XuperCoat™ for Best-in-Class Mould Wear Resistance and Product Quality in Slab, Bloom and Billet Casting

*Mould coatings are a crucial part in continuously improving product quality and reducing operating cost in the continuous steel casting process. Monitor Coatings - a UK based Castolin Eutectic company first developed a unique, ceramic composite coating technology, XuperCoat™, which has produced best-in-class results in terms of mould lifetime, cast product quality and caster operating costs. 30 years of experience are a proven record for this coating type and continuous developments of the technology now allow to the application of such coatings on all types of moulds including bloom and billet tubes. Furthermore, with increasing environment restrictions on hexavalent chromium compounds XuperCoat™ is the most efficient reliable alternative for steel casters moving away from electroplating solutions.*

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In the late 1980’s Davy Distington, Workington (UK), commissioned the second slab caster for British Steel’s Port Talbot facility. The new caster featured a split mould enabling parallel casting of two strands using a central divider. However, due to the harsh environment the divider was worn far earlier than the rest of the mould even though it was being protected by an electroplating layer. It was then, that British Steel and Monitor Coatings came together to develop the very first, and until today, best wear protection coating for casting machine components such as mould plates, dividers and grid plates. Over those last 30 years Monitor Coatings and its customers in the steel industry have constantly worked together on enhancing this solution which is now available worldwide for all caster types and proving its superior performance day by day.

**Product Quality and Wear Issues in the Steel Casting Process**

Continuous caster components are exposed to high temperatures, corrosive environments and wear. The primary function of the mould in the casting process is to control the rate of solidification and the shape of the strand. 60% of the heat exchange with the solidifying steel occurs in the top half of the mould and controlled heat transfer is critical to the rate and homogeneity of steel solidification. In the lower half of the mould wear by the solid steel shell becomes even more significant. The friction developed between the mould wall and the solidifying steel shell is minimized by the combined effect of molten flux or lubricant addition and oscillating mould vibration.
Figure 1: Schematic of phenomena in the mould region

Figure 1 demonstrates typical phenomena in the mould area from which the following features degrade dramatically the product quality as a result of intensive mould wear:

- Deteriorating coating layers lead to pick-up of copper from the mould wall which is then trapped on the hot liquid metal surface and forms *star cracks* which may result in costly coil breaks in the following rolling processes. Manual inspections including surface scarfing on cooled-down slabs are required to detect those cracks and cost days and energy for slab re-heating. In the case of a continuous casting/rolling process, manual inspections are even impossible.

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As mould wear appears typically first in the corners, the slab transforms increasingly into a \textit{W-shape} which leads eventually to rejections due to mismatch with required shape standards. It may also cause longitudinal corner cracks which bear the risk of coil breaks in downstream rolling processes.

Mould wear can be one reason for improper heat exchange causing the steel shell to stick to the inner copper mould surface and to tear. This results in transversal and edge cracks and in the worst case in a \textit{sticker breakout}. This most detrimental incident is not only very costly but is also a serious safety hazard for the operators of the casting machine.

\textbf{XuperCoat\textsuperscript{TM} Technology – Cure to the Disease}

\textit{XuperCoat\textsuperscript{TM}} is the next generation hard-metal composite coating using HVOF techniques\textsuperscript{3} capable of manipulating the coating composition to give an optimum microstructure design\textsuperscript{4}. This goes beyond the simple dual-phase alloys of tungsten carbide and cobalt to composite architectures. Significant performance improvements in coating properties have been achieved (see figure 2) by changes in size, shape and distribution of the phases to produce ultra-fine-grained materials (see Table 1). Despite being very dense, coatings, even tungsten-based hard-metal coatings do not ultimately meet the corrosion- and abrasion-requirements of specific steel industry applications. Micro-porosity (pore size smaller than 5μm) in the coatings can lead to crack initiation. To combat this phenomenon, specialist coatings are also used to densify the underlying coating, forming a physical barrier between the component and the working environment. Unique, thermo-chemically formed ceramic coatings are subsequently formed, where a metal oxide bond is established not only between the particulate materials, grains or powders used to form the coating, but also between the coating and the substrate.

\textsuperscript{3} Kamnis S., Gu S., 3D modelling of kerosene-fuelled HVOF thermal spray gun, Chemical Engineering Science 61 (16), 2006, pages 5427-5439.
\textsuperscript{4} Kamnis S., Gu S., Lu T.J., Chen C., Computational simulation of thermally sprayed WC–Co powder, Computational materials science 43 (4), 2006, pages 1172-1182.
Figure 2: Typical XuperCoat™ microstructure, showing very dense structure with uniform distribution of carbides and minimum in-flight particle decarburisation.

Table 1: Range of (non-thermal spray) coating systems and their corresponding characteristics compared to thermal spray XuperCoat™

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Hardness Vickers (HV)</th>
<th>Friction value</th>
<th>High Stress Abrasive Wear Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carburise Steel</td>
<td>700-900</td>
<td>0.35</td>
<td>4000</td>
</tr>
<tr>
<td>Nitride Steel</td>
<td>400-600</td>
<td>0.25</td>
<td>5000</td>
</tr>
<tr>
<td>PVD TiN</td>
<td>2000-3000</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td>PVD CrN</td>
<td>1800-2500</td>
<td>-</td>
<td>400</td>
</tr>
<tr>
<td>CVD CrN</td>
<td>1100-1300</td>
<td>0.5</td>
<td>300</td>
</tr>
<tr>
<td>CVD CrC</td>
<td>1500-2000</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Chromium Plate</td>
<td>800-1000</td>
<td>0.5</td>
<td>500</td>
</tr>
<tr>
<td>Nickel Plate</td>
<td>250-650</td>
<td>0.7</td>
<td>8000</td>
</tr>
<tr>
<td>Plasma CrO</td>
<td>1200-1600</td>
<td>0.5</td>
<td>1000</td>
</tr>
<tr>
<td>XuperCoat™</td>
<td>1000-1600</td>
<td>0.5</td>
<td>100</td>
</tr>
<tr>
<td>Densifier Coating</td>
<td>1000-2000</td>
<td>0.2</td>
<td>4000</td>
</tr>
</tbody>
</table>

* Friction force divided by the applied load, result is dimension less.

Table 1: Range of (non-thermal spray) coating systems and their corresponding characteristics compared to thermal spray XuperCoat™
Monitor Coatings’ customers reported yield increases in cast steel on the same mould in the range of 2 to 8 fold compared to electroplating solutions (see Figure 3). The actual mould’s life time increase varies dependent on the mode of operation and the nature of the product. Some plants operate thin slab casters or produce stainless steel, which tend to run on higher casting speeds and requires different coating setups compared to the low-speed traditional slab casters.

![Figure 3: Performance benchmark of wear resistance solutions](image)

In addition to increased yield with no operation disturbances noted, even on high casting speed, customers identified additional benefits of the application of XuperCoat™ mould coatings, such as:

- **Improved product quality:**
  - Less star and corner crack defects
  - Less strand shape issues
  - Less stickers and sticker breakouts
- **Reduced operating cost:**
  - Lower consumption of copper moulds
  - Lower consumption of mould flux powder
  - Better economy of scale due to less wear-related enforced stoppages

**Alternative thermal spray solutions**

For many years, hard chrome plating was an industrial standard process for wear and corrosion protection, but due to the European REACH regulations the application of hard
chrome plating will be highly regulated in Europe after 2017. This, not being an isolated trend in Europe, combined with the relatively low wear protection and cracking have prompted the development of alternative thermal spray coating solutions including WC-Co blended powder, Ni-based alloys, Ni alloy plus oxide cermet and functional gradient coatings combining layers of Ni-rich alloys, WC-Co. The friction characteristics of such coatings were superior to those of electroplated chromium under simulated mould wear conditions.

Figure 4: Thermal spray coating systems and their corresponding characteristics

Figure 4 demonstrates the findings that confirm the superior performance of the XuperCoat™ technology over alternative thermal spray coating systems introduced by casting technology suppliers into the market in terms of coating hardness, thermal conductivity and life-time extension (compare also Figure 3).

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5 From 2017 the REACH regulation will enforce considerably stricter regulations for the use of chromium trioxide. The substance is classified as carcinogenic and mutagenic.
Recent Developments for Long Product Casting

The successfully established XuperCoat™ technology for slab mould plates has raised the interest of long product steel producers who wish to benefit from the coatings’ superior properties in bloom and billet moulds. In conjunction with its partners and customers in the UK steel industry, recently Monitor Coatings has managed successfully to develop its XuperCoat™ technology to the required industrial level for application in mould tubes for the continuous casting of long products. The same benefits for producers of blooms and billets have been reproduced as established for slab casters.

Figure 5: XuperCoat™ applied on Billet Moulds

Industrial Experiences

Stainless Flat Steel Plant

In service, the XuperCoat™ coated slab mould life is 4 times that of the conventional copper mould at 100,000t of stainless steel cast. Little mould wear and no detrimental effects were observed. Early successes have now been translated into fully XuperCoat™ protected moulds being used as standard on all mould sizes in the fleet. The annual savings in mould maintenance costs alone are approaching 25%.

Carbon Flat Steel Plant

With XuperCoat™ it has been possible to replace the mould’s CuCrZr base material with plain CuAg, achieving net savings in annual copper costs of 30%. This has not only created increased caster availability and reduced mould maintenance costs but has also resulted in improvements in surface quality on selected grades that were particularly susceptible to off-corner wide side cracks. The level of scarfing has reduced dramatically because of the improved integrity and management of narrow face taper, with little or no wear occurring on the narrow faces. The XuperCoat™ technology is now the standard coating on all four mould faces.
**Carbon Long Steel Plant**

The plant operates a twin-strand large bloom caster (560 x 400mm). All four faces of a mould were coated with XuperCoat™. The mould had achieved 100,000t of steel cast – already three times the previous best performance. The plant has now the whole mould fleet coated with XuperCoat™. Previously, with the conventional mould there would be a significant loss of taper after approximately 200 heats (~16,000t of steel per mould) leading to longitudinal corner cracking of the bloom. Mould taper is now sustained throughout the mould campaign. There has also been a general improvement in overall bloom surface quality.

**Carbon Long Steel Plant**

The plant applies XuperCoat™ technology in casting sections from 230 x 283mm up to 305 x 483mm for a variety of applications. This has achieved a life of four times the previous chrome-plated mould. Recently XuperCoat has been applied on a Caster 5 Bloom Mould with initial results showing mould life improvement of 3 times. Figure 6 shows the mould condition after 600 Heats.

*Figure 6: XuperCoat™ applied on Caster 5 Bloom Mould. Coating condition after 600 heats.*
Summary

Castolin Eutectic’s UK based Monitor Coatings was the first company to introduce high performance ceramic composite coatings to caster copper moulds and has continued to lead the field in innovation and performance, bringing extended benefits to its customers by tailoring the application to their specific requirements. XuperCoat™ coatings capable of functioning in extreme environments where temperature, abrasion, fatigue and friction are merely starting blocks in the design of a coating system, this unique ceramic composite coating technology show significant technical and commercial advantages. With such low wear rates, there are marked improvements in the downstream surface quality of the billets and slabs, while at the same time the integrity of the original copper mould asset is maintained.

Castolin Eutectic will be present from May 8 till 11, 2017 on AISTECH in Nashville, USA and from June 26 till 29, 2017 on the European Continuous Caster Conference in Vienna, Austria.

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