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Mission: To be the flagship thermal spray industry publication providing company, event, people, product, research, and membership news of interest to industrial leaders, engineers, researchers, scholars, policymakers, and the public thermal spray community.

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On the cover: An insulated duct can help reduce condensation inside the dust collector.
Photo courtesy of Donaldson Co. Inc.
Cincinnati Thermal Spray, Solution Spray Technologies Sign Joint Deal

Cincinnati Thermal Spray Inc., Cincinnati, Ohio, and Solution Spray Technologies LLC, Storrs-Mansfield, Conn., have recently signed a nonexclusive license agreement to further commercialize the solution precursor plasma spray process.

Solution Spray Technologies will be working at Cincinnati Thermal Spray’s technology center in Ohio, along with their engineers, to replicate the coating method. Cincinnati Thermal Spray has invested in liquid feeding equipment and next-generation plasma spray process control systems to support the program. Upon installation, the companies will begin a R&D program in Cincinnati. The teams are also working to identify and introduce these coating technologies to a variety of new markets.

The solution precursor plasma spray approach consists of a liquid chemical precursor, containing the desired cations, atomized into the plasma jet. The injected solution evaporates and the resulting salts are pyrolyzed, followed by melting and deposition as micron-sized splats. The development results in smaller splat sizes of < 2 microns.

A fast, high-throughput process for the method can be an enabler for introducing plasma sprayed ceramic coatings for microstructures from thick coatings with controlled vertical cracking suitable for thermal barrier coatings to thin, dense coatings suitable for corrosion protection. It offers the potential of depositing coatings with chemistries that will be expensive to handle through traditional, powder-based plasma routes.

The solution precursor plasma spray process has been under development for more than a decade, with funding from the U.S. Department of Energy through the University Turbine Systems Research program and the Small Business Technology Transfer Research programs for thermal barrier coating development. Shane Elbel, president of Cincinnati Thermal Spray, noted the company is “eager to help cultivate the next generation of thermal spray processes.”

Ways to improve the throughput and robustness of the method will be investigated. Cincinnati Thermal Spray is also discussing it with engine manufacturers, repair entities, and utilities that may be interested in testing the new thermal barrier coating on actual components.

In the future, the teams will be publishing joint papers to disclose achievements and recognize new applications identified for this niche thermal spray process.

Highlighted is the microstructure of a solution precursor plasma spray (SPPS) yttrium aluminum garnet (YAG) thermal barrier coating (TBC). The air plasma spray (APS) yttria stabilized zirconia (YSZ) is also featured.
Höganäs Obtains H. C. Starck’s Surface Technology Division and a New Technology for Spherical Powders

Höganäs AB, Sweden, has signed an agreement to purchase 100% of H. C. Starck Group’s Surface Technology & Ceramic Powders division, STC, Germany, a global manufacturer of surface technology, ceramic, and additive manufacturing powders. It operates as a legally separated, stand-alone division within the group.

“The acquisition of STC also enables us to deliver to new customer segments within aerospace and adds a complementary geographic fit with STC’s strong presence in Europe, in addition to our strong geographical presence in Asia and Americas,” said Fredrik Emilson, Höganäs CEO.

The closing of the transaction is expected during the first half of 2018.

In other recent news, Höganäs has also purchased Metasphere Technology, Luleå, Sweden, a developer of a new technology for atomizing metals, carbides, and ceramics at very high temperatures.

“We will be able to offer new and specialized metal powders for surface coating and additive manufacturing, among other areas,” added Emilson. He noted that the metal powders produced today are well suited for surfaces needing wear, corrosion, and impact resistance.

Current users are supplied with products from the pilot reactor, but work is ongoing to finalize the production reactor, which will be started during the first quarter of 2018.

The high temperatures enable atomizing of raw materials usually not suited for that kind of process, for instance, carbides or ceramics. Some materials may not be possible to recycle, yet could be remelted and atomized in Metasphere’s reactor, so the technology can contribute to increased resource utilization and sustainability in society.

ArcX Europe, the company’s surface coating technology center in Höganas, Sweden, offers coating expertise and equipment to serve European users. Team member Eddy Rohdin is pictured with laser cladding equipment.
Bodycote, a large provider of heat treatment and specialist thermal processing services, revealed its Surahammar, Sweden, hot isostatic pressing location has earned Nadcap accreditation. The site has been producing Powdermet® near net shape and selective surface net shape components for several years, using its experience in manufacturing complex, high-integrity components from powder metal to serve subsea, oil and gas, marine, nuclear, tool steel, and automotive markets.

The company’s hot isostatic pressing now has nine Nadcap-accredited sites globally positioned to serve the world’s aerospace manufacturers and their first-tier suppliers, with additional capacity to meet the demands of future growth in new aircraft programs.

Recent Acquisitions

• **CVD Equipment Corp.**, Central Islip, N.Y., a provider of chemical vapor deposition systems and materials has, through its new wholly owned subsidiary **CVD MesoScribe Technologies Corp.**, bought assets formerly owned by **MesoScribe Technologies Inc.** The business specializes in manufacturing harsh environment sensor products and structurally integrated electronics based on its proprietary direct write thermal spray technology.

• **MB Aerospace**, Glasgow, Scotland, has entered into an agreement to acquire Taiwan-based **Asian Compressor Technology Services Co. Ltd.** The company, founded in 1995 as a joint venture by Pratt & Whitney, China Airlines, and Singapore Airlines Engineering Co., has developed strengths in key technologies including thermal spray coatings. It will trade as MB Aerospace ACTS (Taiwan) once legal completion has been finalized.

• **Integrated Global Services Inc.**, Richmond, Va., a provider of in-situ internal thermal spray surface protection solutions, has purchased **Cetek Ltd.**, merging two critical asset maintenance and coating solution providers. The move also contributes additional lines of ceramic coating technology and maintenance services to Integrated’s surface-protection tools. ▲

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The company’s Surahammar, Sweden, hot isostatic pressing facility has achieved aerospace certification. Pictured is an aerial shot of this location.

Share your company news, facility improvements, acquisitions, and noteworthy events with us.

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Flame Spray Rods Provide Thermal Spray Coating Protection

The line of Rokide® ceramic flame spray rods deliver wear-resistant and corrosion coatings that protect metal and nonmetallic surfaces in high-temperature, abrasive, and corrosive environments. They extend the life of parts and equipment by optimizing deposition efficiency and providing high particle-to-particle cohesive bonding. The process creates hard, chemically inert coatings. The line includes aluminum oxide (A), chromium oxide (C), zirconium oxide (EZ), and bond coat (Ni-chrome) for thermal spraying. Aluminum oxide rods deliver coatings with electrical insulation properties while also providing high abrasion and thermal shock resistance. Chromium oxide rods produce a hard, dense coating that resists wear caused by abrasion, particle erosion, and cavitation. Zirconium flame spray rods deliver coatings with resistance to thermal shock as well as protection against mechanical friction. Ni-chrome bond coat rods impart a smooth surface and improve the bond strength of the ceramic topcoat. This product can be used on new surfaces or to rebuild worn metallic surfaces prior to applying the topcoat for a long-lasting durable finish.

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AWS Releases 2018 Winter/Spring Publications Catalog

The AWS 2018 Winter/Spring Publications Catalog has been published. Its contents include professional and career development, reference materials, processes, industry applications, materials, and more. The manual also highlights thermal spraying guides (p. 42) such as C2.25/C2.25M:2012 (R2018), Specification for Thermal Spray Feedstock — Wire and Rods; ASM Handbook Volume SA: Thermal Spray Technology; Thermal Spraying Practice, Theory, and Application (Historical); C2.16/C2.16M:2017, Guide for Thermal Spray Operator Qualification Programs; C2.20/C2.20M:2016, Specification for Thermal Spraying Zinc Anodes on Steel Reinforced Concrete; C2.18-93R, Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and Their Alloys and Composites; and more. The catalog can be accessed at the website listed below.

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Report Shows Thermal Spray Products Market, Trends, and Forecasts until 2025

The Global Thermal Spray Products Market research report provides insights of the thermal spray products industry over the past seven years, and forecasts until 2025. To research and reveal the market situation and future forecast, the report studies the thermal spray products market status and future trends, and splits thermal spray products by type and applications. It also covers production, consumption, revenue, market share, and growth rate of thermal spray products from 2013 to 2025 in several key regions such as North America, Europe, China, Japan, southeast Asia, and India. The report focuses on manufacturers in the market, with production, price, revenue, and market share covering several companies. It gives insight into sales, volumes, and revenues in the thermal spray products market. Also, it reduces the risks involved in making decisions as well as strategies for companies and individuals interested in the industry.

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Throughout our first 70 years, the International Thermal Spray Association has been closely interwoven with the history of thermal spray development. Founded in 1948, and once known as the Metallizing Service Contractors, the association has been closely tied to most major advances in thermal spray technology, equipment and materials, industry events, education, standards, and market development. As we move into our 71st year, we look to expanding our industrial ties by sponsoring the 2nd Annual Thermal Spray Symposium, which will be combined with our annual meeting. The symposium will highlight thermal spray advancements in the oil and gas industry, and will be held in Texas this fall (more details coming soon). In addition, ITSA will continue our vision for SPRAYTIME — reporting on the news of the thermal spray industry. We will continue to feature more technical articles with the assistance of our new Technical Editor Dan Hayden. We greatly appreciate Dan’s participation with SPRAYTIME and look forward to his technical expertise positively influencing the publication. Readers, we also welcome your ideas. Our goal is to make this publication a reflection of your interests and a valuable benefit of your membership in ITSA.

**ITSA MISSION STATEMENT**

The International Thermal Spray Association, a standing committee of The American Welding Society, is a professional industrial organization dedicated to expanding the use of thermal spray technologies for the benefit of industry and society. ITSA invites all interested companies to talk with our officers and company representatives to better understand member benefits.

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**ITSA MEMBER NEWS**

**Tradeshow Assessment for ITSA Member Eliminated**

Earlier this year, ITSA Members were invited to participate in an ITSA Member Satisfaction Survey, in which they were asked to rate the value of various member benefits. Based on feedback received on the value of ITSA Booth participation at industry tradeshows, at its April 20, 2016, meeting, the ITSA Executive Committee unanimously decided to discontinue ITSA booth activity at tradeshows effective July 2016. As ITSA Members subsidized the cost of ITSA booth activity via annual assessments, this move will result in the elimination of these costly annual ITSA Member assessments going forward.

In lieu of booth representation at tradeshows, ITSA will proactively participate in alternative ways at key industry events. For example, a series of educational presentations promoting thermal spray are being scheduled as free, half-day sessions at tradeshows like FABTECH, POWER-GEN International, and CORROSION.

**ITSA SCHOLARSHIP OPPORTUNITIES**

The International Thermal Spray Association offers annual graduate scholarships. Since 1992, the ITSA scholarship program has contributed to the growth of the thermal spray community, especially in the development of new technologists and engineers. ITSA is very proud of this education partnership and encourages all eligible participants to apply. Please visit thermalspray.org for criteria information and a printable application form.

**ITSA THERMAL SPRAY HISTORICAL COLLECTION**

In April 2000, the International Thermal Spray Association announced the establishment of a Thermal Spray Historical Collection that is now on display at the State University of New York at Stony Brook in the Thermal Spray Research Center, USA. Growing in size and value, there are now more than 30 different spray guns and miscellaneous equipment, a variety of spray gun manuals, hundreds of photographs, and several historic thermal spray publications and reference books. Future plans include a virtual tour of the collection on the ITSA website for the entire global community to visit. This is a worldwide industry collection and we welcome donations from the entire thermal spray community.

**ITSA SPRAYTIME**

Since 1992, the International Thermal Spray Association has been publishing SPRAYTIME for the thermal spray industry. The mission is to be the flagship thermal spray industry publication providing company, event, people, product, research, and membership news of interest to the thermal spray community.

**JOIN THE INTERNATIONAL THERMAL SPRAY ASSOCIATION**

ITSA is a professional, industrial association dedicated to expanding the use of thermal spray technologies for the benefit of industry and society. ITSA Membership is open to companies involved in all facets of the industry—equipment and materials suppliers, job shops, in-house facilities, educational institutions, industry consultants, and others.

Engage with dozens of like-minded industry professionals at the Annual ITSA Membership Meeting, where there’s ample time for business and personal discussions. Learn about industry advancements through the one-day technical program, participate in the half-day business meeting, and enjoy your peers in a relaxed atmosphere complete with fun social events.

Build awareness of your company and its products and services through valuable promotional opportunities—a centerfold listing in the SPRAYTIME Newsletter, exposure on the ITSA website, and recognition at industry trade shows.

Plus, ITSA Membership comes with an American Welding Society (AWS) Supporting Company Membership and up to five AWS Individual Memberships to give to your best employees, colleagues, or customers. Visit aws.org/membership/supportingcompany for a complete listing of additional AWS benefits.

For more information, contact Alfred Nieves at 800.443.9353, ext. 467, or itsa@thermalspray.org. For an ITSA Membership Application, visit the membership section at thermalspray.org.
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ITSA company members are also Supporting Company Members of the American Welding Society (AWS). All AWS Supporting Company Members can have up to 5 individuals (employees, customers, colleagues, etc.) on their company roster who will each enjoy:

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Wall Colmonoy Appoints VP of Finance and Operations

Wall Colmonoy USA, Madison Heights, Mich., has appointed Ed Mohrbach as vice president of finance and operations. He will work closely with the management of all domestic divisions — Alloy Products, Aerobraze, and Franklin Bronze Precision Components LLC — to drive profitable sales growth through the ongoing development and refinement of their respective business strategies and tactical programs. Mohrbach has extensive experience in the industrial segment with leadership roles in sales and marketing as well as general management. For the past 13 years, he was president of PCS Co., a manufacturer and distributor of products within the plastics industry. During his leadership tenure at PCS, the company doubled the size of its business through increased sales coverage, product line expansion, and increased manufacturing capacity. Mohrbach looks to leverage and apply this knowledge with Wall Colmonoy. He holds a bachelor’s degree in mining engineering from Pennsylvania State University and an MBA in finance from the University of Pittsburgh. He has also received Lean Six Sigma Green Belt Certification from Oakland University.

OBITUARY

Rajan Bamola

Rajan “Raj” Bamola passed away on November 7, 2017. He was 56. Born in the Fiji Islands in 1961, he attended the State University of New York at Stony Brook where he obtained dual bachelor and master degrees in engineering chemistry and materials science and engineering. In 1993, he earned his postdoctoral degree in materials science and engineering, specializing in vacuum plasma spray processing. Bamola was vice president of research and development at Turbine Metal Technology from 1989 to 1992. He also served as chief engineer at Bender Systems between 1992 and 1993. From 1993 until his passing, he was president of Surface Modification Systems (SMS), which was founded in Bamola’s garage. By 1996, the company had key national accounts, and Bamola was consulting internationally. In 1997, SMS began to gather a following among the key artificial lift OEM manufacturers. Oil field production companies and oil refineries were using SMS coatings on pumps to continue producing in severe conditions. Over the years, SMS expanded into two large properties of more than 40,000 sq ft in Santa Fe Springs and La Mirada, Calif., to meet production demands as the company diversified from chiefly industry/oil and gas artificial lift and tool coatings, to special materials for OEMs in the energy, aerospace, photovoltaics, large area glass, semiconductor, auto, and NASCAR racing engine parts industries. SMS coatings can be found in combat drones, satellites, and a Mars rover. Bamola’s hobbies included the study of martial arts. He is survived by his wife and two daughters.

Canadian Engineer Recognized for Achievements

Manchang Gui, a licensed professional engineer in Ontario, Canada, has been included in Marquis Who’s Who biographical volumes where individuals profiled are selected on the basis of current reference value. Factors such as position, noteworthy accomplishments, visibility, and prominence in a field are all taken into account during the selection process. Gui has more than 30 years of professional experience and works as a metallurgical and special process engineer and project manager with Safran Landing Systems Canada Inc. Earlier in his career, he served as a research scientist with Beijing Institute of Aeronautical Materials (BIAM). With his team at BIAM, he developed a vacuum liquid method and semisolid bi-stirring process to produce SiC particle-reinforced cast aluminum matrix composites on an industrial scale; he also developed an advanced vacuum investment casting process to produce aluminum matrix composite castings used in aerospace. As a key technical personnel in special processes in the manufacturing engineering department at Safran, he supported HVOF thermal spraying and shot peening processes in manufacturing operations. In the past decade, he has focused on developing and using HVOF thermal spray technology to produce WC-Co casting as a replacement for traditional electrolytic hard-chrome plating in landing gear applications for a variety of components. He also studied cracking and spalling behavior during fatigue testing. Gui has received several awards throughout his career including an Innovation Award from his employer for HVOF coating honing technology. He has also obtained three patents nationally and internationally as well as published more than 50 articles in professional journals. Gui earned a bachelor of science degree in mechanical engineering in 1985 at the Anhui Polytechnic University, Wuhu, China; a master of science degree in 1991; and a postdoctorate degree in 1994, both in materials science and engineering at Harbin Institute of Technology, Harbin, China.

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Local Considerations for Thermal Spray Dust Collection

By Paul Richard

Thermal spray is used across a broad spectrum of industries, and spraying facilities are located in nearly every geography and climate. Many local variables can affect process exhaust and dust collection systems. With proper understanding of local conditions, safe and efficient exhaust systems can be developed to overcome challenges related to outdoor heat, cold, and humidity.

Temperature

Thermal spray, by definition, involves heating various compounds to be sprayed onto surfaces as a coating. The spraying process usually deposits 50% or less of the materials consumed on the surface being coated. Therefore, a need exists to capture the excess airborne compounds exhausted from the booth, along with the heat from the process.

“Thermal spray can create as much as 1,000,000 BTUs per hour,” said Mike Wall of Praxair Surface Technologies, a supplier of thermal spray equipment. “Process air can see a 50°F increase with high-velocity oxygen fuel (HVOF).”

Assuming the air drawn into the thermal spray booth is coming from outdoors through a dedicated make-up air unit, the outdoor air temperature could be in excess of 100°F in hot climate areas. Make-up air units are sometimes directly ducted to the intake of the thermal spray booth. This is often done to insulate the process air from the factory ambient air, which is usually being heated or air conditioned. Considering the exhaust air ducts...
and dust collector could be heated by the sun, temperatures in the dust collector could rise to exceed normal design limitations. This could cause sealing compounds (on filters and bolted joints) to be compromised. As a countermeasure, if high ambient temperatures are expected, the dust collector can be fitted with heat-resistant filter elements, sealing compounds, and even special paint.

Most dust collectors for thermal spray applications use compressed air to clean filters during operation. If moisture is present in the compressed air supplied to the dust collector, cold temperatures can cause problems. Small electrical solenoids that control the cleaning function can sometimes freeze and become stuck open or closed. This can cause an upset condition in the dust collector and risk damage to filters, causing an interruption in the thermal spray process. A solution for cold climates would be a heated solenoid enclosure to help prevent this problem. Furthermore, compressed air piping and associated tubing on the dust collector can be protected with heated insulation (“heat-trace”) — Fig. 1.

Air handling fans used in the dust collection system can also be significantly affected by temperature, according to Adam Conley of Systech Design Inc., which provides fan design and engineering for heavy manufacturing, pharmaceutical, and aerospace facilities.

“A 15-hp, direct-drive fan designed for 5000 ft³/min at 70°F air would need an increase to 20-hp if the temperature was 110°F,” said Conley. This practice, called “derating,” adds mathematical factors based on temperature to correct for the proper fan power needed to meet design criteria.

Condensation can be another challenge related to temperature. At the start of a shift, condensation can sometimes develop in the dust collection system when warm air is drawn into a cold dust collector. Wall, of Praxair, explained that a simple operating step for this particular application can help. “Pulse clean your filters at the end of the day,” he advised. “Run the system for 30 min before you start spraying the next morning. The air from the plant will help to equalize the temperature in the dust collection system before introducing dust.”

Altitude

A local condition that is sometimes overlooked is altitude. “Altitude affects air density,” noted Conley. “The higher you go, the lighter the air.”

This is almost always a local condition that will affect the design of the dust collection fan. Systems installed in mountain regions will not work properly if they were based on the sea-level air density, which is often the default variable used.

“You need more fan, and more motor with the higher altitude,” said Conley. “For example, that 15-hp, direct-drive fan designed for 5000 ft³/min at sea-level would need a 20-hp motor at 2000 ft elevation.”

Colorado, Utah, New Mexico, Wyoming, and Arizona are a few places where high-altitude fans are often needed. In Conley’s experience, at altitudes above 3500 ft, even the fan motors need to be special duty. Fortunately, geographic elevation information is readily available, and fan builders can usually tailor systems to meet the requirements.

Wind and Seismic

As with many design considerations, state, county, and municipal authorities have strict rules about wind and seismic design criteria. California earthquake risks and Atlantic hurricanes are common design constraints, and requirements are usually well understood by local engineering professionals. Dust collectors are among the equipment that needs to meet local wind and seismic design requirements. Keep in mind that the actual limits for wind and seismic loads differ if the collector is located above the ground, such as on a roof or on the upper floor of a facility. Guidance can be found in the Industrial Ventilation manual published by the American Council of Governmental Industrial Hygienists.

Physical Location at the Facility

The location of the dust collection system at your plant — indoors or outdoors — has many determining factors, and weather should be planned into the equation.

Most thermal spray processes require relatively large airflow volumes to properly exhaust particulate and heat from the booth, and the associated dust collectors are usually installed outdoors. There are benefits to this approach. Valuable factory floor space can be used for other purposes, and there is no increase in noise on the factory floor. If there are explosion vents on the dust collector, they can be more easily located to meet regulations.

Along with these advantages to outdoor location, there are some practicalities to consider, such as protection from debris.

“You have snow, ice, and rainfall coming off the roof of the building, and sometimes right down onto the dust collector,” Wall warns. “An appropriate structure to protect the dust collector in severe weather can be very useful.”

The ideal outdoor location should also allow easy access for maintenance. For instance, facility managers have seen dust disposal become an issue.

“With some thermal spray dust, a full 55-gallon drum can weigh well over 1000 lb. You have to know how you’re going to deal with that before you select the location for the dust collector,” Wall advised. “Most people like to use a forklift to move the waste drums, so make sure you have that figured out before you install the dust collector.”

Another consideration in dust collector location are the ducts. It is possible to design a system with ducts over long distances, but there are short and long-term costs to consider. The most obvious are the material and installation costs of the ducts. Longer ducts will require higher static pressure (vacuum) to create the airflow needed. In some cases, that higher static pressure can be enough to collapse the duct itself, so heavier ducts might be needed. Finally, the fan will use additional energy to create the design airflow, so expect this higher cost to be a permanent part of the design.

Indoor installation, although less common, is used in some thermal spray facilities. There might be restrictions to exterior spaces, or even some strict security regarding the collected dust, as in classified military applications. In most cases, the filtered air and gases will have to be exhausted to the atmosphere outdoors. Environmental health and safety managers will typically guide industrial ventilation designers to meet noise, maintenance access, and other important safety requirements.

With either an outdoor or indoor dust collector location, remember that there will likely be high-voltage electricity required to power the dust collection fan. The controls for the dust collector might be installed indoors near the thermal spray process, and associated wiring between the electrical panel and the dust collector can represent a significant part of installation costs — Fig. 2.
In All Conditions

Consistent, clean, and dry compressed air is critical for proper filter cleaning, regardless of location. It is a good idea to have a dedicated compressed air filter at the dust collector, as well as a gauge that allows you to dial in the correct pressure. With compressed air utilized at different locations within the factory, sometimes the dust collector is starved for adequate pressure and flow when it is needed. Managers of facilities should be aware of the additional compressed air requirement and make necessary accommodations.

Once the dust collector filters the particulate from the gas stream, the discharged air should be far enough from building ventilation fans to prevent recirculation of gases into the building. Some thermal spray processes (HVOF) can generate hydrogen and carbon monoxide, so check with local authorities for minimum distances between fan discharge and facility air intake locations.

Conclusion

Local conditions can dramatically affect your thermal spray dust collection system. Temperature, altitude, wind, seismic, and facility layout will determine many of the design decisions required for a safe, efficient system.

When combined with requirements that are universal in thermal dust collection — a dust disposal plan, duct and wiring, compressed air needs, and all associated costs — a comprehensive ventilation solution can be complex to design. Working with an experienced industrial ventilation designer to implement a compliant and efficient system can help engineer a better overall system for your application and facility.

Paul Richard (paul.richard@donaldson.com) is OEM accounts manager, Industrial Air Filtration division, Donaldson Co. Inc., Bloomington, Minn.
Thermal spray technology has been essential to the progress and innovation of many products and processes since its inception in the early 1900s. Further developments have led to a wider use of thermal spray coatings beyond aviation and national defense industries to include applications in agriculture, automotive, and other sectors. Innovators have continued to improve on the original idea to meet increasingly complex demands for effective, rugged, and versatile coatings.

Engineers at Hypersonix LLC recently commercialized hypersonic plasma particle deposition (HPPD), a process that further expands on the concept of thermal spray. It was invented by researchers at the University of Minnesota, and leveraged by Winona, Minn.–based Hypersonix. Together with collaborators at Mesotek Corp. in Toufen, Miao-Li, Taiwan, the company has built a production-level system that utilizes the HPPD process. This method uses a plasma to synthesize crystalline nanoparticles that are deposited as a dense coating via a one-step, vacuum-assisted process. These coatings have exceptional adhesion, hardness, and resistance to fracture due to the deposition process, which involves ballistic impaction of the nanoparticles into a heated substrate.

Due to the mechanical properties of HPPD coatings, they are well suited for applications in which wear and corrosion resistance is critical, such as cutting tools and carbide inserts for machining — Fig. 1. Additionally, HPPD coatings can extend product performance in less obvious wear applications such as in electrical contact switches, turbine rotor fins, food processing equipment, and high-speed hydraulic pumps. There are also biomedical applications for these coatings where a dense, wear-resistant coating applied to medical implants could potentially revolutionize the industry.

HPPD is a novel but complimentary technique to thermal spray and chemical vapor deposition (CVD) and is of value to applications where more specialized coatings are required.

This article introduces the HPPD process and highlights its features and benefits. From the plasma that initiates the process, through the nanoparticle coatings created, this article explores each step of the deposition technique.

A Specialized Plasma

Developers of the HPPD process used a Thermach SG-100 plasma torch, which generates the high-heat plasma necessary for HPPD. Thermach worked with researchers at the University of Minnesota to develop a proprietary cathode-anode pairing that creates the precise environment the process needs to make coatings composed of crystalline nano-sized particles.

To begin the process, the plasma is directed through a specially designed nozzle made of a high-temperature ceramic that can withstand the extreme temperatures of the plasma. This nozzle protrudes into a large vacuum chamber (Fig. 2) held at a moderate level of vacuum (~2 torr). As the plasma stream travels down the nozzle and exits into the vacuum chamber, it expands then collapses, creating a characteristic “bubble” shape. This shape of the plasma is essential to the HPPD process.
The bubble shape is formed because of the pressure difference between the plasma torch and the inside of the deposition chamber. This pressure difference creates hypersonic acceleration, which allows nanoparticles that are made inside the plasma to reach speeds of more than 2000 m/s (about Mach 6). At such great speeds, the nanoparticles ballistically impact into the substrate located downstream of the nozzle. The ballistic impact results in greatly improved adhesion while creating a dense, pore-free coating with deposition rates that can approach 30 microns per min.

To make these crystalline nanoparticles, Hypersonix departs from more traditional thermal spray processes that use ultrafine powders or wire as feedstock. Instead, this process uses high-purity reactive gases that are piped into the system and combined with the plasma. The composition of the nanoparticles, and therefore the coating, is controlled by the type of gases used. Since gases can be purified to a greater extent than solid feedstocks, HPPD dramatically reduces impurities in coatings. Additionally, because the coating is deposited in the air-free environment of a vacuum chamber, undesirable oxides that can occur in other thermal spray coatings are avoided.

Another advantage of using reactive gases is that they can be easily and thoroughly mixed to create unique coating compositions that would be difficult in other thermal spray processes. HPPD has the capability to feed many gases into the plasma at once, making it possible to create coatings that are composed of many different elements (such as SiTiCN). Additionally, its control of gas flow rates allows even simple feedstocks, HPPD dramatically reduces impurities in coatings. Therefore, the coating, is controlled by the type of gases used. Since gases can be purified to a greater extent than solid feedstocks, HPPD dramatically reduces impurities in coatings. Additionally, because the coating is deposited in the air-free environment of a vacuum chamber, undesirable oxides that can occur in other thermal spray coatings are avoided.

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For example, to create a silicon carbide (SiC) coating, silicon tetrachloride (SiCl₄) vapor and methane gas are used to generate Si and C, respectively. As the gases encounter the plasma at extremely high temperatures, the gas molecules dissociate. This means the molecules themselves bust apart into individual atoms. The methane breaks apart into carbon and hydrogen atoms, while the SiCl₄ becomes silicon and chlorine atoms. The plasma stream then serves as an ideal environment for these reactive elements to recombine into tiny, crystalline particles. These particles grow as they travel down the nozzle and into the vacuum chamber, being swept along with the rest of the plasma stream. After exiting the nozzle, the particles ballistically impact into a temperature-controlled substrate to form a dense, crystalline, nanostructured coating.

The Importance of Nanoparticles

Why is a crystalline, nanostructured coating important? Being nanostructured is the reason these coatings have enhanced properties. Nanoparticles are special because they behave differently from their larger “bulk” counterparts, and those differences are mainly because of their size. This concept is shown in a variety of everyday situations. A teaspoon of sugar will dissolve more quickly than a sugar cube when added to hot tea. In a cocktail, crushed ice will melt faster than an ice cube. The end result is the same, though — you have sweetened tea or a disappointing cocktail.

These examples concern materials of different sizes behaving differently because of their size (or, technically, their surface area). The same thing happens when moving from the macroscale to microscale to nanoscale. Materials known for their exceptional mechanical properties, such as silicon carbide, become even more exceptional when their grain size is reduced. This is due to the Hall-Petch relationship, which describes how the strength of materials increases with decreasing grain size. The strengthening mechanism involves microscopic defects shifting inside each grain of the material. If the grain is large, it will contain many defects. These defects allow material to shift and deform under pressure. If the grain is small, it has fewer defects and has no way to shift, therefore becoming harder. HPPD coatings have been tested to have Vickers hardness in excess of 4000 HV.

Being nanostructured affects other mechanical properties as well. For example, the resistance to fracture or cracking is greatly enhanced in HPPD coatings. For a hard ceramic like glass, cracks propagate unchecked until they reach the edge of the workpiece, because there is no internal grain boundary to stop the crack from growing. HPPD coatings, with nano-sized grains, prevent cracks from growing in an uncontrolled manner. Specifically, an HPPD-generated coating of SiC has twice the fracture toughness (6.03 ± 1.95 MPa·m¹⁄₂) and has significantly higher hardness (37 GPa [3800 HV]) than standard SiC bulk material — Fig. 3.

Traditional methods for nanoparticle synthesis — like solution-based chemical methods, mechanical milling, or pyrolyzing processes — create nanoparticles with a wide range of sizes that frequently have impurities and need significant processing to obtain a usable product. Nanoparticles grown in the HPPD process, however, are made directly from reactive gases. There is no solution or solvent, so additional processing or cleaning is not needed. Furthermore, because HPPD-made particles grow as they travel down a nozzle of a fixed length, they all grow to about the same size and shape (they are monodisperse).

Another unique feature of nanoparticles grown during the HPPD process is their crystallinity. By growing the nanoparticles from reactive gases, they form from the atomic level up. They grow as crystalline and retain their crystallinity even after the coating is made. This is different from what happens in most thermal spray processes, where the material being coated is melted and loses its crystallinity, depositing as an amorphous coating.
The Final Product

To get the best coating possible using HPPD, the object to be coated must be at elevated temperatures, more than 800°C (~1400°F). This temperature helps the nanoparticles stick to the substrate and to each other. The combination of ballistic impaction and high temperatures also aids in densification, creating coatings with virtually no inner voids or pores. Due to this requirement, the HPPD process is limited to substrate materials that can withstand high temperatures. While this does exclude the process from some market segments, it also opens doors to applications where a very specialized coating is required.

As with all thermal spray processes, HPPD is a line of sight process where the object to be coated must be located downstream of the plasma. To increase throughput of coated parts, airlocks allow the main vacuum chamber to stay under vacuum during part transfer. Due to HPPD's relatively small deposition area, automation is employed to cover larger areas using a combination of rastering and three-dimensional translation.

The final result is that HPPD creates dense, hard, tough, and well-adherent coatings that are intrinsically nanostructured. The nanoparticles are synthesized inside the plasma and have excellent monodispersity, providing uniformity to the coating — Fig. 4. Deposition rates are much higher than other vapor deposition processes, and a wide variety of coating compositions can be deposited.

Conclusion

To continue innovating and improving technology, new materials must be made, or new processes must be developed. In the world of materials science, one can achieve this by either making a different material (changing composition) or altering the material's structure to make improvements. HPPD goes in both directions at once, providing a high-throughput method for depositing compositionally complex coatings, as well as creating nanostructured or nanolayered structures.

By utilizing a plasma, HPPD nucleates, grows, and deposits crystalline nanoparticles in a precisely controlled environment. Its one-step process allows great control over composition in a contaminant-free vacuum environment. The combination of high-impact velocity and high-deposition efficiency produces strongly adherent coatings at high deposition rates. HPPD coatings' inherent nanostructure improves mechanical properties like hardness and resistance to fracture beyond what is obtainable for bulk materials.

HPPD is a step towards the future of thermal spray processes, employing a novel method to deposit crystalline, nanostructured coatings that may provide revolutionary solutions to the coating needs of tomorrow.

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| MARCH 2018   | **American Coatings Conference**  
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|             | **International Conference on Metallurgical Coatings and Thin Films**  
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|             | **Offshore Technology Conference**  
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2018.otcnet.org |
| APRIL 2018   | **Society of Vacuum Coaters — TechCon 2018**  
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svc.org |
|             | **International Thermal Spray Conference and Exposition**  
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| JUNE 2018    | **NACE Bring on the Heat Conference**  
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|             | **FABTECH Canada 2018**  
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|             | **CSAT 2018**  
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|             | **32nd International Conference on Surface Modification Technologies**  
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| JULY 2018    | **THERMEC 2018: International Conference on Processing & Manufacturing of Advanced Materials**  
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themer2018.sciencesconf.org |
| SEPTEMBER 2018 | **Eurocorr 2018**  
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| OCTOBER 2018 | **EuroBLECH 2018**  
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