A three dimensional modeling of ductile damage

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A Three dimensional modeling of ductile damage

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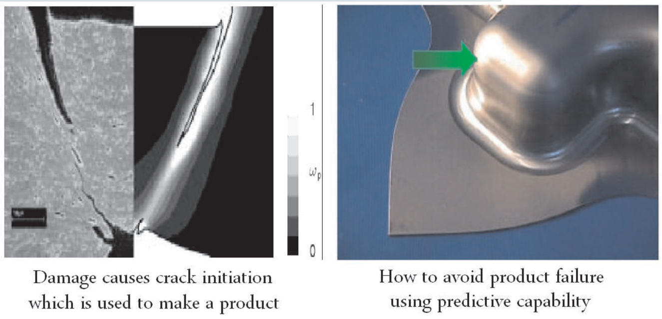
Introduction

Damage in metals, in addition to its negative influence (as the name indicates!), has also a positive side which should be controlled. It has been observed that ductile damage and fracture (crack initiation and propagation) are the result of initiation, growth and coalescence of micro voids inside the material.



Damage causes crack initiation which is used to make a product

How to avoid product failure using predictive capability

Figure 1 *Different aspects of damage.*

Objective

The main goal of this project is to develop a fully three dimensional computational predictive tool in order to account for relevant microscopic phenomena (studied in parallel projects) in an average way and in relation to macroscopic phenomena such as geometrical and physical softening of the material, crack initiation and propagation and finally complete fracture.

Method

Currently sophisticated algorithms are available to predict crack initiation and propagation in two dimensions. However, these algorithms cannot readily be applied to three-dimensional problems.The methodology followed in this project is that damage (D) will determine the location where a crack initiates and the direction in which it propagates [1]. The damage is modeled by a nonlocal damage model coupled to large-strain plasticity. The growth of damage is governed by a kinematical non-local variable $(\bar{z})$ which is obtained from solving a non-local equation together with equilibrium in a fully coupled way [2]:

$$\bar{z} - \ell^2 \nabla^2 \bar{z} = z \tag{1}$$

$$\vec{\nabla}.\sigma = \vec{0} \tag{2}$$

In equation (1) l is a material dependent length parameter, commonly denoted as internal or intrinsic length scale and z is the local value of the damage driving variable which depends on both plastic strain and stress triaxiality as follows:

$$\dot{z} = \langle 1 + A\frac{T_h}{T_{eq}} \rangle \varepsilon_p^B \dot{\varepsilon_p} \tag{3}$$

With A and B material constants and T_h and T_{eq} hydrostatic and equivalent stress respectively. The yield surface of the virgin material is degraded leading to the modified yield function of the type:

$$\phi(\boldsymbol{\tau}, \varepsilon_p, D) = \tau_{eq} - (1 - D)[\tau_y(\tau_{y0}, \varepsilon_p)] \leq 0 \tag{4}$$

Results

The model outlined above was implemented using three dimensional Hexagonal Brick elements. Hyperelasto-plastic behavior is used for the undamaged material and the model is tested using a tensile test. The force versus displacement curve together with the final damage distribution in the sample is plotted in figure 2. The maximum damage values are at the center of the cylindrical bar.

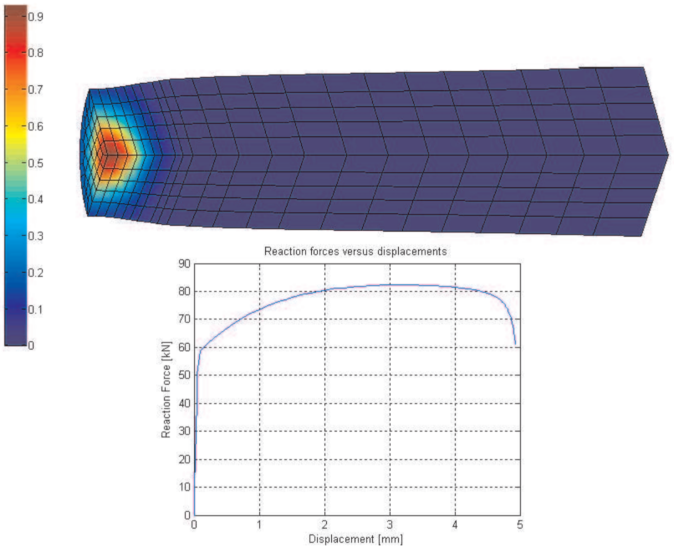


Figure 2 *Softening in cylindrical bar; one eighth of the bar has been modelled.*

Future work

The next step in the project is implementing a solution for the incompressibility problem which occurs in tetrahedral elements. These elements will be used because remeshing which is necessary for crack propagation can be done much easier.

References:

[1] Mediavilla, J.: Continuous and discontinuous modeling of ductile fracture. (Ph.D. thesis, Eindhoven University of Technology, The Netherlands, 2005)

[2] Geers, M.G.D.: Finite strain logarithmic hyperelato-plasticity with softening: a strongly nonlocal implicit gradient framework. (Computer Methods in Applied Mechanics and Engineering, **193**, 3377-3401., 2004)