In The News

New Literature

United Thermal Spray Conference Proceedings

Edited by C.C. Berndt, Jan 1998, ~1000 pages. $155.00 for non-ASM members, $124.00 for ASM/TSS members. ISBN: 0-87170-618-0.

More than 200 papers discuss the latest advances in thermal spray technology, including basic science, equipment, coating processes and properties, testing and characterization, and products and specifications. Section contents include: Infrastructure (equipment, corrosion, and characterization), Process Characterization, Product Development, Thermal Barrier and Oxidation Resistant Coatings, Residual Stress and Mechanical Properties, Structure/Property Relationships, and Aerospace/Transportation/Power Generation. Fully indexed according to author, keywords, and company affiliation.

Contact: ASM International; tel: 800/336-5152, ext. 5900; fax: 440/338-4634.

Damage Mechanics in Engineering Materials

Edited by G.Z. Voyiadjis, J.-W.W. Ju, and J.-L. Chaboche, Jan 1998, 546 pages. $235.00. ISBN: 0-08-043322-7.

This volume contains 30 papers based on the presentations made at the Symposium on the occasion of the Joint ASME/ASCE/SES Mechanics Conference held in Illinois in June/July 1997. The sessions are concentrated mainly on the constitutive modeling of damage mechanics of engineering materials. This volume contains papers representing work conducted on damage mechanics in engineering materials. It encompasses macromechanical/micromechanical constitutive modeling, experimental procedures and numerical modeling. You will find inelastic behavior, interfaces, damage, fracture, failure, and computational methods. The papers discuss topics ranging from theoretical treatments to experimental investigation and investigate both micromechanics and continuum aspects of damage in materials.

Contact: Elsevier Science, P.O. Box 882, New York, NY 10159-0882; tel: 212/633-3730, 888/437-4636; fax: 212/633-3680; e-mail: usinfo-f@elsevier.com.

Wear of Materials

Edited by D. Rigney and R.G. Bayer, April 1997, 740 pages. $281.00. ISBN: 0-08-042841-X.

This book presents the contributions to the Eleventh International Conference on Wear of Materials, where 1997 marked the 20th anniversary of the conference. In celebration, this publication contains a special review of the conference's history, including recollections from past chairpersons. In addition to an enlightening look at the conference's background, this volume presents 67 full papers along with 14 communications and case studies.

Contact: Elsevier Science, P.O. Box 882, New York, NY 10159-0882; tel: 212/633-3730, 888/437-4636; fax: 212/633-3680; e-mail: usinfo-f@elsevier.com.

Review of Progress in Quantitative Nondestructive Evaluation: Volume 16

Edited by D.O. Thompson and D.E. Chimenti, 1997, two volumes/2280 pages. $395.00 ($474.00 outside U.S. and Canada). ISBN: 0-306-45597-8.

Leading investigators working in government, industry, and academia present a broad spectrum of work extending from basic research to early engineering applications. In Part A of Volume 16 they detail the development of NDE techniques, covering such topics as: elastic waves, guided waves, eddy currents, radiation, and thermal techniques; acoustic emission, laser ultrasonics, optical methods, and microwaves; signal processing and image analysis, with an emphasis on interpretation for purposes of defect detection and characterization; and ultrasonic and electromagnetic NDE sensors. Part B addresses advances in materials characterization; engineered materials and composites, bonded joints, pipes, tubing, and biomedical material; linear and nonlinear properties, ultrasonic backscatter and microstructure, coatings and layers, residual stress texture, and construction materials; new inspection procedures, process control, and probability of detection; and ultrasonic, electromagnetic, and radiographic inspection systems.

Contact: Plenum Publishing Corporation, 233 Spring St., New York, NY 10013-1578; tel: 212/620-8047, 800/221-9369; fax: 212/807-1047.

Fracture Mechanics of Ceramics

Volume 11, *R-Curve Behavior, Toughness Determination, and Thermal Shock* and Volume 12, *Fatigue, Composites, and High Temperature Behavior,* Edited by R.C. Bradt, D.P.H. Hasselman, D. Munz, M. Sakai, and V.Ya. Shevchenko. Volume 11: 1996, 600 pages. $145.00 ($174.00 outside U.S. and Canada). ISBN: 0-306-45378-9. Volume 12: 602 pages, 1996. $145.00 ($174.00 outside U.S. and Canada) ISBN: 0-306-45379-7. Set price for Vol 11 and 12: $265.00 ($318.00 outside U.S. and Canada).

This book collects 90 contributions by more than 200 authors discussing the latest in the failure behavior of monolithic engineering and reinforced ceramics. The main topics are *R*-curve behavior, toughness determination, surface effects, composite materials, high-temperature behavior, ceramic-metal joints, and fatigue.

Contact: Plenum Publishing Corporation, 233 Spring St., New York, NY 10013-1578; tel: 212/620-8047, 800/221-9369; fax: 212/807-1047.

Protection of Steel with Thermal Sprayed Coatings

Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and their Alloys and Composites, American Welding Society, 1993, 30 pages. $33.00 ($19.80 for AWS members).

A guide to select, plan, and control thermal sprayed coatings for preservation of steel. Suitable for purchasers, architects, managers, supervisors, and contractors in construction, marine, railroad, fabrication, and repair industries. Features include:

- An easy selection guide for various service environments
- 9 critical quality control check points
- 11 important maintenance and repair steps
- 13 key tables; sample job control record
- Operator qualification and certification
- Step-by-step surface preparation and thermal spray application methods
- Debris containment and control instructions

A tool for any professional charged with analyzing desired service life, environmental envelope, operating duty, and maintenance and repair support for competitive bidding or internal cost containment.

Contact: American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33126; tel: 800/334-9353; fax: 305/443-7559.

ASM Handbook, Volume 20, *Materials Selection and Design*

ASM International, 1997, 900 pages. $160.00 ($128.00 for ASM members). ISBN: 0-87170-386-6.

Major sections are as follows:

- The Design Process describes methods for conceptual and configuration design and developing a product specification.
- Criteria and Concepts in Design discusses special design considerations including product liability, life-cycle analysis, optimizing product quality, safety, and liability.
- Design Tools provides an overview of current CAE tools used to provide design analysis guidance at different stages of the design process.
- The Materials Selection Process describes how to use materials-selection aids such as selection charts, performance indexes, decision matrices, and value analysis.
- Effects of Composition, Processing, and Structure on Materials Properties incorporates the fundamental structure-property relationships in engineering materials.
- Properties versus Performance of Materials covers applications-related design concepts as applied to real-world operating conditions.
- Manufacturing Aspects of Design provides information on modeling, cost estimating, and various manufacturing processes.

Contact: ASM International; tel: 800/336-5152, ext. 5900; fax: 440/338-4634.

Stress and Strain Measurement

Nontraditional Methods of Sensing Stress, Strain and Damage in Materials and Structures (STP 1318). Edited by G.F. Lucas and D.A. Stubbs, 1997, 231 pages. $52.00 ($47.00 ASTM Members). ISBN: 0-8031-2403-1.

This book deals with the advancement and development of innovative ways to evaluate material and structural fatigue and damage behavior. Experts in the field have presented 16 peer-reviewed papers in the following areas:

- Nontraditional Extensometer—three papers explore novel ways to measure point-to-point deformation or strain.
- Nontraditional Crack Measurement Technique—alternative methods for measuring crack length as well as stress-strain measurement and "damage" parameters are discussed in four papers.
- Optical, Non-Contacting Strain Measurement Devices—four papers examine optical methods of measuring both point-to-point and full field strains.
- Ultrasonic and Infrared Techniques—new and promising methods that do not rely on surface features are presented in five papers.

This is an important source for fatigue and fracture researchers and test engineers, biomaterials researchers, ceramics and composites researchers, and professionals in the aerospace and biomedical arenas.

Contact: ASTM Customer Service, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959; tel: 610/832-9585; fax: 610/832-9555; e-mail: service@astm.org.

Fatigue and Fracture

Applications of Continuum Damage Mechanics to Fatigue and Fracture (STP 1315). Edited by D.L. McDowell, Oct 1997, 245 pages. $114.00 ($103.00 ASTM Members). ISBN: 0-8031-2473-2.

This volume introduces state-of-the-art applications of damage mechanics to fatigue and fracture issues in broad classes of materials. Thirteen peer-reviewed papers from the world's leading researchers in the field cover the following areas:

- Damage Mechanics of Composites—six papers deal with varying aspects of modeling damage in composite materials.
- Distribution Effects and Homogenization—issues related to the scaling of effects of distributed damage on behavior at a higher length scale are explored in three papers.
- Local Approaches to Fatigue and Fracture—papers present application examples of continuum damage mechanics, including impact damage, particle erosion damage, and fracture of weldments.

Contact: ASTM Customer Service, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959; tel: 610/832-9585; fax: 610/832-9555; e-mail: service@astm.org.

CRC Handbook of Chemistry and Physics, 78th Edition

Edited by D.R. Lide and H.P.R. Frederikse, June 1997, 2512 pages. $119.00. ISBN: 0-8493-0478-4.

The latest edition of this popular scientific reference features new tables and sections on everything from aqueous solubility of organic compounds to flashpoint data of common substances. Along with the latest facts and figures, the handbook also contains almost all of the most frequently used data in science, including the periodic table of the elements, basic constants and units, and geophysical data. The most accurate and up-to-date information is ensured by critically evaluating the material, adding new data, and updating the existing tables every year.

Contact: CRC Press, 2000 Corporate Blvd., N.W., Boca Raton, FL 33431-9868; tel: 561/994-0555, 800/272-7737; fax: 800/374-3401; e-mail: orders @crcpress.com.

Databook on Fatigue Strength of Metallic Materials

Edited by K. Shiozawa and T. Sakai, 1996, 2574 pages (in 3 volumes). $593.75. ISBN: 0-444-82514-2.

This book is a compilation of the experimental data on fatigue strength of various materials and related information obtained over the last 30 years by many researchers working in universities, technical colleges, public research institutes, and the technical laboratories of industrial companies in Japan. It includes more than 3000 case studies of *S-N* type fatigue data of ferrous and nonferrous metals, which are presented numerically and in *S-N* and/or *P-N* diagrams. The book consists of three volumes. Volumes 1 and 2 contain numerical data of fatigue strength and Volume 3 the graphic presentations. All the data are grouped into fundamental sets of data, each of which contains the fatigue strength of a certain material under the same conditions and a key code consisting of contributors code and series number which is assigned to the respective data sets.

Contact: Elsevier Science, P.O. Box 882, New York, NY 10159-0882; tel: 212/633-3730, 888/437-4636; fax: 212/633-3680; e-mail: usinfo-f@elsevier.com.

What to Consider Before You Blow the Whistle

Suppression Stories, by B. Martin, 1997, 171 pages. $AUS20.00 (~$US15.00). ISBN: 0-646-0349-X. *Whistleblowers*, by Q. Dempster, 1997, 251 pages, $AUS16.95 (~$US12.00). ISBN: 0-7333-0504-0.

The issue of whistleblowing is explored in these books: *Whistleblowers* by Q. Dempster and *Suppression Stories* by B. Martin. As engineers we may sometimes witness unsafe, environmentally damaging or unethical practices in our workplaces. Most of us would probably like to get the situation rectified, perhaps by taking our concerns to management. But what if management refuses to take action, or worse still, responds by "shooting the messenger"? How many of us would then take the matter outside the company? For those who decide to "blow the whistle," the consequences can be devastating. Very few cases of suppression see the light of day. The typical reaction of those who come under attack from their organization's management is to hide their shame. This is because management's attack is rarely directed at the dissenter's views; instead the employee may be told that their work is unsatisfactory, their behavior is unacceptable, and so on. Understandably, many are too intimidated or afraid of losing their jobs or damaging their career prospects, to take the matter further.

Contact: EA Books, P.O. Box 588, Crows Nest, NSW 2065, Australia; tel: 61-2-9438-5355; fax: 61-2-9438-5343; e-mail: eabooks @eol.ieaust.org.au. (This short review has been adapted from one by A. Bunting and was originally published in *Engineers Australia*, Sept 1997, p 32.

Conference Information

2-5 June 1998, Düsseldorf, Germany

31st (ISATA) International Symposium on Automotive Technology and Automation

ISATA will present a new concept of hosting eight simultaneous programs, together with an exhibition. The eight program topics are:

- Automotive Mechatronics Design and Engineering
- Simulation, Virtual Reality and Supercomputing Automotive Applications
- Advanced Manufacturing in the Automotive Industry
- Materials for Energy-Efficient Vehicles
- Clean Power Sources and Fuels
- Automotive Electronics and New Products
- Logistics Management and Environmental Aspects
- Automotive Ergonomics and Safety

In addition to these program topics, special innovative conferences will be held on the following topics: Intelligent Transportation Systems and Telemetrics; Marketing, Vehicle Finance and Leasing; Cost and Innovation Management.

Contact: ISATA Düsseldorf Trade Fair, 32a Queen Street, Croydon, London, CRO 1SY, UK; tel: +44 181 681 3069; fax: +44 181 686 1490; e-mail: 100270.1263@compuserve.com; www: http://www.isata.com.

16-18 June 1998, Aachen, Germany

Fifth International Conference on Brazing, High-Temperature Brazing and Diffusion Bonding (LÖT '98)

The conference will bring together experts in the fields of engineering and research to identify: Industrial areas with high technical demands on quality and cost factors, technological highlights that can be transferred into industrial products, research and development efforts relevant for industrial application, new qualification methods, and materials, processes, and software. The following issues will be covered by the LÖT '98:

- Quality assurance and economic efficiency
- Applications of brazing and diffusion bonding
- Testing technology
- Repair brazing, laser beam brazing, coating by brazing, and design of brazing parts
- Combination of processing and joining technologies
- Ceramic brazing/joining of ceramics to metals
- Joining of light metals, joining of high-performance materials, and composite materials
- Fundamentals of brazing and diffusion bonding, modeling, and simulation

Contact: Deutscher Verband für Schweisstechnik e.V., Aachener Str. 172, D-40223 Düsseldorf, Germany; tel: +49 211-1591-0; fax: +49 211-1591-200.

5-11 July 1998, Las Vegas, Nevada

Fifth International Conference on Composite Engineering: ICCE/5

The major goals of ICCE/5 are:

- To bridge the gap between mechanics, materials science and processing of composites
- To encourage interactions between basic and applied composites research
- To bridge the gap between aerospace and infrastructures composites research

The following symposium will be highlighted:

- Aging and Durability
- Interface and Interphase
- Bio- or Dental Composites
- Joints and Adhesion Chemical Behavior
- Mathematical Modeling
- Ceramic Composites
- Micromechanics
- Computational Mechanics
- Nano-Materials
- Design and Optimization
- Optimization and Design
- Fiber Science
- Particulate Composites
- Fiber/Matrix Characterization
- Processing of MMC, CMC, PMC
- Functionally Gradient Materials
- Smart Composites
- General Applications
- Structural Dynamics
- Impact Damage
- Textile Composites
- Industrial Composites
- Vibration
- Infrastructure Composites
- Wave Propagation
- NDT

Contact: Dr. David Hui, University of New Orleans, Dept. of Mechanical Engineering, New Orleans, LA 70148; tel: 504/280-6652; fax: 504/280-5539; e-mail: dxhme@uno.edu; www: http://www.uno.edu/~engr/composites.html.

13-15 July 1998, Puerto Vallarta, Mexico

First ASM-HTS International Conference on Automotive Heat Treating

A global conference on various aspects of heat treating technology being presented from South America, North America, Europe, and Asia. This conference will provide a forum for interaction between manufacturing and engineering involved in automotive and related application technologies worldwide. This is the first of such conferences with followup conferences being held annually in Japan (1999), USA (2000), and Europe (2001).

The technical program will focus on issues of continuing interest and include the following areas:

- Heat Treating of Ferrous and Non-Ferrous Alloys
- Surface Treatments of Steels
- Equipment and Processes Prediction and Control of Distortion of Treated Parts
- Conservation of Energy and Environmental Concerns of Heat Treatment
- Property and Process Correlation
- Modeling and Simulation of Heat Treating Processes

Contact: Prof. Rafael Colas; e-mail: rcolas@ccr.dsi.uanl.mx; www: http://www.asm-intl.org.

31 August–2 September 1998, Lisbon, Portugal

Fourth European Conference on Composites (ECCM CTS-4)—Testing and Standardization

The European Association for Composite Materials, in association with the Composites Division of the Institute of Materials, is to stage the fourth conference in the series ECCM-CTS dedicated to the theory and practice of testing of composites and the development of established methods in Standards and Codes of Practice. The conference will address testing issues related to all classes of composites, irrespective of matrix. Polymer, metal ceramic, glass, and carbon-matrix composites all have their own specific testing issues.

Contact: Cathy Pearcey, Conference Department, Institute of Materials/EACM, 1 Carlton House Terrace, London SW1Y 5DB, UK; tel: +44 0171 839 4071; fax: +44 0171 839 1702; e-mail: Cathy_Pearcy@materials.org.uk.

7-9 September 1998, Taipei, Taiwan, R.O.C.

Taiwan International Welding Conference '98

The conference aims to promote direct exchange of achievements between the international experts in the welding technology area. Specific technical sessions will be organized, and papers are being solicited in the following topics: Advanced Welding Processes, Sensing, Control and Automation, High-Energy Density Processes, Resistance and Friction Stir Welding, Brazing and Soldering Applications, Micro-Joining Applications, Shipbuilding and

Heavy Manufacturing, Orbital Pipe and Tube Welding, Weldability Testing, Phase Transformation, Micro and Macro Structures, Welding Consumables, Joining of Advanced and Graded Materials, Surfacing and Cladding, Residual Stresses and Distortion, Advanced Methods for Steel Constructions, Fitness-for-Service Assessment Techniques, Qualification and Certification, Hazards Prevention for Colas Transmission Pipelines, Numerical Analysis and Modeling, and PC-Based Computer Software for Welding Applications.

Contact: Prof. Chon-Liang Tsai, Chairman, Technical Program Committee, Taiwan International Welding Conference (TIWC'98), The Ohio State University, 1971 Neil Ave., Columbus, OH 43210-1271; tel: 614/292-0522; fax: 614/292-7852; e-mail: tsai.1@osu.edu.

20-23 September 1998, Hotel Hyundai, Kyongju, Korea

The Third International Meeting of Pacific Rim Ceramic Societies

The list of programs are:

- Advanced Structural Oxide Ceramics
- Nonoxide Ceramics and Composites
- Advances in Zirconia-based Ceramics
- Advanced Ceramics Chemical Processing
- Refectories and Clay Products
- Advances in Cement-based Materials
- Dielectric and Piezoelectric Ceramics
- Advances in Ceramic Sensors
- Ferrite and Related Materials
- Ferroelectric Ceramics and Thin Films I: Theory, Phase Transition, and Structural Analysis
- Ferroelectric Ceramics and Thin Films II: Fabrication, Electrical Properties, and Devices
- Electronic/Energy-Related Ceramics
- Glasses and Bioceramics
- Environment Issues of Ceramics and Glasses
- Reactivity of Ceramic Materials
- Advances in Photonic Glasses
- Ceramic Enterprise around the Pacific Rim—Status and Opportunities
- Satellite Symposia: S1. The Fourth International Symposium on Interfaces of Ceramic Materials; S2. The Second Korea-Australia Joint Symposium; S3. The Korea-Italy Joint Symposium on Electronic Ceramics; S4. The 15th KACG Technical Meeting and Crystalline Particle Symposium (CPS); S5. The Fifth ISO TC 206 WG and Plenary Meetings. (Attendees are limited to delegations of ISO TC 206 member countries.)

Contact: Prof. Sang-Hee Cho, Secretary General, Pac Rim 3, Dept. of Inorganic Materials Engineering, Kyungpook National University, Taegu 702-701, Korea; tel: 82-53-950-6593; fax: 82-53-955-8179; e-mail: shcho@bh.kyungpook.ac.kr.

12-15 October 1998, Chicago, Illinois

Thermal Spray Symposia

The ASM Thermal Spray Society will cosponsor the 15th International Thermal Spray Conference (ITSC '98), 18-22 May 1998 at the Acropolis Convention Center in Nice, France. We would like to invite everyone involved in thermal spraying to attend this international event. In an effort to provide a U.S. forum for those in the thermal spray community who may not be able to attend ITSC '98, we are also organizing several symposia to be presented at the ASM Materials Solutions Conference, Chicago. These symposia will provide a forum for materials and design engineers, research manufacturers, suppliers, and users of thermal spraying to communicate and exchange information on the latest developments in thermal spray technology. Participants will share ideas, problems, and solutions aimed at increasing the awareness of the benefits of thermal spray coatings.

Symposia organizers are currently seeking 150-word abstracts describing a 25-minute presentation for possible inclusion in the technical program. Abstracts are solicited in, but not limited to the following areas:

Research and Technical Focus

- Modeling and Characteristics of Thermal Spray Processes, including HVOF, Plasma, Wire Arc, and Cold Gas Dynamic Spraying
- Thermal Spray Coatings: Structure, Characterization, and Properties
- Research on Thermal Spray Technology: Equipment, Consumables, and Processes
- Oxidation-Resistant and Thermal Barrier Coatings: Production, Characterization, and Properties

Industrial Applications Focus

- Thermal Spray Processes for the Automotive, Infrastructure (steel and concrete structures), and Power Generation Industries
- Thermal Spray Coatings for the Automotive, Infrastructure and Power Generation Industries
- New Applications ofThermal Spraying in the Automotive, Infrastructure and Power Generation Industries

Visit the ASM International Website at www.asm-intl.org, click on "Conferences and Education" and follow the instructions to prepare and submit your abstract on-line. You may also mail, fax, or e-mail your abstract as follows: Conference Coordinator—Materials Solutions '98, ASM International, 9639 Kinsman Rd., Materials Park, OH 44073-0002; fax: 440/338-4634; e-mail: Educatn~po.asm.intl.org.

Authors of accepted papers will be invited to submit a written paper for publication in a special issue of the *Journal of Thermal Spray Technology.* For further information on any aspect of this program, you may contact the ASM Education Department at 440/338-5473, or any of the following organizers: Mr. Paul Kammer, Chairman: fax: 718/445-1784; e-mail: 101760.2364@compuserve. com; Dr. Purush Sahoo: fax: 610/948-0811; e-mail: sermatech!limerick!Sahoo@tfx.attmail.com; Dr. Adil Ashary: fax: 317/240-2464; e-mail: aashary@ geof.psti. praxair.com; Dr. Robert Tucker, Jr.: fax: 317/240-2464; e-mail: rtucker~geof. psti.praxair.com.

15-20 November 1998, Miami Beach, Florida

Advanced Technologies for Particle Processing

This meeting includes four symposia distributed over 38 technical sessions, a workshop on emerging particle technologies, two tutorials on particle technology directed to industrial membership, the Particle Technology Forum

(PTF) Honors Dinner, a meeting with graduate students involved in particle technology, a student poster competition, meetings with representatives from other societies including those from abroad, as well as meetings of two PTF working groups on education and data bases. The symposia are:

- Advanced Technologies for Particle Production (Organizer: Prof. S. Pratsinis)
- Advanced Technologies for Fluid-Particle Systems (Organizer: Prof. H. Arastoopour)
- Advanced Technologies for Powder Mechanics (Organizer: Prof. N. Cristescu and Prof. T. Blake)
- Advanced Technologies for Particles in Environment (Organizer: Dr. Reg Davies and Prof. B. Moudgil)

The Conference has a unifying theme on advanced technologies in particle processing of interest to both industry and academe. More than half of the topics will attract participants from areas traditionally not covered by AIChE, e.g., aerosols, attrition and agglomeration, petroleum and petrochemical industry, pharmaceuticals, food processing, various areas of powder mechanics and powder storage, fine particles in environment. As in the previous PTF meetings, the quality of the participants will be ensured by inviting approximately half of the contributors. Joint sessions are planned with other AIChE divisions or groups: Fundamentals, Materials, Pharmaceutics, and Environment. Strong industry participation will be a main target of the Conference.

Technical sessions include:

Symposium A. Advanced Technologies for Particle Production

A1. Particle Synthesis in Dispersions and Supercritical Fluids

A2. Sol-Gel Synthesis of Particles

A3. Chemical Kinetics during Particle Formation

A4. In-situ Gas Diagnostics during Particle Formation

A5. Agglomerate Particle Dynamics

A6. Computational Fluid Dynamics during Particle Formation and Growth

A7. Aerosol Reactors

A8. Particle Charging

A9. Nanoparticles and Nanostructured Materials

A10. Film Synthesis by Particle Technologies

A11. Particulate Deposits: Transport Mechanisms, Microstructure and Properties

A12. Posters on Advanced Technologies for Particle Production

Symposium B. Advanced Technologies in Fluid-Particle Systems

B1. Fundamentals of Fluidization and Fluid-Particle Systems

B2. Particle Interactions in Fluid-Particle Systems

B3. Circulating Fluidized Beds

B4. Fluidization Application in Petroleum and Petrochemical Industry

B5. Fluidized Bed Combustion

B6. Polymerization Process in Fluidized Bed Systems

B7. Diagnostic Methods for Dense Particle Systems

B8. Fluid Particle Systems in the Pharmaceutical Industry

B9. Drug Encapsulation and Particulate Coating in the Pharmaceutical Industry

B10. Computational Fluid-Particle Flow Systems

B11. Erosion, Attrition, and Pulverization

B12. Applications to Biochemical and Food Processing

B13. Poster Session: general, and a focus on Slurry Reactors

Symposium C. Advanced Technologies in Powder Mechanics

C1. Mechanical Testing of Particulate Materials

C2. Constitutive Modeling of Particulate Materials

C3. Computational Methods for Particulate Materials

C4. Powder Mechanics and Material Storage

C5. Net Shape Processing of Powder Materials

C6 Solids Flow, Handling and Processing

C7. Poster Session: general, and a focus on Particle Sizing

Symposium D. Advanced Technologies for Particles in Environment

D1. Particle Processing

D2. Measurement and Control

D3. Control of Particulates in Environment

D4. Novel Sensors for Environmental Monitoring of Particles

D5. Colloidal Aspects of Environmental Problems

D6. Poster Session: General, and a focus on Dust Control

Chairman: Prof. M.C. Roco, National Science Foundation; 4201 Wilson Boulevard, Suite 525, Arlington, VA 22230; tel: 703/306-1371; fax: 703/306-0319; e-mail: mroco@nsf.gov; www: http://www.eng.nsf.gov/ptf.

Cochairmen: Dr. K.V. Jacob, Dow Chemical Company; tel: 517/636-5706; fax: 517/ 636-4616; e-mail: jacobkv @dow.com.

Prof. S.E. Pratsinis, University of Cincinnati; tel: 513/556-2768; fax: 513/ 556-3473; e-mail: spratsin@alpha.che. uc.edu.

Prof. H. Arastoopour, Illinois Institute of Technology, tel: 312/567-3038; fax: 312/ 567-8874; e-mail: hamid@charlie. iit.edu.

Prof. N. Cristescu, University of Florida; tel: 352/392-6747; fax: 352/392-7303; e-mail: ndc@AeMES.aero. ufl. edu.

Dr. Reg Davies, DuPont Co., tel: 302/695-2839; fax: 302/695-3501; e-mail: DaviesR1@esvax.dnet.DUPONT. COM.

Coparticipation: ASME (Prof. E.E. Michaelides; tel: 504/865-5819; fax: 504/862-8747; e-mail: emichael@

mailhost.tcs.tulane.edu and Prof. AndreaProsperetti;tel:410/516-8534;fax: 410/516-7254; e-mail: prosper@titan.me.jhu.edu).

6-9 December 1998, Brisbane, Australia

Tribology Conference: Austrib '98

Tribology is the science and technology of interacting surfaces in relative motion and the practices related thereto, or more simply: friction, lubrication, and wear. There are very few engineering components that do not embrace tribological principles. The theme of Austrib '98 is Tribology at Work. It is intended to bring together researchers and practitioners working in tribology from around the world. A two-day course on Applied Lubrication will be held immediately after Austrib '98 by the Tribology Group at the Queensland University of Technology.

Contributions are invited on the following broad areas: biotribology, condition monitoring, contact mechanics, education and training, environmental aspects in tribology (biodegradable lubricants, recovery and disposal of lubricants), industrial problems and their solution, innovative application of tribological principles, lubricant chemistry and rheology, lubrication (thick film, thin film, boundary), micro- and nanoscale tribology, surface characterization, surface engineering (wear-resistant and friction-modifying treatments and coatings, processes, properties, etc.), tribology in manufacturing (metal cutting and forming, etc.), tribology of materials (metals, ceramics, polymers, etc.), tribology in machine maintenance, tribology of machine elements (bearings, gears, seals, chains, rams, piston rings, etc.), and wear debris analysis, wear processes and control (abrasive, adhesive, erosive, corrosive, etc.).

Contact: Austrib '98 Secretariat Tribology Research Group, School of Mechanical, Manufacturing and Medical Engineering, Qld University of Technology, GPO Box 2434, Brisbane 4001 Australia; tel: 617/3864-1341; fax: 617/3864-1469; e-mail: d.hargreaves @ qut.edu.au.

Workshops

AGTSR Workshops in 1998

25-27 March 1998, AGTSR Combustion Workshop V, The Berkeley Marina Marriott, Berkeley, California

16-17 April 1998, AGTSR Specialty Coatings Workshop, Castle Point on Hudson, Hoboken, New Jersey

The Advanced Gas Turbine Systems Research (AGTSR) Workshops are sponsored by the U.S. Department of Energy, Federal Energy Technology Center, in support of the ATS program for the advancement of gas turbine R&D in the United States. Both workshops will bring together experts actively working in these fields from industry, universities, and government laboratories—including DOE, DOD, and NASA. The Combustion Workshop will focus on combustion instability research and field results, active control and diagnostics, catalytic combustion, and possibly a session on very small gas turbines for distributed power. The Specialty Coatings Workshop will be limited to approximately 40 to 50 people and will focus on the development, processing, and science issues pertaining to aluminide and platinum aluminide coatings for gas turbine components used in the aircraft propulsion and power generation industries.

Contact: SCERDC, 386-2 College Ave., Clemson University, Clemson, SC 29634-5180; tel: 864/656-2267; fax: 864/656-0142.

27 April 1998, Detroit, Michigan

Introduction to Thermal Spray: Processes, Coatings, and Applications

Sponsored by the American Welding Society and the ASM Thermal Spray Society. This short course includes a brief review of major advanced thermal spray processes, a description of the more commonly used coatings, and selection of coating processes and materials.

Douglas H. Harris, President and cofounder of APS-Materials, Inc. will be the instructor for this course. Mr. Harris, a veteran instructor of this course, has been steadily involved with thermal spray processes from more than 35 years, including work focused on the use of plasma spray technology for a variety of electronic applications. He has published more than 26 papers on various thermal spray topics, has lectured and taught seminars for technical societies, industrial groups and various universities, and has seven patents, either awarded or pending.

Course objective is to provide an introduction to thermal spray to those unfamiliar with the field or who need an update. Topics include: thermal spray process (plasma spray, high-velocity oxyfuel spray, detonation gun deposition, advanced wire arc), coatings structures and properties (metallic, cermet, ceramic), applications (wear, corrosion, thermal barrier, electromagnetic, others). Price: $75 (price includes a refreshment break).

Contact: Ms. Nannette Zapata, Director of Conferences, AWS, 550 N.W. LeJeune Rd., Miami, FL 33126; tel: 305/443-9353; 800/443-9353; fax: 305/443-7559; e-mail: info@amweld. org.

10-11 June 1998, State College, Pennsylvania

Electron Beam-Physical Vapor Deposition Seminar/Workshop

The theme of the seminar/workshop is "Current Developments in EB-PVD Technology." Abstracts for conference presentation should describe original work of recent origin or unpublished results consistent with the Seminar/Workshop theme. Presentations should be 35 minutes in length.

Abstracts should be received by 15 March 1998 and should be limited to a single page, single-spaced. Pictures or diagrams may accompany the abstract, as appropriate. Acceptance notice and presentation instructions and information will be forwarded by 30 March 1998. Final manuscript (camera ready) should be received by 20 May for inclusion into the seminar proceedings packet.

Contact: Dr. Jogender Singh, Applied Research Laboratory, The Pennsylvania State University, P.O. Box 30, State College, PA 16804; tel: 814/863-9898; fax: 814/863-1183; e-mail: jxs46@psu.edu.

18-22 May 1998, University of Missouri-Rolla, Rolla, Missouri

Physical Testing of Paints and Coatings

This workshop is designed to improve quality control protocol for paints and coatings. You will benefit from this course if you are: working in quality assurance for coatings or raw materials, a newcomer to the paint industry in a quality control laboratory, or supervising or expect to supervise a quality control laboratory. This intensive course will show participants how to better measure the quality of paint. The course will explore instrumental methodology, that is, rheology, chromatography, thermal analysis, and spectroscopy as well as some others. All of our tests are based on ASTM methods and other currently acceptable practices.

Course notes are provided for each attendee. There will be approximately 18 hours of lecture, 16 hours of laboratory work, and approximately 2 hours of group discussion. Lectures will concentrate on the purpose, theory, and techniques of quality assurance. Laboratory workshops will include tests on equipment discussed in lectures and how to use the equipment and techniques in your lab.

Contact: Karen K. Markley or Dr. Michael Van Mark, UMR Coatings Institute, University of Missouri-Rolla, 236 Schrenk Hall, 1870 Miner Circle, Rolla, MO 65409-0010; e-mail: coatings@umr.edu or mvandema@umr.edu.

5 November, 1998, Miami Beach, Florida

Emerging Particle Technologies: A Vision to the Future

Experts from both industry and academe will present future technological directions and review most promising, exploratory research opportunities in modeling and simulation of particulate and multiphase flows. The program includes seven presentations in various areas of particle technology:

- Multiphase flow equations in the chemical and oil industries
- DNS for particle-laden flows
- Euler-Lagrangian approach—future directions
- Four fluid models for two-phase flow
- Experimental validation
- CFD software developments
- Discussion: molecular dynamics; future directions
- Panel Discussion: "Troubleshooting Solids Handling Systems"

The objective of the panel discussion is to bring awareness about challenges in troubleshooting solids handling operations. This discussion will focus on sharing industrial experience, problem-solving strategies, and practical application of research in solids handling. The panel will consist of six experts who have extensive experience in solving industrial problems in solids handling and have contributed to advancement of particle technology through research. Each participant will give a short (about 10 minutes) presentation on their approach, challenges, and philosophy on troubleshooting. The floor will be open for discussion and questions thereafter. The total duration of the session will be two hours.

Contact: Jennifer L. Sinclair, Chair, Purdue University; tel: 765/494-2257; fax: 765/ 494-0805; e-mail: jlds@ecn.purdue.e. Mike Roco, Co-chair, NSF; tel: 703/306-1371; fax: 703/306-1371; e-mail: mroco@nsf.gov.

News from the DVS

The German Welding Society (DVS)—Partner of Commerce and Industry

An important technical and scientific association in Germany is the German Welding Society (DVS), the head office of which is in Düsseldorf. In accordance with its statutes the purpose of the DVS is to foster the field of welding technology. This includes brazing, soldering, adhesive bonding, thermal cutting, and thermal spraying, as well as welding itself. Support is also given for the general benefit of areas linked to those listed here. As a result, the following tasks are performed by DVS: encouragement, support, and coordination of work that helps to further the development in the field of welding; fostering and advancement of knowledge by cooperation and exchange of experience; joint research projects; training and advanced training of welding personnel; support and development of literature, illustrative literature and lecturing; consultation and exhibition of technical guidelines; representation of economic interests in national and international standards committees; consultation and involvement in matters relating to quality and testing; support for protection against accidents at the workplace; and cooperation with institutes and organizations at home and abroad that pursue the same objectives or are at least interested in them.

The German Welding Society is non-competitive and is open to everyone. To perform all these tasks, a vast number of people from the fields of commerce, science, and surveillance provide assistance on an honorary basis. DVS itself has more than 20,000 members (private members from industry and skilled trade, companies, small and medium-sized enterprises and corporate bodies), who are looked after by its state and district branches.

Apart from carrying out the tasks already mentioned the DVS.

- Offers an extensive network of approximately 500 DVS training centers in which every year more than 200,000 people are given advanced training or tested in accordance with standardized guidelines

- Annually provides thousands of participants with practical knowledge by staging hundreds of lectures
- Works in close cooperation with more than a thousand specialists from the more than 30 working groups in its technical committee
- Organizes congresses, colloquia, and seminars
- Cosponsors the International Welding Fair, the largest welding fair in the world, which takes place in Essen every four years
- By working closely together with its Welding and Cutting Research Association guarantees that cooperative research is practice-oriented and that its results can be included in regulations
- Conducts research and development projects for third parties
- Has at its disposal numerous advice centers for the transfer of technology in the field of welding
- Cooperates with national and international committees, for example with the German Institute for Standardisation (DIN), the International Institute of Welding (IIW), and the European Federation for Welding, Joining and Cutting (EWE)
- Endeavors to eliminate trade barriers, in particular with regard to the international alignment of practical and theoretical requirements for welding personnel
- Publishes at the DVS Publishing House a large number of specialized welding books and magazines, research reports, software, guidelines and worksheets, foils, pamphlets, teaching and learning materials for occupational training, as well as scientific and practical journals (in German, English, and Chinese)
- Enables, via the joint sponsorship of the Information system for welding technology together with the Federal Department of Material Research and Testing, access to databases all over the world
- Through its welding teaching and research institutes it is officially recognized by governmental authorities, examination boards, manufacturers, and so forth for the expert execution of welding tasks in construction work of all kinds
- Assesses welded constructions with the aid of expert surveys
- Advises clients from the private and public sector on matters relating to the expediency and suitability of welded structures, assists in the selection of suitable basic and additional materials, the application of economical welding, cutting, soldering, and spraying processes, and in matters concerning safety at the workplace
- Is officially recognized by governmental authorities at its welding teaching and research institutes to issue proficiency certificates to welding companies
- Tests materials and welding connections in its laboratories as well as via mobile testing equipment at the building site itself, without risk of damage
- Conducts troubleshooting for all fields of welding
- Works for the transfer of technology in many committees from the field of technology and science together with specialists from companies, colleges and universities, and other research institutes

Contact: Deutscher Verband für Schweisstechnik e.V., Aachener Strasse 172, D-40223 Düsseldorf, Germany; tel: 49/2 11/15 91-0; fax: 49/2 11/15 91-200; e-mail: DVS_EV@compuserve.com.

Recent Conferences

Thermal Spray at Corrosion NACExpo '98

22-27 March 1998, San Diego, California

Research in Progress Symposium

- The Corrosion of Thermally Applied Cermet and Ceramic Coatings, by A. Neville (U.K.)

Technical Committee Meetings

- Thermal Spray Coatings, (T-6H-45), where the thermal spray corrosion coatings inspector program will be discussed

Corrosion and Corrosion Control of Reinforced Concrete Structures Symposia

- Thermal-Spray Titanium Anodes for Cathodic Protection of Steel-Reinforced Concrete Structures, by B.S. Covino, G.R. Holcomb, S.J. Bullard, and S.D. Cramer, Albany Research Center, Albany, OR; G. McGill, Oregon Dept. of Transportation, Salem, OR
- Effect of Composition and Corrosion Properties of the Metallic Matrix on the Erosion-Corrosion Behavior of HVOF Sprayed WC-Coatings, by T. Rogne and T. Solem, SINTEF Materials Technology, Trondheim, Norway; J. Berget, NTNU, Trondheim, Norway
- Corrosion Protection of Offshore Steel Structures with Thermal Sprayed Aluminum Coatings, by T.G. Eggen and U. Steinsmo, SINTEF Materials Technology, Trondheim, Norway
- Effect of Primer Composition on Cathodic Disbonding Resistance and Adhesion Durability of Three Layer Polyethylene Coated Steel Pipe, by S. Tsuri, K. Takao, and K. Mochizuki, Kawasaki Steel Corp., Chiba, Japan
- Large Diameter Wire High Deposition Metallizing: A Competitive Edge for Long Life Coating, by M.S. Wixson, Thermion Metalizing Systems, Silverdale, WA
- Recent FHWA Experience in Testing and Implementing Thermal Spray Coatings for Bridge Structures, by R.A. Kogler, D. Brydl, and C. Highsmith, FHWA, McLean, VA
- 85% Zinc-15% Aluminum Thermal Spray Applications for IL D.O.T./FHWA, by W.J. Gajcak, U.S. Corrosion Engineers Inc., Joliet, IL
- Thermal Spray Coatings Behavior under Oxidizing and Sulfidizing Conditions at Elevated Temperatures, by A. Verstak and S. Baranovski, Metalspray Inc., Richmond, VA

- Sacrificial Cathodic Protection of Reinforced Concrete Using Metallized Zinc, Magnesium and Zinc Based Pseudo Alloys, by R. Brousseau, Corrpro Canada, Orleans, Canada; B. Arsenault and G. Ping, National Research Council of Canada, Ottawa, Canada; B. Baldock, Nepean, Canada
- Maintenance and Repair of Thermal Spray Coatings, by T. Call, Power Spray Inc., Virginia Beach, VA
- Successful Application of an Arc Sprayed 85-15 Zn/Al Coating on Grandstands at Indianapolis Motor Speedway, by C. Stein, Tank Industry Consultants Inc., Indianapolis, IN; C.J. Houghton, Amoco. (UK) Exploration Ltd, London, United Kingdom; M. Swidzinski, Phillips Petroleum, Surrey, United Kingdom
- Application of Thermal Spray Coatings for 304 Stainless Steel SCC Mitigation in High Temperature Water, by Y.-J. Kim and P.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, by I. Smuga-Otto, Edmonton, Canada; K.E. Szklarz, Shell Canada Ltd, Calgary, Canada
- Updated Protective Coating Costs, Products, and Service Life, by K.R. Shields and M.P. Reina, KTA-Tator, Pittsburgh, PA
- Field Performance of Sprayed Zinc Anodes in Controlling Corrosion of Steel Reinforced Concrete, by J.S. Tinnea, John S. Tinnea and Associates, Seattle, WA
- A Review of Power Plant Corrosion Applications and Needs, by R. Bajan, Walbar Metals, Hodges, SC; E.R. Sampson, Tafa Inc., NH
- Results of Field Application and Laboratory Testing of Thermal Spray UNS N10276 Coating for Sour Amine Vessels, by M.G. Hay and J.J. Baron, Shell Canada Ltd, Calgary, Canada; K.G. Goerz and R.W. Schubert, Shell Canada Ltd, Caroline, Canada; F. Easterly, Metalspray, Richmond, VA
- The Electrochemical Corrosion Behavior of High Velocity Oxygen Fuel (HVOF) Sprayed Coatings, by A. Sturgeon, TWI, Cambridge, United Kingdom
- A Review of the Performance and Use of Thermal Spray Aluminum Coatings on North Sea Platforms, by T. Rosbrook, Rosbrook Associates Ltd, Kintore, United Kingdom; C.J. Houghton, Amoco. (UK) Exploration Ltd, London, United Kingdom; M. Swidzinski, Phillips Petroleum, Surrey, United Kingdom
- Duplex Protection System of Powder Coating and Metal Spraying on Steel Articles, by T. Handa and H. Takazawa, Nippon Telegraph & Telephone, Tokyo, Japan
- Corrosion Protection of General Purpose Bombs Using Metal Arc Spray Technology, by D.H. Neale, SAIC, Marietta, GA
- Arc Spray Corrosion Applications, by E.R. Sampson, Tafa Inc., Epsom, NH; D. Varacalle, Vartech, Idaho Falls, ID
- HVOF Coatings in Corrosion Resistance, by R. Thorpe, Tafa Inc., Concord, NH
- Zinc Metallizing Versus Galvanizing—Where and When to Use, by K. Duplissie, Platt Bros & Co., Waterbury, CT

Contact: NACE International, P.O. Box 218340, Houston, TX 77218-8340; fax: 281/228-6329

Industrial News

Howmet Files for Initial Public Offering

Howmet International Inc. has announced that it has filed a registration statement with the Securities and Exchange Commission for a proposed initial public offering of a portion of its outstanding common stock. The shares are being offered by an affiliate of The Carlyle Group, which currently owns 51% of Howmet International's common stock. In a concurrent transaction, this Carlyle affiliate will sell 11% of the outstanding Howmet International shares to Thiokol Corporation, which currently owns 49% of Howmet International's common stock. The underwriting group will be led by Morgan Stanley Dean Witter and Lehman Brothers Inc. headquartered in Greenwich, CT. Howmet International Inc. is the parent holding company of Howmet Corporation, the largest manufacturer in the world of precision investment castings of superalloy and titanium alloys for jet aircraft and industrial gas turbine engines. It is also the largest producer of aluminum investment castings for the commercial aerospace and defense electronics industries.

A registration statement relating to these securities has been filed with the Securities and Exchange Commission, but has not yet become effective. These securities may not be sold nor may offers to buy be accepted prior to the time the registration statement becomes effective. This press release shall not constitute an offer to sell or the solicitation of an offer to buy, nor shall there be any sale of these securities in any state in which such offer, solicitation or sale would be unlawful prior to registration or qualification under the securities laws of any such state.

Contact: Doreen L. Deary, Director, Corporate Communications, 475 Steamboat Rd., Greenwich, CT 06836-1960; tel: 203/625-8735; fax: 203/625-8796.

Howmet International Begins Trading on New York Stock Exchange

Howmet International Inc. announced (26 Nov 1997) that trading in its common stock had commenced on the New York Stock Exchange under the symbol HWM. Fifteen million shares were offered by an affiliate of The Carlyle Group at an initial public offering price of $15.00. The shares being sold to the public constitute 15% of the total outstanding shares. In separate but concurrent transactions, the Carlyle affiliate will also sell a total of 13% of the outstanding Howmet International shares to a subsidiary of the Thiokol Corporation, which will own 62% of Howmet International's stock following these transactions.

Contact: Doreen L. Deary, Director, Corporate Communications, 475 Steamboat Rd., Greenwich, CT 06836-1960; tel: 203/625-8735; fax: 203/625-8796.

Investor relations contact: Shannon Polk, Manager, Investor Relations, Thiokol Corporation; tel: 801/629-2091; fax: 801/629-2222.

Nooter Corporation is First to Receive New ASME Accreditation

Nooter Corporation, St. Louis, MO, a manufacturer of pressure vessels and related equipment for more than 100 years, was the first manufacturer to receive the American Society of Mechanical Engineers (ASME) Section V111, Division 3 stamp accreditation, which was introduced in May. It received the three-year authorization from the ASME on 10 July 1997, after the company completed the application, developed a manual outlining its compliance with the code, and underwent a two-day audit.

ASME Section V111, Division 3, "Alternate Rules for Construction of High Pressure Vessels," was designed by the Special Working Group of High Pressure Vessels, under the Boiler and Pressure Vessel Code Subcommittee V111, for vessels with pressures of more than 10,000 psi. The code uses a lower safety factor on the allowable stress used to design vessels than other ASME pressure vessel codes, but uses additional nondestructive examination, inspection, and design requirements. The Code Division makes static, fatigue, and stress fracture mechanics analysis mandatory; employs stringent material requirements; outlines testing, quality, fabrication, and welding specifications; and provides an internationally accepted code to assist manufacturers, users, insurers, and government.

Focus on Osprey Metals Ltd.

Formed in 1974 to develop and license the Osprey Preform Process, Ospray Metals Ltd. diversified into the development of technology for the production of gas-atomized metal powders in 1977. Since that time Osprey's Powder Division has built up a comprehensive argon and nitrogen gas-atomizing production facility supported by ongoing research and development into the fundamentals of the atomizing process. While small enough to provide a fast and flexible response to our customers, the company is a wholly owned subsidiary of the Sandvik Group since 1985 and is backed by the resources of a worldwide production and marketing organization.

Product Development: With a wide-ranging production experience, combined with R&D resources, Osprey can supply companies developing powder-based products and processes. This diversity brings with it the experience to tailor the product to the customer's specific requirements. If the optimal powder product for an application is not known, Osprey will help establish it by producing small-quantity experimental batches for your evaluation. Osprey has made a substantial contribution to a number of new production techniques by working closely with customers, under conditions of commercial secrecy, and we continue to welcome such collaborative projects. In addition, there are R&D programs that, most recently, have resulted in the production of alloy powders tailored specifically to the MIM and HVOF processes at commercially attractive prices. One of the key features of Osprey's atomizing technology is the ability to maximize the production yield of powders within the different particle size ranges required for different applications. Expertise in this area make Osprey a powerful partner for fabricators striving to improve product quality and production economics, particularly in areas requiring microfine (–22 μm) powders.

Quality Assurance: Osprey's quality assurance procedures are totally geared to fulfilling the customer's needs. The company is accredited to ISO 9001 standard and thus offers quality assurance on both its production and research activities to the highest internationally recognized standards.

Technology: Osprey Powder Division has drawn on the atomizing expertise derived from the development of the Osprey Preform Process to develop "state-of-the-art" gas-atomized powder production technology. This claim is supported by the fact that there are more than 20 licensees operating Osprey technology in Europe, the U.S., Japan, and elsewhere. Powders are produced in melt sizes ranging from 15 to 500 kg using either argon or nitrogen as the atomizing medium, and where appropriate alloys can be melted, dispensed, and the resulting powder stored and sieved, or classified, under argon. The resulting product is a high-quality, spheroidal powder with the composition and particle size distribution designed to provide the optimal solution to the customer's needs.

Applications: Osprey manufactures the widest range of gas-atomized metal powders in the world, excluding from regular production only those materials which are explosive or toxic in finely divided form.

Processes: Brazing—Diamond Setting—Infiltrations, Powder Welding—Fuse Welding—Carbide Setting, Spray Fusing—Furnace Fusing—Sprinkle Fuse, Plasma Spray—Plasma Transferred Arc, HVOF—Detonation Gun, Thermal Spray—Metallizing, Laser Coating, Plating—Codeposition, Thermal Cutting—Blast Cleaning, HIP Consolidation and Coating, Metal Injection Molding, Press and Sinter CIP, Extrusion.

Contact: Ospray Metals Ltd., Red Jacket Works, Millands Rd., Neath, W. Glamorgan, SA11 INJ, U.K.; tel: 01639 634121; fax: 01639 630100; e-mail: 100072.324@compuserve.com.

"Advanced Materials Modeling and Processes" in Singapore

Materials research is now recognized as an engineering frontier that has significant impact on many technological fields, predominantly because it is multidisciplinary in nature and as such integrates applied sciences and engineering to form useful solutions to problems in aerospace, automobile, oil, medical, electronic, and microelectronic industries.

The Advanced Materials Modeling & Processes Strategic Research Program (SRP) aims to synthesize fundamental principles and mechanisms in materials and manufacturing processes and apply these in strategic areas that would impact Singapore's manufacturing industry. The Advanced Materials Modeling & Processes SRP's philosophy in answering the industrial challenges is to develop new technologies that can meet the need for competitive products by high-value-added manufacturing methods. Key, cutting-edge technologies in the following areas are currently being developed: biomaterials, electronic and microelectronic packaging materials, and materials for high-performance engines.

Research Teams: Investigating Key Technologies

Specific research teams have been formed to investigate key technologies that are indispensable to the manufacturing of materials devices and components. These research teams include bioceramic coatings for orthopedic implants, powder injection molding (PIM), advanced electronic devices, synthesis and characterization of novel polymers and polymer blends, advanced materials for environmental protection in power machinery exhausts, and others.

Collaborations: Strengthening Research Links

Research links with established universities and institutes overseas have been made, among these are the National Chemical & Materials Institute and Mechanical Engineering Laboratory (MEL) (Tsukuba, Japan), Cambridge University (U.K.), Ecole des Mines de Paris (France), University of Toronto (Canada), and Aachen Technology University (Germany). While in Singapore, there are ongoing collaborations with local industries such as Union Carbide, Singapore General Hospital, and Singapore Aerospace.

Equipment: Using State-of-the-Art Equipment

In addition, the research efforts of the Advanced Materials Modeling & Processes SRP research teams are supported by state-of-the-art equipment for the structural, chemical, and physical characterization of advanced materials such as a high-temperature dilatometer system, hot isostatic press and cold isostatic press machines, x-ray diffractometer system, a 100 kW computerized plasma spray system, mercury intrusion porosimeter, in-situ dynamic mechanical analyzer for radiation curing of engineering polymers, advanced thermal analysis equipment and an x-ray imaging system to study wear processes.

Role: Embarking on the Role of Global Player

The Advanced Materials Modeling & Processes SRP is well positioned to be a global player in the fast-growing field of Advanced Materials Research, and this augurs well with the plans of the Singapore Government to make Singapore an R&D center for excellence in science and technology.

Contact: Dr. Michael Khor, Advanced Materials Modeling and Processes; e-mail: mkakhor@ntu.edu.sg.

Joining and Welding Research Institute, Osaka University

This institute was originally founded as the Welding Research Laboratory in 1969 according to the advice of the Japan Academic Council to meet the academic and industrial requirements at Osaka University. Later, the Institute was formally approved in 1972 as the Welding Research Institute. The purpose of this institute was to perform research in welding engineering. It has promoted both fundamental and application works for more than 20 years and has become one of the key institutes within the welding community.

However, the wide and comprehensive developments in the field of science and technology over this period have been changing the research method for welding engineering. The economic growth of Japan over the same period has also changed her position and role in the world and has involved changes in her industrial structure. Therefore, Japan has restructured the present research

Research students involved in thermal spraying of advanced coatings system for welding engineering from the view point of both "generalization" and "deepening." Accordingly, it was relaunched as the Joining and Welding Research Institute in May of 1996.

This new institute consists of three divisions and two centers. The three divisions are Materials Processing System, Materials Joining Mechanism, and Functional Assessment. Project research will be performed at the two centers. The development of high or ultrahigh energy heat sources and the examination of their applications will be performed at the Research Center for Ultra-High Energy Density Heat Sources. The newly founded Research Center for Cyclic Loop System for Processing and Maintenance is composed of three divisions. One is Strengthening and Recovery of Function, Environment Tolerant Surface Modification, and Bioremediation and Bioprocessing for Industrial Materials. These three divisions aim to establish new industrial systems whose features are closed cyclic loops for materials cycling, based on new concepts of interaction. Through this reorganization, the new Institute will perform research relevant to the 21st century. The staff will make constant efforts to achieve the present and future targets. The new Institute will play an important role and, with the friendly support from related organizations, contribute to the prosperity and welfare of humankind and world society.

Contact: Joining and Welding Research Institute, Osaka University, 11-1, Mihagaoka, Ibaraki, Osaka, 567, Japan; tel: 06 (877) 5111; fax: 06 (879) 8689; www: http://www.jwri.osaka-u.ac.jp.

News from NASA

Two-Wavelength Pyrometry with Self-Calibration

An improved method of two-wavelength optical pyrometry provides for the determination of different temperatures of a specimen surface at different times. Unlike other pyrometric methods, there is no need for explicit knowledge of such ancillary wavelength-dependent parameters as emissivity of the specimen surface (or ratios between emissivities at different wavelengths) and transmissivity of the optical path from the specimen to the pyrometer. There is also no need for explicit knowledge of the wavelength-dependent voltage response of the pyrometer; in other words, it is not necessary to calibrate the pyrometer. Instead, the method provides for self-calibration through the generation and use of implicit calibration information from pyrometer readings at two wavelengths and at two or more different temperatures. The method requires a pyrometer in the form of a spectrometer plus a computer to acquire and process the pyrometer readings. The method is based on (a) Planck's radiation law as modified for wavelength dependent emissivity and transmissivity, and (b) the fundamental equation for the response of the pyrometer. Planck's radiation law can be expressed as:

$$L(\lambda, T) = \frac{\varepsilon_\lambda \tau_\lambda c_1}{\lambda^5 \left[\exp\left(\frac{c_2}{\lambda T}\right) - 1\right]}$$

where $\lambda(\lambda, T)$ is the spectral intensity of the radiation at wavelength λ arriving at the pyrometer, T is the absolute temperature of the emitting surface of the specimen, ε_λ is the wavelength-dependent emissivity of the specimen surface, τ_λ is the wavelength-dependent transmissivity of the optical path, and c_1 and c_2 are fundamental physical constants. The voltage response of the pyrometer to the incident radiation at wavelength λ is given by:

$$V(\lambda) = \gamma_\lambda L(\lambda, T)$$

Let the unknown wavelength-dependent parameters γ_λ, ε_λ, and τ_λ be lumped into one wavelength-dependent term via:

$$A(\lambda) = \gamma_\lambda \varepsilon_\lambda \tau_\lambda$$

Let pyrometer readings be taken at wavelengths l1 and l2 at two different times ($0, t_1, t_2, \ldots, t$) when the temperatures of the specimen [$T(0)$, $T(t_1)$, $T(t_2)$, ..., $T(t)$] are different. By combining and manipulating the foregoing equations, the four pyrometer readings are shown and related by the following equation:

$$\frac{V(\lambda_1, 0)}{V(\lambda_1, t)} = \frac{\left[1 + \frac{A(\lambda_2)}{V(\lambda_2, t)}\right]\lambda_2/\lambda_1 + 1}{\left[1 + \frac{A(\lambda_2)}{V(\lambda_2, 0)}\right]\lambda_2/\lambda_1 + 1}$$

Least-squares curve fitting of the quantity:

$$y(t) = \frac{V(\lambda_1, 0)}{V(\lambda_1, t)} = \frac{[1 + A(\lambda_2)\, x(t)]\lambda_2/\lambda_1 + 1}{\left[1 + \frac{A(\lambda_2)}{V(\lambda_2, 0)}\right]\lambda_2/\lambda_1 + 1}$$

versus the quantity:

$$x(t) = \frac{1}{V(\lambda_2, t)}$$

from $t = 0$ to time $= t$ determines the quantity $A(\lambda_2)$. One can also formulate this equation with the roles of λ_1 and λ_2 interchanged and solve the equation to obtain $A(\lambda_1)$. Thereafter, one can compute the instantaneous temperature directly from a pyrometer reading at either wavelength, using:

$$T = \frac{c_2}{\lambda \ln\left[1 + \frac{A(\lambda)}{V(\lambda)}\right]}$$

This work was done by D. Ng of Lewis Research Center. Extracted from *NASA Tech. Briefs*, Vol 21 (No. 11), 1997, p 64.

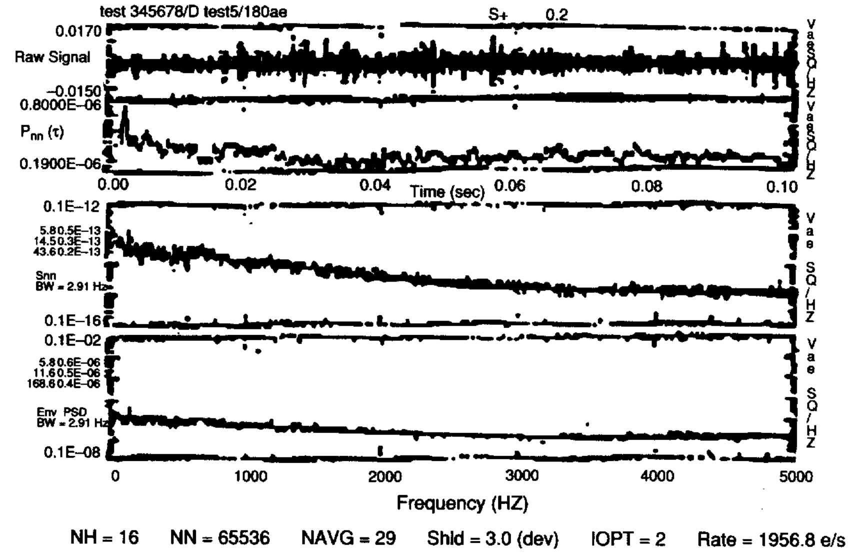
Electrically Conductive Coating Materials

Coating materials that consist largely of tin oxide exhibit a useful combination of solar absorptance, thermal emittance, and electrical conductivity. The materials are intended for use as thermal-control coats for spacecraft. They may also be useful on industrial or scientific vacuum-equipment surfaces that are required to exhibit their specific thermal-radiation and electrical properties. Unlike older materials used for the same purpose, these materials do not lose electrical conductivity during long exposure to vacuum.

A material of this type is made highly electrically conductive by incorporating antimony and indium via chlorides or oxalates in concentrations of 1 to 4 wt% relative to the amount of tin oxide. The antimony and indium produce extrinsic defects within the crystal lattice of the tin oxide. These defects bring electrons in the valence band close enough to the conduction band to make the electrons highly mobile between the bands. This results in high electrical conductivity. The ingredients are mixed in several steps of wet and dry ball milling. The mixture is heated to a temperature between 1000 and 1100 °C for 4 h, then cooled, then milled again. Next, the material is mixed with a resin and solvents to form a liquid mixture that can be sprayed to coat the surface in question.

This work was done by R.J. Mell of Marshall Space Flight Center. Extracted from *NASA Tech. Briefs,* Vol 21 (No. 11), 1997, p 65.

Acoustic-Emission Bearing-Fault Diagnostics System



Point-process spectral analysis was used to extract these bearing signatures from an acoustic emissions transient signal during testing of a good bearing.

A new hardware and software system that uses a state-of-the-art, high-frequency acoustic emissions (AE) sensor and an innovative AE signal-processing technique, called point process spectral analysis (PPSA), has been developed to help prevent catastrophic failures and costly down time due to false alarms during bearing testing. In the past, bearing health monitoring and fault diagnosis within turbomachinery and drive-train systems have been a significant technical challenge for the aeronautics and transportation industries.

Previous techniques to detect bearing faults could not distinguish between transient events related to shaft rotational processes and the signatures associated with defective bearings. Also, these techniques did not involve high-frequency, real-time analysis. To overcome these unique problems, PPSA was developed to meet the high-frequency AE signal processing and fault-detection requirements.

Conventional time series representation of an ultrahigh frequency AE signal requires all data to be sampled over the entire waveform at a high sampling rate. However, PPSA only uses the times occurrence of the transient events, along with their strengths, because these transient events contain the major dynamic information needed for bearing-fault detection. As a result, PPSA requires much less data to analyze the frequency-domain behavior than conventional time-series representation. Additionally, PPSA overcomes the basic limitations of the fast-Fourier-transform-based spectrum for detecting signal components, such as widely spaced, narrow transient spikes that cannot be approximated effectively by a sum of sinusoids.

PPSA uses the first-moment function of time to determine the rate of transient impulse, thresholding the temporal AE waveforms for structural failure detection. Next, a mean-lag-jump product, representing the second moment of a point process, provides a statistical estimation of the correlation between all pairs of event occurrences with common time lags. The frequency-domain representation of the second-moment mean-lag-jump product function is used to create a spectrumlike function of the point process. This point-process spectrum provides a statistical estimation of the event occurrence rate and intensity distribution as a function of frequency.

The superior detection capability of PPSA over conventional envelope analysis in extracting bearing signatures from AE transient signal in a noisy operational environment was demonstrated with two computer-simulation examples and with NASA-provided test data from a bearing test rig. Three test conditions were used: a good bearing, an inner race defect, and a roller defect. PPSA successfully analyzed the data. The results of these proof-of-concept studies indicated that PPSA can provide high computational efficiency in processing ultrahigh-frequency AE signals and is highly suitable for real-time implementation. Using this analysis technique would significantly reduce the digital signal processor requirement in developing a low-cost, commercially viable, on-line bearing-diagnostic system.

This work was done by J.-Y. Jong of Allied Signal Research, Inc., for the Marshall Space Flight Center. Extracted from *NASA Tech. Briefs,* Vol 21 (No. 11), 1997, p 84.

Tests of Thermal Barrier and Wear Coats in Rotary Engines

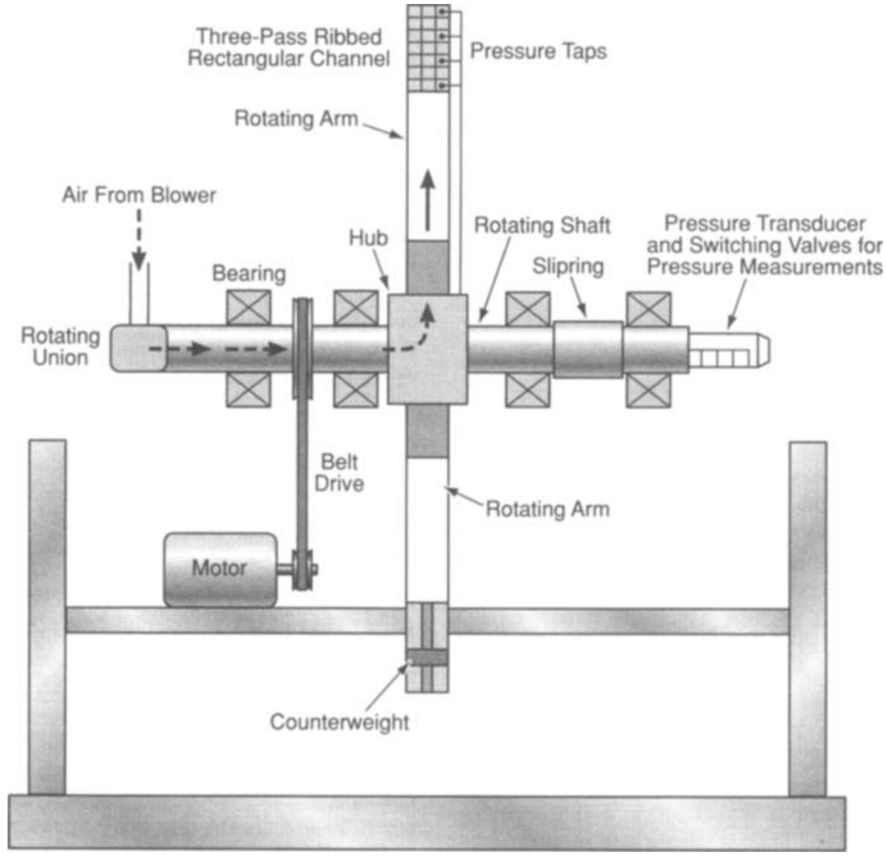
A report describes experiments to evaluate combination thermal barrier/self-lubricating coating layers on the internal sliding-contact surfaces of the housings of air-cooled rotary internal-combustion engines. These coatings were described in "Combination Thermal Barrier and Wear Coatings for Engines" (LEW-15356), *NASA Tech. Briefs,* Vol 19 (No.

5), May 1995, p 62. The tests demonstrated the benefits of the thermal barrier coatings in that specific fuel consumptions of the engines with the coatings were consistently lower than those of the same engines without the coatings. The PS200 wear coats proved to be very durable under severe test conditions.

This work was done by P.S. Moller and M. Weigart of Moller International for Lewis Research Center. Extracted from *NASA Tech. Briefs,* Vol 21 (No. 11), 1997, p 92.

Rotational Apparatus for Heat Transfer Experiments

The figure illustrates a laboratory apparatus that has been proposed for experiments on local heat transfer in and around passages in a rotating arm. The passage geometries and the flows along the passages would be chosen to model heat-transfer and flow conditions like those in the coolant passages of the blades of gas-turbine engines. It is necessary to perform such experimental modeling because there is very little published experimental information on local heat transfer (as distinguished from spatially averaged heat transfer) in passages in the presence of rotation. The data acquired in experiments on the proposed apparatus would contribute to understanding of local heat transfer in gas-turbine blades, thereby helping engineers to design blades for efficient cooling.



Experiments on heat transfer in a channel on a rotating arm would be performed to gain understanding of thermal and flow phenomena in coolant passages of gas-turbine blades.

In a gas-turbine engine, cooling air is bled from a compressor (which is part of the engine) and directed to flow along the internal passages of the turbine blades; of course, this cooling bleed flow is obtained at the expense of total engine output. To maximize turbulence in order to maximize the transfer of heat from the blade to the cooling air, ribs are cast onto two opposite walls of each passage. Rib-induced separation and attachment of flow along the passages create zones of high and low heat transfer. Rotation aggravates the nonuniformity of heat transfer by pushing the flow onto the pressure side :(where heat transfer is thus increased) and away from the suction side (where heat transfer is thus reduced). Therefore, it is necessary to determine coefficients of local heat transfer in order to identify hot spots and quantify enhancements of heat transfer on leading and trailing passage walls in the presence of rotation. Moreover, coefficients of local convective transfer of heat between hot gases and blades are greater than the thermal conductivities of the blades; thus, a blade designer cannot rely on the thermal conductivity of the blade to smooth out local errors in computed heat fluxes, and this makes it imperative to know the coefficients of local heat transfer within the blade passages in great detail.

The arm of the proposed apparatus would be designed to accommodate passages of various geometries. By use of a naphthalene-sublimation technique, local coefficients of heat and mass transfer would be determined for a variety of flow/geometry combinations, including flows in rib-roughened, multipass channels, multiple jets impinging near the leading edge of a blade, and flows around pin-fins near the trailing edge of a blade. Distributions of pressure would be measured by use of a switching-valve unit that would sequentially connect the transducer to pressure taps at various locations in the passages. A slipring assembly would be included to provide an option for conducting heat transfer experiments.

Experiments have been conducted in a two-pass, square-cross-section channel on a small-scale prototype of the pros posed apparatus, using the naphthalene sublimation technique. Local distributions of heat and mass transfer were obtained in cases in which ribs were aligned at various angles. The most significant finding from these experiments was that high rates of heat and mass transfer on the trailing wall can be achieved with ribs smaller than those used conventionally (hydraulic-diameter-to-rib-height ratios of 16 or 32 instead of the conventional values of 8 to 10).

This work was done by R. Kukreja of Lynutech, Inc., for Lewis Research Center. Extracted from *NASA Tech. Briefs,* Vol 21 (No. 12), 1997, p 62.

Digital Particle-Image Velocimetry Enhanced by Fuzzy Logic

A method of digital particle-image velocimetry (digital PIV) involves the use of a combination of fuzzy-logic, cross-correlation, and particle-tracking techniques. As in other PIV methods, the overall task is to estimate the velocity field in one plane of a flowing gas or liquid by (1) seeding the flow with small, highly reflective particles; (2) illuminating the plane of interest with intense light from a pulsed laser or other source, (3) recording a sequence of images of the illuminated particles (see figure), and (4) processing the image data to determine local velocity vectors from displacements of particle images. Older PIV methods described previously in *NASA Tech Briefs* involve various degrees of manual and/or automated processing of image data by hardware and/or software. The present method is a product of a continuing effort to develop a capability for all-electronic, fully automated, software-based processing of digitized seed-particle images to extract the maximum available information about velocities.

In the present method, the same scene is both illuminated by two pulsed lasers via a beam combiner and observed by two charge-coupled-device cameras via a beam splitter. Each camera acquires a single-exposure image (Fig. 1). The reason for using two cameras and two lasers is simply to make it possible to record the two images as close together or as far apart in time as necessary to obtain particle-image displacements in the right size range for extraction of velocity data.

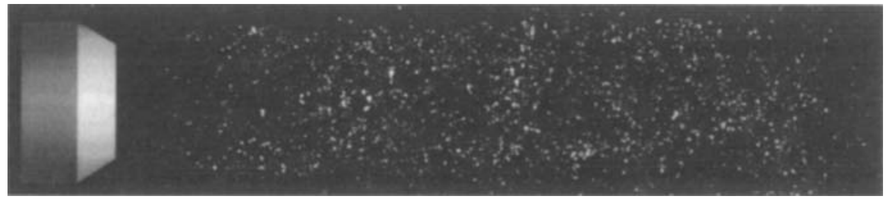


Fig. 1 Seed particles entrained in supersonic flow from a convergent nozzle cab be seen clearly when illuminated by a sheet of a pulsed laser light. This is one of two images that are recorded a short time apart so that velocity vectors can be extracted from displacements between the first- and secondimage positions of the particles.

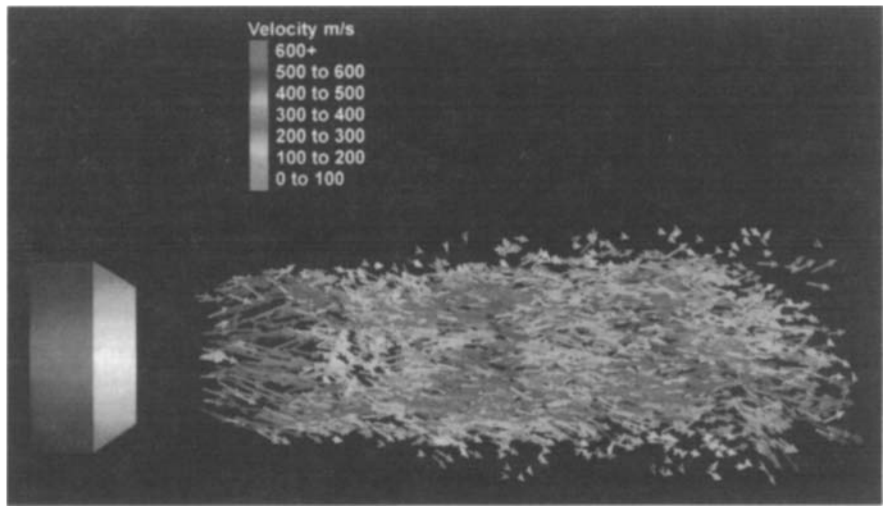


Fig. 2 This velocity-vector map was generated in the second stage (fuzzy-interference particle tracking) of processing of two consecutive images as in Fig. 1.

The image data are then analyzed in a two-stage process. In the first stage, the images from the two cameras are divided into equal-size regions, cross-correlations between corresponding regions are computed, and a fuzzy-logic inference engine is used to maximize the recovery of information from the correlation plane. Ideally, the peak of greatest amplitude on the correlation plane for each region would represent the average particle displacement and thus the average particle velocity in the region. However, when the seed density is low or there is out-of-plane particle motion, image noise, or a velocity gradient, a number of correlation peaks can arise. In an effort to select the correlation peak that represents the true velocity, a fuzzy inference operation is performed. The essence of this operation is to compare the velocity vectors of the five highest correlation peaks in each region with those of the five highest correlation peaks in each of the four surrounding regions and to select, for each region, the velocity vector most similar to the velocity vectors of the selected correlation peaks of the other regions according to a confidence-weighting numerical criterion. The justification for selecting velocity vectors on the basis of similarity to adjacent velocity vectors lies in the fundamental continuity of flow. Of course, because it represents velocities averaged over regions, the resulting velocity map inherently has low spatial resolution.

The second stage of the image-analysis process involves particle-tracking velocimetry, in which (1) the data from each frame are processed independently to determine the particle-image centroids, (2) the centroid locations are used to determine candidate displacement vectors, and (3) velocity vectors are calculated by dividing the displacement vectors by the interexposure-time. The major problem in selecting the displacement vectors is to determine which particle-image centroids in the second frame represent the subsequent positions of which particle-image centroids in the first frame. In the present method, this problem is solved by invoking two schemes, the first being a fuzzy-logic scheme with a selection criterion that is also based on continuity of flow; this scheme was described in "Particle-Tracking Velocimetry With Fuzzy Logic" (LEW-16205), *NASA Tech. Briefs*, Vol 20 (No. 8), Aug 1996, p 62.

In the second scheme, which also involves fuzzy logic, the low-resolution velocity map generated in the first stage is used as a further guide to selection of vectors: For each initial particle location, the four first-stage nearest-neighbor velocity vectors are used to compute a spatially weighted mean vector called the "benchmark" vector, which is then used in pairwise fuzzy comparison with all of the candidate vectors for the particle in question. The candidate vector most similar to the benchmark vector according to a confidence-weighting numerical criterion is selected as the velocity vector for that particle. This process is repeated for each initial particle location, yielding a high-resolution velocity-vector map (see Fig. 2).

This work was done by M.P. Wernet of Lewis Research Center. Extracted from *NASA Tech. Briefs*, Vol 21 (No. 12), 1997, p 81-82.

ATP Can Significantly Accelerate New Technology Development

The Commerce Department's Advanced Technology Program (ATP) is having a significant impact in accelerating the pace of technology development, according to a new study of early ATP award winners. Most companies surveyed estimated that participation in the ATP reduced their technology development cycle by 50%, typically reducing a six-year process to three years. Accelerated technology development translates to dollars and cents according to the majority of companies studied, with estimates of the economic impact of reducing cycle time ranging from 1 million to several billions of dollars for a single year of time saved. The results are documented in a detailed survey of the experiences of 28 project teams funded by the ATP in 1991. The report is one of a series of studies commissioned by the ATP as part of the program's evaluation and analysis efforts.

Managed by the National Institute of Standards and Technology, the Advanced Technology Program provides funding on a cost-shared basis to industry to carry out high-risk research and development of potentially high-payoff technologies. The program concentrates on those technologies that potentially offer significant, broad-based benefits to the nation's economy but are not likely to be developed in a timely fashion without the ATP's support because of the technical risks involved. Industry designs, plans, proposes, and carries out the research projects cost-shared by the ATP. Awards are made by NIST on the basis of announced competitions that consider the technical and business merits of the proposed projects.

"While it is important to remember that we are talking about a fairly small sample in this study, the results are very encouraging," according to Rosalie Ruegg, director of the ATP Economic Assessment Office. "A particularly important finding is that a strong majority of companies, 24 of the 28, reported that working with the ATP had led them to adopt new practices in other, non-ATP, projects which also resulted in reduced cycle times. This suggests that the ATP can initiate positive, systemic changes in a company's R&D culture that in the long run could have important economic benefits even beyond those achieved directly by the project."

Key results noted by the study include:

- Twenty-seven (96%) of the company representatives interviewed estimated that participation in the ATP had helped their companies to reduce their technology development cycle time anywhere from 30 to 66%, with more than half estimating a 50% reduction.
- The interviewees attributed the cycle-time reduction to several factors, including the ATP's requirements for disciplined and integrated project planning and management, achieving a critical mass of resources through ATP funding, attracting additional financial support because of being selected as an ATP project, greater project stability because of the ATP's long-term commitment to the research, and the ATP's emphasis on collaboration.
- Twenty-four (86%) of the interviewees expected the time savings in R&D to be carried forward through product development, production, and marketing, enabling them to move the new technology into the marketplace more quickly.
- More than half (15) of the interviewees were able to quantify "ballpark" estimates of the economic value of reducing cycle time by just one year, and these estimates ranged from 1 million to several billions of dollars, with a median value of $5.5 million.
- Twenty-four (86%) of the interviewees reported that participation in the ATP resulted in cycle-time improvements that carried over to other technology development projects outside of the ATP. They were able to adapt specific ATP practices or methodologies to the firm as a whole and capitalize on the enabling ATP technologies to accelerate the development of related projects and applications.

Details of the study, conducted by industry consultant F. Laidlaw, are found in Acceleration of Technology Development by the Advanced Technology Program: The Experience of 28 Projects Funded in 1991 (NISTIR-6047). Copies of the report may be obtained from the ATP Economic Assessment Office; tel: 301/975-4332; e-mail: atp@nist.gov. News and general information on the National Institute of Standards and Technology are available on the World Wide Web via Internet at http://www.nist.gov.

Kammer Confirmed by Senate as Eleventh NIST Director

The U.S. Senate has confirmed Raymond Kammer as director of the Commerce Department's National Institute of Standards and Technology. The position of NIST director is a presidential appointment. Kammer, 50, was nominated by President Clinton on 4 Sept 1997 to be the 11th director of the agency. He succeeds Arati Prabhakar, who resigned in March to join the private sector.

Kammer, the deputy director of NIST (from 1980 to 1991 and from 1993 to the present), most recently has been serving on an acting basis as chief financial officer, assistant secretary for administration, and chief information officer for the Department of Commerce. From 1991 to 1993, Kammer was deputy under secretary of commerce for oceans and atmosphere, the chief operating officer of the National Oceanic and Atmospheric Administration.

He began his career with Commerce in 1969 as a program analyst. Prior to his appointment as NIST deputy director, Kammer held a number of management positions at NIST and Commerce involving budgetary and program analysis, planning, and personnel management. During his tenure as NIST deputy director, he also served as acting director of NIST, acting director of the National Measurement Laboratory, and acting director of the Advanced Technology Program.

Kammer has chaired several important evaluation committees for the Department of Commerce, including reviews of satellite systems for weather monitoring and the U.S. LANDSAT program, and of the next generation of weather radars used by the U.S. government. He also served on the Board of Directors of the American Society for Testing and Materials, a major international society for the development of voluntary standards for materials, products, systems, and services.

His awards include both the Gold and Silver Medals of the Department of Commerce, the William A. Jump Award for Exceptional Achievement in Public Administration, the Federal Government Meritorious Executive Award, and the Roger W. Jones Award for Executive Leadership. Kammer received his Bachelor of Arts degree from the University of Maryland in 1969.

An agency of the Commerce Department's Technology Administration, NIST promotes economic growth by working with industry to develop and apply technology, measurements and standards. News and general information on the National Institute of Standards and Technology are available on the World Wide Web at http://www.nist.gov.

New Rules for the ATP Emphasize Partnering

The Commerce Department's National Institute of Standards and Technology announced (9 Dec 1997) several changes to the rules that govern the Advanced Technology Program. The major impacts of the new rules, published in the Federal Register, are to strengthen the ATP's emphasis on research ventures and consortia with a broad range of participants and to ensure that large companies pay a majority of costs on their projects.

The changes are the result of a study of the ATP initiated by Commerce Secretary William M. Daley last March. Conducted by the Department's Technology Administration, the study solicited comments from the public and experts on research and technology on strategies to strengthen the program and increase its effectiveness.

The most important changes to the ATP introduced by the new rules include:

- A formal definition of the term "large business," based on total annual corporate revenues, for the purpose of ATP competitions. Previously, the ATP had defined only the notion of a "small business" (based on the definition used by the Small Business Administration), raising the possibility that new program rules intended to apply only to truly "big" businesses would unfairly disadvantage thousands of medium-sized firms with limited resources. The new rule requires the ATP to publish annually, as part of the program's regular "notice of availability of funds," a dollar value to be used as the cutoff for determining "large businesses" during that year's competitions. The rule anticipates the use of standard measures of corporate wealth such as *Fortune* magazine's, *Fortune 500* list.
- A new requirement that large companies, when applying to the ATP as individual firms (outside of a joint venture), must provide cost-sharing funds at a minimum of 60% of total project costs. Previously, all companies had been treated alike regardless of size, and companies applying as individual firms were not required to provide any specific amount as their part of the cost share. All single-applicant companies participating in the ATP still are required to pay all indirect costs on their own, a provision that has not changed. The new rule is intended to encourage large companies to participate in joint ventures with other firms and to ensure that they pay a majority of total project costs.
- Several modifications to the ATP's project selection criteria (used in the evaluation of candidate projects) that place greater emphasis on joint ventures and consortia with a broad range of participants and that are intended to encourage the teaming of large companies with smaller companies.
- A new rule governing the valuation of goods, such as computer software, and related services provided by one member of an ATP joint venture to another, for the purposes of computing contributions to cost shares. Companies may count at least a portion of the actual cost of goods and services that they provide in support of an ATP project toward their share of the project's costs, but this can be difficult to calculate in the case of certain types of goods, company-developed computer software being the outstanding example, where the actual cost of the product is unclear and hard to document. The new rule is intended to provide a clear and consistent method of valuing such contributions.

The new rules also include some changes to ATP administrative and clerical procedures to provide greater clarity and consistency to the process. The multistep ATP selection process, while not changed, is more clearly defined in the new rules. The new rules take effect immediately and will apply to future ATP competitions. They do not apply retroactively to ongoing ATP projects. The Federal Register notice announcing the new ATP rules may be read on the ATP World Wide Web page http://www.atp.nist.gov. Individual copies may be obtained from the ATP by calling 800-ATP-FUND.

Nondestructive Characterization of Plasma Spray Coatings—Some Recent Industry/University Work*

A. Abbate, W. Russell, and P. Kotidis, Textron Systems and C.C. Berndt, SUNY at Stony Brook

Introduction

A nondestructive laser-ultrasonic technique and instrumentation for simultaneously measuring the thickness and the elastic properties of ceramic plasma sprayed thermal barrier coatings (TBCs) is currently being developed by Textron Systems, Inc. in collaboration with the Center for Thermal Spray Research of SUNY at Stony Brook. Tests have been performed on TBC samples ranging in thickness from 100 to 700 μm. These coatings were manufactured from yttria-stabilized zirconia (YSZ) feedstocks of identical chemistry, yet different particle size distributions, to investigate processing effects on coating material

*This is a "work in progress," and readers are invited to contact the authors and submit any comments. Other authors are invited to present short notes concerning current research that should be rapidly communicated.

properties that could result in coatings with different mechanical properties.

Background

Plasma sprayed coatings are widely used to protect parts from aggressive environments. In applications such as land-based gas turbines, TBCs are used to protect the turbine components from very high operating or firing temperatures. The TBCs are commonly applied by the standard air plasma spray process, which is an open-loop operation with no feedback about the coating conditions during deposition (Ref 1). It is very important to be able to assess the properties of the coating layer and its thickness as it is deposited, since on-line variations of the spray conditions, such as continuous wearing of the torch hardware, can adversely affect the coating quality and create significant part-to-part variations. Unfortunately, the standard method of evaluating coatings is destructive in nature; hence these tests cannot be performed on each produced part (Ref 2). As a result, coated parts may not have the consistent quality and durability needed for many applications (Ref 3).

Laser ultrasonics is based on the generation and detection of ultrasonic waves using lasers, thus avoiding any contact to the part (Ref 4). A short laser pulse, typically 10 to 15 ns in duration, is used to generate a thermoelastic stress wave of small amplitude by local heating of the sample. This ultrasonic stress wave has the typical shape of a spike (Ref 5). A second laser beam, located at a fixed distance from the generation point, is used for detection. In a uniform material, such as an uncoated part, the detected ultrasonic signal resembles the laser pulse delayed by the time necessary for the wave to travel from the generation point to the detection point.

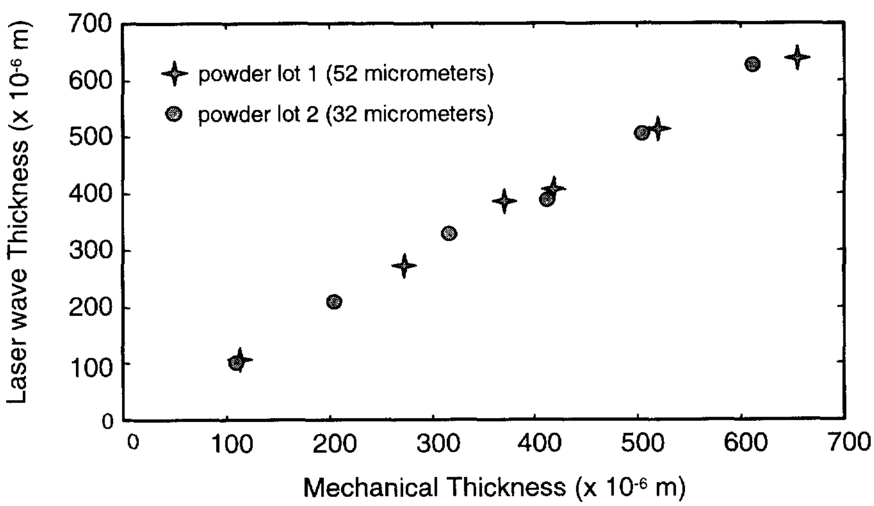


Fig. 1 Comparison between average mechanical thickness obtained using a micrometer and the thickness measured using the laser ultrasonic technique.

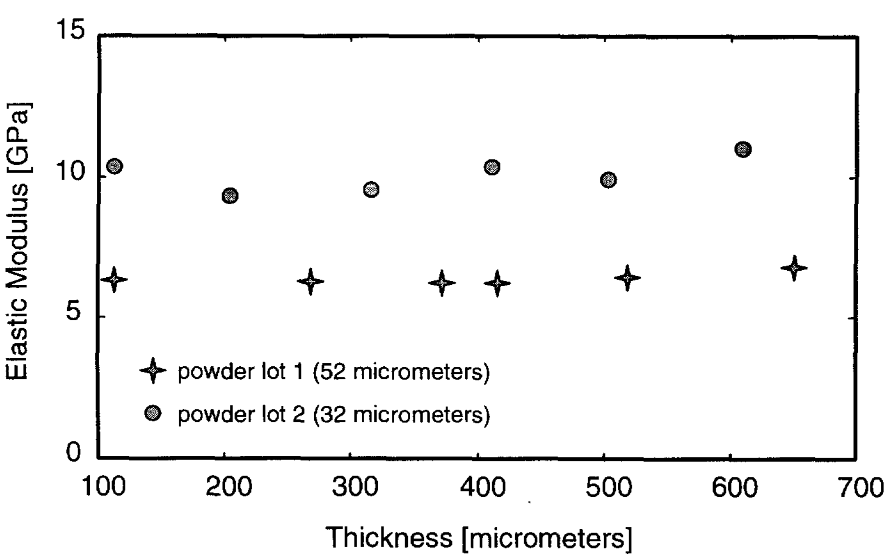


Fig. 2 Plot of the elastic modulus measured using the laser ultrasonic technique.

Results and Summary

The mean powder sizes used in this experiment were 52 and 32 μm, for feedstock lots 1 and 2, respectively. The corresponding densities were measured to be 5.16 and 5.3 g/cm^3, with relative porosities of 12.0 and 11.7%.

By comparison and fit of the experimental signals and the theoretical prediction models of dispersion, the elastic modulus and the thickness of the TBC can be simultaneously obtained. For example, by using the information contained in the signal and the dispersion curve, the elastic modulus and the thickness of the TBC were measured to be 6.7 ± 0.4 GPa and 638 ± 20 μm, respectively. By comparison, the thickness of the coating was estimated to be 621 μm by mechanically measuring the sample before and after the deposition process. The estimated error for the micrometer is about 10 μm.

Thickness readings have been compared to conventional micrometer measurements, and an accuracy of 15 μm for the ultrasonic measurement was established (Fig. 1). This measurement procedure is currently being incorporated into standard LaserWave Analyzer equipment, which will allow real-time control of the plasma process with increased efficiency in deposition.

Figure 2 indicates the nondestructive determination of the modulus for a variety of TBC coatings manufactured from the two feedstocks. These results indicate that the TBC manufactured from the finer powder exhibits the greater modulus, ~10 GPa compared to 5 GPa for the TBCs manufactured from the 52 μm feedstock. It is important to note that whereas the overall porosities of the two types of coating were approximately equivalent (~12%), the porosity distributions (not reported here) indicated that the coarse powder (52 μm) exhibited larger void sizes. These modulus values are lower than destructive measurements reported in the literature. Therefore, it is thought that the laser ultrasonic method allows a direct measurement of splat-to-splat intimacy, and that the numerical measurements obtained in this work better describe the nature of the structure/property relationships of thermal sprayed materials.

Contact: A. Abbate, Textron Systems, 201 Lowell St., Wilmington, MA 01887-2941; tel: 978/657-1910; fax 978/657-6770; e-mail: aabbate@systems.textron.com; or C.C. Berndt, SUNY at Stony Brook, Stony Brook, NY 11794-2275; tel: 516/632-8507; fax: 516/632-8525; e-mail: cberndt@ccmail. sunysb.edu.

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Industry Hopeful about Solvents

The coatings industry is keeping a hopeful eye on a handful of delisting petitions that could ease restrictions on three widely used solvents within the next two years. The Chemical Manufacturers Association (Washington, DC) expects to file a petition soon seeking the removal of ethylene glycol butyl ether (EGBE) from EPA's list of hazardous air pollutants. The EGBE petition joins similar actions filed by CMA for methyl ethyl ketone (MEK) in Nov 1996 and methyl isobutyl ketone (MIBK) in April 1997. The earlier MEK and MIBK filings also included petitions seeking the solvents' removal from the Toxic Release Inventory list of substances that must be reported under the Emergency Planning and Community Right-to-Know Act (EPCRA).

Solvents used in paint formulations are a major source of HAP and VOC emissions because they evaporate into the atmosphere as the paint cures. The 1990 Clean Air Act Amendments call for a progressive reduction in these hazardous air emissions. Thus the coatings industry has been working to lower the solvent content of paints, as well as to reformulate using solvents that are less harmful to the environment.

Industry experts question whether many of the chemicals on the HAPs and toxics lists warranted placement there in the first place, maintaining that their inclusion was based more on political expediency than sound science. For example, in the early 1980s, animal studies on the lowest-molecular-weight EGBE raised concerns about their potential reproductive and developmental toxicity. Despite the fact that subsequent studies showed EGBE and other ethylene glycol ethers do not cause such toxicity, all glycol ethers as a category were later added to the Clean Air Act's HAPs list, according to CMA officials.

Because this listing ignores the substantial toxicological differences among glycol ether types, CMA set out to collect the toxicity and exposure data necessary to petition for delisting. A CMA panel has been working for two years with EPA scientists to develop a "reference concentration" and a "reference dose" for EGBE, which represent the inhalation and oral concentrations below which no adverse human effects would be anticipated. This benchmark will then be used by EPA to assess whether emissions of the solvent at industrial facilities can reasonably be expected to cause adverse health effects. The panel also has compiled the available information on the environmental effects of ethylene glycol butyl ethers, which shows that the solvent does not persist in the environment or accumulate in plants and animals.

If EPA grants the petition, facilities manufacturing, processing, and using EGBE will no longer be subject to the Clean Air Act's maximum available control technology (MACT) requirements.

By Tim Triplett, Senior Editor, excerpted from *Paint and Powder,* Vol 73 (No. 9), 1997, p 28-30.

Excerpts from *Sulzer Technical Review*

Innovation Thrust for Car Engines

Introduction

A new generation of engines for private cars is being fabricated, for reasons of cost and also weight, entirely from AlSi alloys (Fig. 1). The cylinder crankcases are designed in such a way that the insertion of cast iron liners is often no longer possible. For this reason, the running surface is usually coated by using galvanically applied Nikasil, a material containing nickel. The galvanic process, however, is becoming increasingly threatened by environmental regulations. Moreover, one should prevent microscopic particles of nickel, a health hazard, from entering the environment through the exhaust pipe. An alternative is the plasma spraying of coatings. The requirements for plasma spraying of the coatings are short spraying distances for cylinder bores from 70 to 100 mm diameters and a rotating plasma spray torch, so that the cylinder crankcases do not have to be rotated during the coating process (Fig. 2). With the development of the RotaPlasma-500 system and new internal plasma spray torches, the requirements have been met.

Superior to Cast Iron

In internal combustion engines, cylinder bore, piston ring, and lubrication interact in a tribological system. To obtain low-wear operation, a balance must therefore be found between these components. This leads to a definition of the properties for the applied coatings:

- Low coefficient of friction against the piston ring material under the boundary conditions of lubrication
- Lower wear rate than with cast iron liners with lamellar graphite (for the same tribosystem)
- Good resistance to thermal shock
- Minimal tendency for scuffing
- High bonding strength to AlSi cast alloy
- Good mechanical machinability
- Consistent coating properties
- An elastic modulus close to that of the substrate

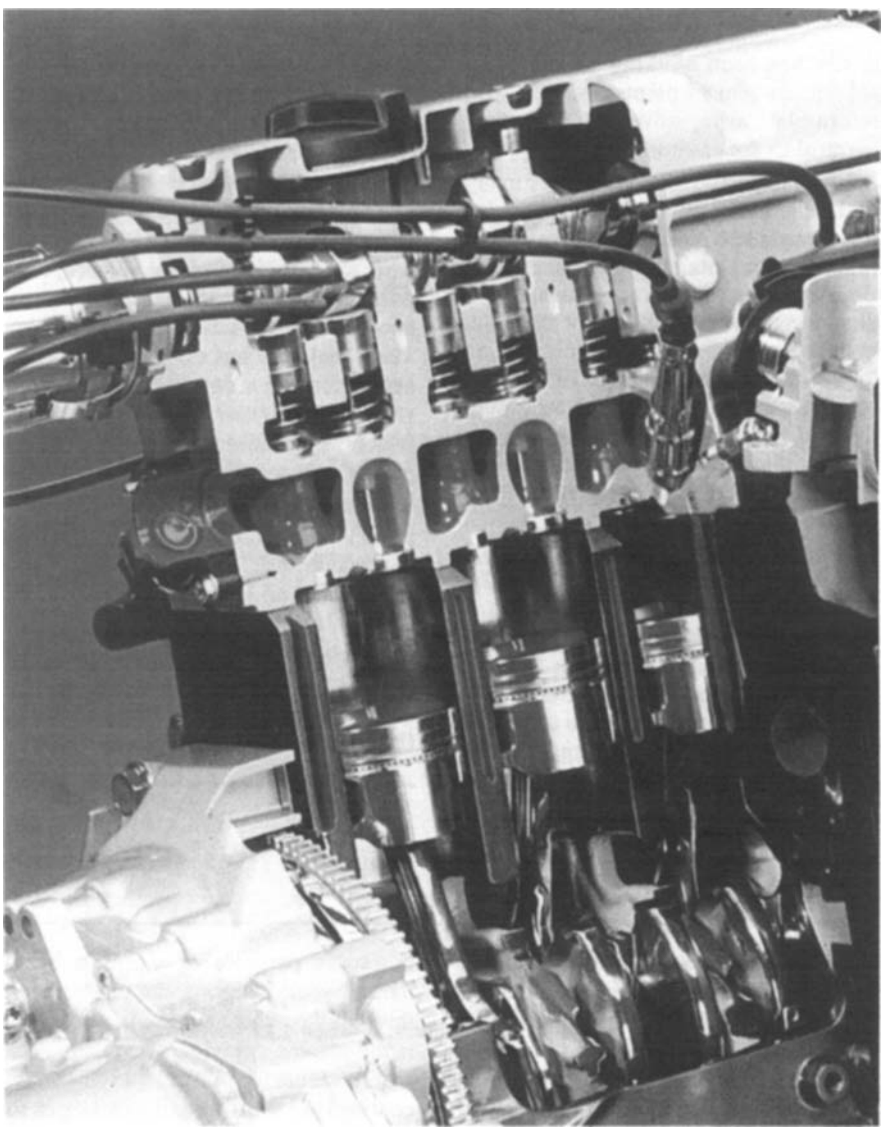


Fig. 1 Cylinder crankcases consist today of almost exclusively of aluminum. Their cylinder bores must be protected against wear. Plasma spraying has proven to be a flexible, economic, and environmentally friendly process for this purpose.

Considerable Savings Potential

These exacting coating properties can only be attained if engine manufacturers, tribologists, materials specialists, and those with knowledge of thermal spraying cooperate with each other. In this way, Sulzer Metco, in cooperation with an important Central European car manufacturer, were able to develop within 18 months coatings that demonstrated that the plasma spray process is a genuine alternative for the protection of cylinder bores in petrol and diesel engines (Fig. 3). During subsequent engine tests, the expected wear and oil consumption were confirmed. As a result of this, the manufacturer decided to order a RotaPlasma pilot plant for coating cylinder crankcases. These results open a considerable savings potential for the automobile industry, because the costs for plasma spraying are noticeably lower than those for galvanic coating (see Table 1). At present, negotiations are in progress with a number of car manufacturers for the development of coatings. Close cooperation already exists with many of these companies.

Fig. 2 RotaPlasma-500 during coating of cylinder crankcases. Within 60 s, the rotary internal plasma spray torch coats a cylinder bore while the housing remains stationary.

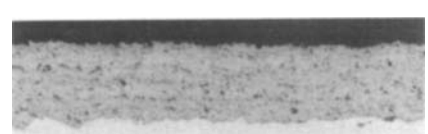


Fig. 3 Plasma sprayed, iron-base coating with a microhardness of 400 HV on the AlSi alloy casting of a crankcase. Engine tests show wear and oil consumption figures that are better than with iron castings.

Table 1 Plasma spraying of cylinder crankcases in figures

Coating time per bore, s	60-80
Plasma torch, rpm	Up to 200
Powder feed rate, g/min	Up to 80
Coating thickness after spraying, μm	120-250
Coating thickness after machining, μm	70-170
Cylinder block temperature during spraying (without active cooling), °C	80-120
Bonding strength on AlSi alloy casting, MPa	40-60
Microhardness (dependent on material), $HV_{0.3}$	350-650
Coating costs per cylinder bore (dependent on powder material)	CHF 8

High Technology Level

Owing to the flexibility of plasma spraying, almost all materials may be applied, provided they exist in powder form and can be melted. The user has the possibility of employing inexpensive, readily obtainable powder materials. In this way, specific coating solutions may be developed for each engine. Possible materials range from ferrous alloys to composites (metal/metal or metal/ceramic). There is a high degree of freedom in the choice of materials. Of great importance for the automobile industry is that these fully automatic spray facilities can be integrated into the production line.

Article by G. Berbezat and S. Keller, *Sulzer Tech. Rev.*, Vol 78 (No. 2), 1996, p 32-33. For more details: Sulzer Metco AG, Gérard Barbezat, Rigackerstralle 16, CH-5610 Wohlen, Switzerland; tel: +41(0) 56-618 8179; fax: +41(0) 56-618 8100.

Fig. 1 Efficiency gains of up to 5% are possible by reducing the clearance between the blade tip and shroud of jet engines. The necessary abradables are able to withstand surface temperatures of up to 1200 °C.

1200 °C Reached

Introduction

In the last two decades, air traffic volume has considerably increased, while the total quantity of fuel consumed has remained almost constant. The jet engine manufacturers contributed strongly toward this by increasing engine efficiency and power, by raising the operating temperatures, efficient aerodynamic design, and use of lightweight materials. As these now are mature technologies, one of the last means of further increasing efficiency, by up to 5%, is to reduce the clearance between the blade tip and casing (Fig. 1). In this manner, airlines can significantly reduce operating costs.

Rubbing Accommodated

The reduction of the blade tip to casing clearance can result in the blades rubbing against the shroud. By coating the shroud with abradables, this interaction can be accommodated. The thermally sprayed coatings are designed to release fine wear debris when machined by the blade while not causing any blade wear. The implementation of abradable coatings also increases the surge margin; hence, engine flow conditions are more stable and thus active safety greater.

Abradables are not restricted to aeroengines. They can also be used in most rotating equipment such as stationary gas turbines, turbocompressors, and pumps (Fig. 2). Sulzer Innotec and Sulzer Metco are the world leaders in the development of abradable coatings and cooperate very closely with most major jet engine manufacturers. The development of further abradables and abrasive blade tipping techniques is assured through participation in research projects such as Brite Euram. Technology developed within the framework of the Hexis project, in which oxidation-resistant and high-temperature materials are developed for solid oxyfuel cells, is applied in the abradable seal development program.

Wear Mechanism Identified

When sliding over the surface of an abradable, the blade tip strikes particles projecting from the coating. The force of impact drives the individual particle into the coating. Stored elastic energy causes the particle to rebound and debond. Because of the newly created free surface, it assumes a larger volume. The wear debris must now have the opportunity of escaping. This requires thin blade tip cross sections or rough sandpaperlike surfaces on the blade tips. If this is not

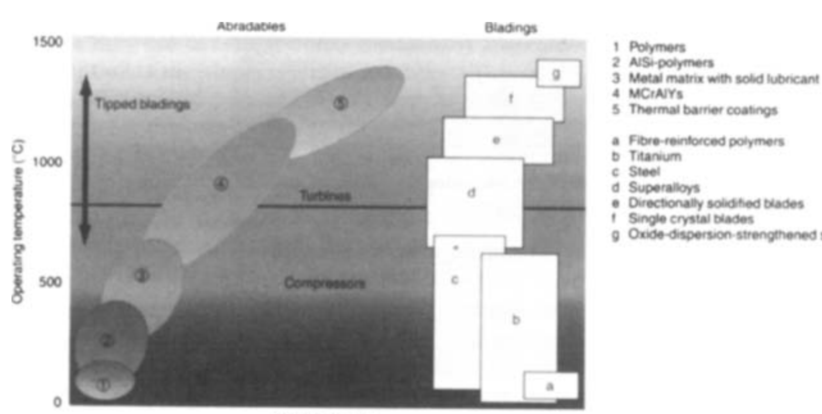


Fig. 2 Abradable families and blading as a function of the engine operating temperature and technology level. The key to the descriptions is: 1, polymers; 2, AlSi-polymers; 3, metal matrix with solid lubricant; 4, MCrAlYs; 5, thermal barrier coatings. a, fiber-reinforced polymers; b, titanium; c, steel; d, superalloys; e, directionally solidified blades; f, single-crystal blades; g, oxide-dispersion-strengthened superalloys

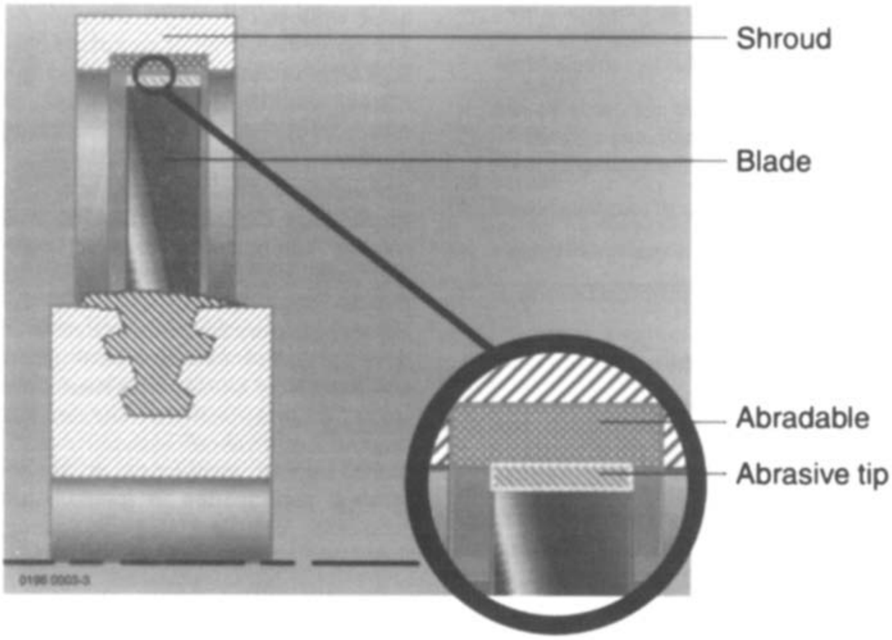


Fig. 3 The ideal abradable remains smooth when machined by the blade and is an effective gas path seal for thousands of hours.

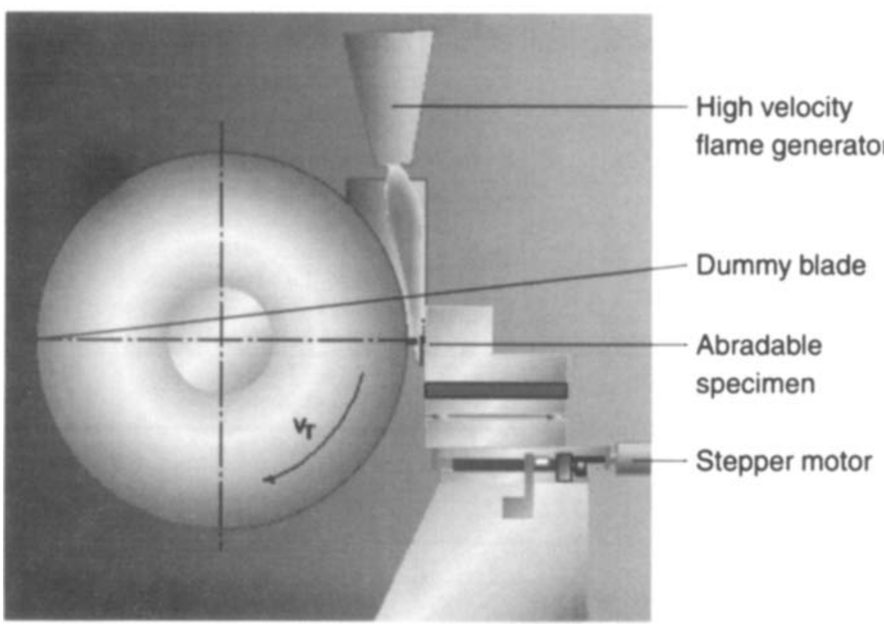


Fig. 4 The Sulzer Innotec test rig for abradables is capable of simulating in-service conditions at temperatures up to 1200 °C.

the case, the particle will become trapped between the blade tip and coating, and then the shearing forces result in local plastic deformation or rupture of the coating.

The energy necessary for the abrading process is supplied by the blade tip. It must suffice to break out individual protruding particles, thereby generating a new surface. The greater the particle bond strength, the more energy the blade tip must supply to break particles loose. If the forces are too high, the blade tip heats up and begins to wear, sometimes by abrasion but predominantly by melting.

Test Rig Improved

The development of abradables necessitates numerous tests, ranging from powder fabrication to the selection of the optimal spray process, to simulative laboratory testing and finally field trials. The goal is to achieve a seal that does not cause blade wear, maintains a smooth shroud surface, and remains intact for thousands of operating hours (Fig. 3).

The Sulzer Innotec abradable test rig shown in the *Sulzer Technical Review* (Vol 4/1990), p 8, has been considerably modified. Today, it is capable of simulating engine conditions up to 1200 °C (Fig. 4). Heating is achieved by means of a high-velocity gas stream passed over the shroud specimen surface. Blade-tip velocity is adjustable from 150 to 5400 m/s. The rate of incursion of the shroud specimen into the rotating rotor, which simulates the actual abradable seal interaction, can be set from 2 to 3000 μm/s.

The wear specimens tested on the rig are subsequently microscopically examined to determine the predominant wear mechanisms acting in abradable seals. The information is required to conduct modeling, which is an important cornerstone of material development. Many conventional and new coatings were evaluated in this manner. In Fig. 5 to 7, typical results are presented.

Successful Modeling

Laboratory tests conducted on a special tribometer made possible the study of the wear mechanisms found when blade tips were cut into abradables. At Sulzer Innotec, this information was converted into a model that takes into account not only the operating conditions but also the structure of the coating, the blade material, and blade tip design. By applying this model, coatings were developed that are capable of operating at surface temperatures of up to 1200 °C. To reduce the energy for detachment, the model calls for small matrix particles, a polymer to generate porosity and solid lubricants or release agents to act as dislocators in the coating. During deposition the polymer phase lowers the coating stresses thereby allowing the deposition of thick coatings. When burnt out in a subsequent heat treatment, the abradability of the coatings is further improved (Fig. 8). In ceramic-matrix abradables, the use of a release agent is not required because they wear in a brittle manner. The design of blade tips is critical. Tips thicker than 0.7 mm prevent particles from escaping. For exam-

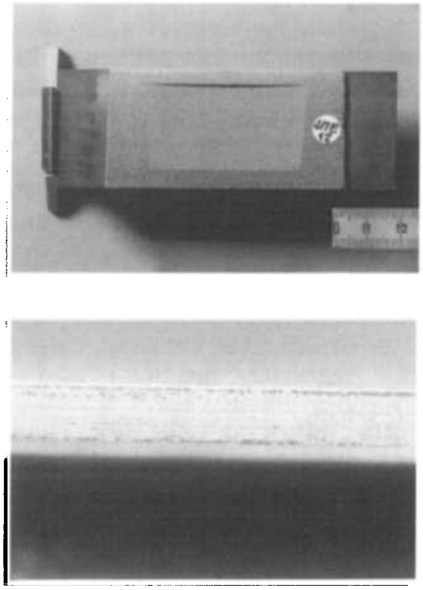


Fig. 5 The APS coating remains smooth after abrading. The 0.7 mm thick blade tip displays no wear (the original machining marks, perpendicular to the running direction are still visible).

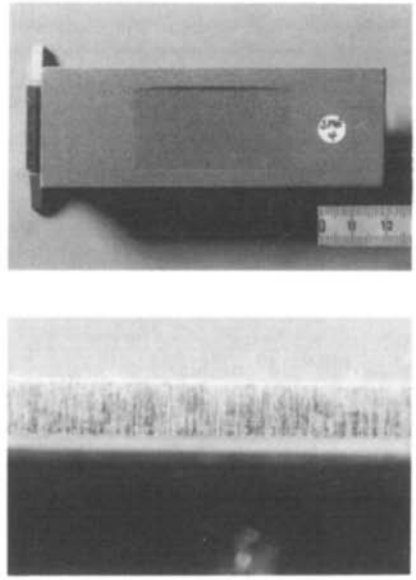


Fig. 6 A nickel-graphite coating tested under the same conditions as Fig. 5. The coating is rougher due to large pores created by the flame spraying. The blade tip is worn (original machining marks are no longer visible).

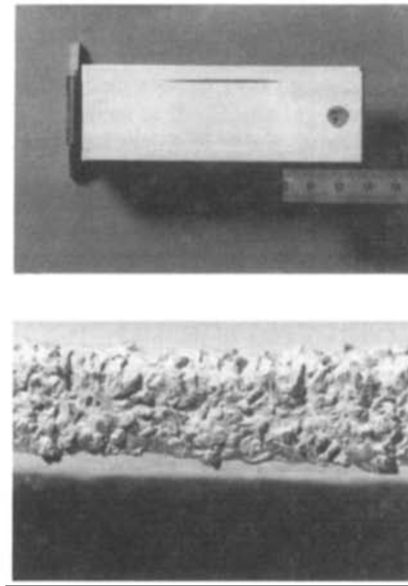


Fig. 7 The blade tip was cladded with abrasives using two laser passes. The tip was not worn during the cut into the ceramic abradable. The rough abrasive blade tip surfaces is replicated in the wear track.

ple, 0.4 mm thick uncoated blade tips are quite capable of machining relatively hard abradables, whereas 1.5 mm thick tips fail. For temperatures over about 800 °C, only ceramic-based abradables are suitable. To run against these abrasive tipping of the blade tips is a must. Very good results are obtained by laser remelting of blade tips with the simultaneous injection of hard particles.

Reproducible Quality

The abradables are applied by flame, high-velocity oxyfuel (HVOF) and atmospheric plasma spraying (APS). Flame spraying is capable of producing very porous coatings, but the reproducibility of this porosity is strongly dependent on the process parameters. In machining there is a risk of compacting the porous coatings. HVOF and APS coatings are sprayed relatively densely, but therefore require a sacrificial phase that can be burnt out to generate porosity. Customers prefer to use APS and HVOF because their controllable spraying parameters ensure reproducible quality.

Customer-Oriented Concept

The collaboration between Sulzer Innotec and Sulzer Metco enables the development of coating solutions for customer needs. In the example of abradable coatings, the engine manufacturers use and certify new coatings to run in their engines. Due to the close cooperation with Sulzer Metco, the customer experience and needs are effectively relayed to the abradables team where they are used to further develop and optimize the abradable family. This leads to improved products with greater benefits for the user.

Article by R.K. Schmid, F. Ghasripoor, and M. Dorfman, *Sulzer Tech. Rev.*, Vol 78 (No. 2), 1996, p 34-37. For more details: Sulzer Innotec AG, Richard K. Schmid, 1511, Postfach 65, CH-8404 Winterthur, Switzerland; tel: +41(0) 52-262 52 26; fax: +41(0) 52-262 0012.

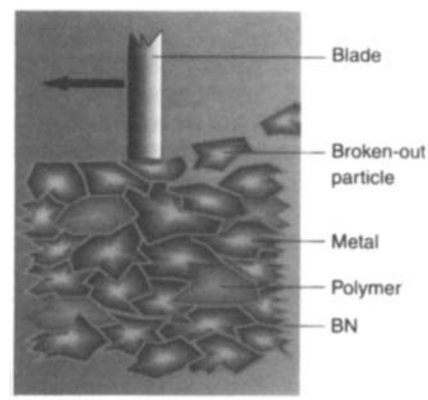


Fig. 8 The Sulzer Innotec Model: small metal particles, polymer (burnt out) and boron nitride (BN) functional as a release agent make up the coating. The energy required for the abrading process is kept low. The narrow blade tip favors the escape of wear particles.

Snowplows

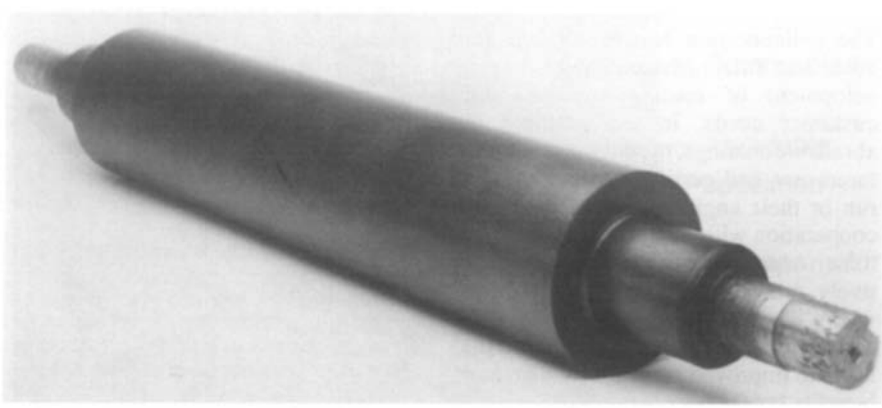
PFS Thermoplastic Powder Coatings introduces a tough, resilient PF 112 (flamespray) and Polyarmor Plus (fluid-bed and electrostatic) coatings on snowplows, which improve wear resistance, lower coefficient of friction, and help prevent ice and snow from building up on and sticking to the blade. Thermoplastic-coated snowplow blade users report being able to move more snow per pass while using less fuel.

Contact: PFS Thermoplastic Powder Coatings, 3400 West 7th, Big Spring, TX 79720; tel: 800/753-5263, 915/263-5263; fax: 915/267-1318.

New Plasmadize TNS Prevents Adhesive Residue Buildup on Metal Parts

A new formulation in the series of self-lubricating Plasmadize thermal spray coatings has been added to the line by General Magnaplate Corp., Linden, NJ. Plasmadize TNS, like the other formulations in the series, provides a high level of protection against corrosion and wear and dramatically improves the performance reliability of all types of metal parts. In addition, the coating eliminates adhesive residue buildup, thereby reducing downtime. Unlike conventional thermal spray coatings, which can be brittle and porous, Plasmadize—the next generation in thermal spray coatings, a true composite of the latest developments in metals, ceramics, polymers, and/or dry lubricants—is tough and flexible. These materials are combined to produce a new "synergistic" surface enhancement with a low coefficient of friction and other unique physical properties. Plasmadize TNS eliminates downtime in applications where adhesive residue and buildup can cause problems, such as adhesives formulating, label printing, tape manufacturing, and converting for any process in which metal parts contact adhesives or glues. Kettles, rolls, sealing bars, guides, slitters, knives, and other parts coated with Plasmadize are kept clean more easily and clean up faster, frequently without the need for chemical-based cleaners.

Contact: Candida Aversenti, General Magnaplate Corp., Linden, NJ 07036; tel: 908/ 862-6200, 800/852-3301; fax: 908/862-6110; e-mail: Info@magnaplate.com; www: http://www.magnaplate.com.



Example of General Magnaplate's coating on a roll

GE Power Generation Approves "BondArc"

Electric power generation owners and maintenance engineers welcomed the approval of TAFA's thermal spray wire 75B((BondArc) by GE Power Generation Engineering. BondArc is used on hydraulic pistons, heavy machinery shafts, wastewater rolls, pump impellers, sheet metal forming rolls, and many other applications. BondArc is a self-bonding material to annealed or hardened carbon steels, annealed or hardened alloy steels, stainless steels, aluminum, nickel, cast iron, titanium, and tantalum. This self-bonding characteristic minimizes costly, time-consuming preparation of the substrate and increases the reliability of top coatings. The BondArc coating is resistant to high-temperature oxidation, thermal shock, and abrasion. The bond strength of BondArc is typically 9100 psi (63 MPa) on clean but unroughened steel substrates. The coating hardness of BondArc typically ranges between 55 and 80 HRB.

Contact: Joan Rich, TAFA Inc., 146 Pembroke Rd., Concord, NH 03301; tel: 603/223-2108; fax: 603/225-4342; www: http://www.tafa.com.

Molycorp Relocates Sales and Customer Service

Effective 1 Jan 1998 Molycorp has relocated its Sales and Customer Service office to: Molycorp Inc., A Unocal Company, P.O. Box 164, 67750 Bailey Rd., Mountain Pass, CA 92366; tel: 760/856-6680, 888/577-7790; fax: 760/856-6676.

News from ITSA

UTSC '97: A Major Success

By sheer numbers, UTSC '97 provided a showcase for thermal spray technology that is unequalled by our traditional thermal spray conferences. More than 8600 visitors streamed through the Indianapolis Convention Center, taking in one or more events, that is, the Materials Exposition, the Heat Treating Exposition, or the United Thermal Spray Exposition. The great benefit to thermal spray exhibitors was an often first-time opportunity to showcase the capabilities of thermal spray technology to new potential users. Several of our members also fielded questions at the "Ask the Experts" event, among them Al Kay, Charles Kay, Charles Aldridge, Chris Berndt, and others. The technical sessions, for which Marc Froning was one of the organizers, provided a rich diversity of information that ranged from the cost of compressed air to the tribology of HVOF sprayed tungsten carbide. However, without a doubt, for ITSA the highlight of the event was the induction of two ITSA members into the Thermal Spray Hall of Fame:

- Robert Mahood "for his leadership in the MSC (the forerunner of ITSA) and thermal spray committees of ASM and AWS."
- Jack Ritchie "for providing dynamic leadership in acting as an ambassador for the expansion of thermal spray technology around the world."

ITSA Membership on the Rise

ITSA Membership Chairman, Marc Froning, reports that more than 22 membership inquiries came in during the third quarter, a large number coming in at the UTSC '97 event, some from SPRAYTIME, and two recommendations from members Jean Mozolic and Douglas Dickerson. Reflecting the growth of thermal spray activity around the globe, inquiries continue to come from countries such as India, Chile, Mexico, and United Arab Emirates.

Marc stresses that bringing these far-flung potential members, as well as other North-American-based members, into the ITSA fold takes more than just a mailing of a membership information kit with an application. Accordingly, he has joined forces with our new Marketing Chairman, Scott Goodspeed, to expedite a membership followup campaign that the two chairmen are putting in place.

ITSA Welcomes AIM & Metallisation

With the addition of two new Associate members, AIM Inc. of Loveland, OH, and Metallisation Inc. of Brunswick, OH, ITSA's membership roster tops the 50 member mark. AIM, which will be represented by Product Manager James Ryan, is a leading international distributor and processor of high-performance raw materials and consumables to the aerospace and petrochemical industries. Their product line includes consumables such as thermal spray powders and preforms.

Contact: AIM Inc., 420 Wards Corner Rd., Loveland, OH 45140; tel: 513/831-2939; fax: 513/831-3859.

Metallisation Inc., which will be represented by CEO John Seaman, designs, engineers, and manufacture equipment and materials for thermal spray processing. Their equipment portfolio includes comprehensive Flamespray wire and powder systems, as well as Plasma and HVOF systems for industrial users. They provide a broad range of engineering materials in wire, powder, and cord form.

Contact: Metallisation Inc., 1126 Industrial Parkway North, Box 9, Brunswick, OH 44212-1055; tel: 330/220-1055; fax: 330/220-5070.

Marketing Committee News

Scott Goodspeed of Praxair takes over as Chairman of the Marketing Committee, replacing Jean Mozolic of H.C. Starck. Jean did an outstanding job of establishing some successful marketing programs, not just for ITSA, but for the thermal spray industry. Goodspeed is building on the momentum of those programs and has established some important new ones, as well. He has enlisted some high-level marketing support from experts at Sulzer Metco and Engelhard and will work closely with John Hayden to bring better thermal spray information to specifiers. The possibility of an ITSA Web Page to showcase the ITSA organization is being pursued. The goals are to bring the thermal spray message to more industrial users and to build a diverse, quality membership.

AWS presented ITSA with a complementary booth and furnishings for the upcoming AWS Welding Conference scheduled for Detroit on 28-30 April 1998. The conference will feature a "Thermal Spray Pavilion" strategically positioned in a central exhibit area, which provides an excellent exhibit opportunity for ITSA member companies. The AWS thermal spray program gets stronger each year.

Contact: Jimmy Walker for information on exhibit space at F.W. Gartner Thermal Spraying Company, 3824 Lamar St., Houston, TX 77023-1305; tel: 713/225-0010; fax: 713/229-9841.

News from ASM-TSS

Prof. Richard Knight is Appointed as the New Chair for Training Committee

This committee has met twice recently, at UTSC '97 and at Drexel University. Draft plans for the TSS Training programs have been formulated. A good start with the plans has been made, but, as with all volunteer organizations, our goals will only be achieved through the efforts and hard work of TSS members. Our immediate need is for members to volunteer as Chairs on a number of subcommittees.

Contact: Richard Knight, Chairman, ASM Thermal Spray Society Training Committee; tel: 215/895-1990; fax: 215/895-2332; e-mail: knightr@duvm.ocs.drexel.edu.

Nomination for the Thermal Spray Hall of Fame

Nominations for the 1999 inductees into the Thermal Spray Hall of Fame are currently being accepted and are due 30 Nov 1998. The Thermal Spray Hall of Fame, established in 1993, is a means of recognizing and honoring leaders who have made significant achievements and contributions to the science, technology, practice, education, management, and advancement of thermal spraying. The ASM Thermal Spray Society is fortunate in having many outstanding people in its membership who are part of the thermal spray industry where outstanding work has been and is currently being done. You are encouraged to nominate an outstanding candidate for the Thermal Spray Hall of Fame.

For more information, contact Kathy M. Dusa, ASM Thermal Spray Society Administrative Assistant, ASM International, Materials Park, OH 44073; tel: 440/338-5151, ext. 5544; fax: 440/338-4634; e-mail: KMDusa@po.ASM-Intl.org.

Opportunities to Contribute to TSS and JTST

The ASM Thermal Spray Society (TSS) is continuously looking for "new blood and ideas" so that there is a constant reinvigoration of TSS objectives and programs. There are positions for suitably qualified volunteers in a number of ongoing efforts. These present wonderful opportunities to not only "learn how the society works" and help it grow into the next century, but will assist your own professional development. Some of these opportunities include:

- People who can contribute to the Proceedings effort of TSS conferences
- Reviewers for manuscripts that are submitted to the *Journal of Thermal Spray Technology* (JTST)
- Assistant editors/guest editors/guest commentators for JTST
- Special features editors for JTST

Please forward your ideas or concepts to Chris Berndt, SUNY at Stony Brook, 306 Old Engineering, Stony Brook, NY11794-2275; tel: 516/632-8507; fax: 516/632-8525; e-mail: cberndt@ccmail.sunysb.edu.

Invitation to Submit Color Photos to JTST

JTST is always on the lookout for photogenic contributions for the front cover. The only condition is that the photograph or picture must be related in some fashion to thermal spray. This could be your chance to have your work on the cover of JTST. Let your artistic imagination run wild and submit contributions to Christ Berndt, SUNY at Stony Brook, 306 Old Engineering, Stony Brook, NY 11794-2275; tel: 516/632-8507; fax: 516/632-8525; e-mail: cberndt@ccmail.sunysb.edu.

WEB Site News

A Quote from Bill Gates

"Use of the web is already rising spectacularly. Two years ago, basically no one got news from the web. Now, even with photos from the Mars Pathfinder mission appearing in the newspapers and on television, millions of people used the web to browse the images at http://www.jpl.nasa.gov/marsnews/img/."

"JournAlert" from ASM International

Do you need to keep up to date on what's being published? Need to streamline your library's routine process? Whether you subscribe to the print edition of ASM's technical journals or not, this free service is designed to quickly keep you abreast of important developments. For each issue, you will be e-mailed the table of contents of the journal (2-4 weeks prior to publication), plus be the first to know of new ASM publications, book sales, and editorial policies.

The offer is available now for the following three of ASM's technical journals: *Journal of Phase Equilibria, Journal of Thermal Spray Technology,* and *Journal of Materials Engineering Performance.* To subscribe, send an e-mail to: majordomo@databack.com, with the message text: "subscribe journal name," where journal name is either JPE, JTST, or JMEP. If you wish to subscribe to more than one JournAlert title, you must send a separate e-mail for each subscription. Also, check the ASM web site at http://www.asm-intl.org for our searchable archive.

Web Site by Olympus

An international Web Site has been created by Olympus in Europe at http://www.olympus-europa.com to provide a new source of information on applications, techniques, equipment, and events of interest to European microscopists. Olympus customers across Europe cover a broad range of applications in research and industry. Their user experience together with the in-house expertise of Olympus applications specialists and engineers provides a ready source of up-to-date information on microscopy methods, supplemented by announcements on the whole product range, highlights from the customer magazine *Mikroskopie,* and information on Olympus activities at congresses and exhibitions.

International Society of Coating Science and Technology

A new organization called the International Society of Coating Science and Technology, Hockessin, DE, has been formed. The group offers a forum for presenting new technologies, encouraging technology transfers, and providing continuing education programs. For more information, visit the web site at http://www.umecheme.maine.edu.iscst or tel: 302/695-3921.

Deicing Strategies for Roads

As anti-icing and other innovative winter maintenance strategies take hold, the benefits are proving substantial. View and examine a report on this technology on www.fhwa.dot.gov/reports/mopeap/eapcov.htm.

Protective Coatings on the Web

The January issues of the *Journal of Protective Coatings & Linings* (JCPL) and *Protective Coatings Europe* (PCE) can be viewed at Protective Coatings worldWIDE. Connect to http://www.protectivecoatings.com.

A Tutorial on Corrosion

At www.avestasheffield.com there is an introductory tutorial on corrosion and on the fabrication and applications of stainless steel. There is also detail, including corrosion tables, on many grades of stainless steel.

WWW Sites of Interest

- The Nickel Development Institute: www.nidi.org
- Carpenter Technology Corporation: www.cartech.com
- The South Africa Stainless Steel Development Association: www.vc.co.za/sassda/
- "Jane's Special Reports" are reknowned and can now be researched on www.janes.com

People in the News

Elena Petrovicova Awarded Fellowship

Elena Petrovicova, Ph.D. student in the Center for the Plasma Processing of Materials (CPPM) in the Department of Materials Engineering at Drexel University, Philadelphia, was awarded an Engineering Foundation (EF) Conference Fellowship for the conference "Thermal Spray Processing of Nanoscale Materials" held in Davos, Switzerland, on 3-8 Aug, 1997. Engineering Foundation Conferences provide an opportunity for the exploration of problems and issues of concern to engineers from many disciplines and help to generate ideas and solutions in new multidisciplinary areas.

The conference fellowship allows young professionals to participate in EF conferences and provides them with valuable experience by promoting interaction with the other participating experts. Elena's research is focused on the thermal spray (HVOF) processing of a range of nanoreinforced thermoplastic polymers. Thermal spraying has proven to be an excellent solution to the processing limitations of reinforced polymers because it eliminates the need for solvents or high processing temperatures. Furthermore, the application of these coatings is not limited by the size of the part, and such coatings can be applied in the field. The significant improvement in scratch and wear resistance obtained offers great promise in surface protection applications as excellent aqueous corrosion barriers where increased scratch and wear resistances are required.

Wang Joins AGTSR

Prof. Ting Wang of the Mechanical Engineering Department at Clemson University will be assisting the AGTSR office on various technical-administrative tasks in support of the Land-Based Gas Turbine Consortium. As a result, he will be involved in AGTSR-related correspondence to facilitate the administration of this nationwide consortium under sponsorship with the U.S. DOE, Federal Energy Technology Center. Contact Dan Fant at 864/656-2267.

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. 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—Grinding Problems: Has anyone done any experimenting with machining, as opposed to grinding, of Metco 71VF-NS? I have aerospace components that are coated on the inside diameter with this powder. The hardness is in the 53 to 58 HRC range. We are repairing this bore, and I know we must grind the final size. However, I would like to remove the old plasma coating quickly. I tried a polycrystalline diamond insert at 250 sfm and 0.005 in. D.O.C., but lost the $50.00 insert after a couple of passes (the thickness to be removed is in the area of 0.025 in.). So I'm wondering if anyone has any suggestions.

Question 2—Thermal Conductivity Data: Does anyone have data on thermal conductivity and specific heat for combustion (or plasma) spray ceramics—particularly zirconia and alumina?

Answer 2a: I can help by pointing you in the right direction to find some references.

There have been several articles/presentations over the past few years by R. Dinwidde (Oak Ridge National Lab) and B. Nagaraj (GE Aircraft Engines) et al. on TBC thermal conductivity.

T.A. Taylor, "Thermal Properties and Microstructures of Two TBC Coatings," International Conference of Metallurgical Coatings and Thin Films—April 1992.

H.E. Eaton and R.C. Novak of United Technologies Research Center had some publications in the 1986 to 1990 time frame about changes in thermal conductivity due to high-temperature exposures.

Answer 2b: Thermal conductivity of ceramic coatings is sensitive to porosity and temperature among other things (e.g., to spraying parameters), so there is a range of values. R.C. Brink (*Journal of Engineering for Gas Turbines and Power,* July 1989, Vol 111, p 570-577) reported some for ZrO_2/NiCrAlY-graded coatings at 400 °C. First group of samples: 5% porosity 1.13 W/m · C, 13% porosity 0.94, 12% porosity 0.93. Second group of samples: 5% porosity 1.15 W/m · C, 12% 0.8, and 4% 0.62. Porosity was determined by the coating specific gravity and thermal conductivity by laser flash measurement technique, both methods are detailed in other references cited in this paper.

Question 3—Masking Materials: Does anyone know of an inexpensive consumable masking material? A difficult geometry prevents us from using traditional methods. Ease of application (and removal, if any) are essential.

Answer 3a: Furon make various metallized masking tapes for thermal spray. Tafa also has a paint on mask material.

Answer 3b: You can use stainless steel foils. You can obtain these foils from cans of vegetable oils. They are inexpensive and very ductile. You can buy these foils from scrap. They work very well, even for HVOF.

Answer 3c: There are many of good tape manufactures, such as Mystik, Tafa, 3M, Sulzer-Metco, and so forth, that supply various types of tapes. You need to determine the type of application, type of metallizing process, and type of blasting operation to come up with the best type of tape. My experience has shown that an aluminum tape with fiberglass backing is a good tape for all thermal spray operations up to plasma spraying. You might have to use two or three layers next to the area that you are going to spray. This will give the substrate added protection from the blasting operation. As to HVOF, up to a year ago there really wasn't a good tape for this process; a lot of tape companies were experimenting with tapes, but they couldn't come up with one that take the heat and velocity of HVOF, so we used fabricated metal masks.

Answer 3d: Tapeworks Engineered Tape Solutions (610/264-5115, Allentown, PA) sells a silicone-based compound that can be molded into any shape desired. Once cured, it will retain its shape and can withstand grit blasting and thermal spray applications. This is excellent for areas that tapes cannot cover, that is, threaded holes, narrow strips, and complex geometries. The consistency of the compound is similar to the "Silly Putty" we played with as children. Once cured at 325 °F for 25 min, it looks and acts more like an eraser on a lead pencil.

Currently, two thermal spray equipment companies market this product under the "MACHBLOC" trade name: Metco and Praxair (formally Miller Thermal). Another suggestion is Airex Rubber Products Corp. (860/342-0850, Portland, OR). They manufacture a rubber masking material that can be reused from one operation to another. Initial costs are probably not in line with tape usage, but being reusable, life-cycle considerations may reflect significant cost saving. An advantage of Airex products is that they can be machined to any shape, size, and area to be masked. They can take a drawing of the part to be masked and generate a mask to fit the area needing masking. After reading some of the responses you received, I agree with the foil-backed tape response as the best if tape is being used. I also agree with the suggestion to use multiple layers. Another suggestion is Teflon tape (not to be confused with teflon tape used as thread sealant). It is not as resistant to thermal spray, but there is not as much buildup of coating material as with foil tapes.

Answer 3e: In using any type of tape as a mask for flame spray operations, you also should consider removal of the tape. Some might leave more of a residue from the adhesive than others.

Question 4—Corrosion Resistance TS Coatings: What is the sense of "Mg" in AlMg5? We have been trying to find out the reason for spraying AlMg5 instead of just "plain old" Al (typical purity 99.7). We found that there is a lot of confusion on this subject. One applicator would claim "better/worse spraying characteristics," others would assert "higher/lower adhesion values," and a third would claim "a significant influence on the corrosion protection." Also, are there any data on the amount of magnesium that actually ends up in the spray coating? To summarize this in one question: Can anybody please give me a rational reason for the use of AlMg5 as a corrosion-resistant thermal spray coating on steel in the marine environment?

Answer 4a: I too have been trying to figure out the advantage of AlMg5 over straight aluminum. I think it might be another gimmick like the 85/15 wire. There are more than 80 years of case studies on pure zinc and pure aluminum. Please let me know if there is any other data on this.

Answer 4b: Here's the story behind Al/high-Mg as I know it. Imagine a closed-carbon steel vessel with a tap (sweet) water where only a portion of the steel surface can be spray coated with an Al-Mg alloy. Both Al and Mg ions dissolve in water protecting the steel structure underneath. Mg is more electronegative than Al, and a Mg-rich coating surface doesn't passivate as fast as an Al surface. In other words, Mg-rich coatings offer a higher "ion throwing power," which is important if the water in the steel vessel is occasionally flushed out and replaced with a fresh water. Obviously, the concentration of Mg in Al-Mg coatings must exceed a certain threshold in order to activate the preferential dissolution of Mg. The threshold value is set by reaction kinetics in a given aqueous environment (not a material constant) that is, depends on makeup of water impurities and must be determined experimentally. It so happens that for the majority of tap waters across the U.S., the threshold concentration of Mg in Al-Mg coating must reach some 3.5 wt% in order to get the required throwing power if the steel vessel is sized like a typical residential water heater.

Now comes Part II—how to deposit an Al-Mg coating, which contains at least 3.5 wt% of Mg. Well, it's not easy since Mg has a high vapor pressure and burns away in molten phase if exposed to air or even to CO_2 or nitrogen. If you conventionally spray Al-Mg alloy wires with an electric arc-spray gun, the recovery of Mg in the deposited coating is next to nothing, and the whole galvanic protection mechanism outlined above won't work. If you spray that with a flame gun, the oxide films covering coating particles will inhibit the desired aqueous dissolution kinetics. If you spray it with a typical plasma gun, you evaporate all Mg, not to mention the fact that this would be quite expensive and risky—handling large quantities of dry and fine Al-Mg powders is dangerous.

In our arc-spray experiments in the past, we tested diverse gas spraying compositions and process parameters (amps, volts, pressures, nozzles, standoffs, etc.) to find combinations which gave us up to 96% recovery of Mg in the coating as verified by chemical analysis. Thus, if you start with an Al-5%Mg feedwire, you'll get more Mg in the coating than you need even if that's done in ambient air, without atmosphere chamber. Subsequently, we run corrosion tests on these coatings and got excellent results. I bet, all "Al-5Mg" coatings you refer to in your mail have less than 1 wt% of Mg, but no one cared to check their real composition assuming that what's in the feedwire ends up in the coating. Additional comments: Yes, Al-Mg coatings spray (atomize) and stick better than Al coatings, especially if sprayed in such a way that the majority of Mg is lost. This is because when Mg burns, the drops landing on substrate are hotter, and the crumbing MgO inclusions relax internal coating stresses so the adhesive strength exceeds the cohesive strength. This doesn't help in galvanic protection of course, but you could beneficially use it to enhance the overall coating adhesion by, first, spraying a thin (~0.003 in. thick) Al-Mg layer with depleted Mg and, second, spraying the "right," Mg-rich, top portion of the coating (~0.007 in. thick) using proper spray conditions. Note, the whole galvanic protection scheme is far less effective in fast-moving sea waters because the throwing power factor can't match the fast transport rates there. Moreover, sea water salinity enhances rather than inhibits dissolution of Al, so there's less need for Mg in the coating. But you may still benefit from the adhesion/cohesion interplay offered by the Mg-depleted Al-Mg coatings if the cost of Al-Mg feedstock you can buy justifies that.

Answer 4c: We arc spray AlMg5 in preference to Al. Some of our experiences are listed below:

- We tried arc spraying one wire 99.99% Zn and one wire AlMg5 both the same diameter. The result of the sprayed coating when analyzed with a electron microscopy was: Al 35.8%, Mg 1.41%, Fe, 0.22%, Zn 62.57%. This infers to me that if we tested 100% AlMg5 the Mg content would remain close to the composition of the feedstock.
- We find smoke levels about half when arc spraying AlMg5 versus Al.
- Sparks are less when spraying AlMg5 versus Al making it easier for the operator to see where they are spraying.
- Sparks are a orange color when arc spraying AlMg5 versus a bright white color when spraying Al, again making it easier on the operator.
- We get a smoother finish when arc spraying AlMg5 versus Al.
- From our adhesion testing I would not like to say whether AlMg5 has higher adhesion than Al both appear about the same with possibly AlMg5 being slightly higher.
- We have had the unwanted experience of Al developing a orange stain, but have not experienced this staining to date with AlMg5.
- In the annealed state (as sprayed) AlMg5 is the much harder/stronger coating—after all AlMg5 is very similar to structural type Al 5356.

My feeling is AlMg5 will perform equal to Al in most situations in corrosion applications if not better. We justify the use of AlMg5 on applicator ease and environmental concerns (less smoke) for the small amount in extra cost of AlMg5. I do not think AlMg5 or ZnAl-15 are gimmicks.

Answer 4d: European fabricators, the FHWA and over 20 Departments of Transportation have tested and do not believe that 85/15 is a "gimmick." We suggest reading those 80 years of experience and also read the 20 years of experience the U.S. and Europe has had with ZnAl-15 on steel. The FHWA also has extensive research done on 85/15, which they will share.

Answer 4e: The Federal Highway Report concludes that there is no difference in corrosion protection between zinc, 85/15, and pure aluminum so why would one pay more for 85/15?

Answer 4f: Corrosion rate of metal is affected by many factors (such as environment, materials, stress conditions, and etc.). It is not wise to jump into the conclusion that the corrosion resistance of one metal is better than the others without specifying the working conditions of these materials.

Answer 4g: In our opinion there is nothing better for the decks of oil rigs and ships that a thermally applied pure aluminum coating. The aluminum becomes extremely hard and resistant to abrasion and corrosion once it oxidizes. It can be applied at rates exceeding 1200 ft^2/h at 10 mils.

Answer 4h: The 1997 Federal Highway Report clearly states that there is no difference, other than cosmetic, between 85/15, zinc and aluminum. Twenty State DOTs have not endorsed 85/15 and, in fact, are reviewing the high cost of 85/15 over zinc when there is little difference between the two, especially because the majority of work includes a seal coat of some kind. As I am not a supplier of wire, my interest is in providing the best coating for the money. We have to be competitive with paint, and there is not enough justification for 85/15 over zinc or aluminum. A good example of this would be the Trenton Bridge project, Aug 1997, where 85/15 was specified, but the engineer in charge could not find one definitive study that showed that 85/15 was that much better than zinc. They saved a ton of money on the project.

Question 5—Reclaiming a Worn Rotor: I have encountered a problem of outer surface of a rotor shaft worn out. We are trying to recover the diameter by either welding or metallizing. The material of the shaft is Ni-Cr-Mo-V forged steel, which has a tensile strength of greater than 750 MPa. We should build up 2 mm in terms of radius. Loads for the worn area of the shaft should be combination of both alternating torsional and bending mode. The stress level is estimated to be 4 kgf/mm^2. If a metallizing process is applicable, it will be more economical than the repair welding. However, I am afraid that it will not tolerate such alternating load. Any experience record for application of metallizing to a shaft repair will be helpful.

Answer 5a: Some important information is required before it is possible to make the determination of a welded versus a TS coating on your rotor: for example, diameter of the worn area, width of the worn area, cause of the wear life of the original untreated part, life required, maximum RPM, temperature of the part during operation, previous repairs conducted or attempted, failures, and ease of access to this part for future repairs.

Answer 5b: TS coatings aren't best for the fatigue cycling, but it's doubtful the shaft section requiring the repair is actually experiencing significant tensile or shearing strains that are most damaging to coatings. Thus, depending on the shaft wear mode you can try a 400-series type steel coating (abrasion resistant) or any of the sliding wear resistant Ni/Co-base coatings. [You'd have to say more about the shaft wear mode and service to make better recommendations on the coating material including the bond coating.] What's really important here is cooling of the shaft and coating during spraying, for example, intermittent spraying—the amount of material required here is large, and proper cooling will eliminate tendency for thermal cracking. Yes, TSCs are popular in similar applications, which at the low end include just mild carbon steel coatings, and weld overlays are more expensive and will result in shaft distortion.

Question 6—Reclaiming Steel Containers: Presently, I'm looking at the repair of a large number of large carbon steel containers. Recycled aluminum, extruded into wire, is being considered, which solves an environmental problem; however, the lifetime costs and issues of cylinder repair are important factors.

Answer 6a: If you are referring to nuclear waste storage containers, I would recommend pure zinc as we have already tested our process which transfers little heat to the substrate and will not cause a problem of instability with the contents. Aluminum is applied at a higher temperature which may transfer some heat through the steel.

Question 7—Spraying of Lead: Can anyone advise on manufacturers of lead wire from 2.3 to 4.8 mm diam precision which is wound on to spools?

Answer 7a: There has been some recent messages on spraying lead. Anyone attempting this should know that this can be quite hazardous and very good safety practice must be followed: high levels of local ventilation; excellent personal protection, such as an air-supplied respirator or appropriate full-face respirator; good personal hygiene and appropriate care of contaminated work clothes; and appropriate cleanup of the workplace and disposal of any collected dusts or residues. You need to review the appropriate safety regulations and, if necessary, consult with an expert.

Answer 7b: I agree with your information on the dangers of lead spray. Maybe you can suggest an alternative material for the typical application of lead, which is corrosion resistance against liquid sulfur. I recommend that before anyone consider spray lead, that they visit the following web site: Triodyne Environmental Engineering, Inc., 5950 West Touhy Ave., Niles, IL 60714-4610; tel: 847/647-6748; fax: 847/647-2047; e-mail: hutter@mcs.com; www: http://www.mcs.net/~hutter/tee/lead.html.

Question 8—Measuring Deposition Efficiency: I want to reduce spray time without detriment to the coating microstructure. So, I intend to measure the deposit efficiency (DE) of the coating. Can someone give me information about a test method for DE?

Answer 8a: What you are proposing is, in my opinion, dangerous, potentially fatal in a coatings sense. It is simply not possible to pick one parameter/characteristic of a process (you don't specify which one) and seek to maximize it without first ensuring that this change has not had a detrimental effect on the microstructure of the coatings you are getting. Remember, it is the coating microstructure which by-and-large governs the properties of the coating and hence its performance in service. You must at least do some verification tests. A good spray procedure should measure DE anyway.

What you need to do is simply measure the amount (gms) of material fed in a given time, then measure what proportion of this is actually deposited on the substrate in this time. If, for example, half of what is going through the gun is actually going where you want it, then you basically have a 50% DE.

Answer 8b: In many cases, the best spray condition overall is also the one giving the highest deposition efficiency (DE). This is a good general rule of thumb. However, there are major exceptions. For example, when the feed material is a powder, you may achieve a high DE by getting some of the largest particles in the powder size distribution to adhere, but these may be loosely bonded, becoming weak spots in the coating. Sometimes, the only way to achieve both high DE and high coating quality is to find a different powder with a more appropriate particle size distribution or other characteristic (that is, spray parameter adjustment alone may be insufficient). Thermal spray equipment manufacturers go to great lengths to optimize their feed materials for best performance in their equipment.

Answer 8c: The method that I use to measure DE is to spray a 1.5 in. diam tube with a pattern 5.5 in. wide, the tube is about 7 in. long. You must stop and start the powder on the part. The rotation of the part is 450 rpm (177 ft/min surface speed) and traverse the part 0.1 in./rev. The spray parameters are confirmed to produce acceptable properties prior to checking DE%, unless you are researching coating property versus DE%. The procedure follows:

1. Weigh the tube prior to spraying.
2. Weigh the powder prior to spraying.
3. Preheat the part if you commonly do so; treat this part as if you were coating your customer's part. Cool if it is called for, do not overheat as DE% can often be increased by excessive heat that may cause flaws in the coating, that is, cracks.
4. While moving with a programmed device, this procedure is not recommended for manual operation, start the spraying process. Spray for at least 4 min and stop the powder while still on the part.
5. Weigh the tube and the remaining powder.
6. Calculate. DE% = [(Starting powder, g − Final powder, g)/(Final tube, g − Starting tube, g)] × 100.

To calculate the coverage factor:

1. Measure the tube prior to starting the deposition while the part is cold.
2. Measure the final tube diameter following coating application when the tube is cold.
3. Determine the coating thickness.
4. Determine the average area of the coating, in my case it is: 3.14 × 1.5 in. + final tube diameter, in.)/2) × 5.5 in./144 in. = square feet.
5. Convert the amount of material used from grams into pounds.
6. Coverage formula is: *X* pounds divided by *Y* sq feet divided by *Z* coating thickness in inches and multiplied by 0.10 in.. Looks like this: $[(X \text{ lb}/Y \text{ ft}^2/Z \text{ in. thickness}) \times 0.01 \text{ in.}]$. This yields the approximate average coverage factor in $\text{lb/ft}^2/0.1$ in. of coating.

Answer 8d: We should not assume that deposition efficiency (DE) is an intrinsic property of a given combination of feed material + spray gun parameters. Assuming that the spray doesn't miss the target, or that spray missing the target is accounted for, there are still many other variables to consider, such as:

- Substrate material, shape and surface roughness
- Substrate temperature
- Thickness deposited per pass
- Effects of cooling jets and exhausts and so on.

A universal standard for DE determination could help us compare results from different sources. Even so, if a coating is being developed for a particular field application, it is useful to have a DE value that applies specifically to that application with its own combination of materials and conditions.

Question 9—Spraying of Polymers: We are spraying various polymer powders by flame spraying and other processes (plasma, HVOF, etc.). We would like to hear comments on testing coating bond strength values to obtain semi- or fully quantitative results. What methods do people typically use; i.e., those adopted from paint testing or those used for other thermal sprayed coatings?

Answer 9a: I have used a number of methods to test the adhesion of thermal sprayed polymers. Because epoxy does not adhere well to the plastic surface, the standard pulloff test ASTM C633 can be modified by placing the grit-blasted stud on to the surface of the molten coating immediately after spraying. This circumvents the need for epoxy; however, most failures occur cohesively. This test is limited to those polymers that are still molten after spraying and does not apply to many high-temperature plastics sprayed with plasma and HVOF. To truly get the adhesive bond strength, I have used a 90° peel test based on ASTM D 3167 specifications. Assuming the plastic coating is flexible enough, the coating is peeled from the substrate at a controlled strain rate and the force to remove the coating is measured.

Question 10—Cosmetic Applications of TS: Is anyone on this list involved with "cosmetic" applications of HVOF-type coatings? In particular, I'm trying to locate vendors who do decorative coatings on automotive components like wheels, valve covers, intake manifolds, and so forth. Please let me know if you either are one or know of one.

Question 11—Powder Velocities of a Process: We are working on the Electromagnetic Powder Deposition (EPD) process that operates in a pulse mode similar to the D-Gun. Does anyone have experience with or references for the measurement of powder velocity in the pulse mode?

Question 12—How to HVOF Coat Cermets: I am looking for experiences or references about the use of HVOF cermet coatings on compressor piston rods under exposure of H_2S traces. How large is the importance of the substrate material (AISI 4140) and its hardness? Is there any comparative study between different compositions and processes (HVOF, D-GUN, etc.)?

Question 13—Grit Blast Panel Standards: When I recently tried to order a grit-blasted reference panel (with "white metal" and three other blast finishes) from NACE, they told us that this was no longer available from them. Where can I obtain a panel like this, that is, an actual panel, not a picture.

Question 14—HVAF versus HVOF: I would like to know anyone who has sprayed with HVAF and axial plasma spraying using WC-Co powders. It seems that these spraying techniques can be a very economical way of producing WC-Co coatings. I would like to have some discussions of the benefit and performance of HVOF versus HVAF and axial plasma spraying.

Question 15—Powder Preparation for SEM Observation: I'd like to know how to prepare the polished cross-section sample of spray dried (granulated) ceramic powder for SEM observation. Molding with epoxy in vacuum could be one choice. But I'm not sure if epoxy gets into the small spacing among tiny particles in granulated powder and binds them tight enough for the subsequent polishing. Does anybody have knowledge in this area?

Answer 15a: We use a low viscosity two-part epoxy, and mix enough carbon black with the epoxy to make the epoxy opaque. Then the black epoxy is added to the plastic cup or ampule, filling the gaps in and among the agglomerates. Filling is enhanced by vacuum impregnation equipment available through Struers, Buehler, and others (or improvise your own unit with a bell jar or desiccator plus a vacuum pump). Slow-curing epoxies allow greater penetration time. Some epoxies can be preheated to lower their viscosity.

Answer 15b: The major metallographic supply houses sell fine granulated fillers for epoxy mounting to make the mounts harder so that they will polish harder. Although it is a loose powder rather than a bonded powder, the epoxy penetrates between the particles so your application should work.

Question 16—Hydraulic Pressure on a HVOF Coating: Does anyone know the maximum hydraulic pressure that an HVOF coating can withstand? Is the upper limit related to bond strength? Are pressures above 20,000 psi unrealistic for either a carbide or metallic coating?

Question 17—Time to Spray after Grit Blasting: I have a question regarding the maximum waiting time allowed before spraying. I know that after grit blasting, it is typically 2 to 4 h. If, however, one has applied a 100 μm NiCr or stainless steel bond coat, would it be acceptable to let the part stand for a much longer time (e.g., days), and then just do compressed air cleaning and a preheat pass before spraying?

Answer 17a: Even though I have little experience in this type of spraying, I would venture making the following comments: The surface that is to be coated must be free of contaminants. These include particles in the air as well as moisture and/or other chemical vapors. In addition, the subject surface needs to be at an optimal temperature for uniform and effective spray coating coverage. If the surface must stand for a number of days, that is, during weekends, holidays, shutdowns, and so forth, then a study should be made to establish if a separate protocol needs to be developed and, if so, to define the correct conditions.

Answer 17b: Having done this type of testing for aircraft engine manufacturers, I would suggest that you brush blast the surface of the bond coat before you finish coat the parts. This is more to ensure that contamination such as oil mists, finger oils, and so forth are removed from the surface of the Ni-Cr or S/S. Also, if you apply these materials as a bond coat, they should be applied with as coarse a surface roughness as you can allow. This will extend the amount of time that you can leave them as you will have maximized the surface roughness for mechanical adhesion.

Answer 17c: Keeping the part clean after the bond coat and before the top coat is all that seems to matter if, you preheat the part before applying the top coat. I have done no bond studies to quantify any changes in bond strength as compared to a "normal" spraying approach.

Question 18—Thermal Diffusivity of Coatings: Does anybody have any experience in determining thermal diffusivity or thermal conductivity on coatings by a simple method?

Answer 18a: Maybe you will find some answers on your question about thermal conductivity in the following national and international standards:

- ENV 1159-2, Advanced technical ceramics; ceramic composites; thermophysical properties; part 2: determination of thermal diffusivity
- ISO 8894-1, Refractory materials; Determination of thermal conductivity; Part 1 : Hot-wire method (cross array)
- DIN 51046-1, Testing of ceramic materials; determination of thermal conductivity up to 1600 °C according to the hot wire method, thermal conductivity up to 2 W/m · K to 1 W
- DIN 52616, Testing of thermal insulation materials; determination of thermal conductivity by means of a heat-flow meter
- ASTM C 177, Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
- ASTM C 714, Test Method for Thermal Diffusivity of Carbon and Graphite by a Thermal Pulse Method

Answer 18b: You can also have some tips about these measurements by reading the following paper: "Thermal Transport Properties of Thermally Sprayed Coatings," L. Pawlowski and P. Fauchais, *Int. Mater. Rev.*, Vol 37 (No. 6), 1992, p 271-290. If you want to read a theoretical approach about thermal conductivity of thermally sprayed ceramic coatings, then refer to "A Model for the Thermal Conductivity of Plasma-Sprayed Ceramic Coatings," R. McPherson *Thin Solid Films*, Vol 112, 1984, p 89-95

Question 19—Safety Hazards of Plasma Overspray: I am looking for documentation or your own experiences relating to the potential explosion/fire hazard problem of collecting the plasma overspray of aluminum powder in dry dust collectors. Does anyone know of proper solutions? How about the content of Al in the powder? At what point does it become dangerous for collection? For example, I have been told that 95/5 NiAl powder causes no potential danger because the Al oxidizes during the spraying process.

Question 20—Spraying of Ti: We would appreciate the group's comments on: When plasma spraying titanium metal with ceramics, is a bond coat necessary? The environment in which the sprayed item is to be exposed is highly corrosive, and we hold concerns that the bond coat will be attacked, NiCrMo is currently proposed, thus undermining the ceramic. We have been given two opinions on the need for a bond coat; one that it is necessary for adhesion, the other that the natural oxide on the titanium provides the key for the coating.

Answer 20a: While it is true that the very thin native oxide layer at the surface of titanium metal provides some adhesive function, I suggest spraying a bond coat of titanium dioxide about 10 to 15 μm thick to extend the native oxide layer. By doing so, we managed to increase the adhesive strength of hydroxyapatite ceramics to Ti-6Al-4V alloy by more than 100%.

Question 21—Advice of Turntables for Spray Systems: I am looking for information on new or used turntables for plasma spray systems. It will be placed in a small hood and used primarily for R&D purposes, so generally small samples will be coated. Preferably the cost should be less than it would be to buy a compact car. Are there any problems associated with a home-built turntable? Any issue with controls and close proximity to the power supply and distribution unit? Any particular specifications that are peculiar to thermal spray applications?

Question 22—Contamination of TBCs: We have observed metallic contamination in some of our TBCs, and we cannot understand where it comes from. Can anybody help? Important to note is that:—most of the metallics are of similar composition to the bond coat; that is, not originating from the gun's nozzle. We use dedicated powder feeders and hoses, so there can be no mixing of bond coat and top coat. We use the same powder port, but we do not think there is residual bond coat in the port because then one would expect the contamination to decrease with time, which it does not. Even in a 300 μm top coat we sometimes get large concentrations of metallics all the way to the top of the TBC layer!

Contamination of bond coat metal into top coat due to the sample polishing process can be ruled out for various reasons (which I will not go into here)—among others, the metallics can be easily observed in a fracture surface of the TBC under a stereo microscope. Contamination is particularly bad if Ni-Al (Metco 450) is used instead of the usual 38 to 90 μm MCrAlY bond coat. The metallics mostly disappear when the TBC is subjected to thermal shock cycles in a propane flame rig. Any suggestions would be much appreciated.

Answer 22a: Is there any chance that bond coat overspray dust that landed inside the exhaust hood on various surfaces is somehow dislodged and blown back onto the TBC layers being deposited? Try removing or covering all obvious bond coat overspray before depositing the TBC; maybe this will help. Metco 450 contains fine aluminum (several microns diameter) and an organic binder, which may somehow aggravate the problem.

Answer 22b: In response to the discussion about contamination in your TBC coating, the following observations are submitted. We too have experienced similar problems; at one time we were getting little black specks of contamination in the ceramic portion of our coatings. We also found that the coatings appeared to be light gray to snow white in color. The end results were that we had experienced a gas leak, which reduced the coating temperature and gave us an anomaly in our coating that appeared like specks of the bond coat mixed in the ceramic coating.