

# Thermal Spray 2003

## Advancing the Science and Applying the Technology

*Proceedings of the*  
2003 International Thermal Spray Conference

*5-8 May 2003*  
Orlando, Florida, USA

*Edited by*  
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Cover Photos:

Left: "Primary Breakup of Metal in the Wire Arc Spray Process." *Authors:* N. A. Hussary and J. V. R. Heberlein, University of Minnesota, Minneapolis, Minnesota, USA. *Photographer:* Nakhleh Hussary. "Breakup of the anode sheet for a wire arc spray process."

Center: "Particle Temperature and Velocity Characterization in Spray Tooling Process by Thermal Imaging Technique." *Authors:* P. S. Mohanty, University of Michigan, Dearborn, Michigan, USA; R. Allor, Ford Research Laboratory, Dearborn, Michigan, USA; and P. Lechowicz, R. Parker and J. Craig, Stratronics Inc., Laguna Hills, California, USA. *Photographer:* Audiovisual Unit, Ford Motor Company. "Rapid tooling process."

Right: "The Effect of a High Thermal Gradient on Sintering and Stiffening in the Top Coat of a Thermal Barrier Coating (TBC) System." *Authors:* S. A. Tsipas, I. O. Golosnoy, and T. W. Clyne, University of Cambridge, Cambridge, United Kingdom. *Photographer:* Sofia Tsipas. "ZrO<sub>2</sub>-Y<sub>2</sub>O<sub>3</sub> top coat after exposure to high thermal gradient."

## Preface

This volume contains the proceedings of the International Thermal Spray Conference 2003 (ITSC 2003) held in Orlando, Florida, 5-8 May 2003. More than 240 papers covering the full spectrum of topics on the science and technology of thermal spray are presented in this book. The contributions highlight a number of areas, including recent advances in the basic science of spraying, diagnostics, process control, particle impact, microstructure, and properties; results on degradation mechanisms, testing and performance evaluation; and developments in new materials, processes, equipment and applications. In short, this collection of papers presents a snapshot of the current state of advancement of the thermal spray field.

Many individuals have contributed to the successful completion of this work. We thank the authors for choosing this venue to share their research results and insights with their peers. We express our appreciation to members of the Editorial Committee, a group of more than seventy experts from fifteen countries, who worked with us in providing objective feedback to authors so they could improve the quality of their manuscripts. We are indebted to Sylvie Lamontagne of the Industrial Materials Institute, National Research Council of Canada for her tireless efforts in addressing issues related to formatting and patiently working with us to process the 1700 pages of text, tables and figures. And finally, completion of this work would not have been possible without a strong commitment from our employer, the Industrial Materials Institute, National Research Council of Canada, to support this endeavor by providing the resources required to accomplish this task.

To everyone involved, we express our sincere thanks.



Basil Marple



Christian Moreau

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**1st National Thermal Spray Conference** (1987) 14-17 September, Orlando (FL).

Reference: "Thermal Spray: Advances in Coatings Technology," Ed. D.L. Houck, Pub. ASM International, Materials Park, OH, USA, 1988, 426+ pages. ISBN: 0-87170-320-3. SAN: 204-7586. 59 papers published and 730 attendees.

**2nd National Thermal Spray Conference** (1988) 24-28 October, Cincinnati (OH).

Reference: "Thermal Spray Technology - New Ideas and Processes," Ed. D.L. Houck, Pub. ASM International, Materials Park, OH, USA, 1989, 469+ pages. ISBN: 0-87170-335-1. SAN: 204-7586. 61 papers published and 1300 attendees.

**3rd National Thermal Spray Conference** (1990) 20-25 May, Long Beach (CA).

Reference: "Thermal Spray Research and Applications," Ed. T.F. Bernecki, Pub. ASM International, Materials Park, OH, USA, 1991, 792+ pages. ISBN: 0-87170-392-0. SAN: 204-7586. 110 papers published and 1600 attendees.

**4th National Thermal Spray Conference** (1991) 4-10 May, Pittsburgh (PA)

Reference: "Thermal Spray Coatings: Properties, Processes and Applications," Ed. T.F. Bernecki, Pub. ASM International, Materials Park, OH, USA, 1991, 556+ pages. ISBN: 0-87170-437-4. SAN: 204-7586. 79 papers published and 1300 attendees.

**13th International Thermal Spray Conference** (1992) (5th National Thermal Spray Conference - 1992) 28 May - 5 June, Orlando (FL)

Reference: "Thermal Spray: International Advances in Coatings Technology," Ed. C.C. Berndt, Pub. ASM International, Materials Park, OH, USA, 1992, 1044+ pages. ISBN: 0-87170-443-9. SAN: 204-7586. 161 papers published and 1600 attendees.

**6th National Thermal Spray Conference** (1993) 7-11 June, Anaheim (CA)

Reference: "Thermal Spray: Research, Design and Applications," Ed. C.C. Berndt and T.F. Bernecki, Pub. ASM International, Materials Park, OH, USA, 1993, 691+ pages. ISBN: 0-87170-470-6. SAN: 204-7586. 105 papers published and 1250 attendees.

**7th National Thermal Spray Conference** (1994) 20-24 June, Boston (MA)

Reference: "Thermal Spray Industrial Applications," Ed. C.C. Berndt and S. Sampath, Pub. ASM International, Materials Park, OH, USA, 1994, 800+ pages. ISBN: 0-87170-509-5. SAN: 204-7586. 126 papers published and 1500 attendees.

**8th National Thermal Spray Conference** (1995) 11-15 September, Houston (TX)

Reference: "Thermal Spray Science & Technology," Ed. C.C. Berndt and S. Sampath, Pub. ASM International, Materials Park, OH, USA, 1995, 774+ pages. ISBN: 0-87170-541-9. SAN: 204-7586. 126 papers published and 1200 attendees.

**9th National Thermal Spray Conference** (1996) 7-11 October, Cincinnati (OH)

Reference: "Thermal Spray: Practical Solutions for Engineering Problems," Ed. C.C. Berndt, Pub. ASM International, Materials Park, OH, USA, 1996, 992+ pages. ISBN: 0-87170-583-4. SAN: 204-7586. 131 papers published and 1350 attendees

**10th National Thermal Spray Conference** (1997) 14-18 September, Indianapolis (IN)

Reference: "Thermal Spray: A United Forum for Scientific and Technological Advances," Ed. C. C. Berndt, Pub. ASM International, Materials Park, OH, USA, 1997, 1020+ pages. ISBN: 0-87170-618-0. SAN: 204-7586. 137 papers published and 950 attendees

**15<sup>th</sup> International Thermal Spray Conference** (1998) 25-29 May, Nice, France<sup>1</sup>

Reference: "Thermal Spray: Meeting the Challenges of the 21<sup>st</sup> Century," Ed. C. Coddet, Pub. ASM International, Materials Park, OH, USA, 1998, 1693+ pages. ISBN: 0-87170-659-8. SAN: 204-7586, 272 papers published

**2<sup>nd</sup> United Thermal Spray Conference** (1999) 17-19 March, Dusseldorf, Germany

Reference: "Tagungsband Conference Proceedings" Ed. E. Lugscheider, P. A. Kammer, Pub. DVS Deutscher Verband für Schweißen, Germany, 1999, 879+ pages. ISBN 3-87155-653-X 170 papers published

**1<sup>st</sup> International Thermal Spray Conference** (2000) 8-11 May, Montréal, Québec, Canada <sup>1</sup>

(The first ITSC sponsored by the ASM-Thermal Spray Society, The DVS-German Welding Society, and the IIW-International Institute of Welding)

Reference: "Thermal Spray: Surface Engineering via Applied Research," Ed. C.C. Berndt, Pub. ASM International, Materials Park, OH, USA, 2000, 1383+ pages. ISBN 0-87170-680-6 SAN 204-7586 199 papers published and 1068 attendees

**International Thermal Spray Conference** (2001) 28-30 May, Singapore

Reference: "Thermal Spray 2001: New Surfaces For A New Millennium," Ed. C.C. Berndt, K.A. Khor, E. Lugscheider, Pub. ASM International, Materials Park, OH, USA, 2001, 1361+ pages. 185 papers published

**International Thermal Spray Conference** (2002) 4-6 March, Essen, Germany

Reference: "Tagungsband Conference Proceedings," Ed. E. Lugscheider, Pub. DVS, Deutscher Verband für Schweißen, Germany, 2002, 1051+ pages. ISBN 3-87155-783-8. 202 papers published

**International Thermal Spray Conference** (2003) 5-8 May, Orlando, Florida<sup>1</sup>

Reference: "Thermal Spray 2003: Advancing the Science and Applying the Technology," Ed. B. R. Marple, C. Moreau, Pub. ASM International, Materials Park, OH, USA, 2003, 1708+ pages. ISBN 0-87170-785-3. 244 papers published

**Footnotes**

<sup>1</sup>These proceedings are still available and can be obtained through ASM International's Customer Service.

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The ASM International Thermal Spray Hall of Fame was established in 1993 by the ASM Thermal Spray Society. Induction to the Hall of Fame is a means of recognizing and honoring outstanding leaders who have made significant achievements and contributions to the science, practice, education, management and advancement of thermal spraying technology.

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