# AMB2022-05 Benchmark Measurements and Challenge Results

Last updated on 07/22/2022

**Overview**

The following describes compiled benchmark challenge measurement results which are used to judge submissions to the 2022 AM-Bench modeling challenges for AMB2022-05. The results presented here are summarized and formatted similar to how modelers were asked to submit their modeling results by July 15, 2022. Additional context, description, or measurement results may also be provided where necessary. Additional information may become available later so updated versions of these documents may be posted. Please check back occasionally.

Please note that the measurement results presented here reflect only a small part of the validation measurement data which will be provided by AM Bench for this set of benchmarks.

AMB2022-05: Microstructure measurement extension to AMB2018-01: laser powder bed fusion (LPBF) 3D builds of nickel-based superalloy IN625 test objects. Detailed descriptions are found here. An informational webinar for AMB2022-05 was held on May 5, 2022 and a link to the presentation is here.

**Challenge**

- Microstructure (CHAL-AMB2022-05-MS): Histograms of direction-specific grain sizes from specified regions within an as-built specimen.

---

**1. Benchmark Challenge Problem Descriptions and Released Data**

AMB2022-05 is a direct extension to the measurement data provided by AMB2018-01. For AMB2018-01, data were provided for laser powder bed fusion (LPBF) builds of IN625, including powder characterization, detailed information about the build process, in situ measurements during the build, ex situ measurements of the residual stresses, part distortion following partial cutting off the build plate, location-specific microstructure characterization, and microstructure evolution during a post build heat treatment. Detailed descriptions of the earlier AMB2018-01 builds and benchmark measurements are found **here** and the AMB2018-01 measurement results are found **here**.

Through interactions with the AM modeling community, it became clear that additional microstructure characterization data would prove useful. AMB2022-05 extends the previous microstructure data to include three additional data sets: 1) large-area SEM characterization of the mid-plane (XZ) of the bridge specimen, including part of the baseplate, 2) multiple SEM cross sections of a complete test artifact parallel to the baseplate (XY), and 3) a 3D microstructure measurement obtained through serial sectioning with optical imaging and SEM characterization. When the original AMB2018-01 specimens were produced, a full build plate of four IN625 bridge specimens was reserved for future use and two of these were used to provide samples for AMB2022-05. Because several microstructure-related challenge problems were conducted for these builds in 2018, we added just a single challenge for these new 2022 data, CHAL-AMB2022-05-MS. Here, we provide the results of the measurements directly associated with this challenge problem.  The other AMB2022-05 data sets will be published soon.

**CHAL-AMB2022-01-MS**

## 2. Measurement Descriptions
### 2.1 XZ Plane Cross Section

After cross sectioning using electrical discharge machining, the specimen was mounted in epoxy resin and progressively polished using 1200, 2000, 4000 grit SiC papers, followed by 1 µm diamond and colloidal silica. Figure 1 shows a photograph of the mounted specimen.

Electron backscatter diffraction (EBSD) measurements were conducted on an FEI Apreo SEM† with the settings listed in Table 1. The individual mapped regions are shown and numbered on Fig. 1.  A montage of the measurement areas was produced by a self-adaptive montage stitching algorithm that maximizes the cross-correlation within the overlapping regions between the tiles. It is assumed that each of the EBSD scans have the same scanning distortion, thus the optimization routine finds the coefficients of a single polynomial spatial warping function that maximizes the summed maximal values of the cross-correlation functions of each overlapped region.  After this optimal warping function is found, the tiles are stitched together by the translations that again maximize the cross-correlation between each tile (note here that unlike the spatial warping function, these translations can be different for each set of tiles).  The data are combined into a single dataset file that then can be analyzed as a whole, or with different sub-regions.

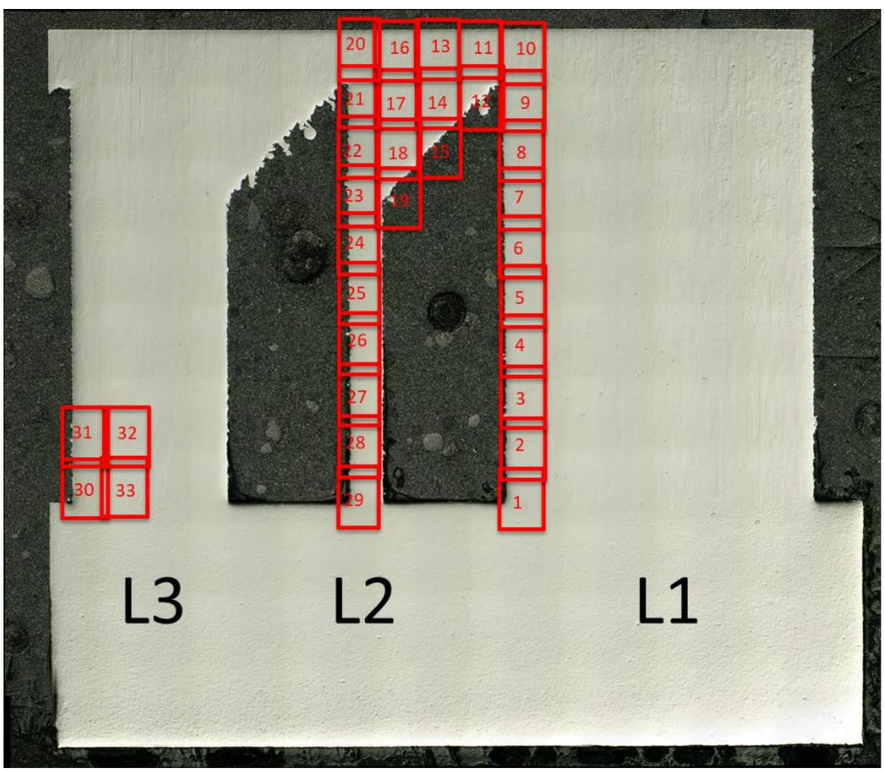


*Figure 1: Photograph of the mounted and polished XZ-plane specimen, AMB2018-625-CBM-B3-P3-L1-L2-L3-O1. The approximate EBSD measurement locations are outlined and numbered.*

*Table 1: EBSD map measurement and display settings*

| EBSD Map Measurement and Display Settings | |
|---|---|
| Accelerating voltage | 20 kV |
| Binning | 4 x 4 |
| Step size | 1 µm |
| Minimum points/grain | 2 |

## 3. Challenge Description and Measurement Results

### 3.1 CHAL-AMB2022-05-MS Challenge Results Description

There are many possible metrics that can be used to evaluate the degree of similarity between measured and simulated microstructures. For this challenge problem, we used a histogram of chord lengths obtained from multiple parallel lines intersecting grain boundaries along the orthogonal directions. Detailed descriptions of this algorithm are given in section 4.1 of the AMB2022-05 Challenge Problem Description Document.

The measurement data used for this challenge problem are the extended XZ-plane large area EBSD map acquired from AMB2018-625-CBM-B3-P3-L1-L2-L3-O1 (as built) as described above. Two nominally 0.6 mm x 1.0 mm regions and one square 1.0 mm x 1.0 mm region from the as built sample are used for the challenge problem. The final measured dimensions of regions 1 and 2 is 0.58 mm x 1.0 mm. As shown in Figure 2, these include a region at the base of a 5.0 mm leg near the edge, a second region toward the top of the same 5.0 mm leg near the same edge, and a third region within the bridge section. The locations and sizes of the specified regions are given in Figure 2.

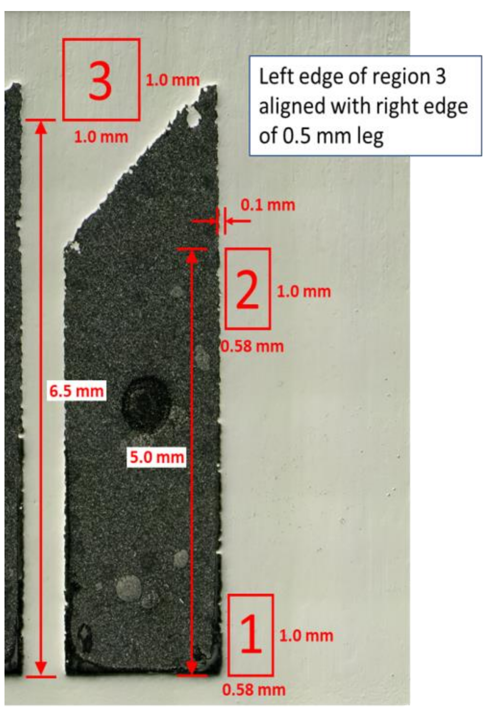


*Figure 2: The sizes and locations of the three modeling challenge regions for CHAL-AMB2022-05-MS*

For this challenge problem, adjacent pixels with at least a 10° misorientation angle define a grain boundary. The line spacing between the parallel lines is 5 µm and the width of the bins for the linear intercept length histograms is 100 µm. The provided measurement data include histograms in the same format as the challenge problem submission template. The submission template for this challenge problem may be found in the Challenge Description Dataset here, with the filename "CHALAMB2022-05-MS submission template.csv".

### 3.2 Example CHAL-AMB2022-05-MS Challenge Results

This section provides a single example of the CHAL-AMB2022-05-MS challenge problem measurement data. The complete data sets and challenge histogram answer keys may be found at https://doi.org/10.18434/mds2-2692. These include orthogonal inverse pole figure (IPF) maps for the scanned areas, full angular data describing the grain orientations, and grain segment length histograms for X and Z directions for all three regions. For convenience, separate IPF maps and angular data files are provided separately for each of the challenge regions. Figure 3 shows an IPF-X map of the full EBSD montage that includes all three of the challenge regions shown in Fig. 2.

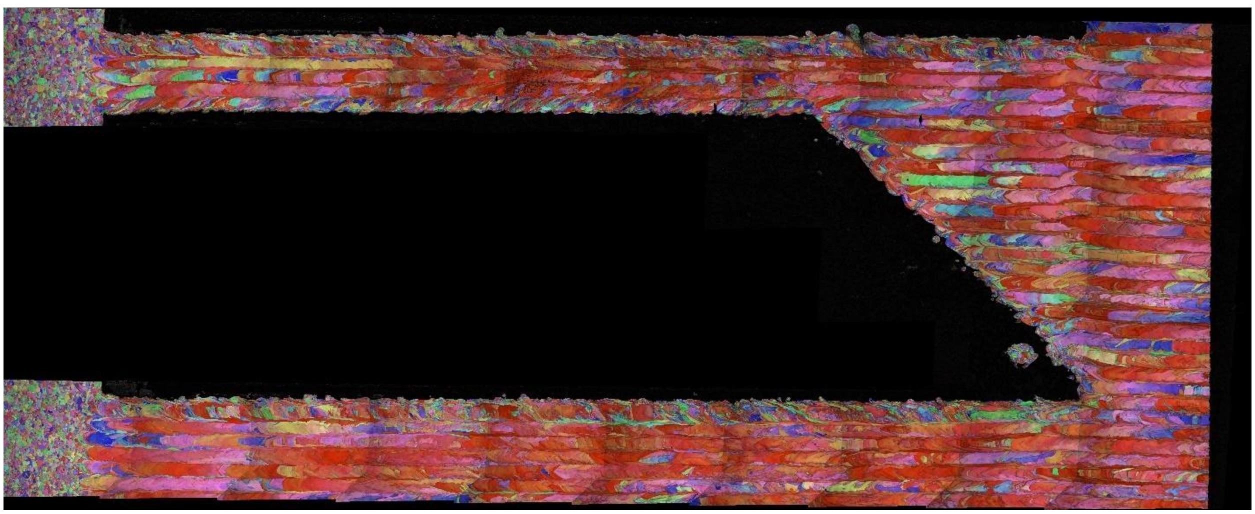

*Figure 3: Montage IPF-X map for the large scanned regions shown in Fig. 1*

## 2. Description and Links to Associated Data

Measurement results data associated with the AMB2022-05 challenge are provided in a NIST Public Data Repository (PDR) dataset, accessible via the following DOI link:

- "AM Bench 2022 Microstructure Measurement Follow-On for AM Bench 2018 IN625 3D Builds" – https://doi.org/10.18434/mds2-2692

New data files, updates, and/or changes to download URLs may be made periodically. Users should refer to the README text file which will record all updates. Additionally, the NIST Public Data Repository (PDR) undergoes frequent updates. If file downloads fail or are unavailable, users should wait several hours before contacting the technical support listed on the AMB2022-05 PDR dataset webpage.

Note that the measurement results dataset is separate from the “Challenge Description” dataset previously made available but may contain some overlapping data. The Challenge description dataset for AMB2022-05 is available here.

**References**

Citations are provided throughout this document as hyperlinked URLs to the associated digital object identifier (DOI). Clicking these hyperlinked texts should open the associated publication or cited source.

**†Disclaimer**