The Effect of Nonproportional Loading Paths on Damage and Fracture Mechanisms: Experiments and Numerical Simulations

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ABSTRACT

The presentation deals with experiments and numerical simulations of proportionally and non-proportionally loaded biaxial specimens. The effects of the loading paths on the damage and fracture mechanisms of the aluminum alloy EN-AW 6082 will be investigated. In this context, a thermodynamically consistent continuum damage model is presented. Its kinematics are based on the introduction of damaged and fictitious undamaged configurations [2]. This leads to a damage affected elastic material law. It is well known that plastic flow, damage and fracture are dependent on stress intensity and stress triaxiality [1, 4, 5]. Under tension dominated stress conditions damage in ductile metals is mainly caused by nucleation, growth and coalescence of voids whereas the formation of micro-shear-cracks is the predominant damage mechanism under shear and compression dominated stress states. Therefore, the damage model considers functions for both different damage modes. In addition, the damage behavior depends strongly on the loading path of the material sample [6]. To investigate this effect, a series of experiments with biaxially loaded new cruciform specimens [3] is performed. In former research activities the loading paths and therefore the stress states have been kept constant. In the presented research the loading is applied sequentially and thus the loading ratio and the stress-state-dependent processes change during the biaxial experiments until fracture. The corresponding numerical simulations with an user-defined material routine are presented and its results compared with the experimental data by force-displacement diagrams and with strain fields determined by digital image correlation techniques (DIC). Based on the examination of the fracture surface under a scanning electron microscope (SEM) the different topologies are a clear indication that different micro-level mechanisms are present and distinct from proportional experiments. This different development of stress states is as well apparent in the numerical simulations and provides indications for a path-dependent damage and fracture behavior of ductile metals.

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