Real-time in-situ X-ray imaging of dynamic shear fracture and spallation in porous metals

José A. Rodríguez-Martínez[1,2]

[1] Department of Continuum Mechanics and Structural Analysis, University Carlos III of Madrid. Avda. de la Universidad, 30. 28911 Leganés, Madrid, Spain
e-mail: jarmarti@ing.uc3m.es

[2]IMDEA Materials Institute, c/Eric Kandel 2, Getafe, 28906, Madrid, Spain
e-mails: joseantonio.rodriguez@imdeamaterials.org

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Recent advances in high-energy X-ray imaging enable real-time, in-situ observation of dynamic deformation and fracture processes in metals subjected to extreme loading. This lecture presents results from impact experiments conducted at the ID19 beamline of the European Synchrotron Radiation Facility, where ultra-high-speed detectors resolve damage evolution over nanosecond to microsecond time scales. The study focuses on additively manufactured Ti6Al4V and AlSi10Mg specimens with controlled porosity, exhibiting void volume fractions from 0.04 % to 0.77 % and broad pore size distributions spanning a few micrometers to more than 180 μm. Dynamic shear fracture is investigated through impact loading of shear–compression specimens in Split Hopkinson Pressure Bar experiments, while spallation is examined through planar plate impact tests performed with a single-stage helium-driven gas gun. These two complementary loading configurations allow the influence of porosity on shear- and tension-dominated failure regimes to be explored within a consistent experimental framework and a wide range of loading rates. Time-resolved radiographic measurements provide direct insight into porosity evolution during dynamic deformation and the formation of shear bands and spall planes. These in-situ observations are complemented by extensive post-mortem X-ray computed tomography, enabling the contribution of individual voids to shear fracture and spallation to be identified. Together, the measurements clarify the interplay between pore collapse, void growth, strain localization, and crack initiation, and distinguish damage mechanisms governed by pre-existing pores from those associated with sub-resolution or dynamically nucleated defects. The lecture concludes with a brief outlook on current limitations and future directions, including three-dimensional time-resolved tomography, higher repetition rates, and tighter integration with physics-based modeling approaches.

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