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High order discontinuous Galerkin method for reduced flow models in fractured porous media

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Abstract

We construct a new symmetric interior penalty discontinuous Galerkin (SIPDG)-method for incompressible flow in fractured porous media. The method is developed for computing accurate approximations of the reduced flow model, where fractures are treated as lower dimensional objects. Unlike previous formulations, the methodology proposed herein shows ability to capture the asymptotic limits of highly permeable and fracture seals, also covering a wider range of values of the quadrature integration parameter which appears in the pressure jumps across the fractures. As a first novel contribution we should mention that the method was developed for specific interface condition in the reduced problem for which known in literature DG method are not applicable. As a second novelty we propose a new penalty technique for stabilization of the method and obtain explicit estimate for the penalty parameters associated with flow in matrix and fractures in order to achieve stability. And finally we derive new high order *hp* type a priori error estimates for the numerical solution in the energy norm. Numerical results illustrate the performance of the proposed SIPDG-method in simulating discrete fracture models.

Keywords: Discrete fracture model; Elliptic problems; Discontinuous Galerkin method; Interior penalty formulation

1. Introduction

It is now well established and widely accepted that the presence of fracture networks distributed in geological formations has a profound impact on flow regimes during fluid withdrawal which appear magnified in the presence of clusters, swarms and fracture corridors [20]. The influence is even more pronounced in the case of fractures enlarged by dissolution processes, in which the network interacts with karst conduits leading to highly concentrated flow patterns [22]. More specifically, features such as profile of breakthrough curves, cumulative production, unexpected fluid leaking through the cap rock and the magnitude of upscaled properties are strongly influenced by the topology of the fracture network. Such a feature involves combination of several aspects of the network where we may emphasize the local arrangement of the elements, type of filling material, roughness, aperture, dip, azimuth, strike and connectivity [1]. Consequently it has become mandatory to develop accurate computational models capable of capturing the detailed influence of fracture networks upon fluid percolation.

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