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Validation of Direct Numerical Simulations in 3D pore geometries and Large-Eddy Simulations

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Numerical solutions of the Navier-Stokes Equations became more popular in recent decades with increasingly accessible and powerful computational resources. Simulations in reconstructed or artificial pore geometries are often performed to gain insight into microscopic fluid flow structures or are used for upscaling quantities of interest, like hydraulic conductivity. A physically adequate representation of pore scale flow fields requires analysis of large domains in combination with turbulence models.

We solve incompressible Navier-Stokes Equations in a cubic lattice and cubic close packing of spheres placed in a square duct with Direct Numerical Simulations (DNS) and analyze the validity of the results. The influence of the number of spheres and mesh discretization is investigated for fluid flow up to Reynolds numbers of 5000 based on the spheres' diameter. The numerical simulations are performed with the OpenFOAM open-source CFD software.

We statistically investigate spatial and temporal properties of the resulting fluid flow field and its kinetic energy spectra, and compare them to Large-Eddy Simulations (LES) performed for the same geometries. Differences between the DNS and LES are discussed together with upscaled hydraulic properties with respect to the number of spheres and the Reynolds number.