doi:10.1017/S1431927615001440
Paper No. 0065
Microsc. Microanal. 21 (Suppl 3), 2015

Micro-scale X-ray Computed Tomography of Additively Manufactured Cellular Materials under Uniaxial Compression

Nikolaus L. Cordes[1], Kevin Henderson[1], Tyler Stannard[2], Jason J. Williams[2], Xianghui Xiao[3], Mathew W. C. Robinson[4], Tobias A. Schaedler[5], Nikhilesh Chawla[2], Brian M. Patterson[1]

[1]Polymers and Coatings Group, Materials Science and Technology Division, Los Alamos National Laboratory, Los Alamos, NM USA

[2]Department of Materials Science and Engineering, School for Engineering of Matter, Transport, and Energy, Arizona State University, Tempe, AZ, USA 85287-6106

[3]Advanced Photon Source, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL, USA 60439-4837

[4]Atomic Weapons Establishment, Aldermaston, Reading, Berkshire, RG7 4PR, UK

[5]HRL Laboratories LLC, 3011 Malibu Canyon Road, Malibu, CA, USA 90265

Additively manufactured (AM) materials are a current "hot topic" in materials science.[1] Current investigations of AM cellular materials, such as polymer foams, include the mechanical performance under compressive strain using 3D X-ray computed tomography (CT) at the micro-scale. This allows for an enhanced visualization of processes such as void collapse, brittle fracture, and increased surface area of AM materials while undergoing compressive strain. The results from this study will include interrupted in situ compression of AM polymer foams using laboratory-based CT as well as dynamic compression of AM polymer foams using synchrotron-based CT.

Laboratory-based interrupted in situ compression of AM polymer foams was imaged using an Xradia (now Carl Zeiss X-ray Microscopy, Inc., Pleasanton, CA) MXCT micro-scale X-ray transmission microscope and a Deben (Suffolk, UK) 500 N tension/compression cell. Micro-scale CT of AM polymer foams under dynamic compression was carried out at Argonne National Laboratory's Advanced Photon Source (APS) using beamline 2-BM, which enabled data acquisition of 1 tomogram per second at a compressive strain rate of 10^{-2} s^{-1}, resulting in 20 successive tomograms per sample.

A variety of imaged samples were fabricated using different AM techniques. However, the majority of the presentation will focus on AM polymer foams printed using an Objet500 Connex 3D printer (Stratasys Ltd., Eden Prairie, MN). The material printed was a rubber-like elastomer. The presentation will also focus on a NiP microlattice: details of the fabrication of the NiP microlattice can be found in reference [2].

Figure 1 (Left) displays four volume renderings of reconstructed tomograms of an AM polymer foam, at four separate strains (0%, 15%, 29%, and 45%), as imaged under dynamic compression using synchrotron-based CT. The sample, fabricated to have parallel tubular pores, exhibits compressive behavior typical of an elastomeric foam (Fig. 1 (Right)) as described by Gibson and Ashby[3]. However, visibly absent from the stress-strain curve is a linear region at low strain, which indicates an absence of bending of the foam ligaments. Figure 2 (Left) displays four volume renderings of reconstructed tomograms of a NiP microlattice, at four separate stages of compression. The corresponding stress-time curve (Fig. 2 (Right)) exhibits high stress (~1300 kPa) at a time of 25 s (corresponding to the 6th tomogram (Figure 2 (Left), top right), after which brittle fracture of the NiP ligaments occurs. We will also demonstrate how CT can accurately measure the change in the surface area of the AM polymer foams while undergoing compression, leading to a more accurate stress-strain curve, when compared to traditional methods.

References
[1] B. C. Gross et al., Anal. Chem., **86**(7) (2014) 3240.
[2] A. Torrents et al., Acta Mater., **60**(8) (2012) 3511.
[3] L. J. Gibson and M. F. Ashby, Cellular Solids: Structures and Properties, 2nd ed., The Press Syndicate of the University of Cambridge, 1997.

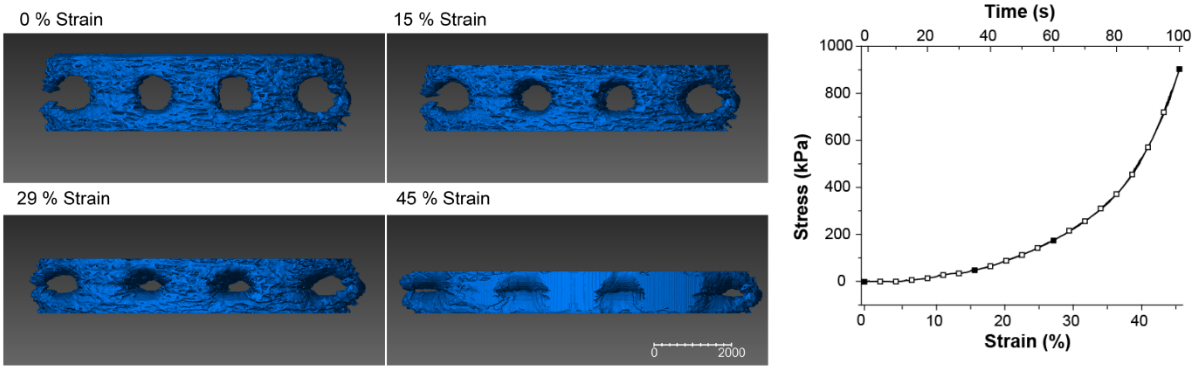

Figure 1. (Left) Micro-scale X-ray CT tomograms (as volume renderings) of an AM polymer foam under uniaxial compressive strains. The scale bar is in micrometers. (Right) Stress-strain curve of the AM polymer foam shown in Figure 1. Data was acquired while the sample was undergoing dynamic uniaxial compression during CT imaging.

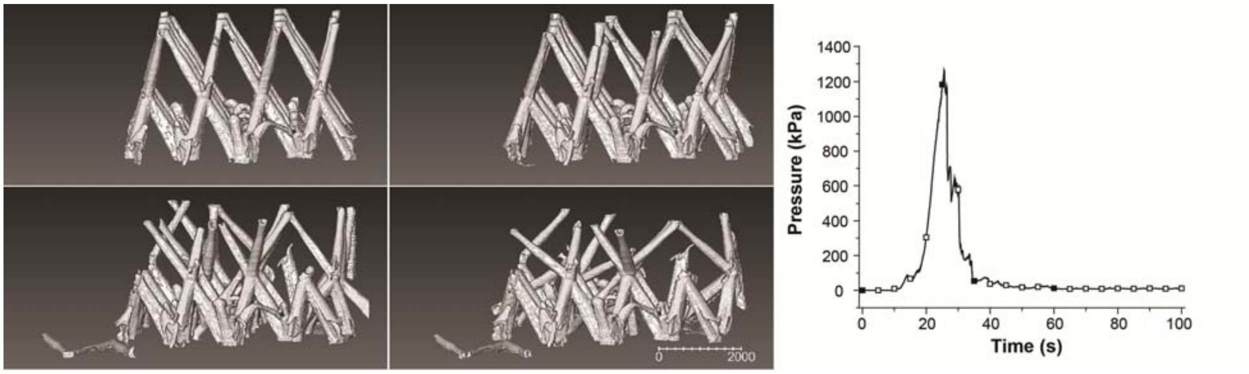

Figure 2. (Left) Micro-scale X-ray CT tomograms (as volume renderings) of a NiP microlattice under uniaxial compressive strains, corresponding to the 1st (top left), 6th (top right), 8th (bottom left) and 13th (bottom right) tomograms. The scale bar is in micrometers. (Right) The stress-time curve of the NiP microlattice, indicating brittle fracture. Black squares correspond to tomograms presented in Fig. 2 (Left). Data was acquired while the sample was undergoing dynamic uniaxial compression during CT imaging.

https://doi.org/10.1017/S1431927615001440