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Multiscale in situ laminography for damage and 3D strain field analysis in alloy sheets under low stress triaxiality and non-proportional loading

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Abstract

Mechanical loading experiments on flat sheet materials allow the investigation of a broad range of stress triaxialities, also varied here during non-proportional loading, which is highly relevant for understanding fracture mechanisms under engineering-relevant conditions [1–3]. While their non-cylindrical shape of such specimen is not suited for conventional computed tomography, X-ray computed laminography (CL) [3] has proven to be a unique and powerful tool for their non-destructive 3D characterization. CL provides high and laterally isotropic resolution without the need for sample dissection, which is crucial for such in situ studies. We present KIT's complementary synchrotron CL instrumentation portfolio: for microscale studies, LAMINO-I at ID19 / ESRF and LAMINO-II at the KIT light source; for nanoscale studies, our mobile setup at ID16b / ESRF [1] and the Hierarchical Imaging Karlsruhe station at PETRA III / DESY. We give an overview of the complementary capabilities of these stations and highlight recent developments, including integration of new loading devices, correlative surface microscopy for macroscopic deformation measurements via digital image correlation (DIC). Further, we introduce so-called

projection digital image correlation (P-DIC), which enables efficient and robust two- and three-dimensional strain measurements in bulk materials with low natural marker density. P-DIC is based on two-dimensional DIC applied to projected three-dimensional data. We systematically investigate its performance and demonstrate distinct advantages over conventional digital volume correlation (DVC) using the SPAM software framework [4]. Furthermore, we show the applicability of P-DIC to different loading scenarios, including plane-strain and triaxial loading. Finally, we demonstrate that P-DIC can be used to initialize DVC, resulting in a substantial reduction of computation time. The described methodological and instrumental developments enabled a range of recent studies on ductile fracture mechanisms under shear and non-proportional loading [5–9]. Here, we highlight the investigation of damage mechanisms under non-proportional loading by studying load-path change experiments from shear to tension [2] and from tension to shear [9]. In these experiments, we observe particle-induced damage and grain-related damage features, where the latter drives the failure of the specimens and will be focused on in this talk. To obtain an understanding of the origin and consequences of the grain-related damage, we characterize strain using P-DIC and employ nanoscale computed laminography in combination with complementary electron backscatter diffraction (EBSD) to study grain related damage mechanisms in shear [8].

Keywords:

computed tomography computed laminography ductile fracture shear damage mechanisms void growth

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