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A Fractional Derivative Model to Quantify Non-Darcy Flow in Porous and Fractured Media

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Abstract : Darcy's law is the fundamental theory in fluid dynamics and engineering applications. Although Darcy linearity was found to be valid for slow, viscous flow, non-linear and non-Darcian flow has been well documented under both small and large velocity fluid flow. Various classical models were proposed and used widely to quantify non-Darcian flow, including the well-known Forchheimer, Izbash, and Swartzendruber models. Applications, however, revealed limitations of these models. Here we propose a general model built upon the Caputo fractional derivative to quantify non-Darcian flow for various flows (laminar to turbulence).Real-world applications and model comparisons showed that the new fractional-derivative model, which extends the fractional model proposed recently by Zhou and Yang (2018), can capture the non-Darcian flow in the relatively small velocity in low-permeability deposits and the relatively high velocity in high-permeability sand. A scale effect was also identified for non-Darcian flow in fractured rocks. Therefore, fractional calculus may provide an efficient tool to improve classical models to quantify fluid dynamics in aquatic environments.

Keywords : fractional derivative, darcy's law, non-darcian flow, fluid dynamics
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