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Rigorous Derivation of Discrete Fracture Models for Darcy Flow in the Limit of Vanishing Aperture

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We consider single-phase flow in a fractured porous medium governed by Darcy's law with spatially varying matrix-valued hydraulic conductivities in both bulk and fractures. In particular, we account for general fracture geometries parameterized by aperture functions on a submanifold of codimension one. Given a fracture with a width-to-length ratio of the order of a small parameter ε, we derive limit models as $\varepsilon \to 0$. In the limit $\varepsilon \to 0$, we obtain discrete fracture models where fractures are represented as submanifolds of codimension one. The limit models provide a computationally efficient description with explicit fracture representation, while avoiding thin equi-dimensional subdomains with a need for highly resolved meshes in numerical methods. The ratio $K_\mathrm{f}^\star / K_\mathrm{b}^\star$ of the characteristic hydraulic conductivities in the fracture and bulk domains is assumed to scale with ε^α for a parameter $\alpha \in \mathbb{R}$. Depending on the value of α, we obtain five different limit models as $\varepsilon \to 0$, for which we present rigorous convergence results. Additionally, preliminary results are also available for the case of two-phase flow.

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