Quantifying microscale drivers for fatigue failure via coupled synchrotron X-ray characterization and simulations

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During cyclic loading, localization of intragranular deformation due to crystallographic slip acts as a precursor for crack initiation, often at coherent twin boundaries. A suite of high-resolution synchrotron X-ray characterizations, coupled with a 3D crystal plasticity simulation, was conducted on a polycrystalline nickel-based superalloy microstructure near a parent-twin boundary in order to understand the deformation localization behavior of this critical, 3D microstructural configuration. Dark-field X-ray microcopy was spatially linked to high energy X-ray diffraction microscopy and X-ray diffraction contrast tomography in order to quantify, with cutting-edge resolution, intragranular misorientation and high elastic strain gradients near a twin boundary. These observations quantify the extreme, sub-grain scale micromechanical gradients present in polycrystalline microstructures, which often lead to fatigue failure, and displays the need for future research to investigate physical phenomena via 3D characterizations.