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Monte Carlo method to solve the heat equation in a complex media

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Porous or fibrous complex medias are widely used for energy applications such as heat storage, thermal insulation, solar absorbers, heat exchangers… There is a need to develop methods that are relevant to solve the heat equation in those complex medias.

Monte Carlo method can be used to solve parabolic partial differential equations such as heat equation in complex geometries [1,2,3] or porous media. It relies on reformulating the thermal model first as an integral and then as an expected value introducing a probability density function. An important point is that this method does not require a volumic mesh which makes it relevant for complex geometries.
Randomly generated paths carry information (known temperature or flux on a boundary, volumetric heat source…) in their weights.The observable - local temperature, mean temperature on a given surface - is then evaluated by computing the arithmetic mean of the weights, based on the Law of Large Numbers. It is noticeable that Monte Carlo method does not evaluate a temperature field but only the observable. Therefore, it reduces the amount of data to handle for post-treatment. The Monte Carlo algorithm can easily be parallelized since each path is independently computed on a single processor. Based on the Central Limit Theorem, the result is always given with its variance and then with the associated uncertainty.

In this work, we solve the thermal model in a diphasic complex porous media.
Geometry has been obtained through tomography technique and is composed of 8×10^6 triangles. This sample has been chosen for its complexity: large range of spatial scales, hollow fibres… Computations have been performed with the free and open-source software Stardis (https://www.meso-star.com/projects/stardis/stardis.html) which is suitable to take conduction, convection and radiation transfers into account. Based on recent work of Tregan [4], Stardis has been extended to non-linear cases to take the radiative term - difference of temperatures to the power four - into account without linearization which is crucial when the difference of temperatures is high.In the present work, the thermal model has been successfully solved to determine the apparent conductivity tensor with and without radiative transfers.

Further work is required to investigate how to solve other advection-diffusion equations with this Monte-Carlo method.

Participation

In-Person

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