From ductile damage to ductile fracture in forming processes

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Introduction

In metal forming processes such as blanking and cutting, the material undergoes large deformations, leading to ductile failure, which is characterized by the formation of voids and the eventual formation of macroscopic cracks. In this research project these phenomena are analyzed from a macroscopic point of view.

Gradient elastoplastic damage model

The behaviour of the homogenized material (voids plus matrix) is obtained by assuming strain equivalence [1] with the elastoplastic matrix. A localization limiter is used to ensure mesh independent results, which leads to a coupled problem [2]. The damage evolution accounts for the fact that ductile failure is triggered by positive triaxiality states and plastic deformation [3].

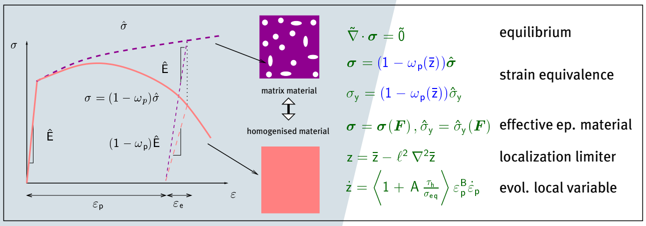

Figure 1 : (left) homogenized damage material and elastoplastic matrix, (right) governing equations.

Simulations on notched bars show that a higher triaxiality, i.e. small notch radius, translates in a smaller ductility. This is in accordance with experiments.

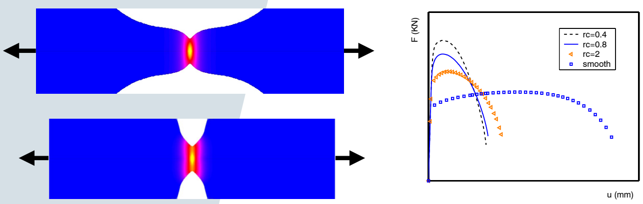

Figure 2 : Tensile test on notched specimens of different radii.

Industrial applications

To model industrial applications, e.g. blanking, the coupled problem, i.e. equilibrium plus nonlocal averaging, is implemented readily in an operator-split (staggered) manner. Adaptive remeshing is used for three purposes: (i) to trace the crack paths, (ii) to prevent large element distortions, (iii) to capture the large gradients in the localisation regions.

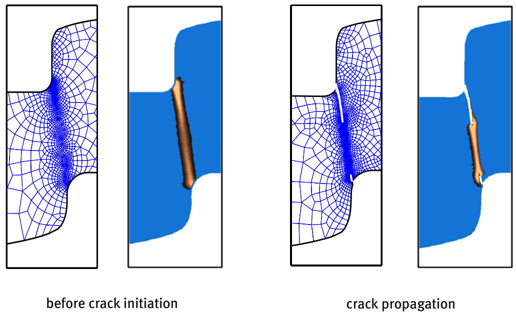

Figure 3 : The element size is distributed according to the damage growth.

Blanking

The numerical simulations are able to reproduce the actual cut profile. Due to damage the transition to the cracked stage is a smooth one.

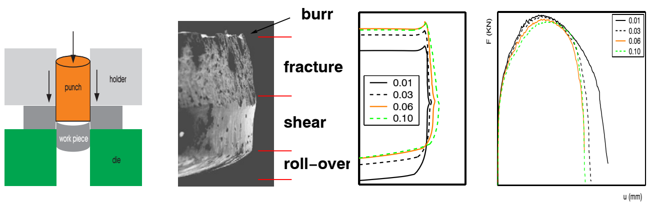

Figure 4 : Blanking. From left to right: (i) setup, (ii) observed cut edge [3], (iii) simulated cut edge, (iv) punch force-displacement response.

Fine blanking

Fine blanking is based on the principle that high hydrostatic pressure improves the material ductility. The resulting profile is much smoother and flatter than with conventional blanking.

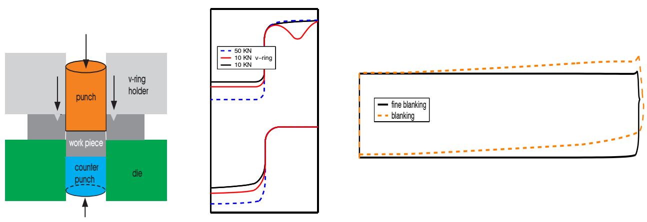

Figure 5 : Fine blanking. From left to right: (i) setup, (ii) profiles at fracture initiation for different pressures, (iii) blanking & fine blanking profiles.

References:

[1] J. Lemaitre: *A Course on Damage Mechanics, Ed. Springer. 1992*

[2] M.G.D. Geers: *Finite strain logarithmic hyperelato-plasticity with softening: a strongly nonlocal implicit gradient framework, Computer Methods in Applied Mechanics and Engineering, 193. 2004*

[3] A.M. Goijaerts: *Prediction of Ductile Fracture in Metal Blanking, PhD thesis, Eindhoven, University of Technology, 2003*

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