Introduction

Porous media are ubiquitous in our common life : typically, the soil, our skin, our clothes, the coffee filters, ... exhibit non-homogeneous properties which allow fluids to flow through the solid matrix. Exploiting the porous properties of these materials is also usual. Indeed, they are present in many application fields such as the forming of composite materials, clean motor device, filtration systems, oil extraction, mixing devices, biological tissue substitution, etc.

In order to deal with all these applications, two main disciplines are involved in the study of porous media : (i) solid mechanics and (ii) fluid mechanics. The first topic concerns the relation between stress and deformation of the solid matrix while the second topic focuses on the flow and pressure field of the liquid phase inside the matrix.

Flows in porous media exhibit among other aspects specific mixing properties. Indeed the solid geometry strongly influences the internal fluid flow and induces increased transport phenomena. This effect has a significant impact on the evolution of different fluid variables (temperature, degree of conversion, ...). However, accurate description of the flow is highly complicated and the prediction of the mixing effect remains a hard task. This issue becomes even more complex when the porous medium is non-homogeneous and non-isotropic and a strong lack of models and validation is observed in this latter case.

Starting from the work of O. Mal (4), we will therefore investigate in this thesis the modelling and validation of transport phenomena in flows in anisotropic porous media.

In the first chapter, we will start by highlighting the difficulties encountered in the modelling of flows in porous media and we will develop a continuous approach to represent the related physics and detail the associated basic assumptions. The laws governing the flow together with energy and species transport will be developed. Hence this will allow us to introduce two main matrix properties associated with flows in porous media : permeability and hydrodynamic dispersion.

In order to overcome some deep modelling difficulties, we will investigate in the second chapter an original strategy, viz. the micro-macro approach, which will allow us to better understand and clarify both effects. In very special cases, a link between micro-parameters and macro-properties will be drawn with the help of this technique. Improvements of the model will also be suggested.

The validation viewpoint is addressed in the third chapter. General aspects and the design of an experimental set-up are described in order to determine permeability as well as hydrodynamic dispersion tensor components. Specific values of these matrix properties are measured. Concluding remarks close this important chapter.

The fourth chapter is devoted to address some numerical difficulties related to the continuous model solution. An original method is developed in order to reach a stable solution for the diffusion-advection equation with the Finite Element Method when advection is dominant. The processing of non-linear and coupled problems is also addressed. Finally basic ideas in order to tackle the moving front issue are suggested.

The fifth chapter essentially deals with non-isotropic modelling. Indeed, a first problem is addressed in order to underline the effect of superposed transversely isotropic porous layers, which results in the generation of a 3D flow. The second issue is to deeper investigate hydrodynamic dispersion modelling and the related dominant terms in very special cases.

Finally, we address the problem of cartilage modelling in the last chapter. Cartilage is indeed a porous medium in which a physiological liquid flows. We analyze the problem for the solid and the fluid phases together. The solution of the resulting coupled and non-linear problem is treated and numerical results are analyzed, emphasizing some physical effects such as the osmosis effect.