depth 50µm
Boronized Compressor Wheel

Inconel® 625

Hardness before: 396 HV

Boronized: 2715 HK

Depth: 60µm
## Ekabor® Boronizing Agents

<table>
<thead>
<tr>
<th>Ekabor® 1</th>
<th>High quality boronizing agent for non- and low-alloyed steel</th>
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<tbody>
<tr>
<td>Ekabor® 2</td>
<td>Standard boronizing agent for all kind of steels</td>
</tr>
<tr>
<td>Ekabor® 3</td>
<td>Quality as Ekabor®2. Easy unpacking (no baking) after boronizing</td>
</tr>
<tr>
<td>Ekabor® Ni</td>
<td>For boronizing of Ni-based alloys</td>
</tr>
<tr>
<td>Ekabor® Paste</td>
<td>Paste for special requirements such as partial boronizing.</td>
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