

2024 ASPE-euspen Summer Topical Meeting on Advancing Precision in Additive Manufacturing

Golden, Colorado, USA
15 - 19 July 2024

ISBN: 979-8-3313-0017-3

Printed from e-media with permission by:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571



Some format issues inherent in the e-media version may also appear in this print version.

Copyright© (2024) by American Society for Precision Engineering (ASPE)
All rights reserved.

Printed with permission by Curran Associates, Inc. (2024)

For permission requests, please contact American Society for Precision Engineering (ASPE)
at the address below.

American Society for Precision Engineering (ASPE)
3434 Edwards Mill Road, Suite 112-325
Raleigh, NC
27612

Phone: (984) 268-9756

www.aspe.net

Additional copies of this publication are available from:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571 USA
Phone: 845-758-0400
Fax: 845-758-2633
Email: curran@proceedings.com
Web: www.proceedings.com

Table of Contents

Preface	ii
Table of Contents.....	iii
Foreword	iv
Meeting Sponsors.....	v
Sustaining Corporate Members.....	vi
Corporate Members.....	viii
Schedule.....	ix
Tutorial.....	xiii
State-of-the-Art Speakers.....	xiv
Technical Index.....	xx
Author Index	133

Technical Index

Monday, July 15, 2024

Tutorial: Nondestructive Testing for Additive Manufacturing

1:00 – 5:00 PM

Orion L. Kafka, Newell Moser and Ward Johnson (National Institute of Standards and Technology, Applied Chemicals and Materials Division, Boulder, CO)

Opening Reception at The Golden Mill

6:00 – 8:00 PM

Tuesday, July 16, 2024

Registration Check-in and Coffee

7:00 AM

Welcome and Opening Remarks

8:30 AM – 9:00 AM

Joy Gockel (Colorado School of Mines), *John S. Taylor, Jaime Berez* (University of North Carolina – Charlotte); *Jason C. Fox* (National Institute of Standards and Technology); *Liam Blunt* (University of Huddersfield, UK)

State of the Art (SOTA) Presentation

9:00 AM – 9:30 AM

1. Additive Manufacturing Research and Education at Mines

Joy Gockel (Colorado School of Mines)No Abstract Available

Session 1

Design for Additive Manufacturing and Applications

9:30 AM – 11:10 AM

Session Chairs: *Jaime Berez* and *John S. Taylor* (University of North Carolina – Charlotte)

1. Ceramic AM Flexure Geometric Feasibility Study

Anand Rathnam, Stuart T. Smith (University of North Carolina – Charlotte).....1

2. Pushing the Dimension Limits of Stochastic Voronoi Lattices Manufactured by Selective Laser Melting to Mimic Bone Anisotropy

Danish Ashraf, Ahmed Tawfik, Paul Bills, Liam Blunt (University of Huddersfield).....No Abstract Available

3. Specification and Characterization of Laser Powder Bed Fusion Surface Textures for Heat Transfer in Internal Channels <i>M M Towfiqur Rahman, Christopher J. Evans, Jimmie A. Miller, Jaime Berez (University of North Carolina – Charlotte); Jason C. Fox (National Institute of Standards and Technology)</i>	5
4. 3D Printed Carbon Fiber For Extreme and Thermal Mechanical Environments <i>Ryan C. Dunn, Michael G. DeLay, and David M. Zilar (Mantis Composites, Inc.)</i>	11

Commercial Exhibition Introductions

1. Boston Micro Fabrication (BMF)
Dan Tucker
2. National Institute of Standards and Technology (NIST)
Jason C. Fox

Coffee Break

11:10 AM – 11:40 AM

Session 2

Rapid Fire Poster Session

11:40 AM – 12:00 Noon

Session Chair: Seno Rekawa (Lawrence Berkeley National Laboratory)

1. Challenges of Additive Manufacturing for Optical Applications <i>James Garcia, Michael A. Cullinan (The University of Texas at Austin)</i>	No Abstract Available
2. Metrology-Optimized Building Plate for Metal Laser Powder Bed Fusion <i>Filippo Zanini, Nicolò Bonato, Simone Carmignato (University of Padova)</i>	15
3. Low-Cost Calibration Plate for Enhanced In-Situ Monitoring in Laser-Powder Bed Fusion (L-PBF) <i>Brett E. Brady, Caleb Campbell, Bradley H. Jared (University of Tennessee, Knoxville); Shuchi Khurana (Addiguru)</i>	19
4. Assessment of Laser Marking Speed Effect on Additively Manufactured Ceramic Part Density <i>Tien P.J. Herd, Sarah-Margaret L. Andrews, Steve R. Schmid (University of North Carolina – Charlotte)</i>	25
5. AS-Printed Surface Topography of Polymer Laser Powder Bed Fusion Parts <i>Aakil R. Lalwani, Christian L. Budden, Venkata K. Nadimpalli, David B. Pedersen (Technical University of Denmark)</i>	29

- 6. Development of a Novel Laser Powder Bed Fusion System**
Justin T. Krantz, Gonzalo S. Reyes-Donoso, *Robert G. Landers*, Edward C. Kinzel (University of Notre Dame); Cody S. Lough, Ben Brown (Kansas City National Security Campus).....No Abstract Available
- 7. A Collaborative Study on the Characterization of Additive Manufacturing Build Surfaces and Solidified Melt Pool Topography**
Jason C. Fox (National Institute of Standards and Technology); Jesse Redford, Christopher J. Evans (University of North Carolina – Charlotte).....33

Lunch

12:00 Noon – 1:30 PM

Session 3

Additive Manufacturing Process Physics

1:30 PM – 3:20 PM

Session Chairs: Joy Gockel (Colorado School of Mines) and Bey Vrancken (Ku Leuven Facturenbureau)

- 1. State of the Art (SOTA) Presentation**
In-situ 2D and 3D Measurements of Process and Performance in Additive Manufacturing: Applications in Metals and Polymers
Orion L. Kafka, Jake Benzing, Nicholas Derimow, Newell Moser, Nikolas Hrabe, Callie Higgins, Jason Killgore (National Institute of Standards and Technology).....37
- 2. A Critical Cooling Constant to Clarify Track-to-Track Overheating in Laser Powder Bed Fusion Additive Manufacturing of IN625**
Jesse Redford, Christopher J. Evans (University of North Carolina – Charlotte);
Jason C. Fox (National Institute of Standards and Technology)..... 40
- 3. Laser Powder Bed Fusion Melt Pool Instability Caused By Plume-Entrained Particles Blocking The Laser**
Jamie Bell, Paul Hooper (Imperial College London)No Abstract Available
- 4. Metrology Efforts in Ceramic Additive Manufacturing**
Russell A. Maier, Lynnora O. Grant (National Institute of Standards and Technology).....No Abstract Available
- 5. Characterization of Powder Packing in Polymer Laser Powder Bed Fusion**
Aakil R. Lalwani, Christian L. Budden, David B. Pedersen and Venkata K. Nadimpalli (Technical University of Denmark).....No Abstract Available

Coffee Break

3:20 PM – 3:40 PM

Session 4

Additive Manufacturing Machine Design, Performance and Control

3:40 PM – 4:40 PM

Session Chairs: Bradley H. Jared (University of Tennessee, Knoxville) and Jaime Berez (University of North Carolina – Charlotte)

- 1. Orthogonal 2-Wavelength Digital Light Processing for Advanced VAT Photopolymerization**
Heyang Zhang, Xiayun Zhao (University of Pittsburgh)..... 46

- 2. Modular System of Additive Manufacturing Benchmarking Artefacts for XCT Inspection Using a Design-for-Metrology Approach**
Darragh A. Broadbent, Wenhan Zeng, Shan Lou (Huddersfield University); David M. Gorman (National Physical Laboratory)..... 51

- 3. Aligning the Laser and Build Plane of an Open Metal LPBF System**
Christian L. Budden, Magnus B. Kjer, David B. Pedersen (Technical University of Denmark)No Abstract Available

- 4. Gas flow in Laser Powder Bed Fusion: What is it Good For?**
Berez, Jaime (University of North Carolina - Charlotte) ...No abstract available

Poster Viewing Time

4:40 PM – 5:15 PM

See Session 2 for Poster Listings

Dinner at the CoorsTek Center for Applied Science and Engineering

6:00 PM – 9:00 PM

Wednesday, July 17, 2024

Registration Check-in and Coffee

7:30 AM

Opening Remarks and State of the Art (SOTA) Presentation

8:55 AM – 9:30 AM

- 1. Putting In-process Monitoring to Work: Towards Real-time Digital Quality Assurance**
Paul Hooper (Imperial College London)No Abstract Available

Session 5

Additive Manufacturing Process Optimization

9:30 AM – 10:50 AM

Session Chairs: Paul Hooper (Imperial College London) and Jason C. Fox (National Institute of Standards and Technology)

- 1. Understanding the Laser Powder Bed Fusion Surface Quality for CPI Aluminum Alloy**
Ozgur Poyraz, Anthony Molyneux, Evren Yasa, James Hughes (University of Sheffield); *Shan Lou*, Yuanshuo Liu, Weidong Liu (University of Huddersfield).....57
- 2. Bayesian Optimization for Process Parameter Development in Wire-Arc Additive Manufacturing**
Jaydeep Karandikar, Chris Tyler, Tony Schmitz (Oak Ridge National Laboratory); Anirban Chaudhuri (The University of Texas at Austin); Joshua Penney, Devon Goodspeed, Bradley Jared (University of Tennessee, Knoxville).....63
- 3. Photoinhibition-Aided VAT Photopolymerization Additive Manufacturing of Bio-Composites**
Yusra Bensouda, Xiayun Zhao (University of Pittsburgh).....67
- 4. Correlation of Porosity and Surface Texture for Additively Manufactured Parts: Impact of Build Orientation, Support Structure and Heat Dissipation Area**
Weidong Liu, Yuanshuo Liu, Yuchu Qin, Wenhan Zeng, *Shan Lou* (University of Huddersfield); Sihe Wang (Xi'an Jiaotong University); Ozgur Poyraz, Evren Yasa, James Hughes (University of Sheffield).....71

Poster Viewing Times

10:50 AM – 11:20 AM (*Posters and Coffee*)

12:20 PM – 1:50 PM (*Lunch and Posters*)

See Session 2 for Poster Listings

Session 6

Machine Learning and Data Fusion

11:20 AM – 12:20 PM

Session Chairs: Samanta Piano (University of Nottingham) and Zachary Snow (Oak Ridge National Laboratory)

- 1. Investigation on the Use of Machine Learning and X-Ray Computed Tomography for Lack-of-Fusion Porosity Prediction**
Nicolò Bonato, Filippo Zanini, Simone Carmignato (University of Padova).....77

2. Multiscale Characterization of AM Components with X-Ray Computed Tomography and Deep Learning

Nathan Johnson, Hrishikesh Bale (Carl Zeiss X-ray Microscopy, Inc); Curtis Frederick, Paul Brackman, Herminso Villarraga-Gómez (Carl Zeiss Industrial Quality Solutions, LLC).....No Abstract Available

3. Interpretable Machine Learning for In-Process Quality Assurance in Metal Additive Manufacturing

Sebastian Larsen, Paul A. Hooper (Imperial College London)No Abstract Available

Lunch

12:20 PM – 1:50 PM

Session 7

Micro-Nano and Lattice Structures

1:50 PM – 3:00 PM

Session Chairs: Bradley H. Jared (University of Tennessee, Knoxville) and Michael A. Cullinan (The University of Texas at Austin)

1. State of the Art (SOTA) Presentation

A Review of the State-of-the-Art and Precision Engineering Challenges in Micro/Nanoscale Additive Manufacturing

Michael A. Cullinan (The University of Texas at Austin).....No Abstract Available

2. Investigation of Positional Inaccuracies to Enable the Fabrication of Precisely Aligned Multi-Material Structures with a Two-Photonlithography Workstation

Eugenia Bosler, Stefan Kühne, Dirk Oberschmidt (Technische Universität Berlin)81

3. Effects on Lattice Minimum Strut Thickness of Using a Reduced Build Volume Setup

Liam Blunt, Ahmed Tawfik, Shan Lou, Josef Ashworth (University of Huddersfield).....No Abstract Available

Break and Introduction to ADAPT Tour

3:00 PM – 3:30 PM

ADAPT TOUR

3:30 PM – 5:30 PM

Dinner on Your Own

Thursday, July 18, 2024

Registration Check-in and Coffee
7:30 AM

Opening Remarks and Session 8
In-Process and In Situ Metrology
8:55 AM – 10:10 AM

Session Chairs: Jason C. Fox (National Institute of Standards and Technology) and Jesse Redford (National Institute of Standards and Technology)

- 1. State of the Art (SOTA) Presentation**
Recent Advances on the Use of In Situ Monitoring as a Nondestructive Evaluation Tool for Additive Manufacturing Processes
Zackary Snow, Luke Scime, Amirkoushyar Ziabari, Vincent Paquit (Oak Ridge National Laboratory); Brian Fisher (RTX Technology Research Center)86

- 2. Structured Illumination Imaging: A New Paradigm for Laser Process Monitoring**
Scott Hunter, Seth Cottrell, Adriana Eres-Castellanos, Daniel E. Adams, Jonah Klemm-Toole, Amy Clarke, Jeff Squier (Colorado School of Mines).....91

- 3. Low-Cost Near-Infrared Sensing for Enhanced In-Situ Monitoring in Laser-Powder Bed Fusion**
Caleb T. Campbell, Brett E. Brady, Bradley H. Jared (University of Tennessee, Knoxville); Eduardo Miramontes, Shuchi Khurana (Addiguru)95

Poster Viewing Times

10:10 AM – 10:40 AM (*Posters and Coffee*)

11:40 AM – 1:10 PM (*Posters and Lunch*)

See Session 2 for Poster Listings

Session 9

Integration of Additive Manufacturing Into Holistic Manufacturing Process

10:40 AM – 11:40 AM

Session Chairs: Liam Blunt (University of Huddersfield) and John S. Taylor (University of North Carolina – Charlotte)

- 1. Improving the Surface Finish in SLM AM Tungsten Components Through a Combination of In-Process and Post-Processing Techniques**
 A. *Tawfik*, C. Jackson, O. Armitage, P. Bills, L. Blunt (University of Huddersfield); M. Zavala-Arredondo, D. Sabu, J. Duncan (UKAEA, Culham Science Centre);
 H. Bramwell, A. Holt (Holdson Ltd).....No Abstract Available
- 2. Post-Processing of Additive Manufactured Medical Metal Parts**
 Eckart Uhlmann, Julian Polte, Toni Hocke, *Christian Lahoda* (Institute for Machine Tools and Factory Management IWF);
 Ghamdan Al-Sanhani (Institute for Production Systems and Design Technology IPK) 100
- 3. Impact of Chemical Machining Treatment on Surface Quality and Fatigue Properties of Laser powder Fusion Processed Parts**
Shubhavardhan Ramadurga Narasimharaju, A. Ramesh Raghavendra, Ken Thomas (South East Technological University-Waterford); Antonio Viscusi (Universitas Mercatorum); Fabio Scherillo, Antonino Squillace (University of Naples Federico II)No Abstract Available

Lunch and Posters

11:40 AM – 1:10 PM

Session 10

Metrological Characterization of Additive Manufacturing Components

1:10 PM – 3:20 PM

Session Chairs: Shan Lou (University of Huddersfield) and Christopher J. Evans (University of North Carolina – Charlotte)

- 1. State of the Art (SOTA 6) Presentation**
Additive Manufacturing of Ceramics: Can Surface Measurements Provide Processing and Part Integrity Insights?
Brigid Mullany, Sarah-Margaret Andrews, Angela Allen (University of North Carolina at Charlotte)..... 105
- 2. Measurement of Laser Powder Bed Fusion Surfaces Using Non-Contact Techniques**
Edwin Glaubitz, Joy Gockel (Colorado School of Mines); Orion L. Kafka, Jason C. Fox (National Institute of Standards and Technology) 110
- 3. Influence of Camera Shutter Type on the Performance of Fringe Projection Profilometry**
 Qingkang Bao, Tibebe Yalew, Xiangjun Kong, Gerardo Adesso, Samanta Piano (University of Nottingham); Chunwei Zhang, Hong Zhao (Xi'an Jiaotong University) 116

4. Characterization of Anomalous (Atypical) Solidified Melt Pools in Solidified Melt Pools in Nickel Superalloy 625 Laser Powder Bed Fusion

Christopher J. Evans, Jesse Redford (University of North Carolina – Charlotte), Jason C. Fox, Jordan Weaver (National Institute of Standards and Technology) 121

5. Morphology Sensing in Digital Glass Forming Processes

Balark Tiwari, Nishan Khadka, Cindy Huang, Matthew Morgan, Tim Welch, Edward C. Kinzel, *Robert G. Landers* (University of Notre Dame); Andre Bos, Douglas Meredith, John Bernardin (Los Alamos National Laboratory)No Abstract Available

6. Scan Strategy Based Measurands for Characterization of Surface Topography in Laser Powder Bed Fusion

Jason C. Fox (National Institute of Standards and Technology); Jesse Redford, Christopher J. Evans (University of North Carolina – Charlotte)..... 127

Coffee Break

3:20 PM – 3:40 PM

2025 Meeting Announcement

3:40 PM – 3:45 PM

Closing Session

What Did We Learn?

3:45 PM – 4:30 PM

Session Chairs: Liam Blunt (University of Huddersfield); John S. Taylor, Jaime Berez (University of North Carolina – Charlotte); Jason C. Fox (National Institute of Standards and Technology); Joy Gockel (Colorado School of Mines)

Closing Reception at Mines Museum of Earth Science

5:30 PM – 7:30 PM

Friday, July 19, 2024

NIST Tour

8:30 AM – 1:30 PM (Tour of NIST is from 9:00 AM – 1:00 PM)

End of Conference