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DON'T MISS THE 2022 ADDITIVE MANUFACTURING BENCHMARK TEST SERIES AND CONFERENCE

Brandon M. Lane,
Brian J. Simonds,
Jonathan E. Seppala,
and Lyle E. Levine

BE PART OF THE CONVERSATIONS

Everyone in AM modelling, simulation, and supporting measures is encouraged to attend, even if you are not involved in the benchmark challenges!

AM BENCH 2022 | ADDITIVE MANUFACTURING BENCHMARKS

August 15–18, 2022
Hyatt Regency Bethesda[a], Bethesda, Maryland, USA

Register for the meeting and reserve a hotel room on the TMS meeting website at
www.tms.org/AMBench2022

Access the benchmark challenges on the NIST AM-Bench website at
www.nist.gov/ambench

a. Certain commercial products or locations are identified in this article. Such identification is not intended to imply recommendation or endorsement by NIST.

The explosive growth of additive manufacturing (AM) is matched by an equally strong push in research and development to support those applications. The relative complexity of these manufacturing processes and the materials they generate still elicit a great need for better understanding of the interactions between the fabrication parameters (e.g., material deposition rate, applied thermal energy, etc.) and the material development and evolution. Complex problems require complex tools, and with the boom in AM, the development of computational models and simulations to predict all aspects of these processes has grown in parallel. Incredible diversity exists in the types of models, the level of physical or computational complexity, the range of materials, and applications. But all require something similar: input of or reference to relevant physical values achieved through accurate measurements. Measurements are essential, not just in the development of AM models, but in the testing and validation of their predictions.

To address this gap, the National Institute of Standards and Technology (NIST) initiated the Additive Manufacturing Benchmark Test Series (AM-Bench), where AM modelers and metrologists compare computational predictions to an array of measurements designed and dedicated to advancing AM modelling. The inaugural AM-Bench conference in 2018 was a landmark in AM model development, where modelling challenges were first described, high-quality data were provided to compare to models, and, importantly, the community came together to discuss what worked, what didn't, and how we could improve the quality, trustworthiness, and value of AM models and simulations.

A SUCCESSFUL 2018 CONFERENCE

The 2018 AM-Bench test series and conference were widely successful, with more than 40 scientists from national laboratories, universities, and private industry participating in the measurements, over 45 submissions to the modelling challenges, and over 160 attendees at the conference held the week of June 18, 2018, at NIST in Gaithersburg, Maryland. A published collection summarizes the measurements and challenges[1]. Apart from stellar presentations from both metrologists and modelers, plenary discussion sessions sparked lively conversations about the state of AM modelling and how AM-Bench can continue to accelerate model development, application, and trust. A major objective of AM-Bench is not just to generate measurement data, but also discourse. This input, along with valuable advice from the AM-Bench scientific committee and stakeholders, helped to guide the planning for AM-Bench 2022.

THE 2022 AM-BENCH MEASUREMENTS

The COVID-19 pandemic prevented key measurements from being conducted and caused a postponement of the meeting from 2021 to 2022. However, it also allowed for more comprehensive planning, with vast improvements and additions to the measurement systems, analysis methods, and data management compared with 2018.

As in 2018, a large focus will be on the connection between processing and microstructure for metals-based laser powder bed fusion (LPBF). A hierarchy of experiments will include feedstock characterization, *in-situ* measurements during the build, post-build characterization of part deflection and location-dependent residual stress and microstructure, and measurements of microstructure evolution during post-build thermal processing. While the 2018 tests were conducted on both commercial and research AM machines, almost all 2022 *in-situ* LPBF measurements and fabrication are done on the NIST Additive Manufacturing Metrology Testbed (AMMT), shown in Figure 1, using the same environment, instruments, and calibrations from the small-scale, individual laser scans to full 3D builds.

The similarities to 2018 mostly end there. AM-Bench 2022 will extend the 2018 focus to include local mechanical behavior, along with greatly improved studies of the fundamental laser-sample interactions. Other extensions include a much wider array of machine performance characterization tests (i.e., calibrations), completely redesigned and vastly improved thermographic system performance, and completely new measurements, such as laser energy absorption and 3D microstructure characterization.

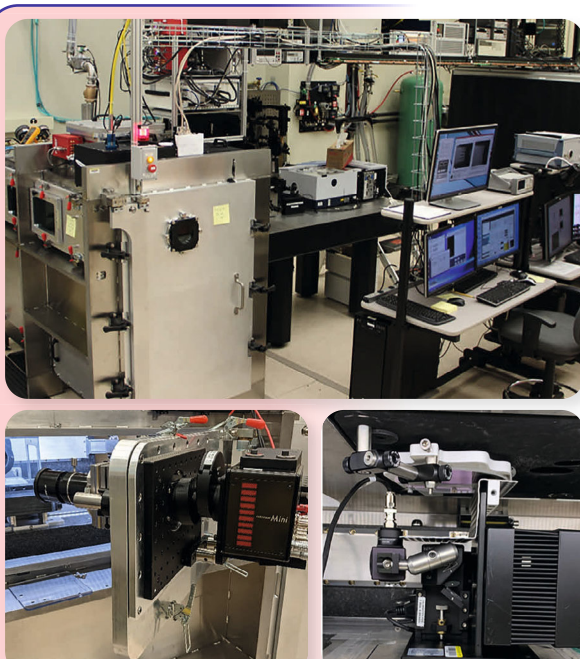

Figure 1: The outside view of the NIST Additive Manufacturing Metrology Testbed (AMMT), used for the metal 3D builds and in-situ *measurements (top). A new high speed, high magnification thermographic camera setup (lower left). The* in-situ *characterization of laser beam energy profile and dynamic performance (lower right).*

AM-Bench 2018 included a large set of measurements on polymer AM, and the lessons learned are being applied to AM-Bench 2022. In 2018, the main focus was on macroscale properties such as part thickness, mass, tensile properties, void distribution, and local anisotropy for samples produced using selective laser sintering (SLS) and material extrusion (MatEx). The corresponding challenge problems did not produce the broad community response engendered by the metal AM challenges and subsequent discussions with stakeholders led to a new focus on the fundamental processes of MatEx, SLS, and stereolithography (SLA).

Another major addition to AM-Bench 2022 is "asynchronous benchmarks" that are not tied to the nominal three-year benchmark cycle to provide increased agility in addressing the needs of our stakeholders. Asynchronous benchmarks are relatively small, stand-alone sets of measurements that address a specific need of the modelling community. The challenge problems for the first asynchronous benchmark were released in January 2022, and the measurements use a combination of high-speed synchrotron radiography and time-resolved, calibrated laser-energy coupling to explore the *in-situ* dynamics of the laser-metal interaction, shown in Figure 2[2]. The AM-Bench 2022 conference will include this asynchronous benchmark in addition to the regular 2022 benchmarks.

An exciting development is improvement to the data management systems. AM-Bench embraces the FAIR data principles of Findability, Accessibility, Interoperability, and Reusability[3]. A broad team of data scientists is developing a combination of robust data and metadata repositories, data and sample tracking systems, Extensible Markup Language (XML)-based schema, and server-side data analysis systems to provide users a free and accessible data management system for exploring, downloading, and analyzing the extensive AM-Bench data sets. Ultimately, it is planned to include vetted analysis codes and measurement data sets submitted by outside participants.

LOOKING FORWARD TO AUGUST 2022

The asynchronous benchmark descriptions and challenge problems were released in January 2022, with challenge problem submissions due in April. The main benchmark test descriptions and details about the corresponding modelling challenges will be released in April 2022 on the NIST AM-Bench website at **https://www.nist.gov/ambench**. Modelers who wish to participate in the AM-Bench challenges should expect to submit their results in July 2022 and the measurement results will be disseminated shortly after.

ABOUT THE AUTHORS

Brandon M. Lane is the leader of the NIST Engineering Laboratory (EL) Metrology for Real-time Monitoring and Control of AM Project, and co-chair of the AM-Bench Organizing Committee. **Brian J. Simonds** is an applied physicist with the NIST Physical Measurement Laboratory (PML) studying high-power laser metrology and applications. **Jonathan E. Seppala** is the leader of the NIST Materials Measurement Laboratory (MML) Polymer Additive Manufacturing and Rheology Project. **Lyle E. Levine** is the leader of the NIST MML Additive Manufacturing of Metals Project, is the founder of AM-Bench, and serves as chair of the AM-Bench Steering Committee and co-chair of the AM-Bench Organizing Committee.

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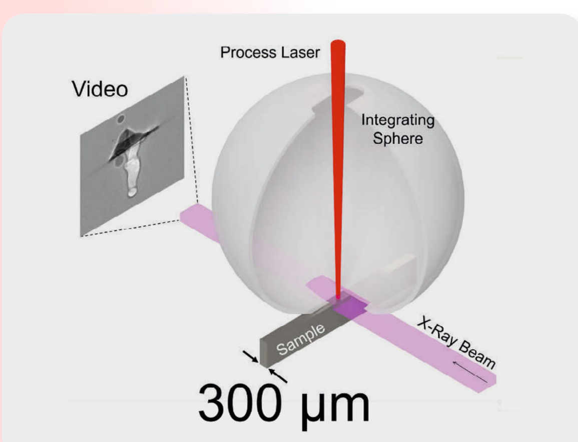

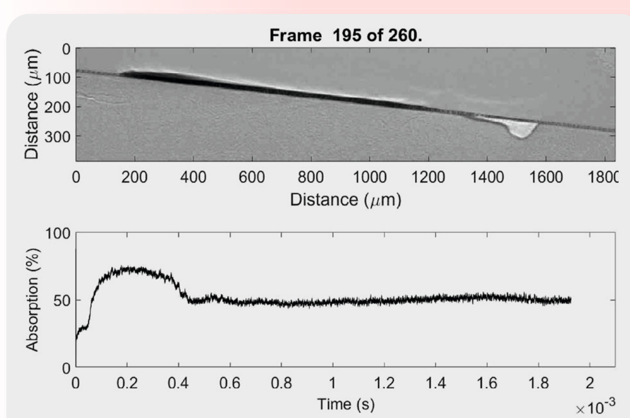

Figure 2: A schematic of the high-speed synchrotron radiography and laser absorption setup at Argonne Advanced Photon Source (left). A synchronized radiographic cross-section of the melt pool and dynamic laser absorption (right).