Uncertainty Characterization of porous materials at a microscopic scale

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Context

Overall, the characterization of the material properties experimentally at a microscopic scale is expensive and time-consuming. Then, it is necessary to supplement experimental analysis with numerical models for two main reasons: i) investigate and reconstruct intrinsic properties, which cannot be directly observed, ii) merge information coming from different measurements to learn about the underlying physical model driving the material properties.

Computational analyses have been typically carried over using a volume-averaged approach, with macroscopic models. Many mathematical models have been proposed to estimate the effective thermal conductivity of porous materials, by describing the influence of each phase (solid, gas) into the final value obtained. However, experimental analyses have demonstrated that these legacy models successfully represent the real characteristics for the case of materials with macro-scaled pores, but they fail regularly when the pores are micro- and nano-scaled [2]. Microscopical analyses are developed to complement the volume-averaged approaches with an analysis which takes into account the real properties of the micro-geometry and allow for the interpretation of experimental data. It is then possible to perform computations over a numerical model that perfectly represents the microgeometry of porous materials (see Fig.1), in order to measure properties which are otherwise beyond reach.
In this project, we want to take into account two sources of uncertainty: i) the geometry, which is intrinsically stochastic, due mainly to fibers orientation, radius and length following some random distributions; ii) the lack of knowledge concerning some physical parameters, such as the porosity, the inherent properties of the fibers and the gas.

Objective

This work aims to develop and apply Uncertainty Quantification (UQ) methodologies (an example of one UQ technique applied to material characterization can be found in [3]) to learn the behavior of macroscopic properties of porous materials, based on tools that simulate their microstructure.

In this study, we will compute material properties from microstructures using the Porous Material Analysis (PuMA) software, developed at NASA Ames Research Center, and the methodologies described in [1].

This work will be held in the Platon Team at CMAP-X. It will be supervised by P.M. Congedo, and O. Le Maître.

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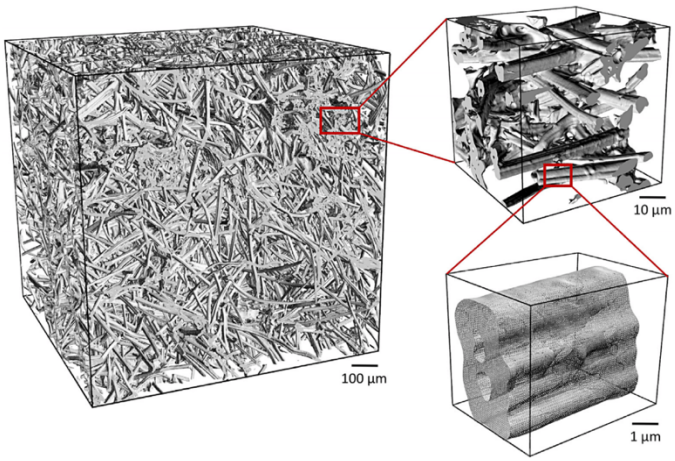

Figure 1 : Typical microstructures dealt with by PuMA, at several scale. Credits to [1].

References

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[3] M. Rivier, J. Lachaud, P.M. Congedo, Ablative thermal protection system under uncertainties including pyrolysis gas composition, Aerospace Science and Technology Vol. 84 (2019).