Research Topic for the ParisTech/CSC PhD Program

***Field (cf. List of fields below):** Mechanics, Materials Science, Fluids*
Subfield: Mechanical engineering, Computational mechanics, Mechanics of Materials.

Title: **Experimental and numerical investigation of non-local damage in polymer based composites accounting for hygro-thermo-mechanical couplings.**

ParisTech School: Arts et Metiers Institute of Technology
Advisor(s) Name: Prof. Fodil Meraghni, Dr-HDR. George Chatzigeorgiou, Dr. Adil Benaarbia
Advisor(s) Email: fodil.meraghni@ensam.eu, adil.benaarbia@ensam.eu, georges.chatzigeorgiou@ensam.eu
Research group/Lab: **SMART** Research group **/ LEM3 UMR CNRS 7239** National Key Lab (Metz)
Project in the framework of scientific collaboration with University of Freiburg (Germany)

Short description of possible research topics for a PhD:

Reinforced thermoplastics remain a very challenging research topic due to their sensitivity to the production process, as well as their actual service conditions. The proposed Ph.D. project aims at developing new experimental and multiscale modelling methodologies to characterize the thermo-hygro-mechanical behavior of these materials and to develop predictive computational tools. The new models should integrate the environmental (humidity, temperature, etc.), as well as the localization effects of the thermoplastic-based composites, addressing also their complex constitutive behavior.

The main experimental challenge is to estimate the different quantities (dissipation, internal energy variations, thermomechanical sources, etc.) necessary for the establishment of a proper energy balance. This task, which is carried out classically on mesoscopic scales, can be advantageously completed by a study of the microstructural evolution mechanisms, mechanisms at the origin of the dissipative effects and the heterogeneous development of the deformation fields. The Ph.D. hosting team has a technological platform with the required experimental techniques. The full-field measurements at different scales of observation using experimental imaging techniques (infrared thermography, digital image correlation), combined with the knowledge of evolution mechanisms at the microscale (microtomography), constitute, in fact, valuable information for research conducted on multiscale methods. All the experimental aspects will be addressed in collaboration with colleagues from I2M (Bordeaux).

The second task of this research project is to facilitate and value the transfer of the results obtained by designing predictive multiscale models, fully adaptable to numerical techniques employed in structural computations via finite element software. Most of the models commonly used in the industry belong to the family of local description models, which cannot handle non-local effects. The challenge is to develop a modelling framework that avoids the pathologies related to localization, taking also into account the environmental effects. A phenomenological thermo-viscoelastic-viscoplastic-damageable model was recently developed by the Ph.D. hosting team to integrate the dissipative and thermomechanical coupling effects observed during the fatigue deformation of a thermoplastic matrix. The developed model was also utilized in a multiscale scheme for thermoplastic woven composites. The existing local model will therefore be regularized by introducing the damage gradient at the level of the constitutive law. To this end, the team will be supported by its established collaboration with TU Bergakademie Freiberg (Germany).

Required background of the student:

Applicants should have, or expect to achieve at least a Master's degree (or an equivalent overseas degree) in Mechanical Engineering. Candidates with suitable experience in numerical modeling, experimental testing and/or measurement skills are particularly welcome to apply.

A list of 5(max.) representative publications of the group: (Related to the research topic)

1- Arif MF., Meraghni F., Chemisky Y., Despringre N., Robert G (2014). In situ damage mechanisms investigation of PA66/GF30 composite: Effect of relative humidity. Composites Part B: Engineering 58, 487-495.
2- Tikkarouchine E., Benaarbia A., Chatzigeorgiou G., Meraghni F., (2020). Non-linear FE^2 multiscale simulation of damage, micro and macroscopic strains in polyamide 66-woven composite structures: analysis and experimental validation. Composite Structures: 255: 112926.
3- Benaarbia A., Chatzigeorgiou G., Kiefer B., Meraghni F. (2019). A fully coupled thermo-viscoelastic-viscoplastic-damage framework to study the cyclic variability of the Taylor-Quinney coefficient for semi-crystalline polymers. International Journal of Mechanical Sciences 163: 105128.
4- Benaarbia A., Chrysochoos A., Robert G (2015). Thermomechanical behavior of PA6. 6 composites subjected to low cycle fatigue. Composites Part B: Engineering 76, 52-64.
5- Chatzigeorgiou G., Charalambakis N., Chemisky Y., Meraghni F (2018). Thermomechanical Behavior of Dissipative Composite Materials. Elsevier.