# Lattice Boltzmann Simulation of Tortuous Flow within Stochastic Porous Media and the Examination of the Tortuosity-Porosity Relationship

A. Ebrahimi and A. Bazylak[1]

Thermofluids for Energy and Advanced Materials Lab

Department of Mechanical and Industrial Engineering
Faculty of Applied Science and Engineering
University of Toronto, 5 King's College Road, Toronto, ON, Canada

A broad range of engineering applications require mathematical modeling of fluid flow within porous media including Lithium-ion batteries, membrane-based fuel cells, water treatment technologies, and geochemical extraction and storage technologies. Accurate estimation of many of the mass transport parameters used in these models requires accurate quantification of the flow tortuosity, including the effective permeability and diffusivity, as in Bruggeman relationship [1]. As a result, the accuracy of these parameters, and consequently the effectiveness of the associated flow and mass transport models depend on the correct calculation of the tortuosity.

In this study, numerical simulations using the Lattice Boltzmann method (LBM) are applied to develop representative tortuosity-porosity relationships within stochastic porous media. Accurate quantification of tortuosity will enhance the local-scale calculation of mass transport properties within the porous media. The resulting transport parameters could then be used to inform large-scale flow simulations.

Using LBM flow simulations in microscale porous geometries, the velocity field and flow path within the simulation domains are obtained (Figure 1), which are used to determine the hydraulic tortuosity of the flow. The geometry used in this study consists of porous structures formed from randomly-placed rectangular grains, similar to the geometry used by Koponen et al. [2]. The numerical results presented here are in good qualitative agreement with Koponen et al, as shown in Figure 2. In this study, functional expressions for tortuosity are examined in order to determine predictive tortuosity-porosity relationships for the simulated geometry. These tortuosity-porosity models obtained from micro and meso scale simulations can be used as inputs for macroscale numerical modeling. This study will serve as the basis for further investigations regarding the enhancement of large-scale simulations of flow within porous media involving tortuosity calculations.

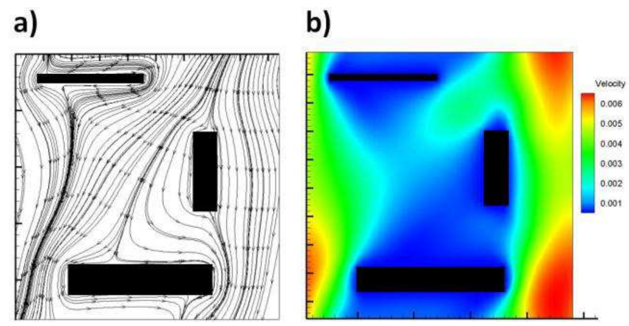


Figure 1. a) Tortuous streamlines of flow through a rectangular grain-based geometry, b) velocity field of the same domain as in (a). This figure shows the continuity of the flow path and the ability of LBM to describe highly tortuous flows.

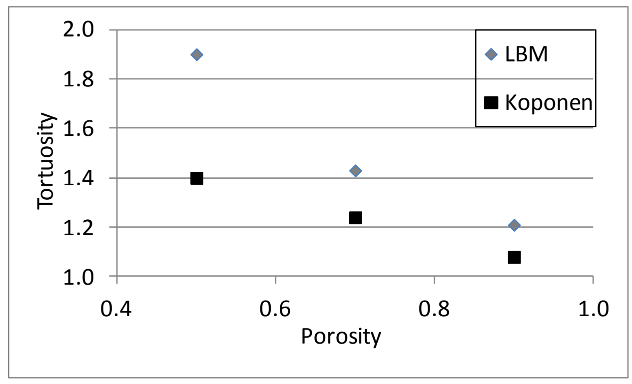


Figure 2. Comparison of tortuosity values vs. porosity between the results predicted by Koponen[2] and our LB model.

## References

[1] Bruggeman D.A.G Ann Phys, (1935) 24: 636.

[2] Koponen A, Kataja M, Timonen J. Phys Rev E (1996) 54(1): 406.

[1] Corresponding Author: abazylak@mie.utoronto.ca; +1 (416) 946-5031