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JTST Highlights
Society News

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About the cover
Twin wire electric arc processing to rebuild worn bearing and seal surfaces on high speed rotating component with pre- and post-machining concentric to critical datum points. Courtesy of ASB Industries; www.asbindustries.com.

Editorial Opportunities for iTSSe in 2012
The editorial focus for iTSSe in 2012 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.

August  Process Industries/Metals Industries

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.
ITSC 2012 –
Big opportunities abound in Houston

ITSC 2012: Air, Land, Water, and the Human Body: Thermal Spray Science and Applications, May 21-24, is being held at the Hilton Americas Houston Convention Center in Texas. If early numbers are any indication, it will be big in Houston! There is a record number of early bird registrations with nearly 400 already registered. Attendees represent 27 countries, and the show floor is almost sold out with 80 exhibitors.

ITSC organizers arranged a dynamic, topical, and wide-ranging event for the thermal spray community. Whether you are an industry expert, an experienced engineer or scientist, or new to the thermal spray field, you will benefit from the 2012 technical program that features the latest in advanced technology, research, and development. With focused symposia, all attendees will learn the latest research and development in their specific field while gaining a global perspective from leading scientists and engineers from around the world.

There are two keynote presentations this year. The first is on May 21 where Brian J. Fitzgerald presents Controlling Maintenance Costs by the Use of Thermal Spray in the Petrochemical Industry. This proves to be timely with the event location and fuel costs worldwide. And, on Wednesday morning, May 23, Mitchell Dorfman, FASM, Sulzer Metco Fellow, presents Global Opportunities and Challenges in the Thermal Spray Industry.

The surface engineering symposium includes invited semi-tutorials that cover the current state of various classes of surface treatments (physical vapor deposition, chemical vapor deposition, electroplating, thermal spray, etc.). Contributed papers present current research and development and applications, particularly those comparing or combining two or more classes of surface treatments. There will also be an interactive Q&A panel discussion.

There are three International Market Talks on Wednesday, May 23. The first, by Bryan Allcock focuses on Technology and Industrial Application Transfers in International Markets. The second, by Alfredo Valarezo focuses on Latin America – An Emerging and Growing Market for Thermal Spray. The final market talk is by Subramanian Rangaswamy and focuses on Thermal Spray in India – Opportunities and Trends.

There is also career board on the expo floor as well as six educational course offerings with noted experts. The Conference and Exposition located in the Hilton Americas Hotel will be a comfortable setting for you to meet, network and learn from others. When added together, we believe this international gathering will meet or exceed your expectations. We look forward to seeing you in Houston and a Banquet on Tuesday evening not to be missed!

Charles M. Kay, president
Thermal Spray Society

Li joins JTST editorial team

Dr. Chang-Jiu Li, professor, School of Materials Science and Engineering, Xi’an Jiaotong University, China joined the Journal of Thermal Spray Technology (JTST) editorial team as associate editor, announced Dr. Christian Moreau, editor-in-chief of JTST, and Dr. Robert C. Tucker, Jr., chair of the JTST Editorial Committee. Li has been an invited guest editor of special issues of Journal of Thermal Spray Technology for the International Thermal Spray Conference annually from 2007 through 2012, as well as the 4th Asian Thermal Spray Conference.

Li leads the thermal spray group at State Key Laboratory for Mechanical Behavior of Materials. His research interests are coating formation mechanisms such as splat formation and lamellar interface bonding, coating microstructure development and control of wear resistant coatings for high performance coating applications, thermal barrier coatings, and different functional coating applications including fabrication of solid oxide fuel cells by thermal spray and assembly of dye-sensitized solar cells by thermal spray. Li joins Dr. Seiji Kuroda and Prof. Armelle Vardelle, who have been JTST associate editors since 2005, and Dr. Kendall Hollis, who has been as associate editor since 2007, as well as Dr. Basil Marple, JTST Lead Editor.
Dr. Wilson Wong, a former student at McGill University, Quebec, Canada, was proclaimed the winner of the 2011 Sulzer Metco Young Professionals Award (SMYPA) for his work, “Understanding the Effects of Process Parameters on the Properties of Cold Gas Dynamic Sprayed Pure Titanium Coatings” at ITSC 2011. The SMYPA was held for the first time in 2011 at the International Thermal Spray Conference (ITSC) in Hamburg, Germany. Engendered by Dr.-Ing Kirsten Bobzin of the University of Aachen, it is funded by Sulzer Metco and supported and organized by the German Welding Society (DVS). It aims to globally recognize students, doctoral candidates, and scientists, and to encourage new talent to engage in the advancements of surface engineering. The inaugural winner, Dr. Wong, impressed the experts with his presentation.

**Thermal Spray Hall of Fame Inductions**

Two leaders and innovators who have shaped the past, present, and future of thermal spray technology will be inducted into the Thermal Spray Hall of Fame in May 2012 during the ITSC Plenary Session in Houston. The 2012 inductees are:

Frank J. Hermanek, FASM — For substantial contributions in thermal spray coatings, materials, and technology developments, and for acting as a mentor and teacher to new upcoming members to the thermal spray industry. Hermanek is a consultant and owner of FJH and Associates, Lawrenceburg, Ind. He has a long career in thermal spray and surface engineering, authoring many papers and receiving four patents. He was deeply involved in the development of the ASM Thermal Spray Div., and the development of the TSS Hall of Fame, and created the International Thermal Spray Association. He had a key role in creating the original thermal spray handbook. He served on various TSS Committees, and received the TSS President’s Award (1990 and 2000), and was named ASM Fellow in 2006. He is an ASM Life Member.

Elliott Sampson — For significant contributions to the development of twin wire-arc spray technology and for providing leadership in promoting thermal spray technology to aerospace markets and in thermal spray education. Sampson (deceased) received his B.S. in forestry from University of Maine, and did graduate studies in metallurgy at New Haven College and University of Connecticut, and received his M.A. degree in business management from New Hampshire College. He was a lifelong contributor to the development and growth of thermal spray technology, and was instrumental in developing and marketing twin wire-arc spray technology.
applications throughout the world including coatings for aircraft engines. He was a leader in mentoring and teaching within thermal spray industry. He authored and coauthored many papers on thermal spray technology. He was a member of ASM and the Thermal Spray Society for 23 years, served on several ASM/TSS committees, as well as the AWS C2 Committee. Sampson received the ASM President’s Award in 2001.

**CTSO program update available**

Certified Thermal Spray Operator (CTSO) designations are being awarded to successful candidates who pass the general written exam on thermal spray fundamentals as well as a process written and practical exams.

For more information on the Certified Thermal Spray Operator program, please visit http://tss.asminternational.org/portal/site/tss/Certification/, email: certification@asminternational.org, or call 440/338-5151, ext. 5694.

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**Thermal Spray Technologies course**

The Thermal Spray Technologies course is taking place June 21-22, 2012 in Charlotte, N.C., USA., at ASM’s AeroMat Conference and Exposition.

The course is taught by Christopher Berndt, PhD, FASM, HoF, and president of ASM International. Thermal spray technology and coatings solve critical problems in demanding environments. They provide “solutions” to engineering needs 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.

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**ITSC 2013: Call for papers**

ITSC 2013: Innovative Coating Solutions for the Global Economy is the world’s foremost conference and exposition for thermal spray technologists, researchers, manufacturers, and suppliers.

ITSC 2013 is being held on May 13-15, at the Busan Exhibition and Convention Center in Busan, Republic of Korea. Mark your calendars, finish your research, and submit your abstract.

Abstract submission deadline is July 31, 2012.

To submit your abstract, visit www.asminternational.org/itsc.

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Effect of Higher Water Vapor Content on TBC Performance

Bruce A. Pint*  
J. Allen Haynes  
Oak Ridge National Laboratory  
Oak Ridge, Tenn.

Coal gasification, or IGCC (integrated gasification combined cycle), is one pathway toward cleaner use of coal for power generation with lower emissions. However, when coal-derived synthesis gas (i.e., syngas) is burned in turbines designed for natural gas, turbine manufacturers recommend “derating,” or lowering the maximum temperature, which lowers the efficiency of the turbine, making electricity from IGCC more expensive.

One possible reason for the derating is the higher water vapor contents in the exhaust gas[1]. Water vapor has a detrimental effect on many oxidation-resistant high-temperature materials[2].

In a turbine hot section, Ni-base superalloys are coated with a thermal barrier coating (TBC) allowing the gas temperature to be higher than the superalloy solidus temperature. TBCs have a low thermal conductivity ceramic top coating (typically Y2O3-stabilized ZrO2, or YSZ) and an oxidation-resistant metallic bond coating. For land-based gas turbines, the industry standard is air plasma sprayed (APS) YSZ and high velocity oxygen fuel (HVOF) sprayed NiCoCrAlY bond coatings.

To investigate the role of higher water vapor content on TBC performance and possible mitigation strategies, furnace cycling experiments were conducted in dry O2 and air with 10% (typical with natural gas or jet fuel) or 50 vol% water vapor[3]. Cycle frequency and temperature were accelerated to one hour at 1100°C (with 10 minute cooling to ~30°C between each thermal cycle) to induce early failures in coatings that are expected to operate for several years with a metal temperature of ~900°C. Coupons (16 mm diameter × 2 mm thick) of commercial second-generation single crystal superalloy CMSX4 were HVOF coated on both sides with ~125 µm of Ni-22wt%Co-17Cr-12Al either with 0.7Y or 0.7Y-0.3Hf-0.4Si. One side was then coated with 190-240 µm of APS YSZ. Coatings were cycled until the YSZ top coating spalled (Fig. 1).

Figure 2 shows the results of the initial phase of experiments. Compared to dry O2, the addition of 10% water vapor decreased the lifetime of MCrAIY by ~30% for the conventional CMSX4 substrates. Higher average lifetimes were observed with Hf in the bond coating, but a similar decrease in lifetime was observed when water vapor was added.

The addition of Y and La to the superalloy substrate did not change the YSZ lifetime with 10% water vapor. However, increasing water vapor content from 10 to 50% did not further decrease the lifetime of either bond coating with the doped superalloy substrate. Thus, these results suggest that higher water vapor contents cannot explain the derating of syngas-fired turbines, and other factors such as sulfur and ash from imperfect syngas cleanup (or upset conditions) need to be explored.

Researchers continue to study effects of water vapor on thermally grown alumina scale (Fig. 1) adhesion and growth rate, and are looking for bond coating compositions more resistant to oxidation in the presence of water vapor.

Acknowledgement: This research was sponsored by the U.S. Department of Energy, Office of Coal and Power R&D, Office of Fossil Energy, (R. Dennis program manager). Coatings were fabricated at Stonybrook University and superalloys supplied by K. Murphy at Howmet.

References
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COATING SOLUTIONS
Energy efficiency of gas turbines is paramount because of fuel costs: the highest operating cost for airlines and a significant cost to the power generation industry. For nearly 30 years, efficiency gains drove most technical innovation within gas turbine engines. Today’s newest generation of turbine engines are helping both the airlines and power generation operators more effectively control fuel costs associated with power system operation and, additional new developments are underway to continue driving up efficiencies of new turbines.

One key technology that can contribute to greater overall fuel efficiency in gas turbines is the use of sophisticated protective barrier coatings on engine components, particularly the clearance-control coatings used on high-pressure turbine blades. Gas bypass between the rotating turbine blade tip and the engine casing affects both the efficiency and power output of an engine. An increase in this clearance of just 125 µm can result in an increase of 0.5% in specific fuel consumption.

Abradable coatings were designed to allow the turbine blade abrasive tip to cut a path into the shroud abradable coating to improve the seal between blade tip and casing. A holistic approach to improving the abradable system (abradable coating and blade tip) is necessary.

Most blade tip systems currently in use were developed in 1990s and are still widely used. Current blade tips are limited, as the matrix oxidizes at high temperature losing its ability to hold, as well as protect, CBN (cubic boron nitride) particles. CBN particles also oxidize at elevated temperatures and have limited service life. Improvement in blade tips, both in cutting particles and the matrix that holds them, will therefore improve abradable system performance and allow the use of denser, more erosion-resistant abradable materials.

Blade tip coating system

The blade tip currently in use has four essential components (Fig. 1) and typically a microstructure such as that shown in Fig. 2. The components are metallic undercoat, metallic matrix, CBN particles, and diffusion coatings.

The metallic undercoat is essentially a bond coat that provides oxidation resistance. As the matrix and CBN particles can rapidly degrade under frictional heat generated during abradable seal cutting, the metallic undercoat provides oxidation protection to the underlying base metal during engine life. CBN particles are held in a matrix material (usually an electroplated MCrAlYHf alloy), and a diffusion aluminate is applied to provide further matrix protection.

Chromalloy has been applying CBN-based electroplated blade tips for more than 15 years, and currently is developing ways to improve existing technology to make these coatings cut better and last longer in gas turbine engines.
The overall system is complex and, therefore, separate development projects are focusing on improvements to each aspect of the blade tip. These include undercoat and matrix compositions, new diffusion coating compositions, and new generation CBN particles for enhanced abrasion and longer life.

**Enhancements under consideration**

**Metallic undercoat:** The current metallic undercoat is CoNiCrAlY, which will be replaced by a hafnium- and silicon-bearing, or a rhenium-bearing NiCoCrAlY system. The newer coatings have better oxidation and creep resistance, and help minimize base alloy cracking and damage after CBN particles wear off.

**Metallic matrix:** The current NiCoCrAIHf matrix will be enhanced by adding hafnium, silicon, or rhenium, or some combinations thereof to improve the oxidation of the matrix. Improving oxidation of the matrix is key, as an improved matrix will better protect CBN particles.

**CBN particles:** A progressive series of CBN particles were tested, including monocrystalline CBN to provide better angular cutting, and other enhanced CBN particles for improved thermal performance. CBN thermal performance is key to improving the blade tip, because a longer lasting CBN provides better incursion of the abradable coating and allows use of denser, more erosion-resistant abradable coatings that maintain their clearance over the engine’s operating life.

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**Fig. 2 — Typical CBN coating tip consisting of a low-pressure plasma spray metallic undercoat, CBN particles embedded in a metallic matrix, and diffusion aluminide overcoat. Magnification: 200×.**
Some novel systems containing stable oxide ceramics are also being developed, which will provide blade tip cutting ability well beyond the initial stage.

**Diffusion coating enhancements:** Due to the inherent nature of the CBN electroplating process, the aluminum content of the matrix is low. MCrAlY coatings depend on an adherent alumina scale to provide good oxidation protection. Therefore, a diffusion aluminide coating is applied to the matrix to provide an aluminum reservoir for extended oxidation protection. Further enhancements to the diffusion coating include applying platinum aluminide or double aluminide coatings, which provide even better protection than traditional aluminide coatings.

Table 1 gives a summary of system enhancements under consideration. All blade tip enhancements underway are available, and Chromalloy offers these coatings to airline customers and gas turbine manufacturers for engine installation. As the basic technology remains the same, and is already in use by several turbine operators in both aerospace and power generation, the enhancements being offered can be easily incorporated into existing customer coating blueprints and specification requirements. This will make introduction of the technologies into turbines faster, and will make greater fuel efficiencies more quickly accessible to airlines and other turbine operators.

For more information: Komal Laul is senior process engineer for the Corporate Coating and Process Technologies Group; 330 Blaisdell Rd., Orangeburg, NY 10962; tel: 845/359-4700; klaul@chromalloy.com; www.chromalloy.com.

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**TABLE 1 — SUMMARY OF THE ENHANCEMENTS BEING CONSIDERED**

<table>
<thead>
<tr>
<th>Undercoat</th>
<th>Matrix</th>
<th>CBN</th>
<th>Diffusion coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current technology</td>
<td>LPPS CoNiCrAlY</td>
<td>Electroplated NiCoCrAl</td>
<td>Polycrystalline</td>
</tr>
<tr>
<td>Enhanced CBN</td>
<td>LPPS NiCoCrAlY with Hf, Si, or Re additions</td>
<td>Electroplated NiCoCrAlY with Hf, Si, or Re additions</td>
<td>Monocrystalline angular</td>
</tr>
</tbody>
</table>
APPLICATION NOTE

Automated Zinc Spray Plant for LPG Cylinders

The use of liquefied petroleum gas (LPG) in cylinders always includes a list of safety instructions applied to equipment and accessories, because the gas is highly flammable. LPG cylinder manufacturing plants also have to meet quality standards. Cylinders are metal, so degradation from corrosion is a severe problem. Therefore, surface treatments such as paints, primers, and zinc spray coatings need to be applied. LPG cylinder and tank manufacturers are using zinc-spray systems that do not require inspection for 10-15 years, so quality concerns have decreased.

Research on LPG shows it can be used in many applications, and increased around the world drives the need to produce more gas, which, in turn, requires an increase in cylinder production. Quantitative quality has become a serious concern. Metallizing Equipment Co. Pvt. Ltd. (MECPL), Jodhpur, India, serves many LPG cylinder manufacturers with automated zinc-spray plants. MECPL’s process decreases problems associated with high production requirements and uneven manual coating.

MECPL recently manufactured a complete automatic zinc-spray plant (Fig. 1) for one of the largest cylinder manufacturers in India. The plant only needs human intervention for loading and unloading cylinders and for supervision. Quality is ensured with quantitative production. Cylinders are hung vertically on overhead conveyors which first go to blasting cabinets and then to spray coating booths.

Vertically hung revolving cylinders come to the airless blasting cabinet (Fig. 2) where surface cleanliness of SA 2.5 is achieved and reusable grit is recycled. Dust is sucked into
a dust collector. After blasting, cylinders reach the metallizing booth (zinc spray booth) where three arc spray guns are fitted on the vertical reciprocating system (Fig. 3). Three cylinders can be coated uniformly at one time by maintaining the speed of the up and down motion. Oversprayed zinc dust particles are sucked out of cabinet by an exhaust fan mounted on the cyclone dust collectors and disposed in an attached well. The complete process is controlled by a PLC system, so the following parameters can be adjusted per production requirements:

- Speed of overhead conveyor
- Rotational speed of cylinder on its own axis
- Up and down speed and stroke length of gun reciprocation
- Wire feeding speed to achieve required production

This project helps simplify the process for cylinder manufacturers by lowering production requirements and uneven manual coating operations. MECPL has been manufacturing thermal spray coating systems for more than 40 years.

For more information: Jaydev Choudhary; Metallizing Equipment Co. Pvt. Ltd.; E-101, M.I.A., Basni II phase, Jodhpur-342005; tel: 0291-2747601/02; fax: 0291-2746359; sales@mecpl.com; bdm@mecpl.com; www.mecpl.com.
The Journal of Thermal Spray Technology (JTST), the official journal of the ASM Thermal Spray Society, publishes contributions on all aspects – fundamental and practical – of thermal spray science, including processes, feedstock manufacture, testing, and characterization. As the primary vehicle for thermal spray information transfer, its mission is to synergize the rapidly advancing thermal spray industry and related industries by presenting research and development efforts leading to advancements in implementable engineering applications of the technology. Articles from the June issue, featuring papers based on presentation at ITSC 2011, as selected by JTST Lead Editor Basil Marple and Editor-in-Chief Christian Moreau, are highlighted here. In addition to the print publication, JTST is available online through www.springerlink.com. For more information, visit www.asminternational.org/tss.

“A Novel Plasma-sprayed Durable Thermal Barrier Coating with a Well-bonded YSZ Interlayer between Porous YSZ and Bond Coat” Chang-Jiu Li, Yong Li, Guan-Jun Yang, and Cheng-Xin Li

Failure of TBCs occurs by the spalling of YSZ coating. Crack propagation leading to the failure of plasma-sprayed TBCs usually occurs within the YSZ coating near the YSZ/bond coat interface. In this study, a novel durable TBC consisting of a YSZ interlayer of well-bonded lamellae between the bond coat and the conventional YSZ porous top coat was introduced. The YSZ interlayer was deposited at different coating surface temperatures, resulting in the formation of YSZ with significantly improved interlamellar bonding. Result shows that the thermal cyclic lifetime of the novel TBCs with the 20-30 μm thick YSZ interlayer increased by a factor of four compared with that of the conventional one. The effect of the YSZ interlayer thickness on the lifetime of TBCs was also investigated.

“Deposition of Composite LSCF-SDC and SSC-SDC Cathodes by Axial-Injection Plasma Spraying” Jeffrey Harris, Musab Qureshi, and Olivia Kesler

Performance of solid oxide fuel cell cathodes can be improved by increasing the number of electrochemical reaction sites, by controlling microstructures, or by using composite materials consisting of an ionic conductor and a mixed ionic and electronic conductor. LSCF (La0.6Sr0.4Co0.2Fe0.8O3−δ) and SSC (Sm0.5Sr0.5CoO3) cathodes were manufactured by axial-injection atmospheric plasma spray, and composite cathodes were fabricated by mixing SDC (Ce0.8Sm0.2O1.9) into the feedstock powders. Plasma power was varied by changing the proportion of nitrogen in the plasma gas. The microstructures of cathodes produced with different plasma powers were characterized by scanning electron microscopy and gas permeation measurements. The deposition efficiencies of these cathodes were calculated based on the mass of the sprayed cathode. Particle surface temperatures were measured in-flight to enhance understanding of the relationship between spray parameters, microstructure, and deposition efficiency.

“Comparison of the Microstructural Characteristics and Electrical Properties of Thermally Sprayed Al2O3 Coatings from Aqueous Suspensions and Feedstock Powders” Filofteia-Laura Toma, Lutz-Michael Berger, Stefan Scheitz, Stefan Langner, Conny Rödel, Annegret Potthoff, Viktar Sauchuk, and Mihails Kusnezoff

Presentation of microstructural characteristics and electrical insulating properties of thermal spray alumina coatings produced by suspension-HVOF (S-HVOF) and conventional HVOF spray processes. Electrical resistance at different relative air humidity (RH) levels (from 6 – 97% RH) and values of dielectric strength were investigated by direct current electrical resistance measurements, electrochemical impedance spectroscopy, and dielectric
breakdown tests. Relationships between electrical properties and coating characteristics are discussed. At low humidity levels (up to 40% RH) the electrical resistivities of S-HVOF and HVOF coatings were on the same order of magnitude (10^{11} \Omega \cdot m). At a very high humidity level (97% RH) the electrical resistivity values for the S-HVOF coatings were in the range 10^7-10^{11} \Omega \cdot m, up to five orders of magnitude higher than those recorded for the HVOF coating (orders of magnitude of 10^6 \Omega \cdot m). The better electrical resistance stability of the suspension-sprayed Al_2O_3 coatings can be explained by their specific microstructure and retention of a higher content of \alpha-Al_2O_3.

Influence of relative humidity on electrical resistivity of S-HVOF and HVOF sprayed coatings (S-HVOF coatings conditioned at different specific RH levels for 48- and 86-h and HVOF coating conditioned for 48-h).
WC-Co/aluminum multilayer coatings developed using warm spray deposition to improve fracture toughness and damage tolerance of conventional WC-Co coatings and to investigate effects of ductile layer addition on their fracture properties. Prior to depositing multilayer coatings, the mechanical properties of three metal coatings of aluminum, copper, and titanium, which were deposited by warm spray, were evaluated. The aluminum coating shows excellent ductility among them and was selected as ductile layers for multilayer coatings.

The fracture behavior of WC-Co/Al coatings was examined by the four-point bending test. Multilayer coatings did not break in a brittle manner after reaching maximum load, but exhibited a plateau as a result of the ductility of the aluminum layers. The fracture behavior was compared with the finite element analysis results, and they show good agreement in a general trend. Ductile metal reinforcements, by advanced thermal spray techniques such as warm spray deposition, are very effective to enhance the toughness and damage tolerance of sprayed cermet coatings.
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