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Non-monotonic effect of compaction on dispersion coefficient of porous medium

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Numerous studies have shown a non-monotonic relationship between the dispersion coefficient and the degree of compaction of porous media [1, 2]. However, the mechanism responsible for the non-monotonic variations of the dispersion coefficient remains unclear, which brings difficulties and challenges for the regulation of the dispersion coefficient of porous media.

By combining the discrete element method and the pore network model, we investigate the impact of compaction on the dispersion coefficient of the porous medium. The dispersion coefficient exhibits a non-monotonic dependence on the degree of compaction, which is distinguished by the presence of three distinct regimes in the slope of the dispersion coefficient to the pressure load. The non-monotonic variation of the dispersion coefficient is attributed to the disparate effect of compaction on dispersion mechanisms. Specifically, the porous medium becomes tightly packed with increasing pressure load, reducing the effect of molecular diffusion that primarily governs at small Péclet numbers. Simultaneously, the elevated pressure load reinforces the heterogeneity of the pore structure while reducing its connectivity, leading to enhanced disorder and elevated proportion of low-velocity regions within the porous media flow, further strengthening mechanical dispersion and hold-up dispersion, respectively, which dominate under high Péclet numbers. The competition between weakened molecular diffusion and enhanced hold-up dispersion and mechanical dispersion, together with the shift in the dominance of dispersion mechanisms across various Péclet numbers, results in multiple regimes in the slope of the dispersion coefficient to the pressure load. Our study provides unique insights into the structural design and modulation of the dispersion coefficient of porous materials.

Keywords: dispersion; compaction; non-monotonic effect.

Reference

[1] E. Charlaix, J.P. Hulin, T.J. Plona, Experimental study of tracer dispersion in sintered glass porous materials of variable compaction, Physics of Fluids 30 (6) (1987).

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[3] Y. Liu, W. Gong, Y. Zhao, X. Jin, M. Wang, A Pore-Throat Segmentation Method Based on Local Hydraulic Resistance Equivalence for Pore-Network Modeling, Water Resour. Res. 58 (12) (2022) e2022WR033142.

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[1] E. Charlaix, J.P. Hulin, T.J. Plona, Experimental study of tracer dispersion in sintered glass porous materials of variable compaction, Physics of Fluids 30 (6) (1987). [2] C.T. Karin C.E. Östergren*, Characterization of hydrodynamic dispersion in a chromatographic column under compression, Chem. Eng. J. (2000). [3] Y. Liu, W. Gong, Y. Zhao, X. Jin, M. Wang, A Pore-Throat Segmentation Method Based on Local Hydraulic Resistance Equivalence for Pore-Network Modeling, Water Resour. Res. 58 (12) (2022) e2022WR033142.

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