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News from Institutes and Research Centers Around the World

This column is a forum to inform the thermal spray community on current activities in institutes and research centers active in the field of the thermal spray. Research efforts carried out by these organizations are oftentimes the starting point of significant developments of the technology that will have an impact on the way coatings are produced and used in industry. New materials, more efficient spray processes, better diagnostic tools, and clearer understanding of the chemical and physical processes involved during spraying are examples of such developments making possible the production of highly consistent performance coatings for use in more and more demanding applications encountered in the industry.

This column includes articles giving an overview of current activities or a focus on a significant breakthrough resulting from research efforts carried out in institutes and research centers around the world. If you want to submit an article for this column, please contact Jan Ilavsky, JTST Associate Editor, address: Argonne National Laboratory, Advanced Photon Source, 9700 S. Cass Ave., Argonne, IL 60439; e-mail: JTST.Ilavsky@aps.anl.gov.

Surface Technologies Group at the Industrial Materials Institute, National Research Council Canada

The National Research Council (NRC) is the Government of Canada's premier organization for research and development, an organization active since 1916. NRC is composed of more than 20 institutes and national programs, spanning a wide variety of disciplines and offering a broad array of services. NRC plays a major role in stimulating community-based innovation.

Since its creation in 1978, the Industrial Materials Institute (IMI) has built a solid reputation as an R&D leader in the field of materials manufacturing and processing, serving Canadian industry. IMI conducts research and development activities on a wide variety of materials (polymers, metals, ceramics, and composites) and their formulation, forming processes, and process modeling and control.

The Surface Technologies (ST) Group carries out innovative R&D work on materials and surface processes and transfers the developed technologies to the industry. Activities aim at improving the understanding and control of transformation processes during deposition and optimizing the coating performance for targeted industrial applications.

Thermal spraying is the main focus of the ST Group's activities. The group is composed of seven researchers, six technicians, and students from different Canadian and foreign universities. Their research spans:

- Coating optimization for targeted industrial applications
- Optical sensors for process diagnostics and control
- Formulation of new materials

The group has developed a strong expertise in coating characterization and performance evaluation (corrosion, erosion, abrasion, fatigue, thermal shock, etc.). A few examples of the projects recently conducted or currently underway are described below.

Replacement of Hard Chrome

The hard chrome plating, which uses a chromic acid solution, releases chromium ions in the hexavalent (Cr^{6+}) state into the air in the form of a fine mist. This form of chromium has long been known to be carcinogenic and to cause other medical problems.

The ST Group over recent years has been strongly involved in the North-American Hard Chromium Alternative Team (HCAT), which regroups various government agencies and approximately 20 firms in the aerospace sector. This team conducts a development program to validate alternative technologies to the hard chromium plating process. The focus of the U.S. and Canadian teams has been on HVOF sprayed WC-Co and WC-C-Cr coatings, respectively. The ST Group was responsible for the optimization of the structure and properties of WC-Co-Cr coatings deposited by HVOF. The group also conducted exploratory work on plasma sprayed coatings as an alternative solution to hard chrome on internal surfaces. More recently, the development of a quality test for evaluating the performance of the HVOF sprayed coatings by acoustic emission was carried out in the ST Group laboratory.

Monitoring of Thermal Spray Processes

The group has been conducting an important development program on optical sensors dedicated to the study and control of thermal spray processes. Its patented technologies are commercialized under license by Tecnar Automation Ltd, a NRC spin-off company. The first sensor developed, the DPV-2000, is now the most used system worldwide in industrial and academic laboratories. The system makes it possible to measure the temperature, velocity, and diameter of individual particles in the spray plume. A second particle sensor, the AccuraSpray, was developed more recently for process control in industry (Fig. 1, Ref 1). This system measures global particle jet parameters such as mean particle temperature and velocity and particle jet orientation, width, and intensity. The ST Group has developed an automatic controller that regulates the particle temperature and velocity by adjusting the input spray parameters. This system makes it possible to increase the reproducibility of the plasma spray process and maintain the deposition efficiency and optimal coating structure in spite of the inevitable electrode wear occurring during spraying.

More recently, the ST Group has developed a new technique (patent pending) for on-line measurement of the coating thickness deposited per pass. This new optical sensor tracks the coating thickness increment associated with the spray torch passage. Coating thicknesses as small as 5 μm can be measured with this approach. The ST Group is currently conducting an R&D program with Tecnar Automation Ltd. aiming at developing a rugged commercial system, called LayerGauge,

Fig. 1 The AccuraSpray system measures ensemble particle jet parameters (jet orientation, width, and intensity, mean particle temperature and velocity) for monitoring thermal spray processes on the production floor.

Fig. 2 An optical triangulation-based prototype sensor, LayerGauge, is used for on-line monitoring of the coating thickness deposited per pass. The system resolution is better than 5 μm.

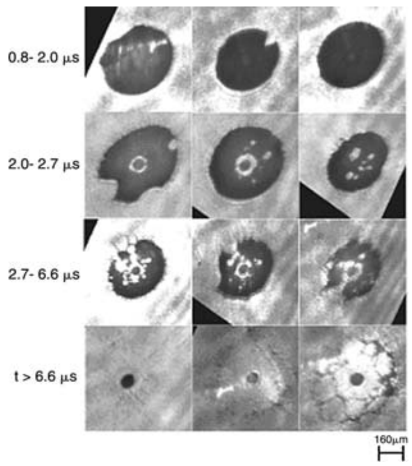


Fig. 3 Plasma sprayed molybdenum particles impacting on a glass substrate at room temperature. Photographs are taken at different times after impact, showing the evolution of the droplet shape.

adapted for the production line. Figure 2 shows the prototype system during measurement of the coating step on a rotating cylinder.

Monitoring of the Impact of Spray Particles on a Substrate

The substrate temperature is known to influence strongly the way the sprayed particles flatten and solidify upon impact on the substrate surface or already deposited layers. When impacting on a hot flat substrate (typically above 300 °C), the particles spread smoothly and solidify rapidly. On a room-temperature substrate, the particles tend to fragment in many small droplets or fingers all round the impact point. These different behaviors are of practical importance as they influence the coating properties.

To study the behavior of the impacting particles, the ST Group has developed a high-speed pyrometer and short exposure (below 10 ns) photograph camera system that makes it possible to measure the cooling rate of the particles in contact with the substrate as well as photograph the shape of the spreading particles at different moments after impact (Ref 2). Figure 3 shows such photographs of plasma sprayed molybdenum particles at different times after impact on a room-temperature glass substrate. One sees that the particles first flatten smoothly forming a nice disk that, afterward, pierces. Holes form and then expand due to the surface tension of the liquid metal. Modeling of the particle impacts is underway in collaboration with the University of Toronto to develop a better understanding of the physics of these transient phenomena.

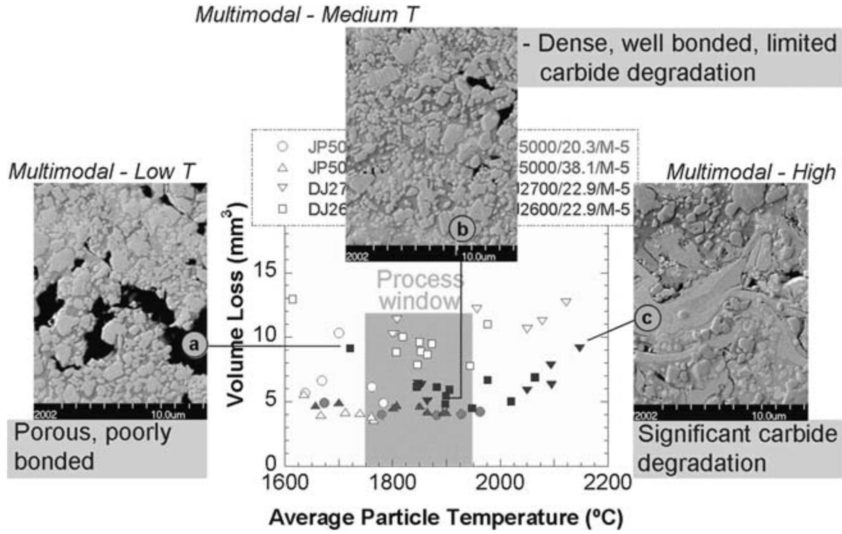


Fig. 4 Results from the HVOF spraying of WC-12Co, showing the volume loss in abrasion, the optimal process window, and the microstructure of coatings within and outside this window

Forming Nanomaterials with Thermal Spraying

This project focuses on the deposition of nanostructured coatings for increased resistance to corrosion, wear, and high temperatures. The research objectives are to better understand how the composition and spray conditions of materials influence the structure and properties of the sprayed coatings.

Research on nanostructured materials focuses on understanding the effect of the process parameters during spraying and the nanostructured feedstock characteristics on the properties and performance of the resulting coatings. The goal has been to identify process windows for engineering coatings for optimal performance. Such coatings are characterized by a bimodal structure, exhibiting regions where the structure is predominantly micron scale within which there are dispersed nanostructured zones. Several systems and processes have been studied to produce coatings for applications where wear resistance is required, for use in the aerospace field, and for the biomedical sector. Figure 4 shows results of a study on WC-12Co involving several powders and HVOF systems (Ref 3). The optimal process window, defined in terms of the in-flight particle temperature, for producing coatings with the highest abrasion resistance was identified. This study showed that the use of feedstock powder having a mixture of nanostructured and microsized WC grains resulted in significantly higher deposition efficiencies and a more robust process.

Research on titania (TiO_2) has demonstrated that the bimodal coatings (made from nanostructured feedstock) exhibit higher toughness and plasticity when compared to conventional coatings (Ref 4). This higher toughness and ductility translates into a superior antiwear performance of the bimodal coatings (Fig. 5). It is interesting to point out that HVOF-sprayed bimodal TiO_2 coatings exhibit bond strength values at least 2.5 times higher than those of hydroxyapatite (HA) coatings on Ti-6Al-4V substrates. Cell culture tests show that human osteoblast cells attach, grow, and proliferate well on the surface of these HVOF-sprayed bimodal coatings; that is, they may be able to re place HA coatings in implants in the future.

Suspension Plasma Spraying

Nanostructured coatings are produced also by suspension plasma spraying, introducing a liquid feedstock into the plasma jet. Nanosized ceramic powders are mixed with a liquid carrier and plasma sprayed, forming thinner coatings with more refined microstructures than conventional plasma spraying. In-flight particle states are measured by using the AccuraSpray sensor, making it possible to determine the relationships between the plasma conditions, in-flight particle states, and resulting microstructure and phase composition of the coatings. Both radial and axial injections of the suspension are evaluated. Figure 6 shows different coating structures obtained using the radial injection approach. Generally, when using an axial injection plasma torch, much higher particle velocities can be obtained producing denser coatings. Figure 7(a) shows the atomization of a nanoparticle liquid suspension within the axial injection plasma torch. Dense coatings can be obtained such as the samarium-doped ceria coating illustrated in Fig. 7(b). Such layers are developed as new electrolyte materials for intermediate temperature solid-oxide fuel cells (SOFC).

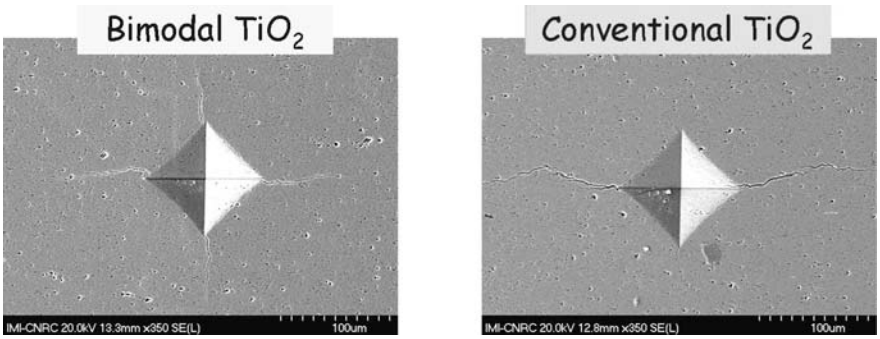


Fig. 5 Differences in the crack propagation resistance between two HVOF-sprayed TiO_2 coatings. The bimodal coating (made from nanostructured feedstock) exhibits higher toughness and isotropic crack propagation when compared to conventional ones.

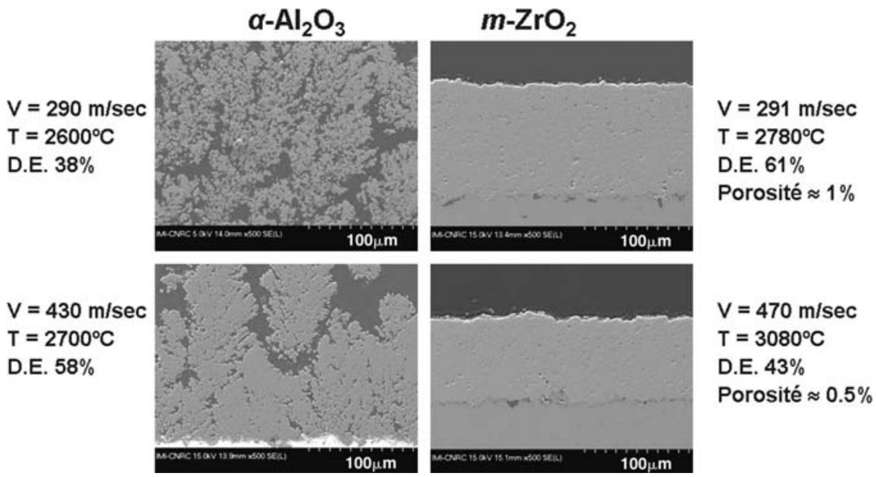
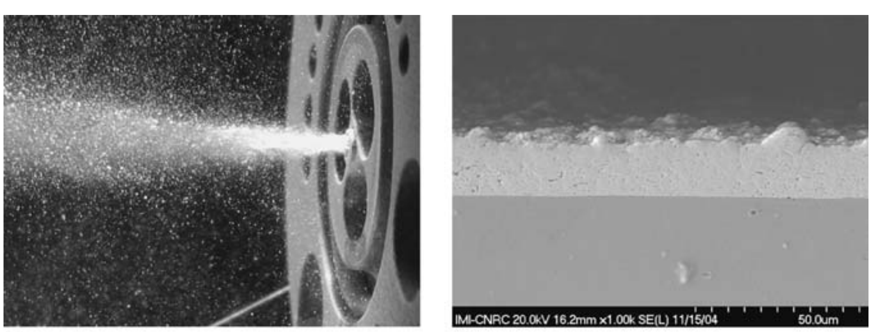


Fig. 6 Examples of alumina and zirconia coatings produced by injecting a suspension of nanoparticles in the plasma jet. The coating structures and deposition efficiencies vary according to the density of the spray materials, and the particle temperature and velocity.



(a) (b)

Fig. 7 (a) Atomization of a suspension of nanoparticles in ethanol on the axis of an axial injection plasma torch (Northwest Mettech Corp.). (b) Dense samarium-doped ceria layer deposited using the axial injection plasma torch.

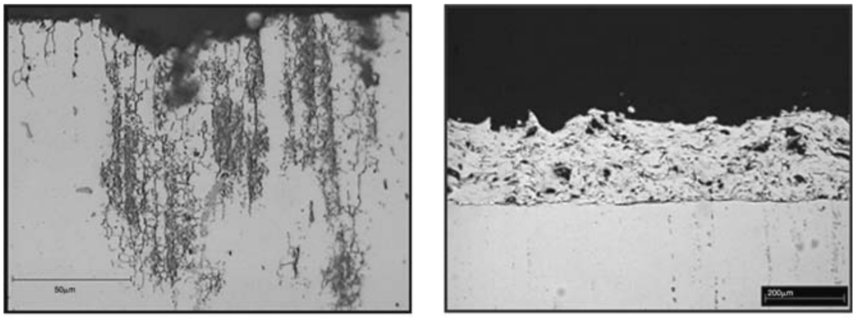
Prevention of Stress-Corrosion Cracking

This project, conducted in collaboration with the Department of National Defense Canada, aims at protecting aircraft primary structures from stress-corrosion cracking (SCC) and corrosion pitting. The structures to be protected are made of aluminum alloys sensitive to localized corrosion such as the 7XXX alloy series. Corrosion control and corrosion cost reduction remain major drivers for the military aerospace engineering support. The main challenge of this project is to develop a corrosion protection coating system that will not reduce the fatigue resistance of the coated parts. Significant progress has been made by using an arc sprayed aluminum-magnesium coating for improving the stress-corrosion resistance (Fig. 8). Advanced surface preparation techniques were used to preserve the fatigue resistance of the 7070 Al alloy. Developments are in progress for simplifying the coating process and inspecting nondestructively the coated parts.

Thermal Spray Consortium: SURFTEC

Started in 1995, this consortium regroups companies, Canadian universities, and three different NRC institutes. Using thermal spray deposition and related technologies, SURFTEC provides its members with capabilities in materials development and in the optimization of processes for surface engineering, particularly thermal spraying. The research program is generic and established with the members during its semiannual meetings. In recent years, the program has been focusing on thermal barrier and wear-resistant coating systems by looking at the fundamental and practical aspects such as:

- Formulation of deposition materials for specific applications
- Effect of thermal spray conditions on deposition and coating characteristics
- Diagnostics and control during processing
- Physical, microstructural, and mechanical properties of coatings



(a) (b)

Fig. 8 (a) A 7075 Al alloy sample after a 30-day accelerated stress-corrosion cracking (SCC) test. (b) The same aluminum alloy sample coated with an arc sprayed Al-5Mg coating shows no SCC and no pitting corrosion after the same accelerated SCC test.

- Coating performance through laboratory and in-service testing

Commercialized Technologies

The ST Group's innovative research activities have led to the development of technologies, for which IMI holds patents and has given commercialization licenses. For example, the following products are commercialized by Canadian firms:

- DPV-2000 (in-flight particle sensor for thermal spraying, commercialized by Tecnar Automation Ltée)
- AccuraSpray (thermal spray particle jet sensor for process monitoring and control, built by Tecnar Automation Ltée. and distributed by Sulzer Metco)
- Alpha-1800 (core wire for deposition of wear-resistant composite coatings by arc spraying, commercialized by SYNTHESARC Inc.)

National and International Collaborations

In addition to conducting R&D projects with many industrial partners, the ST group works in close collaboration with many universities and research centers in Canada and abroad:

- Canada: Université de Sherbrooke, University of Toronto, McGill University, Université du Québec à Rimouski, University of Ottawa, Alberta Research Council, Concordia University
- Czech Republic: Academia of Sciences of the Czech Republic
- France: Université de Limoges, Université de technologies de Belford-Montbéliard
- Singapore: Nayang Technological University
- Taiwan: Industrial Technology Research Institute
- United States: State University of New York, Ohio State University

Equipment

The ST Group's laboratories integrates equipment for the preparation of materials, deposition, characterization, and evaluation of coating performance.

Spraying Equipment

- Plasma torches: SG100, 11MB, F4, F100 and F210
- Axial III axial injection plasma torch (Northwest Mettech Corp.)
- HVOF: JP5000 and Diamond Jet
- Arc spray: Smart-Arc, Miller BP-400, Thermion, Tafa 9000
- Flame spray
- Three robotized spray chambers
- "Rotaplasma" system for coating inner diameters

Diagnostics

- In-flight particle diagnosis systems, DPV2000 and AccuraSpray

Materials preparation

- Spray-dryer
- Fabrication of cored wire for arc spraying
- Various grinders and mixers
- Powder classifiers

Characterization

- X-ray diffraction for phase analysis
- Electronic and optical microscopes
- Image analysis system
- Measurement of thermal diffusivity of thick and thin coatings
- Ultrasonic evaluation of coating elastic moduli
- Evaluation of erosive and abrasive wear resistance (according to ASTM standards)
- Evaluation of high-temperature corrosion resistance and aqueous corrosion resistance
- Adhesion (pull test)
- Evaluation of thermal shock resistance

A new McGill Cold Spray facility will be installed within a few months. This fully integrated facility will comprise two cold spray systems, a robotized spray room, helium recovery system, surface preparation system by laser ablation, and advanced diagnostic sensors.

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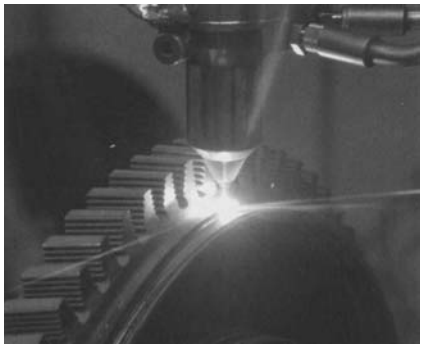

Titanium alloy metal powder guided coaxially to the beam and blown onto the focal point in laser beam buildup welding

Engine Turbine Disks Repaired by Direct Metal Deposition

Direct metal deposition, a technique based on laser-beam precision buildup welding, has been developed for repair of rotors and in turbines and aircraft engines by the Thermal Coating Processes Department at the Fraunhofer Institute for Material and Beam Technology, Germany. Laser beam buildup welding is one of the many generating methods now applied when one item or only a few are produced or have to be individually repaired.

The first step in the repair of a damaged component by this technique is to conduct a three-dimensional scan. A computer program then compares the dimensions of the part with its original measurements and computes what is missing. A software system guides the path of the laser as it melts titanium-alloy powder and reconstructs the damaged area with layers of metallic beads. The entire process chain is a closed cycle and runs automatically from data collection followed by welding to finish machining.

Contact: Dr.-Ing. Steffen Nowotny, Fraunhofer-Institut für Werstoff- und Strahltechnik, IWS Winterbergstrasse 28, 01277 Dresden, Germany; tel: 49 351 2583-241; e-mail: steffen.nowotny@iws.fraunhofer.de; Web: www.fraunhofer.de. Adapted from *Advanced Materials and Processes,* Aug 2005.

Nanocomposite Coatings Raise Durability of Aircraft Parts

Supertough nanocomposite coatings that could improve the performance and durability of aircraft engines are under development at the Air Force Research Laboratory, Wright-Patterson Air Force Base, Dayton, OH. AFRL scientists and engineers, working with university researchers, have identified a mechanism of macroscopic ductility unique to extremely hard nanocrystalline/amorphous composites.

The mechanism is a unique feature of nanocrystalline/amorphous composite design, resulting from a large number of 1 to 2 nm shifts of nanograins inside the amorphous matrix. The experimental research results explain the high fracture toughness of nanocrystalline/amorphous composites when exposed to large contact deformations with high loading rates.

Laboratory researchers initially developed a new class of wear-resistant materials comprising very hard, 3 to 5 nm grains of carbides or oxides embedded in an amorphous matrix of either diamond-like carbon or a metal/ceramic mixture. During this preliminary characterization stage, the new materials exhibited an unusual combination of high hardness (exceeding that of ceramics) and fracture strength (similar to that of tough metal alloys).

Contact: Tech Connect, Air Force Research Laboratory Materials and Manufacturing Directorate, Wright-Patterson Air Force Base, Dayton, OH 45402; tel: 800/203-6451, Reference document ML-03-28; Web: www.afrl.af.mil/techconn.index.asp. Exerpted from Super-Tough Nanocomposite Coatings, *AFRL Horizons,* April 2005.

Systems Monitors Blades in Operating Gas Turbines

An innovative new system that continuously monitors operating blades in gas turbines has surpassed 5000 h of operation, confirming that the technology is ready for commercialization, reports the U.S. Department of Energy and Siemens Power Generation, Alpharetta, GA. The online monitor makes it possible for operators to replace turbine blades based on their actual condition, when the thermal barrier coating is worn or damaged. This capability optimizes the life of the blades, avoids the high cost of unscheduled replacement, and extends the time between preventative maintenance periods, increasing the amount of time the plant is available.

Turbine blades rotate at more than 3600 rpm, with a linear tip speed of 800 mph, under very high pressure (1.5 MPa, or 220 psi) and extremely high temperature (in the range of 1425 °C, or 2600 °F). To operate in these conditions, Siemens Westinghouse developed a cooled optical probe that is installed in the gas turbine reaching down to the moving blades. A near- and mid-wave infrared high-speed camera is also situated in a cooled housing and connected to the probe outside of the turbine.

Contact: David Anna, DOE National Energy Technology Laboratory, Pittsburgh, PA 15236-0940; tel: 412/386-4646; e-mail: david.anna@netl.doe.gov; Web: www.netl.doe.gov. Excerpted from DOE-Online Monitor Snaps Real-Time Photos for Real-Life Savings, *Techline,* June 6, 2005.

News from NASA

Program for Weibull Analysis of Fatigue Data

A Fortran computer program has been written for performing statistical analyses of fatigue test data that are assumed to be adequately represented by a two-parameter Weibull distribution. This program calculates:

- Maximum-likelihood estimates of the Weibull distribution
- Data for contour plots of relative likelihood for two parameters
- Data for contour plots of joint confidence regions
- Data for the profile likelihood of the Weibull-distribution parameters
- Data for the profile likelihood of any percentile of the distribution

- Likelihood-based confidence intervals for parameters and/or percentiles of the distribution

The program can account for tests that are suspended without failure (the statistical term for such suspension of tests is "censoring"). The analytical approach followed in this program for the software is valid for type I censoring, which is the removal of unfailed units at prespecified times. Confidence regions and intervals are calculated by use of the likelihood-ratio method.

This program was written by Timothy L. Krantz of the Vehicle Technology Center of the U.S. Army Research Laboratory for Glenn Research Center. For further information, access the Technical Support Package (TSP) free on-line at www.techbriefs.com/tsp under the Software category. Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Rd., Cleveland, OH 44135. Refer to LEW-17401-1. Excerpted from *NASA Tech Briefs,* Sept 2005.

New Products and Industry News

Dana Corporation Coating Technologies Lower Emissions, Improve Engine Durability and Performance

Dana Corporation, leading supplier of engine, drivetrain, chassis and structural based technologies in Toledo, OH, announced that it has developed two advanced coating processes for engine bearings and piston rings that greatly improve their durability. Products with these advanced coatings were on display at the 61st International Motor Show (IAA) in Frankfurt, Germany.

Chuck Heine, President of Technology Development at Dana, said, "Innovation often happens in the details, as these coating processes demonstrate. These processes and components are invisible to consumers, but the benefits they deliver, such as improved powertrain efficiency and reduced emissions, clearly benefit vehicle manufacturers and buyers alike."

RP100 Coating for Engine Bearings

Dana's RP100 coating for engine bearings utilizes a thermal spray technology, which uses a flame to uniformly deposit a proprietary coating onto connecting rods and main bearings at a very high speed. RP100 is the first use of this thermal spray coating for an engine bearing application.

Benefits include significantly improved bearing strength and wear resistance. The enhanced bearing performance also makes it possible to use less expensive materials for the crankshaft. The process can also be developed to deposit graduated coatings, shifting from a harder interior to a softer layer on the outer surface.

PCF-480 Coating for Piston Rings

Dana's PCF-480 coating for piston rings uses thermal deposition to coat piston rings with a surface that is 30% harder than traditional thermally coated rings. The superior coating provides a significant improvement in the wear resistance of the power-cylinder system. The coating fills a groove on the piston ring face to deliver a long-lasting seal. This, in turn, helps to significantly lower emissions by reducing the amount of lubrication oil entering the combustion chamber.

PCF-480 was developed to offset the increased wear caused by the introduction of exhaust gas recirculation (EGR) systems in diesel engines. While EGR helps reduce emissions, it also exposes engine components, such as piston rings, to more corrosive and abrasive conditions. However, the PCF-480 coated rings can achieve wear characteristics similar to those in non-EGR engines.

"Today's consumers are demanding cleaner running, more efficient diesel vehicles," Heine added. "These coating technologies meet those expectations while also helping to improve durability."

Contact: Dana Corp., Toledo, OH; Web: http://www.dana.com.

FDA Issues Approvable Letter to Biomet for Ceramic-on-Ceramic Hip System

Biomet, Inc., announced that the U.S. Food & Drug Administration (FDA) has issued an approvable letter for Biomet's C2a-Taper Acetabular System. Product rollout in the United States will commence immediately following the receipt of a final approval order, which Biomet projects will be issued by the end of 2005.

"The introduction of the C2a-Taper Acetabular System will further enhance Biomet's hip articulation portfolio and offer surgeons who prefer ceramic-on-ceramic technology a compelling design," noted Biomet President and CEO Dane A. Miller, Ph.D. "The C2a-Taper Acetabular System features Biomet's Porous Plasma Spray (PPS) technology."

Like all other industry participants marketing a ceramic-on-ceramic hip, Biomet sources the C2a-Taper Acetabular System's ceramic head and ceramic liner from CeramTec AG. Biomet has acquired sufficient inventory to immediately complete the C2a-Taper System product launch in the United States upon completion of the regulatory approval.

Contact: Greg W. Sasso, Biomet, Warsaw, IN; tel: 574/372-1528; Web: www.biomet.com.

Raymor Begins Thermal Spray Coatings Contracts with SIEMENS PG for Power Generation Turbines

Raymor Industries Inc. announced that its wholly owned subsidiary, AP&C Advanced Powders and Coatings Inc. (AP&C), has begun fulfilling contracts with Siemens Power Generation (PG) for the application of thermal spray coatings onto turbine components used in power generation. The startup of these contracts with Siemens follows many prequalification steps undertaken over the last six months. Siemens PG, a division of Siemens AG is one of the world's leading suppliers of power plant technology and services.

Siemens PG, with more than 600,000 megawatts of capacity in service around the world, requires thermal spray coating services providers for the repair and overhaul of turbine components. AP&C will provide these services to Siemens PG.

AP&C's Thermal Spray Coatings Division has specialized equipment to offer high-velocity oxyfuel (HVOF), atmospheric plasma spray (APS), and vacuum plasma spray (VPS) coating services, an analytical laboratory, and highly qualified personnel for the production and development of new industrial coatings, including nanocoatings. AP&C intends to become a leader in thermal spray coatings for various applications in the aerospace, aeronautics, and military sectors, as well as other specialized industrial sectors such as turbines used for power generation.

Contact: Raymond Fournel, Raymor Industries Inc. Montreal, Quebec, Canada; tel: 514/932-3485; fax: 514/932-3644; e-mail: investor@raymor.com; Web: www.raymor.com.

News from CTSA

Chinese Thermal Spraying Association—The Connection between the World and China

The Introduction of CTSA. In order to spread the thermal spray technology, the original Chinese economic development committee associated with the original Chinese science and technology development committee held the Chinese thermal spraying (welding) technology popularizing Conference on Oct 21, 1981, in Beijing. The Chinese Thermal Spraying Association (CTSA) was established during this conference and approved by these two committees. Recently, more than 400 companies and organizations have joined CTSA, including more than 40 universities and academies, more than 60 research institutes, and domestic key thermal spray plants.

The Activities of CTSA. Many tasks have been conducted by CTSA, including nine technical experience communication conferences, seven on-the-spot technical experience communication meetings, six large-scale technical lectures, and 35 technical training courses. Ten types of documents and 12 types of bulletins are published every year. CTSA also assists the related companies and governments to popularize thermal spray technology in China. Currently, it pays more attention to international cooperation. Till recently, CTSA has established close contacts with thermal spray associations of Japan, the United States, Germany, France, Russia, Switzerland, Ukraine, Singapore, Canada, and more. Today, thermal spray technology has become the most important part in the field of surface engineering technologies and will be used widely with China economy development. CTSA would like to establish contacts and cooperate with any related domestic and foreign organizations and companies to provide good services for the Chinese thermal spray industry.

CTSA Council. The Director of the CTSA Council is the Beijing General Research Institute of Mining and Metallurgy. The Vice-Directors of the CTSA Council are: China Cooperation Commission of Advanced Technology Development and Promotion, Institute of Metal Research Chinese Academy of Sciences, Shanghai Institute of Iron and Steel Technology, Central Iron and Steel Research Institute, Wuhan Research Institute of Material Protection, Beijing Aeronautical Manufacturing Technology Research Institute, Shanghai Dahao Inframat Nanomaterials and Thermal Spray Co., Ltd., and Tianjin Research Institute of Machine Coat.

The members of CTSA Council include: China Academy of Launch Vehicle Technology, National Key Laboratory for Manufacturing; Guangzhou Research Institute of Nonferrous Metals, Shanghai Institute of Ceramics Chinese Academy of Science, JiangSu CUMT Dazheng Surface Engineering Technology Co., Ltd, Qishuyan Locomotive and Rolling Stock Technology Research Institute, Chendu Daguang Thermal Spray Material Co., Ltd, Shenyang Liming Aero-Group Corporation; Chendu Engine Co., Ltd, Shenyang University of Technology, Changcheng Thermal Spraying Technology Co., Ltd, Xi'an Aero-Engine Co., Ltd, Department of Mechanical Engineering Tsinghua University, Central South University; HuNan Institute of Metallurgy and Material, Shanghai Baosteel Group Corporation, Xi'an Jiaotong University School of Mechanical Engineering, Beijing University of Technology, Wuhan University of Technology, Guizhou Honghu Engine Co., Ltd, Jiujiang Plasma Spraying Co., Ltd, General Research Institute of Nonferrous Metals, and Heilongjiang Institute of Science and Technology.

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