Ph.D. Proposal

Multiscale and multiphysics robust design of a complex microstructure with uncertainties, and driven by target performances

*Keywords:* numerical simulation; robust design; multifunctional material; micro-macro

This Ph.D. concerns the multiscale and multiphysics behaviour of material microstructures, taking into account the uncertainties, for the design of a complex microstructure. The design aims to optimize the performances of micro-architected materials. These microstructures may arise from the processing of biological materials, or from dedicated engineered materials e.g. aerogels, foams, composites, acoustics metamaterials, etc (see Figure).

![Examples of micro-architectured materials: wood (image CSIRO Australia), trabecular bone (image Wired Magazine), metallic foam (image Metafoam)](image)

Figure. Examples of micro-architectured materials: wood (image CSIRO Australia), trabecular bone (image Wired Magazine), metallic foam (image Metafoam)

We intend herein to study the performances of the microstructure at the macroscopic scale to design an optimal microstructure by controlling its parameters at the different modelling scales. We will begin by the thermal properties [1] and then extend the approach to multiphysics behaviour (vibrations [2-3], acoustics of porous materials [4], piezo-electricity, bio-chemical [5-6], etc). The framework of this work concerns primary the modelling and simulation aspects, the experimental point of view could be explored with existing different collaborations.

Optimization of the microstructure performances requires solving the direct problem of performance estimation, and the inverse problem to identify the parameters that control these performances. Several models will then be studied: “quasi-exact” models at fine scale, and coarser models using a homogenized behaviour. This kind of latest model can then be considered as uncertain, and the study will focus on stating stochastic models using the underlying information at fine scale. This stochastic model will rely for its mean on the deterministic homogenized model as a first step, and could be built from a polynomial chaos development [5-8].

Both the deterministic and stochastic parameters at different scales will be used to optimize the performances. With the increase in the number of parameters to be identified, we will need to manage large-scale problems with high performance computing techniques.
Supervision of the Ph.D.

This Ph.D. will take place at the Contact and Structure Mechanical Laboratory (LaMCoS INSA Lyon CNRS UMR 5259, http://lamcos.insa-lyon.fr) at LyonTech campus in Lyon, under the supervision of A/Prof. Beatrice Faverjon (uncertainty quantification) and Prof. David Dureisseix. The PhD student will work closely with Prof. D. Dureisseix, A/Prof. Beatrice Faverjon (uncertainty quantification), one Postdoc, several Master students in our lab and with the international partners of MURMUR. MURMUR is a 2 years project starting January 2018 on the robust design of micro-architectured materials such as acoustics [9] and composite metamaterials. International partners from MURMUR are the University of Southern California, USA, with Pr. R. Ghanem (uncertainty quantification), and University of New South Wales with A/Prof. N. Kessissoglou (acoustics). Other collaborations will be with another group in our lab for micro-architectured materials (Pr. D. Baillis) and a biomechanical group for natural materials (IMFT Toulouse, France, Pr. P. Swider).

Previous work in connection with the current project:


