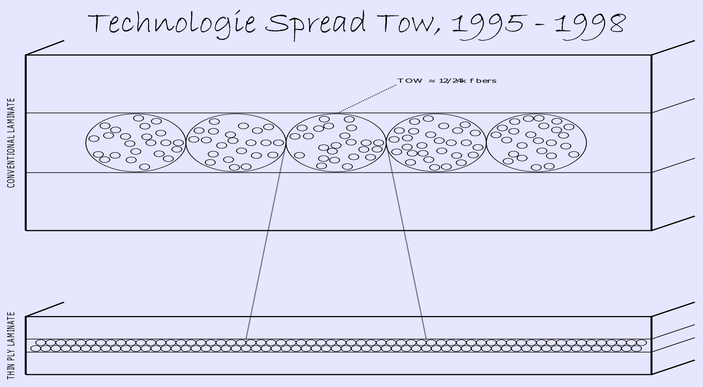
# Modèles micromécaniques du dommage intra-laminaire dans les stratifiés avec couches fines

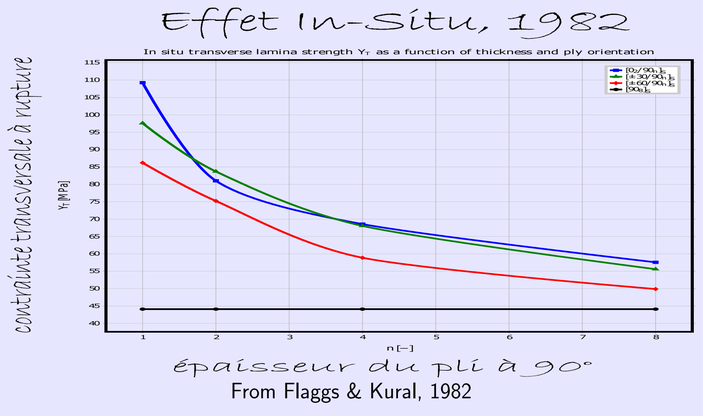
Luca Di Stasio [1,2] Zoubir Ayadi [1] Janis Varna [2]

[1] IJL, EEIGM, Université de Lorraine, Nancy, France

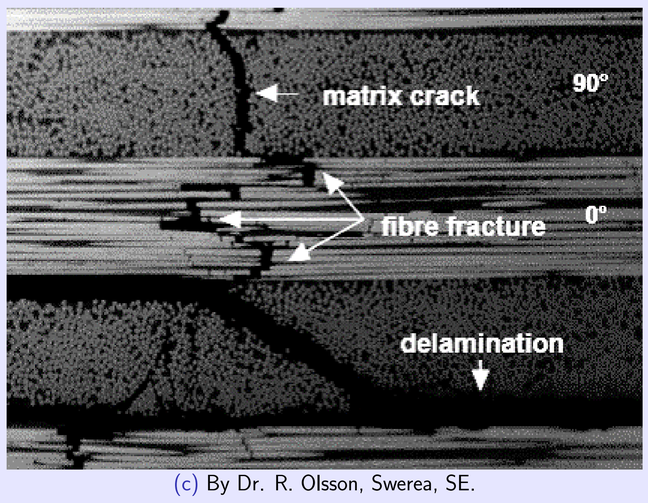
[2] Avdelningen för materialvetenskap, Luleå tekniska universitet, Luleå, Sverige

## Ultra-thin Fiber Reinforced Polymer Composite (FRPC) Laminates: an Introduction

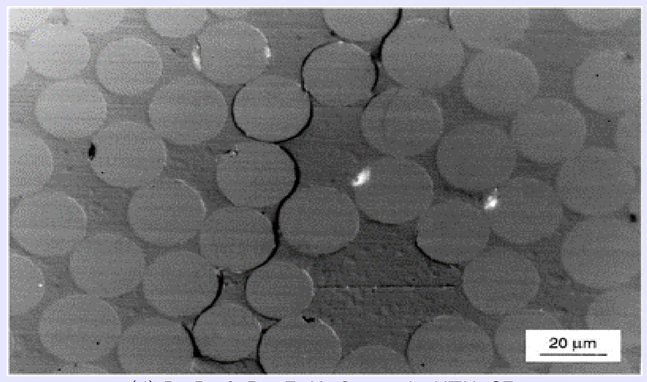




From Flaggs & Kural, 1982




(c) By Dr. R. Olsson, Swerea, SE.




(d) By Prof. Dr. E. K. Gamstedt, KTH, SE.

## Objectifs & Approche

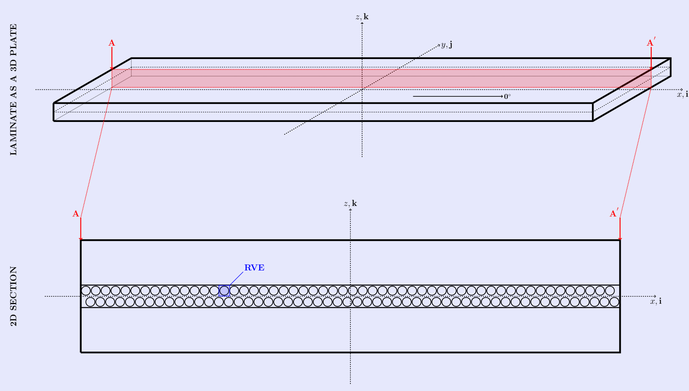
### What do we want to achieve?

- Investigate the influence of volume fraction, material properties, thin ply thickness and bounding plies' thicknesses on crack initiation
- $G_{*c} = G_{*c}\left(\theta_{debond}, \Delta\theta_{debond}, E_{(..)}, \nu_{(..)}, G_{()}, VF_f, t_{ply}, \frac{t_{ply}}{t_{bounding\ \ plies}}\right)$

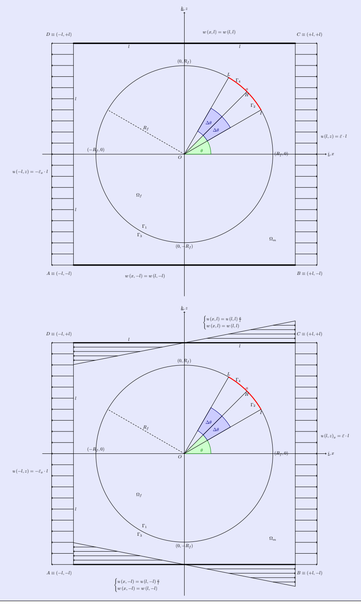
### How do we want to achieve it?

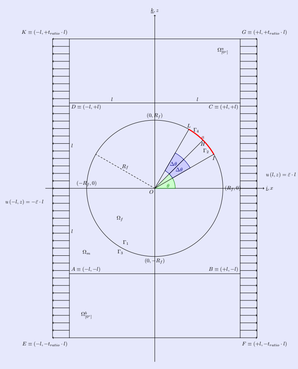
- Design and categorization of several Representative Volume Elements (RVEs)
- Automated generation of RVEs geometry and FEM model
- Finite Element Simulations (in Abaqus)

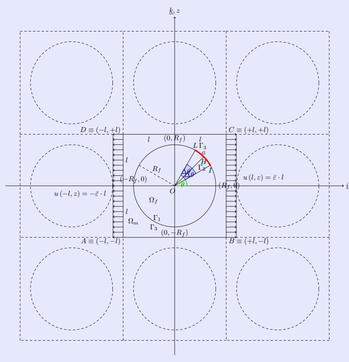
## Conception des modéles de Volumes Élémentaire Représentatif (VER) á l'échelle microscopique

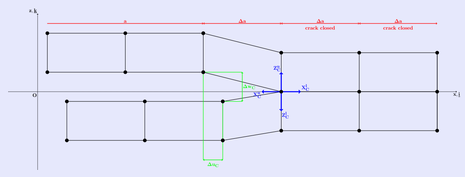



- ✓ 2D space
- ✓ Linear elastic materials
- ✓ Displacement control
- ✓ Dirichlet-type boundary conditions
- ✓ Linear elastic fracture mechanics
- ✓ Contact interaction

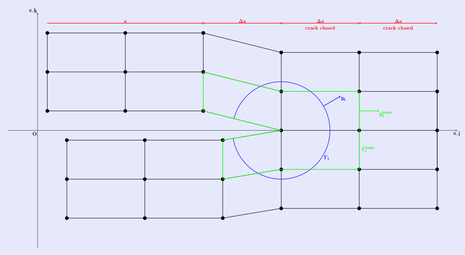






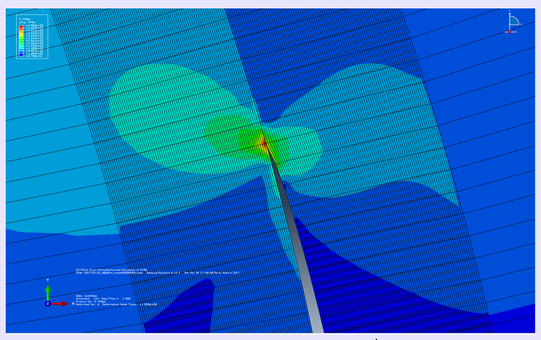


**VCCT:** $G_I = \frac{Z_C \Delta w_C}{2B\Delta a} \quad G_{II} = \frac{X_C \Delta u_C}{2B\Delta a}$

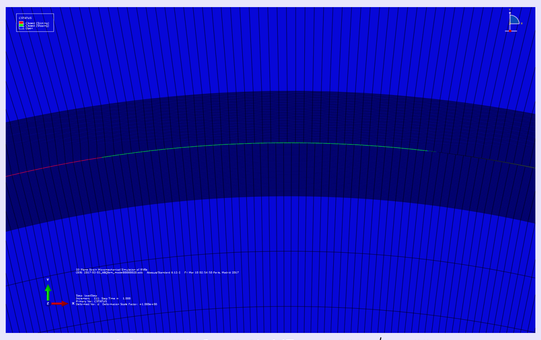


**J-Integral:** $J_i = \lim_{\varepsilon \to 0} \int_{\Gamma_\varepsilon} \left( W(\Gamma)\, n_i - n_j \sigma_{jk} \frac{\partial u_k(\Gamma, x_j)}{\partial x_i} \right) d\Gamma$

## Preliminary Results & Validation

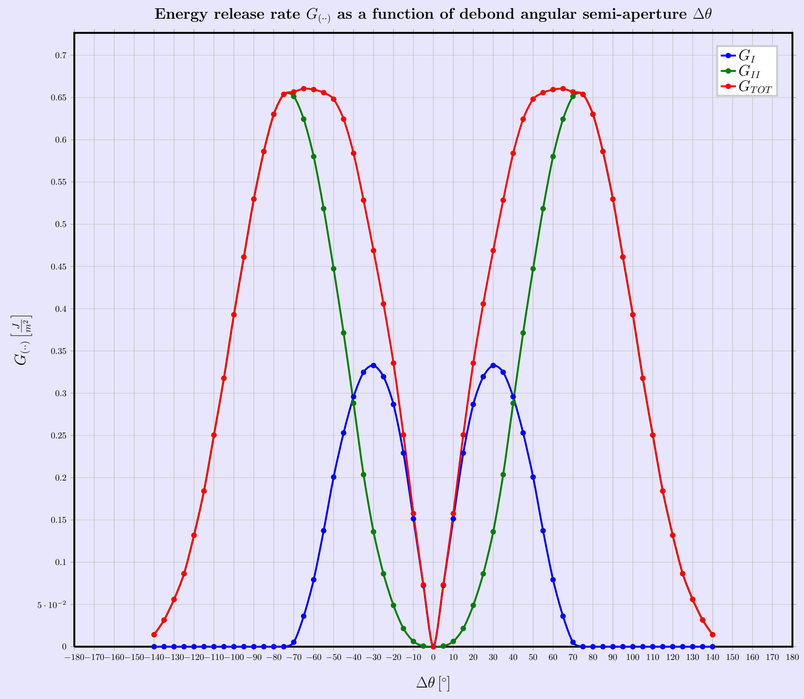


$\Delta\theta = 15°, \delta = 0.4°, VF_f = 0.001, \frac{l}{R_f} \approx 28$



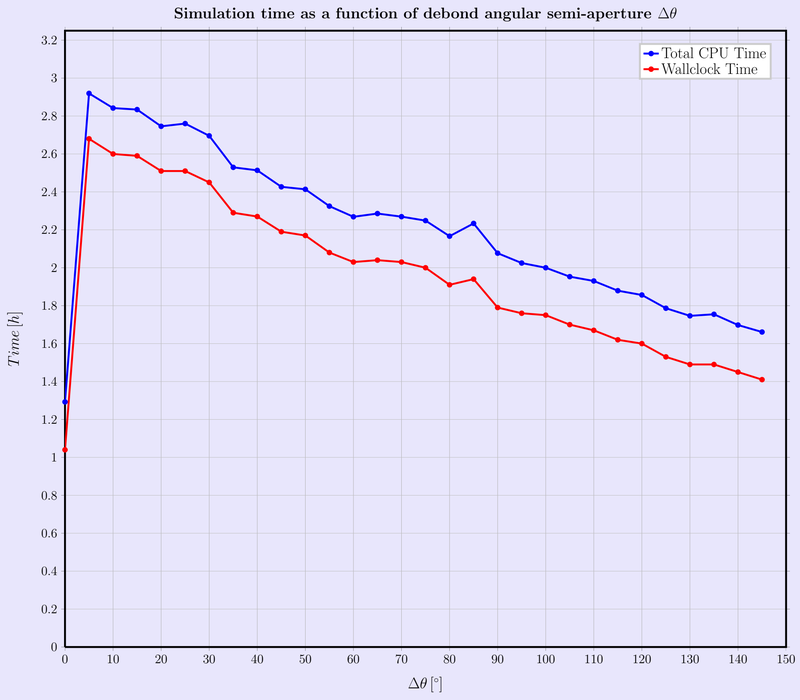
$\Delta\theta = 100°, \delta = 0.4°, VF_f = 0.001, \frac{l}{R_f} \approx 28$

Energy release rate $G_{(..)}$ as a function of debond angular semi-aperture $\Delta\theta$




$\delta = 0.4°, VF_f = 0.001, \frac{l}{R_f} \approx 28$

Simulation time as a function of debond angular semi-aperture $\Delta\theta$




$\delta = 0.4°, VF_f = 0.001, \frac{l}{R_f} \approx 28$

## Remerciements

The support of the European Commission through the Erasmus Mundus Programme is thankfully aknowledged.

## Références

[1] NTPT makes world's thinnest prepeg even thinner. (2017, February 10). Retrieved from http://www.thinplytechnology.com/news-159-ntpta-makes-world-s-thinnest-prepreg-even-thinner
[2] oXeon TECHNOLOGIES. (2017, February 10). Retrieved from http://oxeon.se/technologies/
[3] Donald L. Flaggs, Murat H. Kural; Experimental Determination of the In Situ Transverse Lamina Strength in Graphite/Epoxy Laminates. Journal of Composite Materials, 1982; 16(2).
[4] Toya, M.; A crack along the interface of a circular inclusion embedded in an infinite solid. Journal of the Mechanics and Physics of Solids, 1974; 22(5), pp. 325-348.
[5] París, F., Cano, J., and Varna, J.; The fiber-matrix interface crack - a numerical analysis using boundary elements. Int. J. Fract., 1990; 82(1), pp. 11-29.

**Doctoriales de Lorraine 2018**
15 - 20 avril 2018