

Unique coating technology for superior mould wear resistance and product quality

Mould coatings play a crucial role in improving product quality and reducing operating costs in continuous steel 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 has been applied successfully on slab, bloom and billet moulds and proved to be the most efficient reliable alternative to electroplating solutions.

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

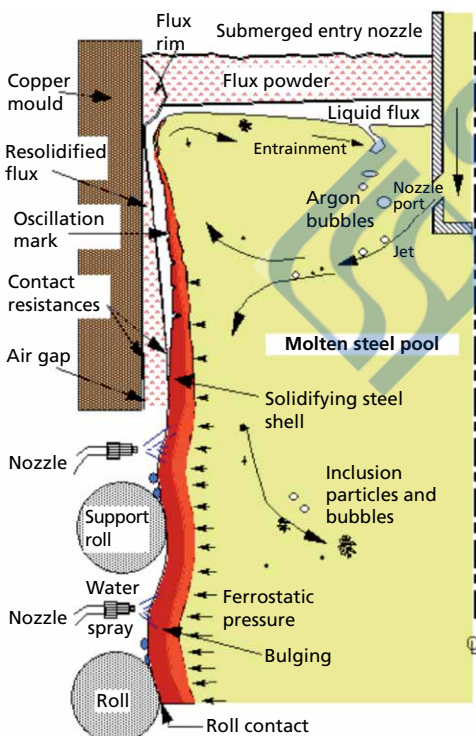
machine components such as mould plates, dividers and grid plates. Over those last 30 years, Monitor Coatings and its customers in the steel industry have constantly worked together on enhancing this solution which is now available worldwide for all caster types and proving its superior performance.

the combined effect of molten flux or lubricant addition and oscillating mould vibration. Despite this, wear by the solid steel shell can still be significant and may result in deteriorating product quality:

- 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 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 reheating. 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

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 is to control the rate of solidification and the shape of the strand. 60% of the heat exchange from the solidifying steel occur 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 is minimized by



Schematic of phenomena in the mould region [1]

Treatment	Hardness vickers (HV)	Friction value*	High stress abrasive wear factor
Chromium plate	800 – 1000	0.5	500
Nickel plate	250 – 650	0.7	8000
Plasma CrO	1200 – 1600	0.5	1000
Densifier coating	1000 – 2000	0.2	4000
XuperCOAT™	1000 – 1600	0.5	100

Range of (non-thermal spray) coating systems and their corresponding characteristics compared to thermal spray XuperCOAT™ (*friction force divided by the applied load)

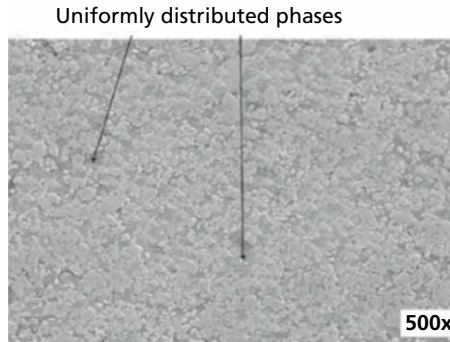
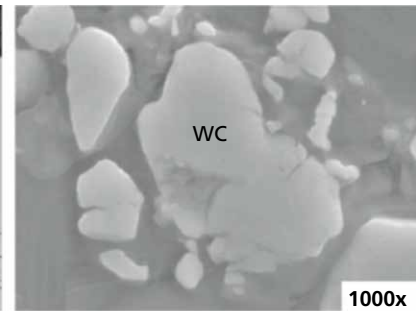
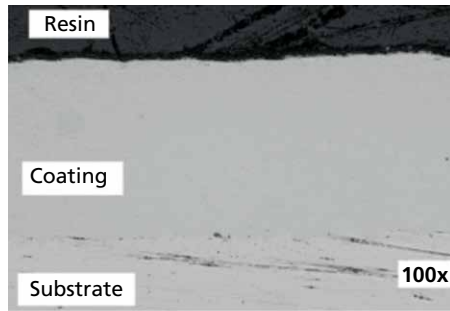
due to mismatch with required shape standards. It may also cause longitudinal corner cracks which bear the risk of coil breaks in downstream rolling processes.

- 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 sticker breakout. This most detrimental incident is not only very costly but also a serious safety hazard for the operators.

XuperCOAT™ technology – cure to the disease

XuperCOAT™ is the next generation hard-metal composite coating using HVOF (high velocity oxygen fuel) techniques [3] capable of manipulating the coating composition to give an optimum microstructure design [4]. The process capabilities go beyond the simple dual-phase alloys of tungsten carbide and cobalt to composite architectures. Significant performance improvements in coating properties have been achieved 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 decarburization.

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 5 μm) 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



Typical XuperCOAT™ microstructure

1. No amorphous phase formation and minimum lattice distortion resulting in higher thermal conductivity compared to other HVOF sprayed WC based coatings.
2. High WC% and uniform distribution allowing for higher wear resistance compared to other HVOF carbide based coatings.

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. The actual mould life 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 with higher casting speeds and which require different coating setups compared to the lower speed traditional slab casters.

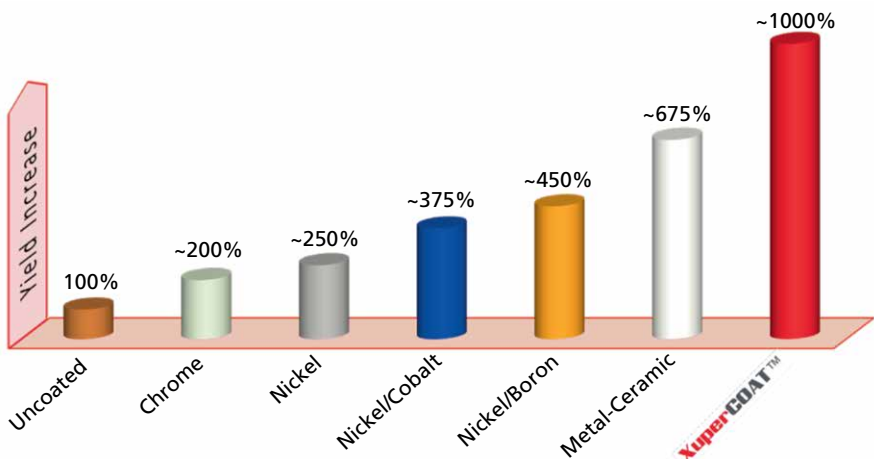
In addition to increased yield with no operation disturbances noted, even

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, and lower operating cost:
- 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



Statistical performance benchmark based on customer feedbacks

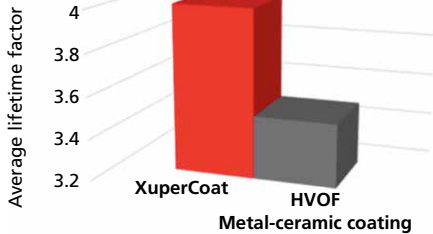
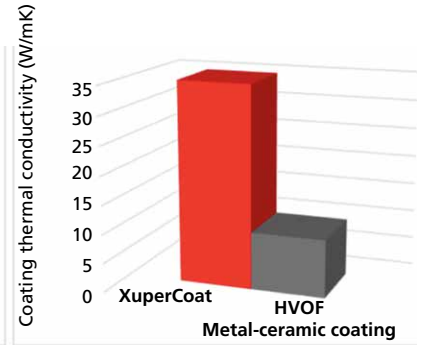
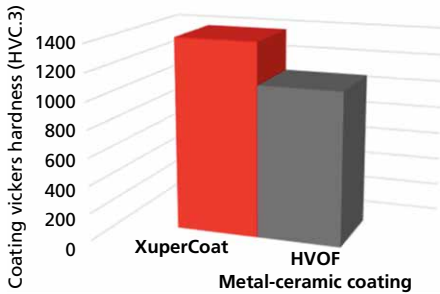
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wear and corrosion protection. However, due to amendments to the European Registration, Evaluation, Authorization and restriction of Chemicals (REACH) regulations coming in force in September 2017, the application of hard chrome plating will be considerably restricted in Europe for health and safety reasons.

This is not just a European trend, and combined with the relatively low wear protection and cracking has prompted the development of other thermal spray coating solutions such as 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]. Findings confirm the superior performance of the XuperCOAT™ technology over alternative thermal spray coating systems from other casting technology suppliers in terms of coating hardness, thermal conductivity and mould life extension.

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 suc-



XuperCOAT™ Advantages

1. High hardness
2. Excellent thermal shock resistance
3. Thick coatings possible
4. Good thermal conductivity
5. Excellent surface finish
6. Low friction

Thermal spray coating systems and their corresponding characteristics

cessfully developed the XuperCOAT™ technology for application inside of one-piece mould tubes used in long products casting. The same benefits for producers of blooms and billets have been reproduced as established for slab casters.

nual savings in mould maintenance costs alone are approaching 25%.

Industrial experiences

Stainless flat steel plant. In service, the XuperCOAT™ coated slab mould life is four times that of the conventional copper mould at 100,000 t 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 an-

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 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. The XuperCOAT™ technology is now the standard coating on all four mould faces.



XuperCOAT™ applied on billet moulds

Carbon long steel plant. The plant operates a twin-strand large bloom caster (560 x 400 mm). All four faces of a mould were coated with XuperCOAT™ and achieved 100,000 t 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 (~ 16,000 t 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 283 mm up to 305 x 483 mm for a variety of applications. This has achieved a life of three to four times the previously used chrome-plated moulds.

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,



XuperCOAT™ applied on a bloom mould; coating condition after 600 heats

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. ■

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