HIGH PERFORMANCE MOLD STEELS FOR INJECTION OF REINFORCED PLASTICS

voestalpine BÖHLER Edelstahl GmbH & Co KG
www.voestalpine.com/bohler-edelstahl
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Modern industrial parts production in mainly automotive and electronic industries is characterized by the trend to substitute metals by reinforced plastics. Being much lighter and therefore weight-saving, such plastic components help to reduce CO₂ emissions, which is a clear ecologic focus worldwide. Intricate geometries, thin wall-thicknesses and large areas of the parts are characteristics that call for a growing amount of glass or carbon fibers in the plastics to obtain sufficient stability.

Plastics reinforced by fibers tend to be much more abrasive than conventional plastics and thus may cause premature wear of an injection mold. In order to counteract excessive and early wear in molds, voestalpine BÖHLER Edelstahl is offering a wide variety of high-quality tooling steels that are setting new standards in the production of heavy-duty components made from reinforced plastics.
TRENDS AND REQUIREMENTS

» New types of high performance plastics (GF, CF, fibre length, filler material)
» Increasing wear resistance requirements on mold material
» Increasing corrosion resistance of mold material
» Complexity of parts increased (light weight construction)
» Increase productivity through shorter cycle times (thermal conductivity)
» Higher closing pressures and processing temperatures

PLASTIC MOLDING
EXAMPLE OF „POLYMERIC LEIGHT WEIGHT CONSTRUCTION“

Prototype: Plastic steering case

» Equal cost part made of 50% glass fiber reinforced PA (Ultramid® A3R) with metal inserts
» Special FEM -Design modification
» Service temperature: max. 125 °C
» 50% weight savings

Source: ThyssenKrupp techforum 1/2014

Prototype: Plastic steering case

Steering casing
Al- HPDC part
(Symbolic picture)
PLASTIC PROCESSING

SELECTED PARTS/COMPONENTS MADE OF LONG FIBER REINFORCED THERMOPLASTIC

AUTOMOTIVE

Long glass-fiber reinforced car frontend
Source: M. Schemme, FH Rosenheim

Short glass-fiber reinforced brake/clutch pedal holder
Source: POLYCOM

Long-fiber reinforced door module
Source: M. Schemme, FH Rosenheim

Oilpan
Source: LANXESS

PA6 – GF65

PA66 – CF35

HOUSEHOLD

PA66 – CF35

PC+ABS – GF40

PA6 – GF40

BÖHLER PLASTIC MOULD STEELS
WEAR MECHANISM

Fiber motion causes abrasive wear by

Beside glass fibers also glass balls, metal oxides (titanium oxide, chromium oxide), calcium carbonates, silica components (sand, quartz), ceramics ... are forcing abrasive wear.

Source: Department of Injection Moulding of Polymers, University of Leoben
INFLUENCING FACTORS

Fiber Length

Typical fiber diameter: 10 µm
- Length up to 200 µm
- 200 µm < L < 500 µm
- 500 µm < L < 1000 µm
- 1000 µm < L < 2000 µm
- Length > 2000 µm

Source: Department of Injection Moulding of Polymers, University of Leoben
# PRODUCT SELECTION – HIGH PERFORMANCE MOLD STEELS

## Non-corrosion resistant steels

<table>
<thead>
<tr>
<th>Hardened and tempered tool steels</th>
<th>BÖHLER grade</th>
<th>Chemical composition in weight %</th>
<th>Standard Carbide vol-%</th>
<th>Wear resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BÖHLER W300</td>
<td>C 0.4 Cr 5.0 Mo 1.3 V 0.4 W 2.6</td>
<td>1.2343 / H11</td>
<td>&lt; 1 ★★</td>
</tr>
<tr>
<td></td>
<td>BÖHLER W400</td>
<td>C 0.4 Cr 5.0 Mo 1.3 V 0.7</td>
<td>1.2340 / H11</td>
<td>&lt; 1 ★★</td>
</tr>
<tr>
<td></td>
<td>BÖHLER W403</td>
<td>C 0.4 Cr 5.0 Mo 2.6</td>
<td>1.2367</td>
<td>&lt; 1 ★★</td>
</tr>
<tr>
<td></td>
<td>BÖHLER W500</td>
<td>C 0.5 Cr 4.5 Mo 3.0</td>
<td>1.2364 / H11</td>
<td>&lt; 1 ★★</td>
</tr>
<tr>
<td></td>
<td>BÖHLER W502</td>
<td>C 0.5 Cr 4.5 Mo 3.0 V 0.6</td>
<td>1.2344 / H11</td>
<td>&lt; 1 ★★</td>
</tr>
<tr>
<td></td>
<td>BÖHLER K490</td>
<td>C 1.1 Cr 8.3 Mo 2.1</td>
<td>1.2345</td>
<td>8.5 ★★★</td>
</tr>
<tr>
<td></td>
<td>BÖHLER K490</td>
<td>C 1.4 Cr 6.4 Mo 1.5</td>
<td>1.2345</td>
<td>10 ★★★★</td>
</tr>
<tr>
<td></td>
<td>BÖHLER K500</td>
<td>C 2.5 Cr 4.2 Mo 3.8</td>
<td>1.2345</td>
<td>17 ★★★★★</td>
</tr>
</tbody>
</table>

- **BÖHLER grade**: K490, K500, W300, W302, W400, W403, W500, W502
- **Chemical composition in weight %**: C, Cr, Mo, V, W, Others
- **Standard Carbide vol-%**: 1.2343 / 1.2344
- **Wear resistance**: < 1

**Examples for processed plastics**:
- PA6 - GF50
- PA66 - GF40
- PA66 - GF35
- PA66 - GF30
- PC + ABS - GF40
- POM - CF35
- PA6 - GF65
- PA6 - CF45

**Microclean**: Powder metallurgical steels

**VMR**: Special materials subjected to vacuum refining or melting during at least one stage of manufacture.

**SDUR**: Cold work tool steels in ESR quality

**SI BLOC**: Hot work tool steels in ESR quality with special heat treatment

**Examples for processed plastics**:
- PA6 - GF65
- PA6 - CF45
- K490
- W300
- W400
- W403
- W500
- W502
- K340
- K390
- K360

**Examples for processed plastics**:
- >58 HRC
- ~56 HRC
- ~50 HRC

**Examples for processed plastics**:
- Universal PM, very good hard machinability
- Higher strength at similar toughness
- Higher toughness, better polishability

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### Corrosion Resistant Steels (Minimum Free Chromium Content in the Matrix of 13%)

#### Hardened and Tempered Tool Steels

<table>
<thead>
<tr>
<th>BÖHLER Grade</th>
<th>Chemical Composition in Weight %</th>
<th>Standard</th>
<th>Carbide vol-%</th>
<th>Wear Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BOHLER M390</strong></td>
<td>C: 0.27, Cr: 14.50, Mo: 1.00, Ni: 0.85, V: +N, Others: +N</td>
<td>~1.2316</td>
<td>&lt; 1</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>BOHLER M303</strong></td>
<td>C: 0.24, Cr: 13.25, Mo: +, Ni: +, Others: +N</td>
<td>~1.2083 / ~420</td>
<td>&lt; 1</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>BOHLER M310</strong></td>
<td>C: 0.38, Cr: 14.30, Mo: –, Ni: 0.20, Others: –</td>
<td>~1.2083 / ~420</td>
<td>1.5</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>BOHLER M340</strong></td>
<td>C: 0.54, Cr: 17.30, Mo: 1.10, Ni: 0.10, Others: +N</td>
<td>–</td>
<td>ca. 8%</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>BOHLER M368</strong></td>
<td>C: 0.54, Cr: 17.30, Mo: 1.10, Ni: 0.10, Others: +N</td>
<td>–</td>
<td>ca. 8%</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>BOHLER M390</strong></td>
<td>C: 1.90, Cr: 20.00, Mo: 1.00, Ni: 4.00, Others: W=0.60</td>
<td>–</td>
<td>ca. 20%</td>
<td>★★★★★</td>
</tr>
</tbody>
</table>

#### Prehardened Tool Steels

<table>
<thead>
<tr>
<th>BÖHLER Grade</th>
<th>Chemical Composition in Weight %</th>
<th>Standard</th>
<th>Carbide vol-%</th>
<th>Wear Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BOHLER M333</strong></td>
<td>C: 0.24, Cr: 13.25, Mo: 1.00, Ni: 0.85, V: +N, Others: +N</td>
<td>~1.2083 / ~420</td>
<td>&lt; 1</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>BOHLER M350</strong></td>
<td>C: 0.54, Cr: 17.30, Mo: 1.10, Ni: 0.10, Others: +N</td>
<td>–</td>
<td>ca. 8%</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>BOHLER M368</strong></td>
<td>C: 0.54, Cr: 17.30, Mo: 1.10, Ni: 0.10, Others: +N</td>
<td>–</td>
<td>ca. 8%</td>
<td>★★★</td>
</tr>
<tr>
<td><strong>BOHLER M390</strong></td>
<td>C: 1.90, Cr: 20.00, Mo: 1.00, Ni: 4.00, Others: W=0.60</td>
<td>–</td>
<td>ca. 20%</td>
<td>★★★★★</td>
</tr>
</tbody>
</table>

**Examples for Processed Plastics**
- PVC, CPVC, PES, PSU, PVDF, ABS

**Special Property and/or Achievement Characteristics**

- **Microclean**
  - Powder metallurgical steels
  - Plastic mould steels in ESR quality

- **Extra**
  - Special property and/or achievement characteristics
HEAT TREATABLE, WEAR RESISTANT MOLD STEEL

The wear is determined either by mass loss or volumetrically by 3D measurement of the sample surfaces before the test and after injection of, for example, 25 kg or 50 kg of glass fiber reinforced plastic molding compound.

The wear apparatus for testing the abrasive / corrosive wear on the tribo-system polymer melt / steel is installed in the injection molding machine in the form of an injection molding tool. The wear samples, which have the same temperature as the melt, form a rectangular gap in which large local shear stresses and shear rates can be generated. The melt is injected through the wear gap and generates the material removal on the surfaces of the two wear samples (each 15 x 12 x 5 mm). The entire dosing volume of the plasticized molding compound is injected at a defined injection pressure, defined injection rate and a specified melt temperature.

The wear is determined by the material removal (mg/cm²) or the material removal height (µm) before and after injected a defined amount of plastic melt.
EFFECT OF CORROSION AND ABRASION – LABORATORY TEST RESULTS
K110 VS. M390 MICROCLEAN, RESULTS FROM PLATES WEAR TESTS

PA 66 + 30% GF/ 300°C

<table>
<thead>
<tr>
<th>Energy of abrasion / area (kJ/cm²)</th>
<th>K110</th>
<th>M390</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>50</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>100</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>150</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>200</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>250</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>300</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>350</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Facts
» Filling materials and additional fibers in various plastic materials have an abrasive effect
» Together with corrosive media (fission products,…) tribochemical wear system emerges

Free Cr

<table>
<thead>
<tr>
<th>%</th>
<th>C</th>
<th>Cr</th>
<th>Mo</th>
<th>V</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
<td>K110</td>
<td>1.55</td>
<td>11.80</td>
<td>0.80</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td>M390PM</td>
<td>1.90</td>
<td>20.00</td>
<td>1.00</td>
<td>4.00</td>
<td>0.60</td>
</tr>
</tbody>
</table>

Hardness

<table>
<thead>
<tr>
<th>Material</th>
<th>Hardness (HRC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K110</td>
<td>58</td>
</tr>
<tr>
<td>M390PM</td>
<td>61</td>
</tr>
</tbody>
</table>

Beside wear and corrosion resistance further important factors to choose the right material are:
» Tool design (complex/simple, deep/shallow cavity, …)
» Tool size
» Surface requirements on the mold

Additional aspects are for instance dimensional stability, edge stability, machinability, ability for coating…

Detailed recommendations have to be checked case by case.
### WEAR RESISTANCE WITH PLATE-WEAR TEST

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean Depth of Abrasion (µm)</th>
<th>Hardness (HRC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M368 BÖHLER</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>M340 BÖHLER</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>M310 BÖHLER</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>M333 BÖHLER</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>M390 BÖHLER</td>
<td>1000</td>
<td>60</td>
</tr>
</tbody>
</table>

**Glass fiber reinforced polymer melt:**
PA 66 + 50 % GF

![Graph showing wear resistance comparison between different materials](image1.png)

### WEAR RESISTANCE WITH PLATE-WEAR TEST – DETAIL

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean Depth of Abrasion (µm)</th>
<th>Hardness (HRC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BÖHLER M333</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>BÖHLER M310</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>BÖHLER M340</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>BÖHLER M338</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>BÖHLER M350</td>
<td>1000</td>
<td>60</td>
</tr>
</tbody>
</table>

**Primary carbides increasing**

![Graph showing wear resistance comparison with increasing primary carbides](image2.png)

**Glass fiber reinforced polymer melt:**
PA 66 + 50 % GF
CASE STUDIES

ELECTRICAL COMPONENTS
BASE PLATES FOR RELAYS

Processed material: PBT Vestodur X7212 NF + 45% GF
Cause for tool damage: Wear

HOUSEHOLD COMPONENTS
GEARS

Processed material: PA66 + GF35
Cause for tool damage: Wear

BÖHLER PLASTIC MOULD STEELS
QUALITY LEVELS
TECHNOLOGIES

Conventional Production

THE „STANDARD“ MATERIAL FOR ORDINARY STRESS, NORMAL LEVEL WITH:

<table>
<thead>
<tr>
<th>Structural conditions</th>
<th>Carbide distribution</th>
<th>Homogeneity</th>
<th>Individual carbides</th>
<th>Degree of purity</th>
<th>Toughness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Microstructure
BÖHLER K110
**Electro Slag Remelting Production**

**IMPROVED SERVICE LIFE DUE TO:**

- Least possible inclusion content
- Lower micro and macro segregation
- Good homogeneity and a higher degree of purity
- Homogenic structure throughout the entire cross-section and bar length
- Producing larger bar dimensions at a constant carbide distribution
- Uniform dimensional stability
- Broad range of application owing to a high degree of toughness

**Microstructure**

BÖHLER K340 in ESR quality

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**Powder Metallurgical Production**

**MICROCLEAN**

**FOR THE HIGHEST DEMANDS:**

- Segregation free high performance steel
- Finest carbide distribution
- Highest metallurgical purity
- Isotropic properties
- Maximum wear resistance with a simultaneously higher toughness
- High degree of hardness
- Very good dimensional stability
- High compressive strength

**Microstructure**

BÖHLER K390 MICROCLEAN