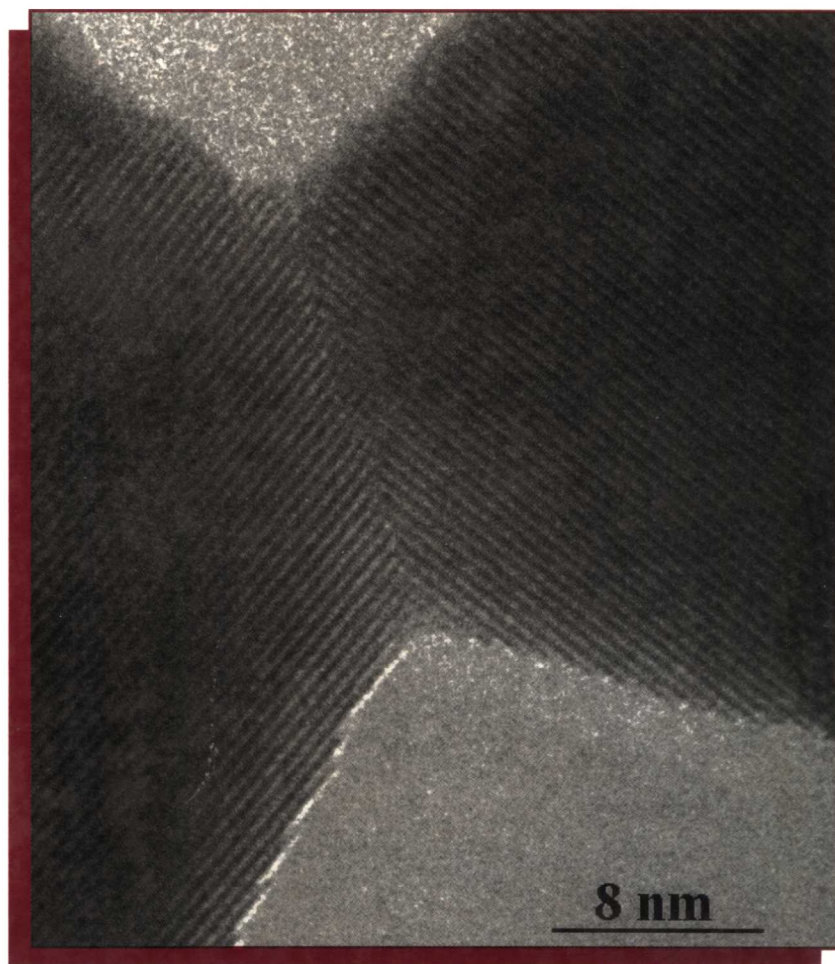


Thermal Spray: A United Forum for Scientific and Technological Advances

15 - 18 September 1997

PROCEEDINGS OF THE
UNITED THERMAL
SPRAY CONFERENCE

Edited by
C.C. Berndt



German Welding Society
(Deutscher Verband für
Schweißtechnik - DVS)



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Preface

The United Thermal Spray Conference '97 (UTSC '97), held in Indianapolis (IN-USA), 15-18 September, marks the beginning of a new era in international conferences in the field of thermal spraying. This Conference is the successor to the National Thermal Spray Conferences (NTSC's) in the US and the Thermal Spray Conferences (TS's) in Germany. Thus, UTSC '97 has been jointly organized under the auspices of the Thermal Spray Society (TSS), an affiliate society of ASM International, and the German Welding Society (DVS – Deutscher Verband für Schweißtechnik). Under this new global span, it is anticipated that this Conference will attract speakers, exhibitors and attendees from around the world and will result in a conference and exposition that will highlight the latest research and commercial developments in the whole field of thermal spray and associated technologies/industries for the entire engineering, academic and scientific communities.

Thermal spray continues to be a dynamic and rapidly changing field and as such is being used in a wider range of industries to solve increasingly challenging problems. These solutions enhance the performance and extend the lives of industrial components and machinery which are subjected to wear, corrosion, friction, heat and combinations thereof, and numerous other practical needs. The conference program was designed to highlight such aspects of this important technology. The 1997 United Thermal Spray Plenary was presented by Prof. B. Kear (Rutgers University, Piscataway, NJ-USA) on the topic of "New and Exciting Potential Developments in Thermal Spraying of Nano-Structured Materials which are Expected to have a Major Impact on Future Coating Technology". As well, a Plenary Symposium on "Key Industries – Uses and Trends for Thermal Spray Coatings" incorporated presentations by N. Solomon (Foster Wheeler Energy Services, Inc., CA-USA), R. Novak (Pratt & Whitney, CT-USA), D. Meyers (General Motors Corp., MI-USA) and B. Bodger (Southwest Aeroservice, OK-USA). Another special event was the "Thermal Spray Research: Progress in Academia Symposium" with presentations from 12 of the world's leading academic researchers. Other special symposia included "Commercial Developments" where suppliers discussed their latest products and "Thermal Spray Support and Services" where leading experts discussed the critical aspects of shop performance. Other sessions were organized into symposia covering: Structure-Property Relationships, Thermal Barrier Coatings, Residual Stress, HVOF, Infrastructure, Aerospace/Transportation/Power Generation, Product Development, and Process Characterization (i.e., modeling and diagnostics).

In addition to the numerous technical and commercial presentations, UTSC '97 incorporated more than 50 exhibitors who highlighted their latest products and services. As well as thermal spray equipment and consumables, a wide range of service organizations that supply coatings and companies that supply other products used by the thermal spray industry attended the conference. Attendees to the exhibition participated in a series of commercial presentations on newly commercialized products and technology in addition to the formal Technical Program. The support of the exhibitors is essential to the success of the Conference and adds greatly to the value received by the conference attendees.

These proceedings are comprised of technical papers presented at UTSC '97. The papers have been accepted "as provided by the author" following a high standard of manuscript preparation in accordance with strict guidelines. The papers in these Proceedings cover a broad range of topics and present the latest developments in both research and industrial applications of thermal spray technology. The primary topics of UTSC '97 are covered under the following 15 chapters within this proceedings.

- | | |
|--|---|
| 1. Industrial Application of Coatings | 9. Diagnostic Measurements and Process Modeling |
| 2. Hard and Erosion Wear Resistant Coatings | 10. Modeling and Measurement of Splat Phenomenon |
| 3. Coatings for Infrastructure and Corrosion Application | 11. Microstructural Characterization and Properties |
| 4. Polymer-Based Thermal Spray Coatings | 12. Mechanical Properties of Coatings |
| 5. Thermal Barrier Coatings | 13. Stress State Considerations of Coatings |
| 6. Emerging Processing Systems | 14. High Velocity Processes |
| 7. Processing Effects on Structure | 15. Standardization |
| 8. Post-Processing of Coatings | |

A 16th chapter contains the abstracts of the 64 presentations for which no paper was available. Four comprehensive indices allow information to be located according to (i) paper title, (ii) author, (iii) company affiliation and (iv) keyword.

The successful execution of the UTSC '97 Conference and Exhibition requires the dedicated efforts of many people. The Organizing Committee wishes to thank all of those who contributed – authors, symposia chairs, session chairs, the Exhibition and Technical Program Committee members and, particularly, the ASM staff members who make it all come together and take place.

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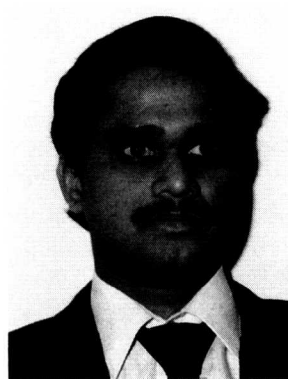


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The United Thermal Spray Conference follows a stream of successful meetings organized by ASM International and Deutscher Verband für Schweißtechnik (DVS); and these are listed below:

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.

TS90/Thermal Spraying Conference (1990) 29-31 August, Essen, Germany.

Reference: *"Thermische Spritzkonferenz '90,"* Published by Deutscher Verlag für Schweißtechnik DVS-Verlag, Düsseldorf, Germany, 1990, 262 pages. Foreword by E.h.H. Sossenheimer and E. Lugscheider. ISBN: 3-87155-435-9. 87 papers published in German & English and 430 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).¹

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.

TS93/Thermal Spraying Conference (1993) 3-5 March, Aachen, Germany.

Reference: *"Thermische Spritzkonferenz '93,"* Published by Deutscher Verlag für Schweißtechnik DVS-Verlag, Düsseldorf, Germany, 1993, 456 pages. Foreword by D. von Hote and E. Lugscheider. ISBN: 3-87155-457-X, ISSN: 0418-9639. 133 papers in German & English and 450 attendees.

7th National Thermal Spray Conference (1994) 20-24 June, Boston (MA).¹

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).¹

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).¹

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.

TS96/Thermal Spraying Conference (1996) 6-8 March, Essen, Germany.

Reference: *"Thermische Spritzkonferenz '96,"* Published by Deutscher Verlag für Schweißtechnik DVS-Verlag, Düsseldorf, Germany, 1996, 444 pages. Foreword by D. von Hote and E. Lugscheider. ISBN: 3-87155-480-4, ISSN: 0418-9639. 129 papers in German & English and 450 attendees.

1st United Thermal Spray Conference (1997) 15-18 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, 1000+ pages. ISBN: 0-87170-618-0. SAN: 204-7586. 137 papers published

15th International Thermal Spray Conference (1998) 18-22 May, Nice, France.

To be organized.

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

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