Materials for 5th Int. Conference on Applications of Porous Media

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Title: A generalized reconstruction operator for coupling FVM and LBM in multiscale simulation and its applications in simulating transport process in porous medium (by He Y. L. and Tao W. Q.)

Abstract:

In this keynote lecture the multiscale simulation of heat transfer and fluid flow problems are presented in detail focused on the simulation through/over porous medium. Following sections are involved.

In the first section the meaning of multiscale problems is briefly introduced. The multiscale problems are divided into two categories: multiscale process and multiscale system; then the numerical approaches at different scales problems are classified. The numerical approaches can be divided into three categories : the first one is based on the continuum assumption-macroscopic method, the second one is so-called meso-scale method, including direct simulation of MC (DSMC), and lattice Boltzmann method. The third approach is the molecular dynamics simulation (MDS). A typical multiscale transport process is the mass and heat transfer in a PEMFC. In the PEMFC the fuel gas flows in polar plate channels occurs at the length scale of millimeters or centimeter, while the chemical reaction at the porous catalyst layer and the transport of proton in the memory occur at micrometer even nanometer scale level.

In the second section the numerical methods for the multiscale problems are described. For the multiscale processes two kinds of method are widely used, i.e., solving the entire process by a general method and solving separately and coupling at the interface. The DNS method for turbulent flow is a typical one of the former, while most multiscale process problems are solved by the later method. The key issue in the “solving separately and coupling at the interface” is the information transfer techniques at the interface. Transfer information at the interface from mirco-results to macro-results is relatively easy, which can be done by a compressor operator, usually being different statistical averaging methods, while transfer information from macro results to micro results is quite difficult, where a re-constructor operator should be developed which can transform less to much.

In the third part, several re-constructors developed in the authors’ group are introduced, with focusing on the recently-developed general re-constructor which can be used to transform different physical quantities from macro FVM results to meso-scale LBM results. Three examples for simulation flow through/past/over porous medium are presented in detail. The first example is the coupled simulation for the fluid flow in a duct within which a porous medium region is included; The second example is the flow past/through a square porous medium region; The third example is the transport processes in a relatively wide open region combined with a local porous region, which is commonly encountered in PEMFC, convective heat transfer in systems including porous inserts and transport processes in macro pores between particles and in micro pores within the particles in micro reactors. The comparisons between computational times from pure LBM and the multiscale method are presented.

Finally some research needs in the multiscale simulation of heat transfer ,fluid flow and chemical reaction are proposed.