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Tortuosity on top of the velocity distribution function

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Introduction

*T*ortuosity is a key quantity that, along with porosity and permeability, describes the flow through porous structures. To this day *no experimental procedure* exists for tortuosity measurement. In order to compute tortuosity one need to integrate velocity field or use streamlines as described i.e. in [Matyka 11].

We present preliminary results of **tortuosity calculation directly from velocity distribution functions**. Using this approach one could get tortuosity from already published velocity distributions.

Such approach may be also used to develop methodology for an experimental tortuosity measurement with particle path-lines computed on top of the measured velocity distributions (i.e. from MRI).

Method

*O*ur procedure starts with pre-processing of the data (sorting, normalization etc.). Then, we use the inverse transform sampling to get two random velocity components (u and v) from the given distributions.

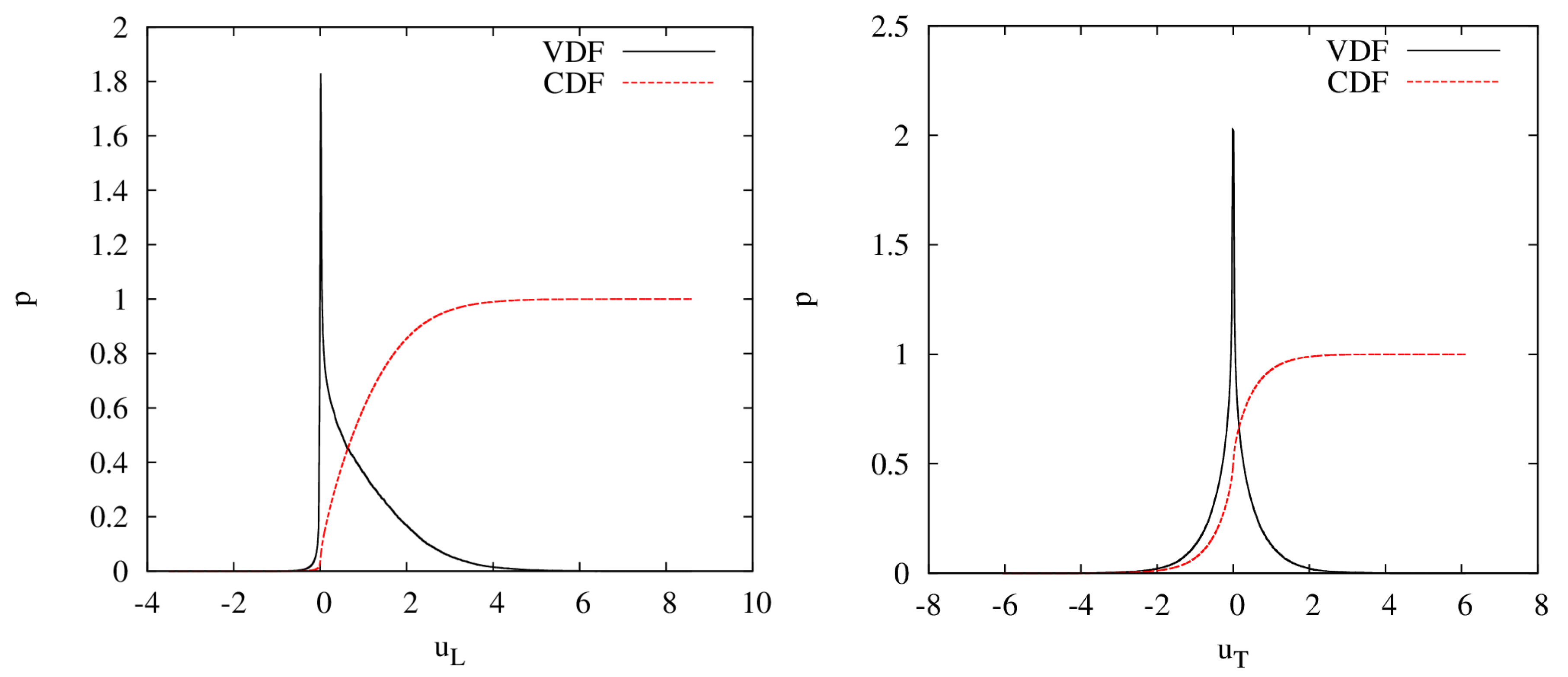

***Fig. 1**: Velocity distribution function and cumulative distribution of velocity component along flow direction (left) and traverse component (right) in flow through overlapping quads in 2D at porosity 0.8.*

Using random velocities we integrate equation of motion of fictious, massless particle advected with the sampled velocity:

$$\frac{dx}{dt} = u,$$

$$\frac{dy}{dt} = v.$$

PDF available: http://www.ift.uni.wroc.pl/~maq/interpore2k15.pdf

Resulting random-like pattern of particle represents its movement in the velocity field. Exemplary particle paths (series of 10) for two various porosities are plotted in Fig. 2.

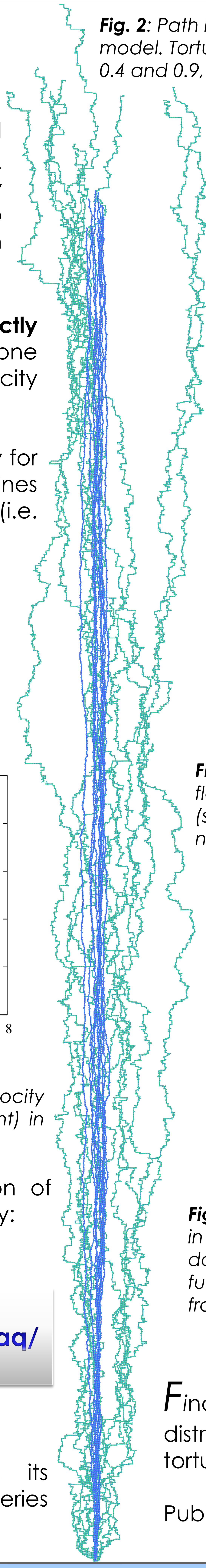

***Fig. 2**: Path lines from VDF in an overlapping rectangle model. Tortuosity calculated: T=2.2 and 1.2 for porosity 0.4 and 0.9, respectively.*

Tortuosity

*W*e compute tortuosity (T) using a path line elongation as given i.e. in [Matyka08]:

$$T = \frac{Le}{L},$$

where Le is the line length and L is the distance travelled.

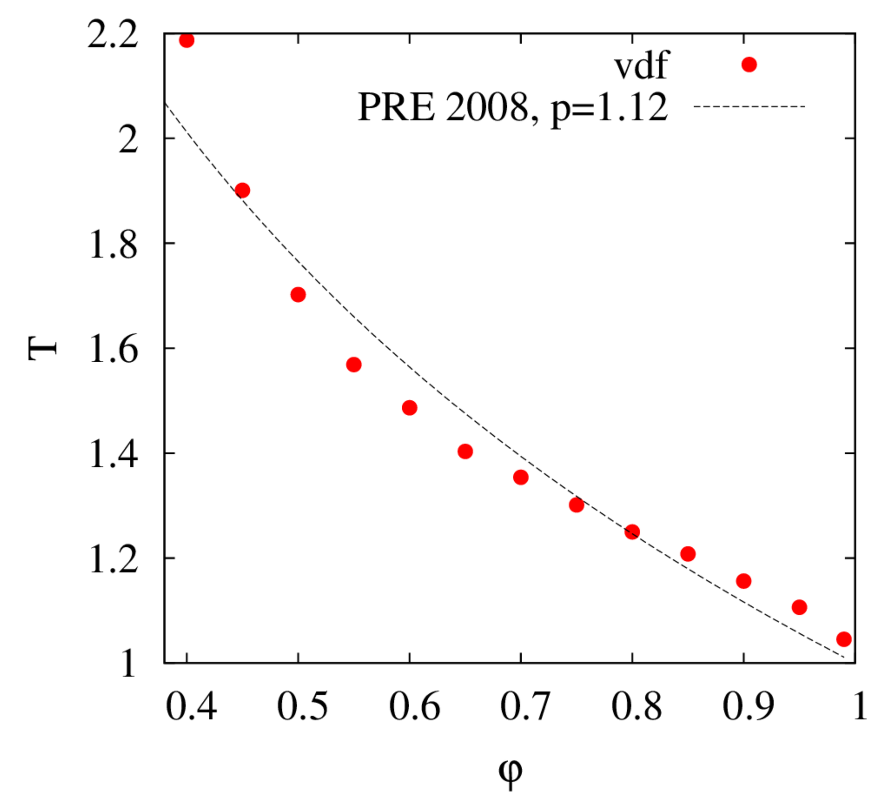

***Fig. 3**: Tortuosity computed from VDF in the flow over a random overlapping model (similar to [Matyka08]). Dashed line represents numerical fit to 1-p*log(phi).*

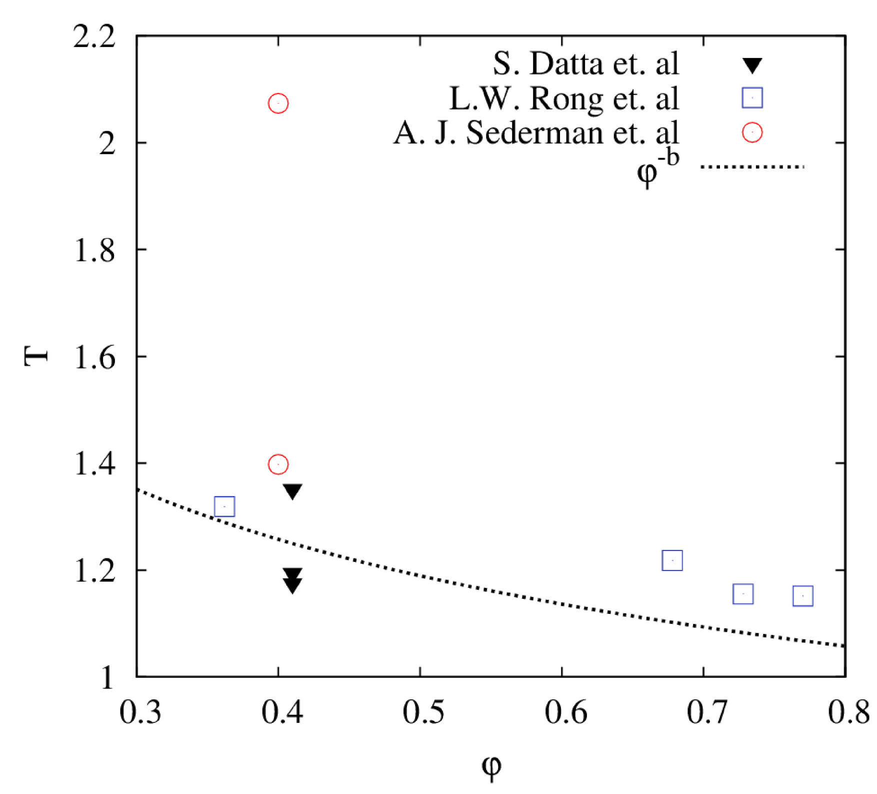

***Fig. 4**: Tortuosity of packed beds from VDF's in [Datta13, Rong13, Sederman97]. The dashed line is a fit of an exponential function to random sphere model data from [Matyka11].*

Future

*F*ind as many papers with a proper VDF distributions as possible and compute tortuosity where possible.

Publish the results along with the code.

[Datta13] Sujit S. Datta, H. Chiang, T. S. Ramakrishnan, and David A. Weitz , *Spatial Fluctuations of Fluid Velocities in Flow through a Three-Dimensional Porous Medium*, **Phys. Rev. Lett.** 111, 064501 (**2013**)
[Matyka08] Matyka, M., Khalili, A. and Koza, Z., *Tortuosity-porosity relation in the porous media flow*, **Phys. Rev. E 78**, 026306 (**2008**)
[Matyka11] Matyka, M. and Koza,Z., *How to Calculate Tortuosity Easily?*, **AIP Conf. Proc.** 1453, 17-22 (**2012**)
[Rong13] L.W. Rong, K.J. Dong, A.B. Yu, *Lattice-Boltzmann simulation of fluid flow through packed beds of uniform spheres: Effect of porosity*, **Chem. Eng. Sci.** Vol. 99, pp. 44-58 (**2013**)
[Sederman97] A. J. Sederman, M. L. Johns, A. S. Bramley, P. Alexander and L. F. Gladden, *Magnetic resonance imaging of liquid flow and pore structure within packed beds*, **Chem. Eng. Sci.**, Vol. 52, pp. 2239-2250 (**1997**)