In The News

New Literature

The Inspection of Coatings and Linings
A Handbook of Basic Practice for Inspectors, Owners, and Specifiers

Price: $125 (SSPC members: $112.50)

This book from SSPC describes the procedures, standards, techniques, and practices used for inspecting surface preparation, coating application, and associated work on industrial steel and concrete structures, as well as procedures for examining and testing newly applied protective coatings and linings. An ideal reference for inspectors, applicators, specifiers, suppliers, and other protective coatings specialists. Hardcover, more than 500 pages, more than 300 photographs and illustrations.

Contact: SSPC Publication Sales, P.O. Box 641256, Pittsburgh, PA 15264-1256 for prepaid orders by check; or SSPC Publication Sales, 40 24th St., 6th Fl., Pittsburgh, PA 15222-4643 for credit-card orders; tel: 412/281-2331; fax: 412/281-9992.

Track Advances in Technology Worldwide with Technical Insights
Intelligence Services
Advanced Coatings & Surface Technology

Twelve issues; $620; outside North America $685

This monthly intelligence service reports and puts into perspective significant developments in coatings and surface modification across a broad range of industry lines. Emphasis is on advanced coating techniques—lasers, vapor deposition, vacuum techniques—offering interdisciplinary analyses of those that have true commercial potential. "Take Note" offers a quick, yet highly detailed, rundown of critically important (and ready-to-use) advances in coatings and surface technology. The "Patent" section provides a rundown of key technologies you may have overlooked.

Contact: Technical Insights, 32 North Dean St., Englewood, NJ 07631-2807; tel: 201/568-4744; 800/245-6217; fax: 201/568-8247.

Handbook of Ternary Alloy Phase Diagrams Version 1.0

Edited by P. Villars, A. Prince, and H. Okamoto, ISBN: PC 0-87170-601-6; MAC 0-87170-602-4 (Available in PC and MAC).

- Available as seven subsets or as the full Handbook for utility and affordability
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- Powerful database searching for crystal structure, melting point, density, author, and more
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A crystallographic database of intermetallic compounds and ternary phases searchable by key descriptors:

- Compound formula
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- Pearson symbol
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- Unit cell dimension or angle
- Density
- Melting point

Contact: Denise Smith, APD Program, Customer Service Center, ASM International, Materials Park, OH 44073-0002; tel: 800/336-5152, ext. 5663 or 440/338-5151, ext. 5663; e-mail: dismith@po.asm-intl.org; www: http://www.asm-intl.org.

p-T-x Handbook Pressure Dependent Phase Diagrams of Binary Alloys

Edited by Y.V. Levinsky and G. Effenberg, Ed., ISBN: 0-87170-622-9. Order No. 57764G-CA; North America: $895 (ASM Member: $825); International: $960 (ASM Member: $890).

Content Highlights

- 12,000+ individual publications evaluated
- 1700+ pages of text, data, and diagrams
- 188 binary systems
- More than 1100 diagrams
- Eight-year update to the latest Russian edition
- Comprehensive 50+ page introduction to *p-T-x* diagrams
- Partial pressure of elements at various binary alloy compositions
- Thermodynamic stability equations
- High- and low-pressure phases identified, and structure defined
- Organized in alphabetical order
- Each system presented in a consistent format for easy location of specific information

The Importance of *p-T-x* Diagrams

High-pressure and high-vacuum processing of metals requires knowledge of the fundamental equilibria and phases present at varying pressures and temperatures.

One of the "last frontiers" of classical investigation, variable pressure processing can result in loss of chemical elements, formation of new, high- or low-pressure intermetallic compounds, chemical gradients, etc.—all of which can advance the discovery of new phenomena and new materials.

Used constructively to "engineer" a material, creative processing by varying temperature, pressure, and time can result in truly novel advanced materials.

For example, the discovery and development of processing to produce "porous aluminum" was a direct result of studying high-pressure equilibria in hydrogen-metal systems.

This "floating aluminum" would probably not have been discovered but for the work of scientists in the Ukraine investigating phase relationships at high pressure and high temperature.

Contact: APD Program, Attn.: Customer Service Center, ASM International, Materials Park, OH 44073-0002; tel: 440/338-5151, ext. 5900; fax: 440/338-4634; e-mail: cust-srv@po.asm-intl.org; www: http://www.asm-intl.org; Customer Service Center/APD Program.

Conference and Workshop Information

Modeling and Characteristics of Thermal Spray Processes Symposium

12 October 1998, Rosemont, IL

Program Organizer: R.C. Tucker, Jr., Praxair Surface Technologies, Indianapolis, IN

Program Description: This symposium will include a variety of papers covering some of the leading modeling of both the thermal spray processes and the formation of the coatings on the surface. There will be a focus on the application of the modeling to coating systems of commercial importance. In addition, the characteristics of both advanced "conventional" and new thermal spray processes will be presented. For example, these processes will include plasma processes, cold spraying, and microwave postcoating processing.

Contact: Customer Service Center, ASM International, Materials Park, OH; tel: 800/336-5152, ext. 5900, or 440/338-5151; fax: 440/338-4634; e-mail: cust-srv@po.asm-intl.org

Monday, 12 October

8:30-11:30 a.m.

Session Chair: *H. Herman,* State University of New York at Stony Brook, Stony Brook, NY

Real Time/On-Line Measurements of Moduli of Thermal Barrier Coatings: *C.C. Berndt,* A.A. Abbati, State University of New York at Stony Brook, Stony Brook, NY

Thermal Spray Processing of Functionally Gradient Coatings Using Single and Multiple Injectors: *J.F. Fincke,* W.D. Swank, D.C. Haggard, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID

Effect of Injector Geometry in a Plasma Sprayed Zirconia: *R.A. Neiser,* D. Beatty, Sandia National Laboratories, Albuquerque, NM

Advanced Process Diagnostics of Wire Arc Spraying: *N. Hussary,* J. Schein, J. Heberlein, University of Minnesota, Minneapolis, MN

Synthesis of Iron Nitride Using Induction Plasma Technology: *H. Herman,* State University of New York at Stony Brook, Stony Brook, NY; F. Gizhofer, University of Sherbrooke, Sherbrooke, Canada; D. Shin, R. Gambino, Hanyang University at Ansan, Kyunggi-Do Ansan, South Korea

Numerical Investigation of the Effects of Voltage Fluctuations on the Behavior of Plasma Sprayed Particles: *Y. Wan,* S. Sampath, J.R. Finck, State University of New York, Stony Brook, NY

Monday, 12 October

2:00-5:00 p.m.

Session Chair: *R.C. Tucker, Jr.,* Praxair Surface Technologies, Indianapolis, IN

A Combined Approach to Modeling Droplet Deformation and Solidification for Thermal Spray: *D.L. Hale,* INEEL, Idaho Falls, ID

Thermal Fracture of Thermal Barrier Coatings with Time-Dependent Behavior at High Temperature: *B.D. Choulos,* K. Kokini, Purdue University, West Lafayette, IN; T.A. Taylor, Praxair Surface Technologies, Inc., Indianapolis, IN

Optimization of Parameters and Characterization of Coatings by the EMC Plasma Spray Process: *S. Reddy,* H. Herman, State University of New York at Stony Brook, Stony Brook, NY; D.R. Marantz, K. Kowalsky, Flame-Spray Industries, Inc., Port Washington, NY

Reactive Sintering of Microwave Heated, Plasma Sprayed Coatings: *R.D. Seals,* M.S. Morrow, D.E. Schechter, Lockheed Martin Energy Systems, Oak Ridge, TN

Cold Gas Dynamic Spraying. What Is It?: *A.N. Papyrin,* The Pennsylvania State University, State College, PA

Interaction of High Speed Solid State Particles with a Substrate in the Cold Spraying Process: *A.N. Papyrin,* The Pennsylvania State University, State College, PA; A.P. Alkhimov, V.F. Kosarev, N.I. Nesterovich, Russian Academy of Science, Novosibirsk, Russia

Oxidant-Resistant and Thermal Barrier Coatings Symposium

12-14 October 1998, Rosemont, IL

Program Organizers: W.J. Brindley, NASA-Lewis Research Center, Cleveland, OH

J.A. Haynes, Oak Ridge National Laboratory, Oak Ridge, TN

Program Description: Presentations in the symposium relate to the multiple challenges presented by current and future high-temperature coatings requirements: increasingly severe engine environments, increased durability and reliability requirements, all while maintaining or reducing coating costs. These challenges require increased understanding on all fronts, from processing to characterization techniques to coatings failure. The Plenary Session addresses the need for coatings in gas turbines in the context of the overall materials systems. The remaining sessions include one session on oxidation-resistant coatings and four on the high payoff technology of thermal barrier coatings.

Contact: Customer Service Center, ASM International, Materials Park, OH;

tel: 800/336-5152, ext. 5900, or 440/338-5151; fax: 440/338-4634; e-mail: cust-srv@po.asm-intl.org

Monday, 12 October

8:30-11:30 a.m.

Sponsored by: Energy/Utilities Industrial Sector, Materials Science Critical Technologies Sector, Specialty Materials Critical Technologies Sector, and Aerospace and Defense Industrial Sector, and ASM Thermal Spray Society

Session Chairs: *P.W. Schilke,* General Electric Co., Schenectady, NY

D.J. Evans, U.S. Air Force Research Laboratory, Dayton, OH

Invited: Aero-Engines: Current Needs and Future Directions: *M.J. Blackburn,* Pratt and Whitney, East Hartford, CT

Invited: DoD and NASA Propulsion Materials Programs: *H.R. Gray,* NASA-Lewis Research Center, Cleveland, OH; D.J. Evans, Wright Patterson Air Force Base, Dayton, OH

Keynote: Directions and Challenges for Aircraft Engine Materials: *J.C. Williams,* General Electric Co., Cincinnati, OH

Keynote: The Role of the Coating and Superalloy System in Enabling Advanced Land-Based Combustion and Turbine Development: *J. Stringer,* Electric Power Research Institute (EPRI), Palo Alto, CA

Invited: Materials Challenges for Combustion Turbines in the 21st Century: *B.B. Seth,* Westinghouse Electric Corporation, Orlando, FL

Invited: Advanced Turbine Systems Program: *R. Harrison,* Materials Process Technology, Cincinnati, OH; M.A. Karnitz, Oak Ridge National Laboratory, Oak Ridge, TN

Monday, 12 October

2:00-5:00 p.m.

Session Chair: *S.J. Dapkunas,* National Institute of Standards and Technology, Gaithersburg, MD

Reliability of Laser Flash Thermal Diffusivity Measurements of the Thermal Barrier Coatings: *H. Wang,* R.B. Dinwiddie, Oak Ridge National Laboratory, Oak Ridge, TN

Elastic Modulus Evolution of Zirconia-Yttria Thermal Barrier Coatings under Laser High Heat Flux Conditions: *D. Zhu,* R.A. Miller, NASA-Lewis Research Center, Cleveland, OH

Microspectroscopy of Plasma Sprayed Thermal Barrier Coatings: *M.J. Lance,* J.A. Haynes, M.K. Ferber, Oak Ridge National Laboratory, Oak Ridge, TN; W.R. Cannon, Rutgers University, Piscataway, NJ

Deformation Mechanisms of Plasma Sprayed Partially Stabilized Zirconia Coatings: *U. Senturk,* C.C. Berndt, SUNY at Stony Brook, Stony Brook, NY

The Effect of Processing Parameters on the Properties of Zirconia Thermal Barrier Coatings Fabricated Using Small Particle Plasma Spray: *J.R. Mawdsley,* Y.J. Su, K.T. Faber, Northwestern University, Evanston, IL; D.E. Boss, MSL-Laminates and Composites, Elk Grove Village, IL

Microstructure and Thermal Conductivity of Thermal Barrier Coatings Processed by Plasma Spray and Physical Vapor Deposition Techniques: *R. Dutton,* L. Semiatin, Air Force Research Laboratory, Wright-Patterson AFB, OH; K.S. Ravichandran, K. An, University of Utah, Salt Lake City, UT

Tuesday, 13 October

8:30-11:30 a.m.

Session Chair: *J.A. Haynes,* Oak Ridge National Laboratory, Oak Ridge, TN

Very Long Term Cyclic Oxidation of RE108 and IN939 Coated with Oxidation-Resistant Coatings: *K.N. Lee,* Cleveland State University, Cleveland, OH; C.A. Barrett, J.W. Smith, NASA-Lewis Research Center, Cleveland, OH

Effect of Minor Impurities on the Oxidation Resistance of Alumina Forming Alloys: *J.G. Smeggil,* S. Bornstein, United Technologies Research Center, East Hartford, CT; W.P. Allen, Pratt & Whitney, East Hartford, CT

Effects of Sulfur Impurity and Pt Incorporation on the Scale Adhesion Behavior of Aluminide Coatings: *Y. Zhang,* University of Tennessee, Knoxville, TN; W.Y. Lee, Stevens Institute of Technology, Hoboken, NJ; J.A. Haynes, Oak Ridge National Laboratory, Oak Ridge, TN

Development of Plasma Spray $(Al,Ti)_3$ Ti Protective Coatings: *D.K. Dewald,* Waubik, Inc., Hancock, MI; D.E. Mikkola, Michigan Technological University, Houghton, MI; S. Sampath, State University of New York, Stony Brook, NY

The Influence of Interfacial Al_2O_3 Scale Thermocyclic Response and Mechanical Properties on Plasma Sprayed TBC Degradation: *J.A. Haynes,* M.K. Ferber, W.D. Porter, Oak Ridge National Laboratory, Oak Ridge, TN; E.D. Rigney, The University of Alabama at Birmingham, Birmingham, AL

Sulfur Effects on Cyclic Oxidation and TBC Life for Single Crystal Superalloys: *J.L. Smialek,* NASA-Lewis Research Center, Cleveland, OH

Tuesday, 13 October

2:00-5:00 p.m.

Session Chair: *W.J. Brindley,* NASA-Lewis Research Center, Cleveland, OH

J.L. Smialek, NASA-Lewis Research Center, Cleveland, OH

Mechanism of Spallation in Platinum Aluminide/Electron Beam Vapor Deposited Thermal Barrier Coatings: *M. Gell,* K. Vaidyanathan, B. Barber, J. Cheng, E. Jordan, University of Connecticut, Storrs, CT

Failure Mechanisms of Plasma Sprayed Zirconia Thermal Barrier Coatings: *J.P. Singh,* M. Sutaria, N. Vasanthamohan, Argonne National Laboratory, Argonne, IL

Oxidation Characteristics and Failure Mechanisms of EBPVD YSZ Thermal Barrier Coatings on Diffusion Aluminide Bond Coats: *M.S. Stiger,* G.H. Meier, F.S. Pettit, University of Pittsburgh, Pittsburgh, PA; J.L. Beuth, Carnegie Mellon University, Pittsburgh, PA

Characterization of the Mechanical Reliability of Thermal Barrier Coatings: *M.K. Ferber,* J.A. Haynes, Oak Ridge National Laboratory, Oak Ridge, TN; M.J. Lance, Rutgers University, Piscataway, NJ

Evaluation of TBC Systems on Novel Substrates: *B.A. Pint,* I.G. Wright, Oak Ridge National Laboratory, Oak Ridge, TN; W.J. Brindley, NASA-Lewis Research Center, Cleveland, OH

Segmentation Cracks in Plasma Sprayed Thick Thermal Barrier Coatings: *P. Bengtsson,* J. Wigren, Volvo Aero Corporation, Trollhättan, Sweden

Failure Mechanisms During Thermal Cycling of Thick Plasma Sprayed ZrO_2-Y_2O_3 TBC and the Effect of a Pre-Oxidized NiCrAlY Bond Coat:

M.J. Kooloos, J. M. Houben, Eindhoven University of Technology, Eindhoven, The Netherlands

Wednesday, 14 October

8:30-11:30 a.m.

Session Chair: *M.R. Dorfman,* Sulzer Metco, Inc., Westbury, NY

Statistical Design of Experiments of Al_2O_3/YSZ Multilayer Coatings Made by Small Particle Plasma Spray: *Y.J. Su,* J.R. Mawdsley, D. Boss, T. Bernecki, Northwestern University, Evanston, IL

Fabrication of Thermal Barrier Coatings by Electrochemical Methods: *K. Barmak,* S.W. Banovic, H.M. Chan, L.E. Friedersdorf, D.F. Susan, M.P. Harmer, A.R. Marder, Lehigh University, Bethlehem, PA

Oxidation of Silicate/YSZ Dual Layer TBCs: *Y. He,* K.N. Lee, S. Tewari, Cleveland State University, Cleveland, OH; R.A. Miller, NASA-Lewis Research Center, Cleveland, OH

Thick Ceramic and Metallic Thermal Spray Coatings for Use in Industrial Gas Turbine High Temperature Shroud Applications: *C.M. Rimlinger,* Z.Z. Mutasim, W.D. Brentnall, Solar Turbines Inc., San Diego, CA

Low Coefficient of Thermal Expansion Bond Coats for Thermal Barrier Coatings: *D.R. Arenas,* D.A. Koss, The Pennsylvania State University, University Park, PA; W.J. Brindley, NASA-Lewis Research Center, Cleveland, OH

Effect of Bond Coating Materials on Thermal Cyclic Life of the Plasma Sprayed Thermal Barrier Coating: *M.-S. Han,* D.-Y. Kim, Hyundai Heavy Industries Co. Ltd., Ulsan, South Korea

Wednesday, 14 October

2:00-5:00 p.m.

Session Chair: *D. Zhu,* NASA-Lewis Research Center, Cleveland, OH

Thermal Barrier Coating Stress Analysis—A Tool for Understanding Failure: *E. Jordan,* J. Cheng, B. Barber, K. Vaidyanathan, M. Gell, University of Connecticut, Storrs, CT

Effects of TBC and Bondcoat Inelastic Behavior (Creep and Plasticity) on Coating Stresses in the Presence of Discontinuities: *J.A. Morrison,* M. Arana, J.G. Goedjen, Westinghouse Power Generation, Orlando, FL

The Time Dependent Response of TBCs with Wavy Interfaces under Thermal Loading: *S.M. Arnold,* NASA-Lewis Research Center, Cleveland, OH; J. Aboudi, Tel-Aviv University, Ramat-Aviv, Israel; M.J. Pindera, University of Virginia, Charlottesville, VA

Residual Stress Generation During Thermal Cycling of TBCs: *A.M. Freborg,* B.L. Ferguson, G.J. Petrus, Deformation Control Technology, Inc., Cleveland, OH; W.J. Brindley, NASA-Lewis Research Center, Cleveland, OH

Thermal Spray Coatings: Structure, Properties, and Characterization Symposium

13-14 October 1998, Rosemont, IL

Program Organizer: A. Ashary, Praxair Surface Technologies, Indianapolis, IN

Program Description: Structure/property relationship and characterization of thermal spray coatings are essential for optimization and successful application of thermal spray coatings. The papers in this symposium discuss wear, corrosion, and mechanical properties of thermal spray coatings and the techniques for their characterization. Properties such as corrosion, sliding, and abrasive wear, strain to failure, and thermal conductivity are related to microstructural elements such as porosity, splat structure, and chemical composition and distribution of phases.

Contact: Customer Service Center, ASM International, Materials Park, OH; tel: 800/336-5152, ext. 5900, or 440/338-5151; fax: 440/338-4634; e-mail: cust-srv@po.asm-intl.org

Tuesday, 13 October

2:00-5:00 p.m.

Session Chairs: *M.F. Smith,* Sandia National Laboratories, Albuquerque, NM

R.A. Neiser, Sandia National Laboratories, Albuquerque, NM

Low Load Adhesive Wear Testing of TWAS and HVOF Sprayed Samples: *D.M. Scruggs,* G.A. Croopnick, ATI, Laguna Niguel, CA

Utilization of the Cold Gas Spray Coating Process for the Improvement of Sliding and Abrasive Wear Performance: *J. Galbraith,* A.E. Segall, A.N. Papyrin, J.C. Conway, Jr., D. Shapiro, M.F. Amateau, T. Eden, The Pennsylvania State University, State College, PA

Effect of the Addition of Solid Lubricants on the Sliding Wear Behavior of HVOF Processed WC-10Ni Cermet Coatings: *J. Voyer,* B.R. Marple, National Research Council Canada, Boucherville, Quebec, Canada

A Study on the Wear Characteristics of the Cr_3-C_2-NiCr-Mo Thermal Sprayed Coatings: *D.-Y. Kim,* M.-.S. Han, K.-K. Baek, Hyundai Heavy Industries Company Ltd., Ulsan, South Korea

Corrosion Behavior of High-Velocity Oxy-Fuel Thermally Sprayed Ti_3SiC_2 Coatings: *R. Knight,* J. Travaglini, M. Barsoum, Drexel University, Philadelphia, PA

Microstructure and Properties of HVOF Thermal Sprayed NiWCrBSi Coatings: *L. Gil,* UNEXPO, Puerto Ordaz, Venezuela; M.H. Staia, Central University of Venezuela, Caracas, Venezuela; A. Scagni, PLASMATEC Ingenieros, Caracas, Venezuela

Wednesday, 14 October

8:30-11:30 a.m.

Session Chairs: *B. Beardsley,* Caterpillar Inc., Peoria, IL

C. Moreau, National Research Council Canada, Boucherville, Quebec, Canada

Keynote: Structure Property Relationship in Thermal Spray Coatings: *C. Moreau,* National Research Council Canada, Boucherville, Quebec, Canada

The Mechanical Performance of DLC Films on Steel Substrates: *J.S. Wang,* Harvard University, Cambridge, MA

Development of Protruded Four-Point Bending Testing Method for Characterizing Interfacial Cracking of Thermal Barrier Coatings: *Z. Zhang,* T.E. Bloomer, J. Kameda, Iowa State University, Ames, IA; S. Sakurai, Hitachi Ltd., Hitachi, Japan

Mechanical Characterization of Thermal Sprayed Ceramic Coatings Using Recording Indentation Technique: *U. Senturk,* C.C. Berndt, SUNY at Stony Brook, Stony Brook, NY

Structural and Morphological Effects on the Properties of HVOF Sprayed Polymer Nanocomposite Coatings: *E. Petrovicova,* T.E. Twardowski, R. Knight, Drexel University, Philadelphia, PA; L.S. Schadler, Rensselaer Polytechnic Institute, Troy, NY

Wednesday, 14 October

2:00-5:00 p.m.

Session Chairs: *G. Blann,* Buehler Inc., Lake Bluff, IL

J.P. Sauer, Metcut Research Associates, Cincinnati, OH

TEM and the Art of Knowing What You are Looking At: *A.H. King,* T. Chraska, State University of New York, Stony Brook, NY

An Update on the Progress of the Recommended Practices Committee Concerning the Metallography Sub-Committee on Preparation of Thermal Spray Coatings: *J.P. Sauer,* Metcut Research Associates, Cincinnati, OH; T.A. Leonhardt, NYMA Inc., Cleveland, OH; A.R. Geary, Metallography Consulting Services, Meriden, CT

The Effect of Varied Metallographic Preparation Procedures on the Resultant Microstructure for Coatings Sprayed via the HVOF Process: *J.P. Sauer,* Metcut Research Associates, Cincinnati, OH; T.A. Leonhardt, NYMA, Inc., Cleveland, OH; A.R. Geary, Metallography Consulting Services, Meriden, CT

The Effects of Pressure Variation and Mounting Material Epoxy on the Microstructure of TBC Coatings: *J.P. Sauer,* Metcut Research Associates, Cincinnati, OH; T.A. Leonhardt, NYMA Inc., Cleveland, OH; A.R. Geary, Metallography Consulting Services, Meriden, CT

The Effect on Epoxy Mounting Material (Hot vs. Cold) on the Resultant Microstructure of Ductile Thermal Spray Coatings: *J.P. Sauer,* Metcut Research Associates, Cincinnati, OH; T.A. Leonhardt, NYMA Inc., Cleveland, OH; A.R. Geary, Metallography Consulting Services, Meriden, CT

Thermal Spray for the Automotive Industry: Processes, Coatings, and Applications Symposium

13 October 1998, Rosemont, IL

Program Organizer: R.C. McCune, Ford Motor Company, Dearborn, MI

Program Description: This session will focus on emerging applications of thermal spray technology in the automotive industry with emphasis on processes that enable such attributes as improved fuel economy, environmental friendliness, and complexity reduction.

Contact: Customer Service Center, ASM International, Materials Park, OH; tel: 800/336-5152, ext. 5900, or 440/338-5151; fax: 440/338-4634; e-mail: cust-srv@po.asm-intl.org

Tuesday, 13 October

8:30-11:30 a.m.

Session Chair: *R.C. McCune,* Ford Motor Company, Dearborn, MI

Thermal Spray Processing of Polymer Coatings: *J.A. Brogan,* Poly Therm Corporation, Stony Brook, NY

Freeform Fabrication of Valve Seat Inserts by Two-Wire-Arc Spray Technique: *O.O. Popoola,* L.V. Reatherford, R.C. McCune, Ford Motor Company, Dearborn, MI

Thermally Sprayed Multilayer Electrical Junction Blocks: *M.J. Zaluzec,* A. Joaquin, Ford Motor Company, Dearborn, MI; P.E. Pergande, D. Collins, Visteon-Automotive Products Operations, Melvindale, MI

The Use of Abradable Coatings for Turbocharger Clearance Control: *K.A. Harrison,* J. DeFalco, M. Dorfman, Sulzer Metco Ltd., Westbury, NY

The Use of Thermal Spray Coatings as a Replacement for Decorative Chrome Plate: *D.H. Harris,* APS-Materials Inc., Dayton, OH

Research on Thermal Spray Technology: Equipment, Consumables, and Processes Symposium

12-13 October 1998, Rosemont, IL

Program Organizer: P. Kammer, Kammer Associates, Charlotte, NC

Program Description: This symposium will provide attendees with information on the current status and future trends in thermal spray technology, via invited keynote speakers and reports on current research and development efforts and results in three key areas of thermal spray technology: high-velocity combustion spraying, arc spraying, and plasma spraying.

Contact: Customer Service Center, ASM International, Materials Park, OH; tel: 800/336-5152, ext. 5900, or 440/338-5151; fax: 440/338-4634; e-mail: cust-srv@po.asm-intl.org

Monday, 12 October

8:30-11:30 a.m.

Session Chairs: *R. Thorpe,* TAFA Inc., Concord, NH

H. Park, Engelhard Surface Technologies, East Windsor, CT

Keynote: HVOF Horizons: The Future of Technology: *A. Rotolico,* Engelhard Surface Technologies, East Windsor, CT

The High Velocity Air Fuel (HVAF) Process—An Economic Solution to High Velocity Combustion Spraying: *G.C. Irons,* Praxair Surface Technologies, Indianapolis, IN

Optimizing the HVAF Process: *J.A. Browning,* Draco Technologies, Hanover, NH

High Velocity Air-Fuel Coatings: A New Level of Quality: *A. Verstak,* V. Baranovski, Metalspray USA, Richmond, VA

The Development and Field Trials of a Mobile Liquid Withdrawal MAPP Gas Delivery System for HVOF Systems: *M. Cole,* BOC Gases Europe, London, U.K.

Monday, 12 October

2:00-5:00 p.m.

Session Chairs: *A. Kay,* ASB Industries, Inc., Barberton, OH

J. Ryan, AIM Inc., Loveland, OH

Keynote: Arc Spray—Accomplishments, Trends and Present Applications: *E.R. Sampson,* TAFA Inc., Concord, NH

Advanced Diagnostics for Wire Arc Spraying: *J. Schein,* N. Hussary, M. Kelkar, J. Heberlein, University of Minnesota, Minneapolis, MN

Structure/Property Analyses of a Novel Arc Spray System Coatings: *R. Unger,* V. Belaschenko, P. Sahoo, TAFA Inc., Concord, NH

The Effect of Inert Gas Atomization in Arc Spraying: *T. Lester,* Metallisation, Dudley, West Midlands, U.K.

Tuesday, 13 October

8:30-11:30 a.m.

Session Chair: *D. Crawmer,* Praxair Thermal Spray Products, Appleton, WI

Keynote: Plasma Spray Technology: *W.G. Wuest,* Sulzer Metco (U.S.) Inc., Westbury, NY

Vacuum Plasma Spray (VPS) Forming of Solar Thermal Propulsion

Components Using Refractory Metals: *F. Zimmerman III,* D. Hissam, H. Garrish, W. Davis, NASA Marshall Space Flight Center, Marshall Space Flight Center, AL

Low-Rate Vacuum Plasma Spraying Metals: *W.S. Crawford,* M. Cappelli, F. Prinz, Stanford University, Stanford, CA

Sealing of Thermal Spray Coatings: *J. Karthikeyan,* C. Aldridge, Heany Industries Inc., Scottsville, NY

Tool Post Grinding Thermal Spray Coatings: *M. Schroeder,* TAFA Inc., Concord, NH

1998 Powder Metallurgy World Congress and Exhibition

19-22 October 1998, Granada, Spain

Special Interest Seminars on Spray Processing (19 October)

Organizers/Co-Chairman: J.M. Guilemany (University of Barcelona, Spain) and Alan Lawley (Drexel University, USA)

Part 1: Thermal Spraying

New Routes to Produce Novel Powders in Thermal Processing, J. Kellie (London & Scandinavian Metallurgical Co., Ltd., UK)

State of the Art in Thermal Spraying, E. Lugscheider (Rhein-Westf. Technical University, Aachen, Germany)

Part 2: Spray Forming

Microstructural Evolution in Spray Forming, P. Grant (Oxford University, UK)

Industrialization of Spray Forming: Automotive, Electronic, Aerospace and Engineering Applications, A. Leatham (Osprey Metals Ltd., UK)

Part 3: Panel Discussion

Thermal Spraying: Process Control, Quality, Markets and New Developments, A.R. Nicoll (Sulzer Metco Holding AG, Switzerland)

Spray Forming: Process Fundamentals, Trends and Developments, P. Grant (Oxford University, UK)

Thermal Spraying and Spray Forming Technical Program (22 October)

Potential of the Phase-Doppler-Anemometry for the Analysis and the Control of the Spray Forming Process, Prof. Klaus Bauckhage, (Institut für Werkstofftechnik, Germany)

New Magnesium Wrought Alloys Made by Spray Forming, T. Ebert (Inst. für Werkstoffkunde und Werkstofftechnik, Germany) and K.U. Kainer (TU Clausthal, Germany)

Electromagnetic Control of Liquid Metal Jets for Spray Forming and Atomization: An Experimental Study, Dr. D.J. Short and P.A. Davidson (Univ. of Cambridge, UK), M.H. Jacobs, R.M. Ward, and A.L. Dowson (Univ. of Birmingham, UK)

Properties of Spray Formed High Speed Steels, Claus Spiegelhauer (Danish Steel Works Ltd., Denmark) and Holger Davin (SMI-Krebsöge, Germany)

Effects of Gas Atomization Parameters on the Spray Forming of Nickel Based Superalloys, Dr. Guoqing Zhang, Guofa Mi, Zhihui Zhang, Zhongwu Liu, and Shifan Tian (Beijing Institute of Aeronautical Materials, China)

Thermal Spraying and Spray Forming (Poster)

Characterization of the Spray Cone of a Free Fall Atomizer and Its Influence on the Spray Forming Process, Dr. Volker Uhlenwinkel (University of Bremen, Germany)

Heat Transfer Phenomena in Spray Formed Tubular Products, Dr. David Gethin and T.P. Sperring (U W Swansea, UK)

Microstructure and Properties of High Strength and High Conductivity Cu-Cr-Zr-Mg Alloy Prepared by Spray Forming, Dr. Jun Shen, C. Cui, Z. Lo, and Q. Li (Harbin Institute of Technology, China)

Development of Spray Forming in China, Prof. Qingchun Li, J. Shen, and C. Cui (Harbin Institute of Technology, China)

Effects of Spray Deposition on the Microstructures and Properties of Al-Li Alloys, Dr. Chengsong Cui, J. Shen, and C. Cui (Harbin Institute of Technology, China)

Numerical Simulation of Heat and Momentum Transfer in Spray Forming Process, Dr. Chengsong Cui, Z. Li, and Q. Li (Harbin Institute of Technology, China)

Novel High Strength and Heat Resistant Aluminum Alloy Produced by Spray Forming, Dr. Jun Shen, H. Fan, C. Cui, F. Cao, and S. Li (Harbin Institute of Technology, China)

Contact: PM98 Congress Secretariat, Viajes Iberia Congresos, Tetuan 24, 41001 Sevilla, Spain; tel: +34-95-4222-4095; fax: +34-95-421-0215; e-mail: congresos-sevilla@v-iberia.com.

Practical Interpretation of Microstructures

10-13 November 1998, Materials Park, OH

In this highly practical, hands-on course, participants will alternate between coverage of microstructures and time spent on actual microscopes. Participants will learn to recognize features in the microstructure that give information about the processing of the parts. Phase diagrams and time-temperature-transformation diagrams are mentioned, but not emphasized. Students are encouraged to bring prepared metallographic specimens for discussion. Students will learn:

- How to correlate microstructures to manufacturing and heat treat processes
- How microstructure changes are caused by manufacturing problems
- How to correlate microstructure to heat treatment and mechanical properties of carbon steels
- How to recognize defects caused by heat treatment and other processes
- How to classify manufacturing processes such as casting, forging, and welding
- Understanding which features are the true microstructure and which are preparation artifacts
- How to correlate microstructure and mechanical properties

Participants will apply what they have learned by examining, describing, and photographing samples

Course Outline

1. Review: Terminology Used in Describing Microstructures
2. How to use a Metallographic Microscope to the Fullest Extent
3. Microstructures of Carbon Steels, including Carburization
4. Microstructures of Stainless Steels
5. Microstructures of Titanium Alloys
6. Microstructures of Aluminum Alloys
7. Defects Caused by Various Processes
8. Corrosion

Who Should Enroll

No prior knowledge of metallurgy is required, though some experience in metallographic sample preparation would be advantageous.

Instructor

Frauke Hogue is a consultant metallographer to several Los Angeles area failure analysis laboratories. Her expertise covers a wide variety of materials. Since 1985, she has conducted many intensive metallography courses at ASM International and other companies in the United States and Canada. She has attained the designation of Materials Engineering Institute Distinguished Educator.

Contact: ASM International, Customer Service Center, Materials Park, OH 44073-0002; tel: 440/338-5151, ext. 5900; fax: 440/338-4634; e-mail: cust-srv@po.asm-intl.org; www: http://www.asm-intl.org.

Materials Research Society Fall 1998 Meeting—Call for Papers

30 November–4 December 1998, Boston, Massachusetts

Symposium M: Fracture and Ductile versus Brittle Behavior—Theory, Modeling, and Experiment

Scientists and engineers from many diverse disciplines are making dramatic progress in, or calling for more effort in, several aspects of the fracture of materials as well as the ductile/brittle transition. Research in these areas is carried out in diverse research communities, and communication among the different groups is limited. The goal of this symposium is to attract attendance and foster input of both theorists *and* experimentalists from the physics, engineering, and materials science communities. The symposium will cover theory, simulation, and experiment—*and integration thereof*—in the following areas, as they apply to fracture of structural materials, composites, disordered materials, polycrystalline and nanocrystalline solids, polymers, thin films, and material interfaces:

- Modeling of fracture and deformation using quantum mechanics, classical atomistic potentials, mesoscale models, statistical models, and (nonlocal) continuum methods
- Multiscale models combining two or more modeling techniques
- Physics at the crack tip and brittle versus ductile behavior
- Local and/or in situ experimental observations
- Dynamic fracture and instabilities
- Quantitative characterization of fracture surfaces and scaling phenomena

Symposium Organizers: Glenn E. Beltz, Department of Mechanical & Environmental Engineering, University of California, Santa Barbara, CA 93106-5070; tel: 805/893-3354; fax: 805/893-8651; e-mail: beltz@semtex.ucsb.edu; www: http://www.me.ucsb.edu/~beltz; Robin L. Blumberg Selinger, Department of Physics, Catholic University, Washington, DC 20064; tel: 202/319-6740; fax: 202/319-4448; e-mail: selinger@cua.edu; www: http://www.cua.ed/~selinger/home.htm; Michael P. Marder, Department of Physics, University of Texas-Austin, Austin, TX 78712; tel: 512/471-3612; fax: 512/471-1558; e-mail: marder@chaos.ph.utexas.edu; and Kyung-Suk Kim, Division of Engineering, Box D, Brown University, Providence, RI 02912; tel: 401/863-1456; fax: 401/863-1157; e-mail: kim@isaac.engin.brown.edu.

International Conference on Advanced Composites

15-18 December 1998, Hurghada, Egypt

Readers are invited to submit an abstract to the International Conference on advanced Composites (icac98). Abstracts should not exceed 250 words and should include author's name, affiliation, and address at the top of the page.

Conference Topics:

- Processing of CMC, MMC, and PMC
- Design and optimization
- Computational mechanics
- Textile composites
- Nondestructive evaluation
- Joints and adhesion
- Life cycle of composites
- Damage and fracture mechanics
- Particulate and nanocomposites
- Composite materials in infrastructure
- Wood composites
- Impact behavior
- CAD/CAM systems
- Mathematical modeling
- Interface, debonding

Contact: Abstracts should be submitted as soon as possible to: Dr. Yasser Gowayed, icac98, Department of Textile Engineering, Auburn University, Auburn, AL 36849-5327, USA; e-mail: icac@eng.auburn.edu. Registration fees may be paid by check to: icac98/Dr. Faissal Abel-Hady, Ain Shams University, Faculty of Engineering, 10, St. No. 5, 4th quarter, Heliopolis, Cairo 11341, Egypt.

United Thermal Spray Conference & Exposition, Coating in Practice

17-19 March 1999, Düsseldorf, Federal Republic of Germany

With respect to the ITSC in May in Nice, DVS has decided to change some of the dates for the UTSC'99 Conference.

The *new date* for the submission of the full manuscripts will be 30 Sept 1998.

The UTSC'99 will be the second conference in the sector of thermal spraying jointly organized by the ASM-TSS and the DVS. It will be accompanied by a company exposition. Like its successful predecessor event in Indianapolis in 1997, it will present the latest status of application, research, and development in thermal spraying. The conference languages will be German and English with simultaneous interpreting.

The UTSC'99 will offer:

- Technical papers (Discussion event)—Highly topical contributions from international specialists
- A technical and scientific poster show—Description of current research and development work
- Workshops—Exchange of experience and discussion of current problems
- Technical films and videos—Technical, economic, and scientific information
- An expert exchange—Free advice from specialists from companies and research facilities
- An interesting supporting program
- A company performance show featuring original products—Devices, equipment, materials, accessories, and services

The UTSC'99 will bring together specialists from industry and research. It will offer users and other interested parties an up-to-date overview of the state-of-the-art and of future development trends. It will give those people active in research and development the opportunity to describe and discuss the results of their work.

With the slogan "Coating in Practice," the following subject areas are to be dealt with at the UTSC'99:

- Application technology and solutions to problems
- Pretreatment and posttreatment
- Equipment technology and process engineering
- Spraying consumables
- Quality inspection, quality assurance, and quality management
- Economic aspects
- Design
- Health and safety at work and environmental protection
- Training and qualification of personnel
- Plasma transferred-arc surfacing (PTA)

Contact: Frau R. Bodgon, Frau B. Brommer, or Frau S. Mahlstedt, Conference Secretariat and Conference Office, DVS, Aachener Strasse 172, D-40223 Düsseldorf; tel: (0211) 1591-0: fax: (0211) 1591-200.

12th International Conference on Wear of Materials

25-29 April 1999, Atlanta, Georgia

This conference is devoted to the understanding and control of all forms of wear of materials and closely related topics. The objective is to provide a forum in which the results of current research and engineering studies can be presented and discussed to promote interaction among researchers and practicing engineers. Thus, the scope of Wear of Materials 99 will include papers in any of the areas listed below:

- Wear mechanisms in closed tribosystems (for example, sliding, rolling, fretting, etc.)
- Wear mechanisms in open systems (for example, abrasion, erosion-corrosion)
- Wear mechanisms in lubricated systems (for example, tribochemical)
- Wear of various materials combinations under various service conditions
- Understanding and control of friction and friction-induced vibration
- Conceptual and engineering modeling of wear and friction mechanisms
- Wear of industrial equipment and products (including case studies; wear-related failure diagnosis)
- Surface engineering, materials selection, and design for wear resistance
- Wear testing/simulation and surface characterization related to wear

Contact: Amy Richardson, Wear of Materials 99 Conference, Secretariat, Elsevier Science, The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, UK; tel: +44 (0) 1865-843643; fax: +44 (0) 1865 843958; e-mail: a.richardson@elsevier.co.uk.

2nd International Conference on Recent Advances in Materials and Mineral Resources (RAMM'99)

3-5 May 1999, Penang, Malaysia

Conference Objective

There have been rapid advances in the techniques of materiel development and processing, and rapid strides have also been made in the phenomenological understanding of materials behavior. Economic development of mineral resources has also been addressed by researchers and industrialists alike. The present conference is intentionally kept broad based to bring academicians, researchers, and practicing engineers to exchange ideas and provide future directions. The conference will involve several parallel session and panel discussions. There will be invited lectures by experts from the industries, research, and academic institutions on the topics of special relevance to Malaysia.

Topics

Materials (Metallic, Ceramic, Polymers, and Composites)—Materials for high-tech application like aerospace engineering and conventional applications—both theoretical and experimental aspects, covering solidification, alloy development, powder metallurgy, electroceramics, engineering ceramics, clay-based ceramics, polymers, and composites would be included.

Mineral Resources—(Industrial minerals such as limestone, silica, clays, feldspar, and mineral-bearing metals like copper, gold, etc.)—Current technologies in mining, quarrying, processing, and production of value-added products and also computer applications in the mineral industry.

Economic, environmental, and marketing issues relating to the materials and mineral industries are also given emphasis.

Contact: The Secretariat, 2nd International Conference on Recent Advances in Materials and Mineral Resources (RAMM'99), School of Materials and Mineral Resources Engineering, University Sains Malaysia, Perak Branch Campus, 31750 Tronoh, Perak, Malaysia; fax: 605 3677444; e-mail: ramm99@eng.usm.my.

International Conference on Advanced Manufacturing Technology

16-18 June 1999, Xi'an, P.R. China

The objective of ICAMT'99 is to provide a forum for experts from international academia and industry community to exchange up-to-date ideas, findings, and experiences relevant to advanced manufacturing technology and innovations in manufacturing engineering education. The conference will consist of keynote speeches, invited papers, and technical sessions, focused on both theory and applications.

Papers describing original work in, but not limited to, the following areas are solicited:

Manufacturing Strategy:

- Agile manufacturing/enterprise re-engineering
- Manufacturing benchmarking
- Environmentally conscious manufacturing
- Intelligent manufacturing

Emerging Manufacturing Technology:

- Rapid prototyping and rapid tooling
- Precision/ultraprecision machining
- Nonconventional machining
- MEMS (microelectromechanical system)

Manufacturing Automation:

- NC/CNC, CAD/CAM/CAPP/CAE
- FMC, FMS, CIM, CIMS
- Robotics and motion control
- Mechatronics, integrated system, components, and control
- Reverse engineering

Information Technology in Manufacturing:

- Virtual design and manufacturing
- Internet/intranet support
- Concurrent engineering

Industrial Engineering/Production Management:

- Production management
- Quality management and system
- Supply chain management and logistics systems

Design Theory and Methodology:

- Modem design
- Accuracy design
- Visualization

Quality Assurance and Diagnostics:

- Measurement, inspection, and quality control
- Monitoring/supervision in manufacturing
- Vibration/noise suppression

Advanced Materials and Processing:

- Advanced materials and equipment
- Materials forming and processing
- Materials surface engineering and tribology
- Computer application in materials processing

Innovative Education for Manufacturing:

- Case study method
- Multimedia-based education/distance learning
- Manufacturing synthesis curriculum

Contact: Dr. Y. Ding or Dr. D. Li, College of Mechanical Engineering, Xi'an Jiaotong University, Xi'an 710049, P.R. China; tel: +86-29-326-8936; fax: +86-29-323-7910; e-mail: srosme@sun20.xjtu.edu.cn.

Conference and Exhibition of the European Ceramic Society, Coatings/Surfaces

20-24 June 1999, Brighton, United Kingdom

Contributions are requested on all aspects of ceramic coating technology, including coating material and process development, property measurement, and modeling and applications development. Of particular interest are papers on thermal barrier coatings, superhard coating materials (diamond, CBN, and CN*x*), and structure/property relationships in ceramic coating systems. Papers introducing novel or improved coating processes, particularly those that have been developed in response to environmental concerns about existing process technologies and papers discussing the use of modeling to optimize coating selection for performance are also welcome.

Contact: Lisa Davies or Tracy Aubin, Conference Department (C914), The Institute of Materials, 1 Carlton House Terrace, London SW1Y 4DB, UK; tel: +44-(0)171-451-7300; fax: +44-(0)171-839-2289; e-mail: Lisa_Davies @materials.org.uk or Tracy_Aubin @materials.org.uk.

International Conference on Thermophysical Properties of Materials (TPPM99)

17-19 November 1999, Singapore

TPPM99 is organized by the Advanced Materials Research Center, Nanyang Technological University, and supported by the Institute of Materials (UK), Institute of Materials (East Asia Branch), ASM International (Singapore), Singapore Plastic & Rubber Institute, Institute of Materials Research and Engineering, Singapore Polytechnic, Gintic Institute of Manufacturing Technology, and Singapore Welding Society.

Scope

The Conference will be devoted to the characterization of thermophysical properties and thermal analysis of materials. A three-day exhibition of thermal analysis and characterization equipment as well as services by leading thermal instrument manufacturers and representatives will be held concurrently with the Conference. The main aim of the Conference is to bring researchers in the area of thermophysical properties and thermal analysis together to exchange ideas on the latest findings and developments in thermal techniques for the characterization of materials as well as on the thermophysical properties of bulk materials, and thin and thick films.

Contact: TPPM99 Conference Secretariat, Attn: Ms. G.B. Dee or Ms. M. Toh, Nanyang Technological University, Conference Management Center/Center for Continuing Education Administration Annex No. 04-06, Nanyang Ave., Singapore 639798; tel: +65-799-4723; fax: +65-793-0997; e-mail: TPPM99 @ntu. edu.sg.

Detect Micro- and Macrocracking of Coatings

A thermal spray coating is not amorphous. It has a very rich microstructure. Macrocracking and microcracking of the material can be monitored using acoustic emission (AE) technology. This would be extremely valuable to operators of turbine equipment, because they could then know with certainty that the microcracking on a turbine blade coating is deteriorating and delaminating.

A group of researchers from China, Korea, and Japan and Christopher Berndt at SUNY Stony Brook tested free-standing alumina-13% titania samples to see if they could determine micro- from macrocracking by acoustic emission. They manufactured the 5 mm thick samples with a water-stabilized plasma spray gun.

Berndt believes the test can distinguish between the acoustic signals produced by microcracking and those produced by macrocracking or failure of the coating.

Berndt acknowledges that fully developing the technology to sense the state of coating by acoustic sensors will require a large research and development effort.

However, applications for this type of acoustic technology could find wide use in predicting maintenance of turbine systems and/or assessing the coating on an orthopedic implant.

An operator of a turbine system could monitor coatings on turbine blades and estimate their remaining life. Acoustic emissions from micro- and macrocracking could monitor coatings on bridges and metal structures of all kinds.

Contact: Christopher C. Berndt, Professor, Department of Materials Science & Engineering, Thermal Spray Laboratory, 306 Old Engineering, State University of New York at Stony Brook, Stony Brook, NY 11794-2275; tel: 516/632-8507; fax: 516/632-8052; e-mail: cberndt@notes.cc.sunysb.edu.

Excerpted from *Adv. Coat. Surf. Technol.*, Vol 10 (No. 12), Dec 1997.

Industrial News

Howmet Offers "Amorphous" Golf Club Material to General Markets

Howmet Corporation (Greenwich, CT) presented a new high-tech material at the National Design Show, which was held at McCormick Place, in Chicago, 16-19 March 1998. The new material, a bulk metallic glass alloy called Vitreloy, is already creating excitement in golfing circles due to its advanced properties. Next week, designers from around the world will have an opportunity to get a closer look at a new engineering material with a unique balance of metallurgical characteristics. Howmet is the exclusive licensee of this material for many commercial applications. The material was invented by scientists at Caltech and is being marketed by Amorphous Technologies International (ATI).

Last year Howmet entered into licensing and manufacturing agreements with ATI. Under these agreements, Howmet and ATI will serve new markets using ATI's patented, amorphous alloy, Vitreloy, and Howmet proprietary casting processes. Howmet will be a primary producer for ATI's subsidiary Liquidmetal Golf, a manufacturer currently supplying amorphous-metal golf products to a number of markets.

"Bringing together Vitreloy and Howmet's advanced casting processes creates a powerful combination," says David L. Squier, Howmet's president and CEO. He is also an avid golfer. "The properties of this new alloy may force a rethinking of what is possible in golf, because of the impact this material is likely to have on current perceptions about distance and control."

"Vitreloy is called an amorphous metal because of the random microstructure of its atoms," explains Thomas Gregg, ATI's director of business development. "Vitreloy's microstructure gives products such as golf clubs high elasticity and unique energy-management properties. What this means is, when a golfer hits a ball with a club made from Vitreloy, the metal absorbs the energy created by the club's impact with the ball, then kicks that energy right back out, enabling the ball to come off the club face with higher energy levels than it does with conventional metals. When clubs of this material are produced by a casting process, they achieve a very smooth, desirable surface. Producing this material with a casting process results in characteristics that hold considerable promise for a variety of applications."

Upon impact with a golf ball, clubs made with Vitreloy transfer energy into the ball at five times the rate of titanium, a currently popular metal that absorbs energy on impact. Laboratory tests have demonstrated that golf club heads made with Vitreloy help golfers achieve 4 to 7% percent greater distances with their shots. Testers also reported that putters produced with Vitreloy give them both more control and a "better feel for the ball."

Beyond sporting goods markets, Howmet and ATI are exploring other market segments—such as aerospace, energy, and marine, to mention only a few—where synergy created by uniting amorphous materials and Howmet casting processes indicates innovative and potentially successful applications.

Contact: Doreen Deary, Howmet Corp., 475 Steamboat Rd., Greenwich, CT 06836-1960; tel: 203/625-8735; fax: 203/625-8771.

Why Municipal Planners and Engineers Are Turning to Arc Spray

Municipal planners and maintenance engineers who want to prevent corrosion are turning to arc sprayed coatings for cost-containment reasons as municipal budgets shrink and the varied costs of painted coatings on steel structures soar. Arc spray provides the highest levels of corrosion prevention, the longest maintenance-free protection, and consequently, the lowest life-cycle costs.

In Trenton, NJ, officials rehabilitated the "No Toll" bridge over the Delaware River between Morrisville and Trenton with arc sprayed zinc. The company commissioned to spray the bridge was Jupiter Painting, headquartered in Croyden, PA.

One hundred fifty thousand pounds of zinc covered the 108,000 ft^2 of steel in 75 days, protecting the structure from atmospheric corrosion for the next 30 years. As one manager put it, "We are on a 20-year maintenance cycle, so a protective coating better last that long, because we can't get back to it any sooner." Case studies by the U.S. Department of Transportation conclude that the thermal sprayed coatings will provide an approximately five-fold saving over alternative coating processes.

After a general contractor removed the asphalt and concrete, and steel workers replaced excessively corroded braces, Jupiter's five-man crew blasted the surface with steel shot and used four of TAFA's (Concord, NH) Model 8860 Arc Spray systems to coat the surface with zinc.

All the spray system's components, except the wire drive units and spray gun, were outside the spray arena. This allowed operators maximum mobility in confined spaces and protected the equipment at the same time.

Contact: Joan Rich, TAFA Inc., 146 Pembroke Rd., Concord, NH 03301; tel: 603/223-2108; e-mail: rich@tafa.com; www: http://www.tafa.com.

Manufacturing with the Spraycast Process

Directly spraying a preform cuts down on processing steps and reduces the lead time required to produce a shape. This process combines technologies to achieve these goals.

Spray deposition techniques have many potential advantages, one of which is the opportunity to produce near-net-shape products at high solidification rates. Near-net-shape manufacturing methods are attractive because they can produce components at very low cost, while the high effective cooling rate obtainable with spray forming is attractive because very fine grain size structures can be obtained with minimum segregation. These advantages were first recognized in the 1970s by a group working out of the University College of Swansea in the United Kingdom, but despite significant efforts by many groups, spray forming has achieved only a limited amount of interest from industry.

The difficulty of controlling the process is probably the principal reason why spray forming has not been more broadly applied in industry. There are other technical difficulties that have slowed the rate of application. Examples include gas entrapment, oxidation, reaction of the molten metals spray with the gas used for atomization, and fissure porosity, particularly on the inside diameter of tubular shape products.

Howmet Corporation (Whitehall, MI) has embarked upon a program to find solutions to these processing difficulties and has worked with several potential customers to evaluate and solve these problems. Over the last two years, significant progress has been made toward making the spray forming process a production reality on advanced nickel-base superalloys such as Inconel 718; currently, developmental product using the process is being produced for evaluation.

The main advantage of directly spraying a preform, and hot isostatically pressing this preform to achieve consolidation, is that the number of processing steps is reduced, which shortens lead time to produce a shape. Using this routine, the process can be used for a rapid prototyping route and, on occasion, preforms have been produced to a customer's drawing within two weeks of receipt of the product definition. This compares to typically many months for the standard pierce-billet and ring-rolling approach currently used by the aerospace industry.

Excerpted from *Foundry Manage. Technol.*, Oct 1997.

Sprayforming

Sprayforming offers the following advantages:

- Processing steps are reduced, thereby saving money.
- Cycle times are significantly reduced, also saving money.
- Unforgeable superalloys are used, which can enhance the performance of many products.
- Properties comparable to wrought are achieved.

Sprayforming has been selected by *Aviation Week & Space Technology* magazine as a candidate in their 1998 Technology Awards competition.

Contact: Greg Butzer, General Manager, Sprayform Technologies International, L.L.C., 1700 Whitehall St., Whitehall, MI 49461-1897; tel: 616/894-7601.

News from NASA

Removable Fillers for VPS Fabrication of Closed Channels

An improved process has been devised for making closed channels (for example, coolant channels) in a heat-exchanger liner or a similar metal object. The process involves the following steps: First, grooves destined to become closed channels are machined into the object from one surface. Next, a ceramic filler material is troweled into the grooves, made flush with the surface, and allowed to harden by evaporation of water. Next, vacuum plasma spraying (VPS) is used to deposit metal on the exposed metal and filler surface areas to cover the grooves and thereby form closed channels (Fig. 1). Finally, the filler material is removed from the channels. This process satisfies a need for making the channels at lower cost and in less time than is possible by an older process in which the grooves are filled with wax, then a thin layer of copper is electroplated on the exposed metal and wax surface areas, then a thick nickel structural jacket is deposited on the copper.

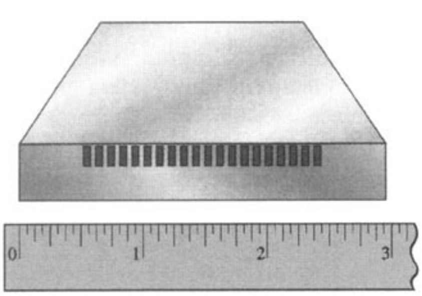

Fig. 1 Channels in a solid metal plate were formed by VPS of metal onto ceramic-filled grooves and adjacent areas of the top surface. In the initial experiments on this process, the plates and the deposited material were made of copper.

The success of the process depends on the proper choice of the filler material. A ceramic is attractive for this purpose because, unlike wax, it can withstand the VPS process temperature. The filler is required to be sufficiently fine grained to enable the deposited metal to have a smooth surface [32 μ in. (0.8 μm) in the original application for which the process was devised]. The filler is also required to be removable after VPS.

The ceramic filler materials found to be most suitable are mixtures of silica powder with water and various proportions of sodium silicate or colloidal silica, which serve as binders. A third binder made of a cellulose ether compound can be used in combination with either of the other two binders to tailor the viscosity of the overall mixture for both troweling the filler into the channels and removing the filler after VPS.

It is desirable to facilitate and accelerate post-VPS removal of the filler by providing flow paths for flushing the filler out of the channels. For this purpose, before the filler material is troweled into the channels, a yarn or rope made of a polymeric material is placed in the bottom of each groove, extending beyond the ends of the groove. The polymeric material should be either one that decomposes and shrinks at the high VPS process temperature or else one that can be pulled out after hardening of the filler or after VPS. After VPS, the filler can be flushed out of the completed channels, for example, by alternating flows of pressurized water and a hot NaOH solution.

This work was done by D. Andy Hissam and Frank Zimmerman of Marshall

Space Flight Center and William M. Davis, Phillip Krotz, Yoon K. Liaw, Peter Oelgoetz, and Heather Sanders of Rockwell International Corporation.

For further information, access the Technical Support Package (TSP) at http://www.nasatech.com under the Manufacturing/Fabrication category.

Excerpted from *NASA Tech Briefs*, March 1998.

In-Process Monitoring and Analysis of Thermal Spray Processes Using Machine Vision

The LaserStrobe Optical Probe is an advanced laser-augmented video-imaging system that observes and measures particle behavior in the harsh environment of a plasma spray chamber. The need for a reliable diagnostic and feedback control system during thermal spray processing spurred the development of this sophisticated system.

LaserStrobe is intended to enable manufacturers of aerospace engine components to reduce production costs while meeting the strict standards of quality for parts that are commonly coated using the plasma spray process.

The conditions inside the low-pressure chamber during plasma spray processes include an extremely bright plasma flame, strong electromagnetic fields, high temperature, and contamination from powder overspray circulating throughout the chamber during operation. LaserStrobe was designed to endure this harsh environment and enable scientists and engineers to measure parameters such as particle velocity and particle distribution during the spraying process.

This water-cooled optical probe has a pulsed laser illumination system and a special-purpose camera head that provide images of extremely bright industrial processes—such as electric arc welding and plasma spray. The optical probe components are attached to a 14 in. (29 cm) diameter flange. The flange is then mounted on the main access door of the plasma spray chamber.

The LaserStrobe Optical Probe system was installed and tested in the Low-Pressure Plasma Spray chamber at Marshall Space Flight Center in Huntsville, AL. Two fan-shaped laser beams are superimposed in the focal plane of the camera head, providing two spot images of each traveling particle in the video frame. With a few microseconds of delay between the first and second laser pulse, "twin images" are produced as the particles move across the camera field of view. During these tests, the optical probe system provides clear imagery of plasma spray plume particles inside the chamber.

This work was done by Jon D. Bolstad, John C. Lagerquist, and Craig L. Shull of Control Vision, Inc., for Marshall Space Flight Center.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; tel: 205/544-0021. Refer to MFS-26424; Technical Support Package (TSP) at http://www.nasatech.com under the Electronic Systems category.

Excerpted from *NASA Tech Briefs*, April 1998.

Improved Nonlinear Mathematical Model of Viscoelasticity

An improved nonlinear mathematical model is being developed for use in predicting the complex, time-varying stress-and-strain behaviors of viscoelastic materials. The development of this model is prompted by (1) the lack of success of older constitutive mathematical models that contain hereditary integrals of linear viscoelasticity (for example, integrals that express current stresses in terms of histories of strains and of relaxation moduli) and (2) the need for a nonlinear model subject to efficient numerical implementation.

A one-dimensional version of the model is given by the equation

$$\sigma(t+\Delta t) = R(\Delta t)\sigma(t) + E_L \int_t^{t+\Delta t} \dot{\varepsilon}(t)dt$$

where $\sigma(t)$ is uniaxial stress, t is the current time, Δt is an increment of time, $R(\Delta t)$ is a relaxation function (which is not the same as a relaxation modulus), E_L is a loading modulus (which is not the same as an initial or tangent modulus), $\varepsilon(t)$ is uniaxial strain, and the overdot signifies differentiation with respect to time. Inasmuch as the time elapsed since initial loading is generally not know in a general-purpose numerical model, it is important that R does not depend on t.

R is defined by applying the equation in the special case of a relaxation test in which ε remains constant for all time. Once R has been defined in this way, E_L is defined by applying the equation to a constant-strain-rate test and rewriting the equation in the following form:

$$E_L = \frac{\sigma(t+\Delta t) - R(\Delta t)\sigma(t)}{\dot{\varepsilon}\Delta t}$$

Fitting this model to experimental data is expected to be much more straightforward than it is for older nonlinear mathe-

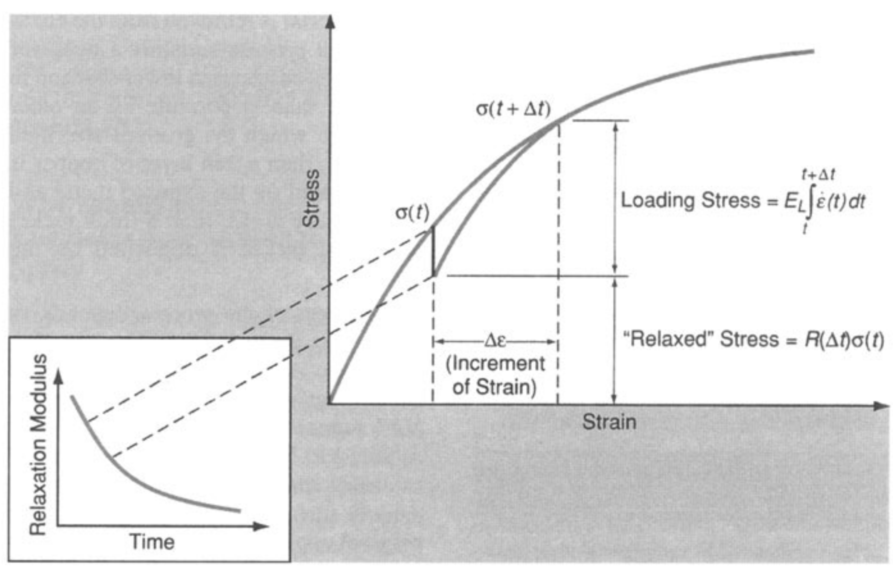

Fig. 1 Stress-vs-Strain Data from a relaxation test are analyzed by use of the model and used to predict the "relaxed" stress in a constant-strain-rate test. The loading modulus is then determined by dividing (the stress measured in a constant-strain-rate test less the "relaxed" stress) by the increment of strain.

matical models of viscoelasticity: Fig. 1 illustrates how this is so. In applying the model, one uses relaxation data to predict relaxation only and loading data to predict loading.

In general, E_L is expected to be a function of strain, strain rate, temperature, and hydrostatic pressure. R can be approximated conveniently by $R(\Delta t) = \exp(-\Delta t/\alpha)$, where α is a parameter used in fitting the model to experimental data.

Continuing efforts are expected to extend the model to three dimensions and to account for compressibility and dilatation. A tentative three-dimensional model in the form of a tensor rate equation has been proposed.

This work was done by Robert S. Dunham of Marshall Space Flight Center.

Contact: Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center; tel: 205/544-0021. Refer to MFS-28623.

Excerpted from *NASA Tech Briefs,* April 1998.

U.S. Government News

Daley Says NIST to Help Small Manufacturers Avoid "Millennium Bug"

The Manufacturing Extension Partnership (MEP) and its nationwide network of centers are stepping up efforts to help smaller manufacturers avoid being bitten by the "millennium bug," Commerce Secretary William Daley and the department's National Institute of Standards and Technology announced 11 May 1998.

The millennium bug, or Year 2000 date problem, refers to a flaw in the way dates traditionally have been entered into computer systems. Many computers that use two digits to keep track of the date will, on 1 Jan 2000, recognize the double zero not as 2000, but as 1900. Because computers use dates to make calculations, this glitch could cause them to shut down or generate erroneous information.

"While there has been a lot of publicity concerning this problem, many small and medium-sized manufacturers have not yet assessed their level of risk," said Daley. "Smaller manufacturers cannot ignore the problem or hope it does not affect them. If they do, it could affect not only their competitiveness but also their ability to survive."

The Gartner Group (Stamford, CT), a leading authority on information technology issues, has reported that as of 1997, 88% of all companies with fewer than 2000 employees had not yet started Year 2000 remediation projects. "Many companies that are addressing problems with their computer systems may be overlooking potential problems embedded in other systems such as machine controllers and telecommunications," said Kevin Carr, director of the NIST MEP.

MEP centers nationwide will be conducting seminars to raise smaller manufacturers' awareness and understanding of the problem and helping client manufacturers assess their systems to determine if they have problems. If needed, MEP centers also will help smaller companies plan remediation. Carr has asked each center to designate at least one person as a Year 2000 "champion" to help coordinate center activities and services.

Working with three MEP centers—the Michigan Manufacturing Technology Center (Ann Arbor), the Great Lakes Manufacturing Technology Center (Cleveland, OH), and the Utah Manufacturing Extension Partnership (Orem, UT)—NIST MEP has developed a toolkit to help center field staff deliver Year 2000 services. The toolkit includes materials to help MEP centers present Year 2000 awareness seminars to executives and senior managers of small manufacturers within their region. Also included are materials for conducting Year 2000 workshops to help manufacturers take a closer look at the problems they may encounter. A reference section is included within the toolkit to assist MEP field staff in identifying the appropriate tools and other resources that small manufacturers will need to plan and implement remediation projects. A self-assessment questionnaire and Year 2000 overview information also will be available on the MEP website at http://www.mep.nist.gov.

NIST's MEP is a nationwide network of manufacturing extension centers providing services to smaller manufacturers in all 50 states and Puerto Rico. Through MEP, manufacturers have access to more than 2000 manufacturing and business "coaches" whose job is to help firms make changes that lead to greater productivity, increased profits, and enhanced global competitiveness. The U.S. Census Bureau surveyed 2350 firms served by MEP centers in 1996. These companies reported an increase in sales of nearly $110 million and showed savings of $16 million in inventory and more than $13 million in labor and material. They also invested more than $85 million in modernization. These companies directly attribute these benefits to the services provided by the NIST manufacturing extension centers.

A nonregulatory agency of the Commerce Department's Technology Administration, NIST promotes U.S. economic growth by working with industry to develop and apply technology, measurements, and standards.

Contact: Jan Kosko; tel: 301/975-2767; e-mail: janice.kosko@nist.gov.; www: http://www.nist.gov.

Excerpts from JCPL

NACE International (Houston, TX) held Corrosion/98 and NACExpo/98, its 53rd annual conference and exposition, 22-27 March 1998, in San Diego, CA. This year's theme was "Leading the Way through New Technologies."

The conference offered a technical program that focused on techniques, products, and research topics for professionals in a variety of industries that deal with corrosion. A list of technical sessions of interest to thermal sprayersn follows.

Thermal Spray—Coating & Corrosion Control

Sponsored by Committee T-6H-45 on Thermal Spray Coatings, this symposium was held 25-27 March 1998 and featured the following papers:

- Effect of Composition and Corrosion Properties of the Metallic Matrix on the Erosion-Corrosion Behavior of HVOF Sprayed WC-Coatings, Trond Rogne and Tone Solem, SINTEF Materials Technology (Trondheim, Norway); and John Berget, NTNU (Trondheim, Norway)
- Effect of Primer Compositions on Cathodic Disbonding Resistance and Adhesion Durability of Three Layer Polyethylene Coated Steel Pipe, Shiro Tsuri, Kenji Takao, and Kazuo Mochizuki, Kawasaki Steel Corp. (Chiba, Japan)
- Large Diameter Wire High Deposition Metallizing: A Competitive Edge for Long Life Coating, Mahlon S. Wixson, Thermion Metalizing Systems (Silverdale, WA)
- Recent FHWA Experience in Testing and Implementing Thermal Spray Coatings for Bridge Structures, Robert A. Kogler, Dan Brydl, and Carl Highsmith, FHWA MS HNR20 (McLean, VA)
- 85% Zinc-15% Aluminum Thermal Spray Applications for Illinois DOT/FHWA, Walter J. Gajcak, U.S. Corrosion Engineers Inc. (Joliet, IL)
- Thermal Spray Coatings Behavior under Oxidizing and Sulfidizing Conditions at Elevated Temperatures, Andres Verstak and S. Baranovski, Metalspray Inc. (Richmond, VA)
- Sacrificial Cathodic Protection of Reinforced Concrete Using Metalized Zinc, Magnesium, and Zinc Based Pseudo Alloys, Rejean Brousseau, B. Arsenault, and Gu Ping, National Research Council of Canada (Ottawa, ON); and Bruce Baldock (Nepean, ON)
- Maintenance and Repair of Thermal Spray Coatings, Ted Call, Power Spray Inc. (Virginia Beach, VA)
- Successful Application of an Arc Sprayed 85-15 Zn/Al Coating on Grandstands at Indianapolis Motor Speedway, Chip Stein, Tank Industry Consultants (Indianapolis, IN); Christopher John Houghton, Amoco (UK) Exploration Ltd. (London, UK); and Michael Swidzinski, Phillips Petroleum (Surrey, UK)
- Application of Thermal Spray Coatings for 304 Stainless Steel SCC Mitigation in High Temperature Water, Young-Jin Kim and Peter L. Andresen, General Electric Corp. R&D (Schenectady, NY)
- Developing a Methodology for Performance Evaluation of Metallic Thermal Spray Coating for Oil and Gas Service, Iwona Smuga-Otto (Edmonton, AB); and Karol E. Szklarz, Shell Canada Ltd. (Calgary, AB)
- Updated Protective Coating Costs, Products, and Service Life, Kirk R. Shields, KTA-Tator, Inc. (Springdale, PA); and Michael P. Erina, KTA-Tator, Inc. (Pittsburgh, PA)
- Field Performance of Sprayed Zinc Anodes in Controlling Corrosion of Steel Reinforced Concrete, John S. Tinnea, John S. Tinnea and Associates (Seattle, WA)
- A Review of Power Plant Corrosion Applications and Needs, Rick Bajan, Walbar Metals (Hodges, SC); and Elliott R. Sampson, Tafa Inc. (Concord, NH)
- Results of Field Application and Laboratory Testing of Thermal Spray UNS N10276 Coating for Sour Amine Vessels, Malcolm Geoffrey Hay and John J. Baron, Shell Canada Ltd. (Calgary, AB); Kevin G. Goerz and Roy W. Schubert, Shell Canada Ltd. (Caroline, AB); and Frank Easterly, Metalspray (Richmond, VA)
- The Electrochemical Corrosion Behavior of High Velocity Oxygen Fuel (HVOF) Sprayed Coatings, Andres Sturgeon, TWI (Cambridge, UK)
- A Review of the Performance and Use of Thermal Spray Aluminum Coatings on North Sea Platforms, Trevor Rosbrook, Rosbrook Associates Ltd. (Kintore, UK); Christopher John Houghton, Amoco (UK) Exploration Ltd. (London, UK); and Michael Swidzinski, Phillips Petroleum (Surrey, UK)
- Duplex Protection System of Powder Coating and Metal Spraying on Steel Articles, Takao Handa and Hisayoshi Takazawa, Nippon Telegraph & Telephone (Tokyo, Japan)
- Corrosion Protection of General Purpose Bombs Using Metal Arc Spray Technology, Douglas H. Neale, SAIC (Marietta, GA)
- Arc Spray Corrosion Applications, Elliott R. Sampson, Tafa Inc. (Epsom, NH); and Dominic Varacalle, Vartech (Idaho Falls, ID)
- HVOF Coatings in Corrosion Resistance, Richard Thorpe, Tafa Inc. (Concord, NH)
- Zinc Metallizing versus Galvanizing—Where and When to Use, Kace Duplissie, Platt Brothers & Co. (Waterbury, CT)

Excerpted from *JCPL,* March 1998.

Excerpts from *Sulzer Technical Review*

New Enhanced Coating for Dental Implants

The use of implants in dental restoration has become a widely accepted, successful therapy. Today's implants are virtually indistinguishable from healthy, natural teeth. With its new CSTi porous coating, Sulzer Calcitek has succeeded in combining the mechanical interlock of screw implants with the surgical simplicity of cylindrical designs.

Patients with dental implants enjoy significant improvements in function and esthetics compared with those more traditionally using crowns, bridges, and dentures. Implants also have the long-term advantage of maintaining bone mass in the maxilla and mandible that is otherwise rapidly lost due to disuse atrophy.

To Thread or Not to Thread

Two designs dominate the dental implant market: screws and cylinders. Screws form an immediate mechanical interlock with surrounding bone tissue, as they are threaded into the bone, thus securing the implant. With the longest clinical history, titanium and Ti-6Al-4V alloy screws are the most widely used dental implants. All screws, however, suffer the drawback of relatively complex surgical implant procedures, as the bone must often be pretapped. Nonetheless, the intuitive concept of mechanical fixation is still preferred by many clinicians.

Because cylinder implants do not offer immediate mechanical attachment, they typically feature coatings, such as plasma sprayed titanium or hydroxylapatite (HA) ceramic. These coatings enhance bone attachment, and implants establish a solid, stable interface with the surrounding bone within months after implantation. HA coatings have proven to be the fastest integrating dental implant surface to date. Additionally, cylinders are easier to implant than screws, as they are simply pushed into a predrilled site. The high success rate of HA-coated cylinders has been well documented over the past decade.

Incorporating Benefits Into One

Sulzer Calcitek has developed the CSTi porous coated dental implant (Fig. 1), which combines the advantages of both screw and cylinder configurations. The porous surface is quickly integrated by the growth of bone into the coating, forming a stable interlock. Because of cylindrical shape, the CSTi implant is easily placed, using the instruments and techniques familiar to most users of Sulzer Calcitek products. The implant system was recently introduced in diameters of 3.25, 4.0, and 5.0 mm, responding to the needs and anatomical limitations of almost every dental implant patient.

Applied Orthopedic Know-How

The CSTi (Cancellous Structured Titanium) surface was adapted from the coating widely used on a number of articulated joint prostheses of Sulzer Orthopedics Inc. The coating is a three-dimensional network of interconnecting pores in a matrix of sintered titanium powder. The name CSTi reflects the physical similarity of the porous coating to human cancellous bone.

Figures 2 and 3 show the CSTi coating in cross section and from the surface. The porous coating provides a substantial volume of void space to accommodate healthy bone. The average porosity of the CSTi coating is 57%. Pores are random in shape, with dimensions ranging from 69 to 662 μm.

Figure 4 shows a cross section of the CSTi coating of a dental implant retrieved from a canine specimen. The void spaces are almost entirely filled with new bone growth after only two weeks. Although this is a best-case example, more than 50% of the pore volume is filed with bone after only three months on average. With this extensive

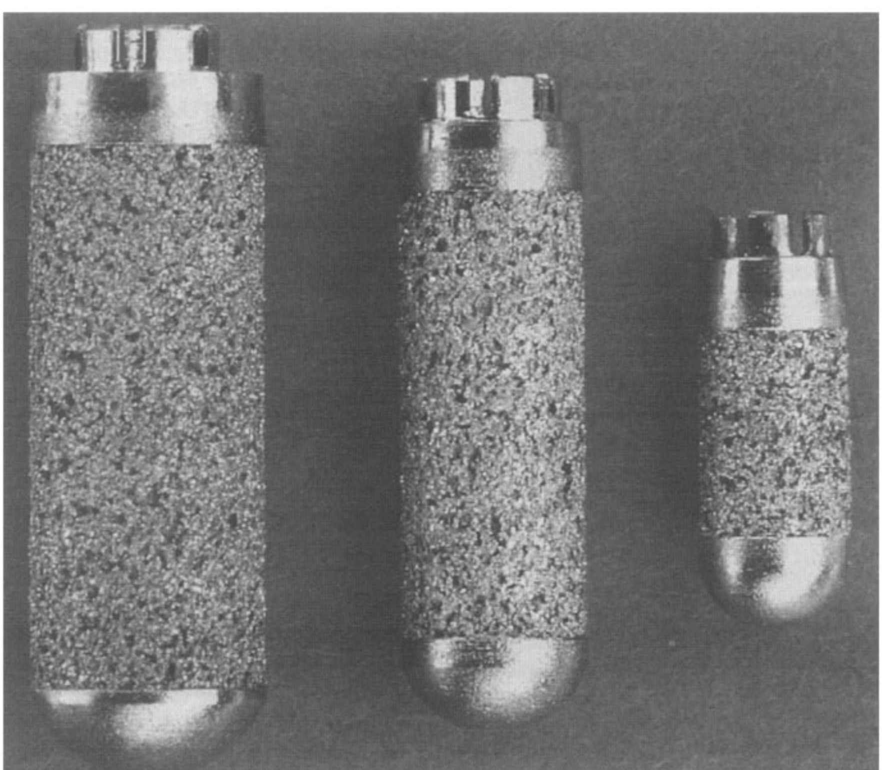

Fig. 1 The recently introduced CSTi dental implants are available in diameters of 3.25, 4.0, and 5.0 mm.

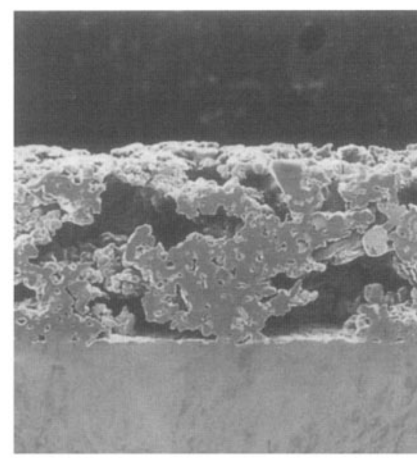

Fig. 2 Cross section of CSTi coating at 200× magnification, revealing the ample void space to accommodate bone ingrowth.

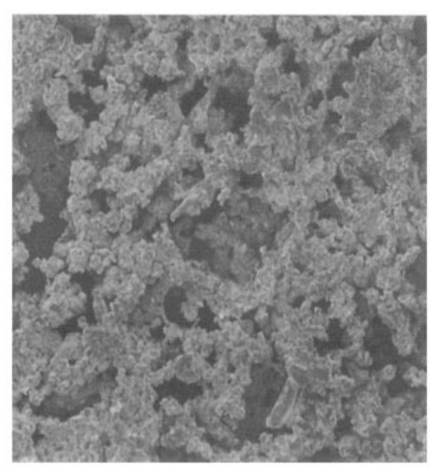

Fig. 3 Surface of cancellous structured titanium coating at 200× magnification, showing random pore shapes and sizes

bone ingrowth, the goal of mechanical interlocking between implant and bone is achieved. The ingrowth process leads to a very strong connection between implant and bone. Albeit not immediate, mechanical fixation is established in less than one month. Animal studies have shown that CSTi-coated dental implants integrate at an equal or faster rate than HA-coated cylinder implants. (Note: Results from animal studies cannot be directly correlated with human clinical results.)

Extensive Adaptation to Dental Needs

The CSTi dental implant is the result of a four-year collaboration between Sulzer Calcitek and Sulzer Orthopedics Inc. The latter has used CSTi coatings for more than ten years on hip, knee, and shoulder implants. The orthopedic and dental coatings are both made of sintered titanium powder, but are quite dissimilar in other respects. The dental implant coating is significantly thinner than the orthopedic coating, requiring new formulations and manufacturing techniques. The two companies continue to work together closely in the areas of manufacturing, testing, and quality assurance.

FDA Approval Granted

In Feb 1998, Sulzer Calcitek gained permission by the U.S. Food and Drug Administration to market the CSTi implant. The initial introduction of the CSTi implant is being limited to a select number of sites as part of a program to document its performance. Clinicians participating in the limited market release are Dr. Joseph P. Fiorellini (Harvard University), Dr. Denis P. Tarnow (New York University), and Dr. Michael A. Pikos (Coastal Jaw Surgery, Palm Harbor, FL). The first human CSTi implantation was performed by Dr. Pikos in Aug 1997 (Fig. 5). Figure 6 shows an x-ray of the patient after placement of a second implant. Broader availability of the enhanced coating is anticipated upon completion of this introductory phase.

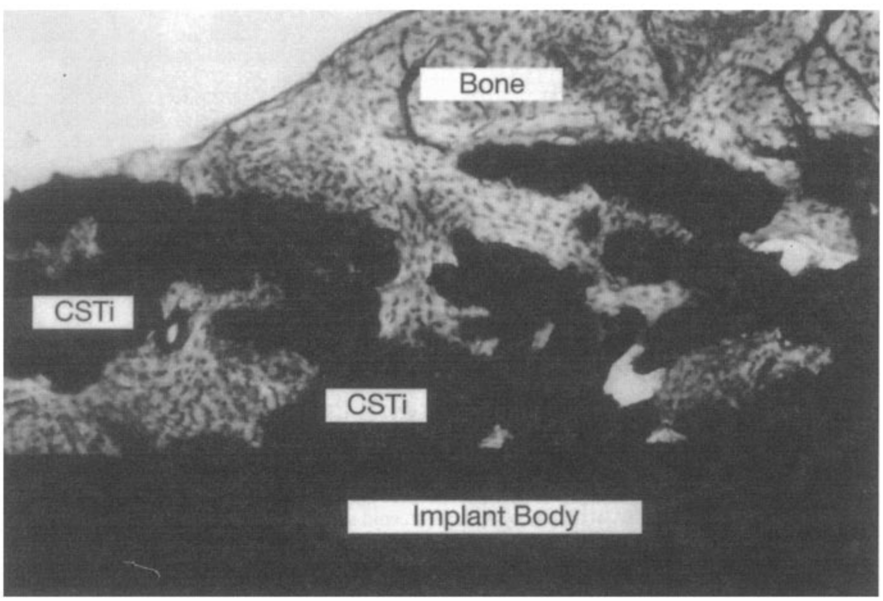

Fig. 4 This implant was retrieved from a canine mandible four weeks after implantation. Note the high degree of bone ingrowth.

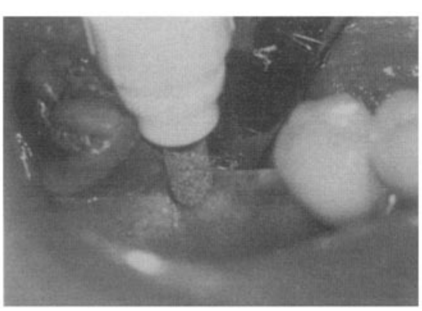

Fig. 5 Aug 1997 marked the first implantation of the new CSTi porous coated dental implant into a human patient.

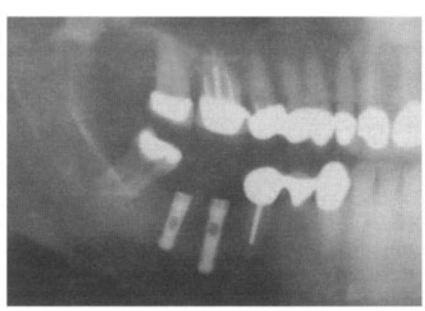

Fig. 6 X-ray of the first human CSTi patient showing two 3.25 mm CSTi implants in the mandible

Contact: Brooks J. Story, Sulzer Calcitek Inc., 2320 Faraday Avenue, Carlsbad, CA 92008-7216; tel: 760/431-9515; fax: 760/431-7811; e-mail: brooksjstory@juno.com.

Article by B.J. Story and W.R. Wagner, *Sulzer Tech. Rev.*, Jan 1998, p 38-40.

Sulzer Technology for China

In some cases, the Yellow River transports more than a half a ton of sand per cubic meter of water during the wet season. This causes excessive abrasion damage to the turbine runners of hydroelectric power stations. The service life of components susceptible to wear can be extended considerably through the application of ceramic coatings. For this purpose, Sulzer Hydro has signed a joint venture with the China North West Electric Power Company in Xian for the coating of water turbine parts that are exposed to wear. The know-how of Sulzer Metco will also be put to good use thereby. The Chinese company operates ten hydroelectric plants on the Yellow River and its tributaries.

The signing of the contract was preceded by joint research activities which indicated the high effectiveness of the selected technology. The choice of suitable types of coating is based on an exact analysis of the wear problems of the affected plant. The high level of hardness of the ceramic coating, combined with an optimized microstructure, extends the service life of turbine blades by a factor of two to three. This enhances the availability of the plants and reduces the costs of the operator.

Excerpted from *Sulzer Tech. Rev.*, Jan 1998, p 43.

Rebuild Instead of Overhaul Pays Off

When all four turbines of the power station at Birsfelden (Switzerland) are modernized in June 1999, 4.2% more electricity will be generated. That is just one reason why rebuilding is a sound investment for Kraftwerk Birsfelden AG. However, just as important, optimized collaboration between client and contractor enables the rebuild time to be shortened from 160 to 148 weeks, preventing a production loss of more than 30 million kWh.

In this rebuilding procedure, the same machine used for turning out the discharge ring is also employed at Birsfelden for coating. After preliminary machining of the ring, a layer of CrNi steel (Metcoloy 2) 4 to 5 mm thick is sprayed onto the base material. Final machining still leaves a coating about 3.5 mm thick. The layer deposited in this way is homogeneous and oxide-free. The selected coating material has been used with success for some time now in Switzerland and abroad. At Birsfelden a first inspection after a year of operation revealed no signs of abrasion or cavitation on the discharge ring.

Contact: Walter Scherer, Sulzer Hydro AG, Postfach, CH-6011 Kriens, Switzerland; tel: 41 0 41 329 5440; fax: 41 0 41 329 5165; e-mail: walter.scherer@sulzer.ch.

Excerpted from article by Markus Rothenfluh and Walter Scherer, *Sulzer Tech. Rev.*, Jan 1998, p 20-21.

News from ITSA and TSS

ASM Thermal Spray Society Celebrates Successful First Year of On-Line Discussion Group and Creation of New Speakers Directory

Sharing information and networking with colleagues is one of the reasons that the ASM Thermal Spray Society (TSS) has grown so rapidly since its founding in 1994. To help foster this exchange of information, TSS has a variety of services for members and nonmembers, including an on-line discussion group and a speakers directory.

On-Line Discussion Group

More than a year ago the TSS Information Development and Delivery Committee established an e-mail discussion group, known as a listserve. This year the discussion group has well over 300 subscribers from around the world, including Argentina, Australia, Belgium, China, Malaysia, New Zealand, Slovakia, and Sweden.

This discussion group has served as a forum for the exchange of thermal spray questions and issues.

"Internet e-mail has become a powerful communications tool, since it can cheaply distribute messages from around the world in a matter of seconds," said Bob Miller of TAFA Inc., chairman of the subcommittee set up to establish the list. "Via the listserve, we have seen a lively exchange of ideas on applications for thermal spray, coating, properties, equipment for sale, powder suppliers, positions wanted and job openings, calls for papers, and other news of interest to the community."

As one subscriber from Jakarta, Indonesia, stated, "We are living in critical times and every effort must pay off immediately. I have used the e-mail discussion list to find low price sources of equipment and materials, to learn the capabilities of arc spray for mold making and how to use an Al-Mg material instead of the expensive name brand materials. I have also received help with application development, such as chromium oxide coatings on alkaline battery compactor rolls."

The on-line discussion group is open to TSS members and nonmembers. Getting involved in this free service is easy. Simply send an e-mail to majordomo@databack.com with the message text **Subscribe TSS.** You will quickly receive information about the list and be eligible to take part in the discussions. To post a message to the group, send an e-mail to TSS@databack.com with the text of your message. It will instantaneously be forwarded to everyone in the group for their comments.

ASM Thermal Spray Society Elects New Board Members

The ASM Thermal Spray Society (TSS) and its president, Robert C. Tucker, Jr., corporate fellow and director of business development, Praxair Surface Technologies, have announced the reelection of three members of the TSS Executive Board:

- **Christopher C. Berndt,** FASM, Professor, Department of Materials Science & Engineering, SUNY at Stony Brook, NY
- **Albert Kay,** President, ASB Industries, Barberton, OH
- **Andrew R. Nicoll,** FASM, Marketing Europe and Global Segment Specialist, Sulzer Metco Holding AG, Switzerland

"Our congratulations to each of them," Tucker said. "All three have made significant and sustained efforts over the years on behalf of the ASM Thermal Spray Society and the thermal spray industry as a whole. We look forward to their continued enthusiasm and contributions in years to come."

The ASM Thermal Spray Society is an affiliate society of ASM International. Its purpose is to be the leading member-driven, international society for thermal spray to foster communication, information development, technology advancement, education, and scientific understanding.

ITSA Welcomes Three New Members

ITSA welcomes a new regular member, brought on board by Lloyd Johannesen of Alloys Sales: Kudu Industries of Calgary, Alberta, Canada. G. Edward Standing will represent the company to ITSA. Kudu, with 20% of their activity in thermal spray, is a manufacturer of oil well pumps. They specialize in the PCP (progressive cavity pump), which offers some important advantages over the conventional beam pump used in that industry. Kudu uses wear-resistant coatings on the impeller shaft, which enables the pumps to move more foil-laden oil at a higher rate of speed. Established in 1989, they now operate three branches—two in Canada, one in Ventura, CA.

Thanks to the efforts of Scott Goodspeed, we are happy to welcome back Bay State Sterling of Massachusetts, formerly Bay State Abrasives, who has reactivated their membership.

Marc Froning reports that two additional membership applications are presently on the ITSA ballot for approval: a research associate member sponsored by

Joseph Stricker: CPPM of Drexel University, which will be represented by Richard Knight, and a regular member sponsored by Charles Kay: Heany Industries of New York which will be represented by Charles Aldridge.

ITSA Power Meeting in Hawaii

ITSA's meeting at the beautiful Maui Mariott Resort was a power event from all points of view and probably one of the best-attended Hawaiian events held. Not only were the business sessions extremely productive, the golfing, beach, and leisure programs offered some refreshing diversions—attendees came face-to-face with dozens of friendly, frolicking whales while snorkeling in a volcanic crater, enjoyed superb dining overlooking the Maui beaches, or simply enjoyed chatting with friends in the welcome warmth and sunshine of Maui.

The generally upbeat business climate reported by our members received an added boost with some extremely valuable presentations. One of the highlights of the sessions was a challenge put forth to ITSA members by Marc Froning of Engelhard. Marc proposed that ITSA assume the industry responsibility for a Standards Committee that would document applications and establish standards for thermal spray as an alternative to chrome plating, then compile the material in a format that could be used by industry.

Mark has begun work with his homologue in TSS to research this project and emphasizes that, "If we can put this kind of information in front of buyers, we should be able to establish a profitable new market niche for thermal spray." Other excellent presentations were given by Jim Ryan of AIM, Terry Lester of Metallisation, Howard Waller of Norton, Scott Goodspeed of Praxair, and Ed Simonds of Sulzer-Metco.

ITSA Scholarship Program Changes

The ITSA scholarship program, established in 1992, has been responsible, in part, for bringing talented young people into the mainstream of the thermal spray industry where increasingly high levels of technical expertise are a requirement. To broaden that program, Scholarship & Award Program Chairman John Read proposed, and the Board agreed, that in 1998 ITSA will issue two $1500 scholarships (rather than three) and divide the third scholarship into three $500 awards for outstanding undergraduate research papers. In another move to broaden our program, John has asked members to send him names of universities with thermal spray programs that offer good potential candidates for ITSA programs.

New TSS/ITSA Speakers Directory

The International Thermal Spray Association and the ASM Thermal Spray Society are proud to announce the creation of a joint Speakers Directory. The goal of ITSA and TSS is to increase understanding and education of the thermal spray industry by promoting this joint compilation of speakers. The Thermal Spray Speakers Directory is a valuable resource in finding a qualified industry expert to speak to your company or organization. Drawing from the combined TSS and ITSA membership provides a diversified network of speakers from a variety of thermal spray professions—conveniently located throughout the United States.

Society Overview

- ASM Thermal Spray Society: Dr. Robert C. Tucker, Jr.
- International Thermal Spray Association: Mr. Joseph P. Stricker

Applications

General Applications

- Mr. Robert Debolt
- Mr. Daren Gansert
- Mr. Greg Klumb
- Mr. Gary Ritchie
- Dr. Ronald W. Smith

Industry Focused Problems and Solutions Using Coatings

- Dr. Robert C. Tucker, Jr.

Onsite Applications

- Mr. Jimmy Walker
- Mr. James Spinella

Plasma Spray Forming

- Dr. Ronald W. Smith

Thermal Barrier Coatings

- Dr. William J. Brindley

Thermal Spray for Industry

- Mr. Albert Kay
- Mr. Charles M. Kay
- Mr. John Lindeman

Thermal Spray in the Automotive Industry

- Dr. Robert C. McCune

Coatings Properties

Coatings Properties/Structure Relationships

- Dr. Robert C. Tucker, Jr.

Coatings Research & Development

Thermal Spray Research and Development

- Prof. Christopher Berndt

Processes

Introduction to Cold Spray Processing

- Dr. Robert C. McCune

Metal Powders for Thermal Spray

- Mr. Richard Mason

Modern Coating Materials for HVOF and Arc Spray

- Mr. Robert A. Miller

Powder Technology for Thermal Spray

- Dr. Ronald W. Smith

Surface Engineering

- Dr. Robert C. McCune
- Dr. Robert C. Tucker, Jr.

Thermal Spray Processes

- Mr. Gary Irons
- Dr. Richard Knight
- Mr. David Lee
- Dr. Robert C. Tucker, Jr.
- Mr. Walter A. Zanchuk

Thermal Spray Technology

- Mr. Daryl E. Crawmer
- Dr. Ronald W. Smith
- Mr. James Spinella
- Mr. Jimmy Walker
- Mr. Walter A. Zanchuk

Treatment of Waste & Chemical Synthesis

- Dr. Richard Knight

Contact: Kathy M. Dusa, TSS administrative assistant; tel: 800/336-5152, ext. 5544 (U.S. and Canada), or 440/338-5151, ext. 5544; fax: 440/338-4634; e-mail: KMDusa@po.asm-intl.org.

Discussion Topics and Threads on Thermal Spray

These questions and answers were extracted from the discussion group of the Thermal Spray Society of ASM International. During the three months of activity that were used to collate this summary, some 350 e-mails were submitted for discussion and comments. The content has been edited for form and content. Note that the comments have not been reviewed. Any further discussion can be submitted to the Editor of JTST.

Question 1

Differences in thermal expansion of ceramic versus the metallic substrates. We have often repaired or fabricated sleeves of stainless steel (SS) and protected them with a chromium oxide coating. I am surprised that the difference of expansion of the chromium oxide and the SS substrate (or even Al for other applications) does not cause coating cracking. During operation the parts reach temperatures up to 200 °C. Can someone explain why the ceramic coatings do not crack or delaminate, de-bond?

Answer 1.1: The main reason is the porosity of the coating. The thermally generated strain is much lower for a coating that it would be for a dense ceramic due to the presence of pore.

Answer 1.2: This question implies that a dense HVOF coating of less than 1% porosity is doomed for failure if used in high working temperature. Depending on the percentage the Co matrix, the coefficient of expansion could be more than 100% that of the substrate, but there are many successful applications of HVOF-WC-Co coatings such as for turbine shafts, etc. I believe the rate of temperature change and bond strength contribute to a successful coating.

Answer 1.3: The compensation of differences in the coefficients of thermal expansion is one of the great advantages of pores (along with being microstructural reservoirs for lubricants). It is possible to apply coatings with almost no porosity, but it would be necessary to match expansion coefficients or, where applicable, use multiphase coatings.

Answer 1.4: The application of a thermal spray coating on any variety of substrate will create stresses of compression or tension, all of which will need to be overcome by bonding strength. Application procedures are designed to minimize such stresses, sometimes successfully, sometimes not, and this results in spalling.

Question 2

Nomenclature for coatings. When referring to a coating that was applied by the process of thermal spraying, would you call this: A, thermal spray coating; B, thermally sprayed coating; C, thermo spray coating; D, other. What would be the reason for your choice, and is there a difference between American and European (British) English in this respect?

Answer 2.1: In my opinion only A and B are applicable.

Answer 2.2: Both A and B appear applicable; however ASM has a glossary of thermal spray terms and definitions at the following address: http://www.asm-intl.org/tss/glossary/t.htm The definition given is: "Thermal Spraying (THSP). A group of processes in which finely divided metallic or nonmetallic surfacing materials are deposited in a molten or semimolten condition on a substrate to form a spray deposit. The surfacing material may be in the form of powder, rod, cord, or wire. *See also* Arc Spraying, Flame Spraying, and Plasma Spraying."

Answer 2.3: I believe the term ThermoSpray was a term used by Metco to define their powder combustion spray process. You can find this term being used in the Metco Flame Spray Handbooks. The term ThermoSpray was and may still be owned by Metco.

Answer 2.4: People in the U.K. generally prefer "Thermal Spraying" and "Thermally Sprayed Coating."

Answer 2.5: I believe it should be alternative D (i.e., other); e.g., thermal sprayed coating. You are talking about a process in its past tense. Thermo spray was a term used by Metco to refer to there combustion guns (5-PII and 6-PII Thermo spray guns).

Question 3

How to deposit a wear-resistant coating for carbon/epoxy.

Answer 3.1: It is difficult to overlay a ceramic coating on carbon/epoxy tubes by thermal spraying processes. Thermal spray will burn out carbon/epoxy tubes. An alternative method is mixing ceramic powder in epoxy and paint this onto the tubes. You can change the percentage of ceramic powder to change the hardness of the overlay coating.

Question 4

What is the effect of an aluminized layer? I have several questions regarding the effect of an aluminized layer on a Mar-M-002 superalloy substrate during vacuum plasma spraying.

I have measured the substrate temperature during the "sputter cleaning" process, and have noticed that the aluminized substrate can reach temperatures that are significantly higher than temperatures reached by the Non-aluminized substrate—about 700° versus 800°. Can anyone tell me why? Is the transferred arc finding more oxides on the surface?

Can anyone give me any information on the thermal conductivity of Mar-M-002 and the aluminized layer?

Answer 4.1: This is an interesting observation. You surmise that for the aluminized surface the reverse transferred-arc attachment (with the workpiece as the electron-emitting cathode) may have more oxide to work with, which will result in more heat input to the part. One way to verify such behavior would be to compare the values of the cathode fall voltage and/or work function for the two conditions to determine whether more energy is being dissipated at the workpiece surface in the case of the aluminized layer.

Question 5

Recondition eroded stationary turbine blades using HVOF. Does anybody have experiences in reconditioning eroded steam turbine blades using HVOF thermal spray?

Answer 5.1: I have had experience in using HVOF to restore dimensions of corroded gas turbine stators. I choose the same superalloy powder as the restored stator base materials. They performed well after 20,000 operating hours.

Answer 5.2: There has been no prior work that I know of where anybody has substantially and structurally repaired turbine blades using a coating process. Surface restoration and enhancement has been accomplished, but due to the bond and interparticle strength limitations of thermally sprayed coatings, no significant dimensional restoration work has been done. Turbine blades are typically highly loaded components, both statically and dynamically, and whatever repair process is used must be able to handle this load. Coatings, as we know them today, are not capable of meeting the structural integrity requirements of a blade repair.

Answer 5.3: Thank you so much to everyone who has kindly responded to my query. Someone has pointed out that HVOF coating may not be applicable to this kind of job, depending on the degree of erosion. I have not seen the eroded blade by myself, but from the photograph I am sure that the damage is 1 to 2 mm. Someone has suggested that this could be repaired by sand blasting and then applying a HVOF coating of some Ti alloy over the blade surface. The approximate thickness is 0.6 to 0.8 mm.

Answer 5.4: Companies such as GE, Mitsubishi, Siemens, and ABB use foil brazing.

Answer 5.5: It all depends on the degree of erosion. Sometimes it is necessary to cut the eroded section and weld a new one. Foil brazing is also used for stellite strips. In your case, the erosion is too deep for the spray process to be effective. We use laser processing in such cases.

Answer 5.6: Has anybody considered using HVOF to apply a blend of braze alloy and parent material to the blade, then putting the part through a braze cycle?

Answer 5.7: Depending on the material thickness to be restored, friction surfacing may be a better option than HVOF. This is a similar technology to friction welding, with the exception that a rotating "filler material" is traversed across the area to be repaired. It is a solid-phase process producing fine-grained, forged microstructures that often have superior mechanical properties to the parent material. The "filler material" composition can be closely matched to the parent. I know that this process has been successfully applied to Rolls Royce turbine blades in the past.

Question 6

Coating problem in an inside diameter. I have a problem in the following coating application. I'm spraying 14 in. deep on a 17 in. I.D. The spray area is about 0.5 in. There is a ledge at the bottom of the spray area that protrudes about 0.050 in. Often I have to apply a coating to both the diameter and the ledge. The coating material is NiAl. We've tried different angles and distances. I'm locked into a process, but have played with the power and gas velocity somewhat. I'd love to apply this coating with an arc gun, but I have to get over this hurdle first. The problem is that I have chipping on the ledge. The solution might lie in the deburring process. I've since found out that our deburring team digs into the coating with rotating disks. This process puts the coating into tension and compression. Pulling on that tiny area might be more than the coating can stand. We are looking at the deburring prior to masking and spraying. Having to spray a part four times makes you think. We might also have a burr on the end of the ledge.

Answer 6.1: I have experienced a similar delamination problem on a short length, large O.D. and adjacent surface. After many years of frustration, it seems that the overspray buildup on the masking had the same effect as excess coating thickness, since the area of overspray was greater than the area we were coating. Re-masking and/or removing the overspray from the tape halfway through the coating cycle has made this problem go away.

Answer 6.2: I appreciate your solution. The adjacent surface might just be suffering from too much material and excess overspray. Removing the overspray by machining is not possible, the parts are usually out of round. But I will get in midway through the cycle and clean the overspray from the ledge.

Question 7

Low-rate vacuum plasma spray. Is there any commercially available VPS that can deposit at very low rates, such as 0.1 to 1.0 g/min of copper? If not, what is the minimum deposition rate available?

Answer 7.1: Powder feed rate is not indicative of a thermal spray process. Powder feed rate is dependent upon setup of the powder feeder, careful calibration of the powder feeder, and powder gas flow rate. Optimized feed rates can be established, however, probably not less than 5 g/min, for most of the commercially available powder feeders.

Answer 7.2: In my experience, I have used a Hi-T Drive Servo actuator powder feeder (Plasma Giken Co., Ltd., Japan), in which the powder particles were agitated by a mechanical stirrer and conveyed by the drive disk to the "escape" orifice, where the carrier gas transported the particles through a narrow line to the injector probe (I was engaged in induction plasma process). The parameter of mean powder feed rate was mainly determined by the rotating velocity of the drive disk. At a velocity of 3 rpm and 5 L/min of Ar as the carrier gas, the powder delivery capacity was measured at about 1.6 to ~1.7 cm^3/min. I often used it at the conditions of 1 rpm, even 0.5 rpm to get the low feed rate. Here in the U.S., Sulzer-Metco can provide this type of feeder (Twin-10 Compact Feeder).

Answer 7.3: You can obtain the same effect with the Praxair powder feeder.

Question 8

Rough WC coating required. We have been asked to refurbish a traction roll that is used in the paper industry. The OEM specifies a 0.15 mm WC coating of Ra 18. The roll runs dry, so corrosion is not an issue. The coating has the appearance of a thermal spray plasma coating, but it was not possible to remove a sample for metallographical evaluation. Looking at the powder suppliers brochures, I have identified the following plasma coatings as possible candidates for use with our Metco 9MB: Praxair 1102 or WC-104, METCO Amdry 5670. Has anybody used any of these coatings for a similar application, how did they perform, and what are the expected Ra values? Are there other potentially suitable coatings that I have not identified?

Answer 8.1: Wouldn't this coating be better applied with a flame spray torch? I don't have the parameters, but one can get a very rough coating with a 6P. The spray rates are high, so you can put the material down more quickly and economically.

Answer 8.2: Ti-di-boride or a WC-Co20% powder has been used for several years with good results. It is applied with flame spray equipment. The cost of the material (Ti-di-boride) is not expensive. Plasma & HVOF using WC/Co is a more expensive way of doing it and also works well.

Question 9

Definition of the HVOF process. What are the technical defining factors necessary for a system to be classified as HVOF?

Answer 9.1: The following key points need to be identified for a HVOF system:

- Internal, pressurized combustion of some kind (there are various designs)
- Gas pressures, flow rates and velocities significantly higher than in a conventional oxyacetylene type torch/flame
- An extended heating zone (3 to 9 in.) in which particulate (powder) materials are heated (melted or softened) and accelerated to velocities of several hundred, even more than 1000 m/s
- Supersonic gas flows, generally evidenced by "shock diamonds" visible as the (under expanded) jet exits the nozzle

There are several "review" type papers in the literature (*Journal of Thermal Spray Technology, The Welding Journal*) that would help explain things in more detail.

Question 10

How to chemically remove a hardface material. I am trying to remove Metco 45VF from Hastelloy X. Due to the thin wall thickness I am unable to use the recommended waterjet method alone. Does anyone know of any chemical that will reduce the bond strength of this coating to the point where I can blast it off without causing blow out? 45VF is 56% Co, 10.5% Ni, 25.5% Cr, 7.5% W, 0.5% C. Our experience with waterjet is that any weakness in our base material will lead to structural failure when the waterjet is applied at the settings required to remove the "as applied" 45VF.

Answer 10.1: Is there any way you can machine most of the coating off? When we have a failure of this coating, we machine the coating and if anything is left over, we just grit blast until the residue is removed.

Answer 10.2: Is it possible to strip the coating by a chemical method? What is the substrate material?

Answer 10.3: For some thermal sprayed carbide coatings, heat treating in air at a higher temperature causes de-carburization, thus making the coating softer and easy to remove by grit blasting.

Question 11

Plasma Sprayed $YBa_2Cu_3O_7$. Does anyone know of reference material for plasma sprayed $YBa_2Cu_3O_7$?

Answer 11.1: There were papers in the Proceedings of the 1988 National Thermal Spray conference (Cincinnati), D.L. Houck, Ed., TMS, for example, Glowacki et al., "Microstructure and Critical Current Characteristics in High T_c Superconductors Produced by Vacuum Plasma Spraying," p 191-196.

Question 12

Particle velocity, 9 MB torch. Can anyone tell me the general velocity (m/s) of particles (say 50 μm size) within the plasma plume created by a Metco 9MB torch? Any material would do, i.e., alumina, Ni-Al, WC-Co. Or, can anyone direct me to a conference paper (preferably from an ASM conference proceedings) that could enlighten me regarding the above questions.

Answer 12.1: The question cannot be answered in its present form. The particle velocity V_p depends on the plasma gas velocity V_g, the spray distance, the kinematic viscosity of the plasma v, plasma density r_g, particle density r_p, dwell time t, particle diameter d_p, and about another dozen of plasma parameters. The plasma gas velocity itself is a function of the plasma power, the nozzle configuration, the spray distance etc. A rough estimation of V_p is as follows:

$$V_p = V_g\{1 - \exp[18\, v\, r_g\, t/(d_p^2\, r_p)]\} \quad \text{for } Re < 1$$

and

$$V_p = [V_g t]/t^* + t;\ t^* = 4\, d_p\, v/3\, C(D)\, r_p \quad \text{for Re} > 2$$

where C_D = drag coefficient.

Answer 12.2: We are distributing/selling an optical sensing device specifically developed to monitor thermal spraying processes that may be helpful to you. The system named the DPV 2000 performs in flight diagnostics on individual particles as well as intensity profiling of the particle plume. It provides precise, reliable, and reproducible temperature, velocity, and diameter measurements of up to 125 p/s.

Question 13

Advanced materials for HVOF. I am examining hard carbides (initially WC, but later TiC and others and also carbonitrides) with intermetallic binders having greater hardness, toughness, and corrosion properties than the traditional cobalt and nickel etc. for HVOF thermal spraying. I would like to ask the group whether there is a large enough market for such advanced materials. Also, assuming that the physical and mechanical properties were significantly better, would people in the thermal spray industry actually pay more for these materials or be content with an inferior product?

Answer 13.1: Customers are all original-equipment-manufacturers, and, to a man, they'll be interested only if it is less expensive than existing coatings. Could you possibly come up with an iron-base coating that has the same properties as a cobalt-base or nickel-base coating?

Answer 13.2: If you achieve your objective then you must be able to finish the coating since thermal spray is only part of the complete process. In several wear applications, the better the finish, the better the wear resistance. If your new materials are to be harder, then you will also need to consider the cost of finishing. This is where TiN has an advantage since it is only microns thick and does not need finishing. I also suggest that you consider AlN as this is a great dielectric and thermal conductor.

Answer 13.3: How can I get some information on the thermal/mechanical properties of coatings sprayed with your powders? I have performed some work on similar materials, but for laser cladding applications. We used WC, Cr_3C_2, and TiC with several intermetallic materials.

Answer 13.4: What are some of those applications for AlN ? I appreciate that it is used as a heat spreader for electronic packaging, but how would thermal spraying be employed? Would a thermal spray coating of AlN be used to replace the bulk AlN used for the packaging application, and if so, what advantages would it offer over the bulk AlN used presently?

Answer 13.5: AlN is certainly one material that hopefully will be examined during this project. The basis for this research is on the particular synthesis method of the materials that employs an advanced ball milling technique that can produce very easily and cheaply nanocrystalline AlN. In fact, the special technique holds terrific promise for mechanical alloying and can produce nanocrystalline or amorphous microstructures in the materials that it mills.

Answer 13.6: A great deal of work has been performed on alternative carbide systems. The challenge for a new material—that does not result in a significant direct cost reduction based on material cost—is to first overcome the resistance to changing a proven material in an important application due to the risk involved and then to justify the cost of running tests to verify the improved performance in a specific application. Hardly anyone will change to a new material based on laboratory results, so actual application tests are needed. The best routes to introducing a new material are (1) to find applications where existing materials are not providing the required performance and aim the research at solving these specific problems or (2) to get the new material involved during the design or prototype stage of a new product that requires a coating. Another good approach is to get a material producer involved in the early stages of development as they usually have better contacts with potential users. In all cases, keep the benefit-to-cost ratio in mind and compare your new developments with existing ones. In spite of these difficulties, opportunities do exist for new materials that are cost-effective solutions to industrial problems.

Answer 13.7: There are quite a few cases of abrasion associated with corrosion and/or high temperatures in industry. They are now attended in a less then totally satisfactory way, both from a technical and an economical point of view. The old, but often misused, argument "a little more expensive, but much lower operation costs" is still valid, but costs, both initial (investment) and operational (per unit produced) are what counts. Agglomeration, spray drying, and crushing usually are economically feasible even in relatively small lots of, say a few hundred to a few thousand pounds, so there should be no problem to find an initial market that can be expanded later. Experiments with 20 or 50 lb usually can be performed, but with lab equipment or at considerable costs for changing parameters and cleaning equipment. Very careful screening is necessary.

Question 14

Corrosion of HVOF coatings. As a thermal spray company specializing in HVOF spraying, we are looking for experiences of HVOF spraying in tanks, vessels etc. The specific problem we are confronted with is corrosion-erosion in a sulfolane regenerator vessel made of carbon steel. The bottom section where liquid particles enter the vessel with a velocity of 7 m/s is corroded and eroded. The customer wants to know if an HVOF coating of the vessel, or of blind plates that would be welded in the vessel, is possible?

Question 15

Source for SiAlON feedstock. Does anyone know of a source of SiAlON-based powders with diameter 10 to 40 μm suitable for plasma spraying?

Question 16

Statistical methods for thermal spray. There are many papers in the literature describing statistical methods for optimizing thermal spray processes, e.g., Taguchi methods. Who has experience with statistical methods for production? Who knows where to buy the PC-software, like ANOVA?

Answer 16.1: There are numerous statistical software packages available that can handle the appropriate analyses for optimizing thermal spray processes. Statgraphcis, Sigmastat, RS1, and Minitab are just a few of the packages available. These packages are not substitutes for a knowledge of statistics, but they do offer the means to analyze well-designed experiments quickly. The analyses take a substantial amount of time to perform without the computer programs. I believe that several of these packages address Taguchi methods. However, Taguchi analysis is not the best method for optimizing thermal spray or other processes. Taguchi analysis is an analysis to determine how robust a process is and which parameters require more, or less, control. One thing Taguchi is very helpful with is determining an operational space where your product would be least sensitive to variations in the process. More traditional statistics approaches are more appropriate for optimizing a process. Factorial experiments, as described in all Statistics texts, can be designed to provide the information you need to optimize most processes on the major known variables. The experiment design process is, however, not trivial. If you are unfamiliar with statistics, a good first step is to consult with a statistician to make sure your experiments are properly designed to provide sufficient valid information to be meaningful.

Question 17

Information on impact resistance coatings. I am looking for information on high impact/wear resistance coating. Several pieces (¼ to 1 in.) of cemented carbides are impacted with high velocity into a weld-overlay protected, steel block. This weld overlay fails after ~ 1 month of service with the disadvantage of costly repairs and downtime. Is there a spray coating that could possibly replace our current weld overlay system?

Question 18

Acid resistance of arc sprayed aluminum. I have a chimney that is made of mild steel. is chimney goes to a kiln. I am planning to coat the inside of this chimney with arc sprayed aluminum. During the curing process, rock salt is thrown into the kiln. As the rock salt decomposes, it forms a weak hydrochloric acid solution. The question I have is aluminum the proper material for this chimney or should I seek to use a stainless steel?

Answer 18.1: Aluminum and hydrochloric acid do not do well together. Depending on the temperatures involved, a material such as Hastelloy C-276 or D would work up to about 240 °F. Beyond that, tantalum and zirconium are good up to about 300 °F.

Answer 18.2: We use aluminum for a variety of mild acidic conditions with excellent results for heat protection and abrasion.

Answer 18.3: I have experienced success with aluminum in hydrochloric conditions of mild concentrations around coal areas without the need of using expensive alloys.

Answer 18.4: Aluminum fails fairly fast in chloride environments, but is relatively resistant to fluorination, oxidation, or aqueous corrosion below 300 °C. Nickel-base coatings or even stainless steel (e.g., 310) would be better choices.