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High Magnification Surface Topography based Digital Image Correlation (DIC) for Identifying Damage Accumulation and Crack Growth in Polycrystalline Nickel

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Abstract

Damage index parameters that have been formulated to identify damage localization in plastically deformed materials typically require all six stress or strain components. Recently, simulations through Crystal Plasticity Finite Element Method (CPFEM) have been widely used to extract damage initiation parameters. However, these models are rarely verified due to the challenges in measuring the out of plane deformation/strain experimentally. A damage index combining the effective plastic strain and surface roughness change is investigated for identifying damage accumulation sites and predicting crack propagation path in polycrystalline pure Nickel. A Digital Image Correlation (DIC) technique is developed to measure both the effective plastic strain and the out-of-plane deformation from surface topography images acquired at different load levels. A simple technique that creates random, micro size reflective speckles for sub-grain strain calculation is demonstrated. Damage accumulation sites detected by the effective strain, surface roughness change, and the combined damage index are assessed in terms of damage localization and localization consistency. The combined damage index provides an enhanced damage localization and localization consistency. The detected damage accumulation sites were correlated with grain orientations that favor "sunken" out-of-plane deformations and large misorientations among neighboring grains. The proposed combined damage index is then used to predict the future propagation path of microstructurally small crack (MSC) in a fatigue sample. Effective plastic strain, surface roughness and combined damage index maps were constructed during the crack arresting time. The crack future propagation path was then constructed by two approaches based on 'highest intensity' and 'confidence threshold'. The predicted path by the three damage indices was compared to the actual crack path. The combined damage index provided a more accurate, consistent, and confident prediction of sharp turns/bends in crack tortuous path. Finally, using the proposed surface topography based DIC, a preliminary study of the feasibility of calculating out-of-plane shear strain from the surface displacement was carried out. For this purpose, a finite element model with surface roughness was generated to study the minimum surface height required for the out-of-plane shear strain estimation.