FIRST QUARTER 2023 | VOLUME 30

SPRAYTIME

American Welding Society | International Thermal Spray Association

Thermal Spray Powders

ADVANCED THERMAL SPRAY SYSTEM

PLASMA SPRAY SYSTEM

MASS FLOW CONTROLLED PLASMA SPRAY SYSTEM
Model - AP-2700

AP-2700 FEATURES :-

- Data logging.
- Recipe selection.
- Remote diagnostics.
- Slave / master / manual modes.
- Meet Requirement of Industry 4.0.
- Touch screen mass flow controlled.
- 80kw Standard, 120kw Optional Power Capacity.

MASS FLOW VIEW PLASMA SPRAY SYSTEM
Model - MPS-80

MPS-80 FEATURES :-

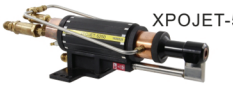
- "CE" Approved.
- PLC Controlled.
- Auto & Manual Modes.
- Support 2 Powder Feeder Operation.
- Can Be Integrated With Chiller, Door, External Interlock.

HIGH VELOCITY OXY FUEL SPRAY SYSTEM

Model - AK-2700

AK-2700 FEATURES :-

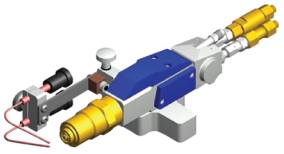
- Data logging.
- Recipe selection.
- Remote diagnostics.
- Slave / master / manual modes.
- Meet Requirement of Industry 4.0.
- Touch screen mass flow controlled.


XPOJET-5250

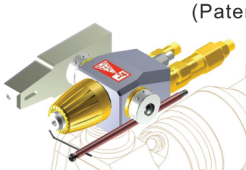

XPOJET-5000


MJP-6000

FLAME SPRAY SYSTEM


POWDERJET-86 A

CERAJET GUN
(Patent Applied)



CONTROL PANEL, HV-3100

- Massflow controlled.
- Auto Ignition.
- Built in powder feeder.

SINCE 1967

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On the cover: AMPERIT® thermal spray powders. (Credit: Höganäs.)

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

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Mollie Blasingame
Chair

2023 is off to an excellent start for the International Thermal Spray Association (ITSA). We are finalizing plans for our next in-person gathering and pursuing opportunities to expand membership activity this year.

With that, I would like to introduce Kirk Fick as the new ITSA vice chair. As ITSA chair, I am looking forward to working with him this year to support our organizational initiatives. Fick will focus on increasing ITSA membership and activity to continue fueling the growth of our organization.

He is a veteran of the industry, currently serving as senior development engineer at Cincinnati Thermal Spray Inc. Fick has been with the company for more than 20 years and has contributed to the growth of thermal spray processes and coatings. He is passionate about advancing the capabilities of the industry. You can learn more about him on page 9.

I am also excited to soon announce the plans for our next in-person ITSA gathering. The ITSA planning committee met on the first week of February to discuss the details of the 2023 Annual Membership Meeting & Symposium. Stay tuned for an official announcement in the next issue of *SPRAYTIME*.

This year promises to be an exciting one with plenty of potential for ITSA!

ITSA MISSION STATEMENT

The International Thermal Spray Association (ITSA), 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.

OFFICERS

Mollie Blasingame, chair, Superior Shot Peening & Coatings

Kirk Fick, vice chair, Cincinnati Thermal Spray Inc.

EXECUTIVE COMMITTEE (above officers plus the following)

Ana Duminie, North American Höganäs
Jim Ryan, TechMet Alloys
David A. Lee, David Lee Consulting LLC
Bill Mosier, Polymet Corp.
Peter Ruggiero, Curtiss-Wright Surface Technologies

ITSA SCHOLARSHIP OPPORTUNITIES

ITSA 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. Visit *thermalspray.org* for criteria information and a printable application form.

ITSA *SPRAYTIME*

Since 1992, ITSA has been publishing *SPRAYTIME* for the thermal spray industry. The mission is to be the flagship thermal spray industry publication providing company, event, personnel, product, research, and membership news of interest to the thermal spray community.

JOIN 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 listing in *SPRAYTIME*, exposure on the ITSA website, and recognition at industry trade shows.

Plus, ITSA Membership comes with an 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 Adrian Bustillo at (800) 443-9353, ext. 295, or *itsa@thermalspray.org*.

For an ITSA Membership application, visit the membership section at *thermalspray.org*.

ITSA Annual Membership Meeting Held during FABTECH 2022

The International Thermal Spray Association (ITSA) Annual Membership Meeting was held in person for the first time in two years on November 9, 2022, in Atlanta, Ga., during FABTECH 2022. About 20 members gathered to discuss topics including financials, the 2024 symposium, the *SPRAYTIME* redesign, and more.

The following attendees gave presentations: Dr. Bala Balachander, principal engineer at Delta Air Lines; Dan Hayden, Hayden Corp.; Richard Bajan, Industriekeramik Hochrhein (IKH) GmbH; Bob Unger, Polymet; Alan Burgess, Spraywerx; and Philip Nodecker, Superior Shot Peening. Each presenter shared valuable industry insights and details about their respective companies. Some highlights included Balachander giving an overview of in-house repairs at Delta; Hayden sharing news about his company's recent acquisition; Bajan introducing IKH as the newest ITSA member; and Unger providing an overview of Polymet, the longest active ITSA member.

The business meeting took place after the presentations. Members conferred about locations for the 2024 symposium and increasing ITSA membership. During the *SPRAYTIME* redesign discussion, the layout and contents of the magazine were reviewed, and members were invited to submit future articles. In addition, it was established that 2023 remains the goal for the ITSA website (*thermalspray.org*) redesign.

ITSA will have its next Annual Membership Meeting in 2023 and a symposium in 2024, with dates and locations to be determined. For updates, visit *thermalspray.org*.

ITSA members gathered for a photo during the Annual Membership Meeting.

Oerlikon Invests in New Assembly and Production Site in Switzerland

Oerlikon, Pfäffikon, Switzerland, a global surface technology, polymer processing, and additive manufacturing provider, is planning a new assembly and production site for its surface solutions and equipment businesses. The group's current locations in Wohlen, Dottikon, and Winterthur, Switzerland, will be merged at the Reichhold Campus in the canton of Aargau, Switzerland.

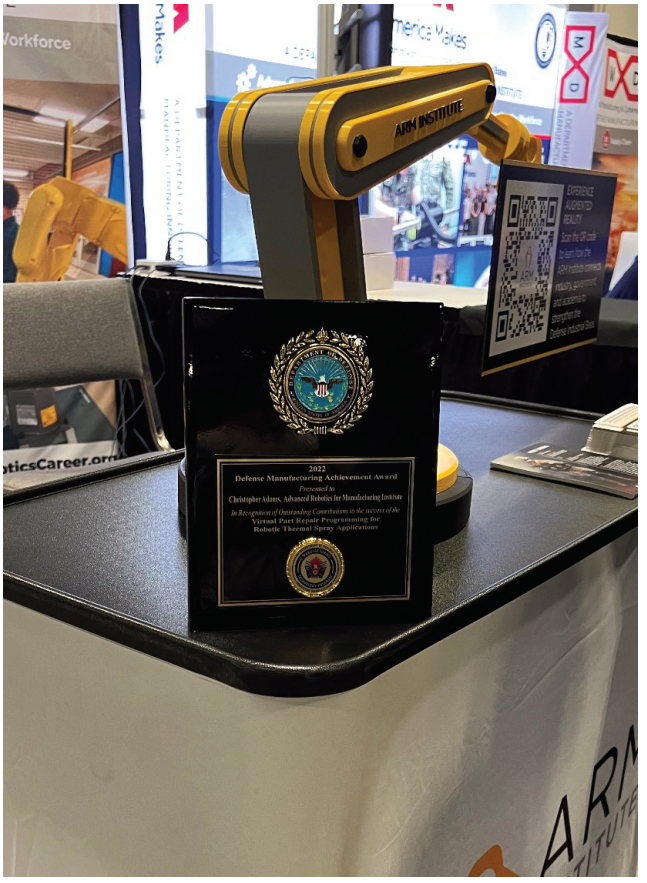
The site is being codeveloped with HIAG Immobilien Schweiz AG, Basel, Switzerland, and will provide customers with Oerlikon Metco thermal spray solutions, including equipment assembling and production services. The Reichhold Campus

location, spread across a total of approximately 14,500 m^2 (about 156,000 sq ft) of production and office space, will also serve as a sales and distribution center for the materials product line, house an IT competence center, and offer about 230 employees a workplace. A strong focus will be placed on sustainability and innovative approaches to future-oriented energy, mobility, and utilization concepts.

The application for the building is planned to be submitted in the summer of 2023. Construction is scheduled to start in the spring of 2024, and the location is expected to be ready for moving in from mid-2025 onward. At the current sites, all activities and work will continue as usual. According to the current plan, the move will begin in the summer of 2025 and will take place gradually to ensure the continued processing of all customer orders.

ARM Institute Team Earns Defense Manufacturing Technology Achievement Award

The Advanced Robotics for Manufacturing (ARM) Institute, Pittsburgh, Pa., Virtual Part Repair Programming for Robotic Thermal Spray Applications Project Team won a Defense Manufacturing Technology Achievement Award (DMTAA) at the 2022 Defense Manufacturing Conference (DMC) in Tampa, Fla. The annual DMTAA Awards are given to teams comprising government, industry, and academia employees responsible for outstanding projects in manufacturing technology. These projects demonstrate technical accomplishments and provide a responsive world-class manufacturing capability that affordably meets the warfighter's needs throughout the defense acquisition lifecycle.



The ARM Institute's 3D-printed arm and award.

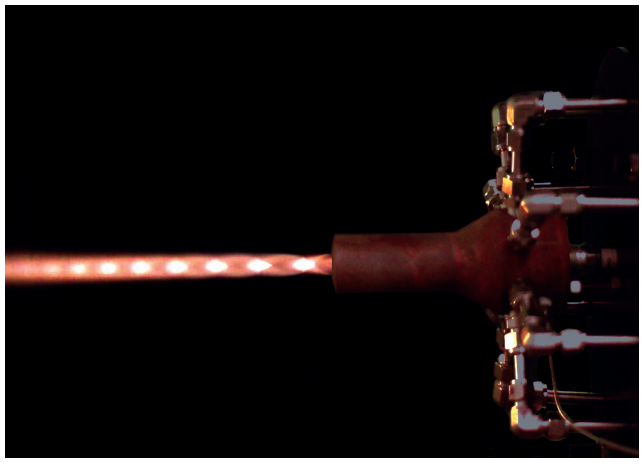
The Virtual Part Repair Programming for Robotic Thermal Spray Applications Project Team is managed at the ARM Institute by Chris Adams, senior programs manager, and composed of ARM Institute members, a group from the University of Connecticut (UConn), and Titan Robotics.

This project developed a virtual method for operators to automatically generate a robotic thermal spray path plan over a repair area on a physical part within a thermal spray booth using an immersive interface.

The project team at UConn designed and developed a sensor system for measuring thickness buildup over a part during various thermal spray processes. The sensory measurement is paired with Titan Robotics' virtual repair programming interface, which allows the operator to highlight (i.e., virtual mask) the repair in the graphical user interface and build up the thermal spray coating to a desired thickness over the selected part area for repair. All work (part localization and repair area selection) performed by the operation takes place in an augmented reality environment through Microsoft HoloLens.

SPEE3D's SPACE3D Program Successfully Trials AM Rocket Engine in First Hot Fire Test

SPEE3D, a supplier of metal-based additive manufacturing (AM) technology based in Melbourne, Australia, has made progress with its SPACE3D program. The project focuses on using cold spray AM and advanced manufacturing methods to build parts for the space industry. Recently, the company successfully conducted the first hot fire test of a prototype rocket engine at a test site in Darwin, Australia.



A high-speed camera capture of a prototype SPEE3D SPACE3D rocket engine during the first hot fire test of the series. The formation of shock diamonds or Mach disks in the exhaust plume indicates supersonic flow.

The laboratory prototype is the first of a series of rocket engines and components that will be designed, manufactured, and tested over the next 18 months. The prototype was designed to harness the power of SPEE3D's cold spray metal printing technology with other new manufacturing processes that collectively aim to deliver reusable rocket engines within lead times and costs that are significantly lower compared to using more-traditional technologies.

"SPEE3D's cold spray technology facilitates new ways to design and manufacture demanding space components potentially more rapidly and at lower cost than incumbent technologies," said Gary Owen, chief space officer for SPEE3D's SPACE3D Program. "Our design, manufacturing, and test expertise, once proven by events such as successful rocket engine hot fire tests, will position us well to play an important role in the rapidly expanding space industry."

Curtiss-Wright Completes Acquisition of Keronite Group

Curtiss-Wright Corp., Davidson, N.C., has acquired Keronite Group Ltd. for $35 million in cash. Keronite is a provider of plasma electrolytic oxidation surface treatment applications offering corrosion protection, wear resistance, thermal protection, and electrical insulation for the defense, commercial aerospace, and industrial vehicle markets. The acquired business will operate within Curtiss-Wright's Aerospace & Industrial segment.

"The acquisition of Keronite increases the breadth of our surface treatment services portfolio with unique and complementary coatings technologies recognized for their critical performance in severe service environments," said Lynn M. Bamford, chair and CEO of Curtiss-Wright Corp.

Keronite, which was founded in 2000 and employs nearly 45 people, is based in Cambridge, UK, and maintains operations in Greenwood, Ind.

AIM MRO Acquires Tribologix

AIM MRO Holdings LLC, Miamiville, Ohio, a manufacturer and supply chain manager of highly engineered consumable repair products and materials used in the aerospace aftermarket, has acquired Tribologix, Golden, Colo., a provider of engineered surface coatings solutions that reduce friction and wear in extreme environments where conventional lubricants do not work. Ben Ehrens, CEO and president of Tribologix, will be staying on with AIM MRO as a consultant.

AIM MRO CEO Scott Wandtke stated, "Tribologix's high-tech, cutting-edge coatings and extensive testing have made it a trusted name in surface engineering for extreme environment applications, where the elimination of friction and wear is a mission-critical factor for nonserviceable mechanical components. We're excited to add these products to our suite of state-of-the-art offerings."

Aerobraze OKC Receives USAF Contract for F-16 Regenerative Heat Exchanger Remanufacture

Aerobraze Engineered Technologies Oklahoma City (Aerobraze OKC), Oklahoma City, Okla., a division of Wall Colmonoy that specializes in the remanufacture/overhaul of F-16 Inconel® and aluminum heat exchangers, was awarded a five-year contract with the U.S. Air Force (USAF) for the remanufacture of F-16 fighter aircraft regenerative heat exchangers at the Tinker Air Force Base.

"As a major manufacturer and overhauler of heat exchangers for the USAF for nearly 40 years, it is with great pride that we continue to provide support to the United States Air Force," said Brian Martin, director of business development, Aerobraze U.S. "This new award demonstrates our ongoing commitment to increasing efficiency and cost savings for our customers through extending the life of critical components for the aerospace industry."

Aerobraze OKC will remanufacture USAF F-16 Fighting Falcon aircraft.

ITSA Appoints Vice Chair

K. Fick

Kirk Fick has been appointed vice chair of the International Thermal Spray Association (ITSA). Fick is an experienced engineering professional who has worked in the thermal spray industry for more than 30 years. His diverse experience extends across the land-based turbine, aircraft engine, medical, commercial, and on-site market segments in both manufacturing and R&D environments. He has been with Cincinnati Thermal Spray (CTS) for more than 20 years, starting as a product engineer and now working in senior leadership for the last 18 years. He currently oversees the operation of the CTS Technical Center, which supports all CTS locations with process development and improvement as well as external customers with projects spanning from R&D to pilot production. Fick has been an active member of ITSA for almost ten years and was instrumental in the organization of ITSA's 2019 Aerospace Symposium in Springfield, Mass. As an industry subject matter expert, Fick also represents CTS in several technical organizations, including the Consortium on Thermal Spray Technology (Center for Thermal Spray Research [CTSR] Consortium), National Research Council Canada (NRC) Surftec Consortium, and ASME Turbo Expo, where he has particpated as a Manufacturing Materials & Metallurgy (MMM) committee member, technical reviewer, and session co-chair.

McLaughlin & Associates Announces New Consultant

McLaughlin & Associates Thermal Spray Inc., Indianapolis, Ind., a company providing products and services for all aspects of thermal spray coatings, has hired Raymond "Ray" Sinatra as a consultant for training, new application development, material specification, and metallographic lab testing. He will also provide assistance as a thermal spray shop business advisor. Sinatra has more than 50 years of experience in surface technology applications and has worked for companies such as Metco Inc., United Airlines, and Rolls-Royce. He has a wide ranging and in-depth knowledge of thermal spray equipment, tools, and processes including plasma spray, wire/powder combustion, and high-velocity oxygen fuel (HVOF). Additonally, he is experienced in coating parameter development to meet application requirements and has concentrated knowledge of thermal spray abradable seal coatings and new material formulations for ceramic matrix composites (CMCs) as well as future engine applications that require higher temperature and longer on-wing service life. Sinatra holds eight U.S. patents.

R. Sinatra

Velo3D Hires Director of Solutions Engineering

R. Stamp

Velo3D, Campbell, Calif., a metal additive manufacturing technology company for mission-critical parts, has welcomed Robin Stamp as director of solutions engineering to help grow the company's metal additive manufacturing technology with new customers and in new industries. He will work with customers to understand their needs, expand the manufacturing capabilities of Velo3D's solutions, and educate customers on how to fully leverage various technology improvements. He will also oversee the development of new standards with regulatory agencies, qualification of new metal alloys for use in the Sapphire family of printers, and collaboration with partners and agencies. Stamp has extensive experience leading teams in the R&D of additive manufacturing technology. He was previously a principal engineer at SpaceX, where he worked on developing technology for space applications. He also

spent more than a decade at Stryker, leading the R&D team responsible for creating new additive manufacturing processes for medical implants.

Wall Colmonoy Welcomes Business Development Manager

Wall Colmonoy (USA), Madison Heights, Mich., a materials engineering group, has added Josh Gardner as its business development manager — Surfacing Products as part of the Alloy Products Americas' sales team. He will be responsible for expanding product applications for new and existing surface coating customers. He will work alongside the sales team, performing technical inputs for surfacing and thermal spraying techniques. Gardner has more than 23 years of experience in thermal spraying; laser cladding; plasma transferred arc welding; high-velocity oxygen fuel; and sales applications for oil and gas, mining, agriculture, and aerospace industries. He has additional experience in training personnel and designing and installing thermal spray systems.

J. Gardner

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High-Volume Production of **WC10Co4Cr Powder** for Use in Flash **Carbide Applications**

BY DAVID SANSOM, ALEXANDER BARTH, AND ARASHK MEMARPOUR

Introduction

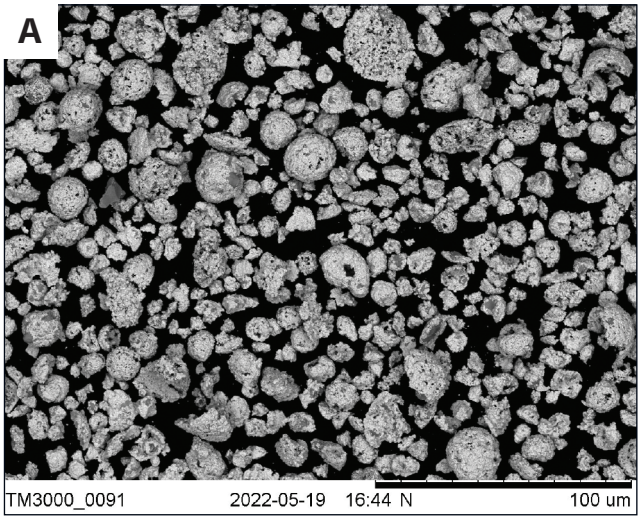
For decades, chrome plating and, more recently, high-velocity oxygen fuel (HVOF) applied coatings have been used on key components in the oil and gas industries to give enhanced protection in aggressive environments. Today, there is a newer application method that is challenging the HVOF status quo, and that is high-velocity air fuel (HVAF). HVAF application methods can produce denser coatings than HVOF methods, allowing for the same performance to be achieved in thinner coatings (Refs. 1, 2). HVOF applications are in the range of 200–250 µm, while HVAF can achieve the same level of performance with 50–100 µm. This is driven by HVAF's higher particle velocities, which reach up to 1300 m/s (Ref. 3).

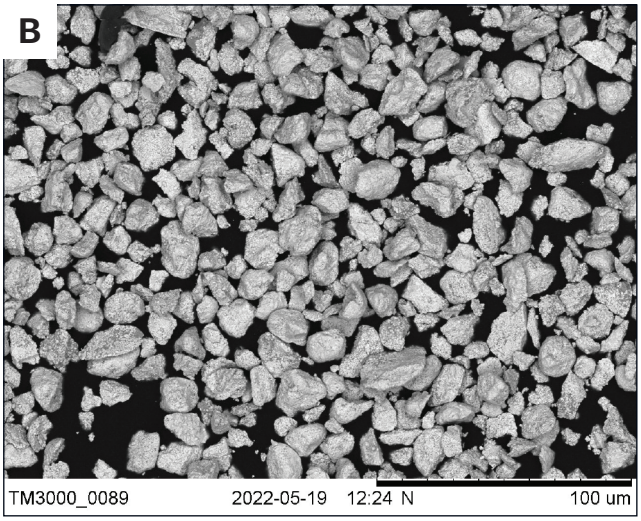
These flash carbide coatings require finer sieve-sized powder as a feedstock. However, this trend toward the use of flash carbides can produce issues. Very fine particle size distribution (PSD) powders may lead to more irregularly shaped particles due to the inhomogeneous structure of the individual particle impairing the flowability of the powder. This can be partially compensated by using smaller primary particles. Also, the production of finer PSD powders in the standard powder manufacturing processes can result in lower available volumes compared to the growth in demand and, going forward, could disrupt the security of supply and add price pressure, eroding the cost benefit of applying the thinner coatings. WC10Co4Cr has an annual market size of $200 million for HVOF applications (Ref. 4). Methods to produce fine HVAF-suitable powders in larger volumes are required to be able to take full advantage of the benefits of HVAF flash carbide applications.

Höganäs has developed a manufacturing method to produce WC10Co4Cr powders in fine PSD but with the capability of large volumes. The assessment of this new powder, named Amperit® 658.067, on key properties is the focus of this work.

Experiment

The new powder was trialed with other existing established Höganäs fine PSD WC10Co4Cr powders (Amperit® 558.052 and 554.067). These WC10Co4Cr powders were manufactured by various methods giving differing morphologies, as identified in Table 1. A scanning electron microscope (SEM) was used to observe the morphology of the powders — Fig. 1.





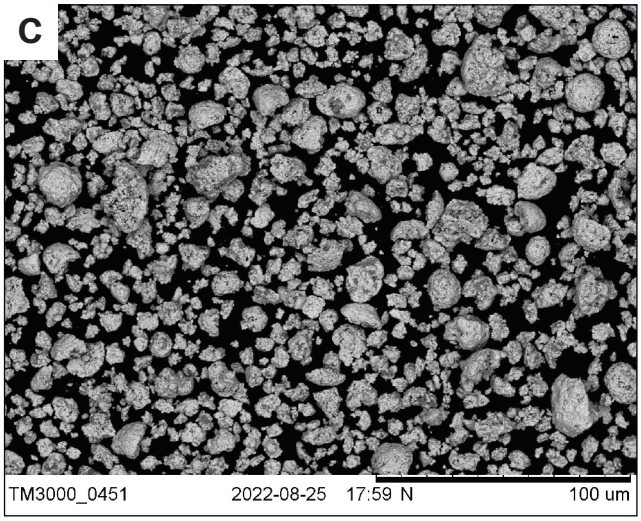


Fig. 1 — The SEM images of the powders: A — Amperit® 558.052 (A&S; P1); B — Amperit® 554.067 (S&C; P2); C — Amperit® 658.067 (New; P3).

The three different powders were applied by HVAF, and the deposit efficiency (DE), roughness, hardness, and wear properties were then characterized. The testing was carried out with the support of University West, Trollhättan, Sweden, using their UniqueCoat M3™ HVAF system. Using four different application conditions gave variations of hotter and colder spray conditions. The four parameter sets were designated N1, N2, N3, and N4 — Fig. 2. (The details of the parameter sets are not given here as the focus of this article is on the observations in behaviors and properties between the different powder types.)

During spraying, the deposit rate in terms of thickness per pass was monitored. The powder P3 (Amperit 658.067) was observed to be more consistent and in most cases gave a higher DE across the various spray conditions evaluated, except for the N1 spray condition — Fig. 2.

Table 1 — Description of WC-Co-Cr Powders

Code	Composition (wt-%)	Particle Nominal Size	Type	Trade Name
P1	WC10Co4Cr	20/5	Agglomerated & Sintered (A&S)	Amperit® 558.052
P2	WC10Co4Cr	15/5	Sintered & Crushed (S&C)	Amperit® 554.067
P3	WC10Co4Cr	15/5	New	Amperit® 658.067

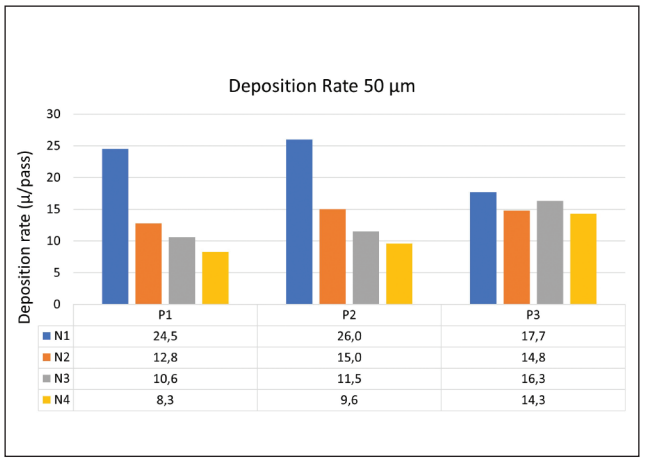


Fig. 2 — Deposit rate by spray condition and powder.

The fine PSD used in the HVAF process led to a very smooth as-sprayed coating surface. The measured values for the average surface roughness (Ra) are shown in Table 2 and range from 1.56 to 2.4 µm. The three powders showed minor differences, while the spray condition had a significant influence.

Metallographic examinations of the samples were also carried out. In all cases, dense coatings were achieved as desired. Typical structures for each are shown in Fig. 3.

The as-sprayed samples were evaluated by microhardness using a Struers Duramin-40 tester with ten indentations at a normal load of 2.94 N (300 gf) and a dwell of 10 seconds — Fig. 4.

The results showed that the hardness achieved per spray condition for the three different powders was similar — Fig. 4. The N1 spray condition showed lower hardness and considerable variation. N2 to N4 conditions gave a hardness of 1300–1500 $HV_{0.3}$.

Table 2 — As-Sprayed Surface Roughness Results (µm)

Parameter	P1	P2	P3
N1	2.19	2.13	2.30
N2	1.81	1.76	1.63
N3	2.03	1.56	1.57
N4	1.74	1.89	1.74

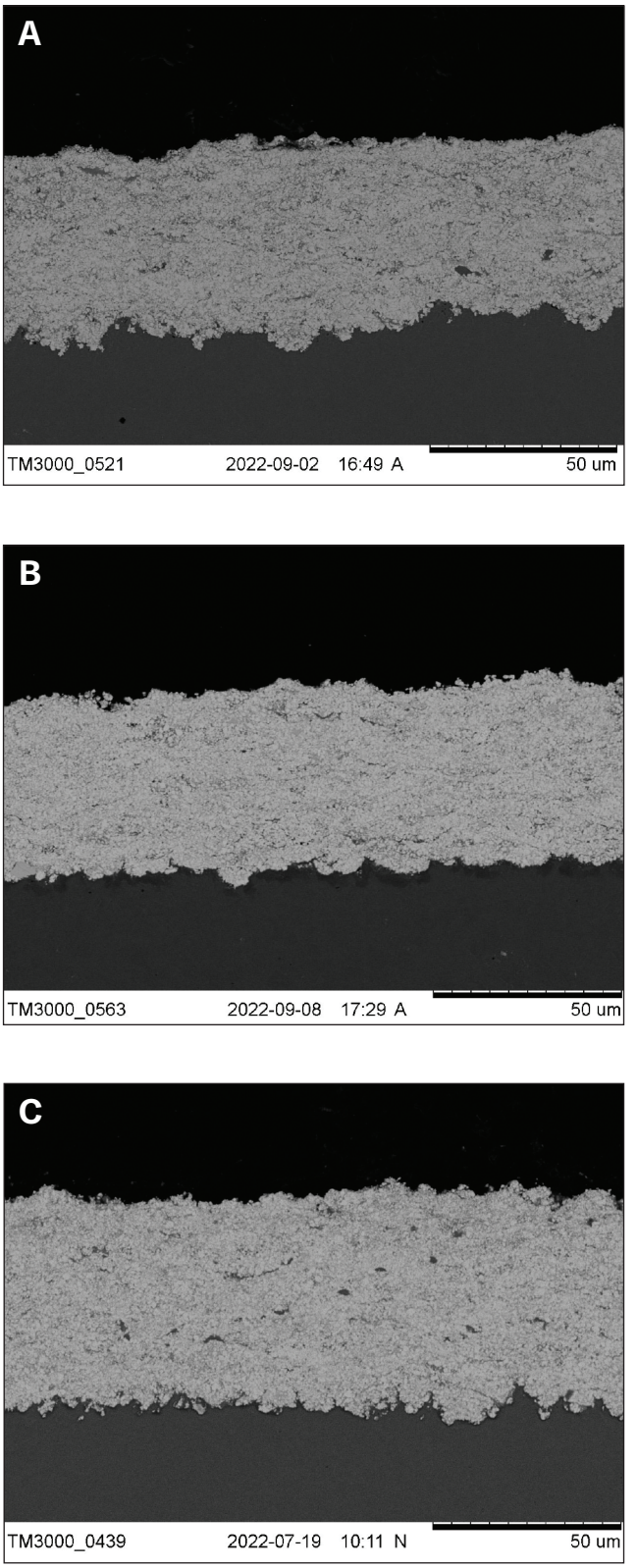


Fig. 3 — Micrographs of P1 (A), P2 (B), and P3 (C) applied with the N3 spray condition.

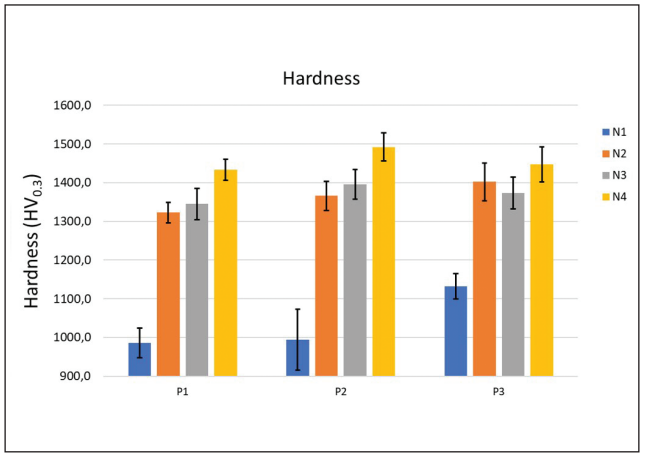


Fig. 4 — Hardness by spray condition and powder.

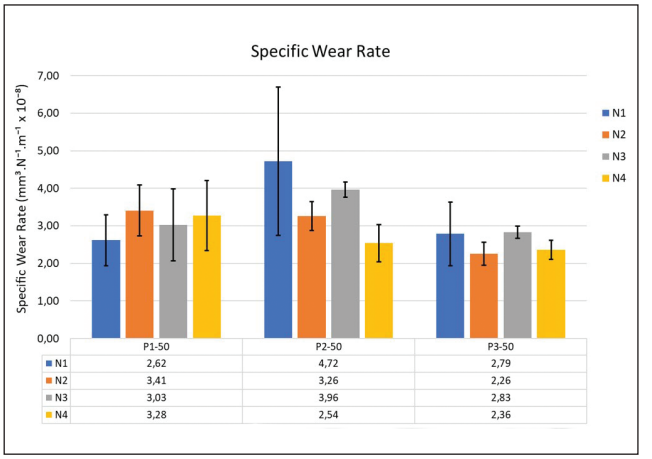


Fig. 5 — Wear rate by spray condition and powder.

Sliding wear was evaluated using a ball-on-disc test on a tribometer Anton Paar TRB³. The linear speed was 20 cm/s, at a 20 N, and a traverse length of 5000 m.

The sliding wear of all samples was low, and results were comparable within the variability of measurement results across all powders and spray conditions — Fig. 5.

Conclusion

The work carried out with these three WC10Co4Cr powders showed that for the key properties of as-sprayed roughness, hardness, and wear, the parameters had more influence on the results observed than the powder feedstock. Results across these powders were similar. The new Amperit® 658.067 produced from the new manufacturing route gave improved DE and an equivalent performance to existing HVAF powders but with higher-volume capability.

The Höganäs 600 series of powders are the designation assigned for sustainable powder solutions. These powders are designated as such because they remove key elements, such as cobalt and nickel. They also actively reduce the use of material required for a given application. The new method of manufacture allows for larger volumes of fine PSD powders to be achieved and is also applicable to compositions other than just WC-Co-Cr. This higher-volume production process enables wider use of flash carbides and thin HVAF coatings, which increases the sustainability for such applications as more can be done with less.

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David Sansom (*david.sansom@hoganas.com*) is vice president of technology, North American Höganäs Co., USA; Alexander Barth (*alexander.barth@hoganas.com*) is director technology EMEA, Höganäs GmbH, Germany; and Arashk Memarpour (*arashk.memarpour@hoganas.com*) is vice president of product development, Höganäs AB, Sweden.

Plasma Nozzle Provides Homogeneous Surface Coating

The RD2005PAD rotary nozzle uses nanocoatings to create specifically functionalized surfaces that are tailor-made to meet customer requirements with regard to planar materials. The spectrum ranges from superhydrophobic, adhesion-promoting to superhydrophilic coatings. It's the company's first rotary nozzle with a precursor feed. The nozzle rotates around a rotation axis, making it suitable for coating flat materials. It also offers homogeneous treatment with high intensity in the PlasmaPlus process. This produces a reliable functional layer that enables optimum bonding, printing, or painting of the coated surface.

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Report Offers Business Outlook, Insights, and Growth Strategies within the Thermal Spray Market

Thermal Spray Market 2023: Demand and Opportunities posits the global market is projected to rise by $3.7 billion, and it is aniticpated to expand at a compound annual growth rate of 4.6% during the stated forecast period. The 87-page report provides comprehensive information on the thermal spray market. It also includes in-depth information about market drivers, opportunities, industry restraints and growth with challenges, and cumulative growth analysis. Moreover, the report also provides an in-depth analysis of research and information collected from various sources that have the ability to help the decision makers in the global market. The report presents and showcases a dynamic vision of the global scenario in terms of market size, market statistics, and competitive situation. With a 360-deg analysis of industry, it assists readers with understanding the market and implementing business expansion strategies. This report determines the market value and the growth rate based on the key market dynamics as well as the growth-improving factors.

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Report Discloses Lucrative Revenue Prospects

Thermal Spray Coatings Market Analysis by Product (Ceramics, Intermetallic, Polymers, Carbides, Abradables), by Technology (Plasma Spray, Flame Spray, HVOF, Electric Arc Spray), by Application, by Region — Global Insights 2022 to 2032 predicts the thermal spray coatings market will reach $15 billion by 2032, growing at a compound annual growth rate (CAGR) of 6.6% between 2022 and 2032. Applications across key industries, such as aerospace and industrial manufacturing, are expected to propel market demand in the coming years. During the 2015–2021 period, sales of thermal spray coatings flourished at a 6% value CAGR, with the market closing in at a valuation of $7.1 billion. The COVID-19 pandemic had a negative impact on the market, attributed to the imposition of lockdowns. However, since 2022, prospects have exhibited a gradual incline. Additionally, because of the growing environmental issues caused by coal-fired power plants, the global focus on decarbonization is increasing. This has prompted many companies to work on developing power generation systems to achieve carbon-free power generation. This will significantly broaden adoption of thermal spray coatings.

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Richie Gimmel | *richie@atlasmachine.com*
(502) 584-7262 | *atlasmachine.com*

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(323) 232-2371 | *benderccp.com*

Byron Products
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Keith King | *kking@byronproducts.com*
(513) 870-9111 | *byronproducts.com*

Cincinnati Thermal Spray Inc.
Cincinnati, OH
Kirk Fick | *kfick@cts-inc.net*
(513) 699-3992 | *cts-inc.net*

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Peter Ruggiero | *peter.ruggiero@cwst.com*
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Jeff Fenner | *jfenner@fusionhouston.com*
(713) 691-6547 | *fusionhouston.com*

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Dan Hayden
daniel.hayden@haydencorp.com
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Matt Watson | *mwatson@hfwindustries.com*
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Triratna Shrestha | *tshrestha@metcut.com*
(513) 271-5100 | *metcut.com*

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Pat Pelzer | *patp@nationcoating.com*
(937) 746-7632 | *nationcoatingsystems.com*

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Indianapolis, IN
Michael Brennan
michael_brennan@praxair.com
(317) 240-2500
praxairsurfacetechnologies.com

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Daniel Allford | *dan@arcspecialties.com*
(713) 631-7575 | *arcspecialties.com*

Ardleigh Minerals Inc.
Beachwood, OH
Ernie Petrey | *epetrey@ardleigh.net*
(216) 464-2300 | *ardleigh.net*

Carpenter Powder Products
Pittsburgh, PA
Jason Simmons | *jsimmons@cartech.com*
(412) 257-5102 | *carpentertechnology.com*

CenterLine (Windsor) Ltd.
Windsor, ON, Canada
Julio Villafuerte
julio.villafuerte@cntrline.com
(519) 734-8464 | *supersonicspray.com*

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Narragansett, RI
Rebecca Auger
rebecca.auger@rogerscorp.com
(401) 789-9736 | *rogerscorp.com*

Donaldson Torit
Minneapolis, MN
Paul Richard | *paul.richard@donaldson.com*
(603) 343-2448 | *donaldsontorit.com*

Global Tungsten and Powders Corp.
Towanda, PA
Laura Morelli
laura.morelli@globaltungsten.com
(570) 268-5182 | *globaltungsten.com*

Haynes International
Mountain Home, NC
Brandon Furr | *bfurr@haynesintl.com*
(713) 937-7597 | *haynesintl.com*

IKH USA-Inc.
Wellford, SC
Richard Bajan | *richard.bajan@ikh-usa.com*
(864) 431-4134 | *ikh-usa.com*

Imerys Fused Minerals
Greeneville, TN
Mitch Krieg | *mitch.krieg@imerys.com*
imerys.com

Imperial Systems
Mercer, PA
Tomm Frungillo
tfrungillo@isystemsweb.com
(724) 662-2801 | *imperialsystemsinc.com*

Lincoln Electric
Cleveland, OH
Thomas Brown
thomas_brown@lincolnelectric.com
(216) 383-2951 | *lincolnelectric.com*

Lineage Metallurgical
Baytown, TX
Landon Hendricks | *lhendricks@lineagemet.com*
(281) 731-7358

Metallisation Ltd. Dudley
West Midlands, United Kingdom
Stuart Milton | *sales@metallisation.com*
+44 1384 252464 | *metallisation.com*

Metallizing Equipment Co. Pvt. Ltd.
Jodhpur, India
Ankur Modi | *ankur@mecpl.com*
+91 0291 2747601 | *mecpl.com*

Midwest Thermal Spray
Farmington Hills, MI
Alex Pocket | *ap@midwestthermal.com*
(248) 442-6540 | *midwestthermal.com*

North American Höganäs
Hollsopple, PA
Andy Hoffman | *andy.hoffman@nah.com*
(814) 361-6875 | *hoganas.com*

Oerlikon Metco (US) Inc.
Westbury, NY
Karen Sender | *karen.sender@oerlikon.com*
(516) 334-1300 | *oerlikon.com/metco*

Polymet Corp.
West Chester, OH
Bob Unger | *runger@polymet.us*
(513) 874-3586 | *polymet.us*

Praxair Surface Technologies
Concord, NH
Richard Thorpe | *richard_thorpe@praxair.com*
(603) 224-9585
praxairsurfacetechnologies.com

Rockwell Carbide Powders
Ontario, Canada
Frank Shao | *sales@rockwellpowders.ca*
(905) 470-8885 | *rockwellpowders.ca*

Saint-Gobain Ceramic Materials
Worcester, MA
Shari Fowler-Hutchinson
shari.fowler-hutchinson@saint-gobain.com
(508) 795-2351
coatingsolutions.saint-gobain.com

TechMet Alloys LLC
Sealy, TX
James Ryan | *j.ryan@techmet-alloys.com*
(979) 885-7180 | *techmet-alloys.com*

Thermach LLC
Appleton, WI
Tim Vanden Heuvel
timvandenheuvel@thermach.com
(920) 779-4299 | *thermach.com*

Thermion
Silverdale, WA
Dean Hooks | *dhooks@thermioninc.com*
(360) 692-6469 | *thermioninc.com*

ASSOCIATE MEMBER ORGANIZATIONS

Advanced Materials and
Technology Services Inc.
Simi Valley, CA
Robert Gansert | *rgansert@adv-mts.com*
(805) 433-5251

Airglide
Fort Lauderdale, FL
John Dixon | *jdixon@airglide.expert*
(954) 249-0127 | *airglide.expert*

David Lee Consulting
Ligonier, IN
David Lee | *dlee@daltsc.com*
(574) 849-3636

Florida Institute of Technology
Melbourne, FL
Frank Accornero | *faccornero@fit.edu*
(386) 506-6900 | *fit.edu*

Florida International University
Department of Mechanical and Materials Engineering
Miami, FL
Arvind Agarwal | *agarwala@fiu.edu*
(305) 348-1701 | *mme.fiu.edu*

Mason Global Management LLC
Killingworth, CT
Richard P. Mason
rmason@masonglobalmanagementllc.com
(724) 554-9439
masonglobalmanagementllc.com

The Mozolic Group
Londonderry, NH
Jean Mozolic | *jean.mozolic@comcast.net*
(508) 254-4375

State University of New York at Stony Brook
Stony Brook, NY
Sanjay Sampath
ssampath@ms.cc.sunysb.edu
(631) 632-8480 | *ctsr-sunysb.org*

Stronghold Coating Systems
Franklin, OH
Larry Grimenstein | *strongholdone@cs.com*
(937) 704-4020 | *strongholdone.com*

SUPPORTING MEMBER SOCIETIES

DVS, The German Welding Society
Jens Jerzembeck
jens.jerzembeck@dvs-hg.de
dvs-home.de/en

GTS E.V., The Association of Thermal Sprayers
Werner Kroemmer
werner.kroemmer@gts-ev.de
+49 89 31001 5203 | *gts-ev.de*

Institute of Materials Malaysia (IMM)
Johar Juhari
johar_juhari@petronas.com.my
(603) 5882-3584 | *iomm.org.my*

Japan Thermal Spray Society (JTSS)
Nick Yumiba | *jtss@mb8.seikyou.ne.jp*
+81 6 6722 0096 | *jtss.or.jp*

Metal Powder Industries Federation (MPIF)
James R. Dale | *jdale@mpif.org*
(609) 452-7700 | *mpif.org*

Surface Engineering for Advanced Materials (SEAM)
Christopher Berndt | *cberndt@swin.edu.au*
61(0)4 28 237 638 | *arcseam.com.au*

Thermal Spraying Committee of China Surface Engineering Association (TSCC)
Huang Xiao | *xiaoou@chinathermalspray.org*
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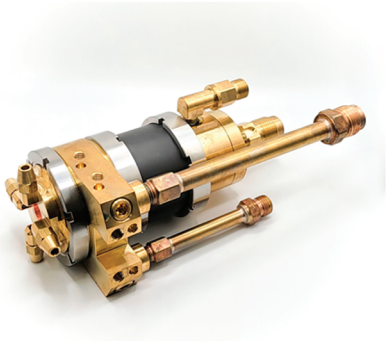

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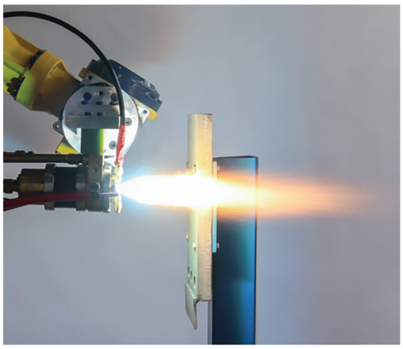

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