

High Velocity Flow in Porous Media

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Abstract. Experimental observations have established that the proportionality between pressure head gradient and fluid velocity does not hold for high rates of fluid flow in porous media. Empirical relations such as Forchheimer equation have been proposed to account for nonlinear effects. The purpose of this work is to derive such nonlinear relationships based on fundamental laws of continuum mechanics and to identify the source of nonlinearity in equations.

Adopting the continuum approach to the description of thermodynamic processes in porous media, a general equation of motion of fluid at the macroscopic level is proposed. Using a standard order-of-magnitude argument, it is shown that at the onset of nonlinearities (which happens at Reynolds numbers around 10), macroscopic viscous and inertial forces are negligible compared to microscopic viscous forces. Therefore, it is concluded that growth of microscopic viscous forces (drag forces) at high flow velocities give rise to nonlinear effects. Then, employing the constitutive theory, a nonlinear relationship is developed for drag forces and finally a generalized form of Forchheimer equation is derived.

Key words. Porous media, high velocity flow, non-Darcy flow, Forchheimer equation, inertial effects, constitutive equations.