

Crack Propagation in poly crystalline materials

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In industrial forming processes metals are subjected to large plastic deformations. Related to the plastic deformation pores will start to grow, merge and finally lead to micro cracks within the material. Macroscopically this is recognized as a loss of stiffness of the structural behavior. This effect is usually modeled in the context of damage mechanics, where in the last fifteen years several theories were established to circumvent the mesh dependent localization. Most of them are based on the introduction of a new degree of freedom for the thermodynamic driving force of the damage. This new degree of freedom is then computed by solving an additional scalar balance equation of Helmholtz type. Nevertheless, if damage evolves and is used to predict macro cracks the global stiffness matrix becomes ill conditioned. Furthermore cracks are just represented in a smeared way and their dimension is related to the mesh size and some artificial internal length parameter. To overcome this drawback the damage is transferred to discrete cracks if it exceeds a material depended threshold value. The representation of fracture is modeled with the eXtended Finite Element Method (XFEM). This numerical tool enables a nearly mesh independent crack representation. The strong discontinuities are modeled by level set functions and the spatial discretization of the displacement field becomes enriched. The enrichment functions are chosen in a way to enable discontinuities in the displacement and even singularities or nearly singularities in derived quantities. Within the XFEM only a local neighborhood of the crack becomes enriched and the overall number of unknowns increases only moderately. Since classical crack propagation criteria loose their validity in a finite deformation context and inelastic material behavior one has to think about new ones. The argumentation for the chosen damage based criterion is that once the crack is initiated it will propagate if the pores around the crack front will continue to coalesce. So the mechanism for crack initiation and propagation is the same. The problem of evolving the front is treated with a purely geometric approach, which preserves the property of perpendicular level sets. After the propagation no remeshing is needed, but the enrichment scheme has to be updated in the vicinity of the crack front. There is also a need for adapting the history variables in these elements. This becomes necessary because the integration points in the new crack front elements are replaced in a way to consider the discontinuous character of the displacements within these elements.

This framework is used in combination with a crystal plasticity model with viscous regularization to predict the evolution of microcracks. The solution path of cracking structures are highly challenging. That's the reason why neither an entirely force driven nor a displacement driven simulation is able to follow the path and an adaptive arc length approach is used which avoids artificial unloading.