3DFRAC - 3D numerical modeling of ductile fracture

Cifre TRANSVALOR

Research Laboratory: CEMEF (Mines ParisTech)

Context & Objectives

Transvalor is a software engineering company developing products dedicated to material forming processes applications. The main product FORGE® is a finite element software that enables to model material behavior under large plastic strain and complex loading conditions representative of forming processes. FORGE® is a leading software in this field with more than 350 users worlwide in various sectors of the mechanical industry's including automotive, aerospace and energy industry.

In most forming processes, it is essential to predict and avoid the initiation of defects during material forming. Such predictions require appropriate material behavior law and ductile damage models, already availables in FORGE® [1-3]. However, in some cases, the **modeling of failure** is essential and an accurate and robust numerical technique is necessary to predict correct failure surfaces (blanking and fine blanking processes, machining …).

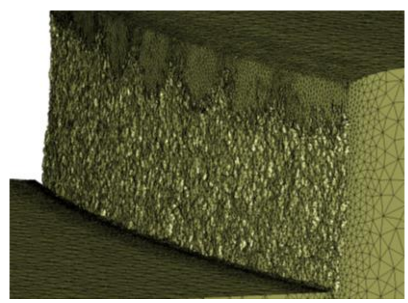

Figure 1 Rough fracture surface obtained during blanking simulation using the kill-

Nowadays, the modeling of fracture in the finite element (FE) software Forge® is based on the so-called "kill-element" technique. This technique consists in deleting elements from the mesh once a user-defined damage variable reaches a threshold. The kill-element technique is both easy to use and robust, but it also has some limitations. Its main limitation relies on its inherent mesh dependency. Once the threshold reached in an element, the element is entirely and instantaneously deleted from the mesh, which makes the control of fracture energy very difficult. The accuracy of the failure surface also depends significantly on the mesh refinement in the damaged area. In addition, this approach gives raise to volume loss and the prediction of an accurate fracture surface is impossible (See Fig. 1). It is therefore necessary to improve the way fracture is modeled in a 3D environment and within the context of metal forming applications. To reach this goal, TRANSVALOR has hired a Cifre PhD student in order to collaborate with CEMEF for its scientific supervision.

CEMEF (Center for Material Forming Processes) MinesParisTech has a strong expertise in the numerical modeling of material forming processes (in particular in FORGE®) and a long experience in the study and the modeling of ductile damage [1-3] and fracture with advanced use of automatic remeshing techniques [4, 7-10].

The aim of this PhD is the modeling of 3D ductile fracture in the FE software FORGE®. This requires the development of new numerical techniques to model surface discontinuities and automatic crack propagation in a robust environment.

Work program

In order to address the objectives mentioned above, the scientific program is the following:

- **Improved kill-element technique**

This first axis consists in improving the actual kill element technique by the use of an error estimator based both on damage and damage gradient fields in order to generate an anisotropic mesh with extreme refinement perpendicular to the failure plane. Such technique enables less volume loss during kill-element and induces smoother fracture surfaces [4]. A smoothing technique could be added afterwards in order to improve surfaces smoothness if necessary.

- **Damage to fracture transition and crack initiation**

Many studies were conducted in the past to predict ductile fracture in FORGE® [1-3]. Ductile damage models of failure criteria define a damage variable that grows and give raise to failure initiation once a threshold is reached. This damage analysis is based on continuous mechanics and the transition to discontinuous fracture is addressed here. In particular, the insertion of a discontinuity, representing the crack surfaces, is handled in a full 3D parallel environment based on continuous damage fields [5, 6].

- **3D Crack propagation**

Once initiated, 3D crack propagation is addressed with two main challenges: (i) prediction of crack path based on damage fields and (ii) development of advanced remeshing techniques to propagate cracks in the 3D mesh [6-8]. The idea is to define fracture surfaces by Level-Set functions and to enhance a recently developed body-fitted mesh adaptation technique [9,10] to handle 3D crack propagation in a robust way.

The PhD student benefits from lectures in materials science, non-linear solid mechanics, damage and fracture. These competences provide opportunities to develop future activities in various R&D sectors in energy, transport and metallurgical industries.

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