Accepted Manuscript

Modeling flow in porous media with double porosity/permeability: A stabilized mixed formulation, error analysis, and numerical solutions

S.H.S. Joodat, K.B. Nakshatrala, R. Ballarini

PII: S0045-7825(18)30174-9
DOI: https://doi.org/10.1016/j.cma.2018.04.004
Reference: CMA 11855

To appear in: *Comput. Methods Appl. Mech. Engrg.*

Received date : 12 June 2017
Revised date : 2 March 2018
Accepted date : 2 April 2018

Please cite this article as: S.H.S. Joodat, K.B. Nakshatrala, R. Ballarini, Modeling flow in porous media with double porosity/permeability: A stabilized mixed formulation, error analysis, and numerical solutions, *Comput. Methods Appl. Mech. Engrg.* (2018), https://doi.org/10.1016/j.cma.2018.04.004

Highlights of this paper

- A stabilized mixed finite element formulation has been presented for the double porosity/permeability mathematical model.
- A systematic error analysis has been performed.
- Numerical convergence analysis and patch tests have been used to illustrate the convergence behavior and accuracy.
- The mathematical properties that the solutions of the double porosity/permeability model enjoy have been utilized to construct mechanics-based *a posteriori* error measures to assess the accuracy of the numerical solutions.
- The performance under steady-state and transient settings has been illustrated using representative numerical examples.
- Some of the **significant findings** of the paper can be summarized as follows:
    - Equal-order interpolation for all the field variables, which is computationally the most convenient, is stable under the proposed stabilized mixed formulation.
    - Patch tests revealed that the classical mixed formulation produces spurious node-to-node oscillations in the pressure fields under equal-order interpolation for all the field variables. On the other hand, the proposed stabilized mixed formulation passed the patch tests up to the machine precision.
    - The numerical convergence rates obtained using the proposed stabilized formulation were in accordance with the theory for both *h*- and *p*-refinements.
    - The proposed stabilized mixed formulation suppressed the unphysical numerical instabilities but yet captured the underlying physical instability (which is similar to the classical Saffman-Taylor instability) when applied to a coupled flow and transport problem in porous media with dual pore-networks.
    - Thus, the proposed formulation will be particularly attractive for studying physical instabilities, which arise in porous media.