Thermal Spray Coatings in the Aerospace and Defense Industries

JTST Highlights
Society News
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About the cover
Aero-engine repair thermal spray booth at Metallisation Ltd., Dudley, UK. www.metallisation.com

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

May Energy/Power Generation Industries
August Automotive Industry/Industrial Applications
November Emerging Technologies

To contribute an article to one of these issues, please contact the editors c/o Julie Kalista at Julie.Kalista@asminternational.org.

To advertise, please contact Kelly Thomas, Kelly.Thomas@asminternational.org.
Market for TS Coatings in Aerospace Promising

This issue focuses on thermal spray coatings and engineered surfaces in aerospace and military/defense industries. In the aerospace industry, thermal spray coatings are used in a large number of applications including airframe and propulsion for meeting high performance levels and high quality requirements. These coatings include ceramic (e.g., zirconia-based), metal (e.g., MCrAlY), cermet (e.g., tungsten carbide based), and composite (e.g., abradable) materials.

Coatings range from engine to landing-gear applications. Thermal spray coatings protect engine turbine blades from extreme temperatures, and ensure increased reliability for extended periods of time. In landing-gear applications, these coatings are replacing hard chromium plating as the preferred coating method to provide improved performance. Applications in these and other aerospace applications may include:

- Landing gear (bearings, axles, pins, etc.)
- Jet engines (blades, vanes, combustion liners, compressor casings, nozzles, etc.)
- Actuation systems (pistons, pumps, flaps, etc.)
- Engine cowling, wing structures

In the defense industry, thermal spray coatings are used across the various branches (Air Force, Army, Navy, Marines) to enhance and protect components on military platforms (aircraft, surface ship, submarine, etc.), and in machinery and weapon systems.

Included in this issue are articles from the Curtiss-Wright Corp. and The Boeing Co. Curtiss-Wright is a diversified global provider of highly engineered products and services in motion control, fluid control, and metal treatment. Curtiss-Wright has a significant presence in the highly engineered thermal spray coatings industry and we look forward to their advancements in the industry.

The Boeing Co. is a recognized leader and their efforts provide a glimpse of what major organizations view as important areas in the future. Boeing regularly forecasts their commercial aircraft business, and has forecasted a long-term demand for 34,000 new airplanes, valued at $4.5 trillion over the next 20 years. In the Defense & Space sectors, Boeing is also a leader in providing large-scale systems that combine sophisticated communications with air-, land-, sea- and space-based platforms for military, government, and commercial applications around the world.

The demand for thermal spray coatings and engineered surfaces looks promising in the aerospace and military/defense industry for decades to come. You can learn more about the advancements in thermal spray technology in aerospace as well as many other industries at the International Thermal Spray Conference and Exhibition being held May 13-15, 2013. Innovative Coating Solutions for the Global Economy will be held in Busan, Republic of Korea, and will provide premier technical programming and products from the world’s leading thermal spray and surface engineering experts and suppliers.

Robert Gansert, Ph.D.
iTSSe co-editor
Advanced Materials & Technology Services Inc.

Nominations Sought for ASM Thermal Spray Society Board

The terms of three current members of the ASM Thermal Spray Society Board will expire in 2013. The ASM TSS Nominating Committee is currently seeking nominations to fill these positions. Nominees must be a member of the ASM Thermal Spray Society and must be endorsed by five TSS members. Board members whose terms are expiring may be eligible for nomination and possible re-election on an equal basis with any other nominees. Nominations must be received no later than March 1, 2013.

A nomination form can be obtained via the ASM TSS website at http://tss.asminternational.org.

For more information, please contact Sarina Pastoric at sarina.pastoric@asminternational.org.
The ASM Thermal Spray Society Board appointed chairs to each of its committees for the 2012-2013 term as follows:


If you are interested in serving on an affiliate society committee, please contact the respective committee chair, or Sarina Pastoric at sarina.pastoric@asminternational.org; fax: 440/338-6614.

**Solicitations for Student Members to the TSS Board**

The ASM Thermal Spray Society is seeking applications for...
the two student board member positions. Nominations are due by March 1, 2013. Students must be a registered undergrad-uate or graduate during the 2013-2014 academic year, studying or involved in research in an area closely related to the field of thermal spray technology. To apply, submit an application package consisting of:

• Current resume/CV
• Two-page essay (typed and double-spaced in English) addressing your interest in participating in the program including:
  • What experiences led to your interest in the program?
  • What qualities, characteristics, and skills do you possess that will make you a strong candidate to serve as a student representative on the TSS Board?
  • What do you hope to learn/gain from this program?
  • Students also must submit two letters of recommendation from faculty.

Applications will be reviewed by the TSS Nominating Committee, and candidates approved by the TSS Board. Selected participants will be notified by June 1, 2013, and they will begin their nonvoting, one-year term as student representatives on the TSS Board of Directors in October 2013. Student representatives must attend one regularly scheduled TSS Board meeting held in the U.S. each year, with expenses for travel, hotels, and meals paid for by ASM-TSS, and must participate in two interim TSS Board teleconferences. Student representatives will receive a one-year complementary membership (worth $25) in Material Advantage, the program that provides student membership of ASM, TMS, AcerS, and AIST.

Please send your application package to sarina.pastoric@asminternational.org.

Thermal Spray Technology Course
Instructor: Christopher Berndt, FASM, HoF
May 14-15, 2013, ITSC, Busan, Republic of Korea
June 18-19, 2013, ASM Headquarters Materials Park, Ohio
October 30-31, 2013, MS&T, Montreal, Canada

Thermal spray coatings solve critical problems in demanding environments. They provide solutions to engineering problems involving wear, high temperature and aqueous corrosion, and thermal regulation and degradation. Thermal spray is being increasingly used to manufacture net-shapes, advanced sensors, and materials for the biomedical and energy/environmental marketing sectors. Visit www.asminternational.org/portal/site/www/education to learn more.

Thermal Spray for Gas and Oil Industries
Instructor: Andre G. McDonald
May 23, 2013 ASM World Headquarters, Materials Park, Ohio

This course is beneficial to thermal spray operators in the...
oil and gas industry. Given the special needs of the oil and gas sector for long lasting wear and corrosion resistant coatings, the certification process and validation of the coatings produced by those examining them will need to be different. Therefore, this course will include training and testing information that applies specifically to the oil and gas sector. Visit www.asminternational.org/portal/site/www/education to learn more.

Joe Dewhirst Receives 2012 Cold Spray Leadership Award

Mr. Joe Dewhirst, of Detroit Diesel Remanufacturing, is the 2012 recipient of CenterLine (Windsor) Ltd.’s Supersonic Spray Technologies Div. (SST) Cold Spray Leadership Award. This annual award is in recognition of outstanding contributions made to the industrial development and application of cold spray technology. The award was presented on October 31 for Dewhirst’s leadership in advancing the commercial use of cold spray as an approved coating process.

Introduction to Thermal Spray
(Previously Thermal Spray Operator Course)
Instructor: Rick Sayman
May 21-22, 2013,
ASM Headquarters, Materials Park, Ohio
October 1-2, 2013,
ASM Headquarters, Materials Park, Ohio

Thermal spraying has evolved from a technology designed to be a cost-effective method of repairing worn components and machined parts to a process used to provide improved part performance and add longer life to components. As the thermal spray profession has changed, so has the need to ensure safe and consistent methods for thermal spray operators. ASM International brought together the leaders in the Thermal Spray Society to compile their knowledge and experience in a comprehensive, easy-to-understand course. Visit www.asminternational.org/portal/site/www/education to learn more.
Ultrasmooth, Dense Hardface Coating
Applied by Advanced HVOF Process

Xingqin Ma* and Peter Ruggiero*
Curtiss-Wright Surface Technologies
East Windsor, Conn.

The “gold standard” refers to hard chromium and is of great interest as industry strives to implement a safe, economic, and performance-enhanced surface alternative. The leader of the pack is high-velocity oxy-fuel (HVOF) applied tungsten carbide (WC-Co-Cr). Many papers and articles over the past several years addressed the evolution of this newly applied technology compared with hard chromium. It is hoped that this alternative surface treatment will be used in products that currently use hard chromium.

As aerospace and power generation industries engage in this evolution, a key coating property is surface finish as applied by the HVOF process without requiring post processing. The typical Ra of as-applied HVOF WC-Co-Cr is in the range of 2.5 to 3.5 µm. We aim to reduce as-applied coating surface finish to an ultrasmooth coating level less than 1.0 µm without post finishing. The improved process would provide a finish much closer to that of as-applied hard chromium. This could also open new opportunities for internal engine gas-path applications. The objective is to develop an advanced HVOF process capable of producing ultrasmooth and dense WC-based cermet coatings for better aerodynamics, wear, and corrosion resistance, as well as to provide lower manufacturing cost by reducing the post finishing operation.

Several surface engineering strategies were used to develop an advanced HVOF process. Selecting appropriate feedstock material achieves a resultant coating with homogenous chemistry, high hardness, and low porosity. WC-CoCr feedstock is manufactured by agglomeration and sintering and followed by further densification. Densification significantly increases powder density to >5.0 g/cm³ relative to a typical powder density of 3.0 g/cm³. In addition, selected particle sizes are in the range of -10 to +2 µm, which is much smaller and narrower in size distribution compared with commercial powder sizes (-45 to +10 µm).

Another strategy is to customize an existing HVOF system to achieve constant feeding of small-particle feedstock. A special designed powder feeder with closed-loop control of feed rate provides a steady feed rate of 45 to 100 g/min. Spray conditions were optimized with the aid of in-flight particle diagnosis tools. Jet-Kote HVOF system coupled with the setup of Accuraspray and DPV diagnosis systems, temperature, and velocity of in-flight particles in HVOF flame was monitored and recorded while varying spray parameters (mainly spray distance, powder feed rate, oxygen/fuel flow rate and ratio, and special gun components). As a result, optimal spray parameters and redesigned gun components were used to deposit an optimized coating.

The temperature and velocity of in-flight particles are shown in Fig. 1. Spray distance has the main effect on particle temperature and especially velocity. Increasing spray distance from 6 to 10 in. decreases temperature slightly, but dramatically reduces velocity. With improved gun component design, particle velocity increased without negatively affecting temperature. The special gun modification accelerates particles to 1000 m/s, much faster than the velocity of 700 m/s using standard components. Coating microstructure is shown in Fig. 2.

The coating is very dense with porosity less than 0.5%. Also, the majority of pores are submicron sized, and thus, much less deleterious compared with micron-sized pores in a commercial coating. The etched coating reveals that it is built up with small splats stacking in a dense pattern. Submicron-sized WC is distributed homogenously in Co-Cr metal.
lic matrix, and splat boundaries are not clearly identified. Therefore, it is believed that the coating has much higher cohesive and adhesive strengths and less coating defects. This is largely attributed to the fact that small particles become well melted and impact the substrate at a high velocity more effectively than the industry standard larger particles.

HV300 microhardness was 1250 and 1400 for coatings made using commercial powder and small-sized powder, respectively. Therefore, the advanced HVOF process produces a coating with homogenous structure, near-zero porosity, and high hardness, attributes that enhance coating performance in terms of wear and corrosion resistance.

Surface morphologies of as-sprayed coatings are measured and compared in Fig. 3. The average surface roughness $R_a$ is about 2.5 to 3.0 $\mu$m for a commercial coating and 1.0 to 1.5 $\mu$m for a small-particle coating. After wheel polishing, the $R_a$ value for small-particle coating is further reduced to 0.75 $\mu$m, which is nearly equivalent to the surface finish of a cold-worked or machined substrate.

The effects of other factors on coating finish also were investigated. For example, surface $R_a$ is reduced from 1.5 to 1.0 $\mu$m when the spray angle changes from 90 to 45 degrees. Process validation was demonstrated on a complex airfoil. Surface $R_a$ is about 1.0 $\mu$m on the concave side and about 1.2 $\mu$m on the convex side. With the low surface roughness, it is acceptable to use an as-sprayed coating without post finishing, which is an expensive operation for complex parts such as airfoils. As the basic HVOF tech-
nology platform already exits, the advanced HVOF process can be readily implemented for aircraft and gas turbine applications with the benefit of high coating performance at a reduced cost.

Bibliography


For more information: Xinqing Ma, Ph.D., is development engineering manager, Curtiss-Wright Surface Technologies, 12 Thompson Rd., East Windsor, CT 06279; tel: 860/623-9901; chin.ma@cwst.com; www.cwst.com.
Thermal spray technology at The Boeing Co. dates back to 1968 when the first thermal spray specification, “Plasma Flame Spray Coating,” was released. The company continued to develop thermal spray technology by participating in the Hard Chromium Alternative Team activities in the 1990s. As a result, Boeing led the aerospace industry in adapting and implementing the use of thermal spray coatings as an alternative for hard chromium plating on numerous structural components used in the 767-400 main landing gear.

Since the first Boeing thermal spray specification was released, over 19 thermal spray vendors have been qualified nationally and internationally to coat parts for the company. Based on Boeing’s diverse portfolio of products (commercial aircraft, military aircrafts, and rotorcrafts, space, and satellite vehicles), the use of thermal spray technology has gained significant attention, specifically in past decade.

With a focus on lower operating costs and production, delivery of the game-changing 787-8 and 787-9 demanded a lighter structure using aluminum alloys, titanium alloys, and carbon laminates (Fig. 1). Dramatic changes in structural material and design of next-generation aircraft and rotorcraft requires unconventional coating/substrate system design that meets new demanding requirements. Some of the challenges for coating design are:

- Design and processes for next-generation environmentally friendly, damage-tolerant (wear, corrosion, and fatigue resistant) coatings
- Design of multifunctional surfaces with high surface quality to combat erosion and abrasion while providing EME (electromagnetic effects) protection and ice repulsion
- Integration of communication antennas, loading, and damage-sensing functionalities into the structure

The commercial airplane market is expected to expand over next two decades (Fig. 2), and requires prompt implementation of reliable coating technologies that can keep up with manufacturing and overhaul demands. Thus, another challenge is the short period of maturity required for potential technologies to be implemented in final products. Additionally, another development opportunity (or challenge) in the aerospace industry is improvement of the repeatability and reproducibility aspects of processes that results in more reliable and predictable coating performance.

Boeing Research and Technology’s Chemical Technology group is staffed with a balanced mix of high-performing technicians, engineers, and world experts developing novel, high impact technology solutions. Within that group, the thermal spray team is rapidly developing state-of-the-art material and process solutions for novel, differentiated products.

The team has extensive experience in materials engineering and thermal spray process technologies, with educational backgrounds in material science, chemical engineering, and metallurgy. The research and development thermal spray laboratory is currently expanding its capabilities. The thermal spray facility comprises a 6-axis robot, liquid fuel and gas fuel HVOF systems, twin wire arc system, plasma systems, different coating material feeding systems for slurry and submicron powders, and process diagnostic tools. The team is working closely with different laboratories within Boeing, and has access to state-of-the-art facilities such as EME and rain-erosion laboratories.

Boeing Research and Technology thermal spray team strategically collaborates with industry, universities, and research centers nationally and internationally.

For more information: Arash Ghabchi; The Boeing Co.; Thermal Spray Technology; P.O.Box 3707, MC 19-FC, Seattle, WA 98124-2207; tel: 206/662-1883; arash.ghabchi@boeing.com; www.boeing.com.
ITSC 2013
Innovative Coating Solutions for the Global Economy

May 13–15, 2013
Busan, Republic of Korea

International Thermal Spray Conference and Exposition (ITSC), the world’s foremost international conference and exposition for thermal spray technologists, researchers, manufacturers, suppliers, and users, takes place May 13–15, 2013 at the Busan Exhibition and Convention Center (BEXCO) in the Republic of Korea. The international delegation will gather to exchange ideas and discuss the challenges and opportunities for the future of thermal spray. Experience premier technical programming from the world’s leading thermal spray experts and an unparalleled exposition featuring the largest gathering of thermal spray equipment suppliers, consumable and accessory suppliers, vendors, and service providers. In addition, benefit from dynamic educational programs and networking events.

Keynote presentations

Hyung-Jun Kim, group leader, RIST (Research Institute of Industrial Science & Technology) Coating & Joining Group, and president, KTSA (Korea Thermal Spray Association) will present an overview of thermal spray in Korea and R&D activities at RIST including the history and current status of thermal spray industries and R&D activities in Korea. Topics include early thermal spray research projects for the steelmaking industry; research projects and applications on cold spray, such as cold spray on canisters to contain high-level nuclear waste and metallic sputtering targets for photovoltaic applications; and aerosol deposition projects for biomedical applications such as implants and spine screws and SOFC fuel cells.

The other keynote presentation is TBA.

EXHIBIT DATES AND TIMES

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Networking reception

5:00 p.m. – 7:00 p.m.

Exhibit hours are subject to change.

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Exhibitor list current as of November 30, 2012.
The Journal of Thermal Spray Technology (JTST), the official journal of the ASM Thermal Spray Society, publishes contributions on all aspects—fundamental and practical—of thermal spray science, including processes, feedstock manufacture, testing, and characterization. As the primary vehicle for thermal spray information transfer, its mission is to synergize the rapidly advancing thermal spray industry and related industries by presenting research and development efforts leading to advancements in implementable engineering applications of the technology. Articles from the February and March issues, as selected by JTST Editor-in-Chief Christian Moreau, are highlighted here. The March issue will feature papers based on presentations at ITSC 2012, and the last three articles highlighted below are from this event. In addition to the print publication, JTST is available online through www.springerlink.com. For more information, please visit www.asminternational.org/tss.

“Color Matching in Decorative Thermally Sprayed Glass Coatings”
Thierry Poirier, Pierre Bertrand, and Christian Coddet

Colored coatings were obtained on steel by plasma spray without severe in-flight alteration of pigments, taking advantage of the low thermal conductivity of the glassy matrix of glaze particles. Color matching was studied by mixing three different glazes, comparing Grassmann and Kubelka-Munk based algorithms. Results suggest that the latter method is preferred over the Grassmann method, particularly when light absorption/dispersion ratios of colored feedstocks are very different.

“Liquid-Solid Self-Lubricated Coatings”
S. Armada, R. Schmid, S. Equey, I. Fagoaga, and N. Espallargas

Production of thermal spray coatings containing liquid lubricants has not yet been achieved because of the complexity of keeping a liquid in a solid matrix during the spray process. The first liquid-solid self-lubricating thermal spray coatings are presented here. Coatings are produced by inserting lubricant-filled capsules inside a polymeric matrix. The goal of the coating is to...
release lubricant to the system when needed. Initial coatings consisted solely of capsules to confirm the feasibility of the process. To obtain such a coating, liquid-filled capsules were injected into the thermal spray flame without other feedstock material. Once the concept and the idea were proven, a polymer was co-sprayed together with capsules to obtain a coating containing the lubricant-filled capsules distributed in the solid polymeric matrix.

“Process Conditions and Microstructures of Ceramic Coatings by Gas Phase Deposition Based on Plasma Spraying”
G. Mauer, A. Hospach, N. Zotov, and R. Vaßen

Plasma spray at very low pressure (50-200 Pa) is significantly different from atmospheric plasma conditions (APS). By applying powder feedstock, it is possible to fragment the particles into very small clusters, or even to evaporate the material. As a consequence, the deposition mechanisms and the resulting coating microstructures could be quite different compared with conventional APS liquid splat deposition. Thin, dense ceramic coatings and columnar-structured strain-tolerant coatings with low thermal conductivity can be achieved, offering new possibilities for application in energy systems. To exploit the potential of such a gas phase deposition from plasma spray-based processes, the deposition mechanisms and their dependency on process conditions must be better understood. Thus, plasma conditions were investigated by optical emission spectroscopy. Coating experiments were performed, partially at extreme conditions. Based on the observed microstructures, a phenomenological model is developed to identify basic growth mechanisms.

“Engineering HVOF-Sprayed Cr$_3$C$_2$-NiCr Coatings: The Effect of Particle Morphology and Spraying Parameters on the Microstructure, Properties, and High Temperature Wear Performance”
Dominique Poirier, Jean-Gabriel Legoux, and Rogerio S. Lima

Chromium carbide-based thermal spray coatings are widely used in high temperature wear applications. In these extreme environments, several phenomena will degrade, oxidize, and change the microstructure of the coatings, thereby affecting wear behavior. This study intends to develop a better understanding of the effect of spray parameters on resulting chromium carbide coating microstructure after high temperature operation and high temperature sliding wear properties. Microstructures of different coatings produced from two morphologies of Cr$_3$C$_2$-NiCr powders and under a window of in-flight particle temperature and velocity values were characterized through x-ray diffraction and scanning electron microscopy. Sliding wear at 800°C was performed and wear behavior correlated with the spray parameters and coating microstructure. Vickers microhardness (300 gf) of the coatings before and after sliding wear was also measured.

W. Tillmann and M. Abdulgader

Wire tips in twin-wire arc-spray (TWAS) are heated in three different zones. A high-speed camera captured melting behavior, metal breakup, and particle formation under different operating conditions. In zone I, wire tips are melted (liquidus metal) and directly atomized in the form of smaller droplets. Their size is a function of the specific properties of the molten metal and aerodynamic forces. Zone II is directly beneath zone I and the origin of the extruded metal sheets at the wire tips. Extruded metal sheets in the case of cored wires are shorter than those observed while using solid wires. In this study, the effects of adjustable parameters and powder filling on melting behavior, particle formation, and process instability were revealed, and solid and cored wires were compared. Findings can improve the accuracy of TWAS process modeling.

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