XuperCoat™ mould coatings for improved wear resistance and product quality

Mould coatings play a crucial part in improving product quality and reducing operating costs in continuous casting. Monitor Coatings, a UK-based Castolin Eutectic company, has developed a unique ceramic composite coating technology, XuperCoat™, which has produced best-in-class results in terms of mould life, cast product quality and caster operating costs. The technology is suitable for all types of moulds and, with increasing environmental restrictions on hexavalent chromium compounds, it is the most efficient reliable alternative to electroplating solutions.

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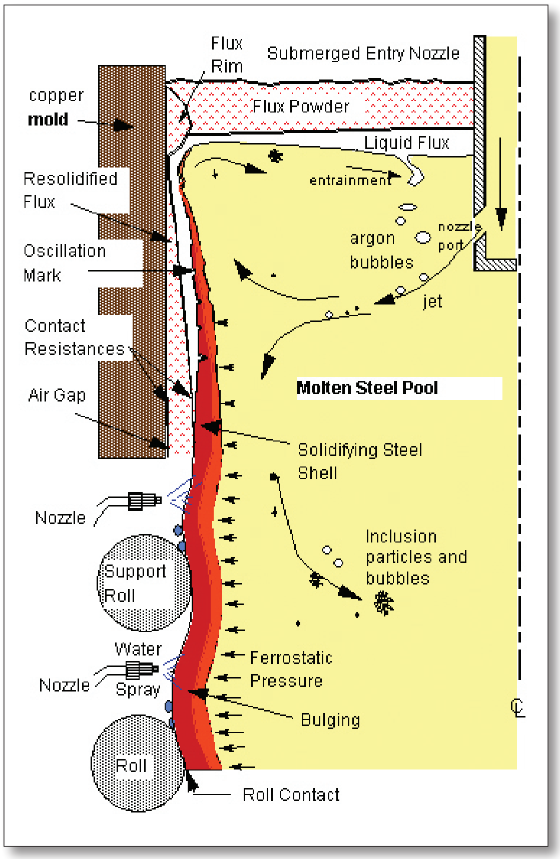

Fig 1 **Schematic of the casting process [1]**

In the late 1980s, 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 wear protection coating for casting machine components such as mould plates, dividers and grid plates. Since then Monitor Coatings and its customers have worked together on enhancing this solution which is, today, available worldwide for all caster types and is proving its superior performance.

PRODUCT QUALITY AND WEAR ISSUES IN CASTING

Continuous caster components are exposed to high temperatures, corrosive environments and wear. The primary function of the mould is to control the rate of solidification and the shape of the strand. A total of 60% of the heat exchange from 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. Friction developed between the mould wall and the solidifying steel shell, as illustrated in *Figure 1*, is minimised by the combined effect of molten flux or lubricant addition and oscillating mould vibration, but despite this, wear by the solid steel shell can still be significant.

Extensive mould wear can result in deteriorating steel quality and production:

- 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 **[2]** which may result in costly coil breaks in the following strip rolling processes. Manual inspection on cooled slabs is required to detect these cracks, followed by surface scarfing as required. This leads to increased costs through delays, yield losses and the energy needed for slab re-heating. In the case of a continuous casting/rolling process, manual inspections may not even be possible.

- As mould wear typically appears first in the corners, the slab transforms increasingly into a 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 transverse and edge cracks and, in the worst case, in a sticker breakout. This most detrimental incident is not only very costly, but is also a serious safety hazard for the plant operators.

XUPERCOAT™ TECHNOLOGY

XuperCoat™ is the next generation hard-metal composite coating using (high velocity oxygen fuel) HVOF techniques **[3]** capable of manipulating the coating composition to give an optimum microstructure **[4]**. The process capabilities range from 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 showing very dense structure with uniform distribution of carbides and minimum in-flight particle decarburisation. A comparison of the properties of non-thermal spray coating systems and XuperCoat™ is given in *Table 1*.

Despite being very dense, coatings – even tungsten-based hard-metal ones – 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 so 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.

Monitor Coatings' customers have reported two to eight-fold cast steel yield increases on the same mould compared to electroplating solutions (see *Figure 3*). The actual mould life time increase varies depending on the mode of operation and the nature of the product. Some plants operate thin slab casters or produce stainless steel, ▷

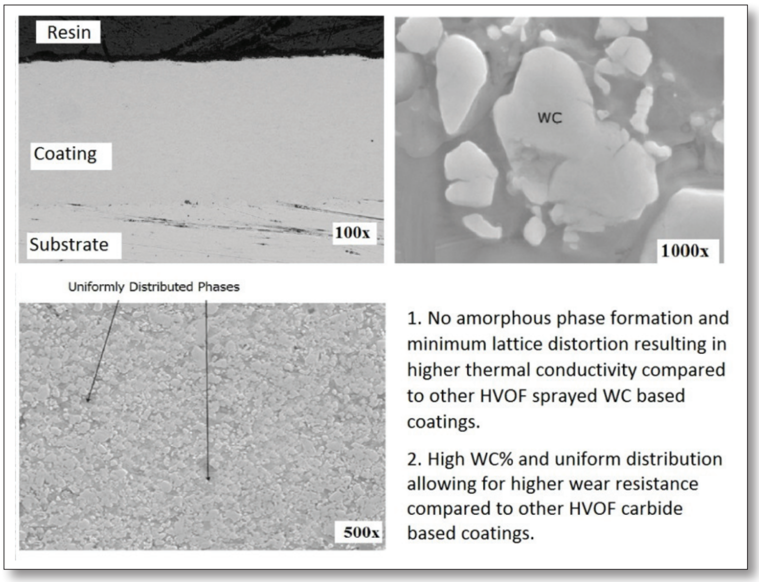

Fig 2 **Typical XuperCoat™ microstructure**

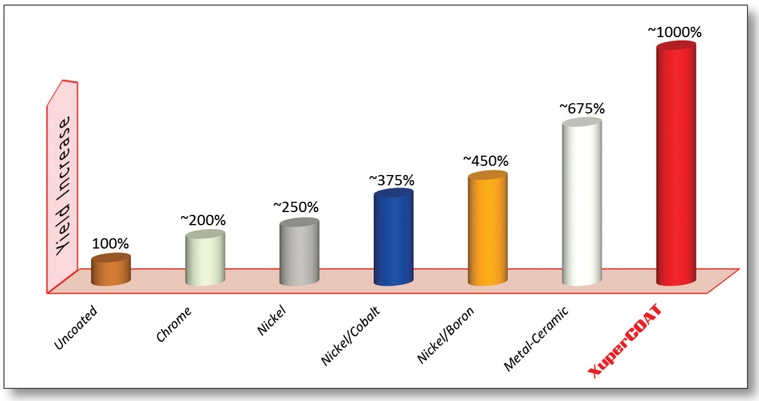

Fig 3 **Statistical performance benchmark of wear resistance solutions based on customer feedback [yield increase defined as percentage of tonnes cast with coated mould vs. tonnes cast with uncoated mould]**

Treatment	Hardness Vickers (Hv)	Friction value[a)]	High stress abrasive wear factor
Carburised steel	700-900	0.35	4,000
Nitrided steel	400-600	0.25	5,000
PVD[b)] TiN	2,000-3,000	0.5	-
PVD[b)] CrN	1,800-2,500	-	400
CVD[c)] CrN	1,100-1,300	0.5	300
CVD[c)] CrC	1,500-2,000	0.5	200
Cr plate	800-1,000	0.5	500
Ni plate	250-650	0.7	8,000
Plasma CrO	1,200-1,600	0.5	1,000
Densifier coating	1,000-2,000	0.2	4,000
XuperCoat™	**1,000-1,600**	**0.5**	**100**

a) Friction force divided by applied load is dimensionless.

b) Plasma Coating Deposition (PVD) technology (vacuum coating). The materials are vapourised under vacuum coating conditions. A vacuum chamber is necessary to avoid reaction of the vapourised material with air.

c) Chemical Vapour Deposition (CVD) is an atmosphere controlled process conducted at elevated temperatures (~1,050° C) in a CVD reactor. During this process, thin-film coatings are formed as the result of reactions between various gaseous phases and the heated surface of substrates within the CVD reactor.

Table 1 **Comparison of non-thermal spray coating systems with XuperCoat™**

which tend to run with higher casting speeds and which require different coating setups compared to the lower speed traditional slab casters.

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

- Improved product quality
- Fewer star and corner crack defects
- Fewer strand shape issues
- Fewer stickers and sticker breakouts
- Lower operating cost through
- Reduced consumption of copper moulds
- Reduced 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.However, due to the European Registration, Evaluation, Authorisation and restriction of Chemicals (REACH) regulations, the application of hard chrome plating will be highly regulated in Europe after 2017. Considerably stricter regulations for the use of chromium trioxide, which is classified as carcinogenic and mutagenic, will be enforced.

This is not just a European trend and, when combined with the relatively low wear protection and cracking of thermal spray coating, has prompted the development of new options including WC-Co blended powder, Ni-based alloys, Ni alloy plus oxide cermets and functional gradient coatings combining layers of Ni-rich alloys and WC-Co. The friction characteristics of such coatings were superior to those of electroplated chromium under simulated mould wear conditions **[5]**.

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

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 similarly benefit in bloom and billet moulds. In conjunction with its partners and customers in the UK steel industry, Monitor Coatings has successfully developed this technology and the same benefits for producers of blooms and billets have been reproduced as established for slab casters. *Figure 5* illustrates two examples.

INDUSTRIAL EXPERIENCE

Stainless flat steel plant In service, the XuperCoat™ coated slab mould life is four times that of the conventional copper mould at 100,000t of 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 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, but has also resulted in improvements in surface quality on specific 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. XuperCoat™ 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™ and achieved 100,000t of steel cast – already three times the previous best performance. The plant now has 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 blooms. Mould taper is now sustained throughout the mould campaign and there has also been a general improvement in overall bloom surface quality.

Carbon long steel plant The plant applies XuperCoat™ technology in casting blooms from 230 x 283mm up to 305 x 483mm for a variety of applications. This has achieved a life of three to four times the previously used chrome-plated moulds. *Figure 6* shows the condition of one mould 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 function in extreme environments of temperature, abrasion, fatigue and friction and generate significantly lower mould wear rates than conventional coatings, leading to lower operating costs, and technical and commercial advantages. MS

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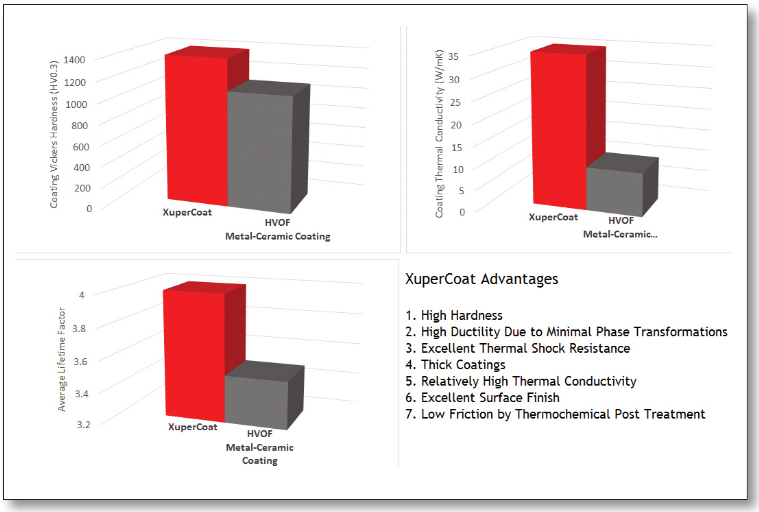

Fig 4 Thermal spray coating systems and their corresponding characteristics

Fig 5 XuperCoat™ applied on billet moulds

Fig 6 XuperCoat™ applied on a bloom mould. Coating condition after 600 heats