Abstract

Rapid development in plastics processing and new applications for plastics, require new steel grades. Plastic mould steels such as 1.2083, 1.4028, 1.2316 and 1.2085, currently available on the market, are often not able to fulfill the high requirements of the plastic processing industry.

Polishability to a mirror finish, improved thermal conductivity, high levels of toughness and hardness, very good corrosion resistance, machinability, are typical requirements for new steel grades for the plastic moulds with the highest demands. It is not enough to design a new tool steel composition, the optimal production route is also very important.

Modern development tools and modern production methods allow to design new steel grades optimized for their typical application. This report describes new development trends at for corrosion resistant plastic mould steels with improved characteristics to satisfy the demands of the plastic processing industry.

Keywords: Plastic mould steel; corrosion resistant steel

INTRODUCTION

Modern plastic products have to fulfill different demands and perform under different conditions in use. Plastics are able to fulfill some of demands themselves, but others, such as an excellent polished surface, or structured surface, are influenced by the mould and thus by the steel used for the mould.
The design of more difficult moulds shorter cycle times during production; new plastics; and decreasing delays between conception and realization of plastic products all call for plastic mould steels with improved characteristics in machining, toughness, thermal conductivity, polishability, corrosion resistance, etc.

These new, increased requirements on tool steels resulted in new development trends at Böhler Edelstahl GmbH Co KG in accordance with the special demands of tool manufacturer and customers.

NEW MOULD GRADE

CHEMICAL COMPOSITION

Most corrosion resistant moulds for plastics processing are made of 13 %-chromium, martensitic steels such as 1.2083 or 1.4028. Table 1 shows the chemical composition of the new Böhler grade M333 ISOPLAST compared to other martensitic chromium steels.

Table 1. Chemical composition of the new steel grade M333 ISOPLAST in comparison to established martensitic chromium steels

<table>
<thead>
<tr>
<th>Alloy</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cr</th>
<th>Mo</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2083</td>
<td>0.38-0.45</td>
<td>max 1.00</td>
<td>max 1.00</td>
<td>12.50-13.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4028</td>
<td>0.28-0.35</td>
<td>max 1.00</td>
<td>max 1.00</td>
<td>12.00-14.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M310 ISOPLAST</td>
<td>0.40</td>
<td>0.70</td>
<td>0.40</td>
<td>14.30</td>
<td>0.60</td>
<td>+V</td>
</tr>
<tr>
<td>M330 VAR</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>13.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M333 ISOPLAST</td>
<td>0.28</td>
<td>0.30</td>
<td>0.30</td>
<td>13.50</td>
<td></td>
<td>+N</td>
</tr>
</tbody>
</table>

As a result of the installation of a P-ESR plant, Böhler is able to use nitrogen as a further alloying element [1, 2]. Nitrogen has a lot of positive effects on martensitic chromium steels. The partial replacement of carbon with nitrogen leads to an increase in corrosion resistance and toughness. General corrosion is reduced as well as pitting and crevice corrosion. The improvement in toughness results primarily from the very homogeneous distribution of fine precipitates Fig. 1a and Fig. 1b [3].

New slag technology was also developed in combination with the new P-ESR plant. With this combination it is possible to reach a minimum content of non-metallic inclusions, Table 2.
PROPERTIES OF THE NEW STEEL GRADE

Polishability. New applications for plastics such as CD – production, car headlights, and optical lenses force tool makers to produce moulds with a perfect surface. A product is only as good as the surface finish of the tool in which the product is formed. Particularly in the field of mirrored finishes no mistakes are condoned. Irregularities on the surface are immediately visible.

Homogeneous distribution of precipitates and a good cleanliness in respect of non-metallic inclusions are the basic requirements for optimum mirror finish polishability [4]. Because of the new chemical composition and new re-melting technology in the PESR plant, M333 has an excellent polishability. Fig. 2 shows the result of a polishing investigation carried out by several polishing companies in Austria and Germany.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>thin</td>
<td>heavy</td>
<td>thin</td>
<td>heavy</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>
Corrosion resistance. In the plastics processing industry, corrosion resistance is very important. The plastic materials are generally not chemically aggressive, but for example at a temperature above 165 °C hydrogen chloride separates out of PVC and combines with moisture in the air to form hydrochloric acid. This and other highly corrosive media can cause corrosion. To examine the corrosion resistance, salt spray tests according to DIN 50021 were carried out, Fig. 3.
After a testing time of two hours, M333 ISOPLAST shows a better corrosion behaviour compared to the reference steels. It has the smallest corroded area. The reason for this good corrosion behaviour is the new chemical composition, the very homogeneous microstructure and the good cleanliness in respect of non-metallic inclusions.

**Thermal conductivity.** Improvements in productivity lead to a reduction in cycle time during plastics processing. Moulds with a higher thermal conductivity are required. The thermal conductivities of M333 ISOPLAST and 1.2083 were investigated in the temperature range between 100 °C and 500 °C. Fig. 4 shows that M333 ISOPLAST has an improved thermal conductivity compared to 1.2083. This improvement results primarily from the chemical analysis, but also from the homogeneous microstructure and good cleanliness.

![Improved thermal conductivity of M333 ISOPLAST compared to 1.2083 ESR.](image)

**Toughness.** Toughness depends not only very strongly on the heat-treatment but also on the microstructure and on non-metallic inclusions. Fig. 5 shows a curve of impact energy dependent on the tempering temperature. Impact strength was measured using unnotched specimens.

There is a big variation in impact energy but the minimum is at an untypically high level for 13 %-chromium steels. These excellent toughness
values are due to the very homogeneous microstructure and the low number of non-metallic inclusions.

**NEW MOULD HOLDER GRADE**

Requirements on mould holder steels are not as high as those for mould steels such as 1.2083, 1.2316, 1.4028, etc. In addition to corrosion resistance, mould holder steels have to be easy to machine to reduce manufacturing costs, however fewer demands are made with respect to mechanical properties. The aim of this development was a new mould holder steel with improved machinability, good corrosion resistance and adequate mechanical properties.

**CHEMICAL COMPOSITION AND MICROSTRUCTURE**

Compared to a typical mould holder steel such as 1.2085, the new Böhler M315 EXTRA has a reduced carbon and chromium content, Table 3.
Table 3. Chemical composition of the new mould holder steel M315 EXTRA in comparison to 1.2085

<table>
<thead>
<tr>
<th>Alloy</th>
<th>C</th>
<th>Cr</th>
<th>Mn</th>
<th>S</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2085</td>
<td>0.35</td>
<td>15.60</td>
<td>1.40</td>
<td>0.14</td>
<td>0.60</td>
</tr>
<tr>
<td>MS315 EXTRA</td>
<td>0.05</td>
<td>12.70</td>
<td>0.90</td>
<td>0.14</td>
<td>0.40</td>
</tr>
</tbody>
</table>

In addition to improved machinability due to the higher sulphur content, the new grade has a dual phase microstructure, Fig. 6.

The second phase (ferrite) also leads to an improvement in machinability, the amount of ferrite must be less then 15%. More then 15% decreases the mechanical properties and reduces corrosion resistance.

**PROPERTIES OF THE NEW MOULD HOLDER GRADE**

**Hardening and tempering behaviour.** Fig. 7 shows the tempering behaviour of M315 EXTRA. Mould holder steels are typically delivered in the pre-hardened condition. The hardness level is usually approximately
300 HB. If required, M315 EXTRA is able to reach a hardness level of up to 360 HB.

![Figure 7. Tempering behaviour of M315 EXTRA.](image1)

**Corrosion Resistance.** Despite the reduced chromium content the new grade has a good corrosion resistance. Fig. 8 shows M315 EXTRA in comparison with 1.2085 after a salt spray test according to DIN 50021. The good corrosion resistance is based on the new chemical composition and a special heat treatment.

![Figure 8. Corrosion resistance of M315 EXTRA in comparison to the reference steel 1.2085.](image2)
Machinability. The largest fraction of the costs incurred when manufacturing a mould frame are the machining costs. The main goal of the development of M315 EXTRA was an improvement in machinability and thus a reduction in the manufacturing costs of mould frames. Figure 9 shows the results of milling tests done on M315 EXTRA and 1.2085. The improvement in the machinability of M315 EXTRA is immediately apparent. This excellent machinability in comparison to 1.2085 types is primarily due to the chemical composition, with the reduced carbon and chromium content, but also due to the specific sulphur addition and the dual phase microstructure.

Figure 9. Improved machinability of the new steel M315 EXTRA in comparison to 1.2085.

CONCLUSION

Modern plastics and plastic products require mould steels with improved characteristics. These increased requirements led to the development of new corrosion resistant plastic mould steels.

- M333 ISOPLAST: A mould steel with excellent polishability for a mirror finish combined with improved corrosion resistance, thermal conductivity and toughness.

- M315 EXTRA: A mould holder steel with essential improved machinability, good corrosion resistance and adequate mechanical properties.
REFERENCES


