Coupled Experimental-Numerical Analysis of Strain Partitioning in Metallic Microstructures: The Importance of Considering the 3D Morphology

M. Diehl[a], D. Yan[1], L. Morsdorf, D. An, C.C. Tasan[2], S. Zaefferer, F. Roters, D. Raabe

Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Str. 1, 40237 Düsseldorf, Germany; [1]now at Chinese Academy of Sciences, Institute of Mechanics, No.15 Beisihuanxi Road, Beijing, China; [2]now at Massachusetts Institute of Technology, Department of Materials Science and Engineering, 77 Massachusetts Ave., Cambridge, Massachusetts, 02139, USA

[a]m.diehl@mpie.de

Abstract. A coupled experimental-numerical approach is used to investigate the strain partitioning in high-strength steel microstructures. The comparison between calculated and measured strain fields reveals significant deviations in some regions of the microstructure; These deviations can be explained by the missing subsurface microstructure in the simulated microstructure. Therefore, the effects of the subsurface microstructure on strain partitioning in a 2D region of interest is systematically evaluated. The results clearly show that for both, experimental analyses and numerical investigations, the consideration of the full 3D morphology is of utmost importance.

Introduction

Understanding how the microstructure affects the local strain and stress distribution in metallic materials is of high importance for the development of improved strong yet damage tolerant engineering alloys. Digital image correlation (DIC) techniques allow investigating the strain partitioning in metallic microstructures during deformation at high spatial resolution. Crystal plasticity modeling based on the measured microstructure can complement such investigations and provide stress fields in addition to the experimentally obtained strain fields.

Experimental Characterization and Numerical Simulations

We present DIC investigations on dual phase (DP) [1,2] and martensitic steel microstructures together with results of corresponding crystal plasticity simulations. Scanning electron microscopy is used to acquire the initial microstructure that lays the basis for the crystal plasticity model [3] as well as the microstructure at subsequent deformation states required for DIC. The comparison between calculated and measured strain fields reveals significant deviations in some regions of the microstructure. Post-mortem investigations on the specimens show that the subsurface microstructure, which is absent in the simulations owing to the confinement to experimental 2D data, can explain these deviations. To confirm these findings and quantify the deviations between a 3D and a corresponding 2D simulation, we calculate the deformation of a 3D microstructure acquired by 3D electron backscatter diffraction (EBSD) [4]. We show that taking the full 3D microstructure into account drastically changes the stress and strain partitioning in comparison to a 2D simulation approach.

Conclusions

Our findings have consequences for both, simulation studies and experimental investigations: When performing simulations, it is imperative to use a 3D model unless micromechanical effects stemming from the microstructure beneath the surface can be excluded or quantified. When analyzing results of 2D DIC measurements, it is infeasible to understand the strain partitioning from the observed 2D microstructure alone.

References

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