Numerical modelling of ductile damage

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Introduction

A proper understanding of damage and fracture phenomena gives us the capability to:

- Predict metal behavior in extreme loading cases
- Avoid using limited empirical knowledge

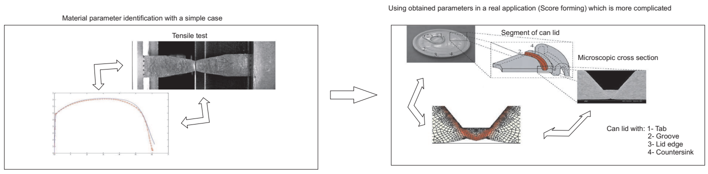

Fig. 1 *Modelling used in an industrial application.*

This understanding consists of:

- Relevant microscopic phenomena (obtained in a parallel project)
- Macroscopic phenomena: geometrical and physical softening of the material, crack initiation and propagation and finally complete fracture

Objective

This project aims to develop fully three dimensional computational predictive tools for damage and crack propagation.

Methods

The remeshing step in the crack propagation framework requires a tetrahedral element, which compared to a hexagonal element, can more easily deal with complex 3D shapes. A version of this element which does not show plastic locking has been developed for large-strain elasto-plastic analyses coupled with damage.

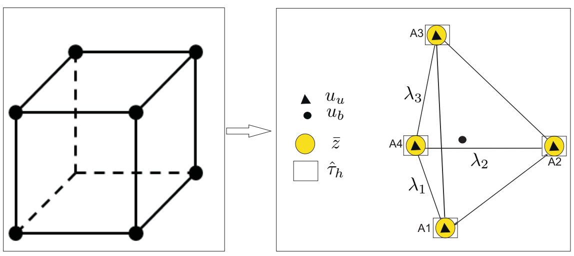

Fig. 2 *Tetrahedral elements instead of hexagonal.*

The methodology used here is that in order to solve the final strong form

$$\vec{\nabla}\cdot[(\tau^h\mathbf{I}+\boldsymbol{\tau}^d)\frac{1}{J}] = \vec{0} \quad (1)$$

$$\hat{\tau}^h = \frac{1}{2}K\mathbf{I}:\ln\mathbf{b}_e \quad (2)$$

$$\bar{z}-\ell^2\nabla^2\bar{z} = z \quad (3)$$

the standard displacement field is enriched by an additional displacement field called bubble displacement:

$$\vec{u} = \vec{u}_u + \vec{u}_b \quad (4)$$

The bubble displacement ($\vec{u}_b$) is defined at the element level, which makes it possible to do static condensation. In addition, as shown in the strong form of the governing equations, the stress is decomposed into its hydrostatic and deviatoric part:

$$\boldsymbol{\tau} = \tau^h\boldsymbol{I} + \boldsymbol{\tau}^d \quad (5)$$

Therefore, in addition to the displacement field ($\vec{u}_u$) we also have hydrostatic stress (τ^h) and the non-local damage driving variable ($\bar{z}$) as primary unknowns, which makes it a three field implementation.

Results

A benchmark problem (Cook's membrane) was used to study the performance of the element. It is a tapered plate clamped at one of its sides, with a transversal distributed load applied to the opposite side - see Figure 3. This figure shows that the force versus displacement curve obtained using the new element in a coarse mesh is much closer to the refined meshes using the standard formulation and thus does not show a pathologically stiff behaviour.

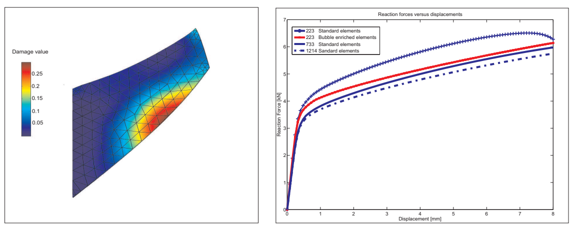

Fig. 3 *Force versus displacement of the standard and new element while using different mesh refinement.*

Conclusions

The results obtained from the element performance in benchmark problem shows the superiority of this element over the standard elements in dealing with incompressibility.

References:

[1] J. Mediavilla, R. H. J. Peerlings, M. G. D. Geers : *A nonlocal triaxiality-dependent ductile damage model for finite strain plasticity* (Computer Methods in Applied Mechanics and Engineering, 2006, 195, 4617-4634.)