Development of digital materials for microstructure design: application to polymeric foams

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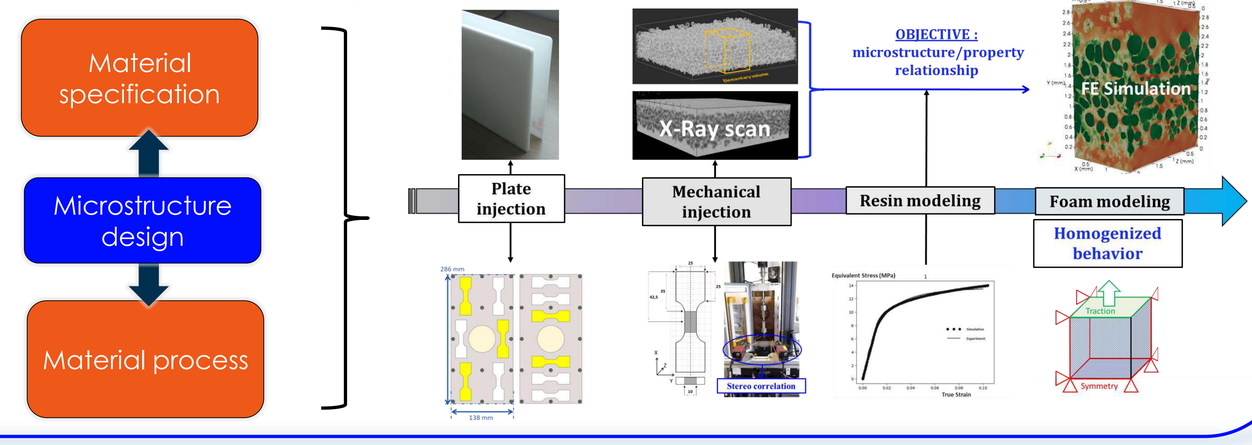
Context and Objective

Context: Globalization and carbon footprint reduction policies push industries to further increase their competitiveness. Digital transformation is one of the solutions for reducing development costs and time to market and for enhancing the competitiveness of industry.

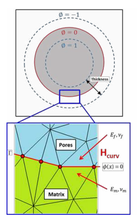
Objective: development of innovative and advanced numerical tool for modeling digital materials with the purpose of capturing the relationship between microstructure morphology and mechanical properties.



Numerical strategy

Cimlib library:

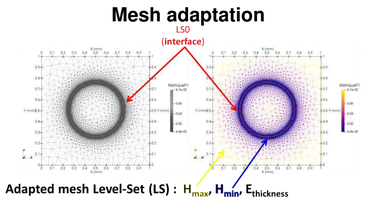
- Generation of digital microstructure
- Level-Set (LS) approach
- Mesh adaptation and remeshing techniques
- Proper management of moving interfaces that allows introducing damage mechanisms, with a robust control of mesh quality.
- Mean field and full field approaches



Level-Set Approach

$$\begin{cases} \phi(x) = \pm d(x,\Gamma), x \in \Omega \\ \Gamma = \{x \in \Omega, \phi(x) = 0\} \end{cases}$$

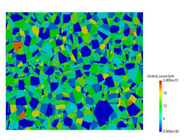
Mesh adaptation



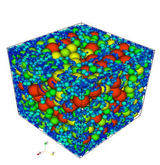
Shakoor et al. (2015-2016), Shakoor (2016) PhD thesis

Digital materials

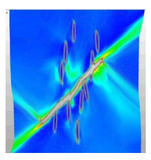
Polycrystalline microstructure



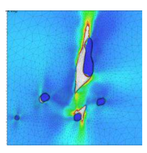
3D powder RVE

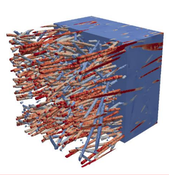


Short glass reinforced composite



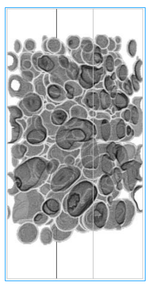
Ductile damage modeling



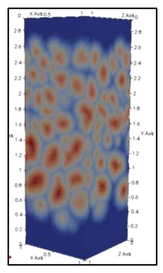


Modeling real microstructure

Tomography 3D

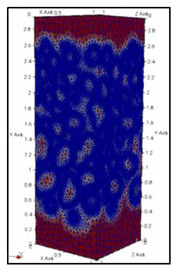


Reconstruction of interfaces

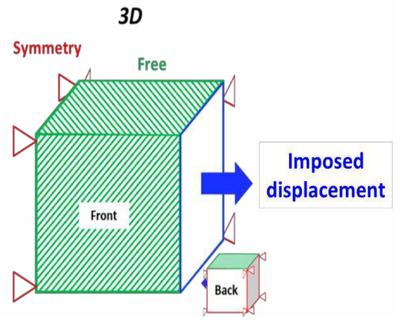


Pores representation

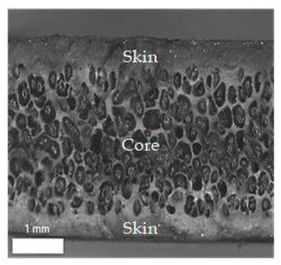
Adaptative meshing



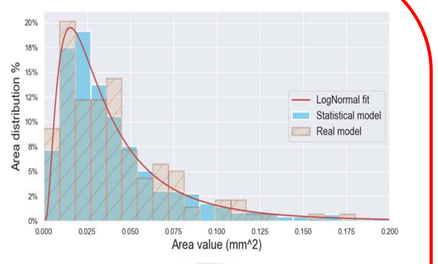
3D

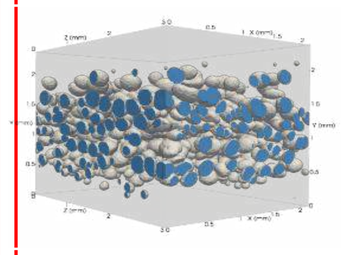


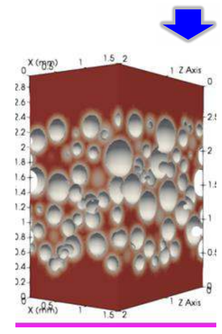
Statistically generated microstructure



Pore size distribution + Mean distance distribution between pores

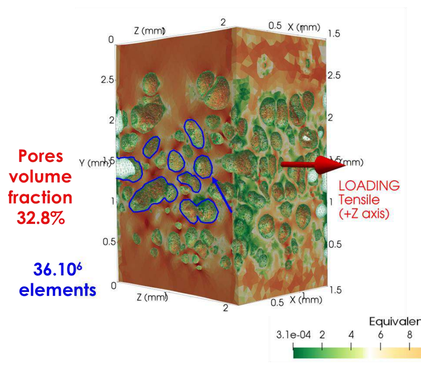




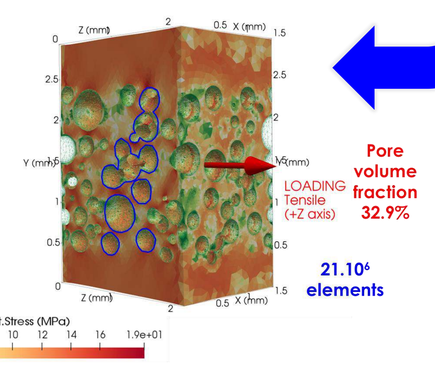


- Pore size distribution
- Constant circularity = 1
- Mean distance distribution

Real microstructure



Statistically generated microstructure



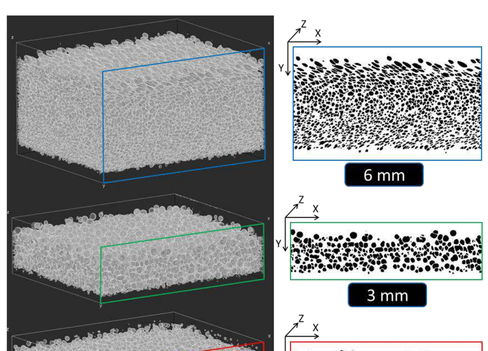
6% of deformation

Comparison to experimental tensile tests

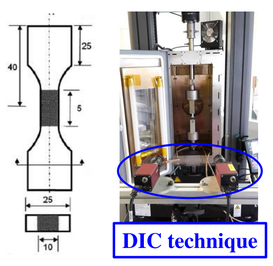
Material → **Mechanical Characterization** → **Modeling**

Polypropylene Foamed material

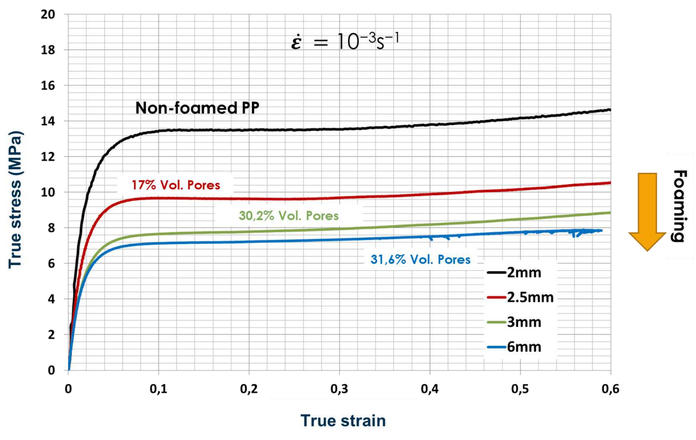
Three different plate thicknesses with fixed injection parameters



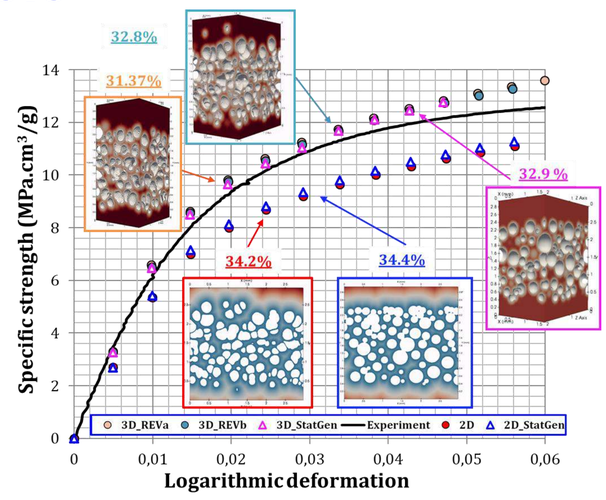
Three different microstructures



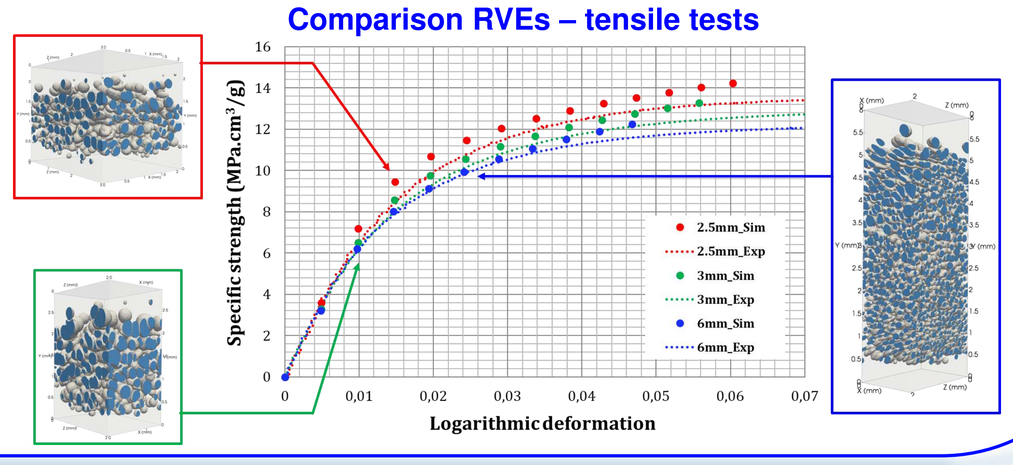
DIC technique



Comparison 2D/3D RVEs



Comparison RVEs – tensile tests



Conclusions

- A numerical strategy was used to compare real and generated microstructures tested by FEM
- Convergence analysis was performed for both 2D & 3D cases to determine the REVs size
- Real and generated microstructures can capture mechanical behavior such as tensile tests (similar comparison verified for compression tests)
- Such methodology can be used to provide virtual material that may help the foam design to sustain specific material properties