Forchheimer equation @model

@wikipedia

The momentum balance equation relating a pressure gradient ∇p in porous medium with induced fluid flow (percolation) with velocity $\mathbf{u}$

(1) $$-\nabla p = \frac{\mu}{k}\mathbf{u} + \beta\,\rho\,|\mathbf{u}|\,\mathbf{u}$$

where

k	formation permeability
μ	fluid viscosity
β	Forchheimer coefficient

Forchheimer coefficient depends on flow regime and formation permeability as:

(2) $$\beta = \frac{C_E}{\sqrt{k}}$$

where C_E is dimensionless quantity called Ergun constant accounting for inertial (kinetic) effects and depending on flow regime only.

C_E is small for slow percolation (thus reducing Forchheimer equation to Darcy equation) and grows quickly with high flow velocities.

Forchheimer equation can be approximated by non-linear permeability model as:

(3) $\mathbf{u} = -\frac{k}{\mu}\,k_f\,\nabla p$	(4) $k_f(\lvert\nabla p\rvert) = \frac{2}{w}\left[1-\sqrt{1-w}\right]$	(5) $w = 4\left(\frac{k}{\mu}\right)^2\beta\,\rho\,\lvert\nabla p\rvert\, < \,1$

See also

Physics / Fluid Dynamics / Percolation

[Darcy Flow Equation]

Reference

Philipp Forchheimer (1886). "Über die Ergiebigkeit von Brunnen-Anlagen und Sickerschlitzen". Z. Architekt. Ing.-Ver. Hannover. 32: 539–563.