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Empowering High Tech Materials
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Doug Puerta

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About the cover
SEM image of an HVOF sprayed nylon splat after impact onto a glass slide. The unique “fried-egg” morphology is characteristic of HVOF sprayed polymers, and is believed to be formed by polymer particles having a low temperature, high viscosity core together with a high temperature, low viscosity surface. Image courtesy of Milan Iosevic, Richard A. Cairncross, and Richard Knight, Drexel University, Philadelphia, Pa., and taken as part of an NSF-funded research project to attain improved understanding of transport and splat formation during HVOF deposition of polymeric coatings. Color enhanced.
Welcome to the premiere issue of International Thermal Spray & Surface Engineering – The Official Newsletter of the ASM Thermal Spray Society! This new publication will center on thermal spray and other surface engineering technologies and our goal is to provide ASM Thermal Spray Society (TSS) members with news and information on what’s happening within TSS and within industry. This will include membership information, updates on committee activities, information on members in the news, and technology updates from around the world. With the International Thermal Spray Association (ITSA) resuming control of SprayTime, which was jointly published with ASM-TSS for a number of years, the TSS leadership felt that it was important to have a publication serving our more than 1500 members around the world. This is also an opportunity to broaden the scope beyond thermal spray, since many other technologies are used in the field of surface engineering.

We envision a publication that will not only provide global technical and commercial information about thermal spray and related surface engineering technologies to our members and subscribers, but also represent a platform for us to broaden the reach of thermal spray technology into new industries and new applications. Inclusion of the newsletter with ASM's Advanced Materials & Processes is an important step, ensuring that International Thermal Spray & Surface Engineering will hit the ground running with an immediate circulation of more than 30,000!

It is perhaps fitting then that this new publication is being launched at “Seattle 2006” where, for the first time, ITSC-2006 (International Thermal Spray Conference & Exposition), AeroMat (Advanced Materials and Processes for Aerospace Applications), and the International Surface Engineering Congress are being co-located. Seattle 2006 is unique in several ways. First, ITSC-2006 will celebrate the first centenary of thermal spray, an important milestone in our history. Thermal spray has come a long way since Dr. Schoop’s pioneering work a century ago, yet the basic principles remain unchanged, underscoring the significance of that original work. Second, thermal spray is approaching a crossroads. Future growth of the industry will require new applications and new markets – we must no longer “preach to the choir.” Co-locating with AeroMat and Surface Engineering, together with a simplified registration structure allowing participants to seamlessly attend all three events, will promote cross-fertilization and stimulate new ideas and opportunities. Our goal should be that “thermal spray” becomes a household term, so please join me in spreading the word!

Richard Knight, FASM
2004-06 President
ASM Thermal Spray Society
Acting Editor
Sprayable ceramic-base coating protects steel and superalloys

A sprayable ceramic-based coating for steel and superalloys that prevents corrosion, oxidation, carburization, and sulfidation in gas, liquid, steam and other hostile environments has been developed by researchers at Pacific Northwest National Laboratory (PNNL), Richland, Wash.

The new coating bonds with the metal substrate and is “resilient, inexpensive, and simple.” Because the coating is processed at temperatures significantly lower than typically required for conventional ceramic coatings, the new technology also can save energy and reduce harmful emissions.

The coating is produced on a steel part by mixing a liquid preceramic polymer with aluminum metal-flake powders to form a slurry that can be applied by dipping, painting, or air-spraying. The coating is cured in a commercial ruthenium-based catalyst that dries the slurry to a green state and enables polymer cross-linking.

The coated steel is then heated in air, nitrogen, or argon at 700 to 900°C. The heat converts the coating into an aluminum diffusion/reaction layer that permeates the surface of the steel and forms an iron aluminide surface. According to PNNL Commercialization Manager Eric Lund, the diffusion reaction makes the coating so durable that it can’t be chipped or scratched off.

The reaction layer is much stronger than an external coating because it is an integral part of the steel. This layer develops even further during service as the coating is heated at very high temperatures, such as those during the heating of pipes in a process facility.

Unlike similar products, the liquid form of the coating can be applied with a spray gun. This feature makes the PNNL coating practical for protecting large areas.

For more information: Eric Lund, Pacific Northwest National Laboratory, Richland, WA 99352; tel: 509/375-3764; eric.lund@pnl.gov; www.pnl.gov.

Comprehensive line of thermal spray, industrial spare parts

The launch of a comprehensive product line of thermal spray spare parts will be announced by SpaCom, the Spare Part and Component Company, during the International Thermal Spray Conference (ITSC) 2006 in Seattle, Wash. The SpaCom exhibit will include selected samples of its offering, including spare parts such as nozzles, air caps, electrodes, wire guides, and others for equipment from major manufacturers.

“The key advantage of our products is low cost while maintaining a high level of quality and providing fast delivery and customer service,” said Peter Hanneforth, president and founder of SpaCom. “Based on customer requests we can add any new products to our portfolio, which includes parts not only for thermal spray, but also for various other metal fabrication processes, such as blasting, PTA, and welding.”

For more information: SpaCom LLC, 223 Wall Street, #160, Huntington, NY 11743; tel: 866/3SPACOM (within U.S.) or 631/757-7799; info@spacom.com; www.spacom.com.

ASB Industries acquires most advanced HVOF system in North America

ASB Industries, Inc., recently announced its acquisition of a Sulzer Metco UniCoat LF HVOF system. A first in North America, the UniCoat HVOF system ensures remarkable technology, process, and material options for improved process reliability and greater cost efficiency.

The UniCoat controller delivers high-quality, reproducible coatings. It features an easy-view touch screen with advanced system diagnostics for rapidly finding and correcting system faults and utilizes a PC-card storage system for holding parameters and up to 100 recipes.

“The addition of the new HVOF system is a natural progression for ASB, since it adds versatility for surfacing on components already supported by our many other services,” said Al Kay, ASB Industries president.

For more information: Susan Haas, WhiteSpace Creative, 24 North High Street, Suite 200, Akron, OH 44308; tel: 330/762-9320; susan@whitespace-creative.com; www.asbindustries.com.

New boron nitride spray coating eliminates methylene chloride

The Ceramics division from GE Advanced Materials has introduced a new grade of its boron nitride (BN) spray coating that eliminates the use of methylene chloride. GE’s Boron Nitride (BN) Spray II may be used as a release agent and lubricant in a wide range of applications, including metalforming, glassmaking, plastics molding, high-temperature sintering, and welding and brazing.

GE’s Boron Nitride II spray coating offers the following benefits:

• High-temperature resistance for demanding applications
• High-purity crystalline structure for improved lubrication
• Non-reactive formulation for excellent release qualities and chemical stability
• Easy application using a convenient aerosol package

For more information: Monica Ettamarna, GE Advanced Materials, Quartz & Ceramics, Strongsville, OH 44149; tel: 440/878-5740; monica.ettamarna@ge.com.
New plasma spray gun offers improved throughput, extended range of applications

A recently redesigned offering from the Triplex gun family, the Sulzer Metco TriplexPro-200, can be used industry wide and provides improvements that processors have been seeking. Throughput is greatly improved, reducing material usage, generally the largest cost in thermal spray coatings, and processing time, the second largest cost. Gun maintenance can be performed on the shop floor, yet maintenance outage and cost are reduced by the long service life of gun wear components.

Designed for universal use, the TriplexPro-200, is capable of coating applications across the full spectrum of plasma spray. A selection of standard and optional nozzles, powder injectors, and injector holders has been designed for metals and alloys, carbides, abrasables, and ceramics. The current portfolio of nozzles has a range of exit diameters from 5.5 mm to 11 mm, with various lengths and dynamically shaped bores.

The new gun offers facilities that spray a single coating on a large scale, either in mass production environments or on large components requiring long spray campaigns, the benefits of little to no process drift and a better control of the process window. Flexible application range and improved reproducibility will benefit facilities that apply many different coatings. The 90-degree design of the TriplexPro-200 permits its use on part configurations that were very difficult or impossible with previous Triplex guns.

Because the gun operates at higher voltages with the amperage evenly divided across three electrodes, the wear on gun components is greatly reduced, so there is no need to use thoriated tungsten for gun components, eliminating this waste disposal issue and the costs associated with it. The service life of these components far exceeds that of conventional plasma spray guns, with 200 hours of spray time or more.

For more information: Adriana Fitting, Sulzer Metco (US) Inc., 1101 Prospect Avenue, Westbury, NY 11490; tel: 516/338-2422; adriana.fitting@sulzer.com; www.sulzermetco.com.

Fig. 1 – High-speed photographic comparison of the plasma plume of a conventional plasma spray gun (top) vs. the TriplexPro-200 (bottom)

Fig. 2 – The redesigned gun leverages the previous benefits of the Triplex gun family, but in a compact design with simple maintenance.

Fig. 3 – TriplexPro-200 extends the range of plasma spray applications. Shown here are plasma plumes under several different operating conditions.

Fig. 4 – Example photomicrographs of coatings sprayed with TriplexPro-200: a) Aluminum Silicon Polyester Abradable; b) Chrome Oxide; c) 88% Tungsten Carbide, 12% Cobalt
2006 Excellence in Hot-Dip Galvanizing Awards winners announced

The American Galvanizers Association (AGA) has announced the 14 winning projects of its 2006 Excellence in Hot-Dip Galvanizing Awards competition. The following winning projects were honored for their utilization of hot-dip galvanizing in an ideal, creative, innovative, and/or monumental fashion. Winners are listed at the AGA website at www.galvanizeit.org.

For more information: American Galvanizers Association, 6881 South Holly Circle, Suite 108, Centennial, CO 80112, tel: 720/554-0900; aga@galvanizeit.org.

In late 2004, the Charlotte Douglas International Airport broke ground on a 3,000 space parking facility. To accomplish the designer’s vision of a facility that would mirror the curvature of an airplane wing, the architect and engineer decided to attach stainless steel cladding to a galvanized structural steel frame. Galvanized steel was specified for its exceptional maintenance-free service life, overall aesthetic appearance, and compatibility with stainless steel. By specifying a hot-dip galvanized coating instead of a paint system, the garage will not require costly maintenance, and will remain a corrosion-free, attractive piece of the airport landscape well into the future.

The Schooner Isaac H. Evans, originally built in 1886, was rebuilt in the early 1970s, and designated a National Historic Landmark in 1991. Since 1973, the vessel has been carrying groups of people on sailing vacations on Penobscot Bay in Maine. In 2004, Captain Brenda Walker noticed some rot in the fore cross trees, and decided the best way to preserve the fittings was to hot-dip galvanize the metal bands, futtock shrouds, and other small pieces. Many of the original parts had been galvanized, and still exhibited corrosion-protective zinc, but after more than 100 years of ocean use, were in need of a new galvanized coating, which will last another 100 years. Using galvanized steel helped restore the historic vessel to its original luster and strength and will enable it to withstand the corrosive elements from the ocean and extreme climates of Maine.

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INDUSTRY NEWS
CGT GmbH, ASB Industries, and Linde AG partner to supply cold gas spray equipment for North America

ASB Industries, Inc. recently announced its partnership with CGT-Cold Gas Technology GmbH and Linde AG, Linde Gas Division that will allow it to become a strategic supplier of cold gas spray equipment, offering the same equipment license rights in North America as currently enjoyed by European markets. Linde Gas will support these efforts by being involved in nitrogen and helium supply to the kinetic process.

Designed and built by CGT of Ampfing, Germany, the Kinetics 3000 Cold Spray System is a true advancement in the production of cold spray systems. The system is highly versatile and delivers high-quality, reproducible coatings. It features a touch screen with system diagnostics and utilizes a PC-card storage system for holding parameters along with updating software using a direct modem line to CGT. With its closed-loop, computerized operation, Kinetics 3000 is an ideal system for individual part processing and production environments.

For more information: ASB Industries Inc., 1031 Lambert St., Barberton, OH 44203-1689; tel: 330/753-8458; susan@whitespace-creative.com; www.asbindustries.com.

Gridiron Capital acquires aviation-repair business from Praxair

Gridiron Capital, LLC and Praxair Inc., have entered into a definitive agreement for Praxair to sell the aviation services division of Praxair Surface Technologies, Inc. to a new corporation established by Gridiron Capital, as lead investor, and Skyview Capital, as a minority participant. The acquisition is expected to close in the second quarter of 2006.

Praxair Aviation Services repairs commercial and military aviation engine and airframe components, and applies protective coatings to the repaired parts. The division employs about 520 people and serves about 250 aviation customers worldwide.

“Praxair Aviation Services has been an innovator of industry-leading technical repair processes and is well positioned for further growth,” said Gridiron Capital’s managing partner, Eugene Conese, Jr. “The company has carved out a strong niche as the leader in innovative high technology repairs, and has a solid base for introducing new repair designs and expanding market share. We are committed to supporting their strong performance by providing additional resources to support and grow the business.”

For more information: Susan Szita Gore, Praxair, Inc. 39 Old Ridgebury Road, Danbury, CT 06810, tel: 203/837-2311; susan_szita-gore@praxair.com; www.praxair.com.

PS: A Puzzle for Sprayers Contributed by Chris Berndt

ACROSS
2. A failure process that occurs under thermal cycling. (two words)
6. An acronym for an important high temperature application.
9. In modeling exercises these are features that allow lines to be connected.
10. A process that is used to create coatings. (two words)
11. Without this fundamental property, a coating would not stick to a substrate.
13. A destructive technique that permits structural examination of a material.
15. This term describes the surface morphology of a coating and is termed as the “Ras”.
17. An acronym for a professional society.
19. A popular conference series that is focused on coatings technology.
20. Particles that exhibit this morphology will flow quite well.
21. Very small features that, eventually, give rise to failure.
23. An acronym for a method that allows identification of chemical structures.
27. A piece of aerospace machinery that needs coatings technologies.
28. A material undergoes this type of “stretching” as it is heated and cooled.
30. A term that may be used to describe the movement of atoms.
31. A layer within a thermal protection system that is close to the substrate.
32. An acronym of a USA organization that performs aerospace R&D.
34. An acronym for a European based aerospace manufacturer.
35. These are the fundamental building blocks of a thermal spray coating.
37. The 4th state of matter.

DOWN
1. A class of materials that are used in rotating aerospace machinery environments.
3. This term is used to describe the fine structure of a material.
4. A scientific method that is used to allow cracking processes to be “heard.”
5. The generic designation of metals that are used within high temperature machinery.
7. An acronym that describes an inter-layer that is close to the substrate.
8. An acronym for the composition of a popular material.
9. This feature of a coating confers thermal insulation capacity.
10. A term that is used to describe the grid that is necessary to carry out computational calculations.
12. A class of materials that exhibit good high temperature resistance.
18. A high temperature test method that simulates operational environments. (two words)
21. An engineering term that describes the initial stress vs. strain response of a material.
22. A mechanical property that employs an indentation test.
24. An acronym that is used to describe the Ra detail.
25. “Sty bitzy” small particle. (abbreviation)
26. A ceramic material that is used for high temperature applications.
27. An acronym for a family of coating processes.
29. The chemical formula for aluminum.
33. An acronym for a coating process that produces dense coatings.
Altair Nanotechnologies enters into supply and distribution agreement with Sulzer Metco

Altair Nanotechnologies Inc. announced that it has entered into a supply and distribution agreement with Sulzer Metco for the industrial market. Altairnano and Sulzer Metco have agreed upon a framework to supply and sell what is projected to be tons of nano-structured titania-dioxide and nano-structured yttria stabilized zirconium oxide. The parties will determine which Altair nano-structured powders will be manufactured and licensed for thermal spray applications and develop a five-year marketing and distribution plan outlining projected purchase quantities, pricing, and marketing plans for the product. Once a powder is designated to be supplied under the agreement, Sulzer Metco has the right to be the exclusive distributor of that product in the spray coating field assuming that certain purchase and other commitments are met.

Altairnano President and CEO Alan J. Gotcher commented, “The thermal spray market, with annual revenues in excess of $1.5 billion, presents an excellent opportunity for use of our innovative materials. Combining Sulzer Metco’s industry expertise with Altairnano’s nano-structured materials has the potential to deliver improved strength, performance and longer life for thermal spray coatings over coatings from conventional materials that have been used in the thermal spray industry.”

Sulzer Metco Vice President, Ceramics and Clad Composites, Michael Mueller, said, “We believe that Altairnano’s nano-structured powders will increase the adhesiveness of our thermal coatings, improve their thermal barrier performance and provide improved corrosion and abrasion resistance. These enhanced thermal spray coating materials may provide new market opportunities for our company, especially within major gas turbine and aerospace companies.”

For more information: Robert Pedraza, Altair Nanotechnologies, Inc., 204 Edison Way, Reno, NV 89502; tel: 775/856-2500; rpedraza@altairnano.com; www.altairnano.com

US, Polish researchers develop technology for antiwear polymer films

When Michael Furey, professor of mechanical and biomedical engineering, at Virginia Tech, met Czeslaw Kajdas, then with the Radom Technical University in Poland, at a conference in Europe in 1981, they had differing views on how to form polymer films on surfaces to reduce wear. The result of their eventual collaboration has been fundamental discoveries in surface chemistry and dozens of compounds that reduced wear in metals, advanced alloys, and ceramics. These include ashless antiwear additives for fuels, such as for diesel, jet, and two-cycle gasoline fuels; lubricants for automotive and industrial applications; and a variety of applications in which environmental concerns are important.

Tribo-polymerization, developed by Furey and Kajdas, involves continuous formation of thin polymeric films on rubbing surfaces to reduce wear and surface damage. The films are self-replenishing. Specifically selected small molecules (monomers) adsorb on surfaces. Under the action of sliding contact, thin protective polymer films will form.

Tribochem International Ltd., the Institute for Terotechnology in Radom, Poland, and the Central Laboratory of Petroleum in Warsaw recently agreed to collaborate to move the discoveries and knowledge into practical and industrial applications.

For more information: Susan Trulove, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061; tel: 540/231-5646; strulove@vt.edu.
One of the more common problems in the metallography lab is how to differentiate features inherent within a thermal spray coating from those induced during metallographic preparation. Fortunately, there are a few simple yet reliable tools that can be used to make a proper evaluation.

When evaluating a thermal spray coating, remember that there are a limited number of features that can be induced into the coating. These features include cracks, delaminations, separations, porosity, and, to some extent, phase. Features such as unmelts, oxides, thickness, and interface contamination have limited sensitivity to metallographic preparation.

Fluorescent or colored dye, mixed with a two-part resin and hardener cold mount epoxy, is an effective tool for identifying operator-induced artifacts within porous (>2% porosity) coatings. During the mounting process, voids (including cracks) inherent to the coating will fill with epoxy, assuming that a sufficiently low-viscosity epoxy in combination with a vacuum chamber is used. During subsequent evaluation of the coating, inherent features should be filled with epoxy and will be readily visible because of the added dye. In contrast, features induced during grinding and polishing will not have had the opportunity to be filled with epoxy and will differ in appearance from the inherent features.

This method is very reliable as long as any damage induced during sectioning has been removed. This is accomplished by grinding the sample to a depth beyond all sectioning damage. The required depth for grinding may be up to 0.060” (1.52 mm) for large samples sectioned using an abrasive saw. If this sectioning damage is not removed, it can also fill with epoxy and will appear as inherent porosity. Figure 1 illustrates the use of a fluorescent epoxy for identifying porosity.

For dense coatings, a lack of interconnected pores may prevent the liquid epoxy from fully impregnating the sample. In this case, analysis of a fracture surface of the coating can provide a qualitative measure of the porosity present within the coating. This procedure will be covered in a future *How to*… article.
Focus on Plasma Spray Processors

The first thermal coating company in India, Plasma Spray Processors was founded in 1984 by Mr. Navin Doshi. Mr. Doshi, who was involved in production and sales of textile spare parts, installed the first plasma spray system for in-house production of wear resistance coatings on textile components. Since the company's inception, partners Shri Dhimant N. Doshi and Shri Himansu N. Doshi have continuously upgraded facilities in order to keep pace with technological developments. The company today has 15 employees and offers seven coating and surface modification processes. These include powder flame spray, wire flame spray, two (one each of gas and liquid fuel) HVOF systems, two twin wire arc spray systems, three plasma spray systems, plasma transferred arc welding and TIG MIG welding. Plasma Spray Processors is the only company in India that provides different thermal spray and finish machining processes under one roof, and is also the only company of its kind certified as ISO 9001:2000.

With offices in Mumbai and the plant 25 miles away in Taloja, Plasma Spray Processors serves the aeronautical, cement, marine, oil field, paper and pulp, power generation, petrochemical, wire drawing, pump, printing, and machine manufacturing industries, with expertise specifically in gas turbine components and to the steel and paper industries.

Equipment installed at Plasma Spray Processors includes various surface preparation systems, multiple spray and welding systems, robots and job manipulators, and finish machining equipment.

Pre-coating preparation facilities contain pressure blasting cabinets with dust collectors, portable pressure blasters, and a vacuum suction blaster. Gun manipulating facilities include a five-axis and a six-axis robot, both with controller and teaching pendant, an X-axis manipulator of variable length, an X- Y- axis manipulator of up to 8 meters in length, and a 250-kg turntable. Plasma Spray Processors also has a bench drill machine, a buffing and polishing machine, a plasma ID coating gun, a super finishing machine, a bench grinding machine, and center lathes. Measuring facilities include Vernier calipers, micrometers, and surface profilometers.

Plasma Spray Processors can handle parts up to a maximum weight of 5000 kg, and can coat parts as large as 1.5 meters in diameter by 6 meters in length. They have three acoustic spray cells, including the longest in India at 9m x 4m x 3m. Many of the applications offered were initially developed in India by Plasma Spray Processors.

Dhimant Doshi has been a sustaining member of ASM/TSS since 1979. He is a member of almost every Organizing Committee for conferences and shows organized by the ASM India Chapter. At present, he serves as Executive Member of Technical Programming Committee, ASM India Chapter, and as “contact person” for any technical enquiries.

Owners of Plasma Spray Processors are Navin C. Doshi, president; Dhimant N. Doshi, executive director; and Himansu N. Doshi, director.

Contact information:
Registered Office: B-16/18, Vatsa House, 2nd Floor, Mumbai 400 001 Maharashtra, India; tel: 091-022-22836581 or 091-022-22870192 fax: 091-022-22870226; e-mail: plasma@vsnl.com
Plant: C-20 /4 M.I.D.C. Taloja, Maharashtra, India; tel: 091-022-27412575 or 27412785

Wear and corrosion resistant coating is applied to boiler tube using the JP-8000 kerosene process.

Nickel/carbide coating is applied by the plasma system to this paper and pulp winder roll to aid gripping and long term wear resistance to aid in high production paper winding.
This is from a prize-winning poster in the 2005 IMS Metallographic Contest. The images show the microstructural characterization of the Stellite/steel interface.

M.G. Burke and T.G.Hicks
Bechtel Bettis Inc.
West Mifflin, Pennsylvania

M.W. Phaneuf
Fibics Inc.
Ottawa, Ontario

Worn valve mainseats that leak unacceptably may require repair or replacement to restore required sealing performance. Typically, repair via arc-based welding processes is not viable, due to distortion and cracking that can arise from the thermal energy and stresses involved. Laser beam welding (LBW) was evaluated as a method to refurbish worn Stellite (CoCrW alloy) surfaces of disks from large gate valves. Initial LBW trials resulted in the localized delamination of the underlying hardfacing deposit. The microstructure in the region associated with the failure was characterized to assess the likelihood for similar in-service delamination.

Initial characterization

Initial characterization was conducted using light optical microscopy (LOM).

Fig. 1 — (a,b) DIC micrographs (arrows indicating direction of illumination) of as-polished Stellite/steel hardfacing interface. (c) LOM micrograph of etched Stellite/steel hardfacing interface. (2% nital).

Fig. 2 — TEM image of interface region similar to that region highlighted in Fig. 1c. Inset Fig. 5 — TEM micrograph of the Fe₃C carbides formed in the steel substrate in the region adjacent to the fusion zone, as result of the thermal cycle from the deposition of the original hardfacing deposit.

Fig. 3 — Complementary (a) bright-field and (b) dark-field TEM images of the Cr-enriched and Fe-Co-enriched phases formed in the fusion zone. The interconnected structure is consistent with the α-α’ phase formation in Fe-Cr-Co alloys. This structure is associated with increased hardness. STEM-EDS measured composition of the darkly-imaging phase in (a) is: Fe – 25Cr – 22Co – 3W, and the composition of the brightly-imaging phase in (a) is: Fe – 9Cr – 32Co – 2W.

Fig. 4 — (a) Bright-field TEM image of the Fe-Cr-Co martensitic structure adjacent to the fusion line. (b) Dark-field TEM image of fine Fe-Cr-Co decomposition products formed near the fusion boundary.
Metallographic samples were evaluated in the as-polished condition (Fig. 1a-b) using Differential Interference Contrast (DIC) lighting. Samples were also evaluated after etching with 3% Nital (Fig. 1c). LOM revealed several different phases and constituents in the Stellite and near the Stellite/carbon steel fusion line, but could not resolve the structure adjacent to the fusion line.

**Analytical electron microscopy** was performed on cross-section specimens from the fusion line region, to identify microstructure responsible for fracture (Fig. 2-6). Specimens were prepared using the **Focused Ion Beam (FIB) technique** (Micron 2500 operated at 50kV) to “micromachine” and thin site-specific electron-transparent samples for subsequent characterization (Fig. 6).

**Microstructural analysis**

Microstructural analysis showed that the local composition of the fusion zone led to the formation of complex transformation products associated with the Fe-Co-Cr system. The delamination occurred in the multi-phase microstructure near the fusion line, and was related to the interface between a martensitic structure and the complex interconnected Cr-enriched/Fe-Co-enriched multi-phase region.

Unique site-specific specimens for detailed microstructural characterization were successfully prepared by the FIB technique. This complex microstructure at the Stellite/carbon steel interface experienced considerable tensile stresses during the LBW repair because of the low heat input and preheat temperatures involved. These stresses caused delamination of the original Stellite deposit from the carbon steel, which would not have occurred otherwise. Stresses of this magnitude and orientation are not expected during normal service. Thus, this delamination event should pose no concern for in-service component failure.

For more information: Dr. M.G. Burke is an Advisory Scientist at Bechtel Bettis Inc., West Mifflin, PA 15122; tel: 412/476-5883; burkemg@bettis.gov; www.bettis.gov.

![Fig. 6 —(top) FIB secondary electron image of a delaminated Hardfacing layer showing multiphase region and strained Stellite matrix (and FIB trenches) prior to the micromachining of the lift-out TEM specimen. The tungsten layer is deposited on the surface of the sample to protect the delaminated surface. Note that the orientation of the delaminated sample is 180 degrees to the orientation of the micrographs in Figures 1 and 2.

(middle) TEM image of FIB-ed lift-out specimen showing the multiphase region, which consists of a Stellite matrix with fine $M_7C_3$ carbides and coarser $M_2C_3$ interdendritic carbides in the as-solidified layer.

(bottom) Detailed image of the multi-phase region: ion damage is visible in the lower Stellite region.](image-url)
In the thermal spray process, a coating is formed by melting the coating material and then quenching the molten droplets. Hence thermal sprayed coatings in general have microstructures with varying degrees of porosity, oxides and other inclusions, and low corrosion resistance characteristics. Recently, a newer spray process, known as cold spray, has been introduced to address some of these issues and produce metal, alloy, and composite coatings with superior qualities. Cold spray is a solid state process that uses high velocity rather than high temperature to produce coatings and thereby avoids or minimizes many deleterious high temperature reactions.

Typical advantages of cold spray coatings include compressive rather than tensile stresses, a wrought-like microstructure, near theoretical density, and coatings free of oxides and other inclusions, etc. Moreover, the footprint of the cold spray beam is very narrow, yielding a high-density particle beam, which results in a high growth rate of coating thickness with excellent control over the shape of the coating without masking requirements.

The basic principle of the cold spray process is very simple: A high velocity gas jet is used to accelerate powder particles and spray them onto a substrate. The kinetic energy of the particles helps these particles to plastically deform on impact and form splats, which bond together to produce coatings (Fig. 1).

Inception Stage (1900-1990)
The concept of using a carrier gas jet to accelerate solid particles had been in use for a century or more. The idea of producing a gas-particle two-phase jet and using the impact energy of the particles to produce a coating had evolved even before Schoop invented the thermal spray process. For instance, Thurston patented on August 12, 1902, “a method for carrying out the process of coating one metal with another,” whereas Schoop’s thermal spray patent is dated March 30, 1915.3 If Schoop had taken note of the basic phenomenon of his invention, solid state deposition by impact energy, cold spray would have been the first thermal spray process and not the most recent one!

Establishment Stage (1990-2000)
A U.S. government sponsored collaborative research and development agreement (CRADA) under the National Center for
Manufacturing Sciences (NCMS) brought cold spray out of Russia. Under this CRADA, Anatoli Papyrin, the leader of the cold spray group in Russia, moved to the U.S., built a system at NCMS, and carried out basic studies. Albert Kay, ASB Industries, visited NCMS and bought the license to build cold spray systems and use them for supplying industrial coatings. This CRADA established the feasibility of the cold spray technique, but did not lead to industrial adaptation in aircraft, auto, or general industries. The prototype cold spray system, built during the CRADA activities at Delphi of GM, was used by their engineers to develop their own version of high velocity deposition systems.

Another CRADA was formed with Sandia as the lead organization with Alcoa, ASB, Ford, Pratt & Whitney, Ktech, and Siemens Westinghouse as members. This CRADA developed cold spray into an engineered coating process. Modeling studies were taken up and various diagnostic techniques were developed to understand and enhance performance. Systematic spray optimization experiments were executed to produce and characterize various coating materials. A number of studies were also carried out outside the CRADA by various organizations such as ASB Industries (developed a patented cold spray system and worked with many customers to produce engineered coatings for their specific industries), Penn State University (cold sprayed coatings for defense applications), Delphi (developed kinetic spray systems to produce coatings using coarse particles), and others.

Heinrich Kreye, German Armed Forces University, Hamburg, did a large and exhaustive study on all aspects of the cold spray process, including theory, modeling, design and development of guns and nozzles, preparation and characterization of coatings, and development of application coatings. German Aerospace Industry (EADS) also initiated cold spray research directed towards both protective coatings and fabrication of bulk forms.

Expansion Stage (2000 – Present)
The new millennium saw exponential growth of cold spray technology around the globe. A conference on cold spray technology, Cold Spray 2002, held in Albuquerque in September 2002, attracted 75 participants. Two years later, the same conference (Cold Spray 2004) was attended by 151 participants from 14 countries.

Success of cold spray technology induced many groups to come out with their own high velocity spray systems. These include Innovati’s Kinetic Metallization system (which uses sonic instead of supersonic gas jets), Delphi’s Kinetic Spray (which uses coarse particle sizes compared to fine used in cold spray), Centerline’s SST system (which uses a composite powder to produce metallic coatings) and others.

Germany realized that the availability of a reliable cold spray system to produce reproducible coatings was of paramount importance and that cold spray system development is a multi-disciplinary one. Hence, they formed a consortium of Federal Armed Forces University, Hamburg; Linde R&D; and CGT Technologies to pool their respective specialties in materials science, gas technology and process control equipment to evolve the Kinetic 3000 cold spray system. A large number of spray experiments were carried out, which resulted in many industrial applications including the world’s first mass production application of the cold spray process, viz., thermal management layers on high performance heat sinks.

Present Status (2006)
Cold spray has been established as a viable coating process to produce protective coatings, performance enhancing layers, ultrathick coatings, freeforms, and near net shapes (Fig. 2). Cold spray parameters have been optimized to produce coatings of many materials with desired microstructures (Fig. 3).

A reliable and state-of-the-art cold spray system is available from CGT Technologies. Kinetic 3000 systems have the capability to produce good quality coatings using both nitrogen and helium as process gases. Recently, ASB Industries, CGT Technologies, and Linde Gas Company have joined forces to bring world class CGT cold spray systems to North America. Since this facilitates easy commercial availability of a complete cold spray facility in North America, it is expected that cold spray activity and the market will take a quantum leap in the near future.

Table 1 – Typical Application Studies

<table>
<thead>
<tr>
<th>Sprayer</th>
<th>Collaborator</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASB</td>
<td>Pratt &amp; Whitney, NASA</td>
<td>Space structures, thermal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>management layers,</td>
</tr>
<tr>
<td></td>
<td>Alcoa, ExxonMobil</td>
<td>refurbishment, joining,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>protective coatings, NNS, etc.</td>
</tr>
<tr>
<td>Delphi</td>
<td>Various</td>
<td>Protection coatings, joining,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>corrosion</td>
</tr>
<tr>
<td>Penn State Univ.</td>
<td>Defense</td>
<td>Protective coatings</td>
</tr>
<tr>
<td>Sandia</td>
<td>Ford</td>
<td>Automotive</td>
</tr>
<tr>
<td>Linde, Germany</td>
<td>Various</td>
<td>Various</td>
</tr>
<tr>
<td>CSIRO, Australia</td>
<td>Various</td>
<td>Various</td>
</tr>
<tr>
<td>Hanyang Univ., South Korea</td>
<td>Various</td>
<td>Various</td>
</tr>
</tbody>
</table>

During this period, most activities involved development of engineered coatings for specific applications (Table 1).

References

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Peter Hanneforth  
SpaCom LLC  
Huntington, New York

The thermal spray industry has been subject to much speculation in recent years. On one hand, optimists continue to call it a strong industry with abundant growth potential. On the other hand, a more pessimistic view, expressed especially during the recent recession and associated troubles of the stationary and aero turbine industries, has prevailed in many companies that saw themselves exposed to ever increasing financial and strategic risks. Then and now the main question on people’s minds is: Where are we headed? Rather than trying to give all the answers, this article will ask some critical questions and offer thoughts on what might be needed to rejuvenate an industry celebrating its 100th anniversary this year.

Who are we?
Often a diligent analysis of the most fundamental of all questions can provide the answer to one’s existence. So who are we as an industry? The opinions, which vary widely but are justified depending on one’s unique perspective, range from thermal spray being part of the global materials industry to representing a critical element of the aerospace and turbine supply chain to being an industrial capital equipment supplier or specialized services company. Although all of these are correct, in the strictest sense the thermal spray industry is part of a larger surface engineering industry that encompasses a multitude of technologies and processes that modify the surfaces of engineering components to improve performance, working lifetimes, aesthetic appearance, or economics of production (Fig. 1). Aside from relations and interdependencies within surface treatment technology, thermal spray also touches on and has to be compatible with pre and post surface treatment processes.

The multitude of possible perspectives demonstrates the complexity of the thermal spray industry and the challenges management faces to position companies for sustainable growth and success. However, where there are challenges there are opportunities, and the fact that thermal spray touches a variety of industries, applications, technologies, value chain stages, product and service combinations, and geographic regions enlarges the strategic space individual companies can carve out to create their competitive advantage in the market.

What is at stake?
The market for thermal spray equipment, consumables, and services is big enough to support a large number of companies ranging from small service shops and hardware suppliers to mid-sized family owned and entrepreneurial driven companies to divisions of multi-national public corporations. In 2004 the market size for such products and services was estimated at US $5.2 billion, of which North America and Western Europe represented almost two thirds, while Japan, Asia, and other regions made up the rest (Fig. 2).

Based on average industrial productivity and profitability ratios the global thermal spray industry employed ca. 30,000 people and should have created EBITA of ca. $400-500 Mio. That’s not bad, but to put it into perspective, during fiscal year 2005 General Electric generated $150 billion in sales with an EBITA of $38 billion, and an employment of ca. 316,000! So while thermal spray still provides bread as well as “soul food” for a lot of people worldwide, as an industry we are rather small, especially when compared to some of our most important customers.

That’s not to say there is no financial value in being in the thermal spray industry. Although the equipment and consumable materials side of the business has traditionally received more attention and publicity both scientifically as well as commercially, the lion’s share of revenue generated and most likely the value created is in the service side of the business (Fig. 3).
This should not come as a surprise to anyone since it follows the model of quite a few other industries that have discovered over time that service rather than hardware can be the key to success. Unfortunately, there are still very few companies, if any, who have found the key to successfully unlocking the value on the service side on a grander or global scale. Most of the service activity still takes place in a rather fragmented and regionally isolated fashion. Secrecy still dominates over open demonstration of market leadership. Hence, very few synergies are being generated from a manufacturing, market access and suppliers negotiation point of view. While the market for materials and hardware continues to become more and more competitive, service is likely to offer the more attractive growth and profit opportunities.

Where do we stand now?
The direction and future of an industry strongly correlates to its respective life cycle stage. Industries, like products, usually go through distinctive life cycle stages from embryonic to growth to maturity and eventual death, and conventional textbook wisdom suggests respective strategies for each stage. Although some industries/companies have been giving in to their destiny, others have experienced a second spring by reinventing themselves. On one hand, pessimists are declaring the thermal spray industry in a mature stage and consequently are following conventional wisdom behavior of cost reduction, operational process optimization, risk minimization, investment restriction, be it in creative or hard asset capital, and a general doomsday attitude. Unfortunately, this tends to amplify the demise rather than stopping it. On the other hand, the optimists believe that thermal spray has only scratched the surface (no pun intended) and there are still abundant opportunities of growth to be realized, if only applications as successful and profound as turbine coatings, which make up ca. 60% of the industry’s revenues, could be found, developed, and marketed (Fig. 4).

That is a big “if,” and while the remaining potential industrial applications related to wear, tear, corrosion, thermal barrier, restoration, or decorative coatings seem to be indeed abundant in a variety of industries, very little is being done by the industry as a whole to aggressively uncover these on a grand scale. In addition the industry does not get very high marks for its innovation rate. While plasma and HVOF have replaced the dominance of powder and wire combustion since the ’60s, not much groundbreaking has happened over the last 50 years to push the technological envelope (Fig. 5).

New promising processes, such as cold spray, are embraced by only a few visionary entrepreneurs and are likely to follow the industry’s slow penetration and adoption curve due to a lack of deep pockets. Imagine where the industry could be if it had followed Moore’s law or some of the other high tech industries? Are physical limitations preventing that from happening, or is it something else?

As many other industries and companies have proven, rejuvenation and even creation of new markets and business models is a function of truly visionary thinking, technical innovation, risk taking, flawless execution, and, of course, financial performance. Whereas physical limitations always play a role, they have been tamed by technological innovation in many cases, such as in semiconductors, opto-electronics, information displays, biotechnology, nanotechnology, and various other forms of materials and other sciences. So if it is not the physical laws, what needs to be done to reach the next level?

Continued
What’s next?
The thermal spray industry has still plenty of room to grow but it needs to embrace some of the outstanding examples of life cycle rejuvenation and start investing in technological innovation, application, and market development in order to realize these opportunities. From a corporate strategy point of view, there are still many ways to differentiate and take a position in a unique space within the value chain. (Fig. 6). Forward or backward integration, diversification into related processes, globalization into emerging markets, consolidation to reinforce existing strengths or balance weaknesses and, of course, good old customer service excellence are only a few options at hand to create the ever sought after shareholder value.

These, by the way, are not options only for a privileged few with deep pockets and lavish multi-national offices. Smaller companies can take advantage of multiple opportunities by forming partnerships, alliances, and consortia, and acting quickly and determinedly while the former are still refining their business plans and seeking corporate approval and funding.

In summary, after an exciting lifespan of one century the thermal spray industry does not show signs of having lost its stamina for survival, and there are still opportunities to rejuvenate and grow the industry. The key to unlock these opportunities will be given to the few who demonstrate visionary leadership and excellence in technological innovation and entrepreneurship. But then, what else is new?

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**Land-Based Turbine Applications**

*Irene Nava*  
*Solar Turbines Inc.*  
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Today’s turbine engines are designed around the use of high-performance materials that rely heavily on thermal sprayed coatings to increase life span and operation efficiency. The engine materials range from aluminum alloys, cast iron, high-strength steels, stainless steels, nickel-base alloys, and superalloys to single-crystal materials. The external exposure temperature of the engine might range from cold environments of –40 °C (–40 °F) to extreme heats of 55 °C (130 °F). The internal sections of the compressor vary from the atmospheric suction air temperature to combustion temperatures in the fuel-fired combustion liner or cans and the turbine section. Additionally, contaminants inherent in the environment and fuel play a role in the life of turbine components. The coating material and method of application are usually designed according to the particular service and the expected life of the coating, which is defined by a time between major inspections. The coating can be applied onto newly manufactured or overhauled bearing journals, bearing seals, stub shaft journals, labyrinth seals, blades, nozzles, tip seals, inlets and exhausts, and housings. Figure 1 illustrates an engine cutaway and locations where thermal spray coatings are applied.

**Wear Resistance**

A wide array of solid-surface mechanical interaction mechanisms occurs in turbine systems, causing wear processes such as abrasion, erosion, fretting, and galling. The wear effect in many areas is enhanced by the synergistic effect of low- or high-temperature oxidation and corrosion. Many of the wear interactions are mitigated with lubricant oils. Components exposed to elevated temperatures might face severe wear problems due to inability to provide lubrication. Wear-resistant coatings are widely applied on turbine and compressor shafts, bearing journals, thrust collar diameters and seats, and labyrinth seals (Fig. 2).

It is known that a wear-resistant coating can extend component life. For instance, a WC/Co coating on a rotating shaft can increase the shaft life from a couple of months to a couple of years. Specifically, the life of a carbide-coated gas compressor shaft can be extended from six months to more than five years. The coatings can be applied on the newly manufactured part to prevent wear. A wear coating can be applied to a serviced part to bring it to dimensional tolerances.

**Oxidation and Corrosion Resistance**

Turbines can be located in harsh, corrosive environments, including high-temperature deserts, offshore platforms, and humid rural and city areas. To provide corrosion and oxidation resistance, nickel- and/or cobalt-base alloyed coatings are used. These materials typically are high-chromium-containing alloys. Iron-base alloys could also be used for corrosion resistance. Most of these coatings are applied by HVOF or plasma spray. Most TBCs require a high-oxidation, corrosion-protective bond coating. The MCrAIY coatings offer these superior properties. Often, the MCrAIY coatings are post-heat treated to increase bond strength via a diffusion bonding mechanism, which improves the performance of the coating significantly. Oxidation-and corrosion-resistant coatings are applied on air inlets, combustor liners, injectors, turbine tip shoes and nozzles, and exhausts.

**Abradables and Seals**

To maintain tight blade-tip clearances, it is necessary to apply abradable coating materials to the engine turbine shrouds and compressor case. Additionally, the abradable coating offers wear protection to the shroud material and rubbing blades. A good abradable coating should be soft enough to prevent blade damage and strong enough to resist abrasion and spallation during rubbing. According to the exposure temperature, abradable coatings could be broadly classified into low-temperature abradables, typ-
Typically below 540 °C (1000 °F), and mid-to-high-temperature abradables, from 540 to 980 °C (1000 to 1800 °F).

Typical low-temperature abradables consist of porous, aluminum-base coatings (e.g., aluminum-silicon alloys) containing polyester, polyimide, or boron nitride, and nickel-graphite coatings (Ref 1, 2). Due to the high risk of moisture in the cold compressor section, aluminum-base rather than nickel-base composites are perhaps more suitable to avoid damaging the steel case by galvanic coupling. At the high end of the temperature range, above 450 °C (840 °F), compressor abradables might also include MCrAlY/polyester/BN (Ref 2). Other low-temperature seals that are not interacting with the blades are also part of the engine system. In these sealing areas, coatings typically run against labyrinth seals along the engine shafts in the compressor and turbine, sealing either gas or oil paths, and are usually composed of Babbitt, bronzes, and AlSi/polyimide. The seals and compressor abradables are usually deposited by plasma, low-velocity combustion flame, or twin-wire arc spray.

Nickel-base and MCrAlY-type coatings are typically applied onto mid-turbine hot-section tip seals or shroud surfaces using thermal spray techniques. These coatings may contain softer agglomerates, such as polyester, boron nitride, hollow ceramic particles, bentonite, or graphite. Caution is recommended in the use of graphite-containing nickel-base coatings due to the risk of autocatalytic galvanic oxidation, which significantly reduces coating life. In some application cases, these coatings consist of a MCrAlY alloy (no addition of fugitive compounds), which is not, by definition, an abradable. They are designated rub-tolerant coatings, offer a relatively softer rubbing surface at high temperature, and are oxidation and corrosion resistant. High-temperature abradables and rub-tolerant coatings are applied through HVOF, plasma spray, or low-velocity combustion spray.

In an increased effort to augment turbine efficiency through higher operation temperatures, turbine manufacturers have introduced ceramic abradable coatings into the hot section of the turbine shroud. Ceramic systems with sufficient substrate backside cooling would provide a thermal barrier effect between the hot gas path and the metallic shroud surface. Considering that there is a temperature drop of 3 to 4 °C (5 to 7 °F) per 25 µm (0.001 in.) for a typical YSZ thermal barrier coating (Ref 3), the top surface temperature of a 2 mm (0.080 in.) thick ceramic abradable coating at the flow path might reach up to 1200 °C (2190 °F), while the superalloy would remain at an acceptable lower temperature. For comparison, the maximum service temperature of MCrAlY coatings is approximately 980 °C (1800 °F), which is on the order of the tip seal surface temperature for industrial gas turbines. Ceramic abradable coatings are, however, hard on the blade tip; hence, it is mixed with softer materials (e.g., boron nitride, poly-ester) to reduce hardness and increase abradability (Ref 4). The manufacturer can also choose to use abrasive blade tips to rub against a TBC.

**Thermal Barrier Coatings**

Plasma spray TBCs are of great use in the hot section of turbines, such as the combustor liner (cans), transition ring, splash plate, and fuel injector. These coatings help to increase thermal efficiency and reduce exposure temperature, thereby extending component life and generally mitigating oxidation and corrosion. In general, the bond coat must offer high-temperature protection to oxidants and contaminants that might infiltrate through the ceramic coating to the bond coating. The most frequently used ceramic coatings are zirconia-base ceramics and include:

- Yttria-stabilized zirconia or ZrO₂-Y₂O₃ (6 to 8 wt%)
- Ceria-stabilized zirconia (CeO₂-YSZ)
- Ceria- and yttria-stabilized zirconia (ZrO₂-25CeO₂-Y₂O₃) (2 to 3 wt%)
- Calcium titanate (CaTiO₃) is also used in some applications.

Common bond coatings are applied by plasma spray; however, there is an increased use of HVOF processes. These coatings are typically 100 to 200 µm (0.004 to 0.008 in.) thick MCrAlY coatings. The TBC of choice seems to be YSZ, due to its acceptable resistance to thermal shock and its overall durability. A combustor liner with a 380 µm (0.015 in.) thick TBC may last more than 30,000 h in a turbine at full load with metal temperature exposures up to 870 °C (1600 °F).

In searching for higher-thermal-resistant coatings, the tendency for thermal sprayed ceramics is to deposit thicker coatings to increase thermal barrier capabilities. Due to the demands for higher temperatures in gas turbine hot sections, components have increased thickness requirements of YSZ coatings to 635 to 1000 µm (0.025 to 0.040 in.), in spite of the eventual reduction of their thermal cyclic lifetime. Attempts have been made to replace YSZ with newer materials with lower thermal conductivity.

Continued on page 28
Pushing the Envelope of Materials Performance

The materials science and engineering communities are coming to Seattle May 15–18 to discuss new developments and new ways to increase performance while meeting the industry’s needs for lower cost, longer service life, maximum safety and minimal impact to the environment.

During this historic event, AeroMat (Advanced Materials and Processes for Aerospace Applications) and the International Surface Engineering Congress—both sponsored by ASM International, The Materials Information Society—will be co-located with ITSC 2006, the International Thermal Spray Conference & Exposition, sponsored by the ASM Thermal Spray Society, the German Welding Society (DVS), and the International Institute of Welding (IIW).

Celebrating the 100th year of thermal spray technology, ITSC looks boldly into the future and sees many ways to provide its aerospace-proven benefits for numerous other industries—from mining, chemical, and oil processing to automotive and specialty markets. With participation from more than 35 countries, the 2006 technical program is the largest ever.

The ITSC plenary session will be held on Tuesday, May 16, 7:45–9:00 a.m., and features “Aero Gas Turbines—Surface Engineering,” by Dr. Malcolm G. Thomas, director of materials and mechanical behavior, Rolls-Royce.

A session on Health, Safety, Economic, Defense and Personnel Agencies (Economic and Regulatory, champions: K. Legg and K. Middledorf) will be held on Thursday, May 18 from 8 – 9:40 a.m.

Highlights of a representation of the many excellent technical sessions from which attendees may choose are listed here...

**Applications and Properties**

Champions: P. Sahoo and A. Kay

**Wednesday, May 17, 2006 - 10:10 a.m.**

This presentation is part of Session 11: Thermal Spray & Other Surface Engineering Technologies

“Thermal Barrier Coating Systems for Gas Turbine Engines by Thermal Spray and EBPVD – A Technical and Economic Comparison”


The most advanced thermal barrier coating (TBC) systems for aircraft engine and power generation hot section components consist of EBPVD applied yttria stabilized zirconia and platinum modified diffusion aluminide bond coating. Thermally-sprayed ceramic and MCrAlY bond coatings, however, are still used extensively for combustors and power generation blades and vanes. This paper highlights the key features of plasma spray and HVOF, diffusion aluminizing and EBPVD coating processes.

**Summary:** Thermal barrier coatings for aircraft engine and power generation hot section components are generally applied by thermal spray processes and most recently by EBPVD (TBC) and diffusion aluminizing (bondcoat). The coating characteristics of thermally sprayed MCrAlY bondcoat as well as Low Density and DVC (Zircat) TBC are described.

**Wednesday, May 17, 2006 - 10:50 a.m.**

This presentation is part of Session 11: Thermal Spray & Other Surface Engineering Technologies

“Evaluation of Adhesion Strength and Residual Stress of HVOS Sprayed Metallic Coatings”

M. Watanebe, K. Yokoyama, S. Kuroda, National Institute for Materials Science, Ibaraki, Japan; Y. Gotoh, Science University of Tokyo, Chiba, Japan

The adhesion strength of thermal sprayed coatings is very important because it dominates the total performance of coatings. However, the correlation between the adhesion strength and residual stress is still unclear. The purposes of the present study are firstly to establish a reliable experimental method to evaluate the adhesion strength and secondly to reveal the relationship between the adhesion strength and the residual stress.

**Summary:** The adhesion strength of stainless steel coatings deposited by the HVOF spray technique was evaluated by a modified tensile adhesion test. The residual stress in the coating was also evaluated by measuring the relaxed strain during thinning of the coating.

**Biomedical Coatings**

Champions: B. Marple, M. Khor, and V. Guipont

**Tuesday, May 16, 2006 - 9:00 a.m.**

This presentation is part of Session 3: Bioprocessing and New Coating and Testing Development

“The Role of Hydroxylapitate Coating Characteristics in Bone Integration after Two Decades of Follow-up in Human Beings”

P. Frayssinet, N. Rouquet, D. Hardy, Urodela, St Lys, France

We had the opportunity to perform histological analysis on human femurs containing HA-coated hip prostheses implanted for various periods from a few days up to several years. It was shown that the coatings degraded after a few weeks and the released debris particles behaved differently according to their size and shape. Some general rules can be drawn regarding the coating characteristics necessary for an optimized biocompatibility.

**Summary:** The hydroxyapatite coating characteristics influence its integration and degradation when implanted in human bones. After two decades of clinical use, it seems that there are key characteristics essential for good clinical performances.

**Cold Spray Symposium**

Champions: J. Karthikeyan, H. Hoell, P. Richter, and J. Villafuerte

**Monday, May 15, 2006 - 9:00 a.m.**

This presentation is part of Session 1: Cold Spray 1: Process Development

“The Cold Spray Process and Its Optimization”

H. Kreye, F. Gaertner, T. Schmidt, T. Stoltenhoff, Helmut Schmidt University Hamburg, Hamburg, Germany

In cold spraying bonding occurs when the impact velocity of the particles exceeds a critical value. The bonding mechanism was analyzed by cold spray experiments, up-scaled single impacts of metal balls and subsequent modeling. Based on the deeper knowledge, concepts are provided for how cold spraying can...
be tuned with respect to process efficiency and coating quality. By following such routes for typical, metallic spray materials, cold spraying is already capable of providing coating qualities very similar to those of work hardened bulk material at powder feed rates similar to those of thermal spraying and deposition efficiencies of about 90%.

**Summary:** The presented optimization procedure covers principles to increase gas and particle velocities and rules to decrease the critical velocity for bonding.

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### Equipment & Processes

**Champions:** R. Thorpe and E. Lugscheider  
**Thursday, May 18, 2006 - 8:40 a.m.**  
*This presentation is part of Session 13: Plasma 4*

**“Effect of Copper Ion Doping on Photocatalytic Performance of Liquid Flame Sprayed TiO₂ Coatings”**

C.J. Li, G.J. Yang, C.X. Li, Y.Y. Wang, X.C. Huang, School of Materials Science and Engineering, Xi’an Jiaotong University, Xi’an, China

Copper, iron and zinc ions were added in liquid feedstock to deposit ion doped TiO₂ photocatalytic coatings through liquid flame spraying. XRD analysis showed that the crystalline structure of coatings was not significantly influenced by the metal ion doping. The photocatalytic activity of the TiO₂ coatings was enhanced by the metal ion doping at low dosage. High dosage of ion doping even decreases the activity. XPS analysis showed that the adsorbed oxygen concentration was increased with the increase of copper ion dosage and decreased with the further increase of ion dosage.

**Summary:** Ion doped TiO₂ photocatalytic coatings were deposited through liquid flame spraying. Results suggested that enhancement can be attributed to adsorption ability of oxygen and other reactants on the surface of low concentration doped TiO₂ coatings.

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### Modeling & Simulation

**Champions:** C. Berndt, J. Mostaghimi, and A. Vardelle  
**Monday, May 15, 2006 - 4 p.m.**  
*This presentation is part of Session 2: Thermal Spray Process Modeling & Simulation 2 – Thermal Spray Process*

**“Modelling a Plasma Torch for Atmospheric Plasma Spraying (APS): Optimization of Particle Injection Near the Torch Outlet According to the Gas Flow within the Torch”**

J.L. Marques, K. Ramachandran, R. Vaßen, D. Stöver, Institut für Werkstoffe und Verfahren der Energietechnik (IWV1), Forschungszentrum Jülich GmbH, Jülich, Germany

Understanding the particle injection into the gas flow issuing from an APS torch is necessary to optimize the spraying parameters. In order to numerically solve this task, the distribution of gas velocity and temperature at the torch outlet is required. In this work this is achieved by developing a model that not only delivers the solution for the electric charged gas flow within the torch, but also includes the thermodynamic condition of minimal entropy production. This additional condition fixes the size of the electric arc inside the torch, whose radius is particularly responsible for the form of the calculated velocity and temperature profiles at the torch nozzle. The velocity and viscosity of the gas flow near the torch outlet mainly control the trajectory of particles injected into the gas flow. For the typical gas mass flow and torch power used in APS, the resulting temperatures at the gas core are slightly above the ionization temperature of the gas species. The radial location of the viscosity maximum corresponding to the ionization temperature is calculated, since this maximum strongly influences the particle trajectory. Finally a relation for best injection into the gas flow is developed.

**Summary:** The radial constriction of the gas flow within an APS torch determines the distribution of velocity and temperature near the torch outlet. Combining the numerical solution of the gas flow and non-equilibrium thermodynamics, the gas viscosity profile is calculated at the point of particle injection. The aim is to optimize such injection.
ATSC 2005, the First Asian Thermal Spray Conference

The first Asian Thermal Spray Conference, ATSC-2005 was held at the Nagoya International Congress Center, Japan, on Nov. 28 and 29, 2005. It was my great pleasure and honor to act as the chairperson of the conference, together with a team of local executive committee members. Total participants were about 150, including 26 from Korea, 10 from China, 2 from Singapore and 3 from other countries. More than 60 oral presentations, including 30 from overseas, were delivered in two parallel sessions following two plenary lectures. In addition, 20 exhibitors displayed their latest technology and products.

For us in Asia, ITSC has been and will be an excellent opportunity to learn about the latest scientific and technological development in the world, network with world experts, and present our R&D results and products. However, we have no organization representing Asia as the counterpart to the two organizations jointly running the ITSC series. If we can collect views and ideas from Asian thermal spray leaders more effectively, we will be able to contribute with greater efficacy and cogency to the ITSC series. Therefore, we agreed to hold ATSC in Asia in the years when ITSC is not held in Asia (two times in every three years) The next ATSC will be in Korea in 2006, followed by a meeting in Singapore in 2008 and in China in 2009. In 2007, all members of ATSC will wholeheartedly support ITSC in China.

ATSC 2005 was the first time that the thermal spray community in Asia had gathered at one place through their own initiative. Special features of the conference were that it was organized and administered by a relatively younger generation of leaders in the thermal spray field and that it was intended to provide opportunities for young researchers, engineers, and industrialists to acquire international experience, meet experts, and exchange views and ideas at an affordable conference registration fee.

Contributed by Masahiro Fukumoto, chairman ATSC-2005, director of Research Center for Future Vehicle, Toyohashi University of Technology, 11 Tempaku Cho, Toyohashi. 441 8580 Japan, tel: 091-81532446692; email: fukumoto@tutpse.tut.ac.jp.

Invitation to ATSC 2006
We would like to invite you to ATSC (Asian Thermal Spray Conference) 2006, which will be held in Gyeongju Hilton, Gyeongju, Korea, on November 6-7, 2006. This follows a successful ATSC held in Nagoya, Japan, in 2005. ATSC 2006 will be the best conference to exchange ideas and information of all aspects of thermal spraying in Asia. Gyeongju, a capital city of the Shilla Dynasty, is a famous resort city is located at an hour’s drive north of Busan and one hour by air from Seoul. The nearest airport of Gyeongju is Ulsan airport. Industrial tours of Pohang Iron and Steel Company and the POSCO Museum, RIST (Research Institute of Industrial Science and Technology), POSTECH (a famous engineering college), and the Pohang Accelerator Laboratory will be included. I would ask you to be prepared to attend and enjoy the conference. I look forward to seeing you in Gyeongju.
Soon Young Hwang
RIST, Pohang, Korea
email: syhwang@rist.re.kr

SPCTS Research News
SPCTS (Science des Procédés Céramiques et de Traitements de Surface) – UMR CNRS 6638 in Limoges, France, has been conducting research around four major axes.

1) Modeling of mechanisms occurring during plasma spraying

Intensive activity has been dedicated to transient 3D modeling of plasma flows, taking into account the electric arc generation and its fluctuations, and their interactions (mass, heat and momentum transfers) with injected feedstock particles. Objectives pursued include reaching a better understanding of involved phenomena and their criticality in regards with coating formation mechanisms, and developing new plasma torch concepts permitting the generation of more stable flows and ultimately more homogeneous coating structures.

2) Diagnostic of particle spreading under plasma spray conditions

Real time diagnostics of plasma sprayed particles at impact, based on laser anemometry, fast (50 ns) pyrometry and fast imaging (100 ns) have permitted the quantification of matter ejection: impact splashing occurring right at impact (first hundreds of ns) and then flattening splashing at the end of the particle flattening, which occurs only if the smooth substrate temperature is below the transition temperature. Cooling laws, depending on plasma torch operating parameters, substrate characteristics, especially their topology, and preheating temperature have also been established. This clearly demonstrated that the substrate topology plays a relevant role in spreading and solidification mechanisms, not only at the microscopic scale, but at the nanoscopic scale. The transition temperature depends on the one hand on desorption of adsorbates and condensates and on the other on surface skewness at the nano scale, modified by oxidation for metal substrates, both phenomena being linked to preheating.

3) Thermal Barrier Coatings (TBCs) with improved performance

Controlling and managing the heat fluxes to substrates during thermal barrier coating manufacturing permits architecture of the coating structures and hence improvement of their properties, especially in term of thermal conductivity but also in terms of compliance to strain (and hence
their resistance to thermal shocks). Intensive work has been carried out in connection with industrial companies in order to develop TBCs with superior properties.

4) Suspension/Solution Plasma Spraying

Suspension plasma spraying and solution plasma spraying appear as innovative processes to manufacture finely structured coatings at the nanoscopic scale. These processes also permit the manufacture of thinner layers (i.e., 5-10 μm) than in conventional plasma spraying. Developing such new processes requires:

- Adapting slurry characteristics (i.e., stability, viscosity, loading, etc.) to render them suitable to injection within a plasma flow
- Developing specific slurry injector and related injection parameters
- Understanding (by modelling and diagnostics) the interactions between the slurry and the plasma flow (i.e., fragmentation, solvent vaporization, feedstock particle melting, solution chemical reactions, etc.)
- Controlling the interaction between d.c. plasma jet fluctuations and the liquid jet instabilities
- Controlling the size distribution and morphology of the particles within the suspension
- Managing the thermal flux issued from the plasma torch (since the spray distance is shorter in suspension/solution plasma spraying compared to conventional plasma spraying, the heat flux is higher, by an order of magnitude, at least),
- Studying the structure and related properties of sprayed layers.

The research finds application, in particular, by the development of SOFC cells.

In addition to these activities, SPCTS joined the new excellence center (Pôle de Compétitivité) related to ceramics and supported by the French ministry of education and research, the CNRS, and various other institutional and private partners. Soon, a new 20,000 square meter building will be erected in Limoges to welcome SPCTS and its research activities.

Contributed by Pierre Fauchais, professor, University of Limoges, Faculty of Science, 123 Rue Albert Thomas, Limoges Cedex, F-87060, France; tel: 335-5545-7435; email: fauchais@unilim.fr.

The GTS Quality Certificate – successfully benefiting members

The GTS certificate is the only quality certificate worldwide that, in addition to the quality management elements of DIN EN ISO 9001:2000, includes a personnel, process, and, on request, also a product certification for thermal spraying. The rules for certification were created by thermal spray users for thermal spray users and have proven to be very effective.

GTS – from idea to established association

Among surface coating technologies, thermal spraying offers one of the widest applications across industries and academia – an ideal opportunity to combine the interests of leading representatives of an expanding field. Hence the association of thermal sprayers “Gemeinschaft Thermisches Spritzen” (GTS) was founded in 1992. The association’s main objective is to promote thermal spray technology and secure the long term survival of its members in the thermal spraying sector in cooperation with the German Welding Society.

The GTS Executive Board includes the chair of the Quality Committee, which is responsible for the GTS certification process. The Quality Committee includes a representative of an independent certification authority (currently SLV-Munich). This independent certification authority is essential to ensure that the regulations and procedures drawn up by the Quality Committee are observed and thus that the sovereignty of GTS is maintained.

Activities of the Japan Thermal Spraying Society

Japan Thermal Spraying Society (JTSS) is the only specialized organization on thermal spray technology in Japan. Established in 1957, JTSS is engaged in the improvement of thermal spray technology through its various activities including the annual meetings, publication of journals, standardization (JIS, ISO), qualification of “Thermal Spray Technique Manager” and so on. The society chairman is Dr. Kazuo Ueno, deputy director of Energy Technology Research Institute of National Institute of Advanced Industrial Science and Technology (AIST).

Currently more than 80 thermal spraying or related companies and 400 individual engineers and researchers comprise the membership.

JTSS has eight committees such as Research and Planning, Editing and Publication, Thermal Spray Standards, Committee, etc., to determine its policies. There are five branches for more specific activities based on their local communities.

JTSS puts much effort in international activities, such as Korea and Japan Joint Conference in 1997 and ITSC 1995 to which JTSS con-

The GTS Certificate

Conventional quality management (QM) systems, such as those that comply with DIN EN ISO 9001, are recognized around the world and have already been introduced to a large extent in industry. The extensive QM system of DIN EN ISO 9001 has elements that must be examined during the certification process. These elements are designed to make operational procedures transparent and comparable by means of extensive documentation. However, DIN EN ISO 9001 does not tackle the process-specific needs of industry or individual sectors thereof. From the beginning it was clear that securing the high level of thermal spraying technology could not be achieved solely by the general certification of member companies by state or state-accredited institutions in the sense of DIN EN ISO 9000. Therefore a GTS quality certificate was created with an extensive range of regulations.

DIN EN ISO 9001 and GTS certificate – A major difference

This general quality management system was not sufficient for the founders of the GTS to enable thermal spray companies to become established in the market place. Their idea was that GTS members should be highlighted by means of a defined and verifiable quality standard of the high quality products manufactured using thermal spraying.

The structure of GTS certification

The principles of GTS certification can be demonstrated using the example of a building, from the laying of the foundation to the finished, furnished home. Existing standards, regulations, and notice sheets for thermal spraying form the strong foundations of GTS certification.

A functional QM system must exist for the GTS certification procedure. The GTS regulations state that 11 QM elements based on DIN EN ISO 9001 must be examined in full during the certification procedure. These elements, listed below, form the sturdy walls of the GTS structure.

- management responsibility
- contract review
- document and data control
- control of customer-supplied products
- product identification and traceability
- process control
- inspection and testing
- control of inspection, measuring, and test equipment
- control of non-conforming products
- corrective and preventive action
- control of quality records.

The GTS QM specimen manual, which has been adapted to the needs
of thermal spraying and has been supplied to every member in written form, provides valuable assistance in the production of the prescribed, company-specific GTS QM manual.

The process-, personnel- and product-related certificate

The core of the GTS certification process is the first process-, personnel-, and product-related certificate for thermal spraying in the world. The quality control procedures for the products can be completed without any bearing on competition and without any transfer of expertise—simply by inspection and monitoring procedures that have an influence on the manufacture of the product. For the GTS these procedures include a personnel test, which ensures a defined standard of training and skills of thermal spray personnel, and a process test, which ensures functionality and fitness of thermal spray equipment.

Finally, the GTS member also has the opportunity of having his product certified by means of a voluntary product test. This test is purposefully designed in such a manner that no confidential information about parameters needs to be disclosed.

The quality management system established by GTS is a pioneer with its requirements to the process, the QM System, and personnel in practice. The requirements are complemented by internationally accepted EWF-training and education guidelines (European Federation for Welding, Joining, and Cutting) for supervising and floor personnel. These harmonized international guidelines also comprise the new DIN EN ISO standards corresponding to each subject (e.g., Thermal Spraying Coordinator and the Approval Testing of Thermal Sprayers).

ETS- and ETSS-education and training in demand

Experience shows that the EWF-education and training and standards are much in demand. Contrary to expectations that companies desire a sprayed coatings test in accordance with DIN EN ISO 14918 only for their experienced co-workers, it shows that the need and demand for the complete EWF-education and training is high due to a lack or gaps of basic theoretical knowledge among many practicing thermal sprayers and operators.

The GTS certificate– a guarantee to satisfy high-quality demands

After passing the GTS company test and being awarded GTS certification, the bearer of this certificate has a QM system that has been tailored specifically for the demands of thermal spraying. As a result of its close and productive cooperation with the DVS the GTS enables its members to obtain additional certification pursuant to DIN EN ISO 9001, which, in combination with the GTS certification, takes very little time and is very cost-effective.

The GTS obliges its members to assure the quality of thermal spraying in accordance with the GTS quality management regulation. The observance of these requirements is supervised by the certified GTS members by means of internal monitoring and also by means of an audit completed by an independent institution every three years. Interim audits for members are also possible at any time.

Enjoy a lead over your competitors with the GTS certificate

The successful GTS company test on the basis of a quality assurance system specifically designed for thermal spraying, entitles the GTS members to hold and use the GTS certificate in the market place. Many purchasing decision are already being made or influenced by the pre-requisite of holding the GTS certificate and we anticipate that the GTS certificate will soon form the basis for acquiring orders for all GTS members from industry and trade who coat finished parts or semi-finished products by means of thermal spraying.

Additional services GTS offer its members

GTS promotes the flow of information relating to thermal spraying
and supports the exchange of experience and know-how between its members in a variety of ways:

- A journal, *GTS-Strahl*, published semi-annually to provide members with free information about the thermal spray industry.
- Regular circulars from the GTS head office inform members of internal association matters and new and amended standards and regulations.
- GTS sponsored informational events and attendance at trade fairs and conferences
- Assistance with and lobbying for laws and standards
- Complete patent information service
- Events calendars and many other special services

For more information about GTS, please visit our website at www.gts-ev.de. Detailed information about the GTS certification process is also available in the ITSC 2006 proceedings.

**Contribution** by Dieter Böhme and Rolfe Huber, SLV Munich, branch of GSI mbH; Dieter Grasme, OBZ; and Peter Heinrich, Linde AG, Carl Von Linde Strasse 25, Unterschleissheim, D-85716 Germany; tel: 49 89 3100 1654; email: peter.heinrich@gts-ev.de.

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Global market for medical device coatings will reach $5.31 Billion in 2010

According to a new technical market research report, *Medical Device Coatings (RGB-327)* from BCC Research (www.bccresearch.com), the value of worldwide sales for all categories of coatings and surface treatment processes used in manufacturing medical devices reached $2.96 billion in 2005. Fueled by explosive growth in high-value combination products, the market will increase at an average annual growth rate (AAGR) of 12.4% to more than $5.31 billion by 2010. The greatest demand for coated medical devices will come from cardiovascular medicine, dentistry, general and plastic surgery, general hospital settings, neurology, ophthalmology, orthopedics, and radiology.

Sales in the total United States market were worth nearly $1.5 billion in 2005, approximately 50% of the global market for that year. Though the U.S. market will grow to more than $2.7 billion by 2010, its global market share will only reach 51%—still the largest by a considerable margin.

The European market will hold the highest growth rate through the forecast period, growing at 13.3% to reach 26% of the total market in 2010. The swift acceptance of drug-eluting stents as a “gold standard” treatment by surgeons around the globe suggests that the demand for other coated versions of existing medical devices will be equally swift.

For more information: BCC Research, 25 Van Zant Street, Norwalk, CT 06855; tel: 203/853-4266, ext. 309; publisher@bccresearch.com; www.bccresearch.com. BCC Research is the source and publisher of the report “Medical Device Coatings” (RGB-327).

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Global Demand for Medical Device Coatings, 2010 ($ Billions)

- United States: $2.71
- Europe: $1.38
- Other Developed Nations: $0.32
- Rest of the World: $0.09

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**Join the world’s leading thermal spray society.**

As a member of the ASM Thermal Spray Society, you will:

- Receive the official TSS newsletter, providing the latest coverage of the thermal spray industry
- Save on registration for the International Thermal Spray Conference (ITSC)
- Receive Advanced Materials & Processes magazine every month
- Access the TSS Membership Directory and TSS Online Discussion Group
- Save on publications (like the *Journal of Thermal Spray Technology*) and seminars
- Support the growth of thermal spray technology beyond aerospace to other industries, including automotive, electronics and medical

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**ADVANCED MATERIALS & PROCESSES/MAY 2006**

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The mission of the Thermal Spray Society Programming Team is to provide the leading forum for the exchange of information in the thermal spray community via technical programs, proceedings, and expositions at TSS sponsored events around the world. The team currently comprises 30 members from 10 countries representing industry, government, and academia.

During monthly telephone conferences and semi-annual meetings each member has the opportunity to contribute either through leadership of a task or by being an advisor within a specific discipline, industry, or geographic region. This diversity and commitment in conjunction with the close and productive collaboration with ASM staff has enabled the team in recent years to come up with successful events and conferences. This article will outline recent events and the general activities of the Programming Team, as well as provide some little known background on the origins of the ITSC.

The International Thermal Spray Conference & Exposition (ITSC)

The precursor to the ITSC series was the “IMSC” (International Metal Spraying Conference). The first IMSC was held in 1956 in Halle in the former East Germany. This series continued for several years, meeting in Birmingham, U.K., in 1958; Madrid, Spain, in 1962; Halle, East Germany, in 1963; Warsaw, Poland, in 1966; and Paris, France, in 1970. The 7th IMSC was held in London, U.K., in 1972. The name change to the ITSC occurred for the next conference, the first one in North America, which was held in Miami, Fl., in 1976.

In many ways this name change arose from the recognition that thermal spray was opening markets to encompass the full spectrum of materials. The numbering sequence continued on from the established IMSC series; i.e., the 1976 event in Florida was the 8th meeting. From the 9th ITSC (The Hague, 1980), through to the 13th ITSC (Orlando), the events were held every three years and became an established series of meetings. These meetings were organized under the auspices of the International Institute of Welding (IIW).

In 1987 the 1st National Thermal Spray Conference (NTSC) was held in Orlando, Fl., NTSC was designed for the North American community and was held in various locations in the U.S. for the next 10 years. ITSC meetings were still being organized in parallel with NTSC and the German Welding Society (DVS) also held “Thermal Spray” conferences every two years in Germany. The 15th ITSC (Nice, France, 1998) was the last organized by the IIW.

DVS and ASM International combined forces to present the United Thermal Spray Conference (UTSC) meetings in 1997 in Indianapolis and in 1999 in Düsseldorf.

The ITSC series was rejuvenated in 2000 in Montreal under the sponsorship of DVS and ASM International. These partners agreed to name the Montreal meeting the 1st ITSC to reflect the rebirth of thermal spray as it emerged into a new century. (IIW agreed that the “ITSC” designation can be used by DVS and ASM.) The collaboration between these partners has allowed one single international thermal spray event to be held every year rather than multiple meetings, a significant boon to the industry and participants since resources can be maximized.

ITSC has been designed to be an annual, geographically rotating event between North America, Europe, and Asia in order to give each part of the world the opportunity to showcase their contributions and enable a maximum number of people to attend. Organizing responsibility is split between DVS and ASM/TSS and project management responsibility lies with the organization in whose territory the event takes place. The next ITSC venues were Singapore, 2001; Essen, Germany, 2002; Orlando, Fl., 2003; Osaka, Japan, 2004; and most recently Basel, Switzerland, 2005.

In 2006 the TSS Programming Team has been working on the largest ITSC ever, since for the first time it will be co-located with two other successful ASM conferences—Advanced Aerospace Materials Conference & Exposition (AeroMat) and the International Surface Engineering Conference (ISEC). The objective of colocalizing these events is to increase overall attendance of each individual event, provide more technical programming, increase the number of exhibitors, offer cross-fertilization opportunities, and – in a nutshell – provide more value to attendees, exhibitors, and participants.

With an expected total conference attendance of more than 1,200 and 150 exhibitors, the Seattle 2006 event promises to break all previous records for each individual event. With 260 oral papers organized in six symposia and about 100 poster presentations, ITSC 2006 will also offer a record breaking substantial technical program. In addition, ITSC will mark and celebrate the 100th anniversary of thermal spray technology, an accomplishment not many technologies and industries can look back on.

The TSS Programming Team is already looking ahead to ITSC 2007, in Beijing, China, in May 2007 in cooperation with DVS and the Chinese Thermal Spray Committee. It will be the 20th edition of a series of very successful thermal spray conferences.

Regional workshops and events

Besides the ITSC, the Programming Team is also engaged in organizing regional “mini-events” and workshops. These focus on specific industries, technologies, or applications and address a more industrial and practically oriented audience. The events provide networking platforms for periods when there is no ITSC in North America. The series started in this specific context with the Cold Spray Workshop in Akron, Ohio, in September 2004. Spearheaded by Al Kay from ASB Industries, this event was an overwhelming success and was attended by more than 130 participants from all over the world. In October 2004, this was followed by a workshop on “Sensors & Controls” in Montreal, Canada. Organized under the leadership of Christian Moreau from the National Research Council Canada, this event was also a big success with more than 100 attendees. During the first half of 2005, the team and especially Event Chairman Mitch Dorfman from Sulzer Metco were busy preparing for the first Combustion Turbine Coatings Symposium, which took place in October 2005 in Houston, Texas. With 35 keynotes and papers and more than 150 attendees, the event was the largest yet.

Based on the success and apparent strong market demand for such events, the team continues to identify relevant topics for future regional workshops. Currently we are strategizing about a 2006 late fall event and the overall 2007 regional programming. The team is very open to productive suggestions and volunteers who wish to contribute by taking the lead in organizing an event and taking advantage of the opportunity to proactively involve their companies as sponsors or contributors.

International and other conferences and events

The TSS Programming Team manages and supports TSS involvement in certain domestic and international conferences relevant to the thermal spray industry. The team also maintains strong relationships with a number of international thermal spray societies, which is essential to ensure the global reach and success of the TSS events.

Finally, I would like to thank all the members of the Programming Team for their contributions that make all these events possible and successful. I would also like to invite anyone who is interested in joining this team and being part of our exciting planning program to do so. Please consult the ASM/TSS website for a membership roster and further information.

Note: Special thanks to Chris Berndt for his extensive knowledge of the origins of ITSC.

For more information: Peter Hanneforth, SpaCom, 223 Wall Street, #160, Huntington, NY 11743; tel: 631/757-7799; email: peter.hanneforth@spacom.com.

The Accepted Practices Committee on Metallurgy is currently performing a round robin on Metco 312, which is a nickel base (Ni 4Cr 4Al) abradable coating. This committee currently consists of nine captive and independent test labs, which strive to determine best practices through round robin testing. Previously, coatings such as TBC, chrome carbide, copper nickel indium, and tungsten carbide have been analyzed. Formal documentation of these round robins is being generated and will be posted on the TSS website.
“Role of the Laser Surface Preparation on the Adhesion of Ni-Al 5% Coatings Deposited Using the PROTAL Process”

Hui Li, Sophie Costil, Hanlin Liao, and Christian Coddet

The PROTAL process combines a laser surface preparation and the thermal spraying stage. This laser surface preparation avoids some of the traditional drawbacks of the degreasing and sand-blasting stages which is an important factor especially for the notch-sensitive materials. Previous studies showed that deposit adhesion obtained with the PROTAL process is similar to that produced by traditional surface preparation despite the absence of mechanical anchorage offered by surface roughness. In order to get a better knowledge of the effects of such a laser treatment, a Ni-5%Al coating was plasma sprayed using the PROTAL process under different surface conditions. The morphology of the impinging splats and adhesion of the deposits were then examined. Removal of the surface contaminants, adsorbates and oxides was confirmed and the role of the laser irradiation on the coating adhesion is discussed.

“Plasma Sprayed Cast Iron Coatings Containing Solid Lubricant Graphite and h-BN Structure”

Yoshiki Tsunekawa, Ismail Ozdemir, and Masahiro Okumiya

Water atomized cast iron powder of Fe-2.17C-9.93Si-3.75Al (in wt.%) were deposited onto an aluminum alloy substrate by atmospheric DC plasma spraying to improve its tribological properties. Pre-annealing of the cast iron powder allows considerable amounts of graphite structure in the powder to precipitate. However, significant reduction in graphitized carbon in cast iron coatings is inevitable after plasma spraying in air atmosphere due to the in-flight burning and the dissolution into molten iron droplets. Hexagonal boron nitride (h-BN) powders which have excellent lubricating properties like graphite were incorporated to the cast iron powder as solid lubricants by sintering process (1300 °C) to obtain protective coatings with low friction coefficient. Cast iron coatings sprayed with water atomized and water atomized h-BN composite powders show high seizure point and exhibit good anti-wear performance. The coatings with relatively low hardness containing solid lubricant experience the lowest friction coefficient at higher loads, mainly due to the self-lubricating effect.

“Effect of Deposition Conditions on the Properties and Annealing Behavior of Cold Sprayed Copper”

Eklavya Calla, Graham McCartney, and Philip Shipway

Copper was deposited by cold gas dynamic spraying using helium at 298 K and 523 K. Evidence is presented which indicates that the material sprayed at 298 K exhibits a lower dislocation density throughout the grain structure that the material sprayed at 523 K. The low stacking fault energy of copper restricts recovery during annealing and thus microstructural changes only proceed once recrystallization begins. The material sprayed at 298 K exhibited recrystallization at annealing temperatures as low as 373 K with a corresponding reduction in hardness. However, the copper sprayed at 523 K was resistant to annealing at temperatures up to 473 K due to dislocations in the...
structure preventing recrystallization; recrystallization occurred at higher annealing temperatures. The fracture behavior of the copper cold sprayed at 523 K, both in the as-sprayed condition and following annealing, was measured and explained in terms of the annealing mechanisms proposed.

**“Cold Spray Processing of a Nanocrystalline Al-Cu-Mg-Fe-Ni Alloy with Sc”**

Leonardo Ajdelsztajn, Alejandro Zúñiga, Bertrand Jodoin, and Enrique Lavernia

This work describes recent progress in cold spray processing of conventional and nanocrystalline 2618 (Al-Cu-Mg-Fe-Ni) aluminum alloy containing Sc. As-atomized and cryomilled 2618+Sc aluminum powder were sprayed onto aluminum substrates. The mechanical behavior of the powders and the coatings was studied using micro and nanoindentation techniques, while the microstructure was analyzed using scanning and transmission electron microscopy (SEM and TEM). The influence of powder microstructure, morphology, and behavior during deposition on the coating properties was analyzed. This work shows that Al-Cu-Mg-Fe-Ni-Sc coatings with a nanocrystalline grain structure can be successfully produced by the Cold Spray process. Inspection of the scientific literature suggests that it is the first time that a hardness value of 181 HV has been reported for this specific alloy.

**“Particle Loading Effect in Cold Spray”**

Karen Taylor, Bertrand Jodoin, and Yossi Karov

Cold Gas Dynamic Spray is a deposition process that uses a supersonic flow to accelerate small particles (micron size) above a material dependent critical velocity. When particles impact the substrate, they plastically deform and bond to form a coating. The objective of this research is to investigate the influence of the particle mass flow rate on properties of coatings sprayed using the Cold Spray process. Varying the mass flow rate at which the feedstock particles are fed into the carrier gas stream can change the thickness of the coating. It was shown that poor coating quality (peeling) was not a result of flow saturation, instead, excessive particle bombardment per unit area on the substrate. By increasing the travel speed of the substrate this can be overcome and well-bonded dense coatings can be achieved.

Nanindentation marks on the cross section of the nanocrystalline cold-sprayed coating (5 µm and 500 nm indentation depth).

Cold Spray coating sprayed at a powder mass flow rate of 5 g/min and a propellant gas temperature of 5°C.

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**Best Paper Awards to be presented at ITSC 2006**

Best Paper Awards from two volumes of JTST will be presented at ITSC 2006. Roland Seals, chair of the JTST Best Paper Subcommittee, and Joachim Heberlein, chair of the Awards Committee, announced that the JTST Volume 14 winning paper is:

“Advanced Microstructural Characterization of Plasma-Sprayed Zirconia Coatings Over Extended Length Scales” Authors: Anand A. Kulkarni, Allen Goland, and Herbert Herman, University at Stony Brook, Stony Brook, N.Y.; Andrew J. Allen, Jan Ilyasky, and Gabrielle G. Long, National Institute of Standards and Technology, Gaithersburg, Md.; and Francesco De Carlo, Advanced Photon Source, Argonne National Laboratory, Argonne, Ill.

The JTST Volume 13 winner is:

“Neural Computation to Predict In-Flight Particle Characteristic Dependencies From Processing Parameters in the APS Process” Authors: Sofiane Guessasma, Ghislain Montavon, and Christian Coddet, Laboratoire d’Études et de Recherches sur les Matériaux, les Procédés et les Surfaces (LERMPS), Université de Technologie de Belfort-Montbéliard (UTBM), Belfort Cedex, France.

Special thanks to the members of the JTST Best Paper Subcommittee who evaluated the papers and especially to chair Roland Seals for coordinating the process. Warmest congratulations to all winners!

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**CALENDAR**


14-18 June Superalloys for Heavy Duty and Aircraft Type Gas Turbines - Processing and Structures: Ithaca, NY. Contact IMR Test Labs, Lansing, NY; tel: 607/533-7000; email: info@imrtest.com; Web: www.imrtest.com.


June 19-23 Aerospace Metallography and Coating Evaluation (course): Ithaca, NY. Contact IMR Test Labs, Lansing, NY; tel: 607/533-7000; email: imr@imrtest.com; Web: www.imrtest.com. (Also offered August 14-18 and November 13-17, 2006)


5 July Environmental Impact of Coatings: Loughborough, U.K. Organized by Thermal Spraying and Surface Engineering Association. Contact TSSEA, Rugby, U.K.; tel: +44 (0)870 760 5203; email: info@tssea.org; Web: www.tssea.co.uk.


July 30–Aug. 3 Microscopy & Microanalysis 2006: Chicago, IL. Sponsored by MSA, MAS, IMS, and MASC/SMC. Contact Philip Ridley, M&M-2006, Chicago, IL; tel: 312/644-0828; email: pridley@bostrom.com; Web: http://mnm2006.microscopy.org.

Land-Based Turbine Applications, continued from page 18

Alternatives are gadolinia-yytria-zirconate, samarium- and neodymium-containing zirconates, perovskite, and pyrochlore materials. However, these might be considered at the developmental stage compared to the YSZ coatings with more than 25 years of acceptable performance in industrial applications.

Buildup and Repair Coatings

Sometimes, it is necessary to build up a worn, damaged, or mismatched component. The coating thickness required may vary between 0.075 and 2.54 mm (0.003 and 0.100 in.) and usually needs finishing to correct dimensional tolerances and to comply with surface smoothness requirements. The rule of thumb is to use a buildup material similar to the base material. If dissimilar materials are used, the properties of the coating and part should have a similar thermal expansion and resistance to galvanic coupling.

Buildup coatings have a wide variety of compositions, such as iron-base (stainless steel) and nickel-base (NiCrMo, NiMoAl, alloys 718 and 625, NiAl, and NiCr) materials. The preferred deposition methods are HVOF and plasma spray, due to the higher bonding strength. Applications by twin-wire arc spray are common on nonrotating components, such as ball bearing seats and shroud flanges, between stages. Some large-power-size turbines also have Babbitt bearings restored using the arc spray process.

Other Nonthermal Spray Coatings Used in the Industry

Low-pressure plasma spray MCrAlY coatings are used on blades and vanes for oxidation and corrosion protection and as a bond coating for TBCs. Simple aluminides, platinum-aluminides, or MCrAlYs deposited by physical vapor deposition or chemical vapor deposition are used on blades and nozzles for protection against oxidation and corrosion. Also, physical vapor deposition coatings are a layer of a special alloy selected for maximum environmental resistance and deposited on the metal surface. These can be made thicker than diffusion coatings, which may provide more protection to the base metal. The microstructure of an overlay coating is shown by the middle portion of the coating in the figure. It consists of intermetallic compounds in a matrix. These compounds are aluminides – NiAl, Ni3Al, or CoAl. The matrix consists of Ni, Co, Cr, and Y.

There are a wide variety of overlay coating compositions. These coatings are usually called MCrAlY (pronounced “M crawl-ee”) coatings, since Cr, Al, and Y are almost always present. ‘M’ is either Ni, Co, or a mixture of these. The concentrations of the elements depend on the intended use of the coating. Other elements such as Si, Hf, and Ta are sometimes added to improve performance. Overlay coatings, such as NiCrSi, also can be made without Al or Y and can provide protection at lower temperatures.

Overlay coatings are generally applied by plasma spray, HVOF, or electron beam physical vapor deposition (EBPVD). Frequently, a diffusion anneal treatment is carried out after coating to obtain diffusion between coating and substrate, which gives good bonding, and homogenizes the as-sprayed microstructure.

References


To view the Table of Contents and a sample chapter from the Handbook of Thermal Spray Technology, visit www.asminternational.org. You may order online or contact Customer Service at 800/336-5152 or 440/338-5151. Cost to members is $148, cost to non-members is $185.
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Key words: powder, wire, rod, strip, nanoparticle, nanotube, thermal spray, plasma spray, PTA, HVOF, cold spray, flame spray, intermetallic, hard facing, metal, alloy, ceramic, composite, polymer, abrasive, conductive, magnetic, coated, encapsulated, colloidal, additives, fillers, reinforcements, foam, custom and toll processing / blending, packaging, USP and FCC

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