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EARLY PREDICTION OF PLASTIC STRAIN LOCALIZATION FROM OBSERVATION OF MESOSCALE SURFACE ROUGHENING

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The experimental and numerical investigations are performed to reveal a correlation between mesoscale surface roughness and local plastic deformation in titanium specimens under uniaxial tension. The evolution of surface profiles is experimentally studied in selected regions of the specimens in a wide range of strains. A dimensionless parameter is introduced to quantify mesoscale roughness patterns. Unlike the conventional methods of roughness estimation, the analysis is performed for unfiltered profiles in order to take into account the deformation mechanisms operative throughout all length scales falling within the profile evaluation length. Based on the experimental data, a 3D polycrystalline model is constructed and implemented in crystal plasticity finite-element simulations. The experimental and numerical results show a series of multiscale surface undulations, characterized by different amplitudes and frequencies, developing in the course of tensile deformation of the material on its free surface. Roughening is observed to intensify on a larger scale when smaller length scale deformation mechanisms are exhausted. The mesoscale dimensionless roughness parameter calculated for unfiltered profiles is shown to be fairly sensitive to and well correlated with the local strains of the regions under study. Particularly, in the specimen subsections, where a macroscopic neck is formed in the pre-fracture loading stage, the mesoscale roughness begins to increase nonlinearly well ahead of the visible plastic strain localization, while in the other regions of interest it ceases to increase at all. The results obtained support the assumption that the mesoscale roughness can be successfully used for predicting plastic strain localization and fracture far in advance of these processes becoming apparent on the macroscale.

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