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LAT-PIV 法による多孔質媒体の間隙流速測定と CTRW パラメータの関係性
Estimation of the parameters of CTRW model by means of LAT-PIV pore-velocity measurement

新屋 樹 [1*], 田嶋 脩平 [1], 羽田野 祐子 [1]
Itsuki Araya[1*], Shuhei Tajima[1], Yuko Hatano[1]

[1] 筑波大学大学院システム情報工学研究科
[1]Graduate School of Systems and Information Engineering,University of Tsukuba

Recently, the CTRW (Continuous-Time Random Walk) model has been acknowledged that it can reproduce the behavior of substances in the groundwater. This model can describe the anomalous diffusion and includes the ADE (Advection-Dispersion Equation) as a special case. However, in the CTRW model, it is one of the most difficult problems that the parameters in the model cannot be fixed a priori.

In the present study, we propose a method that can estimate the most crucial parameter, alpha, in the CTRW model with the aid of LAT-PIV (Laser-Aided Tomography and Particle-Image Velocimetory) method.

With the LAT-PIV method, we can visualize the internal structure of porous media, and tracks down tracers in the pore fluids. We packed the glass beads of diameter 2 mm ~ 5 mm into a rectangular acrylic-resin container (400 mm x 100 mm x 100 mm) and filled the container with silicone oil, tracer particles dispersed.

Silicone oil is discharged in the box with a peristaltic pump with a specific flow rate.

Laser-sheet light is projected in the box from the side, parallel to the front face of the container in order to glow the tracers.

With a CCD camera, we obtain successive images of the tracers. Then a histogram of velocities is generated.

We repeat the same procedure for another porous medium, consisted of sphere particles of 7 mm in diameter.

We improved the PIV procedure in two ways. One is that we re-edited the images in order to make glass particles invisible.

Secondly, we revised the computer program of the velocimetory part. These revisions are in order to eliminate unwanted effects due to the existence of solid particles. After these revisions, we confirmed that the mean flow velocity, estimated by the pump rate, actually agrees very well with that obtained by the PIV velocimetry.

To estimate the model parameter of CTRW, we have to convert the pore-velocity histograms into the waiting-time distribution.

The waiting-time distribution is the essential element of the CTRW model, so this is important.

We converted them in the following method.

First, after a study by Borgne et al. (2011), we conducted a Monte Carlo simulations; we choose values of the pore velocity randomly within the range of measurement. Then we sum up these values until the total displacement reaches at the pore length. The numbers summed up can be regarded as the waiting time. We repeat this 1,000,000 times and obtained the distribution of the waiting time.

Second, we estimate the value of parameter alpha. We make a log-log plot of the waiting-time distribution and the slope of the graph corresponds to the value of alpha.

As a result, we found that the waiting-time distribution follows the power law that is assumed in the CTRW model.

We obtained values of alpha of the model, which are in the range of 1.6 ~ 2.4. We also found that the anomaly of the diffusion is stronger in a medium packed with irregular particles than a sphere-packed medium.

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