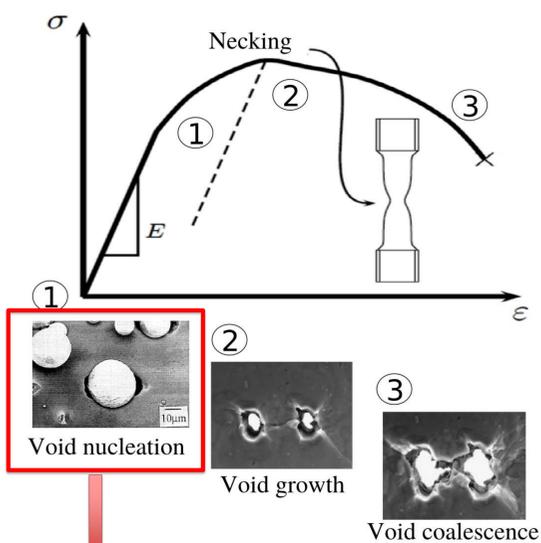


# R&D in code\_aster

## Numerical modelling of ductile tearing with locking-free regularized GTN model in the presence of two populations of inclusions

### CONTEXT

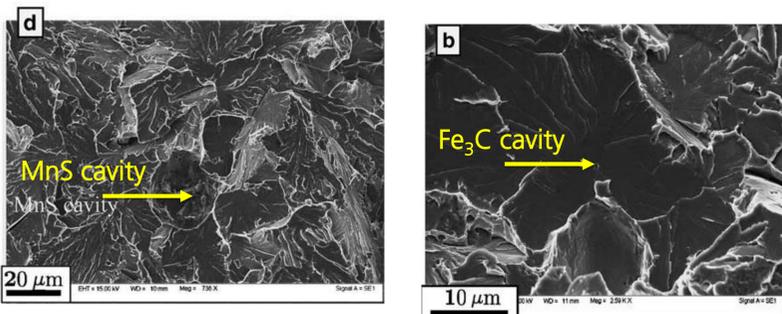
3 main stages of the ductile fracture



Void initiation sites are mainly iron based carbides ( $Fe_3C$ ) and manganese sulfides (MnS) inclusions.

The role of MnS clusters as stress concentrators has been identified and modelled in a number of studies. The role of  $Fe_3C$  in the nucleation of microcavities is still not well understood.

The major goal of this work is to develop a robust modelling strategy for the simulation of ductile damage tearing in the presence of both MnS and  $Fe_3C$ .



Different cleavage triggering sites (B.Tanguy, 2005)

### USING IN CODE\_ASTER

Micromechanically-based non-local GTN model to simulate all three stages of the ductile fracture with nucleation of cavities on two populations of inclusions (MnS and  $Fe_3C$ ):

```

DEFI_MATERIAU(
  ECRO_NL = _F(
    RO = RO,
    RH = Rh,
    R1 = R1,
    GAMMA_1 = b1,
    R2 = R2,
    GAMMA_2 = b2,
  )
  GTN = _F(
    Q1 = q1,
    Q2 = q2,
    PORO_INIT= MnS,
    COAL_PORO = fc,
    PORO_RUPT = fr,
    NUCL_FN = Fe3C,
  )
  NON_LOCAL = _F(
    C_GRAD_VARI = c,
    PENA_LAGR = r,
  )
)

```

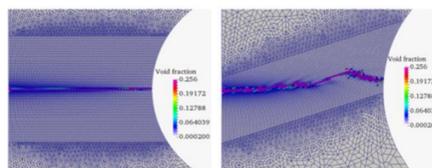
### PHD THESIS



- Y. Zhang - Modélisation et simulation robuste de l'endommagement ductile - Ecole des Mines ParisTech - 2014
- Y. Chen - Modélisation de la rupture ductile par approche locale : simulation robuste de la déchirure - Ecole des Mines ParisTech - 2016-en cours
- A. Amzil - Compréhension et modélisation des mécanismes et des effets de géométrie dans la transition ductile-fragile - Ecole des Mines ParisTech - 2017-en cours

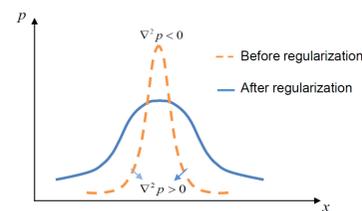
### SCIENTIFIC CHALLENGES

Mesh dependency



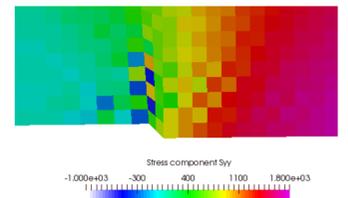
Origin: lack of interaction between neighboring points

Solution: Non-local model with enriched energy



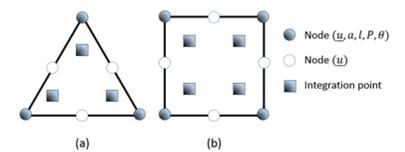
Principle of regularization with gradient of the internal variable  $p$

Volumetric locking



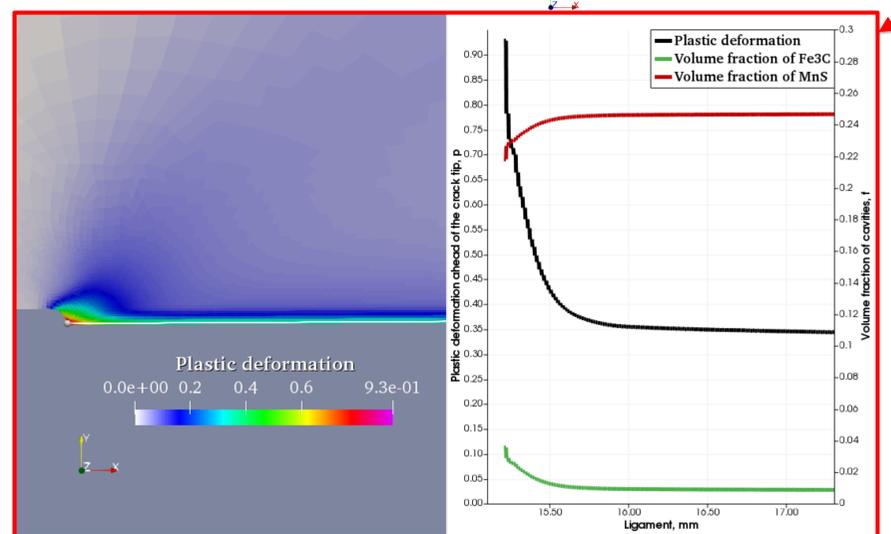
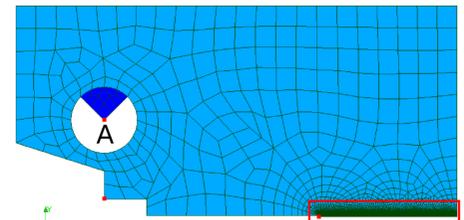
Origin: Discretized space not rich enough to solve all the equations at all Gauss points

Solution: Mixed element enriched with additional fields (volume variation and pressure)



Examples of 5-field elements: (a) triangle element; (b) quadrangle element

### MODEL VALIDATION



### SOME PUBLICATIONS

- A.L. Gurson - *Continuum theory of ductile rupture by void nucleation and growth: part I-yield criteria and flow rules for porous ductile media* - J Eng Mater Technol., 99 (1977), pp. 2-15
- V. Tvergaard, A. Needleman - *Analysis of the cup-cone fracture in a round tensile bar*- Acta Metall., 32 (1984), pp. 157-169
- E. Lorentz, S. Andrieux - *A variational formulation for nonlocal damage models* - Int. J. Plas., 15 (1999), pp. 119-138
- J. Besson - *Continuum models of ductile fracture: a review* - Int J Damage Mech., 19 (2010), pp. 3-52
- Y. Zhang - *Ductile damage modelling with locking-free regularised GTN model* - Int J Numer Methods Eng., 113 (2018), pp. 1871-1903