CI²MA
Centro de Investigación en Ingeniería Matemática

Seminario de Análisis Numérico y Modelamiento Matemático de Estudiantes

Mixed Finite Element Methods for Fluid Filtration through a Saturated Porous Medium with Heterogeneous Permeability: A Priori and A Posteriori Error Analysis

In this talk, we discuss the analysis and numerical treatment of mixed finite element methods for modeling the filtration of an incompressible fluid through a non-deformable saturated porous medium with heterogeneous permeability. The flow behavior is governed by the Brinkman-Forchheimer equations in regions of high permeability and by the Darcy equations in areas of lower permeability. The transmission conditions between these regions are defined by mass conservation and momentum continuity. We present the mixed variational formulations employed, which include a standard mixed approach for the Brinkman-Forchheimer region and a dual-mixed approach for the Darcy region, ensuring continuity of the normal velocities through a Lagrange multiplier. The finite element discretization utilizes Bernardi-Raugel and Raviart-Thomas elements for the velocities, piecewise constants for the pressures, and continuous piecewise linear elements for the Lagrange multiplier. We outline the stability and convergence analysis, as well as the derivation of a priori error estimates for the Galerkin scheme. In addition, we discuss the development of a reliable and efficient a posteriori residual-based error estimator for this 2D problem. The reliability analysis leverages the inf-sup condition, the strong monotonicity of the operators involved, and a stable Helmholtz decomposition, while efficiency is established through inverse inequalities, localization techniques using bubble functions, and prior results. To conclude, we present numerical examples that validate the theoretical properties, illustrate the accuracy of the estimators, and showcase the performance of adaptive algorithms, including cases involving flow through heterogeneous porous media.

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