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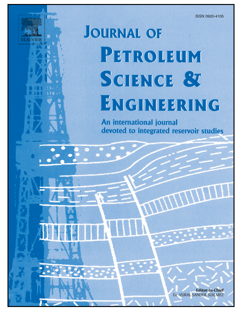

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Physics-Preserving Averaging Scheme based on Grunwald-Letnikov Formula for Gas Flow in Fractured Media

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Abstract

The heterogeneous natures of rock fabrics, due to the existence of multi-scale fractures and geological formations, led to the deviations from unity in the flux-equations fractional-exponent magnitudes. In this paper, the resulting non-Newtonian non-Darcy fractional-derivatives flux equations are solved using physics-preserving averaging schemes that incorporates both, original and shifted, Grunwald-Letnikov (GL) approximation formulas preserving the physics, by reducing the shifting effects, while maintaining the stability of the system, by keeping one shifted expansion. The proposed way of using the GL expansions also generate symmetrical coefficient matrices that significantly reduces the discretization complexities appearing with all shifted cases from literature, and help considerably in 2D and 3D systems. Systems equations derivations and discretization details are discussed. Then, the physics-preserving averaging scheme is explained and illustrated. Finally, results are presented and reviewed. Edge-based original GL expansions are unstable as also illustrated in literatures. Shifted GL expansions are stable but add a lot of additional weights to both discretization sides affecting the physical accuracy. In comparison, the physics-preserving averaging scheme balances the physical accuracy and stability requirements leading to a more physically conservative scheme that is more stable than the original GL approximation but might be slightly less stable than the shifted GL approximations. It is a locally conservative Single-Continuum averaging scheme that applies a finite-volume viewpoint.

Keywords: Grunwald-Letnikov, fractured porous media, fractional derivatives, physics preserving, average.

1 Introduction

Numerous geological formations and multi-scale fractures existing within rock fabrics affect the heterogeneity of the simulated systems. Also the fluids flows are affected by the porous medium and flow conditions such as system geometry, shear rates, shear stresses, durations of shearing, etc. (Chhabra and Richardson, 2011). Combining a collection of these properties, we end up with a Non-Newtonian Non-Darcy flow equations system (Amir and Sun, 2017). That system can easily be simplified into the typical Newtonian Darcy flow system through substituting each superscript n and α

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