Discrete Fracture Model For Coupled Flow And Geomechanics

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The Discrete Fracture Model (DFM) has been widely used to model the flow and transport in natural geological porous formations. Here, we extend the DFM approach to model deformation. The flow equations are discretized using a finite-volume method, and the poroelasticity equations are discretized using a Galerkin finite-element approximation.

Discrete fracture model for coupled flow and geomechanics ...
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Discrete Fracture Model For Coupled Flow And Geomechanics
An efficient discrete-fracture model is used to explicitly model the fractured system. Flexible unstructured gridding is employed to model arbitrarily-oriented fractures. The interrelations among pore volume, permeability and geomechanical conditions are considered dynamically using two-way coupled flow and geomechanics computations.

Sequentially coupled flow and geomechanical simulation ...
extensively. To represent the fracture deformation explicitly, the discrete fracture model has been more widely used recently in coupled fluid flow and geomechanics problems. A fracture is defined as two surfaces in contact in the dis-crete fracture model presented by Garipov et al,18 in which a mechanical model for the fractures is derived to describe the changes in the stress and the displacement fields through the surfaces representing the fractures.

A coupled compressible flow and geomechanics model for ...
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Discrete Fracture Model For Coupled Flow And Geomechanics
The ?rst hybrid model couples an embedded-discrete-fracture model (EDFM) with multiple interacting continua (MINC) into EDFM/MINC, which simulates the fracture network characterized by...

(PDF) Hybrid Coupled Discrete Fracture-Matrix and ...
A continuum model for coupled stress and ?uid ?ow in discrete fracture networks Quan Gan . Derek Elsworth Received: 23 September 2015/Accepted: 9 December 2015/Published online: 5 January 2016 The Author(s) 2016. This article is published with open access at Springerlink.com Abstract We present a model coupling stress and

A continuum model for coupled stress and fluid flow in ...
In this work we consider a discrete fracture–matrix (DFM) model, where the fractures are modeled as lower dimensional interfaces embedded in the rock matrix. We assume Darcy flow both in the matrix and the fracture, and we only consider the case where the permeability in the fractures are orders of magnitude larger than in the matrix.

A simple embedded discrete fracture–matrix model for a ...
In this paper, a numerical model is developed for coupled analysis of deforming fractured porous media with multiscale fractures. In this model, the macro-fractures are modeled explicitly by the embedded discrete fracture model, and the supporting effects of fluid and fillings in these fractures are represented explicitly in the geomechanics model. On the other hand, matrix and micro-fractures are modeled by a multi-porosity model, which aims to accurately describe the transient matrix ...

An efficient hydro-mechanical model for coupled multi ...
A “discrete fracture network” (DFN) refers to a computational model that explicitly represents the geometrical properties of each individual fracture (e.g. orientation, size, position, shape and aperture), and the topological relationships between individual fractures and fracture sets.

The use of discrete fracture networks for modelling ...
Discrete Fracture Model For Coupled The Discrete Fracture Model (DFM) has been widely used to model the flow and transport in natural geological porous formations. Here, we extend the DFM approach to model deformation. The flow equations are

Discrete Fracture Model For Coupled Flow And Geomechanics
DOE PAGES Journal Article: A continuum model for coupled stress and fluid flow in discrete fracture networks. A continuum model for coupled stress and fluid flow in discrete fracture networks. Full Record; References (26) Other Related Research; Authors: Gan, Quan; Elsworth, Derek

A continuum model for coupled stress and fluid flow in ...
The sub-model is coupled to the discrete fracture sub-model through the fracture surface. The domain size of the sub-model is such that the dominant, time-variable, dynamic transport processes during the expected years of reservoir exploitation are captured within this geometry.

A New T-H-M-C Model Development for Discrete-Fracture EGS ...
In this study, we developed a new numerical manifold method model for analysis of fully coupled hydro-mechanical processes in porous rock with discrete fractures. In this model the porous rock and the fractures are both deformable and fluid conductive with large contrast of mechanical and hydraulic properties.

A numerical manifold method model for analyzing fully ...
The discrete fracture networks (DFNs) is quantitatively constructed according to the fracture density and stimulated reservoir area (SRA). This model is used to analyze the temporal/spatial evolution of the gas pressure and the net desorption rate.

Quantitative study in shale gas behaviors using a coupled ...
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Discrete Fracture Model For Coupled Flow And Geomechanics
A model based on the code CrunchClay is presented for a fracture-clay matrix system that takes electrostatic effects on transport into account. The electrostatic effects on transport include those associated with the development of a diffusion potential as captured by the Nernst-Planck equation, and the formation of a diffuse layer bordering negatively charged clay particles within which ...

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The discrete fractures were idealised as lower-dimensional geometric objects with the discrete fracture elements located on the edges of continuum elements sharing the same nodes. The coupling between the two flow systems was achieved by using the principle of superposition.

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Transient transfer shape factor between matrix and fracture should be considered. Considering the transient transfer, a simulation workflow is developed using Discrete-Fracture and Continuum Models, i.e., embedded-discrete-fracture model (EDFM) and dual porosity (DP) model. We consider the SRV region and USRV region respectively.

Naturally fractured reservoirs (NFRs) hold a significant amount of the world's hydrocarbon reserves. Compared to conventional reservoirs, NFRs exhibit a higher degree of heterogeneity and complexity created by fractures. The importance of fractures in production of oil and gas is not limited to naturally fractured reservoirs. The economic exploitation of unconventional reservoirs, which is increasingly a major source of short- and long-term energy in the United States, hinges in part on effective stimulation of low-permeability rock through multi-stage hydraulic fracturing of horizontal wells. Accurate modeling and simulation of fractured media is still challenging owing to permeability anisotropies and contrasts. Non-physical abstractions inherent in conventional dual porosity and dual permeability models make these methods inadequate for solving different fluid-flow problems in fractured reservoirs. Also, recent approaches for discrete fracture modeling may require large computational times and hence the oil industry has not widely used such approaches, even though they give more accurate representations of fractured reservoirs than dual continuum models. We developed an embedded discrete fracture model (EDFM) for an in-house fully-implicit compositional reservoir simulator. EDFM borrows the dual-medium concept from conventional dual continuum models and also incorporates the effect of each fracture explicitly. In contrast to dual continuum models, fractures have arbitrary orientations and can be oblique or vertical, honoring the complexity and heterogeneity of a typical fractured reservoir. EDFM employs a structured grid to remediate challenges associated with unstructured gridding required for other discrete fracture models. Also, the EDFM approach can be easily incorporated in existing finite difference reservoir simulators. The accuracy of the EDFM approach was confirmed by comparing the results with analytical solutions and fine-grid, explicit-fracture simulations. Comparison of our results using the EDFM approach with fine-grid simulations showed that accurate results can be achieved using moderate grid refinements. This was further verified in a mesh sensitivity study that the EDFM approach with moderate grid refinement can obtain a converged solution. Hence, EDFM offers a computationally-efficient approach for simulating fluid flow in NFRs. Furthermore, several case studies presented in this study demonstrate the applicability, robustness, and efficiency of the EDFM approach for modeling fluid flow in fractured porous media. Another advantage of EDFM is its extensibility for various applications by incorporating different physics in the model. In order to examine the effect of pressure-dependent fracture properties on production, we incorporated the dynamic behavior of fractures into EDFM by employing empirical fracture deformation models. Our simulations showed that fracture deformation, caused by effective stress changes, substantially affects pressure depletion and hydrocarbon recovery. Based on the examples presented in this study, implementation of fracture geomechanical effects in EDFM did not degrade the computational performance of EDFM. Many unconventional reservoirs comprise well-developed natural fracture networks with multiple orientations and complex hydraulic fracture patterns suggested by microseismic data. We developed a coupled dual continuum and discrete fracture model to efficiently simulate production from these reservoirs. Large-scale hydraulic fractures were modeled explicitly using the EDFM approach and numerous small-scale natural fractures were modeled using a dual continuum approach. The transport parameters for dual continuum modeling of numerous natural fractures were derived by upscaling the EDFM equations. Comparison of the results using the coupled model with that of using the EDFM approach to represent all natural and hydraulic fractures explicitly showed that reasonably accurate results can be obtained at much lower computational cost by using the coupled approach with moderate grid refinements.

Discrete Fracture Network Modeling of Hydraulic Stimulation describes the development and testing of a model that couples fluid-flow, deformation, friction weakening, and permeability evolution in large, complex two-dimensional discrete fracture networks. The model can be used to explore the behavior of hydraulic stimulation in settings where matrix permeability is low and preexisting fractures play an important role, such as Enhanced Geothermal Systems and gas shale. Used also to describe pure shear stimulation, mixed-mechanism stimulation, or pure opening-mode stimulation. A variety of novel techniques to ensure efficiency and realistic model behavior are implemented, and tested. The simulation methodology can also be used as an efficient method for directly solving quasistatic fracture contact problems. Results show how stresses induced by fracture deformation during stimulation directly impact the mechanism of propagation and the resulting fracture network.

Discrete Fracture Network Modeling of Hydraulic Stimulation describes the development and testing of a model that couples fluid-flow, deformation, friction weakening, and permeability evolution in large, complex two-dimensional discrete fracture networks. The model can be used to explore the behavior of hydraulic stimulation in settings where matrix permeability is low and preexisting fractures play an important role, such as Enhanced Geothermal Systems and gas shale. Used also to describe pure shear stimulation, mixed-mechanism stimulation, or pure opening-mode stimulation. A variety of novel techniques to ensure efficiency and realistic model behavior are implemented, and tested. The simulation methodology can also be used as an efficient method for directly solving quasistatic fracture contact problems. Results show how stresses induced by fracture deformation during stimulation directly impact the mechanism of propagation and the resulting fracture network.

The development of naturally fractured reservoirs, especially shale gas and tight oil reservoirs, exploded in recent years due to advanced drilling and fracturing techniques. However, complex fracture geometries such as irregular fracture networks and non-planar fractures are often generated, especially in the presence of natural fractures. Accurate modelling of production from reservoirs with such geometries is challenging. Therefore, Embedded Discrete Fracture Modeling and Application in Reservoir Simulation demonstrates how production from reservoirs with complex fracture geometries can be modelled efficiently and effectively. This volume presents a conventional numerical model to handle simple and complex fractures using local grid refinement (LGR) and unstructured gridding. Moreover, it introduces an Embedded Discrete Fracture Model (EDFM) to efficiently deal with complex fractures by dividing the fractures into segments using matrix cell boundaries and creating non-neighboring connections (NNCs). A basic EDFM approach using Cartesian grids and advanced EDFM approach using Corner point and unstructured grids will be covered. Embedded Discrete Fracture Modeling and Application in Reservoir Simulation is an essential reference for anyone interested in performing reservoir simulation of conventional and unconventional fractured reservoirs. Highlights the current state-of-the-art in reservoir simulation of unconventional reservoirs Offers understanding of the impacts of key reservoir properties and complex fractures on well performance Provides case studies to show how to use the EDFM method for different needs

Hydraulic Fracture Modeling delivers all the pertinent technology and solutions in one product to become the go-to source for petroleum and reservoir engineers. Providing tools and approaches, this multi-contributed reference presents current and upcoming developments for modeling rock fracturing including their limitations and problem-solving applications. Fractures are common in oil and gas reservoir formations, and with the ongoing increase in development of unconventional reservoirs, more petroleum engineers today need to know the latest technology surrounding hydraulic fracturing technology such as fracture rock modeling. There is tremendous research in the area but not all located in one place. Covering two types of modeling technologies, various effective fracturing approaches and model applications for fracturing, the book equips today’s petroleum engineer with an all-inclusive product to characterize and optimize today’s more complex reservoirs. Offers understanding of the details surrounding fracturing and fracture modeling technology, including theories and quantitative methods Provides academic and practical perspective from multiple contributors at the forefront of hydraulic fracturing and rock mechanics Provides today’s petroleum engineer with model validation tools backed by real-world case studies

This dissertation intends to advance fundamental understanding of two areas of interest in the petroleum industry: complex stimulated fracture network during hydraulic fracturing treatments and induced seismicity during wastewater disposal operations. Successful completion of hydraulic fractures in unconventional formations has been the primary source of increased oil and gas production in the US. However, field observations suggest that the hydraulic fracture networks are much more complex and different from the classical description of bi-wing planar fractures. Thus, the attempts to optimize this stimulation technique are hindered by the uncertainties in predicting the complex fracture network. A by-product of massive improvement in oil and gas production is a significant amount of water being co-produced from these formations. The common practice in the industry is to recycle wastewater for hydraulic fracturing purposes or reinject it into the reservoir through disposal wells. In certain regions of the US, this wastewater injection has led to historically high seismicity rates and earthquakes of Magnitude 5 and above which caused the public to be concerned. To maintain the social license to continue such operations, these concerns need to be addressed, and the physics behind such induced events need to be understood. Two novel hydraulic fracturing and induced seismicity simulators are developed that implicitly couple fluid flow with the stresses induced by fracture deformation in large, complex, three-dimensional discrete fracture networks. The simulators can describe the propagation of hydraulic fractures and opening and shear stimulation of natural fractures. Fracture elements can open or slide, depending on their stress state, fluid pressure, and mechanical properties. Fracture sliding occurs in the direction of maximum resolved shear stress. Nonlinear empirical relations are used to relate normal stress, fracture opening, and fracture sliding to fracture aperture and transmissivity. Field-scale hydraulic fracturing simulations were performed in a dense naturally fractured formation. Height containment of propagating hydraulic fractures between bedding layers is modeled with a vertically heterogeneous stress field or by explicitly imposing hydraulic fracture height containment as a model assumption. The propagating hydraulic fractures can cross natural fractures or terminate against them depending on the natural fracture orientation and stress anisotropy. The simulations demonstrate how interaction with natural fractures in the formation can help explain the high net pressures, relatively short hydraulic fracture lengths, and broad regions of microseismicity that are often observed in the field during stimulation in low permeability formations, some of which were not predicted by classical hydraulic fracturing models. Depending on input parameters, our simulations predicted a variety of stimulation behaviors, from long hydraulic fractures with minimal leakoff into surrounding fractures to broad regions of dense fracturing with a branching network of many natural and newly formed fractures. Induced seismicity simulator was developed to investigate the effects of multiple operational, hydraulic, and geophysical parameters on the magnitude of induced earthquakes. The rate-and-state framework is implemented to include the effect of fault nonlinear friction evolution and to model unstable earthquake rupture. The Embedded Discrete Fracture Model (EDFM) technique is used to model the fluid flow between the matrix and fractures efficiently. The results show that high-rate injections are more likely to induce a more significant earthquake, confirming the statistical correlation attributing induced events to high-rate injection wells. To understand the seismic occurrence outside of the injection zone, the effect of fault permeability structure on seismicity is studied by assigning non-uniform permeabilities as an input parameter. The model shows that the fault rupture is dominantly controlled by initial pressure and stress heterogeneity which ultimately affect the magnitude of an induced earthquake event

Tight gas and shale oil play an important role in energy security and in meeting an increasing energy demand. Hydraulic fracturing is a widely used technology for recovering these resources. The design and evaluation of hydraulic fracture operation is critical for efficient production from tight gas and shale plays. The efficiency of fracturing jobs depends on the interaction between hydraulic (induced) and naturally occurring discrete fractures. In this work, a coupled reservoir-fracture flow model is described which accounts for varying reservoir geometries and complexities including non-planar fractures. Different flow models such as Darcy flow and Reynold's lubrication equation for fractures and reservoir, respectively are utilized to capture flow physics accurately. Furthermore, the geomechanics effects have been included by considering a multiphase Biot's model. An accurate modeling of solid deformations necessitates a better estimation of fluid pressure inside the fracture. The fractures and reservoir are modeled explicitly allowing accurate representation of contrasting physical descriptions associated with each of the two. The approach presented here is in contrast with existing averaging approaches such as dual and discrete-dual porosity models where the effects of fractures are averaged out. A fracture connected to an injection well shows significant width variations as compared to natural fractures where these changes are negligible. The capillary pressure contrast between the fracture and the reservoir is accounted for by utilizing different capillary pressure curves for the two features. Additionally, a quantitative assessment of hydraulic fracturing jobs relies upon accurate predictions of fracture growth during slick water injection for single and multistage fracturing scenarios. It is also important to consistently model the underlying physical processes from hydraulic fracturing to long-term production. A recently introduced thermodynamically consistent phase-field approach for pressurized fractures in porous medium is utilized which captures several characteristic features of crack propagation such as joining, branching and non-planar propagation in heterogeneous porous media. The phase-field approach captures both the fracture-width evolution and the fracture-length propagation. In this work, the phase-field fracture propagation model is briefly discussed followed by a technique for coupling this to a fractured poroelastic reservoir simulator. We also present a general compositional formulation using multipoint flux mixed finite element (MFMFE) method on general hexahedral grids with a future prospect of treating energized fractures. The mixed finite element framework allows for local mass conservation, accurate flux approximation and a more general treatment of boundary conditions. The multipoint flux inherent in MFMFE scheme allows the usage of a full permeability tensor. An accurate treatment of diffusive/dispersive fluxes owing to additional velocity degrees of freedom is also presented. The applications areas of interest include gas flooding, CO2 sequestration, contaminant removal and groundwater remediation.

The aim of this monograph is to describe the main concepts and recent - vances in multiscale ?nite element methods. This monograph is intended for thebroaderaudienceincludingengineers,appliedscientists,andforthosewho are interested in multiscale simulations. The book is intended for graduate students in applied mathematics and those interested in multiscale compu- tions. It combines a practical introduction, numerical results, and analysis of multiscale ?nite element methods. Due to the page limitation, the material has been condensed. Each chapter of the book starts with an introduction and description of the proposed methods and motivating examples. Some new techniques are introduced using formal arguments that are justi?ed later in the last chapter. Numerical examples demonstrating the signi?cance of the proposed methods are presented in each chapter following the description of the methods. In the last chapter, we analyze a few representative cases with the objective of demonstrating the main error sources and the convergence of the proposed methods. A brief outline of the book is as follows. The ?rst chapter gives a general introductiontomultiscalemethodsandanoutlineofeachchapter.Thesecond chapter discusses the main idea of the multiscale ?nite element method and its extensions. This chapter also gives an overview of multiscale ?nite element methods and other related methods. The third chapter discusses the ext- sion of multiscale ?nite element methods to nonlinear problems. The fourth chapter focuses on multiscale methods that use limited global information.

Scientific understanding of fluid flow in rock fractures--a process underlying contemporary earth science problems from the search for petroleum to the controversy over nuclear waste storage--has grown significantly in the past 20 years. This volume presents a comprehensive report on the state of the field, with an interdisciplinary viewpoint, case studies of fracture sites, illustrations, conclusions, and research recommendations. The book addresses these questions: How can fractures that are significant hydraulic conductors be identified, located, and characterized? How do flow and transport occur in fracture systems? How can changes in fracture systems be predicted and controlled? Among other topics, the committee provides a geomechanical understanding of fracture formation, reviews methods for detecting subsurface fractures, and looks at the use of hydraulic and tracer tests to investigate fluid flow. The volume examines the state of conceptual and mathematical modeling, and it provides a useful framework for understanding the complexity of fracture changes that occur during fluid pumping and other engineering practices. With a practical and multidisciplinary outlook, this volume will be welcomed by geologists, petroleum geologists, geoengineers, geophysicists, hydrologists, researchers, educators and students in these fields, and public officials involved in geological projects.

Constitutive modelling is the mathematical description of how materials respond to various loadings. This is the most intensely researched field within solid mechanics because of its complexity and the importance of accurate constitutive models for practical engineering problems. Topics covered include: Elasticity - Plasticity theory - Creep theory - The nonlinear finite element method - Solution of nonlinear equilibrium equations - Integration of elastoplastic constitutive equations - The thermodynamic framework for constitutive modelling – Thermoplasticity - Uniqueness and discontinuous bifurcations • More comprehensive in scope than competitive titles, with detailed discussion of thermodynamics and numerical methods. • Offers appropriate strategies for numerical solution, illustrated by discussion of specific models. • Demonstrates each topic in a complete and self-contained framework, with extensive referencing.