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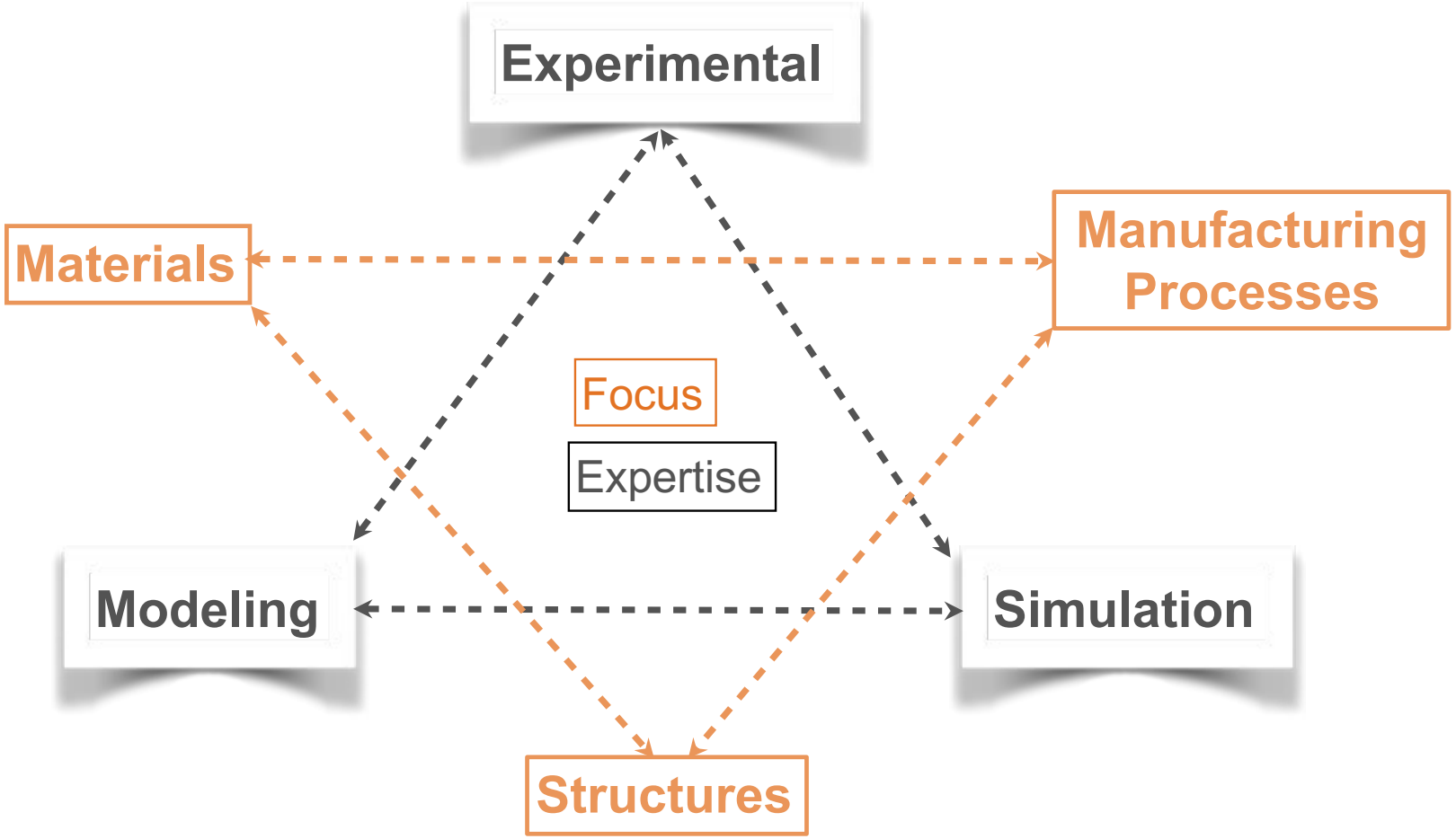
Latest news from the academic research

OUTLINE

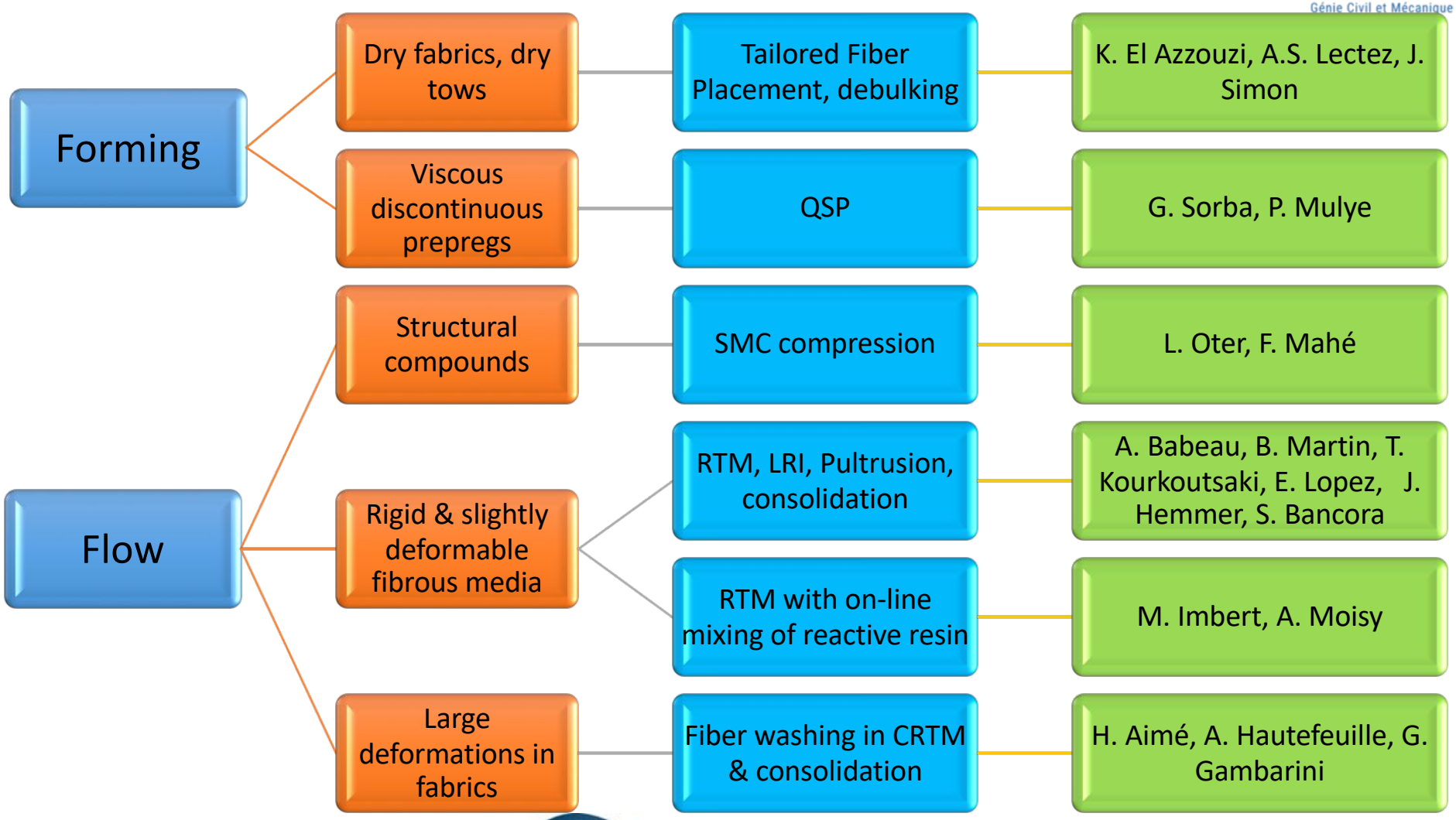
- Institute of Civil Engineering & Mechanics (GeM) at a glance
- Overview of recent research topics addressed in composite processing
- Examples

Research scope @ GeM

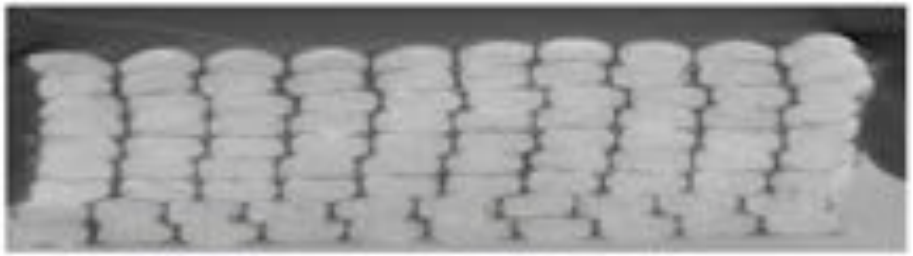
Research scope @ GeM



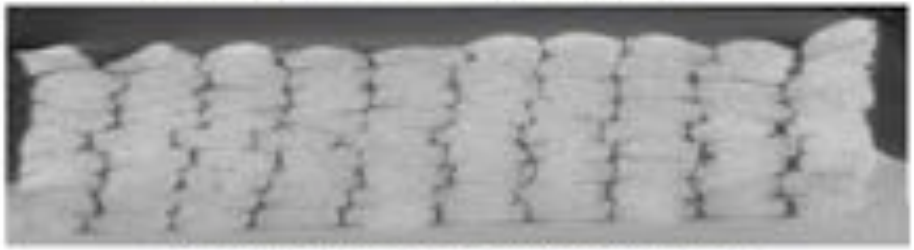
Overview of recent Composite Manufacturing Research Topics



Compaction of dry fabrics : mesoscale modelling



TIGHT STITCH - dry compacted state (60mbar, raw data)



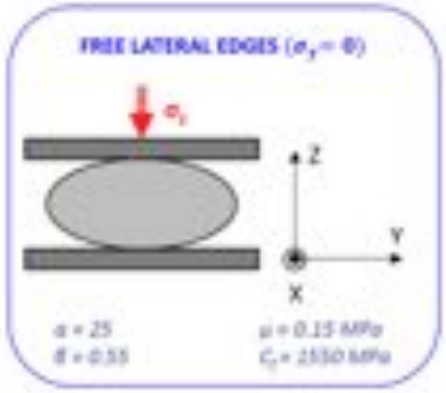
LOOSE STITCH - dry compacted state (60mbar, raw data)

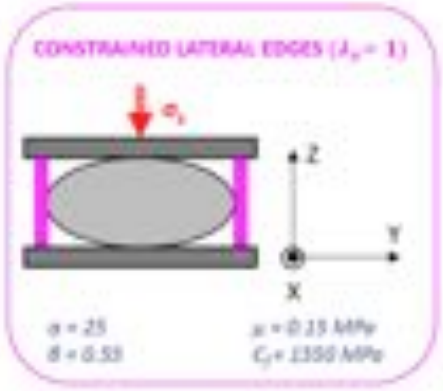
$$W_{GW} = \frac{\mu_{GW}}{\alpha^2}\left(\underbrace{\lambda_x^\alpha + \lambda_y^\alpha + \lambda_z^\alpha - 3}_{\text{isotropic stiffness}} + \underbrace{\frac{1}{\beta}(J^{-\alpha\beta}-1)}_{\text{compressibility}}\right) + \underbrace{C_1(I_4-1)^2}_{\text{inextensibility}}$$

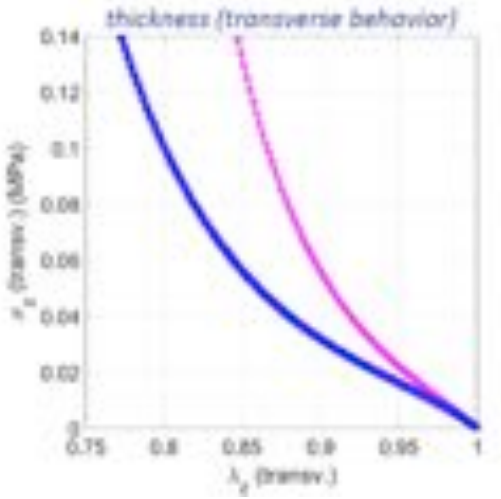
$$\sigma_i = \frac{1}{J}\lambda_i\frac{\partial W}{\partial \lambda_i}$$

$$\sigma_y = \frac{\mu_{GW}}{\alpha}\frac{1}{\lambda_z}\left[\lambda_y^{\alpha-1} - \lambda_z^{-\alpha\beta}\lambda_y^{-\alpha\beta-1}\right]$$

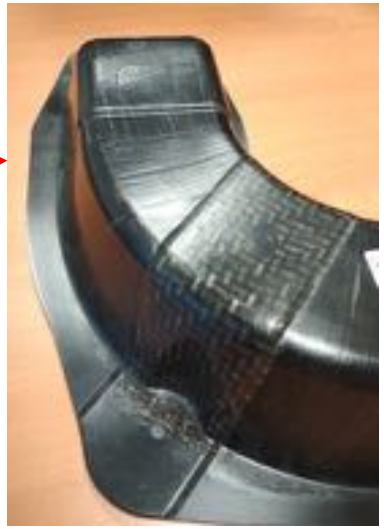
$$\sigma_z = \frac{\mu_{GW}}{\alpha}\frac{1}{\lambda_y}\left[\lambda_z^{\alpha-1} - \lambda_y^{-\alpha\beta}\lambda_z^{-\alpha\beta-1}\right]$$





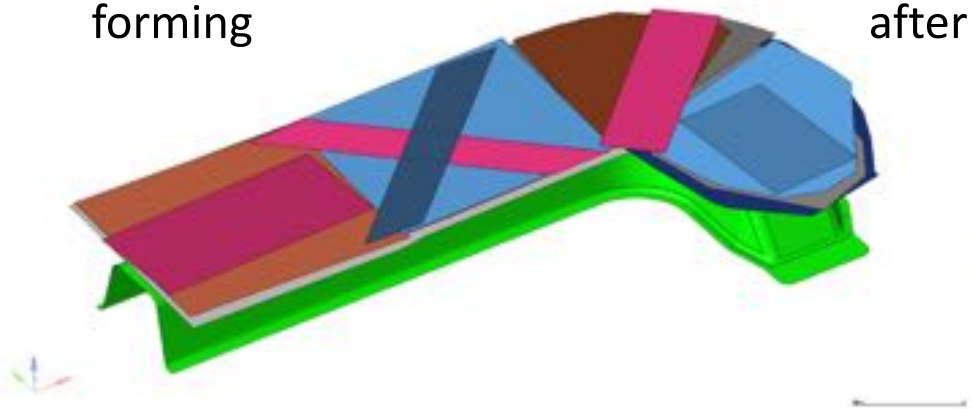


Forming of discontinuous TP composite layups



2D ply stack before forming

Final formed component after QSP



Altair

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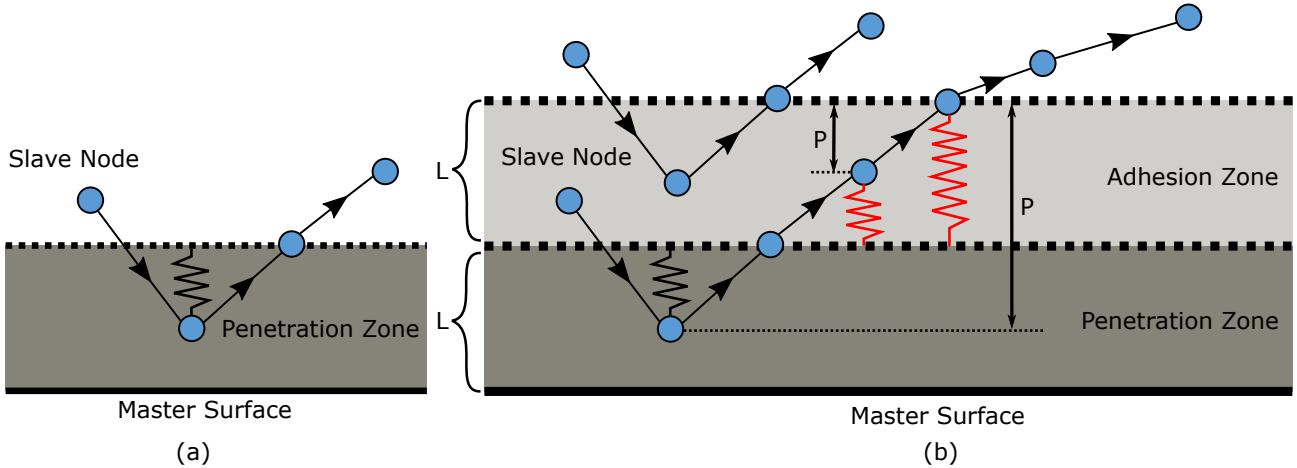
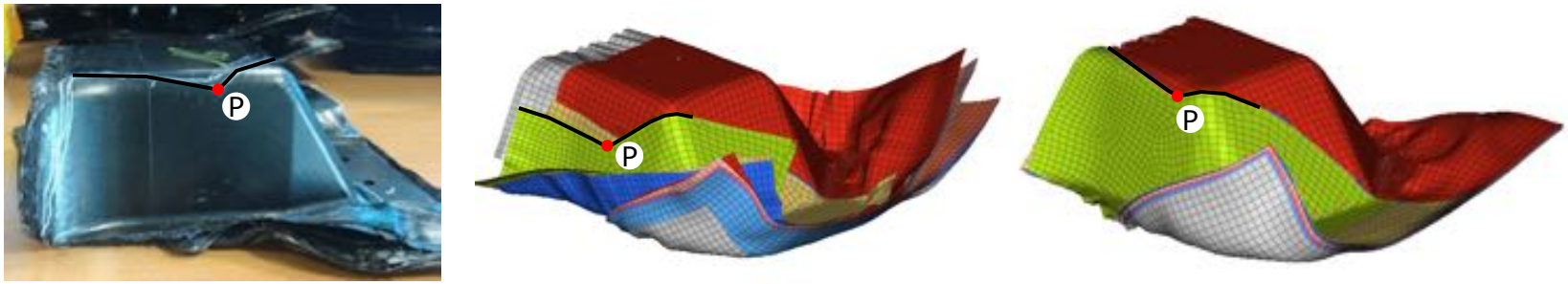
Nantes Métropole

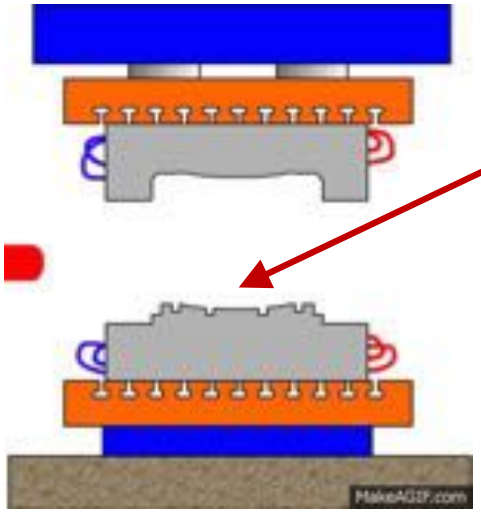
Forming of discontinuous TP composite layups

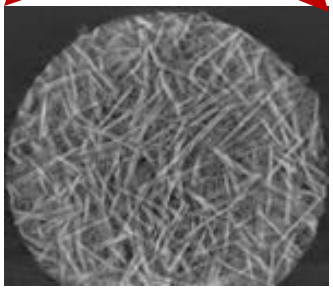




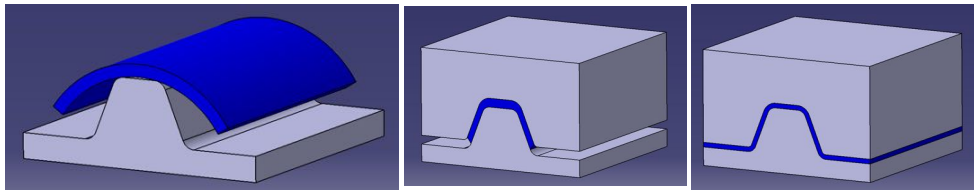
Mulye P.D. et al, Numerical modeling of interply adhesion in composite forming of viscous discontinuous thermoplastic prepregs, submitted

SMC Compression

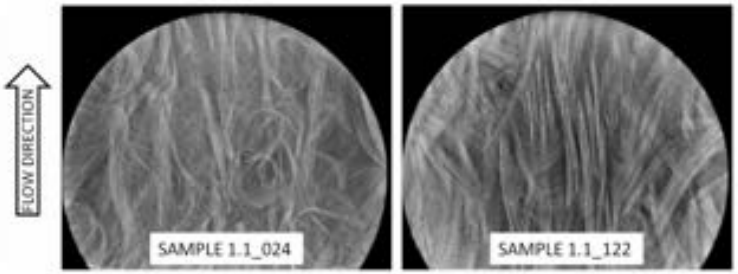




Charge lay-up | Forming | Flow and curing



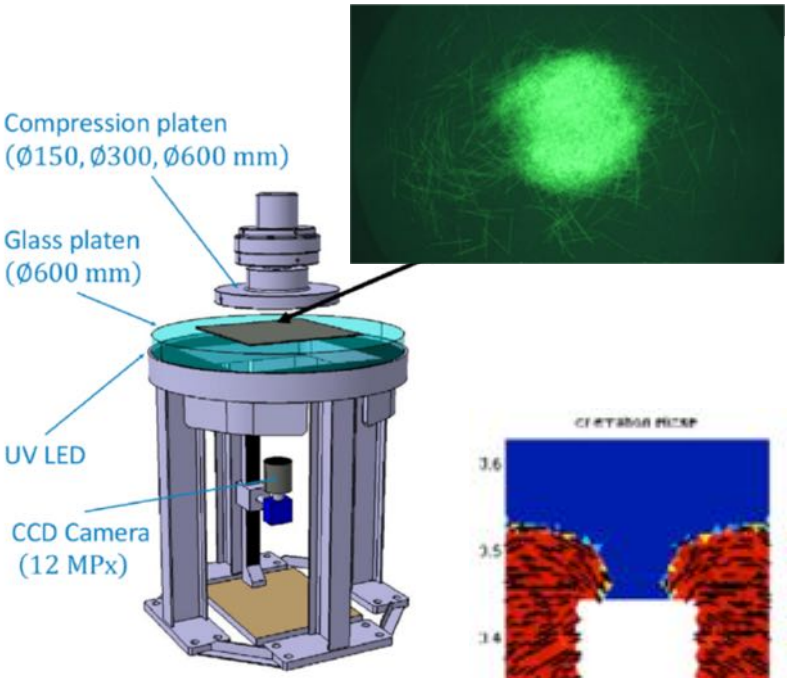
Initial microstructure

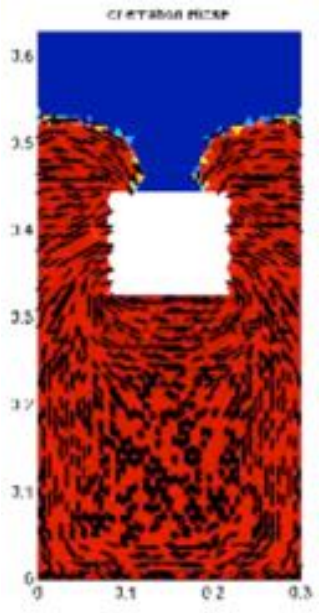


Final microstructure after SMC compression

Oter, L. et al. A step towards the numerical simulation of SMC compression moulding. In *AIP Conference Proceedings* (Vol. 1769, No. 1, p. 170026). AIP Publishing.

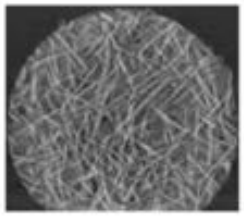
SMC Compression





Flow of fiber suspensions

- Injection (reinforced thermoplastics, BMC,...)
- Compression molding (Sheet Molding Compounds)

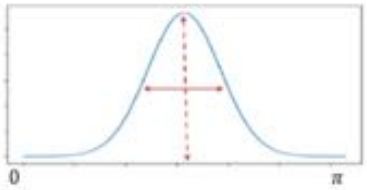


Theory of fiber suspensions [2, 3]

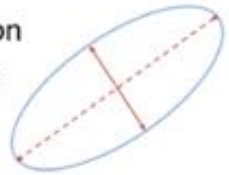
Shape parameter

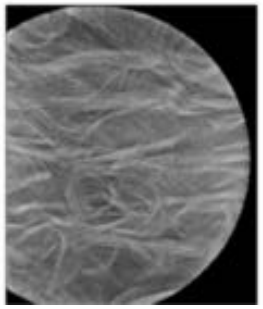
$$\frac{d}{dt}\boldsymbol{A_2} = \underbrace{\boldsymbol{W}\boldsymbol{A_2} - \boldsymbol{A_2}\boldsymbol{W}}_{\text{Rotation due to the vorticity}} - \Lambda\underbrace{(\boldsymbol{D}\boldsymbol{A_2} + \boldsymbol{A_2}\boldsymbol{D} - \boldsymbol{D} : \boldsymbol{A_4})}_{\text{Alignment with the shear flow}}$$

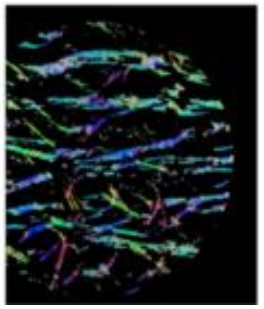
Distribution of orientation



Orientation tensor $\boldsymbol{A_2}$



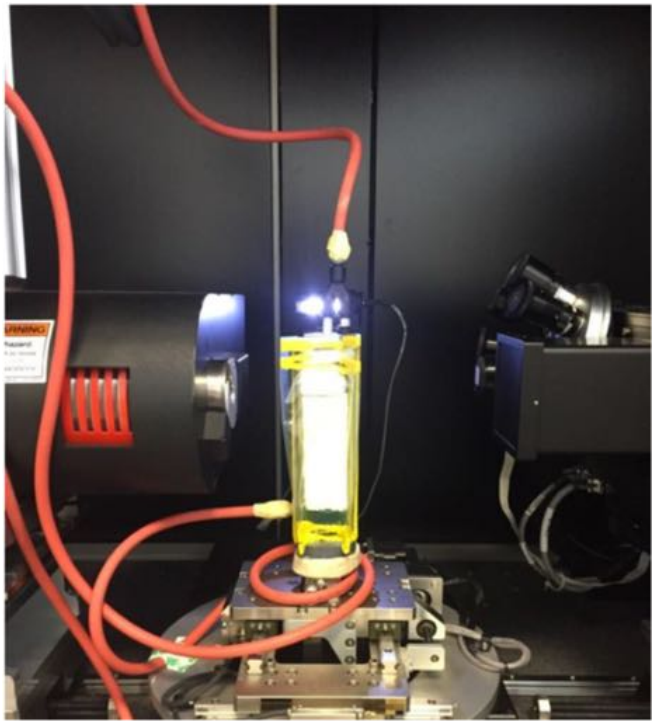




Classic assumptions :

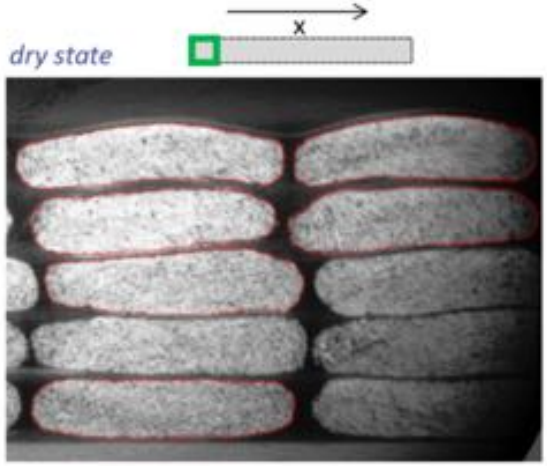
- Undisturbed flow
- Moving solid particles

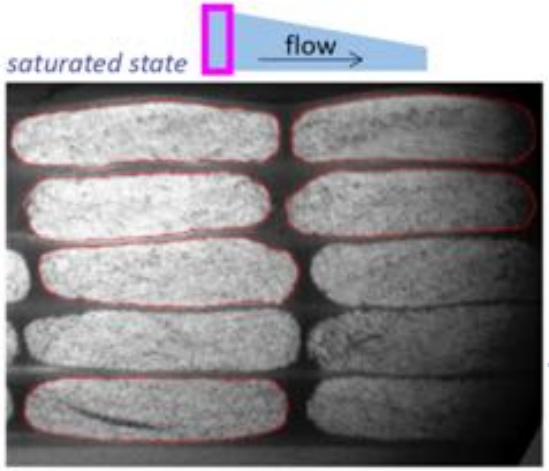
Liquid Resin Infusion



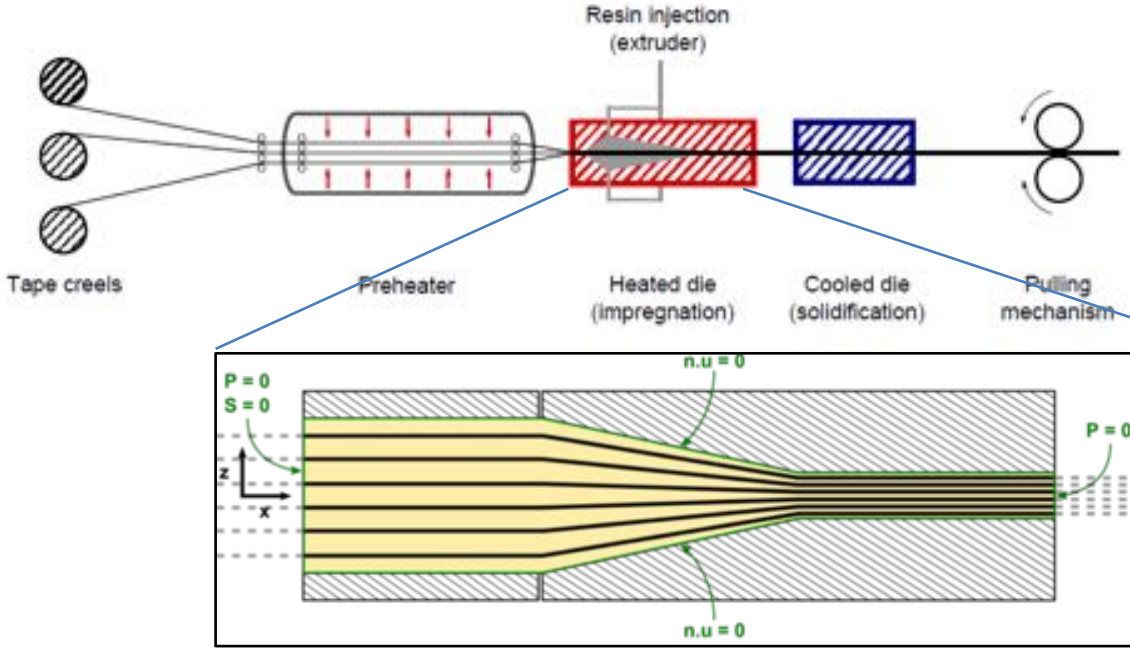
Micro-CT : In-situ experiment

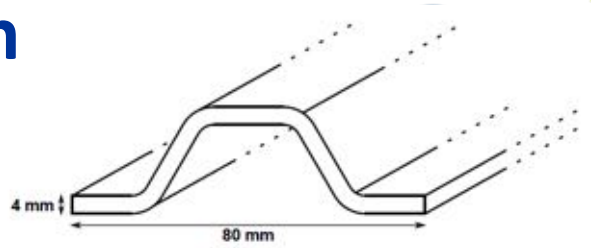
Hemmer, J., Burtin, C., Comas-Cardona, S., Binetruy, C., Savart, T., & Babeau, A. (2018). Unloading during the infusion process: Direct measurement of the dual-scale fibrous microstructure evolution with X-ray computed tomography. Composites Part A, 115, 147-156.

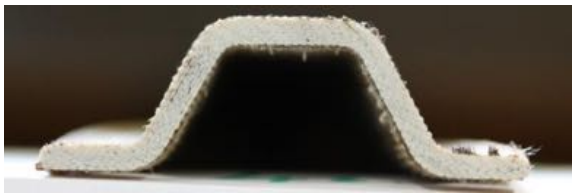




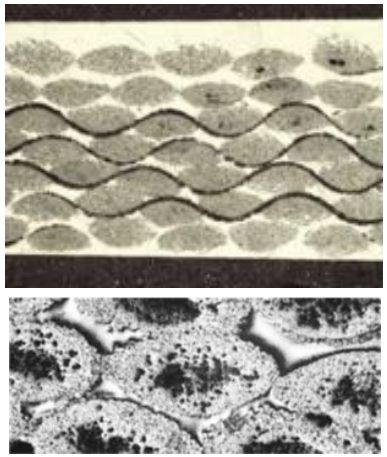
Wet TP pultrusion







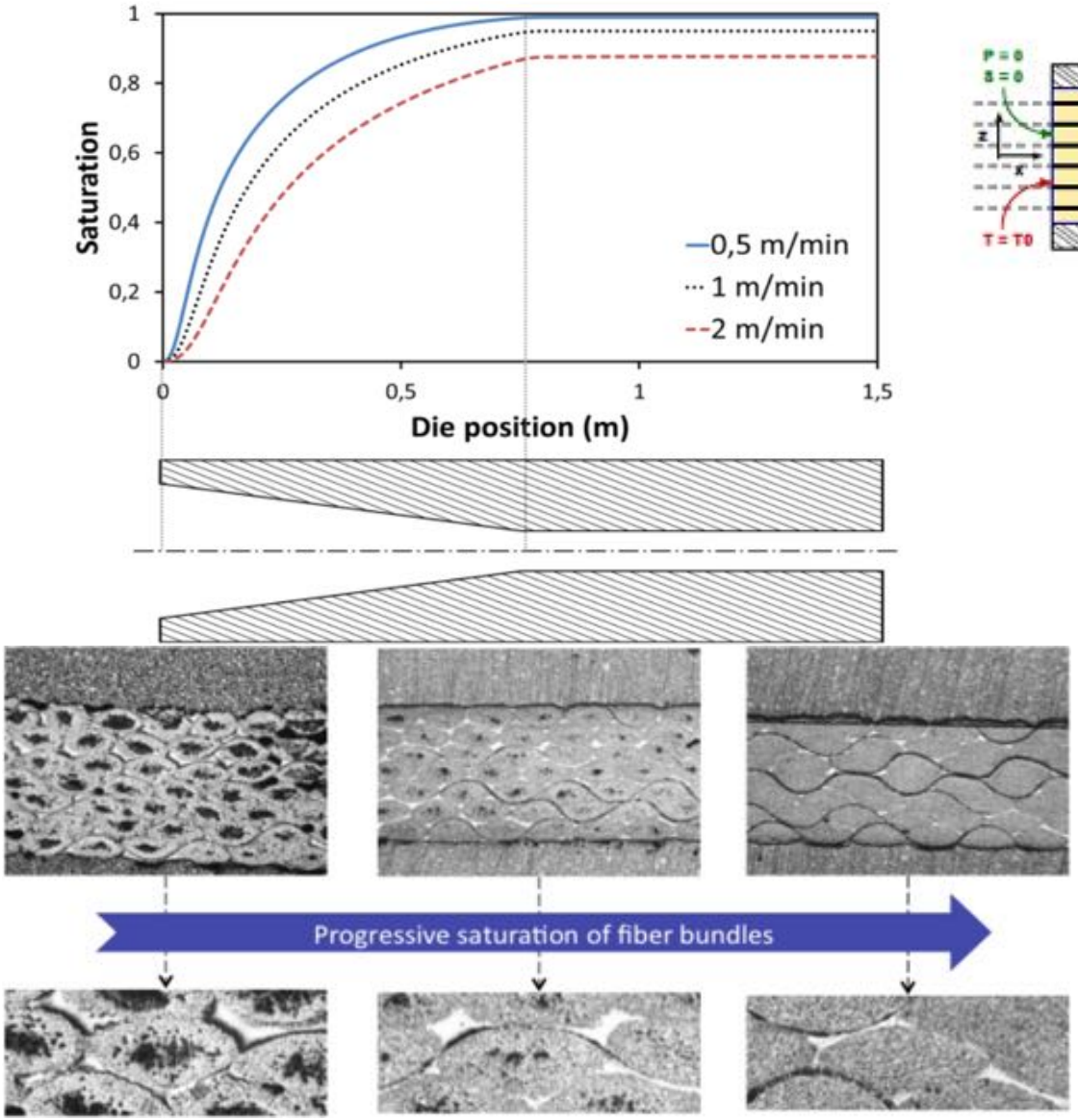
Compaction and Impregnation increase

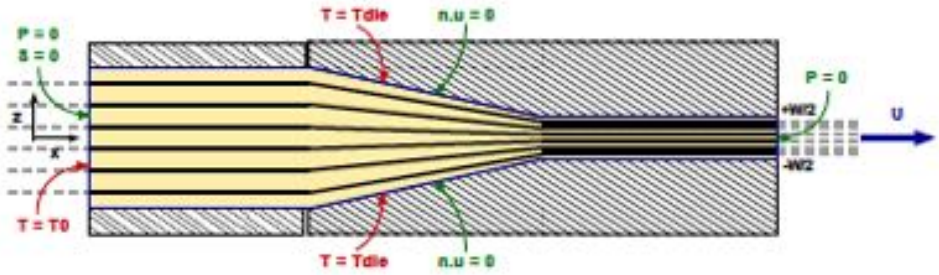


Product scale

Tow scale

Wet TP pultrusion





$$\nabla . u = -q(P,S)$$

$$q = \epsilon_{micro}(1-\epsilon_{macro})U\frac{dS}{dx}$$

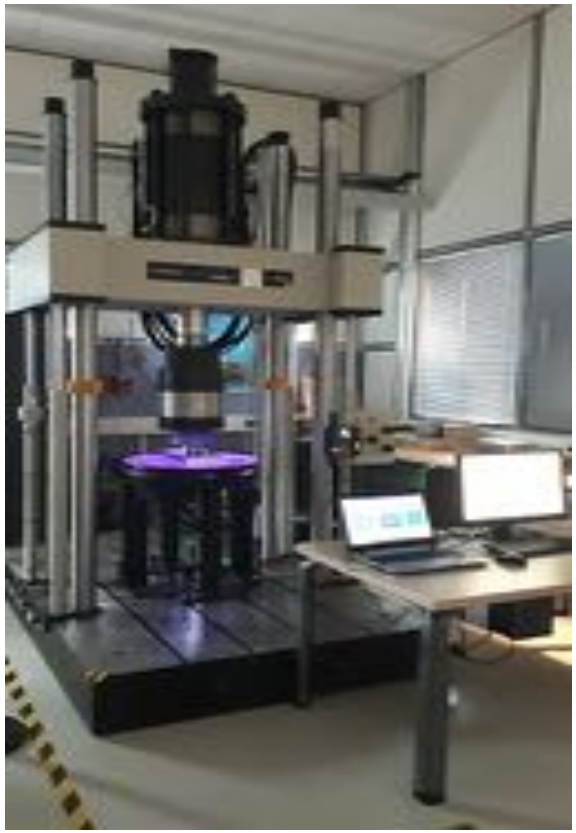
$$\frac{dS}{dx} = \frac{1}{U}\frac{aP}{\beta\eta}(e^{(b(1-S)^c} - 1)$$

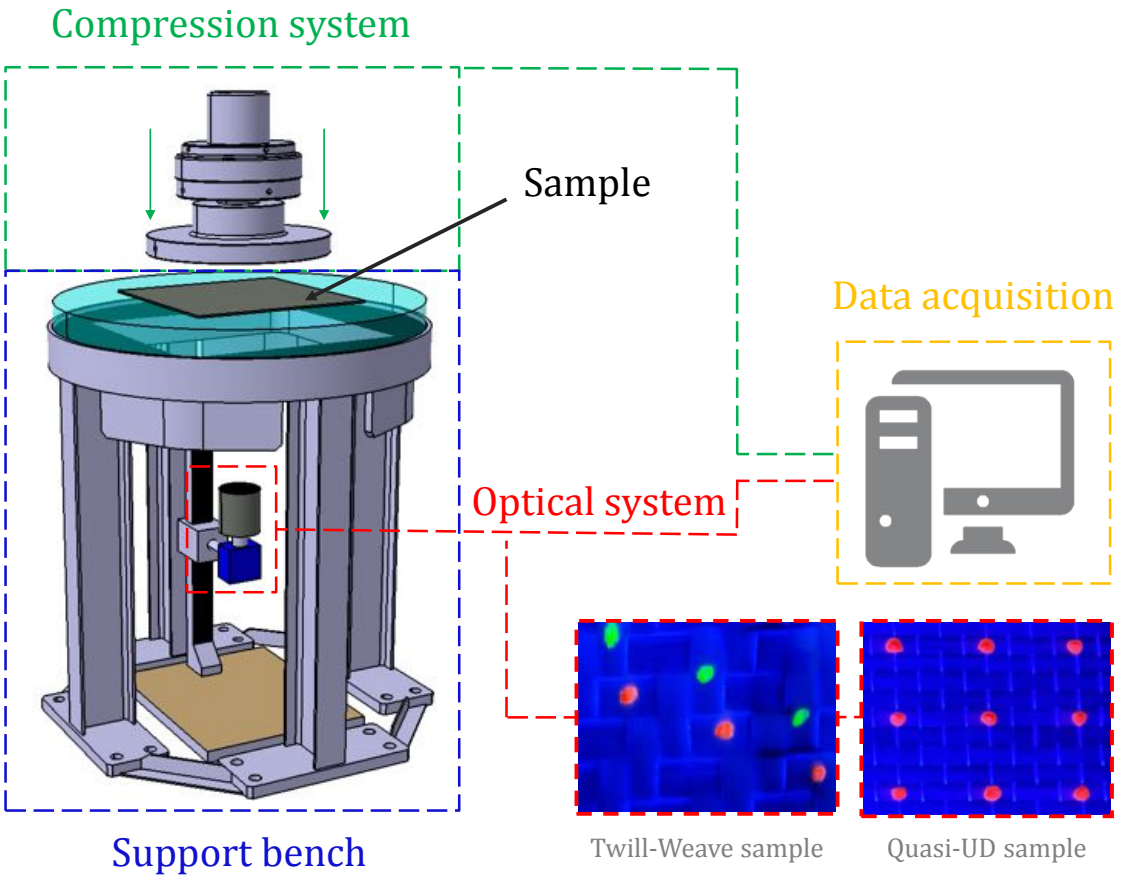
$$\langle u \rangle - \epsilon_{macro}U = -\frac{K}{\eta}\nabla P$$

$$\rho c U\frac{\partial T(x,z)}{\partial x} = \frac{\partial}{\partial z}(k\frac{\partial T(x,z)}{\partial z})$$

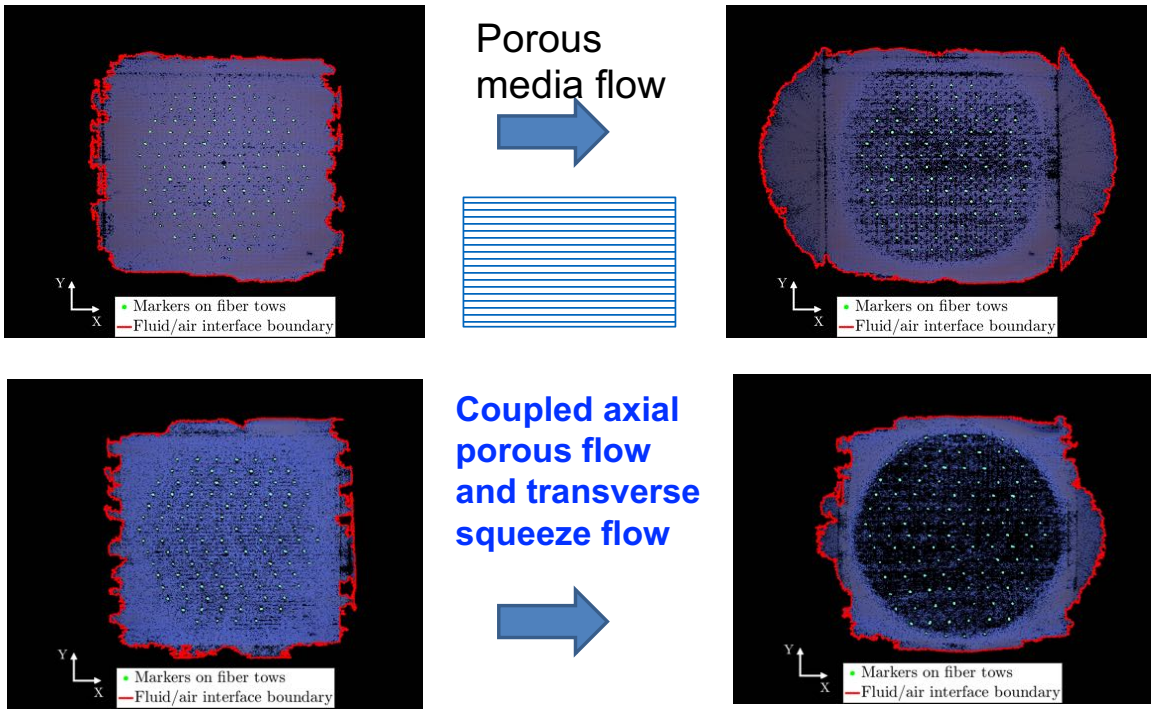
$$\eta(T) = a\exp(-\frac{T}{b})$$

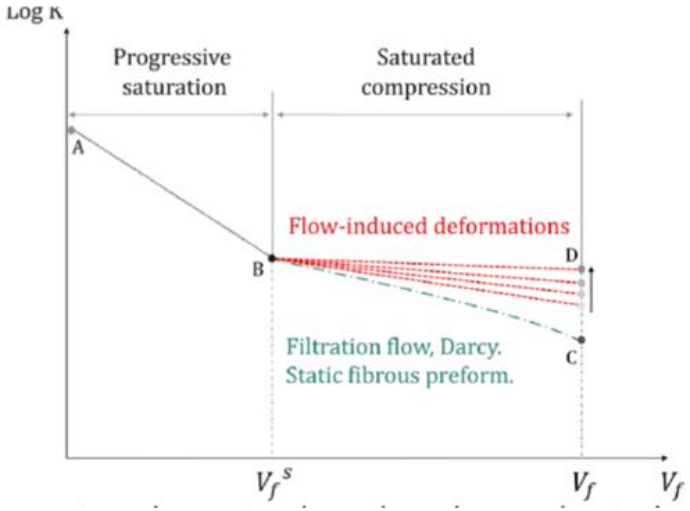
Fiber washing





Fiber washing





Hautefeuille, A., Comas-Cardona, S., & Binetruy, C. (2019). Mechanical signature and full-field measurement of flow-induced large in-plane deformation of fibrous reinforcements in composite processing. Composites Part A, 118, 213-222.

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European Regional Development Fund

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Institut de Recherche en Génie Civil et Mécanique

Q&A

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Thank you!