Conference Report

Advances in Materials Processing

Schenectady, New York, May 12-13, 1992

The Eastern New York Chapter of ASM International and the Hudson-Mohawk Chapter of TMS cosponsored a two-day meeting in May 12-13, 1992 at GE Corporate Research & Development (CRD), Schenectady, New York. The conference, titled "Advances in Materials Processing," focused on thermal spraying, and this report details several papers in this area. Other papers were also of immediate interest to thermal sprayers, because issues and technologies related to thermal spray were addressed, for example, powder processing and spray forming.

The organizers of the meeting were Li-Chyong Chen and Kathryn Dannemann of GE (CRD). They can be contacted at (518) 387-5429 and 387-6863, respectively. The short abstracts of the six presentations that directly apply to thermal spray technology are detailed below. The abstracts, as supplied by the authors to the conference participants, have been modified by incorporating some of the subject content of each presentation.

"Gas Atomization for High-Technology Applications," John H. Moll, Technical Director, P/M and Titanium, Crucible Research Division, Crucible Materials Corporation, Pittsburgh, PA 15230, (412) 923-2955.

Gas atomization has been developed as a means for producing high-quality rapidly solidified prealloyed powders for high-technology applications. The production techniques used to manufacture these powders were discussed. The influence of various process parameters such as open and closed stream methods determines the powder physical characteristics, i.e., particle morphology and size distribution. The unique rapidly solidified microstructural features of gas atomized powder can be altered by the nature of the atomizing gas. For example, the thermal conductivities of the nitrogen, argon, and helium gases may influence the solidification kinetics of the droplets. Argon is the most common gas for superalloy materials.

The application of the atomizing process includes the production of materials for tool steels, superalloys, corrosion-resistant alloys, magnetic alloys, and titanium alloys. A recent application of gas atomization is to produce titanium aluminide alloy powders for evaluation as matrix materials for aerospace metal matrix **composites.**

"Spray Forming," Mark G. Benz and Thomas F. Sawyer, General Electric Corporate Research and Development, P.O. Box 8, Schenectady, NY 12301, (518) 387-5688 and (518) 387-5867 respectively.

The Osprey® process has been studied at GE since 1984. An experimental spray-forming unit has been used to form superalloy forging and rolling preforms. This unit consists of a melting crucible, a melt guide tube, and a gas atomizer that is scanned over the deposition collector mandrel. The atomized droplets are collected and solidified on a mandrel in the shape of a formed body such as a tube, billet, plate, etc. Densities of up to 99.8% can be achieved for the metals that are typically sprayed.

As the preform is "grown," all portions of the preform are first liquid, and then solid. The preform is held at an ever-decreasing temperature as the deposition continues and the distance from the deposition interface increases. The experimental arrangement incorporates an infrared CID video camera so that temperature profiles can be measured *in situ* and the process parameters adjusted accordingly.

"Trends in Coatings for Aircraft Engine Applications," Robert V. Hillery, General Electric Aircraft Engine, One Neumann Way, Cincinnati, OH 45215, (513) 243-5580.

Coatings are widely used in aircraft engines to extend component life by providing environmental protection or enhanced wear and erosion resistance. The use of coatings has become commonplace throughout the engine over the past 15 to 20 years, and a wide variety of coating processes are in place at original equipment manufacture and overhaul facilities to permit this life extension. Thermal spraying, chemical vapor deposition, physical vapor deposition, plating, and many other techniques have been used to apply a wide variety of coating systems for both military and commercial application to all major component areas of the engine.

Although significant advances have been made in coating deposition techniques, in the characterization of coating properties and in evaluation and process control, protective coatings are rarely included in the initial design of a component and are frequently treated as necessary, but unplanned, additions to the primary component material. As long as coatings were regarded only as providing life extension, this philosophy was acceptable and indeed has provided significant benefit to the industry.

Changes are taking place in coatings requirements as aircraft manufacturers seek higher operating temperatures. Improvements in reliability and quality of coatings as well as process understanding are necessary as this philosophy is modified and coatings are used for performance benefit and become more fully integrated into component design.

"Thermal Spray Processing—Principles and Applications," Christopher C. Berndt, The Thermal Spray Laboratory, SUNY at Stony Brook, Department of Materials Science and Engineering, Stony Brook, NY 11794-2275, (516) 632-8507.

Thermal spraying is a generic term that describes a family of processes that all rely on the splat consolidation of materials (i.e., rapid solidification processing methods) that repeatedly impact against a substrate. It is important to emphasize that the material properties, and hence applications, of the so-formed deposits are dissimilar to the corresponding properties of the parent bulk materials.

The triad of processing, structure, and properties of thermal spraying are all related, and it is thus essential to discuss these topics together. The major areas of thermal spray include air plasma spraying (APS), vacuum plasma spraying (VPS), flame spraying, arc spraying, detonation gun spraying, and high-velocity oxygen-fuel (HVOF) spraying. The fundamental concepts of these processes are the same, and they result in a deposit that evolves from the rapid solidification of particles about 20 to 100 μm in size.

A challenge for the wide-scale implementation of thermal spray technology is the specification of coating characteristics such as adhesion strength, microstructure, and, on a fundamental level, the phase structure. Major areas of interest with regard to applications of coatings include implementation in the infrastructure (such as zinc for protection of reinforced concrete), the spraying of hydroxyapatite for biomedical applications, manufacture of near-net shapes, and new coatings for high-temperature wear applications. Future research initiatives are oriented to modeling the microstructure, in particular the porosity, of coatings with reference to material properties.

"Innovative Foil Manufacturing Processes," Sunil Jha, Texas Instruments Incorporated, 34 Forest Street, Attleboro, MA 02703, (508) 699-1131.

Titanium matrix composites made by foil-fiber-foil technology are becoming the materials of choice for advanced aircraft, both in airframe structures as well as engine components. The extremely high specific strength and specific modulus of these materials make them extremely attractive for high-temperature applications.

One of the major barriers to the use of this class of materials is high cost. Today, the α/β and near α alloys of titanium as well as the titanium aluminides are prohibitively expensive in foil form (0.006 in., or 0.150 mm, or less). The Texas Instruments Metallurgical Materials Division is working to effect an order of magnitude reduction in the cost of such foils through innovative thermal mechanical process technology. Foils, with widths of 36 to 48 in. (0.9 to 1.2 m) exhibit uniform gage, a good surface finish, minimal porosity, and good mechanical properties.

The R&D program has developed a cold rolling process for the manufacture of titanium alloys and various α 2 titanium aluminides and/or the manufacture of titanium alloys and various α 2 titanium alloys. Gamma titanium aluminide foil (alloy 48-2-2) has also been successfully cold rolled. Finally, the feasibility of roll consolidating plasma-sprayed precursors (0.010 to 0.020 in., or 0.25 to 0.51 mm, thick) into high-integrity foils has been demonstrated.

"Fabrication of Advanced Metal Intermetallic Matrix Composites by Powder Cloth and Arc Spray Techniques," John W. Pickens, SVERDRUP Technology, Inc., NASA Lewis Group, 2001 Aerospace Parkway, Brookpark, OH 44142, (216) 891-2988.

The use of metal and intermetallic matrix composites (MMC and IMC) depends on the development of fabrication processes and on understanding the relationships of process variables to material structure and properties. Composite fabrication processes can be organized into general categories that include fiber/foil, powder metallurgy approaches, pressure casting, vapor deposition, and thermal spray deposition approaches. The relative benefit of any given approach may change depending on the particular material system or application involved.

Two processes are under development at NASA Lewis Research Center. One is a powder metallurgy, tape-forming approach referred to as the powder cloth process. Processing effects influence strength and integrity of fibers (e.g., alumina, tungsten, and molybdenum). Surface modification of the fibers can severely enhance, or degrade, the overall performance of the composite. The other method uses thermal spray deposition. In this process, the fibers are wound onto a mandrel and then arc sprayed with an overlay coating that is intended to form the matrix material. The mechanical properties of arc sprayed composites compared favorably with materials fabricated with other techniques. It is critical to control the spray parameters so that surface damage of the fibers, which may nucleate fracture sites, is minimized.

Concluding Remarks

The other 12 presentations that were covered are presented below:

Presentation	Author(s)	Affiliation
Processing SiC-Based Monolithic Ceramics and Reinforced Composites	F. Mazandarany	GE/CRD
Rapid Solidification Processing of Aluminum Alloys	P.S. Gilman	Allied Signal Inc.
Processing of Nanostructured Ceramics	H. Hahn	Rutgers University
Casting of Reactive Alloys	R.S. Diehm	Howmet Corporation
Centrifugal Casting	A.R. Griffin	Wisconsin Centrifugal Casting
Continuous Casting	A.W. Cramb	Carnegie Mellon University
Metal Injection Molding	M. Tasovac	Remington Arms Company, Inc.
HIP Technology	R. Widmer	IMT Industrial Materials Technology, Inc.
Chemical Vapor Deposition	E. Einset and P. Kosky	GE/CRD
Ion Beam Assisted Deposition	G.K. Hubler	Naval Research Laboratory
Sputtering and Evaporation Processes	D.W. Skelly	GE / CRD
Chemical Processing of Nonoxide Ceramics	L.V. Interrante	Rensselaer Polytechnic Institute

The overall quality of this regional conference was uniformly high. This can be attributed primarily to the thorough organization by the conference conveners. For instance, all contributions were invited presentations, and a well-focused conference theme enabled continuity of the subject area. An additional aspect of this meeting was the high attendance by local GE/CRD scientists, and thus, this forum presented the opportunity of discussing areas of mutual interest. No proceedings of this conference will be available.

Next year (1993), there will probably be another conference in Schenectady tentatively entitled, "High-Temperature Materials and Applications." If this next conference follows the same high standard as the 1992 meeting, then attendance is highly recommended.

Reported by:
Christopher C. Berndt
The Thermal Spray Laboratory
SUNY at Stony Brook
Stony Brook, NY 11794-2275

Maintenance of Steel and Reinforced Concrete

Orlando, Florida, June 2-5, 1992

The infrastructure of America, if not the world, is falling down at an ever-increasing rate. Bridges, roads, waterway structures, etc., are in need of significant capital outlay to maintain functionality. Existing technologies for rehabilitation are capital expensive and, in some cases, environmentally prohibitive. Against this backdrop of critical need, the International Thermal Spray Conference (ITSC) at Orlando in mid-1992 included a panel discussion on **"Thermal Spray and The Civil Infrastructure."** This session was co-sponsored by the Thermal Spray Division of ASM International, the American Welding Society C2 Committee, and the International Thermal Spray Association. The five presentations for the program were organized by Prof. Herb Herman and Mr. Bob Sulit and are shown in the table below. The attendance at this particular forum was astounding, especially considering that it was added to the overall program at the last minute, and it competed with two other sessions. There were some 60 participants at this session who represented the worldwide economy.

Thermal spray processes are increasingly being considered and used for large-scale applications for infrastructural applications. For example, deterioration of concrete structures due to reinforcement corrosion and of steel bridges due to general lack of maintenance is an expensive problem that is particularly prevalent in highway structures subjected to deicing salts, marine structures, and the infrastructure. Thermal spraying of infrastructure highway steel and concrete represents a major opportunity for the industry. The rehabilitation of engineering structures has high economic cost to the country. The commercial potential for the coatings and methods developed by thermal spraying are very high.

Successful field trials of thermally sprayed zinc anodes for cathodic protection of reinforcement have been conducted by the California DOT (Caltrans), Ontario Ministry of Transportation, Virginia DOT, and Florida DOT. Sprayed zinc anodes have been demonstrated to fulfill the necessary criteria of uniform current distribution, low consumption rate, durability, and cost-effectiveness. Examples of trial structures used for evaluation of thermally sprayed zinc impressed current anodes include a pier of the Richmond-San Raphael Bridge (San Francisco), soffit and top of the East Camino under-crossing bridge deck (Placerville, California), a pier of the Willoughby Spit Bridge (Norfolk, Virginia), and pier bents of the Leslie Street Bridge (Ontario). All of these structures were subjected to chloride-induced corrosion of reinforcement.

Although there is a long history of use of thermal spray for these applications in many parts of the world, the technology is just beginning to achieve wider recognition in the United States. The panel at the ITSC meeting discussed both technical and commercial aspects of thermal spray for civil works, with special emphasis on opportunities and obstacles facing contractors.

The measure of the success and interest of this topic can be gaged from the fact that another infrastructure panel has been organized for 1993 at the National Thermal Spray Conference in Anaheim (7-11 June).

Reported by:
Chris Berndt and Herb Herman
The Thermal Spray Laboratory
SUNY at Stony Brook
Stony Brook, NY 11794-2275

1992 International Thermal Spray Conference—Infrastructure Program

Speaker	Company	Presentation title	Phone
R.A. Zatorski	Engineered Coatings Inc.	Equipment and special considerations	(203) 257-1119
R. Krepski	Intermet Technology	Materials: Standard and novel	(412) 573-7754
C.C. Berndt	SUNY at Stony Brook	Why thermal spray onto concrete	(516) 632-8507
A. Kay	ASB Industries Inc.	Commercial perspective	(216) 753-8458
R. Sulit	Surface Engineering Consultant	Realities: Learning for the naval experience	(619) 597-1213