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Structural Integrity of Additive Manufactured Materials and Parts

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Editors:

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Structural Integrity of Additive Manufactured Materials and Parts

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Foreword

THIS COMPILATION OF Selected Technical Papers, STP1631, *Structural Integrity of Additive Manufactured Materials and Parts*, contains peer-reviewed papers that were presented at a symposium held October 7–10, 2019, in National Harbor, MD, USA. The symposium was sponsored by ASTM International Additive Manufacturing Center of Excellence and additional ASTM Technical Committees.

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Overview

To ensure the structural integrity of additively manufactured (AM) parts, there is a need for establishing feedstock-process-structure-property-performance relationships, specifically where these components and structures are being used in safety critical applications. Therefore, the Fourth ASTM International Symposium on the Structural Integrity of Additive Manufactured Materials and Parts took place from October 7–10, 2019, in the Washington, DC, area in coordination with partners from government, industry, and academia, to provide a forum for the exchange of ideas regarding the structural integrity of parts fabricated using additive manufacturing with a focus on the lack of industry standards, design principles, as well as qualification and certification challenges.

The first event of this kind was sponsored by ASTM International Committee E08 as a workshop in San Antonio in May 2016. The second event was sponsored by Committees E08 and F42 as a symposium in Atlanta in November 2017. The third event was held in Washington, DC and sponsored by Committees F42, E08, and E07 in November 2018.

After the creation of ASTM International Additive Manufacturing Center of Excellence (AM CoE) in early 2018 and the growth of the AM industry, the effort has been centralized and is now being led and sponsored by the AM CoE, involving several co-sponsoring ASTM technical committees, including: B09 on Metal Powders and Metal Powder Products; D20 on Plastics; D30 on Composite Materials; E07 on Nondestructive Testing; E08 on Fatigue and Fracture; F04 on Medical and Surgical Materials and Devices; and F42 on Additive Manufacturing Technologies. In addition, the fourth event was supported by the National Aeronautics and Space Administration (NASA), National Institute of Standards and Technology (NIST), European Structural Integrity Society (ESIS) TC15, and the Food and Drug Administration.

This event continues to receive interest from the international community and has been growing drastically, becoming the main gathering around standardization, qualification, and certification for additively manufactured materials and parts. This year we are pleased to report that we have 133 talks, including 44 invited speakers, 10 posters, 25 student competition talks, 3 panel discussions, and over 300 attendees, representing industry, academia, and government from more than 30 countries.

There are 24 selected technical papers (STPs) in this collection that will provide an opportunity to delve more deeply into the wide variety of topics covered during the symposium. While individual papers often touch on multiple topics, the

following list presents the major areas covered in the symposium and the papers that address each topic as their primary focus.

A significant emphasis of this symposium was on nondestructive evaluation in situ monitoring and process control of AM parts, and the below articles are in this category:

- Optimizing X-Ray Computed Tomography Settings for Dimensional Metrology Using 2D Image Analysis
- Challenges in Inspecting Internal Features for SLM Additive Manufactured Build Artifacts
- A Critical Discussion on the Diffraction-Based Experimental Determination of Residual Stress in AM Parts
- X-Ray Computed Tomography Inspection in Metal Additive Manufacturing: The Role of Witness Specimens
- Perspective on Nondestructive Evaluation of Additive Manufactured Components
- Demonstration of Closed-Loop Control for Laser Powder Bed Fusion (LPBF)

As the lack of understanding of the factors affecting the structural integrity of AM parts and the related standards is still a major roadblock against the adoption of AM in load-bearing, safety critical applications, many papers related to fatigue, fracture, tensile, and corrosion behavior of materials and parts fabricated using AM were presented. Effects of design, process, and post-process parameters on fatigue and fracture properties as well as process optimization to improve structural integrity of AM parts were also discussed extensively. Applicability of existing test methods to AM materials and parts and innovative approaches to standardization were specifically emphasized in this symposium. The following papers focus on related topics for this category:

- Prediction of Residual Stress Evolution for End-To-End Process Chain of Laser Powder Bed Fusion Process and Determination of Fatigue S-N Curves
- Design of Coupons and Test Methodology for Orthotropic Characterization of FFF-Processed Ultem 9085
- Intrinsic Threshold Stress Intensity of Additive Manufactured Metals
- A Multiscale Material Modeling Approach to Predict the Mechanical Properties of Powder Bed Fusion (PBF) Metal
- Alternate Method for Determining Yield Strength of Polymer Additive Manufacturing
- Effects of Surface Roughness and Porosity on Fatigue Behaviors of AlSi10Mg Produced by Laser Power Bed Fusion Process
- Characterization of Functionally Graded Materials Based on Inconel 718 and Stainless Steel 316L Manufactured by DED Process
- Fretting Fatigue Characterization in Press-Fit Joints of AM Parts by X-Ray Tomography and Digital Image Correlation

- Effect of Microstructure and Internal Defects on the Mechanical Properties of Ti6Al4V Gyroid Lattice Structures for Biomedical Implants
- Full-Scale High-Load, Thermal, and Fatigue Testing of Additive Manufactured Powder Bed Fusion Component for Oil Field Applications
- Dynamic Compression Response of Porous Zirconium-Based Bulk Metallic Glass (Zr₄₁Ti₁₄Cu_{12.5}Ni₁₀Be_{22.5}) Honeycomb: A Numerical Study
- Preclinical Testing of a Novel, Additive-Manufactured, Three-Dimensional Porous Titanium Structure
- Investigation of Microstructure and Mechanical Properties of SLM-Produced Inconel 718 and Hastelloy-X Alloys
- Residual Stress Formation in Laser-Based Powder Bed Fusion (PBF-LB) of Invar 36
- On the Challenges toward Realization of Functionally Graded Structures by Electron Beam Melting—Fe-Base Shape Memory Alloy and Stainless Steel
- Origin of Oxides and Oxide-Related Pores in Laser Powder Bed Fusion Parts
- Toward Understanding the Role of Surface Texture for Additively Manufactured Metal Parts

Finally, recent advances in standardization, qualification, and certification were discussed. The following paper provides a snapshot of such discussions:

- Analysis of Data Streams for Qualification and Certification of Inconel 738LC Airfoils Processed through Electron Beam Melting

Following the successes of these events, we are excited to announce that starting in 2020, the event will be organized as the ASTM International Conference of Additive Manufacturing (ASTM ICAM) with a wider scope, while still focusing on standardization, qualification, and certification. This will be a major event involving additional ASTM committees and external stakeholders from the international community, such as NIST, FAA, NASA, FDA, America Makes, ESIS, ESA, EASA, CECIMO, and more, setting the stage to bring experts from all around the world to exchange and share the latest development in the field of additive manufacturing.

We would like to extend our gratitude to everyone who made this symposium possible. The hard work of the authors, co-authors, our symposium co-chairs, peer reviewers, ASTM personnel, ASTM Committees and ASTM AM CoE partners, as well as the support of NASA, NIST, FAA, FDA, and ESIS TC15, all played a major role in the success of the symposium and this publication.

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