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Solid Earth
Discussions

Interactive comment on "Pore-scale permeability prediction for Newtonian and non-Newtonian fluids" *by* Philipp Eichheimer et al.

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The paper describes a modification of the existing codebase to simulate flow of Newtonian and non-Newtonian fluids on the pore level. I found the paper to be sound and scientifically robust. It is very well-structured and writing is also good.

For aforementioned reasons i strongly recommend the paper for publication: it presents new code (which is probably more accurate that other existing FDM alternatives), it presents a rescaling technique that help to improve the quality of the solution, it presents a realization for non-Newtoniam fluids. The manuscript is good 'as is', but i still recommend the Authors to consider following changes before submitting their very final version of the paper:

1) I guess as the code is the part of the LaMEM now, it should be open source, isn't it? If so, please, provide a link to the repository somewhere at the relevant part of the paper.

2) Within your abstract and introduction you mention that non-Newtonian code is necessary for nano-fluids and some related problems. I would suggest a couple of sentences to explain this a bit, because technically you provide a solution for micro-scale. I would also guess that magma flow is a potential object of simulations with your code.

3) Equation 5 is a technically valid for any flow direction, not sure why do you talk about z-direction here. I would suggest re-writing it for the general case, especially considering that later on in Eq.6 you do you generalized form to compute permeability.

4) Something went wrong with Eq.12-13 (probably while converting to pdf?). Please, fix these.

5) Could not completely catch the meaning of all elements on Fig.3. You have black lines with attached numbers of 3 and 0.25 (the latter is partially covered by the tube flow figure inset). Please, consider fixing this.

6) I found a disagreement between Eq.18 and Fig.4 - in the text you assign R3=4, R4=8, while the pipe #3 is larger on the figure, plus you report that #3 contributed more to the flow. Seems like you interchanged #3 and #4 at some point.

7) Fig.5 - you have quite slow (blue) flow lines at the same positions as higher (yellow-red) flow lines at the same locations along the flow direction. I find this to be somewhat strange, considering that the flow should be symmetrical around the spheres under periodic boundary conditions (you should use them, otherwise you can't compare against analytical solutions for drag forces).

8) Not 100% sure here, but i do not think that Eq.19 was derived by Bear, as analytical solutions for spheres (not only SC, but BCC and FC packings) comes from preceding papers, e.g.: Sangani, A.S., Acrivos, A., 1982. Slow flow through a periodic array of

spheres. Int. J. Multiph. Flow 8, 343–360. doi:10.1016/0301-9322(82)90047-7

9) Fig.8 and the text related to this figure. First, how did you produce those different resolution figures? From the results i would guess you simply "magnified" each voxel 2 times to consist of 4 voxel for each magnification step. Please, describe your methodology. Because i would expect somewhat different behavoir if you would scale your samples while conserving its spatial statistics: Karsanina, M. V., & Gerke, K. M. (2018). Hierarchical Optimization: Fast and Robust Multiscale Stochastic Reconstructions with Rescaled Correlation Functions. Physical Review Letters, 121(26), 265501. Now, you mention that LBM also converges from above and cite some papers with such behaviour. I guess these papers used single-relaxation LBM. Technically, LBM can converge from below, above, and from below and above at the same time. To improve this section of the text i recommend reading and citing the following papers: Khirevich, S., Ginzburg, I., & Tallarek, U. (2015). Coarse-and fine-grid numerical behavior of MRT/TRT lattice-Boltzmann schemes in regular and random sphere packings. Journal of Computational Physics, 281, 708-742. Khirevich, S., & Patzek, T. W. (2018). Behavior of numerical error in pore-scale lattice Boltzmann simulations with simple bounce-back rule: Analysis and highly accurate extrapolation. Physics of Fluids, 30(9), 093604. Zakirov, T., & Galeev, A. (2019). Absolute permeability calculations in micro-computed tomography models of sandstones by Navier-Stokes and lattice Boltzmann equations. International Journal of Heat and Mass Transfer, 129, 415-426.

10) I would recommend to present a very brief comparison against existing FDM codes, for example FDMSS. I would expect that your code is more accurate, yet takes much longer time to converge and more computationally heavy in terms of CPU and RAM.

All in all, i think this work to be of very good quality and ready to be published with Solid Earth. My comments are more "cosmetic" in this regard.

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