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A parallelized method to model combined conductive-radiative heat transfer at local scale within highly porous media

Thursday, 3 June 2021 10:30 (15 minutes)

In the field of high temperature applications such as energy conversation processes based on concentrated solar heating or the design of thermal protection systems for space vehicles, porous materials with high porosity (75-95 %) know today a growing interest. Two categories of porous materials which can be commonly described by an interconnected network of solid constituents surrounded by a fluid phase are thus investigated: cellular materials and fibrous materials. Indeed, they globally exhibit a high strength-to-weight ratio, a high volumetric surface, a good flow-mixing capability with other interesting properties. The solid network confers to these materials, a complex texture from which the intimate link between its main textural descriptors and its physical properties still remains unclear and impede their industrial uses.

This latter statement is particularly true for the effective thermal conductivity (ETC), especially when temperatures becomes high (T> 1000°C). The ETC depends on conduction and radiation heat transfers occurring simultaneously within the volume of the porous medium [1]. To get a better understanding on this quantity, a parallelized numerical solver based on domain decomposition applied to a 3D voxelized image where the whole physics is portrayed, is developed. This discrete scale approach which requires a prior and accurate knowledge of local thermal properties of constituents (thermal conductivity and optical properties) constitutes an alternative solution to those based on the continuous scale approach which requires the prior and exact knowledge of the effective thermal properties [2] (effective solid thermal conductivity, effective extinction coefficient, albedo and scattering phase function). Once the 3D image is described and analysed using the free morphology analysis software iMorph, a subdivision of the numerical domain is performed to provide suitable subdomains in which conjugated heat transfers are computed. The dimensions of the subdomains are selected to respect the underlying physics. Then, a Finite Volume Method is applied to solve the conductive transfers for the associated set of voxels within a subdomain, and an accelerated ray tracing method is applied to treat the radiative heat transfers between subdomains. This strategy allows to gain the computational time without compromising with the accuracy of the global solution. After validating the new code on academic 3D porous geometries for which the thermal behaviours at high temperatures had been previously computed [3], ETC computations are carried out on cellular samples, and the results obtained by varying the contribution of conduction and radiation on effective heat transfer i.e., by varying the Stark number [3] will be presented during the communication and discussed.

[1] Badri MA, Favennec Y, Jolivet P, Rousseau B. Conductive-radiative heat transfer within SiC-based cellular ceramics at high-temperatures: A discrete-scale finite element analysis. Finite Elements in Analysis and Design. 2020;178.

[2] Leroy V, Goyeau B, Taine J. Coupled Upscaling Approaches For Conduction, Convection, and Radiation in Porous Media: Theoretical Developments. Transport in Porous Media. 2013;98:323-47.

[3] Perraudin DY, Haussener S. Numerical quantification of coupling effects for radiation-conduction heat transfer in participating macroporous media: Investigation of a model geometry. International Journal of Heat and Mass Transfer. 2017;112:387-400.

Time Block Preference

Time Block B (14:00-17:00 CET)

References

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