Collective dynamic damage growth in a quasi-brittle material

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Model and Setup

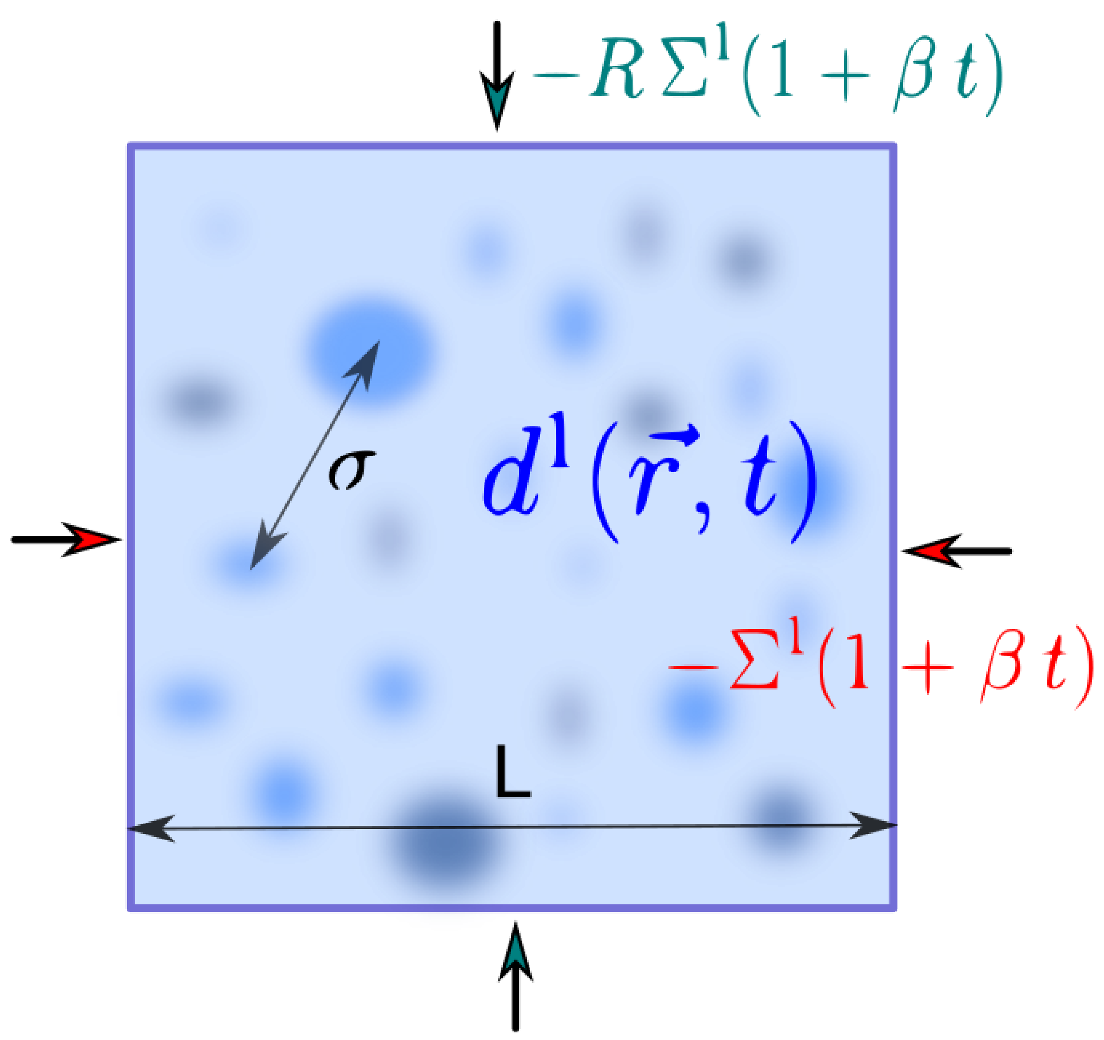
Work based on a quasi-static version of the study published by V. Dansereau et al. [1].

- damage variable d : microcrack density at the mesoscale : $d(\vec{r},t) = d^0(t) + d^1(\vec{r},t)$
- Elastic modulus perturbed by d^1 :

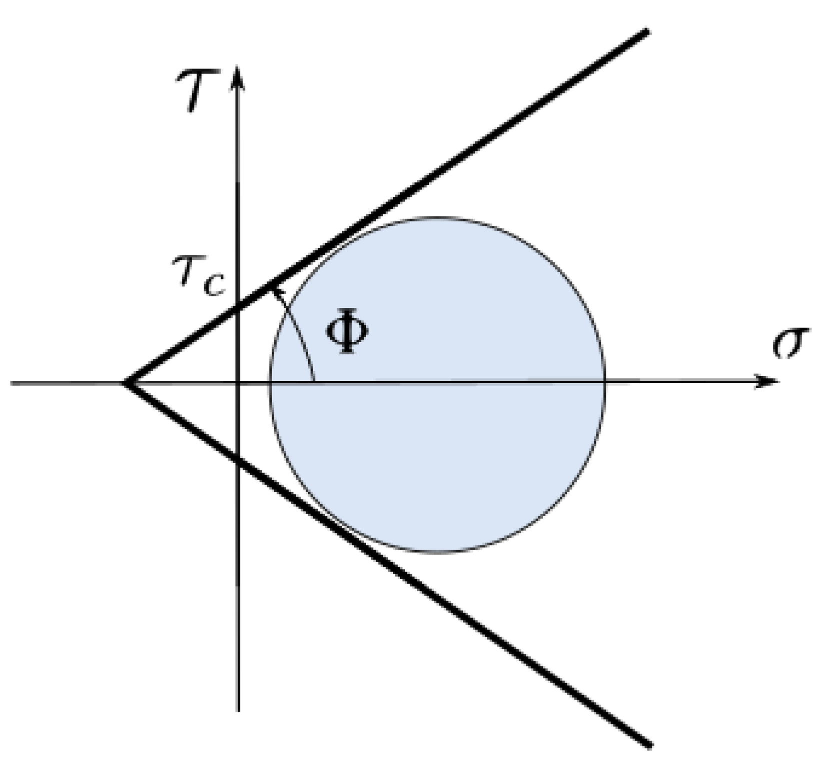
$$\mathbb{C}(\vec{r},t) = \mathbb{C}^0 + \mathbb{C}^1(\vec{r},t)$$

- homogeneous time varying loading : $\underline{\underline{\sigma}}^0(t)$

$$\underline{\underline{\sigma}}^0(t) = -\Sigma^1(1+\beta\, t)\begin{pmatrix}1 & 0\\ 0 & R\end{pmatrix}$$



- Local damage law : cohesive Mohr Coulomb



Damage law

- viscous evolution of the damage variable
- $\mathcal{Y}(\underline{\underline{\sigma}}, \tau_c, \Phi, d)$ driving force : deviation from Mohr Coulomb threshold

$$\alpha\,\frac{d\,d}{dt} = \mathcal{Y}(\underline{\underline{\sigma}}, \tau_c, \Phi, d)$$

Dynamic Stress redistribution

- Emission of a perturbed stress field due to the damage evolution $\underline{\underline{\sigma}}^1(\vec{r},t)$
- memory term

$$\underline{\underline{\sigma}}^1(\vec{r},t) = \int_0^t \underline{\underline{\mathcal{G}}}(\vec{r}-\vec{r'}, t-t', \underline{\underline{\dot{\sigma}}}^0)\, d^1(\vec{r'},t')\, dt'\, d\vec{r'}$$

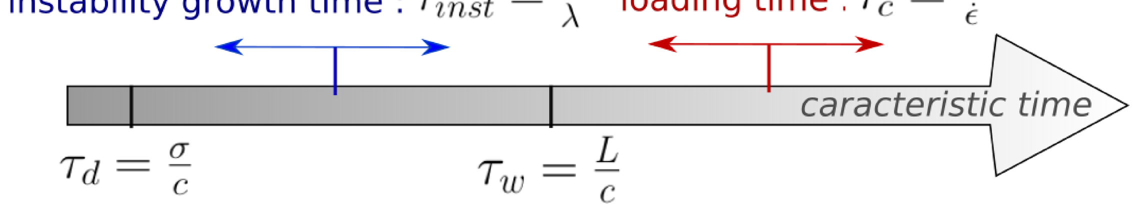
Evolution equation

$$\rho^0\,\frac{\partial^2 \vec{u}^1(\vec{r},t)}{\partial t^2} - \nabla.(\mathbb{C}^0 : \underline{\underline{\epsilon}}^1(\vec{r},t)) = \nabla.(\mathbb{C}^1(\vec{r},t) : \underline{\underline{\epsilon}}^0(t))$$

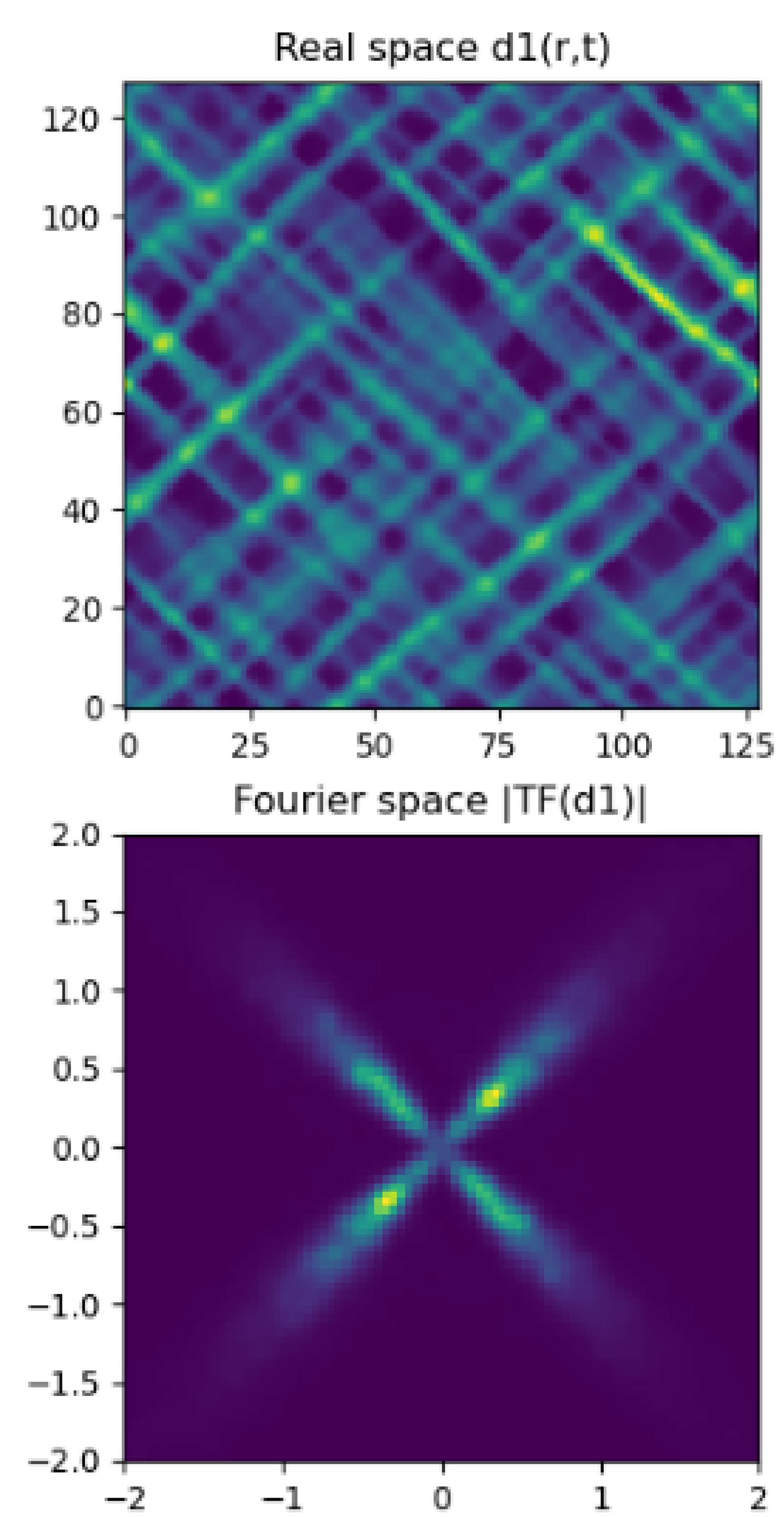
wave equation at (0) order = Source term (damage gradient)

Characteristic times of the system

- loading time $\tau_c = \frac{1}{\dot{\epsilon}}$
- instability growth time $\tau_{inst} = \frac{1}{\lambda}$
- waves travel time across the box $\tau_w = \frac{L}{c}$
- waves travel time across disorder characteristic size $\tau_d = \frac{\sigma}{c}$

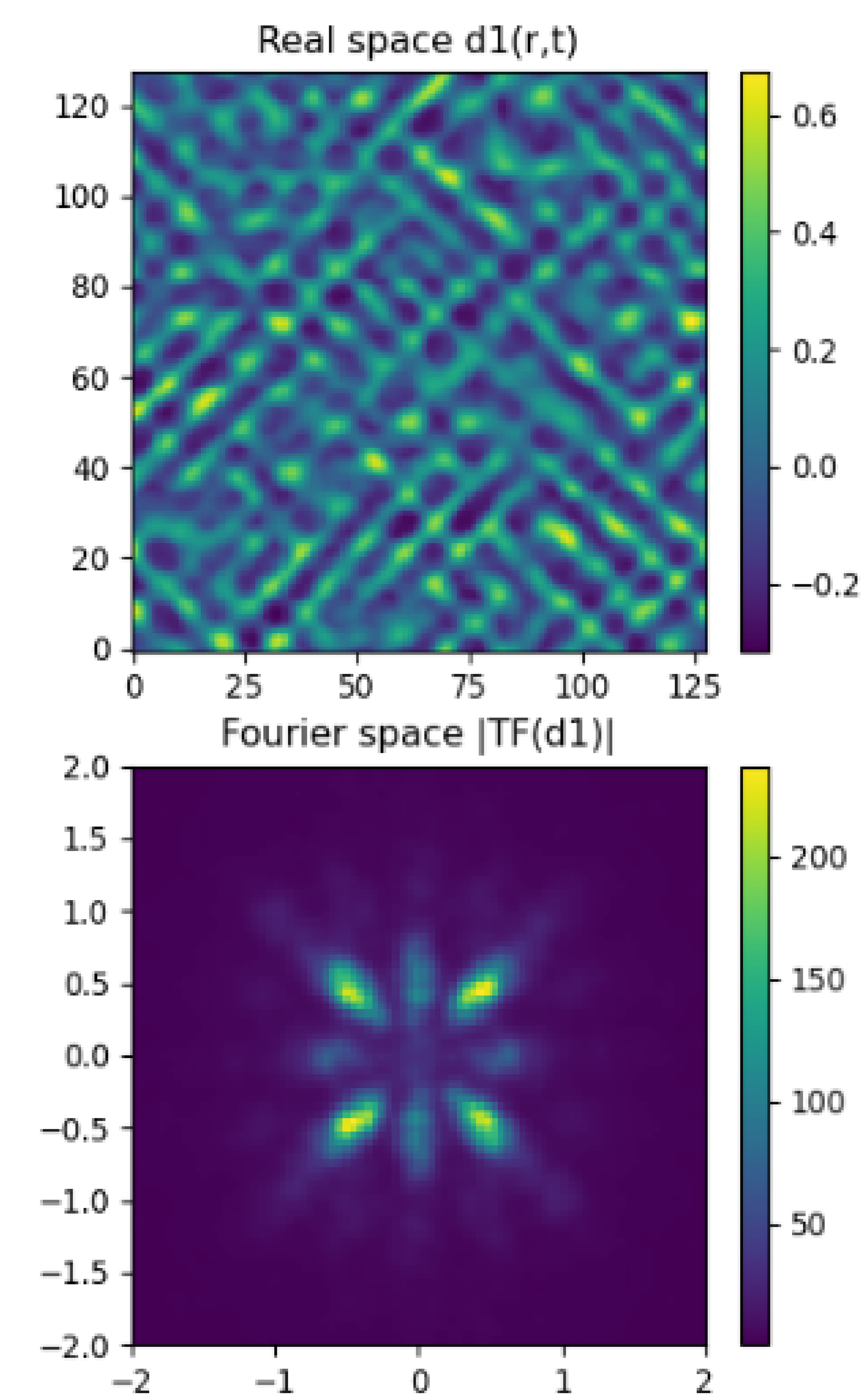


Quasi-Static results



Simulation of the quasi-static kernel, $\Phi = 40°$, $\dot{\epsilon} = 10^{-4}$

Dynamic results



Simulation of the dynamic kernel, $\Phi = 40°$, $\dot{\epsilon} = 10^{5}$

Conclusion and perspectives

- Inertia modify the quasi-static shear band localization
- Characteristic size emerges from the collective behavior

- Parametric study of the different regimes
- Modification of the damage law (inertial terms)
- Comparison with molecular dynamic simulations

References

[1] V. Dansereau, et al.
Collective damage growth controls fault orientation in quasibrittle compressive failure.
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