Research Topic for the ParisTech/CSC PhD Program

Field : Materials Science, Mechanics, Fluids
Subfield : Fluid mechanics, applied mathematics, process engineering.
Title: Tackling a scientific challenge impacting 21st century technologies : heat transfer coefficients in porous materials.
ParisTech School: Arts et Métiers ParisTech.
Advisor(s) Name: Azita Ahmadi, Jean Lachaud
Advisor(s) Email: azita.ahmadi-senichault@u-bordeaux.fr , jean.lachaud@u-bordeaux.fr
Lab, website : *https://www.i2m.u-bordeaux.fr/*

Short description of possible research topics for a PhD:
Numerous technologies in development rely on porous materials : heat exchangers for solar concentrators, biofuel production processes, new generation energy storage as fuel cells and supercapacitors, space vehicle heat shields, etc. Chemical engineers and researchers at the forefront of their own fields and leading 21st century innovation would greatly benefit from fundamental developments in heat and mass transfer to reinforce application-specific phenomenological models. The contribution of this PhD project will be to develop a generic numerical framework to assess and model heat exchanges between the solid structure of a porous material and fluid flowing through the network of pores.
The study will fall into 3 interrelated tasks relying on a multi-scale approach. (1) Idealized and realistic microscopic material architectures will be produced by 3D printing. Experimentally, a cold gas will be flown through hot porous structures and the gas temperature evolutions will be measured. (2) Direct numerical simulations will be carried out at the microscopic scale to analyze and model heat exchanges between solid and fluid phases. (3) High order homogenization techniques will be used to develop macroscopic scale two temperature models. Effective heat exchange coefficients models will be developed based on experimental and numerical analyses on a wide range of Reynolds and Péclet numbers.
Finally, a verified numerical simulation tool implementing the microscopic and macroscopic models will be made available to impact the 21st century industrial challenges. The simulation tool will allow computing heat exchanges within the pores from three-dimensional tomography images. This advanced capability will be integrated in the Porous material Analysis Toolbox based on OpenFoam (PATO) released open source by NASA (https://software.nasa.gov/software/ARC-16680-1A).

Required background of the student: mechanical engineering, numerical simulation.

A list of 5 representative publications of the group
Ucar, E., Mobedi, M. & Ahmadi, A., Interfacial convective heat transfer for randomly generated porous media, Heat Transfer Research 49 (1) :1–14 (2018).
J. B. E. Meurisse, J. Lachaud, F. Panerai, C. Tang, N. N. Mansour. Multidimensional material response simulations of a full-scale tiled ablative heatshield. Aerospace Science and Technology. 76 : 497–511, 2018.
J. Lachaud, J. B. Scoggins, T. E. Magin, M. G. Meyer, N. N. Mansour. A generic local thermal equilibrium model for porous reactive materials submitted to high temperatures. International Journal of Heat and Mass Transfer. 108 : 1406-1417, 2017.
J. Lachaud, N. N. Mansour. Porous material analysis toolbox based on OpenFoam and applications. Journal of Thermophysics and Heat Transfer, 28 (2): 191-202, 2014.
Lux, J, Ahmadi, A., Gobbé, C., Delisée, C., Macroscopic thermal properties of real fibrous materials: Volume averaging method and 3D image analysis, International Journal of Heat and Mass Transfer, 49 : 1958-1973, 2006.