Evaluation of Tortuosity in High Porosity Media Using the Lattice Boltzmann Method

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Abstract

SOFC is a promising device for getting electrical and thermal energy due to its efficiency and high power rate. Some parts of the SOFCs are fabricated with porous materials, e.g., anode/cathode supporters and active layers. The porous material allows the fuel and reactant gases getting the solid electrolyte for producing the energy conversion. The study and analysis of porous material are important in the modeling of different physical and chemical phenomena that occur into the SOFC. Lattice Boltzmann Method (LBM) has proven to be suitable for solving problems in complex geometries, e.g., porous media and periodic boundaries.

The purpose of this work is to show the dependence of the tortuosity value with the computational time used during the calculation process. The porosity selected for this study is held constant by all tortuosity calculations. The solid material is placed in invariable positions over the computational domain. The velocity field through the domain is calculated using D2Q9 LBM scheme. The tortuosity is calculated using the velocity field found in a determined time interval. The tortuosity is calculated for different time steps getting different values. Finally the time step of the modeling process is increasing until a certain interval to get the constant tortuosity value.

Keywords: Porosity, Tortuosity, LBM.

Scientific approach

- Lattice Boltzmann Equation
- Scheme used: D2Q9.
- Momentum conservation equation.
- Porosity established as a constant.
- Tortuosity calculated using the 2D velocity field.

Governing equations

$$\varphi = \frac{void\ area}{total\ area} \qquad \tau = \frac{\sum_{i,j} u_{mag}(i,j)}{\sum_{i,j} |u_x(i,j)|}$$

$$\frac{\partial f_i(r,t)}{\partial t} + c_i \nabla f_i(r,t) = \frac{1}{\tau_1}\left[f_i^{eq}(r,t) - f_i(r,t)\right]$$

Conclusions

- The velocity field using D2Q9 LBM scheme was calculated.
- Velocity field results depends on the time step used in the model.
- Tortuosity is calculated taking into account the 2D velocities.
- The porosity of the domain is 0.9468
- The tortuosity when the fluid reach the steady state is 1.0071

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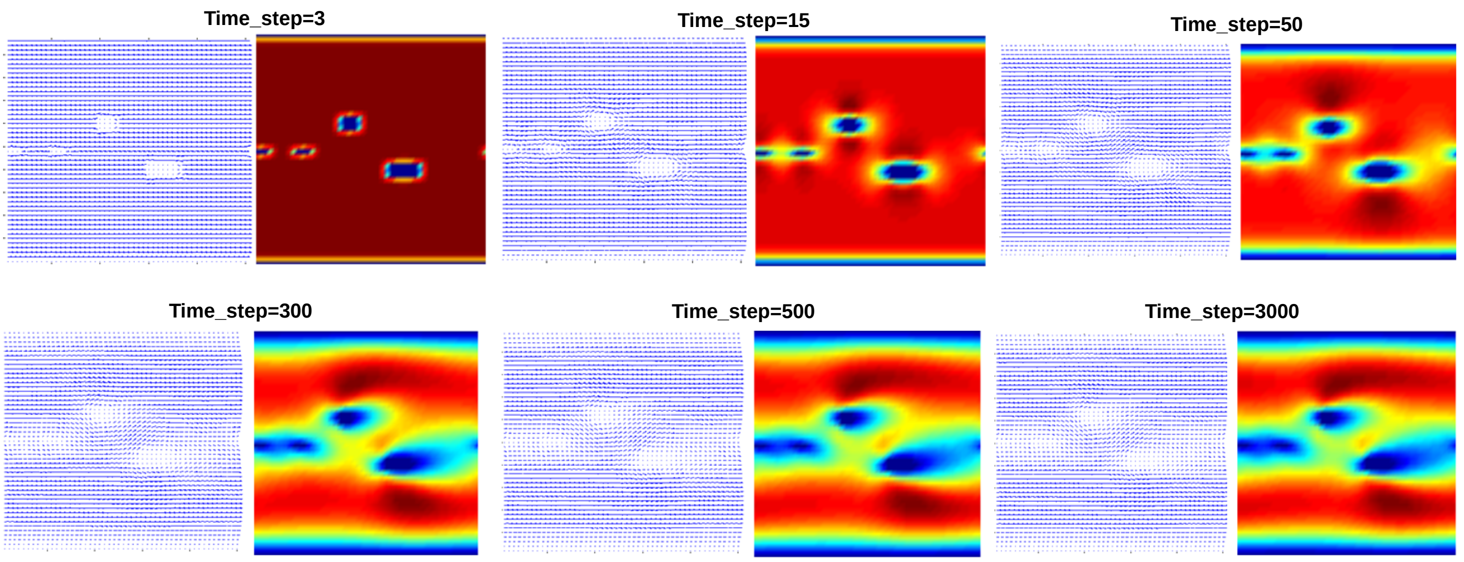
Results – Velocity Field



Results – Tortuosity Calculations

t_step	Porosity	Tortuosity
3	0.9468	1.0003
5	0.9468	1.0008
10	0.9468	1.0020
15	0.9468	1.0032
20	0.9468	1.0043
30	0.9468	1.0054
50	0.9468	1.0063
100	0.9468	1.0076
200	0.9468	1.0082
300	0.9468	1.0080
400	0.9468	1.0076
500	0.9468	1.0073
1000	0.9468	1.0071
2000	0.9468	1.0071
3000	0.9468	1.0071