AMB2022-06 Benchmark Measurements and Challenge Problems

Last updated on 5/6/2022

Modelers are invited to submit simulation results for any number of challenges they like before the deadline of 23:59 (ET) on July 15, 2022. Instructions for how submissions are to be formatted are included in this document and simulation results may be submitted **here** . A Q&A webinar was held on May 6 and a recording of the presentations and an FAQ will be posted shortly. Additional information may become available later so updated versions of this document may be posted. Please check back occasionally.

All evaluations of submitted modeling results will be conducted by the AM-Bench 2022 organizing committee. Award plaques will be awarded at the discretion of the organizing committee. Because some participants may not be able to share proprietary details of the modeling approaches used, we are not requiring such details. However, whenever possible we strongly encourage participants to include with their submissions a .pdf document describing the modeling approaches, physical parameters, and assumptions used for the submitted simulations.

Please note that the challenge problems typically reflect only a small part of the validation measurement data provided by AM Bench for each set of benchmarks. The Measurement Description section, below, describes the full range of measurements conducted.

AMB2022-06: Thermoplastic material extrusion of polycarbonate test objects. Detailed descriptions are found below, and simulation results may be submitted **here**.

Challenges

- **Road width (CHAL-AMB2022-06-EW)**: The maximum and minimum horizontal width of a single-printed road. [scalars]
- **Road Dimensionless Cross-Section (CHAL-AMB2022-06-DCS)**: Shape of the cross-section of a single road. The submissions will be scaled to match benchmark results. [2D area or perimeter submitted as a bitmap image].
- **Road Cross-Section (CHAL-AMB2022-06-CS)**: Shape of the cross-section. The submissions will not be scaled, must be dimensionally accurate. [2D area or perimeter submitted as a bitmap image].

Overview and Basic Objectives

The goal of the Thermoplastic Material Extrusion AM-Bench 2022-06 Benchmark Challenge is to accurately model the relationship between material properties (viscoelasticity) and print parameters (temperature, rate, nozzle diameter) and the resultant single-layer part dimension (i.e. width and cross-section) of an amorphous polymer. The primary objectives are to predict the width and cross-sectional shape of the printed material. The improved prediction of these relations will foster enhanced tool path part performance.

Experimental data for model calibration and challenge comparison are provided through material characterization (**linear rheology**) and system calibration (**extrudate temperature**). These experiments were carried out at the National Institute of Standards and Technology. Released calibration measurements were performed on two commercial filaments. Most of the calibration data are included below and additional data will be available for download shortly.

Sample and extrusion processing

Polymer

Commercial bisphenol-A-polycarbonate filament (T_g = 154 °C, M_n = 30.1 kg/mol, M_w = 68.7 kg/mol) was used to prepare the samples. The filament is nominally 2.85 mm, with actual dimensions of 2.84 mm ± 0.03 mm.

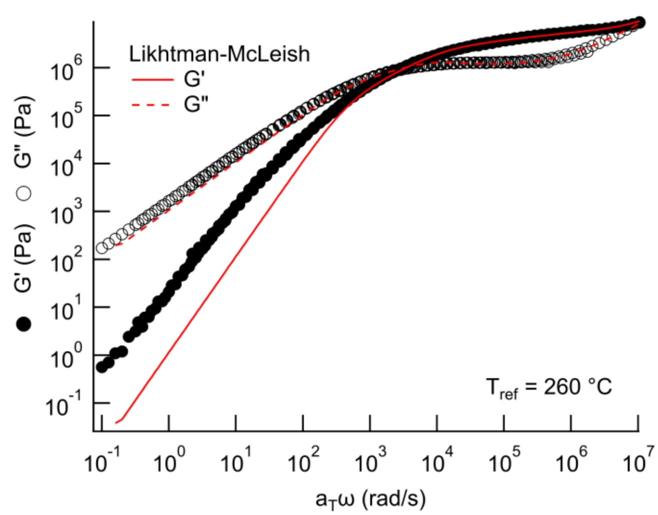

Figure 1: Linear rheology of polycarbonate

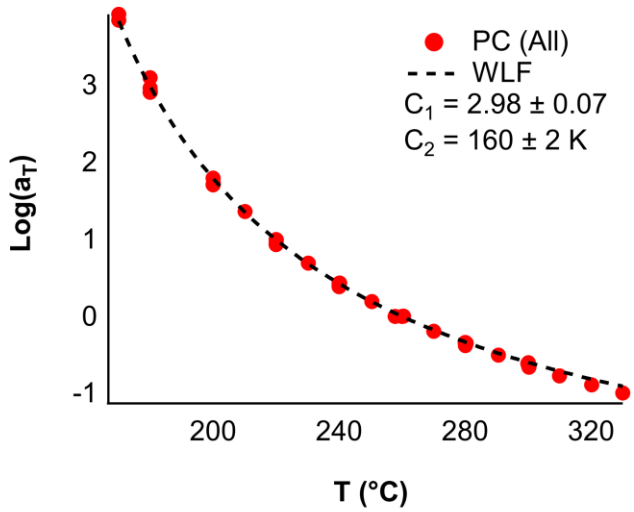

Figure 2: Shift factors for polycarbonate

Printing

The sample is two layers high, one extrudate wide, and 150 mm long, with one layer high, 1 cm by 1 cm adhesion feet at either end. The polycarbonate filament was dried at 120 °C under vacuum for 12 h. The build plate is borosilicate glass painted with a thin layer of polyvinyl alcohol water-soluble adhesive. The printing system was preheated for 10 min. The extruder nozzle was purged prior to every print. The sample order was randomized. The bed set point was 145 °C with a measured surface temperature of 118.3 °C ± 0.1 °C. Extrusion setpoints are 240 °C, 260 °C, 280 °C, 300 °C, 320 °C, and 340 °C. However, the actual extrusion temperature is 50 °C to 60 °C lower (updated extrusion temperatures to follow). Print head translation speeds are 10 mm/s and 100 mm/s. The nozzle diameter is 0.51 mm. The hot end is Al, 1 cm in length with a 3.1 mm internal diameter which extends into the nozzle which has a short 45° taper ending in the 0.51 mm nozzle opening, see Figure 3. (nozzle specs, A2 hardened tool steel, hardness 56RC, thermal conductivity 27 W/m-K).

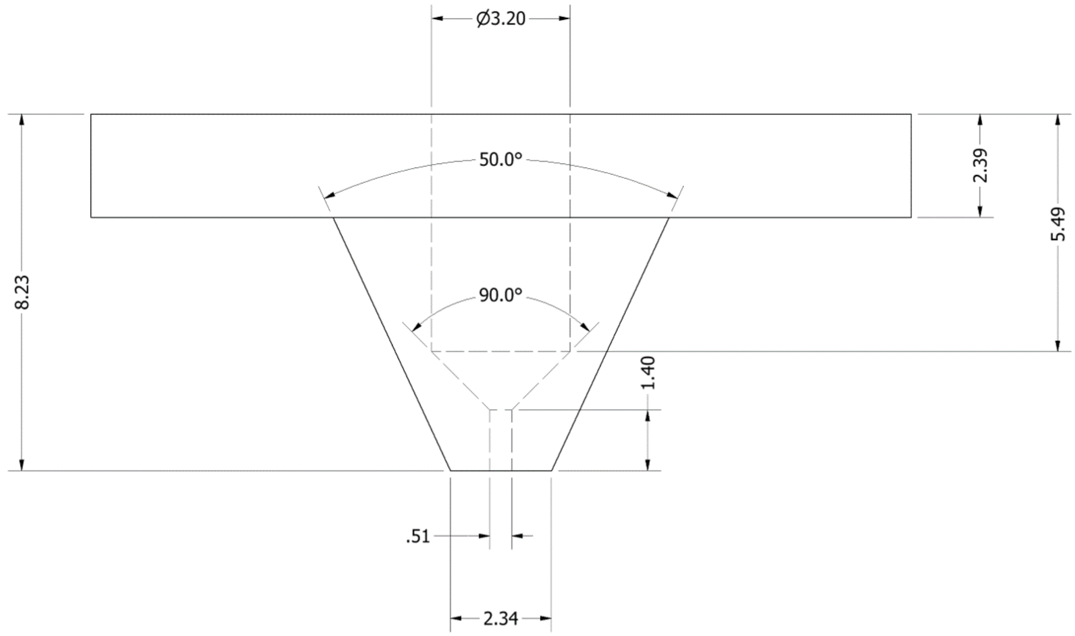

Figure 3: Nozzle drawing

The first layer is printed with square, 1 cm by 1cm “feet” at each end to help with adhesion. The feet are always printed at $v_{x,y}$ = 20 mm/s, additionally, all travel moves are the same. The first layer printed between the “feet” is printed at the “challenge” speed, as is the 2nd layer. See Figure 5 for an example of the printed sample. The timing for each layer section of the is provided in Table 1.

Table 1: Printing times for each section of the sample.

$v_{x,y}$ (mm/s)	Start foot time (s)	First layer time (s)	Back foot time (s)	Travel time (s)	Second layer time (s)
10	23.25	11.95	23.25	3.91	15.0
30	23.25	3.98	23.25	3.91	5.0
100	23.25	1.19	23.25	3.91	1.5

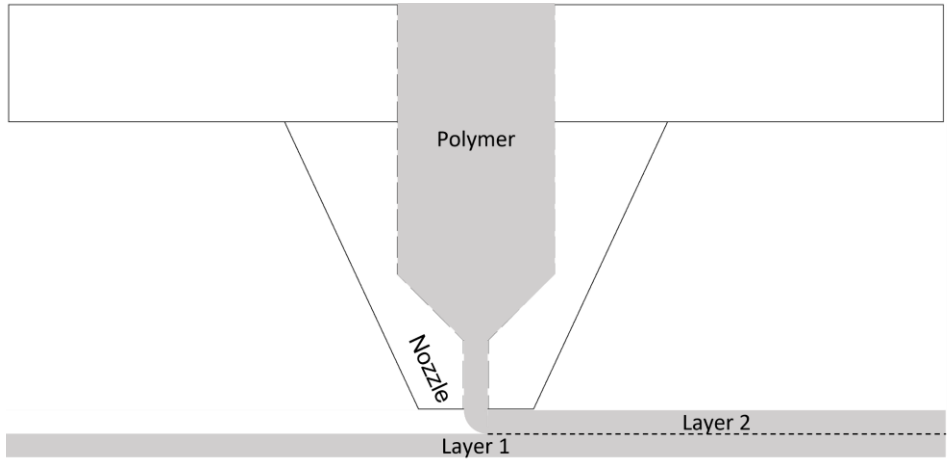

Figure 4: Illustration of sample printing.

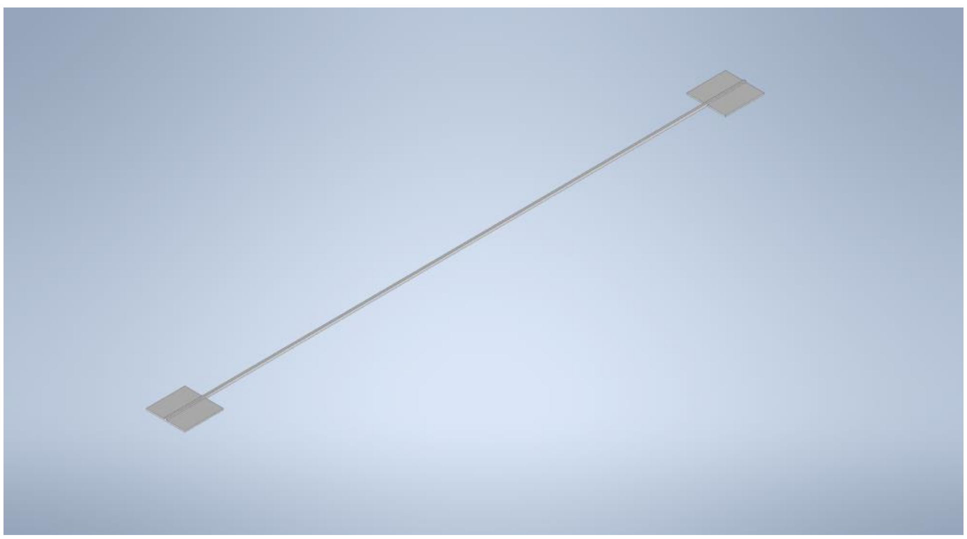

Figure 5: Illustration of the printed sample.

Measurement descriptions

Widths and cross-sections are characterized by x-ray computer tomography. Cross-sections from x-ray computer tomography will average approximately 1 cm of extrudate or road length and provide a cross-section with approximately 2 μm voxels, which results in 4 μm to 6 μm cross-section "pixels".

Benchmark Challenge Problems

CHAL-AMB2022-06-EW

In the extrudate width (EW) challenge we ask the modeler to predict the maximum (extrudate) and minimum (interface) width of the extruded layer parallel to the build plate and normal to the print direction. See Figure 6 for an illustration of the widths of interest.

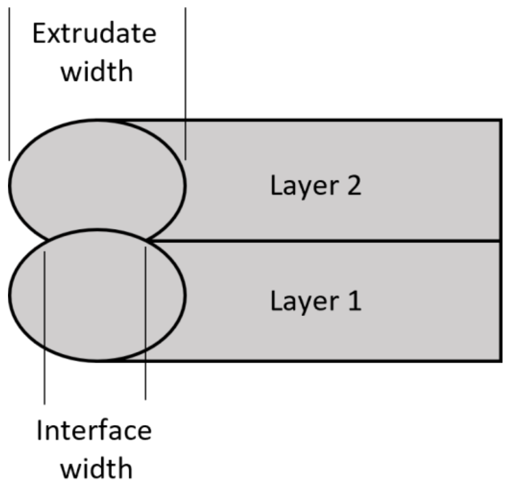

Figure 6: Illustration of the two-layer sample with extrudate and interface widths.

CHAL-AMB2022-06-DCS

In the dimensionless cross-section (DCS) challenge we ask the modeler to predict the cross-section shape of the 2nd layer up to the interface or both layers, but not necessarily match the exact dimension. The prediction will be scaled to match the measured cross-section. See Figure 7 for an illustration of the perimeters of interest.

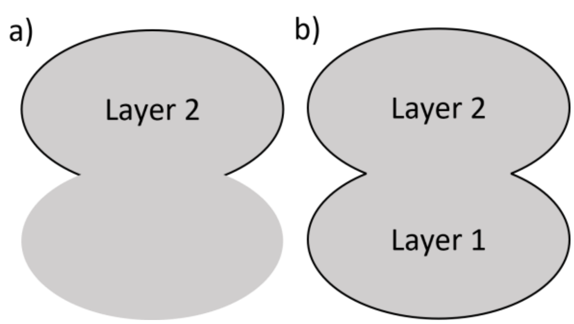

Figure 7: Illustration of a) Layer 2 cross-section perimeter (black line) and b) Layer 1 and Layer 2 cross-section perimeter (black line)

CHAL-AMB2022-06-CS

In the cross-section (CS) challenge we ask the modeler to predict the exact cross-section shape of the 2nd layer up to the interface or both layers. See Figure 7 for an illustration of the perimeters of interest.

Description and Links to Associated Data

All data available to support the AMB2022-06 challenges are contained in the “Polymer properties and printer calibration (AMB2022-06)” dataset *to be released shortly*.
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 AMB2022-06 dataset webpage.

References

N/A