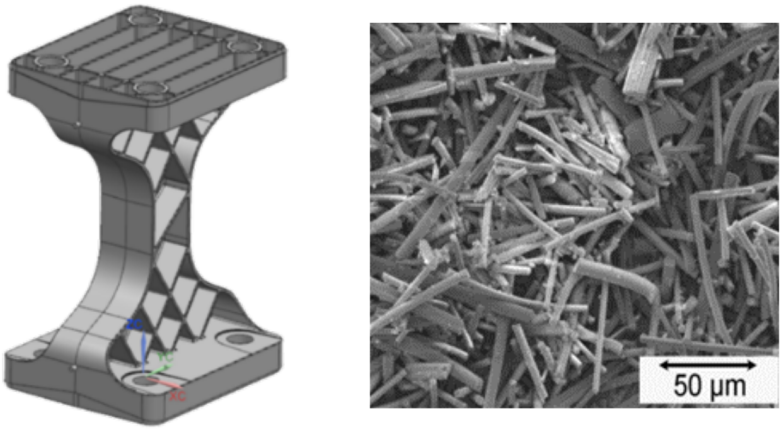
INTERNSHIP OPPORTUNITY – M2 / Final-Year Engineering Project 2027

Efficient multiscale modeling for predicting the mechanical responses of short-fiber composite materials

Background and motivation:

The multiscale modeling of heterogeneous materials is a central challenge in computational mechanics, as their macroscopic mechanical response is closely related to the underlying microstructural morphology, which might induce strong local field heterogeneity. **Short-fiber-reinforced composites (SFRCs)** (see below right) provide a representative example of such materials, exhibiting complex microstructures characterized by heterogeneous fiber orientations, spatial distributions, and local anisotropy. Accurately capturing these microstructural features and their influence on effective material behavior is essential for developing reliable microstructure-informed constitutive models, to be further integrated into design and reliability assessment of industrial parts (see below left).



Industrial demonstrator studied in the AnoHonA project, supplied by Domo Chemicals (120 × 140 × 210 mm, left), and SEM image of the composite microstructure (right).

Classical mean-field homogenization approaches offer computationally efficient estimates of effective mechanical properties but often rely on simplified assumptions regarding microstructural geometry and phase interactions. In contrast, full-field computational homogenization methods, typically based on finite element simulations of representative volume elements (RVEs), can explicitly resolve local mechanical fields and complex fiber arrangements. However, their computational cost becomes prohibitive when repeatedly employed within multiscale simulations.

Bridging the gap between these approaches motivates the development of efficient reduced-order homogenization strategies. In particular, **self-consistent clustering analysis (SCA)** provides a promising framework for approximating heterogeneous local fields through a reduced number of interacting clusters. Combined with **realistic microstructure generation for short-fiber composites**, this approach offers opportunities to investigate how fiber morphology, orientation distributions, and spatial correlations influence the effective mechanical response.

The ultimate motivation is to integrate such microstructure-informed reduced-order models into **multiscale simulation frameworks**, enabling an efficient connection between microscopic heterogeneity and macroscopic constitutive behavior while maintaining a suitable balance between predictive accuracy and computational efficiency.

Objective:

Navier Laboratory UMR 8205
École Nationale des Ponts et Chaussées
6/8 avenue Blaise-Pascal – F-77420 Champs-sur-Marne, France

The objective of this internship is to develop an efficient microstructure-informed computational framework for the multiscale modeling of short-fiber-reinforced composites. The work will focus on generating representative microstructures with realistic fiber distributions and orientations, investigating self-consistent clustering analysis (SCA) as a reduced-order homogenization approach, and evaluating its ability to capture microstructural interactions and predict effective mechanical properties. Finally, the developed reduced order micromechaical modeling will be incorporated into the concurrent multiscale simulation framework by using commercial finite element analysis (FEA) software, e.g. ABAQUS.

Proposed Work Plan:

- Literature review on micromechanics theory, particularly the self-consistent theory, Hashin–Shtrikman variational formulation and associated interaction tensors.
- Implement the self-consistent clustering analysis for linear elastic homogenization analysis, associated with fast Fourier transformation (FFT) based numerical simulations.
- Carry out the microstructure generation for short-fiber reinforced composite microstructure.
- Integrate the self-consistent clustering analysis into multiscale simulation.
- Validate the developed tools against numerical solutions and compare to classical analytical bounds and estimations.

Candidate Profile:

- First/second-year master or second/third-year engineering school student (or equivalent) in mechanics, civil engineering or applied mathematics.
- Strong interest in micromechanics, computational solid mechanics and multiscale modeling.
- Desirable skills: programming (e.g., Python, JAX, C++).

What Can We Offer You:

- **Research Environment:** Work in a collaborative research environment at Navier Laboratory, with access to state-of-the-art GPU computing resources for advanced numerical simulations.
- **Scientific Collaboration:** Engage with researchers and PhD students across different work packages in computational mechanics and multiscale modeling.
- **Scientific Publications:** Potential co-authorship of peer-reviewed journal articles and conference papers, depending on research contributions and outcomes.

Duration: 5–6 months, starting in spring 2027.

Location: Laboratoire Navier, CNRS UMR 8205, University Gustave Eiffel, École nationale des ponts et chaussées, Institut Polytechnique de Paris, Marne-la-Vallée, 77420, France

Advisors: Tong-Rui Liu, Michel Bornert, Jérémy Bleyer, Frédéric Legoll.

Applications and Further Information:

Please send your up-to-date CV and motivation letter to:
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[1] **AnoHonA**: Advanced NOnlinear HOmogenization for structural aNAlysis. A 48-month collaborative research project funded by the French National Research Agency, involving six French laboratories: LMA (CNRS UMR 7031, Marseille), Navier (CNRS UME 8250, École des Ponts), LEM3 (CNRS UMR 7239, University of Metz), PPrime (CNRS UPR 3346, ISAE-ENSMA Poitiers), JLRA (CNRS UMR 7190, Sorbonne University), and CEA (IRESNES Institute, Cadarache Center), together with an international partner (University of La Plata, Argentina).