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Additive manufacturing inspired machine learning and synchrotron experiments: Diffraction and dynamic X-ray radiography

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Optical and SEM characterization of powders used in additively manufacturing (AM) reveals a variety of morphologies and size distributions. Computer vision (CV), as a subset of machine learning, has been successfully applied to classify different microstructures, including powders. The power of CV is further demonstrated by application to detecting and classifying defects in the spreading in powder bed machines, where the defects often correspond to deficiencies in the printed part. Synchrotron-based 3D X-ray computed microtomography was performed at the Advanced Photon Source on AM samples of Ti-6Al-4V using both laser (SLM) and electron beam (EBM) powder bed; Inconel 718 and Al-10Si-1Mg from SLM were also characterized. In addition to the printed material, a wide range of powders were measured and invariably exhibited porosity to varying degrees. Outside of incomplete melting and keyholing, porosity in printed parts is inherited from pores or bubbles in the powder. This explanation is reinforced by evidence from simulation and from dynamic x-ray radiography (DXR), also conducted at the APS. DXR has revealed entrapment of voids (from powder particles) in melt pools, keyholes (i.e., vapor holes) and hot cracking. Keyhole depth is linearly related to the excess power over a vaporization threshold. Concurrent diffraction provides information on solidification and phase transformation in, e.g., Ti-6Al-4V. High Energy (x-ray) Diffraction Microscopy (HEDM) experiments are also described that provide data on 3D microstructure and local elastic strain in 3D printed materials, including Ti-6Al-4V and Ti-7Al. The reconstruction of 3D microstructure in Ti-6Al-4V is challenging because of the fine, two-phase lamellar microstructure and the residual stress in the as-built condition. Both the majority hexagonal phase and the minority bcc phase were reconstructed.

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