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Dispersion in Hyperporous Fractures: Surface Properties and Scaling

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Permeable and hyperporous surfaces are common in natural systems, such as fractured rocks. Flow and transport above such surfaces is significantly affected by the surface properties, e.g., matrix porosity and permeability. However, the relationship between such properties and macroscopic solute transport is largely unknown. We focus on mass transport in a two-dimensional fracture with permeable porous walls under fully developed laminar flow conditions. By means of perturbation theory and asymptotic analysis, we derive the set of upscaled equations describing mass transport in the coupled fracture-permeable matrix system and an analytical expression relating the dispersion coefficient with the properties of the surface, namely porosity and permeability. Our analysis shows that their impact on dispersion coefficient strongly depends on the magnitude of Peclet number, i.e., on the interplay between diffusive and advective mass transport. Additionally, we demonstrate different scaling behaviors of the dispersion coefficient for thin or thick porous matrices. Our analysis shows the possibility of controlling the dispersion coefficient, i.e. transversal mixing, by either active (i.e. changing the operating conditions) or passive mechanisms (i.e. controlling matrix effective properties) for a given Peclet number. This work lays the foundation to understand the impact of matrix permeability on transport in fractures. The proposed upscaled model is validated against microfluidic experiments.

References

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