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About the cover
Hot dip sink roll used in a molten metal zinc bath for a strip steel coating line – HVOF thermal spray processing, courtesy of ASB Industries Inc., www.asbindustries.com.

Editorial Opportunities for iTSSe in 2013
The editorial focus for iTSSe in 2013 reflects established applications of thermal spray technology such as power generation and transportation, as well as new applications representing new opportunities for coatings and surface engineering.

November Emerging Technologies
To contribute an article to one of these issues, please contact the editors c/o Julie Kalista at Julie.Kalista@asminternational.org.
To advertise, please contact Kelly Thomas, Kelly.Thomas@asminternational.org.
After much handwringing, ITSC 2013 was held May 13-15 in Busan, Republic of Korea. Despite the intense geopolitical situation in the months preceding the event and its inevitable impact on attendance, ITSC was a great success. Close to 1000 attendees enjoyed 196 presentations, including many about applications in the automotive industry.

Forty-three posters were also presented during the conference, and the exposition featured 81 booths from 58 companies—a record for an ITSC held in the Pacific Rim. The week started with a well-attended plenary session on Monday morning. After opening remarks, several important awards were presented including:

- Christian Moreau (National Research Council of Canada) and Brad Beardsley (Caterpillar) were inducted into the Thermal Spray Hall of Fame
- Joachim Heberlein (University of Minnesota) received the 2013 TSS President’s Award


ITSC featured another plenary talk on Tuesday by H.J. Kim (RIST), in which he gave a comprehensive overview of thermal spray in Korea and R&D activities at RIST.

On Tuesday evening, ITSC attendees went to the Nurimaru APEC House, a breathtaking venue by the sea, for a networking gala dinner followed with a lovely traditional Korean entertainment performance.

ITSC concluded on Wednesday with the Sulzer Metco Young Professional Competition, organized and led by Sanjay Sampath (SUNY). This year’s winner was Emine Bakan from Jülich, Germany. For the benefit of those who could not join us in Busan, I can confirm that there are a lot of promising young talents out there!

Of course, such a successful event would not be possible without the hard work and dedication of several people as well as the support from many organizations, so please allow me to extend very special thanks to:

- Our distinguished Korean hosts, Drs. Kim and Lee, and the entire KTSA
- Our partners, DVS and IIW
- Dedicated ASM and DVS staff
- Many TSS volunteers led by John Hayden, TSS vice president
- Exhibitors and sponsors
- All attendees

On behalf of the ASM Thermal Spray Society, DVS, and IIW, I thank you again for your participation and support, and I look forward to seeing you all again next year in Barcelona.

Luc Pouliot, president, Thermal Spray Society

Nominations Sought for Thermal Spray Hall of Fame

The Thermal Spray Hall of Fame recognizes and honors outstanding leaders who have made significant contributions to the science, technology, practice, education, management, and advancement of thermal spray. For a copy of the rules, nomination form, and list of previous recipients, visit www.asminternational.org/tss. Click on networking and membership followed by TSS Awards. Or contact Sarina Pastoric at sarina.pastoric@asminternational.org. Nominations are due September 30.
Two Inducted into the Thermal Spray Hall of Fame

Christian Moreau and Brad Beardsley were both inducted into the Thermal Spray Hall of Fame at ITSC 2013. Christian Moreau, FASM, and the Editor-in-Chief of Journal of Thermal Spray Technology since 2004, was inducted into the Thermal Spray Hall of Fame “for advancing thermal spray science and technology through the development of innovative scientific and control diagnostics, advanced coating materials systems, and for leadership in thermal spray communications.”

Moreau was selected based on both his personal contributions to thermal spray technology, as demonstrated by his seven patents and many publications, as well as for his management of an internationally recognized research organization. He has advanced the understanding and development of thermal spray technology through his significant role in the development of optical systems for the measurement of the plasma effluent and particle temperature, velocity, and their distributions.

Moreau is an active member of the Thermal Spray Society and ASM International and served on the Thermal Spray Society Advisory Council from 2011 to 2013, the TSS Nominating Committee from 2010 to 2012, and is a member of both TSS Publications and Communications as well as the TSS Program Committee from 1999 to 2013.

Along with Moreau, Brad Beardsley of Caterpillar Inc. was also inducted into the TSS Hall of Fame during ITSC “for advancing thermal spray science and technology through the development of innovative scientific and control diagnostics, advanced coating materials systems, and for leadership in thermal spray communications.”

Beardsley joined Caterpillar in 1977 and worked in the areas of heat treat, gear technology, casting, fatigue, fracture, and thermal spray technology prior to his retirement in April 2013. He developed thermal spray coating applications including coatings for remanufacturing as well as chrome plate replacement. His leadership resulted in significant growth in Caterpillar’s Remanufacturing Division using twin wire arc and plasma transferred arc bore spray technologies. He also led the implementation of HVOF coatings to replace thick chrome plateings used on Caterpillar large mining truck suspensions.

ITSC 2013 Best Paper Award

The ITSC 2013 Best Paper Award was presented to Navid Sharifi, Fadhel Ben Ettouil, Milad Mousavi, Martin Pugh, Christian Moreau, and Ali Dolatabadi for their paper, Superhydrophobicity and Water Repelling Characteristics of Thermally Sprayed Coatings.
**Handbook of Thermal Spray Technology hits bookshelves this month**

A new addition to the ASM Handbook Series hits bookshelves this month. Based on the success of *Handbook of Thermal Spray Technology*, Dr. Robert C. Tucker, Jr. took the lead as editor to update and expand this book into what is now *ASM Handbook, Volume 5A, Thermal Spray Technology*. It is written for those new to the industry, design engineers, thermal spray job shops, management and sales, and as a knowledge “springboard” for scientists and universities.

*ASM Handbook Volume 5A* contains core fundamentals, insights from experts, and an expanded section on application stories. Every page contains information that may help solve problems. Visit the bookstore at asminternational.org to purchase your copy today.

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**Reliability, Durability and Performance Assessment of Thermal Spray Coatings Conference**

October 8-9, 2013
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This conference features invited talks and keynote presentations by technical experts in a variety of industries who will share their knowledge and experience. Sign up for the Introduction to Advanced Diagnostic Techniques Applied to Thermal/Cold Spray Processes education course or sign up to tour the GE Power & Water Factory or Test Solutions Industry (ITS). Visit www.asminternational.org/content/Events/tscoatings to learn more.

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**ITSC 2014 Call for Papers**

This annual event is jointly organized by the German Welding Society (DVS), ASM Thermal Spray Society (TSS), and the International Institute of Welding (IIW). ITSC 2014 presents the latest applications, research, and developments in the field of thermal spray.

All oral/poster manuscripts must be written in English and submitted electronically. The manuscript deadline for all contributions is December 13, 2013. Selected conference contributions (oral and poster) will be published in the conference proceedings. Visit www.dvs-ev.de/itsc2014 to submit today.

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Product quality, maintenance costs, and production requirements drive engineering improvements where surfacing technologies play an important role in steel production. To enhance product quality, the steel industry employs various surface-modification technologies. Thermal spray is one such process. This article reviews both thermal spray materials and equipment—and provides examples of where coated components result in improved performance.

High-velocity oxyfuel (HVOF) and detonation gun technology are considered mainstream thermal spray techniques in steel manufacturing plants. Applications ranging from melting and transferring steel to end product integration require all types of coatings, with WC-Co and Cr$_3$C$_2$-NiCr cermets playing important roles. Properly applied coatings can withstand extreme wear and corrosion, resulting in longer production life and better quality steel strip, bars, and billets.

During steel production, components are exposed to a combination of high temperatures, corrosive environments, and various wear mechanisms, resulting in a wide range of degradation mechanisms. This leads to reduced product quality and operating efficiencies, and greater maintenance costs and downtime. Recent advances in materials, equipment, and processes, along with growth in the automotive sector in traditional and developing countries, should expand the use of thermal spray technologies. Dramatic growth has occurred in HVOF technology and in key cermets such as WC-Co(Cr) and NiCr-Cr$_3$C$_2$ for many different roll applications.

Areas of concern during steel manufacturing include heat, corrosion, and wear. To enhance equipment life, a number of thermal spray coatings are being used. Figure 2 shows a hot coil wound from strip steel. Wrapper rolls, which force the strip to turn into a coil, use a nickel-base self-fluxing alloy that is combustion sprayed and fused. This is one of a select group of coatings that works well in this extreme environment. The temperature of the steel strip shown in Fig. 2 is estimated at over 1400°C (2500°F); note the high-pressure cooling water flowing onto the coil as it is being wrapped. This is one of the harshest environments in strip steel manufacturing. Other surface-modification processes, such as submerged arc or welded coatings, can also be used in this demanding environment.

Many surface-modification processes are proprietary to steel manufacturers or coating applicators, but basic thermal spray coating applications are well understood. The desired quality and surface finish of the final product are critical to process and material selection. Wires, rods, sheet, and billets are just a few forms that steel can take before its release to second-tier industries. Specific areas of steel production where coatings are used include:

- Gas ducting system from molten metal
- Gas injection tuyeres, lances, and nozzles
- Molten steel process—ceramic nozzles
- Continuous casting molds
- Continuous casting rolls
- Various processing rolls (i.e., bridle, deflection, and annealing furnace rolls)

Following are a few important applications where coatings extend equipment life in the steel industry:

**Continuous casting molds:** Casting molds control the rate of solidification and shape of resulting billets. Mold life (gaged by the number of pours and tonnage) is limited by the coating’s ability to withstand wear that could transfer marks onto the slab or billet. Coating materials for this type of application include carbides, cermets, and ceramics.

**Coiling mandrels:** In steel applications, hot mill strip products typically require further processing. The transfer of coils to other continuous process lines requires the coil to be unwound then rewound, holding the core...
Friction, grip, and long-wearing surfaces allow proper strip tension from the initial weld joining to final trimming and wrapping. Rolls with HVOF-applied carbide coatings have harder surfaces than strip materials. Optimized surface profiles and high friction coefficients support gripping of strips to rolls without harming the strip’s surface finish properties.

Annealing line rolls: Today’s production rolls use either HVOF or detonation gun coatings. Proprietary coatings with oxidation-resistant MCrAlY cermets are used for extremely high furnace temperatures. For lower-temperature heat treatment of low-manganese steels, NiCr-Cr3C2 coatings are used. For high-temperature annealing of low-manganese steels, oxides and/or borides, or cermets of MCrAlY and alumina have been used in production. High-manganese steels cause more severe problems for rolls. Corrosion and oxidation products, typically in the form of oxides of chromium and aluminum on MCrAlY coatings, react with manganese from the steel, reducing coating service life and steel sheet quality. Many proprietary coatings feature optimized MCrAlY chemistries, along with additions of alternative oxides and/or carbides.

Continuous galvanizing line: Degradation of sink rolls and other rolls associated with continuous galvanizing lines is due to zinc and/or aluminum reactions with iron from the steel rolls. These reaction products—sometimes called dross particles—degrade rolls and affect the surface of steel products. The most commonly used zinc baths consist of galvanized zinc with minor concentrations of aluminum. Coatings use tungsten carbide/cobalt powders applied via HVOF or detonation gun technology. Success of these coatings depends on the spray parameters, powder manufacturing method, and sealant system. The key to increased life is to reduce the amount of free cobalt in the coating.

For more information: Charles Kay is vice president of marketing at ASB Industries Inc., 1031 Lambert St., Barberton OH, 44203, 330/753-8458, cmkay@asbindustries.com, www.asbindustries.com.

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Application of Automotive Thermal Spray Coatings

Danilo Lazzeri, Ralph Herber, and Silvano Keller
AMT AG
Döttingen, Switzerland

Robert Gansert*
Advanced Materials & Technology Services
Simi Valley, Calif.

Thermal spray coatings play an important role in the automotive industry from the high-performance racing sector to domestic automotive production. In North America alone, an estimated 15.6 million light-vehicle automobiles will be produced in 2013, representing a considerable market opportunity for the coatings industry. Thermal sprayed parts and components for these vehicles involve a large network of organizations including automotive manufacturers, tier one suppliers, thermal spray companies, equipment producers, and materials suppliers. Equipment manufacturers such as AMT AG design, build, and supply high-volume production thermal spray coating cells for this vast network.

Figure 1 shows a production spray cell provided to the European market for synchronizer rings and shifter forks. This particular application is used to apply molybdenum coatings. The combustion wire spray guns use acetylene, oxygen, and air. While newer wire-arc systems have been developed since the early days of the combustion process, the flame spray process is still used to impart essential mechanical properties such as hardness.

High-volume coating cells consist of multiple stations including load, grit blasting, cleaning, thermal spray coating, cooling, and unloading points. These stations can be seen in Fig. 2.

This turnkey system was specifically designed to mass produce a coating for certain automotive parts. The production cell is based on a MP 200 wire flame spray system, and simultaneously controls three wire flame spray guns. The complete cell consists of:

- Wire flame spray system, with three thermal spray guns
- Control module (MP 200)
- Gas module (MP 200) for three simultaneous gun operations

One prominent component of these production cells is a sophisticated multi-process control system, AMT’s MP 200 system (Fig. 3). This control module features intuitive, color touch screens that allow operators to program all process parameters involved in controlling the coating process. A separate gas module for the thermal spray guns controls the process gases used in production. This particular cell was provided to a European car manufacturer and sprays three parts per minute, enabling 3500 coated parts per day, in a three-shift operation.

Various manufacturers provide other thermal spray cells for coating automotive parts in North America and Europe as well. As automotive manufacturers continue to build vehicles to satisfy consumers and meet federal regulations for higher fuel efficiency, the thermal spray industry will continue to design and supply thermal spray cells and advanced coatings to address these needs.

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Increased power with decreased downtime is a constant challenge for power producers. Thermal spray technologies, such as HVOF and arc spray, are now widely accepted in the power generation repair community. The electric arc spray process in particular offers low cost, viable coatings that boost both cost savings and reliability of power generation systems, which run at 100% capacity for months at a time.

Thermal spray coatings extend operating time and increase the lifespan of stationary boiler steam driven power plants (Fig. 1). Generating (water wall tubes) and super heater banks, which suffer from ravages of sulfuric and vanadium gases in coal-fired boilers, see vast increases in longevity when sprayed with CrC-NiCr coatings using the liquid-fueled HP/HVOF process (Fig. 2)[1]. Where application requirements permit use of the electric arc spray process, the coatings effectively increase service life. Arc sprayed materials successfully in use in global boiler applications include: Tafa 45CT, a high chromium content nickel alloy for prolonging the life of coal fired boiler tubes; Tafa 95MXC, an FeCr based alloy that exhibits a very high hardness not typ-
ically found in most arc spray coatings (as high as 1180 DPH Vickers), ideal for the coal fired boiler environment; and TAFA 140MXC, an amorphous matrix nanocomposite material proven effective in wear and high temperature corrosion protection in the flu gas path of the boiler[2].

Development and application of thermal spray technologies is widely accepted for use in the main tube banks of boilers. An effort to promote these same benefits to critical secondary systems is now underway. By expanding the scope of thermal spray applications, the overall lifecycle of the entire boiler can be improved. Boiler systems include the fly ash handling system, induced draft fan, and the fuel handling system.

A variety of solid fuels are used in stationary power plants, with coal being the most prevalent. As the quest for fossil fuel alternatives continues, wood and trash fuel sources are gaining wider popularity. The main problem with solid fuels—whether coal, wood, or trash—is the large amount of particulate matter that carries through the entire flu gas path, from the fire box to the exiting stack, causing significant erosion of many components. This aspect of the process creates unique challenges.

A critical task in any power generation facility is to maintain environmental discharges at acceptable limits. One such emissions factor is limit of opacity—the amount of particulate matter that passes through the entire flu path and is discharged into the atmosphere via smoke stacks. In order to keep the opacity level within a specific mandated level and reuse as much potential energy from the fuel source as possible, fly ash is re-injected back into the boiler prior to the induced draft fan using a classifier, which separates the exiting char. The re-injected char goes back into the hottest part of the furnace and passes through the rest of the flu gas path.

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**Fig. 3 — Amorphous work hardening coatings produced with materials such as TAFA 95MXC and TAFA 140MXC display favorable results with the electric arc spray process.**
The path until it is burned into a small enough size to pass beyond the classifier, and into the exiting particulate scrubber system prior to (or within) the plant’s exit stack.

In wood fire systems, the re-injected char is highly abrasive. It can severely erode classifier componentry and cut deep grooves into the re-injection piping, causing insufficient flow which, in turn, creates unacceptable limits in opacity discharge. This can lead to premature outages during the power station’s run schedule. Electric arc spray coatings considerably extend the operating life of these systems. Materials used to manufacture char re-injection systems and flue gas duct work are generally inexpensive low carbon steels which, while cost effective, cannot withstand the abrasive nature of the material passing through them.

Amorphous work hardening coatings produced with materials such as TAFAL 95MXC and TAFAL 140MXC display favorable results with the electric arc spray process in applications within both the firebox of boilers (on the generating and super heater tubes) and induced draft fans (Fig. 3). These same materials can be used with comparable results within the fly ash system.

Another material to consider is TAFAL 97MXC Ultra Hard Duocor Wire. It uses titanium and tungsten carbide within an amorphous matrix, providing high abrasion resistance. For example, the material successfully coats blades of induced draft fans to prevent the erosion and resulting imbalance that occurs from contact with particulate matter traveling within the high volumes of gasses exiting the boiler.

The last critical system to impact boiler uptime and reliability is the fuel handling equipment. These systems have many points of contact that cause extreme wear, such as conveyor rollers and bucket elevators. Additionally, auger screws and the troughs in which they rest can experience high rates of wear as fuel passes through the screws at high feed rates. The same amorphous arc spray coatings used in the boiler and fly ash system can be applied to improve wear resistance in the fuel handling system.

Users of thermal spray technology in the boiler repair field are encouraged to seek applications beyond coating boiler tubes to prolong the overall life of power stations.


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References:
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The Journal of Thermal Spray Technology (JTST), the official journal of the ASM Thermal Spray Society, publishes contributions on all aspects — fundamental and practical — of thermal spray science, including processes, feedstock manufacture, testing, and characterization. As the primary vehicle for thermal spray information transfer, its mission is to synergize the rapidly advancing thermal spray industry and related industries by presenting research and development efforts leading to advancements in implementable engineering applications of the technology. Articles from the June and August issues, as selected by JTST Editor-in-Chief Christian Moreau, are highlighted. June is a special issue on “Coatings for Energy Applications,” organized by guest editors Armelle Vardelle and Robert Vassen. The first three articles highlighted below are from that issue. In addition to the print publication, JTST is available online through www.springerlink.com. For more information, visit www.asminternational.org/tss.

“Advances in Thermal Spray Coatings for Gas Turbines and Energy Generation: A Review”  
Canan U. Hardwicke and Yuk-Chiu Lau  
Functional coatings are widely used in energy generation equipment in various industries. Intelligent thermal spray processing is vital in many of these areas for efficient manufacturing. Advanced thermal spray coating applications include thermal management, wear, oxidation, corrosion resistance, sealing systems, vibration and sound absorbance, and component repair. This paper reviews the current status of materials, equipment, processing, and properties’ aspects for key coatings in the energy industry, especially the developments in large-scale gas turbines. In addition to the most recent industrial advances in thermal spray technologies, future technical needs are highlighted.

“A Novel Hybrid Axial-Radial Atmospheric Plasma Spraying Technique for the Fabrication of Solid Oxide Fuel Cell Anodes Containing Cu, Co, Ni, and Samaria-Doped Ceria”  
Mark Cuglietta, Joel Kuhn, and Olivera Kesler  
Composite coatings containing Cu, Co, Ni, and samaria-doped ceria (SDC) were fabricated using a novel hybrid atmospheric plasma spraying technique. A multi-component aqueous suspension of CuO, Co3O4, and NiO was injected axially simultaneously with SDC injected radially in a dry powder form. Coatings were characterized for their microstructure, permeability, porosity, and composition over a range of plasma spray conditions. Deposition efficiency of the metal oxides and SDC was estimated. Depending on conditions, coatings displayed either layering or high levels of mixing between the SDC and metal phases. Deposition efficiencies of both feedstock types depend strongly on nozzle diameter. Plasma-spray metal-supported solid oxide fuel cells using anodes fabricated with this technique demonstrate power densities at 0.7 V as high as 366 and 113 mW/cm² in humidified hydrogen and methane, respectively, at 800°C.

“Flexible and Conducting Metal-Fabric Composites Using the Flame Spray Process for the Production of Li-Ion Batteries”  
Joel Voyer  
Wire flame spray was used to produce electrically conductive and flexible Al coatings on diverse textile fabrics. The influence of spray parameters and fabric materials on the electrical conductivity of the metal-fabric composites was studied. Production of flexible Li-ion batteries with good electrical properties based on the use of such flame-sprayed aluminum cathode current collectors was shown to be viable. A coating quantity threshold of about 20 mg/cm² exists to obtain a sufficient electrical surface conductivity for commercial use of the produced metal-fabric composites. Excellent electrical surface conductivity of the composites (about 500 SA) could be achieved through an adequate optimization of spray parameters. Production of electrically conductive and flexible metal-fabric composites having sufficient electrical conductivity for the manufacture of flexible Li-ion batteries is possible.
A novel application of thermal spray coating is demonstrated by incorporating a plasma-sprayed Mo layer coating as a precursor step within an integrated coating design. The effectiveness of the two-step design is illustrated for aluminoborosilica coatings on SiC/C composites and W substrates based on the plasma-sprayed Mo precursor and subsequent codeposition of Si and B by a pack cementation method. Even with incomplete precursor coverage, an aluminoborosilica coating is developed due to the high initial fluidity of the as-pack coating. Effective oxidation resistance is achieved following exposure at elevated temperatures (1373-1673 K) in ambient air and during torch testing at 1773 K, providing clear evidence that plasma spraying of Mo is a viable precursor step in the formation of the oxidation-resistant Mo-Si-B-based coating.
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