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Multiscale Model Reduction for Fluid Infiltration Simulation through Dual-Continuum Porous Media with Localized Uncertainties

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ABSTRACT

Here, we present some Reduced Basis (RB) methods for fluid infiltration problems through certain porous media modeled as dual-continuum with localized uncertainties. We apply dimension reduction techniques to construct a reduced order model. In the RB methods, to perform the offline-online computation decomposition, the model inputs need to be affinely dependent on the uncertainties. We develop a Proper Orthogonal Decomposition and Greedy (POD-Greedy) RB method for stochastic dual-continuum models. In the POD-Greedy RB framework, for heterogeneous porous media, we need to solve the stochastic dual-continuum models many times using very fine grid to construct a set of snapshots for building optimal reduced basis. This offline computation may be very expensive. To improve the offline computational efficiency, we further develop a local global RB method, which integrates the coupled multiscale and multicontinuum approach using Generalized Multiscale Finite Element Method (GMsFEM) to the POD-Greedy RB method. To illustrate the efficiency of the proposed methods, we present two numerical examples for stochastic dual-continuum models. Our numerical results show that both the POD-Greedy RB method and the local global RB method greatly improve the computation efficiency with high approximation accuracy.

keywords: Reduced basis methods, GMsFEM, Local global RB method, Greedy algorithm, Proper orthogonal decomposition, Stochastic Dual-continuum model

1 Introduction

Fluid infiltration in porous media has a wide range of scientific and engineering applications [18, 22, 6, 23]. Typical examples include the fluid flow through natural strata (e.g. groundwater and hydrocarbon) and composite materials (e.g. membrane and catalysis) [43, 38, 12, 27, 26]. Very often, there are some degree of fissuring developed in porous media, participially in natural strata presented in the format of fractures [3, 28]. For those fractured porous media, the dual-continuum model after Barenblatt et. al [4] has been the standard approach, based on a very insightful concept and reasonable simplification. The concept of dual-continuum model comes into place by considering dual interconnected parallel systems that distribute all over the domain at any point

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