Current R&D concepts and recent developments of special material sheets and plates for Oil & Gas / CPI applications
voestalpine Group

Steel Division

High Performance Metals Division

Production Mills:
- va BÖHLER Bleche
- va BÖHLER Edelstahl
- Uddeholms
- Buderus Edelstahl
- Villares Metals

Value Added Services:
- Distribution & Service Network (NA, EU, Asia)

Metal Engineering Division

Metal Forming Division

Key figures 2016/17 voestalpine group:

- Employees: 49,703
- Turnover: 11,294.5 Mio. EUR
- EBITDA: 1,540.7 Mio. EUR
- EBIT: 823.3 Mio. EUR
- EBIT-Margin: 7.3%
Product portfolio of voestalpine BÖHLER Bleche

- HIGH SPEED STEEL
- TOOL STEEL
- SPECIAL MATERIALS
  - Chemical Processing
  - Aerospace
  - Power Generation
  - Pressplates & Specials
va BÖHLER Bleche is a producer of single cross-rolled sheets and plates in special materials (no coil production)

- Hot rolled down to 2 mm / 0.078”
- va BÖHLER Bleche focusses on high alloyed materials for demanding applications and niche products
- We value long-term partnerships with our clients
- va BÖHLER Bleche offers competent technical support and tailor made solutions
voestalpine BÖHLER Bleche at a glance

- 510 employees (BY 2017)
- € 138 million revenue (BY 2017)
- 98% export rate
- Final Products 24,000 tons
- Advanced production facilities
- Pre-material from group companies
Turnover per product segment (FY2018)

- Special Materials: 47%
- Tool Steel: 14%
- HSS: 39%

- CPI: 28%
- Power Generation: 21%
- Aerospace: 17%
- Press Plates & Specials: 21%
New Two-High Mill:
Width: 2,000mm/78”
Length: 7,000mm/275”
Thickness: up to 110mm/4.3”*
*depending on grade

Two-High Mill and Two-High Fine Mill:
Width: 2,000/1,000mm
Length: 7,000/5,000mm
Thickness: 2-10/7mm
(integrated heat treatment for some grades)

Cold Rolling Mill:
Width: 1,250mm/49”
Length: 5,000mm/196”
Thickness: 0.8-6mm/.003-.23”
## Cutting Equipment

<table>
<thead>
<tr>
<th>Cutting Equipment</th>
<th>Tolerance</th>
<th>Speed</th>
<th>Edge quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear cutting</td>
<td>+5.0/-0.0mm +.2/-0.0”</td>
<td>↑↑↑</td>
<td>↑↑</td>
</tr>
<tr>
<td>Sawing</td>
<td>+2.0/-0.0mm +.0078/-0.0”</td>
<td>↑</td>
<td>↑↑</td>
</tr>
<tr>
<td>Plasma cutting</td>
<td>+10.0/-0.0mm +.39/-0.0”</td>
<td>↑↑↑</td>
<td>↑</td>
</tr>
<tr>
<td>Laser cutting</td>
<td>+0.5/-0.0mm +.02/-0.0”</td>
<td>↑↑</td>
<td>↑↑</td>
</tr>
<tr>
<td>Waterjet cutting</td>
<td>+0.5/-0.0mm +.02/-0.0” per 5.0mm/.2” thickness</td>
<td>↑</td>
<td>↑↑↑</td>
</tr>
</tbody>
</table>
PRO PLATE Investment

15.5 M€ investment

Finalization: Mid 2019

Real time material tracking system

Revamp 3-high-mill

New roller levelling machine

New multi-chamber furnace
New multi-chamber furnace

» Max. plate size: 7,500 x 2,950 x 90 mm
   295” x 116” x 3.54”

» Min. plate size: 1,825 x 920 x 2 mm
   7.28” x 36.3” x .078”

» Payload: max. 4,500 kg
   max. 9921 lb

» Temp. range: 700 – 1,250°C
   1292 – 2282°F

» Temp. constancy: furnace class 3 (± 8°C)

» Quenching: still air / forced air / waterspray
Revamp: 3-high mill into 2-high mill

- Increased thickness range
- Increased capacity
- Improved flatness after rolling
- No Change of rolling parameters
  - furnace temperature
  - rolling temperature
  - reduction per pass
- Fully automated dimension control
Recent R&D projects

CrMnN Plates

Clad Plates

718API

Titanium
Types of Corrosion

» General Corrosion
» Pitting
» Crevice Corrosion
» Intergranular Corrosion
» Erosion Corrosion
» Stress Corrosion Cracking
» Corrosion Fatigue
» Leaching
» ...

![Diagram showing the relationship between environment, temperature, and alloy in the context of corrosion types.](image-url)
## Corrosion vs AlloYing Elements

<table>
<thead>
<tr>
<th>Nickel alloys</th>
<th>Pure Nickel</th>
<th>Nickel 200/201</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni-Cu</td>
<td>Alloy 400</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alloy 500</td>
<td></td>
</tr>
<tr>
<td>Ni-Cr-Mo</td>
<td>Alloy 625</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alloy 22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alloy C-276</td>
<td></td>
</tr>
<tr>
<td>Fe-Ni-Cr-Mo</td>
<td>Alloy 825</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alloy 20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alloy 28</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alloy G-3</td>
<td></td>
</tr>
<tr>
<td>Super Austenitic</td>
<td>UNS S31254</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UNS N08926</td>
<td></td>
</tr>
<tr>
<td>Super Duplex</td>
<td>F55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F53</td>
<td></td>
</tr>
</tbody>
</table>

### Reducing Acids:

<table>
<thead>
<tr>
<th>H₂SO₄ (Sulfuric Acid) and HCl (Hydrochloric Acid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>→ Highly Mo-grades recommended: 625, 825, 20, C276 and SASS</td>
</tr>
</tbody>
</table>

### Oxidizing Acids:

<table>
<thead>
<tr>
<th>HNO₃ (Nitric Acid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>→ Highly chromium alloyed grades are recommended:</td>
</tr>
<tr>
<td>Alloy 625, Alloy 825, Titanium</td>
</tr>
</tbody>
</table>

### HF in H₂O (Hydrofluoric Acid)

| → Best: Alloy 400, Good: Nickel 200, Fair: Alloy 600 |

### Organic Acids:

<table>
<thead>
<tr>
<th>Acetic, Formic, Lactic...</th>
</tr>
</thead>
<tbody>
<tr>
<td>→ Alloy 625, 825, Alloy 20, Alloy 22, Alloy C276</td>
</tr>
</tbody>
</table>

### Caustic and Strong Alkali:

| Materials with high nickel content: Alloy 200, Alloy 400 |

### Seawater:

| High PREN-Value, Titanium |
| Cl-induced SCC: High Nickel (Copson diagram), Titanium |
Rules of thumb for material selection

Special materials like Niobium, Tantalum and Zirconium

Titanium

Ni-Mo-Cr

Ni-Mo

Alloy 20

316 / SS

Increasing oxidizing agent

Increasing reducing agent

Increasing Cl⁻ concentration

No Cl⁻
# Grades for Chemical Industry Applications

<table>
<thead>
<tr>
<th>Böhler</th>
<th>UNS</th>
<th>Name</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>N</th>
<th>PREN</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A220</td>
<td>S31603</td>
<td>316L</td>
<td>17,4</td>
<td>13,9</td>
<td>2,8</td>
<td>0,1</td>
<td>28,9</td>
<td>Standard Stainless</td>
</tr>
<tr>
<td>A903</td>
<td>S32205</td>
<td>2205</td>
<td>22,8</td>
<td>7,2</td>
<td>3,2</td>
<td>0,17</td>
<td>38,5</td>
<td>Standard Duplex</td>
</tr>
<tr>
<td>A911</td>
<td>S32760</td>
<td>2507</td>
<td>25,5</td>
<td>5,8</td>
<td>3,8</td>
<td>0,23</td>
<td>44,9</td>
<td>Super Duplex</td>
</tr>
<tr>
<td>A959</td>
<td>N08028</td>
<td>Alloy 28</td>
<td>26,7</td>
<td>31,3</td>
<td>3,3</td>
<td>0,1</td>
<td>40,4</td>
<td></td>
</tr>
<tr>
<td>A952</td>
<td>N08031</td>
<td>Alloy 31</td>
<td>27</td>
<td>31</td>
<td>6,5</td>
<td>0,2</td>
<td>54,5</td>
<td>Super Austenite</td>
</tr>
<tr>
<td>A965</td>
<td>S31254</td>
<td>6Moly</td>
<td>20,3</td>
<td>17,7</td>
<td>6,1</td>
<td>0,2</td>
<td>46,7</td>
<td></td>
</tr>
<tr>
<td>L825</td>
<td>N08825</td>
<td>825</td>
<td>21,5</td>
<td>40</td>
<td>2,8</td>
<td>0,2</td>
<td>30,7</td>
<td>Super Austenite (high Ni)</td>
</tr>
<tr>
<td>L625</td>
<td>N06625</td>
<td>625</td>
<td>20</td>
<td>Base</td>
<td>9</td>
<td></td>
<td>49,7</td>
<td>Nickel-base</td>
</tr>
<tr>
<td>L276</td>
<td>N10276</td>
<td>C276</td>
<td>15</td>
<td>Base</td>
<td>15</td>
<td></td>
<td>64,5</td>
<td></td>
</tr>
<tr>
<td>L059</td>
<td>N06059</td>
<td>Alloy 59</td>
<td>22</td>
<td>Base</td>
<td>15</td>
<td>0,47</td>
<td>71,5</td>
<td></td>
</tr>
<tr>
<td>P512</td>
<td>S34565</td>
<td>Alloy 24</td>
<td>25</td>
<td>16,5</td>
<td>4,5</td>
<td>0,47</td>
<td>54,0</td>
<td>CrMnN-Austenite (16Mn)</td>
</tr>
<tr>
<td>P576</td>
<td>P576</td>
<td></td>
<td>20</td>
<td>7,5</td>
<td>2,3</td>
<td>0,7</td>
<td>48,6</td>
<td>CrMnN-Austenite (20Mn)</td>
</tr>
</tbody>
</table>

PREN = %Cr + 3.3*%Mo + 30*%N
CrMnN alloying concept

<table>
<thead>
<tr>
<th>UNS</th>
<th>Name</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>Mn</th>
<th>N</th>
<th>PREN</th>
<th>Microstructure</th>
<th>R_m [MPa]</th>
<th>Rp_0,2 [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>S32750</td>
<td>2507 SDSS</td>
<td>25,5</td>
<td>5,8</td>
<td>3,8</td>
<td>0,6</td>
<td>0,23</td>
<td>44,9</td>
<td>Duplex</td>
<td>750</td>
<td>550</td>
</tr>
<tr>
<td>N08031</td>
<td>Alloy 31</td>
<td>27</td>
<td>31</td>
<td>6,5</td>
<td>1</td>
<td>0,2</td>
<td>54,5</td>
<td>Austenite</td>
<td>690</td>
<td>340</td>
</tr>
<tr>
<td>S31254</td>
<td>6Moly</td>
<td>20,3</td>
<td>17,7</td>
<td>6,1</td>
<td>0,6</td>
<td>0,2</td>
<td>46,7</td>
<td>Austenite</td>
<td>670</td>
<td>340</td>
</tr>
<tr>
<td>S34565</td>
<td>Alloy 24</td>
<td>25</td>
<td>16,5</td>
<td>4,5</td>
<td>4,5</td>
<td>0,47</td>
<td>54,0</td>
<td>Austenite</td>
<td>800</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>7,5</td>
<td>2,3</td>
<td>20</td>
<td>0,7</td>
<td>48,6</td>
<td>Austenite</td>
<td>900</td>
<td>530</td>
</tr>
<tr>
<td>P576</td>
<td></td>
<td>21</td>
<td>1,5</td>
<td>0,25</td>
<td>23</td>
<td>0,85</td>
<td>47,0</td>
<td>Austenite</td>
<td>1000</td>
<td>630</td>
</tr>
</tbody>
</table>

Stabilizers of austenitic phase

- Increases solubility of N
- Increases mechanical properties in solid solution
- Improves PREN
Tensile Strength vs CPT

Alloy groups with distinctive properties

» CrMnN steels

» appealing from mechanical point of view

» Fair corrosion resistance compared to SDSS and Ni-base

» Weldability can be an issue
What do we want?

Combination of properties → Clad Plates

Price

Strength

Corrosion Resistance
Clad plate concept

- New method to join different steel and nickel plates (no roll cladding or explosion-bonded cladding)
- Fully bonded material
- High flexibility in thicknesses
- Tailor made solutions
- Combination of high strength and high corrosion resistant grades possible
- Possibility of multi-layer structure

1mm/.04” Alloy 625
5mm/.2” SDSS
Clad plate concept

1mm/.04” Alloy 625

5mm/.2” SDSS
Titanium Plates
by voestalpine BÖHLER Bleche
Why does voestalpine BÖHLER Bleche start producing titanium?

- Extension of existing product portfolio
- A lack of European titanium plate producers
- Increasing demand in aerospace industry
- All relevant equipment available at BÖHLER Bleche
- Already a lot of production experience due to long history in hire rolling of titanium plates in Grades 2 and 5
Titanium main grades, main applications

- Titanium Grade 23 ELI
- Titanium Grade 5
- Titanium Grade 1-4, Grade 7, 9, 12

Applications:
- Aerospace
- Automotive
- Power Generation
- Engineering and Medical Applications
- Oil, Gas, CPI
Advances of Titanium in O&G applications

» Highest corrosion resistance in chloridic and sulfidic environments

» Immune towards sea-water and different brine solutions

» Grade 12 could be a choice for sour gas environments

» Titanium and Ti-alloys are relatively competitive concerning total life-cycle cost and very stable in price compared to SS and Nickel alloy in particular

» Attractive weight to strength ratio

» Available at many distributors, not “exotic” anymore

» Not final solution for everything, but advantage for certain applications
Titanium plate production

Titanium Sponge

**Pre-Material**
- Single or double VAR
- Slab Forging

**Titanium Slab Production**

**Hot Rolling**
- Intermediate Inspection
- Defect Grinding

**Heat Treatment and Levelling**
- Mill Annealing
- Vacuum Creep Flattening
- Roll Straightening

Processed at voestalpine BÖHLER Bleche

Processed in Europe

Western World

voestalpine High Performance Metals GmbH

26 | 06.06.2019 |
Titanium plate production

Processed at voestalpine BÖHLER Bleche
**Dimensions**

**CP Titanium**
- **Thickness [mm]**: 2.0 mm / .078''
- **Width**: ≤ 2,000 mm
- **Length**: ≤ 6,000 mm
- **Flatness**: according to ASTM B265 and DIN 17860

**Ti Grade 2, commercially pure**
- **Thickness [mm]**: 70 mm / 2.75''

**Ti Alloy**
- **Thickness [mm]**: 10 mm / .39''
- **Width**: ≤ 2,000 mm
- **Length**: ≤ 6,000 mm
- **Flatness**: < 2 mm/m

**Ti Grade 5, Ti6Al4V**
- **Thickness [mm]**: 50 mm / 1.96''

*voestalpine High Performance Metals GmbH*
Your benefits

- Wide range of grades and dimensions
- Competitive lead times
- Vacuum creep flattened Ti-plates
- According to all relevant international standards
- European production guaranteed

voestalpine High Performance Metals GmbH

06.06.2019
718 API

» Up to now 718 produced at vaBBG only for aerospace, but not according API or NACE

» On laboratory scale mechanical and microstructure testing on a 6,2mm/.244” plate

Solution annealing at 1021°C/1870°F 1h, aging for 8h at 760°C/1400°F

Obtained values of transverse direction:

\[ R_m = \sim 1230 \text{ MPa/178.4 ksi} \quad A_{50mm} = 28.5\% \quad Z = 47\% \]

Hardness: \sim 38.9 HRC (min 34 HRC / max 40 HRC)

Impact toughness: \sim 87 J at -60°C on average (min 60 J)
718 API – further steps

» Perform tests for greater gauges to define limits of our production equipment

» Repeat tests for statistical validation

» Cooperations for possible applications are welcome

» We are thankful for any support from partners
Thank you

Clemens Vichytil
T. +43/664/883 23073
clemens.vichytil@voestalpine.com