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Dispersion Control in Fractured Multi-Layer Porous Media System

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Multi-layered porous media are present in a variety of natural and engineered systems, and their structure can have a significant impact on flow and transport processes. This study proposes a hybrid analytical-numerical solution to examine the relationship between scalar dynamics and media properties in coupled systems comprising a two-dimensional free flow layer and a heterogeneous porous medium operating under fully developed laminar flow conditions. Perturbation and homogenization methods are used to obtain a set of one-dimensional upscaled equations for passive scalar transport. These equations are then used to develop a semi-analytical solution based on integral transforms, which enables the relationship between the properties of the porous system and scalar mixing and spreading to be determined. To validate the solution for the upscaled system, we compare the results with numerical findings for two-dimensional scalar transport. In addition, we analyze the influence of the multilayered system on macroscopic transport by examining the breakthrough curve, dispersion coefficient, and mixing of the scalar cloud. The results suggest that the semi-analytical solution can be used to optimize and determine the arrangement of porous media properties to achieve desired mixing objectives.

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References

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