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Steady-state flow transitions in ordered porous media investigated using an artificial compressibility finite difference method

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Steady-state transitions in porous media, here defined as a discontinuity in one or more macroscopic observables as a function of Reynolds number while the flow remains steady, are known to occur for a multitude of different types of porous media. In previous studies, it has been discovered that these transitions coincide with the development of inertial cores and a reduction in the spatial variance of the velocity field [1]. Recently, flow through an ordered porous media cell consisting of a staggered cylinder packing was investigated using tomographic particle image velocimetry [2]. The results reveal a complex three-dimensional steady-state flow pattern, occurring in the region where inertial effects are expected to become dominant. The peculiar flow pattern, which significantly increases the vorticity and flow resistance, indicates that the transition may need more explanation than the development of inertial cores as suggested by earlier studies.

The investigation is confined to single-phase, fully saturated Newtonian flow through porous media. By making use of an in-house GPU implementation of an artificial compressibility finite difference method the transition from the stokes flow region, to the end of the steady inertial region, is performed on three types of ordered porous media. These are a staggered packing of mono-radii cylinders, a staggered packing of quadratic cross-section rods and a body-centred cubic packing of mono-radii spheres as disclosed in the figure. Here, also the flow regions are presented where the Reynolds number increases from left to right and the velocity magnitude is visualized by a volume rendering. When increasing the Reynolds number it is concluded that in addition to the transition resulting in an increase of the spatial variance of the velocity, as known from earlier studies, it coincides with a rise in the absolute value of the pressure integral across the solid surfaces. These observations, together with an observed increase in the absolute value of the pressure velocity coupling, indicate that the flow tends to alternative flow paths which reduces impingement on the solid surfaces.

Participation

In-Person

References

[1] - Johns, M. L., et al. "Local transitions in flow phenomena through packed beds identified by MRI." AIChE journal 46.11 (2000): 2151-2161.

[2] - Forslund, Tobias OM, et al. "Non-Stokesian flow through ordered thin porous media imaged by tomographic-PIV." Experiments in Fluids 62.3 (2021): 1-12.

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