

Reliable and efficient simulation of ductile rupture over long distances

Amar EL OUAZANI TUHAMI

(2018 – 2021)

Industrial Partner: TRANSVALOR

Supervisors: BESSON Jacques, Stéphane QUILICI, Sylvia FELD-PAYET

- Ductile rupture,
- Numerical simulation,
- cracking

Abstract:

The prediction of crack resistance is essential to guarantee the safety of industrial installations (nuclear reactors, pipelines, ...), means of transport (airplanes, automobiles, rockets, etc.). Fine fracture analysis is also required for forming processes such as folding or cutting. Nowadays, the design methods are based essentially on "global" approaches that assume the existence of a crack and use quantities from the non-linear mechanics of the fracture. However, these methods are limited when used in analyzing complex situations: crack initiation, non-proportional loading, heterogeneous zones such as welds, etc.

To overcome these difficulties, many behavior models that takes into account the physical mechanisms of degradation have been developed. However, their implementation in structure computations remains problematic. The main difficulties are: (i) a pathological dependence on the mesh (size, type, orientation), (ii) a volume locking linked to the large plastic deformations, (iii) the need to use a very fine mesh on the crack path. It is this last point which will be treated during this thesis. The first two points have been the subject of previous works [1,4].

The main purpose of the thesis is to propose a strategy of crack propagation simulations over long distances (10 to 100cm) while keeping a reasonable problem size (i.e. less degrees of freedom). It must be adapted to the context of major transformations. We will use well known behavior models [3]. The use of internal length models will make it possible to overcome the mesh dependence and to simulate non-trivial cracking paths (e.g., change of direction or plane-bevel crossing). From the continuous fields provided by these regularized models, a technique recently developed at ONERA will be used to determine the orientation of the crack increment to be inserted by remeshing [2]. A hard point of this thesis will be the determination of the insertion moment. Indeed, from a physical point of view, it is necessary to check the conservation of energy before and after insertion. On the other hand, from a numerical point of view, it would be advisable not to remesh the damaged zone too often (important cost of fields transfer, risk of introducing error when transferring fields with strong gradients). A compromise will have to be found. Ahead of the crack tip, a finely meshed zone will be introduced to represent the new PZ. On the other hand, the broken zone can be unrefined. However, to avoid affecting the calculation, the smoothing of gradients should be far enough of the crack tip. An existing experimental base (X65 pipeline steel) will be used for the applications and will notably allow the verification of crack propagation speeds.

1. Feld-Payet, S. and Feyel, F. and Besson, J., Finite element analysis of damage in ductile structures using a nonlocal model combined with a three-field formulation, *Int. J. Damage Mech.*, 20, 655-680 (2011).
2. S. Feld-Payet, V. Chiaruttini, J. Besson, F. Feyel, A new marching ridges algorithm for crack path tracking in regularized ductile media, *Int. J. Solids Struct.*, 71, 57-69 (2015) .
3. Besson J., Continuum models of ductile fracture : a review, *Int. J. Damage Mech.*, 19, 3-52 (2010) .
4. Bargellini R., Besson J., Lorentz E. and Michel-Ponnelle S., A nonlocal Finite Element based on volumetric strain gradient: application to ductile fracture, *Comput. Mat. Sci.*, 45 [3] 762-767 (2009).
5. Y. Zhang, E. Lorentz, J. Besson, Ductile damage modelling with locking-free regularized GTN model, to appear in *IJNME*.

DUCTILE FRACTURE OF MY HYPERALLOY

Jean TOTO
(2015 – 2018)

Industrial Partner: Science Corp
Supervisors: E. Einstein, M. Nobody



- Ductile fracture is important
- Model accounting for anisotropy, kinematic hardening and dual phase microstructure
- Application to a new plane

Abstract:

Ibi victu recreati et quiete, postquam abierat timor, vicos opulentos adorti equestrium adventu cohortium, quae casu propinquabant, nec resistere planitie porrecta conati digressi sunt retroque concedentes omne iuventutis robur relictum in sedibus acciverunt.

Unde Rufinus ea tempestate praefectus praetorio ad discrimen trusus est ultimum. ire enim ipse compellebatur ad militem, quem exagitabat inopia simul et feritas, et alioqui coalito more in ordinarias dignitates asperum semper et saevum, ut satisfaceret atque monstraret, quam ob causam annonae convector sit impedita.

Hanc regionem praestitutis celebritati diebus invadere parans dux ante edictus per solitudines Aboraeque amnis herbidas ripas, suorum indicio proditus, qui admissi flagitii metu exagitati ad praesidia descivere Romana. absque ullo egressus effectu deinde tabescebat immobilis.

Sed (saepe enim redeo ad Scipionem, cuius omnis sermo erat de amicitia) querebatur, quod omnibus in rebus homines diligentiores essent; capras et oves quot quisque haberet, dicere posse, amicos quot haberet, non posse dicere et in illis quidem parandis adhibere curam, in amicis eligendis negligentis esse nec habere quasi signa quaedam et notas, quibus eos qui ad amicitias essent idonei, iudicarent. Sunt igitur firmi et stabiles et constantes eligendi; cuius generis est magna penuria. Et iudicare difficile est sane nisi expertum; experiendum autem est in ipsa amicitia. Ita praecurrit amicitia iudicium tollitque experiendi potestatem.